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Diatoms (Bacillariophyceae) from the Valley of the Great Lakes in Western Mongolia

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Abstract

The Valley of the Great Lakes (VOGL) in western Mongolia is dominated by two main (Uvs, Khyargas) and many minor closed basin lake systems. In 2004 and 2005, we sampled diatom communities from the surficial sediment of 64 lakes in the western Mongolian provinces of Uvs, Khovd, Zavkhan, and Bayan-Ulgii. Lakes ranged in water chemistry from fresh to hypersaline, oligotrophic to hypertrophic, and from low elevation VOGL lakes to high elevation lakes in the Altai Mountains. Over 300 diatom species were identified in the sediment samples including a diverse flora limited to saline lakes, many widespread taxa, many new reports for the Mongolian diatom flora, and several new and possibly endemic species. We also review recent diatom literature from Mongolia including floristic surveys, paleo-ecology, and water quality studies.

Key words: diatoms, Bacillariophyceae, Valley of Great Lakes, paleoecology, taxonomy

Introduction

Researchers have been studying the Mongolian diatom flora for over 100 years. The first published investigation of diatom distribution was a report on species found in Lake Hővsgől by Dorogostaïsky in 1904 (Edlund *et al*., 2001). Diatom studies by Russian, Mongolian and international scientists have proceeded through the last century (e.g., Skvortzow, 1937; Morales & Edlund, 2003; Edlund *et al*., 2003; Metzeltin *et al*., 2009); however, work has been largely focused on occurrence and distribution with little ecological or applied focus. In recent decades, interest has been building in Mongolia and surrounding regions to use diatoms in paleo-climatological (Tarasov *et al*., 2000; Peck *et al*., 2002; Soninkhishig *et al*., 2003; Fedotov *et al*., 2000, 2004; Rudaya *et al*., 2008; Shinneman *et al*., 2009b, c), paleo-ecological (Shinneman *et al*., 2009a, b; Mackay *et al*., in press), and ecosystem health assessments (Soninkhishig *et al*., 1999, Soninkhishig and Edlund, 2001); making an understanding of the distribution and taxonomy of diatoms in Mongolia an important line of study for applied research.

Here we expand on the known diversity and distribution of diatoms in Mongolia with a checklist of over 300 diatom taxa identified from 64 surficial sediment samples from western Mongolian lakes. Mongolia, and much of Central Asia, have not been well surveyed and continued exploration has yielded many new species, new reports, and broader distributions in the Mongolian diatom flora. The importance of Mongolian diatom studies is also being realized with recent large-scale research programs using diatoms in biogeography, taxonomy, bioassessment, and paleolimnology studies.

Material and Methods

Study region - The Valley of the Great Lakes lies in the far west of Mongolia, bounded by the Mongol Altai Mountains to the west, the Khangai Mountains to the east, and the Gobi Desert to the south (Fig. 1). The Great Lakes region is part of the endorheic Central Asian Basin and includes several smaller closed drainage basins with lakes ranging from fresh to hypersaline (Dulmaa, 1979; Shinneman *et al*., 2009a). Many of the large terminal basins in the valley are believed to be

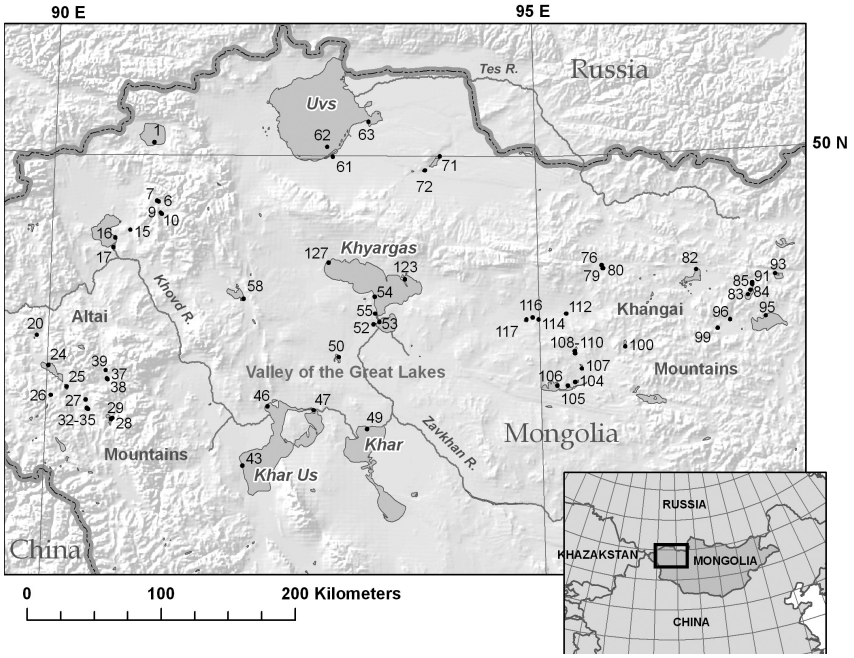

Figure 1. Valley of the Great Lakes region in western Mongolia with 2004-2005 sampling sites indicated (see Shinneman *et al*., 2009a).

remnants of large Tertiary or Quaternary paleo-lakes (Grunert *et al*., 2000). Sample sites included three large terminal basins in the area, Khyargas, Uvs, and Uureg. There are additionally numerous large and small ephemeral ponds, playa lakes, floodplain lakes, and dune-blocked lakes.

During two field seasons (August 2004 and August 2005) we sampled 64 lakes in the western Mongolian provinces of Uvs, Khovd, Zavkhan, and Bayan-Ulgii. At each lake a surface sediment sample (0-1 cm sediment depth) was collected from the deepest site accessible by canoe using a line-operated "Wiegner" gravity corer. The sediment was preserved in 10% formaldehyde solution and prepared for microscopy following Renberg (1990). Cleaned material was mounted on microslides with Zrax and random transects examined with an Olympus BX50 microscope capable of 1250x and n.a. 1.40 until 400 valves were counted. Data handling and analysis are described in Shinneman *et al*. (2009a).

Results

Over 300 species were identified in 64 sampling sites across the region, including new distributional reports for nearly 100 taxa in the VOGL and/or the Mongolian flora, in addition to the identification of several new species (Appendix 1; Fig. 1). Some of the new distributional records in the VOGL have also been reported in other studies of Mongolian waterbodies, notably the studies from Buir Nuur, Khugnu Khaan, and the Khentii Mountains (Soninkhishig & Edlund, 2001; Soninkhishig *et al*., 2002; Metzeltin *et al*., 2009).

Five VOGL lakes were sampled and found to have no diatoms present; these had a specific conductance greater than 170,000 µS cm^{-1} and were presumably too saline to support or preserve a diatom community. In lakes where diatoms were present, either salinity or trophic status had any apparent effect on total species richness; however, community assemblages were linked strongly with both salinity and trophic status (Shinneman *et al*., 2009a).

In deep, freshwater lakes, *Cyclotella* and *Discostella* species (*Cyclotella ocellata* Pantocsek, *Discostella pseudostelligera* (Hust.) Houk & Klee) were most common, as were several species of the genus *Staurosirella*. Highly saline lakes had abundant *Amphora* floras; *Anomoeoneis sphaerophora* (Ehrenb.) Pfitzer and its varieties and *Chaetoceros* spores were also common, though typically low in relative abundance. In more dilute waters the community was shifted to high percentages of *Pseudostaurosira elliptica* (Schumann) Edlund, Morales & Spaulding and *Staurosirella pinnata* (Ehrenb.) D.M.Williams & Round as well as a number of *Cyclotella* species found in lower abundance. Highly eutrophic

systems were typically characterized by several nitzschioid diatoms (*Nitzschia bacillum* Hust., *Nitzschia constricta* (Kütz.) Ralfs) as well as *Stephanodiscus minutulus* (Kütz.) Cleve & J.D.Möll. and an unknown *Gomphonema* species, which were not found in abundance in the more nutrient-poor systems. Because surface sediments are often biased toward planktonic assemblages, much greater diversity would be expected if diatoms from littoral and wetland areas had been systematically sampled.

Large, saline terminal basins, while retaining high overall diversity, were often dominated (20-60%) by a single taxon including several unknown and apparently endemic species. These included the terminal basins of Khyargas Nuur and Uureg Nuur. The sole member of the Khyargas Nuur plankton community is the endemic species *Puncticulata khyargasiana* Shinneman, Edlund & Soninkhishig, whereas the sole member of the Uureg Nuur plankton community is the endemic *Cyclotella uuregensis* Shinneman, Edlund & Soninkhishig.

Discussion

The first assessment of diatom diversity in Mongolia was published nearly 10 years ago (Edlund *et al*. 2001) and reported 547 diatom taxa based on review of the published literature and new distributional reports. A revision of that checklist (including other algal groups) has been published by Dorofeyuk and Tsetsegmaa (2002). Since the original checklist, other studies have expanded sampling efforts to new regions, including the western Valley of the Great Lakes (Soninkhishig *et al*., 2003; Shinneman *et al*., 2009a, b, c; Edlund *et al*., 2009, this study), the Buir Nuur region (Soninkhishig & Edlund, 2001), the Lake Hövsgől region (Edlund *et al*., 2006; Levkov, 2009), the Khugnu Khaan region (Soninkhishig *et al*., 2002), the Kharaa River basin (Bukhchuluun *et al*., this volume), an overall lake survey (Tsetsegmaa, 2008), the Khentii Mountain region (Metzeltin *et al*., 2009), and Nur bog (Kulikovskiy *et al*., 2010). These surveys have added considerably to the diversity and documented distributions of diatoms in Mongolia.

Other studies have focused on specific elements of Mongolia's diatom flora for their taxonomic or biodiversity interest. Edlund *et al*. (2000, 2001, 2006) used Mongolian material to study uncommon diatom groups such *Eunotia clevei* Grunow *ex* Cleve, *Biremis zachariasii* (Reichelt) Edlund, Andresen & Soninkhishig, and *Decussata placenta* (Ehrenb.) Lange-Bertalot & Metzeltin. Shinneman *et al*. (submitted) monographed the *Cyclotella sensu lato* flora of western Mongolian lakes. Some diatom groups, such as *Hannaea arcus* (Ehrenb.) R.M. Patrick and its allies have especially high diversity in and near Mongolia (Bixby 2001; Bixby *et al*. 2005). Levkov *et al*. (2009) used material from Lake Hövsgől as part of his monograph of the genus *Amphora sensu lato*. Yoshitake *et al*. (2009) also used Hövsgől material to identify multiple forms of *Gomphonema ventricosa* W. Greg. and to compare Hövsgől's populations to other collections. Other examples of high or interesting diversity in Lake Hövsgől include the small fragilarioid taxa (Morales & Edlund, 2003; Morales *et al*., 2010), the plankton (Edlund *et al*. 2003), and the *Navicula reinhardtii* Grunow in Cleve & J.D.Möller complex (Edlund *et al*. 2006; Edlund & Soninkhishig, 2009).

With so much work focused on the diversity and taxonomy of Mongolia's diatoms, many new species have been discovered and described in the last decade. The largest addition to the flora was Metzeltin *et al*. (2009), in which 64 new species were formally described and 615 total taxa were reported from collections made primarily in the Khentii Mountains. Kulikovskiy et al. (2010) described 18 new species from a Mongolian bog and used Mongolian material to support the description of one new genus. Williams and Reid (2006) described a new taxon from a Mongolian spring, *Amphorotia stoermeri* Williams & Reid, in their monograph of the new genus *Amphorotia*. Lake Hövsgől continues to be a Mongolian biodiversity hotspot. Edlund *et al*. (2003) described two new *Stephanodiscus* species and Pappas & Stoermer (2003) described a new *Asterionella* from the Hövsgől plankton. Morales & Edlund (2003) and Morales *et al*. (2010) described three new small fragilarioid species from the Hövsgől region. Levkov (2009) described four new *Amphora* species and identified strong connections between the *Amphora* floras of Lake Hövsgől and Lake Baikal. Finally, Edlund and Soninkhishig (2009) formally described the members of the Hövsgől *Navicula reinhardtii* species flock.

New species have also been discovered in Mongolia's VOGL region. Edlund *et al*. (2009) described a small *Amphora* species, *A. soninkhishigae* Edlund, Shinneman & Levkov, found in two saline lakes, Uvs Nuur and Oigon Nuur. Shinneman *et al*. (submitted) described three new cyclotelloid species from western Mongolian lakes. Two of the species, *Puncticulata khyargasiana* Shinneman, Edlund & Soninkhishig and *Cyclotella uuregensis* Shinneman, Edlund & Soninkhishig, appear to be endemic to their type localities, Khyargas and Uureg Nuur, respectively. Notable within the list of diatom species found in western Mongolia are the large numbers of provisionally named taxa (Appendix 1), such as the *Opephora* spp. Diatoms given provisional identifiers represent taxa that are likely undescribed. Efforts have been made to formally describe provisional taxa that were found in relatively high abundance (Edlund *et al*. 2009; Shinneman *et al*., submitted), but the minor provisionally named taxa are a testament to the undiscovered diatom diversity that awaits researchers working in Mongolia.

Diatoms are increasingly being used in Mongolia in applied studies such as indicator species for water quality assessments (Soninkhishig *et al*., 1999, 2001). Importantly, several studies over the last decade have made use of diatoms as paleo-ecological and paleo-climate studies (Tarasov *et al*., 2000; Peck *et al*., 2002; Soninkhishig *et al*., 2003; Fedotov *et al*., 2000, 2004; Rudaya *et al*. 2008; Shinneman *et al*., 2009a, b,c), highlighting the need for a continued dialog on the taxonomy and ecological distributions of the group. Sampling for the current VOGL survey was designed to develop a diatom calibration model that could be used to interpret historical ecological change in sediment records (Shinneman *et al*., 2009a). Diatom abundance and distribution in western Mongolian lakes were strongly controlled by specific conductance, bicarbonate ion, and total phosphorus; as such, subfossil diatom assemblages could be used to quantitatively reconstruct trophic state and lake salinity (Shinneman *et al*., 2009a, b, c). Diatoms in recent sediment records record an increase in nutrients in five western Mongolian lakes; these recent changes could be attributed to both increased intensity of grazing and recent climatic warming (Shinneman *et al*., 2009b). Diatoms in longer sediment records record a negative correlation between temperature and effective moisture (Shinneman *et al*., 2009c). Assemblage changes in the most recent decades in the long cores indicate a more complex set of drivers are likely affecting lakes in western Mongolia including landscape-level changes in nutrient dynamics (livestock), and climate change, which is primarily manifested as an ecological response to warmer winters. The recent changes in diatom assemblages in western Mongolian lakes are unprecedented in the longer core records (Shinneman *et al*., 2009c) and convey a critical need to better understand the connections between aquatic biodiversity, water quality, and the landscape and climate drivers that are impacting Mongolia's lakes.

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Хураангуй

Монгол орны баруун хэсэгт байрлах Их Нууруудын Хотгорын (ИНХ) ай сав нь хоёр үндсэн (Увс, Хяргас) томоохон нуур болон

олон жижиг гадагш урсгалгүй нууруудын системээс бүрдэнэ. 2004, 2005 онд бид Баруун Монголд байрлах Увс, Ховд, Завхан, Баян-Өлгий аймгийн нутагт 64 нуурын ёроолын өнгөн хурдаснаас цахиур замгийн дээж цуглуулсан юм. Нуурууд ИНХ-оос Алтайн өндөр уулсын хооронд янз бүрийн өндөрлөгт орших ба усны химийн хувьд цэнгэгээс хэт давстай, олиготрофоос хэт трофик шинжтэй байв. Хурдаснаас 300 гаруй зүйлийн цахиур замаг илрүүлсний дотор өргөн тархалттай болоод давстай нуурт тохиолдох зүйлүүд цөөнгүй байгаагийн зэрэгцээ Монголын цахиур замгийн бүрэлдэхүүнд олон зүйл шинээр тэмдэглэгдэж, эндемик байх магадлалтай хэд хэдэн зүйл бүртгэгдлээ. Мөн энэ өгүүлэлд Монгол орны цахиур замгийн бүрэлдэхүүн, палео-экологи, усны чанарын сүүлийн үеийн судалгааны бүтээлүүдийг тоймлон өгүүлсэн болно.

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Appendix 1. Diatom species recorded from 64 surface sediment samples from lakes in western Mongolia's Valley of the Great Lakes region. Taxa with ([1]) are new species described from VOGL samples and taxa that are underlined represent new reports for Mongolia since Edlund *et al*. (2001) was published; however, some of the new taxa have been reported in other recently published studies.

Centric diatoms
Aulacoseira ambigua (Grunow) Simonsen
Aulacoseira granulata (Ehrenb.) Simonsen
Chaetoceros mong. 1 (provisional name)
Chaetoceros mong. 2 (provisional name)
[1]*Cyclotella buyantsogii* A.L.C. Shinneman, M.B. Edlund & N. Soninkhishig
Cyclotella choctawatcheeana Prasad
Cyclotella meneghiniana Kütz.
Cyclotella ocellata Pant.
Cyclotella siberica Skabitschevsky
[1]*Cyclotella uuregensis* A.L.C. Shinneman, M.B. Edlund & N. Soninkhishig
Discostella pseudostelligera (Hust.) Houk & Klee
Melosira monofiliformis (O.F. Müller) Agardh
[1]*Puncticulata khyargusiana* A.L.C. Shinneman, M.B. Edlund & N. Soninkhishig
Puncticulata radiosa (Lemmerman) Hekansson
Stephanodiscus minutulus (Kütz.) Cleve & J.D.Möll.

Araphid diatoms
Asterionella formosa Hass.
Ctenophora pulchella (Ralfs ex Kütz.) D.M.Williams & Round
Diatoma moniliformis Kütz.
Diatoma tenue C. Agardh
Diatoma vulgaris Bory
Fragilaria capucina mesolepta (Rabenh.) Rabenh.
Fragilaria capucina Desm.
Fragilaria nanana Lange-Bert.
Fragilaria tenera (W. Smith) Lange-Bert.
Fragilaria vaucheriae (Kütz.) Petersen
Fragilariforma virescens (Ralfs) D.M.Williams & Round
Martyana martyi (Héribaud) Round in Round, Crawford & Mann
Opephora mong. 1 (provisional name)
Opephora mong. 2 (provisional name)
Opephora mong. 3 (provisional name)
Opephora mong. 4 (provisional name)
Opephora mong. 5 (provisional name)
Pseudostaurosira brevistriata var. *inflata* (Hust.) D.M. Williams & Round
Pseudostaurosira brevistriata (Grunow in VanHeurck) D.M. Williams & Round
Pseudostaurosira elliptica (Schumann) M.B. Edlund, Morales & Spaulding
Pseudostaurosira elliptica var. *1* (provisional name)
Pseudostaurosira polonica (Witak & Lange-Bert.) Morales & M.B. Edlund
Pseudostaurosira pseudosconstruens (Marciniak) D.M. Williams & Round
Pseudostaurosira robusta (Fusey) D.M.Williams & Round
Pseudostaurosira subsalina (Hust.) Morales
Staurosira construens binodis (Ehrenb.) P.B.Ham. in Ham., Poulin, Prévost, Angell & Edlund
Staurosira construens mong. 1 (provisional name)
Staurosira construens mong. 2 (provisional name)
Staurosira construens trinodis (Ehrenb.) P.B.Ham. in Ham., Poulin, Prévost, Angell & Edlund
Staurosira construens Ehrenb.
Staurosira construens subsalina Hust.
Staurosira construens pumila (Grunow) Kingston
Staurosira venter mong. 1 (provisional name)
Staurosira venter mong. 2 (provisional name)
Staurosira venter mong. 3 (provisional name)
Staurosirella lapponica (Grunow in VanHeurck) D.M. Williams & Round)
Staurosirella oldenburgiana Hust. (Morales)
Staurosirella pinnata var. *intercedens* (Grunow in VanHeurck)
Staurosirella pinnata var. *lancettula* (Schumann) E.Y.Haw. & M.G.Kelly
Staurosirella pinnata Ehrenb.
Synedra cyclopum Brutschy
Synedra parasitica (W. Sm.) Hust.
Synedra radians Kütz.
Synedra ulna (Nitzsch) Ehrenb.
Synedra ulna acus Kütz.
Tabularia fasciculata (C.Agardh) D.M.Williams & Round

Eunotioid diatoms
Eunotia septentrionalis Østrup
Eunotia clevei Grunow ex Cleve

Monoraphid diatoms
Achnanthes bahusiensis (Grunow) Lange-Bert.
Achnanthes conspicua Mayer
Achnanthes holsatica Hust.
Achnanthes laevis Østrup
Achnanthes minuscula Hust.
Achnanthes ziegleri Lange-Bert.
Achnanthes brevipes C. Agardh
Achnanthes cf. grischuna (provisional name)
Achnanthes grischuna Wuthrich
Achnanthes jourascence Heribaud
Achnanthes levanderi Hust.
Achnanthes mong. 1 (provisional name)
Achnanthes rosenstockii Lange-Bert.
Achnanthidium exiguum (Grunow) Czarn.
Achnanthidium minutissimum var. *inconspicuum* Østrup
Achnanthidium minutissimum (Kütz.) Czarn.
Cocconeis disculus (Schum.) P.T. Cleve in P.T. Cleve & Jentzsch
Cocconeis neothumensis Krammer
Cocconeis pediculus Ehrenb.
Cocconeis placentula var. *klinoraphis* Geitler
Cocconeis placentula var. *baicalensis* Skvortzow
Cocconeis placentula var. *euglypta* (Ehrenb.) Grunow
Cocconeis placentula var. *lineata* (Ehrenb.) VanHeurck
Eucocconeis flexella (Kütz.) Cleve
Karayevia clevei (Grunow in Cleve & Grunow) Round & Bukhtiyarova
Karayevia clevei var. *rostrata* (Hust.) J.C. Kingston
Lemnicola hungarica Grunow (Grunow)
Planothidium delicatulum (Kütz.) Round & Bukhtiyarova
Planothidium dubium (Grunow) Round & Bukhtiyarova
Planothidium frequentissimum (Lange-Bert. in Krammer & Lange-Bert.) Lange-Bert.
Planothidium lanceolatum var. *biporoma* (Hohn & Hellermann) Lange-Bert.
Planothidium lanceolatum var. *rostratum* (Østrup) Hust.
Planothidium lanceolatum (Bréb. ex Kütz.) Round
Planothidium peragalli (Brun & Héribaud) Round & Bukhtiyarova
Psammothidium bioretti (H. Germ.) Bukhtiyarova & Round
Psammothidium cf. sacculum (Carter) Bukhtiyarova

Naviculoid diatoms
Anomoeoneis sphaerophora (Ehrenb.) Pfitz.
Anomoeoneis sphaerophora (Kütz.) A.M.Schmid
Brachysira aponina Kütz.
Brachysira liliana Lange-Bert.
Brachysira unknown 1 (provisional name)
Brachysira vitrea (Grunow) R.Ross in B.Hartley
Caloneis bacillum (Grunow) Cleve
Caloneis schumanniana var. *lancettula* Hust.
Caloneis schumanniana (Grunow) Cleve
Caloneis silicula (Ehrenb.) P.T. Cleve
Craticula accomoda Hust.
Craticula ambigua (Ehrenb.) D.G.Mann in Round, Crawford & Mann

Craticula cuspidata (Kütz.) D.G.Mann in Round, Crawford & Mann
Craticula halophila (Grunow) D.G. Mann in Round, Crawford & Mann
Diploneis elliptica (Kütz.) P.T. Cleve
Diploneis puella (Schum.) P.T. Cleve
Fallacia pygmaea (Kütz.) Stickle & D.G. Mann in Round, Crawford & Mann
Geissleria decussis mong. 1 (provisional name)
Geissleria decussis (Østrup) Lange-Bert.&Metzeltin
Geissleria schoenfeltii Hust.
Gyrosigma obtusatum (Sulliv & Wormley) Boyer
Gyrosigma spenceri (Quek.) J.W.Griff. & Henfr.
Hippodonta capitata (Grunow) Lange-Bert., Metzelin & Witkowski
Hippodonta costulata (Grunow) Lange-Bert., Metzelin & Witkowski
Hippodonta hungarica (Grunow) Lange-Bert., Metzeltin & Witkowski
Hippodonta linearis (Østrup) Lange-Bert., Metzeltin & Witkowski
Hippodonta subcostulata (Hust.) Lange-Bert., Metzelin & Witkowski
Luticola mutica Kütz.
Mastogloia elliptica (Agardh) Cleve in Schmidt et al.
Mastogloia smithii var. *amphicephala* Grunow
Mastogloia smithii var. *lacustris* Grunow
Mastogloia smithii Thwaites
Navicula absoluta Hust.
Navicula capitatoradiata Germain
Navicula cari Ehrenb.
Navicula cincta (Ehrenb.) Ralfs
Navicula clementis Grunow
Navicula clementoides Hust.
Navicula concentrica J.W. Bailey
Navicula crucicula var. *cruciculoides* Brockmann
Navicula cryptocephala Kütz.
Navicula cryptotenella Lange-Bert.
Navicula digitoradiata (Greg.) Ralfs in A.Pritch.
Navicula diluviana Krasske
Navicula eidrigiana Carter
Navicula elegans W.Sm.
Navicula germainii Wallace
Navicula gottlandica Grunow
Navicula gregaria Donkin
Navicula incerta Grunow
Navicula jaernfeltdii Hust.
Navicula jentzschii Grunow
Navicula libonensis Schoeman
Navicula menisculus Schum.
Navicula menisculus var. *upsaliensis* (Grunow in Cleve & Grunow) Grunow in VanHeurck
Navicula minima Grunow in Van Heurck
Navicula moskalii Metzeltin, Witkowski & Lange-Bert.
Navicula oblonga (Kütz.) Kütz.
Navicula phyllepta Kütz.
Navicula placentula (Ehrenberg) Grunow
Navicula praeterita Hust.
Navicula protracta (Grunow in P.T. Cleve & Grunow) P.T. Cleve
Navicula pseudanglica Lange-Bert.
Navicula pseudolanceolata Lange-Bert.
Navicula pseudoscutiformis Hust.
Navicula pseudotuscula Hust.
Navicula pseudoventralis Hust.
Navicula radiosa Kütz.
Navicula recens (Lange-Bert.) Lange-Bert.
Navicula reinhardtii Grunow in P.T. Cleve & J.D. Möller
Navicula rhynchocephala Kütz.
Navicula salinarum Grunow
Navicula scutelloides W. Sm.
Navicula slesvicensis Grunow
Navicula subplacentula Hust.
Navicula subrotunda Hust.
Navicula tenelloides Hust.
Navicula trivialis Lange-Bert.
Navicula trophicatrix Lange-Bert.
Navicula veneta Kütz.
Navicula vitabunda Hust.
Navicula humerosa Breb. ex W. Sm.
Neidium ampliatum (Ehrenb.) Krammer in Krammer & Lange-Bert.
Neidium distincte-punctatum Hust.
Parlibellus crucicula (W.Sm.) Donkin
Pinnularia brebissonii (Kütz.) Rabenh.
Pinnularia lundii Hust.
Pinnularia subrostrata (A.Cleve) A.Cleve
Pinnularia viridiformis Krammer
Pinnularia microstauron (Ehrenb.) P.T. Cleve
Pinnularia petersenii Krammer & Lange-Bert.
Pleurosigma australe Grunow
Pleurosigma salinarum Grunow
Sellaphora bacillum (Ehrenb.) D.G. Mann
Sellaphora pupula (Kütz.) Mereschk.
Sellaphora auldreekie D. G. Mann & S. M. McDonald
Stauroneis anceps fo. *gracilis* Rabenh.
Stauroneis smithii Grunow

Amphiproroid diatoms
Entomoneis mong. 1 (provisional name)

Amphoroid diatoms
Amphora aequalis Krammer
Amphora coffeaeformis (C.Agardh) Kütz.
Amphora coffeaeformis var. 1 (provisional name)
Amphora coffeaeformis var. 2 (provisional name)
Amphora commutata Grunow
Amphora inariensis Krammer
Amphora libyca Ehrenb.
Amphora ovalis (Kütz.) Kütz.
Amphora perpusilla (Grunow) Grunow in VanHeurck
[1]*Amphora soninkhishigae* Edlund, Shinneman & Levkov
Amphora thumensis (Mayer) A.Cleve
Amphora unknown 1 (provisional name)
Amphora unknown 3 (provisional name)
Amphora veneta var. *capitata* E.Y.Haw.
Amphora veneta Kütz.

Gomphocymbelloid diatoms
Cymbella affinis Kütz.
Cymbella amphicephala Nägeli
Cymbella cf. stigmaphora (provisional name)
Cymbella cymbiformis C. Agardh
Cymbella ehrenbergii Kütz.
Cymbella hantzschiana Krammer
Cymbella helvetica Kütz.
Cymbella laevis Nägeli ex Kütz.
Cymbella neocistula Krammer
Cymbella neoleptoceros Krammer
Cymbella reinhardtii Grunow
Cymbella stigmaphora Østrup
Cymbella subaequalis Grunow
Cymbella subhelvetica Krammer
Cymbella vulgata Krammer
Cymbella subleptoceros Krammer
Encyonema cf. silesiacum (provisional name)
Encyonema minutum (Krasske) C.W.Reimer
Encyonema minutum (Hilse in Rabenhorst) D.G. Mann in Round, Crawford & Mann
Encyonema silesiacum (Bleisch in Rabenhorst) Mann in Round, Crawford & Mann
Encyonopsis cesatii (Rabenh.) Krammer
Encyonopsis microcephala (Grunow) Krammer
Gomphonema angustum (Kütz.) Rabenh.
Gomphonema auritum A. Braun ex Kütz.
Gomphonema dichotomum Kütz.
Gomphonema gracile Ehrenb. emend. VanHeurck
Gomphonema herbidense Gregory

Gomphonema mong. 1 (provisional name)
Gomphonema olivaceum var. *calcareum* (P.T. Cleve) P.T. Cleve
Gomphonema pumilum (Grunow) Reich. & Lange-Bert.
Gomphonema tenellum Kütz.
Gomphonema truncatum Ehrenb.
Gomphonema utae Lange-Bert. & Reich.
Gomphonema parvulum Kütz.(Kütz.)
Navicymbula pusilla (Grunow) Krammer
Reimeria sinuata Gregory (Kociolek & Stoermer)
Rhoicosphenia abbreviata (C. Agardh) Lange-Bert.

Epithemioid diatoms
Denticula kuetzingii Grunow
Denticula subtilis Grunow
Denticula tenuis Kütz.
Epithemia adnata (Kütz.) Bréb.
Epithemia frickei Krammer
Epithemia smithii Carruthers
Epithemia sorex Kütz.
Rhopalodia gibba (Ehrenb.) O.Müll.

Nitzschioid diatoms
Hantzschia amphioxys (Ehrenb.) Grunow
Hantzschia distinctepunctata (Hust.) Hust.
Nitzschia acuminata (W.Sm.) Grunow
Nitzschia angustata (W.Sm.) Grunow
Nitzschia bacillum Hust.
Nitzschia bergii Hust.
Nitzschia commutata Grunow
Nitzschia constricta (Kütz.) Ralfs
Nitzschia dissipata var. *media* (Hantzsch) Grunow
Nitzschia dissipata (Hantzsch) Grunow
Nitzschia eglei Lange-Bert.
Nitzschia frustulum mong. 1 (provisional name)
Nitzschia frustulum (Kütz.) Grunow
Nitzschia graciliformis Lange-Bert. & Simonsen
Nitzschia heufleriana Grunow
Nitzschia inconspicua Grunow
Nitzschia lacuum Lange-Bert.
Nitzschia levidensis var. *salinarum* Grunow
Nitzschia liebetruthii Rabenh.
Nitzschia mong. 1 (provisional name)
Nitzschia mong. 2 (provisional name)
Nitzschia mong. 3 (provisional name)
Nitzschia obtusa var. *schweinfurthii* (Grunow) Grunow in Cleve & Grunow
Nitzschia palea (Kütz.) W.Sm.
Nitzschia pura Hust.
Nitzschia pusilla Grunow
Nitzschia recta Hantzsch ex Rabenh.
NItzschia sigmoidea (Nitzsch) W. Sm.
Nitzschia sublinearis Hust.
Nitzschia thermaloides Hust.
Nitzschia acicularis (Kütz.) W. Sm.
Nitzschia amphibia Grunow
Nitzschia intermedia Hantzsch
Nitzschia linearis var. *subtilis* (Grunow) Hust.
Nitzschia linearis (C. Agardh) W.Sm.
Nitzschia paleacea Grunnow in Van Heurck
Nitzschia perminuta (Grunow) Perag.

Surirelloid diatoms
Campylodiscus bicostatus W.Sm. in Roper
Campylodiscus clypeus Ehrenb.
Cymatopleura elliptica var. *hibernica (W.Sm.) Van Heurck*
Cymatopleura elliptica (Bréb. in Kütz.) W. Sm.
Cymatopleura solea var. *apiculata (W. Sm.) Ralfs*
Cymatopleura solea (Bréb. & Godey) W.Sm.
Surirella bifrons Ehrenb.
Surirella brebissonii Krammer & Lange-Bert.
Surirella brightwellii W. Sm.
Surirella capronii Breb. in Kitton
Surirella minuta Breb. in Kütz.
Surirella peisonis Pant.