water

Article

Revision of Monoraphid Diatom Genus *Platessa* with Description of *Platesiberia* gen. nov. from Ancient Lake Baikal

Maxim S. Kulikovskiy [1,*], Anton M. Glushchenko [1], Sergei I. Genkal [2], Irina V. Kuznetsova [1] and John Patrick Kociolek [3]

1 K.A. Timiryazev Institute of Plant Physiology RAS, IPP RAS, 35 Botanicheskaya St., 127276 Moscow, Russia
2 Papanin Institute for Biology of Inland Waters, Russian Academy of Sciences, 152742 Borok, Russia
3 Museum of Natural History, Henderson Building, 15th and Broadway, Boulder, CO 80309, USA
* Correspondence: max-kulikovsky@yandex.ru; Tel.: +7-916-456-4370; Fax: +7-499-678-5420

Abstract: A new monoraphid diatom genus, *Platesiberia* gen. nov., is described based on a detailed morphological investigation using light and scanning electron microscopy. The genus is based upon *P. rhombicolanceolata* Kulikovskiy & Lange-Bertalot and includes *Platessa baicalensis* Kulikovskiy & Lange-Bertalot, both species previously described from ancient Lake Baikal. *Platesiberia* gen. nov. is characterized by having biseriate striae on the raphe valves with uniseriate striae on the rapheless valves. Morphology of striae is helpful to distinguish the genus *Platesiberia* from *Platessa* and other monoraphid genera, and we provide a comparison of the new Baikalian genus with other freshwater monoraphid groups.

Keywords: *Platesiberia*; *Platessa*; new genus; morphology; Eastern Siberia; Baikal

check for updates

Citation: Kulikovskiy, M.S.; Glushchenko, A.M.; Genkal, S.I.; Kuznetsova, I.V.; Kociolek, J.P. Revision of Monoraphid Diatom Genus *Platessa* with Description of *Platesiberia* gen. nov. from Ancient Lake Baikal. *Water* **2022**, *14*, 2957. https://doi.org/10.3390/w14192957

Academic Editors: Kay Van Damme and Alexey A. Kotov

Received: 17 August 2022
Accepted: 16 September 2022
Published: 21 September 2022

1. Introduction

Over the past 25 years the monoraphid diatoms have been the focus of intense research on their diversity, taxonomy and systematics. Whereas 2–3 generations ago, the freshwater representatives of monoraphid diatoms were treated as two genera, *Achnanthes* Bory and *Cocconeis* Ehrenberg [1–3], now there are over 14 genera of freshwater monoraphid diatoms that were once considered part of or assignable to *Achnanthes* sensu lato [4–12]. This discovery of diversity amongst the freshwater achnanthioid diatoms, both through recognition of past genera and newly discovered taxa, has been facilitated by observations made with scanning electron microscopes, revealing morphological features and patterns not previously recognized. New species descriptions from the world over have shown many consistencies in the distribution of the features used to diagnose new genera of monoraphid diatoms. However, there have also been some "intermediate" species recognized that might serve to link genera previously recognized as separate [13,14]. Molecular data have revealed that there have been several different, independent lineages within which the monoraphid condition has evolved [9,15], while many of the newly created and resurrected genera have been shown to be monophyletic [9].

More than 1500 species of diatoms inhabit Lake Baikal [7–9,16–36]. During a revision of the monoraphid diatoms from Lake Baikal, about 55 new species were described [7,8,35,36]. *Karayevia* Round & Bukhtiyarova 1998, *Skabitschewskia* Kulikovskiy & Lange-Bertalot 2015, *Nupela* Vyverman & Compère 1991 and *Planothidium* Round & Bukhtiyarova 1996 have the greatest diversity of species among the monoraphid diatoms in the world's oldest lake [8]. During this revision, many new monoraphid taxa were described from the genera: *Eucocconeis* P.T. Cleve ex F. Meister 1912, *Karayevia*, *Nupela*, *Planothidium*, *Platessa* Lange-Bertalot 2004 [8], *Skabitschewskia*, *Trifonovia* Kulikovskiy & Lange-Bertalot 2012 and *Gliwiczia* Kulikovskiy, Lange-Bertalot & Witkowski 2013. Two species of the diatom genus, *Platessa*, *P. baicalensis* Kulikovskiy & Lange-Bertalot and *P. rhombicolanceolata* Kulikovskiy & Lange-Bertalot, were described during this revisionary work [8].

In the last revision of the genus *Platessa* Lange-Bertalot, we indicated that eight groups within the genus could be recognized on the basis of morphological features [9]. Two interesting species previously described and placed in the genus *Platessa* stood out as a separate group [9]. This group includes both *P. baicalensis* and *P. rhombicolanceolata* [8], which are characterized by having biseriate striae on the raphe valve and uniseriate striae in rapheless valves. Most *Platessa* species have biseriate striae on both valves. In light of this difference, we postulated that the morphology of these species differs from the generitype of *Platessa*, *P. bavarica* Lange-Bertalot & Hofmann [37] and thus may require an independent genus to accommodate them [9]. It is interesting that Lake Baikal harbors taxa that do not share important morphological features typical of the generitype.

We have also carefully described all morphological features important for the taxonomy of monoraphid diatoms and postulated striae that are uniseriate, biseriate or multiseriate on the raphe and rapheless valves, as well as combinations of these features, which are important for the taxonomy of this group of diatoms. The same opinion was supported by molecular investigations for species and genera of monoraphid diatoms when possible [11,38–42]. Lange-Bertalot [37] proposed *Platessa* on the basis of morphological features with predominantly biseriate striae in both valves and small, elliptic, flat valves with morphologically similar raphe and rapheless valves; the presence of a stauros-like structure on the rapheless valves; and areolae of both valves occluded by hymenes. Since its original description, *Platessa* has become a catch-all genus with taxa representing many monoraphid genera with unknown taxonomical positions [9,43].

The aim of this publication is to provide additional morphological evidence for two monoraphid diatoms, *Platessa baicalensis* Kulikovskiy & Lange-Bertalot and *P. rhombicolanceolata* Kulikovskiy & Lange-Bertalot, and, based on the results of this study, to describe the genus *Platesiberia* gen. nov.

2. Materials and Methods

For this study we used samples from Lake Baikal collected by A.P. Skabitschewsky on 20 July 1965 from bottom deposits surrounding Ushkan'i Islands, obtained from the collection of Galina Khursevich (Minsk, Belarus). For a complete list of samples, please consult Kulikovskiy et al. [36]. The genus proposed here is based on species present in two samples: sample number 15,645 m—substratum: sand, Ushkan'i Islands 42 m depth, off Bolshoi Ushkan'i Island—and sample number 15,651 m—substratum: sand, Ushkan'i Islands 4 m depth, eastern shore.

The samples were boiled in concentrated hydrogen peroxide (≈37%) to dissolve organic matter. The samples were then washed with deionized water four times at 12 h intervals. After decanting and rinsing with up to 100 mL of deionized water, the suspension was spread onto coverslips and left to dry at room temperature. Permanent diatom slides were mounted in Naphrax®. Light microscopic (LM) observations were performed with a Zeiss Scope A1 microscope equipped with an oil immersion objective (100×, n.a. 1.4, differential interference contrast [DIC]) and Zeiss AxioCam ERc 5s camera. For scanning electron microscopy (SEM), parts of the suspensions were fixed on aluminum stubs after air-drying. The stubs were sputter coated with 50 nm of gold. Valve ultrastructure was examined by means of a JSM-6510LV scanning electron microscope (Institute for Biology of Inland Waters RAS, Borok, Russia).

3. Results

Platesiberia Kulikovskiy, Glushchenko, Genkal & Kociolek gen. nov.

Type species (designated here): *Platesiberia rhombicolanceolata* (Kulikovskiy & Lange-Bertalot) Kulikovskiy, Glushchenko, Genkal & Kociolek comb. nov.

Description. LM, raphe valves (Figure 1A–H). Valves elliptical to rhombical-lanceolate, ends broadly rounded in longer specimens and somewhat cuneately rounded in shorter specimens. Valves with straight, filiform raphes which are gradually expanded towards the central ends. Axial area more or less widely extended transapically defined by 1–4 irregularly shortened adjacent striae. Striae radiate and biseriate.

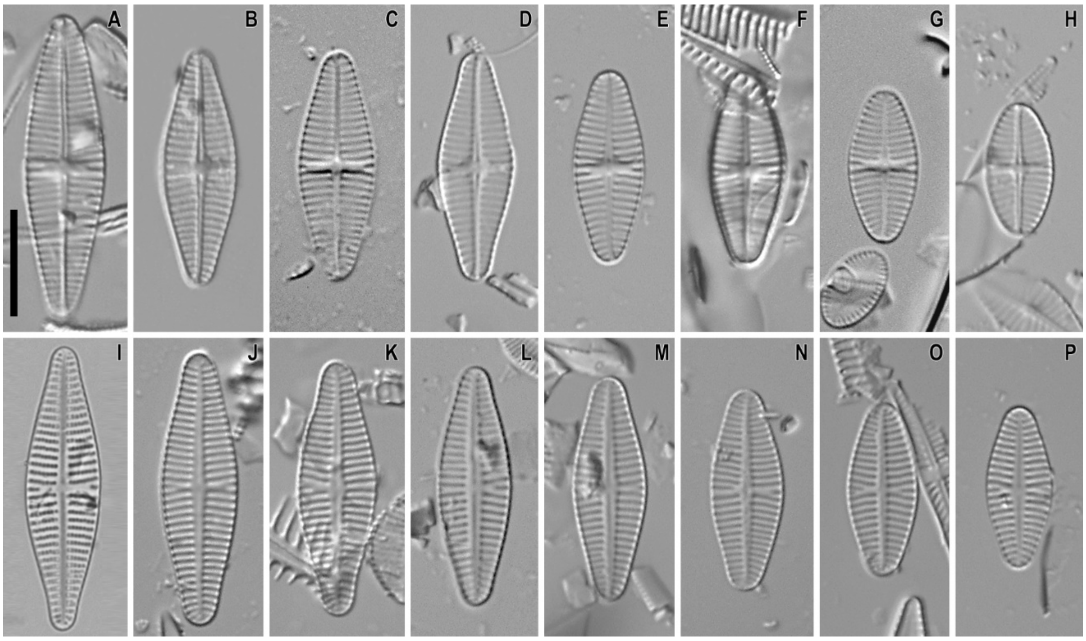

Figure 1. *Platesiberia rhombicolanceolata* (Kulikovskiy & Lange-Bertalot) Kulikovskiy, Glushchenko, Genkal & Kociolek comb. nov. Slide no. 15645m. Light microscopy, differential interference contrast, size diminution series. (**A**–**H**). Raphe valves. (**I**–**P**). Rapheless valves. Scale bar = 10 μm.

LM, rapheless valves (Figure 1I–P). Valves elliptical to rhombical-lanceolate, ends broadly rounded in longer and somewhat cuneately rounded in shorter specimens. Axial area widely extended transapically. The central area is almost absent and defined by 1–2 shorter striae. Striae uniseriate.

SEM, raphe valves (Figure 2A–H). Axial area flat, central area expanded on flat valve and organized by elevated interstriae outside. Axial area elevated internally, sternum evident, central area has evident stauros that is defined by highly elevated interstriae between shorter 1–2 striae. Striae biseriate and covered by silica membrane externally. Raphe filiform, distal raphe ends are tear-shaped, extending slightly onto valve mantle and turned in opposite directions externally. Internally, raphe is filiform, distal and central ends are turned to different sides. Central raphe ends are tear-shaped, straight externally and almost straight internally.

SEM, rapheless valves (Figure 3A–H). Interstriae very prominent, the same width as striae internally. Externally valves are flat, but the central area has elevated interstriae between a few shorter striae. Striae uniseriate. Axial area broad and widened towards the central area. Sternum evident and elevated internally.

Etymology. Combining epithet refers to the similarity with the genus *Platessa* and the locality from Eastern Siberia (Lake Baikal).

New combinations:

Platesiberia rhombicolanceolata (Kulikovskiy & Lange-Bertalot) Kulikovskiy, Glushchenko, Genkal & Kociolek comb. nov.

Basionym: *Platessa rhombicolanceolata* Kulikovskiy & Lange-Bertalot 2015. Lake Baikal: Hotspot of endemic diatoms II. Iconographia Diatomologica. V. 26. pp. 67–68. Figs 75: 11–13.

Platesiberia baicalensis (Kulikovskiy & Lange-Bertalot) Kulikovskiy, Glushchenko, Genkal & Kociolek comb. nov. (see Figure 4).

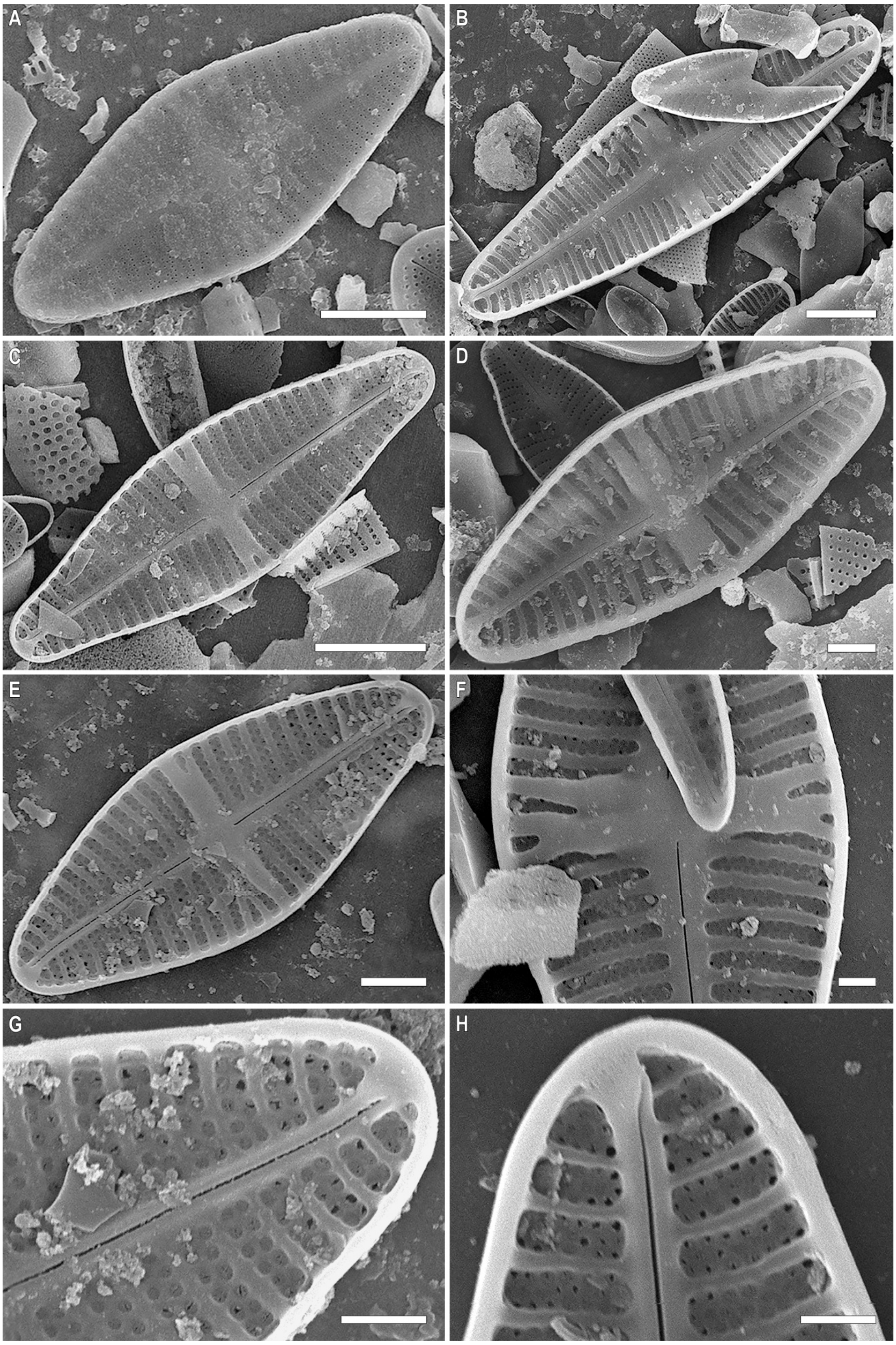

Figure 2. *Platesiberia rhombicolanceolata* (Kulikovskiy & Lange-Bertalot) Kulikovskiy, Glushchenko, Genkal & Kociolek comb. nov. Scanning electron microscopy. Raphe valves. (**A**)**.** The whole valve, external view. (**B**–**E**). Entire valve, internal views. (**F**). Central area, internal views. (**G**,**H**). Valve ends, internal views. Scale bar (**A**–**C**) = 5 µm; (**D**,**E**) = 2 µm; (**F**–**H**) = 1 µm.

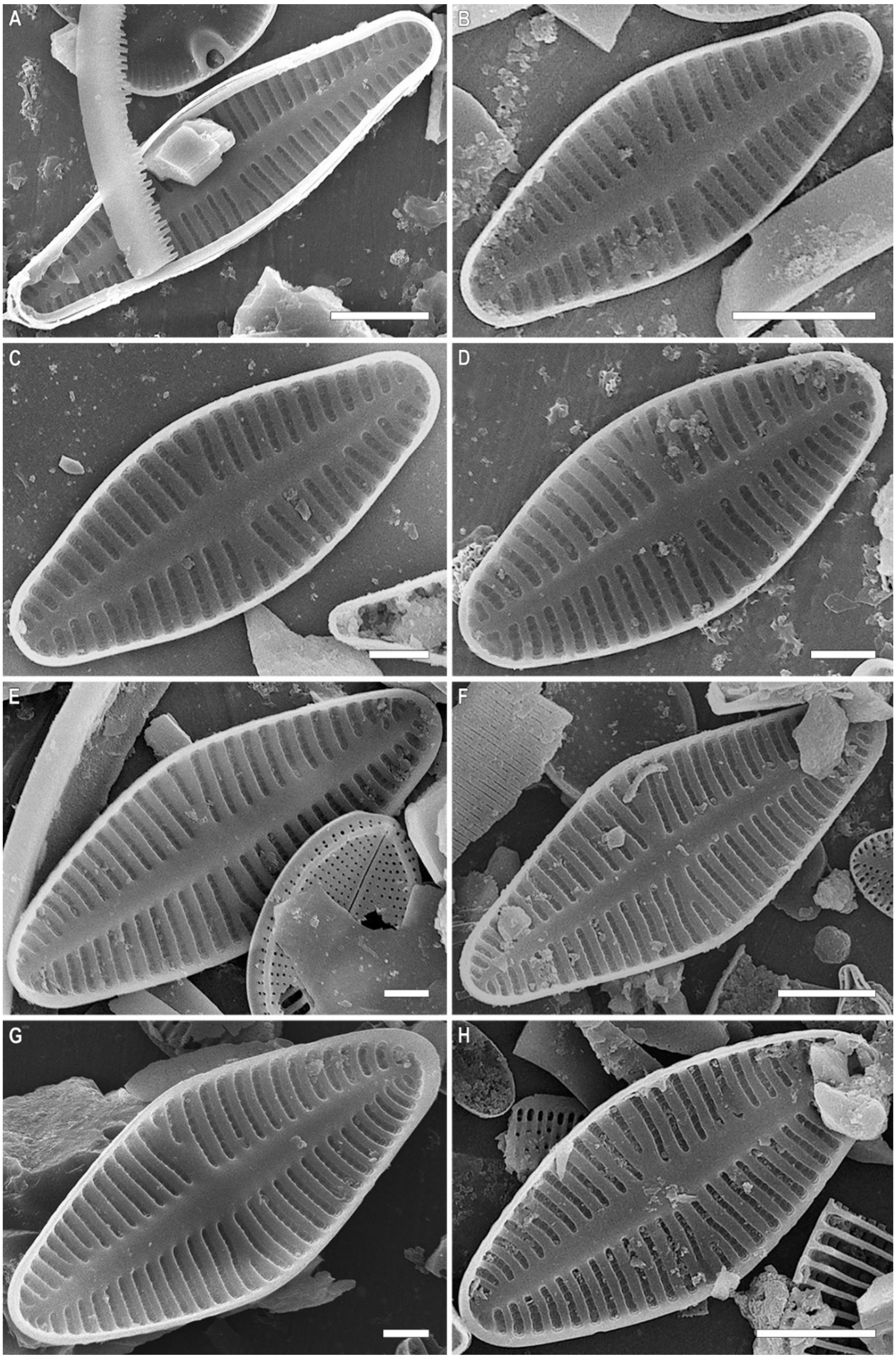

Figure 3. *Platesiberia rhombicolanceolata* (Kulikovskiy & Lange-Bertalot) Kulikovskiy, Glushchenko, Genkal & Kociolek comb. nov. Scanning electron microscopy. Rapheless valves, internal views. Scale bar (**A**,**B**,**F**,**H**) = 5 μm; (**C**–**E**,**G**) = 2 μm.

Basionym: *Platessa baicalensis* Kulikovskiy & Lange-Bertalot 2015. Lake Baikal: Hotspot of endemic diatoms II. Iconographia Diatomologica. V. 26. pp. 64–65. Figs 75: 1–10.

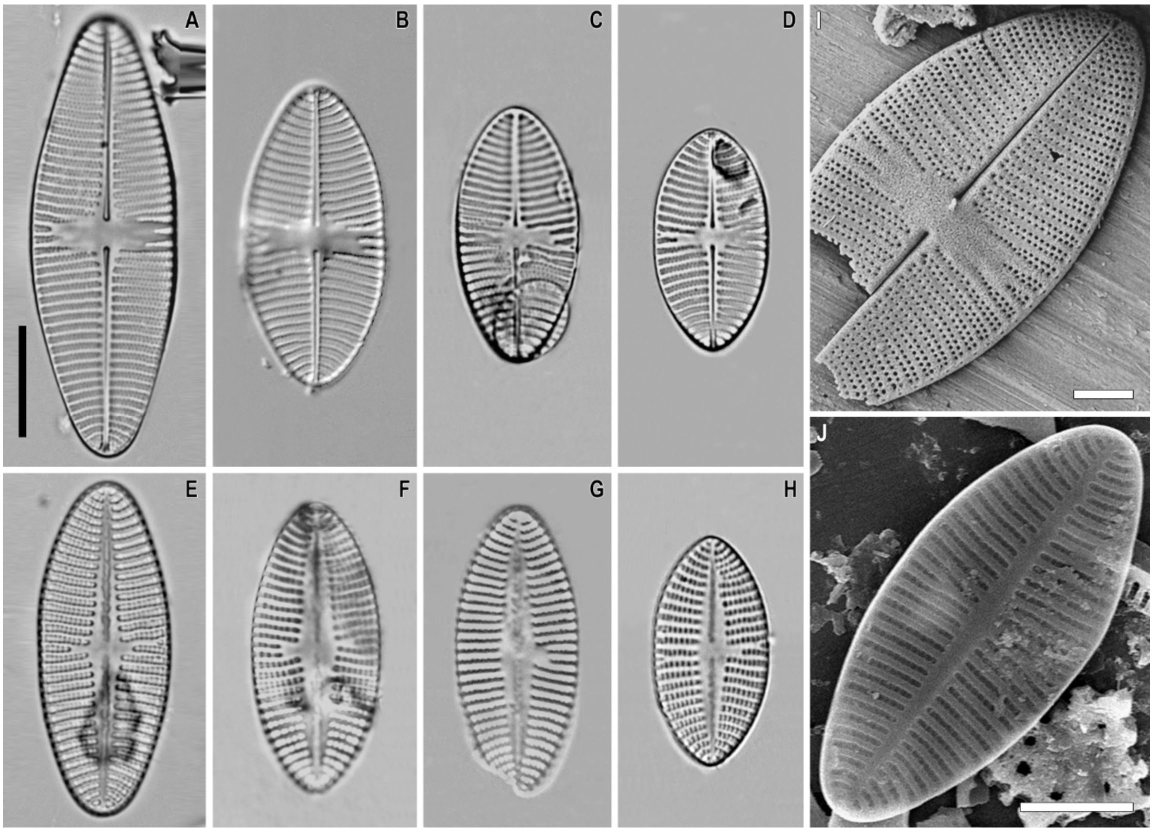

Figure 4. *Platesiberia baicalensis* (Kulikovskiy & Lange-Bertalot) Kulikovskiy, Glushchenko, Genkal & Kociolek comb. nov. Slide no. 15651m. (**A**–**H**). Light microscopy, differential interference contrast, size diminution series. (**I**,**J**). Scanning electron microscopy. (**A**–**D**,**I**)**.** Raphe valves. (**E**–**H**,**J**). Rapheless valves. Scale bar (**A**–**H**) = 10 µm; (**J**) = 5 µm; (**I**) = 3 µm.

4. Discussion

Platesiberia gen. nov. is a new genus that is very easily distinguished from other known freshwater monoraphid genera such as *Platessa*, *Achnanthidium*, *Skabitschewskia*, *Planothidium*, *Crenotia*, *Eucocconeis*, *Gliwiczia*, *Lemnicola*, *Psammothidium*, *Trifonovia* and *Platebaikalia* (see Tables 1 and 2) [6,9]. Our new genus is distinguished from other freshwater monoraphid genera on the basis of striation on both raphe and rapheless valves. *Platesiberia* gen. nov. is characterized by the presence of biseriate striae on raphe valves and uniseriate striae on rapheless valves, separating it from *Platessa* as typified by *P. bavarica*. Our new genus is somewhat similar to the genus *Lemnicola* on the basis on shape of the valve, which are elliptical or rhombical-elliptical.

However, *Lemnicola* is very easily distinguished by having areolae that are biseriate on both valves. *Skabitschewskia* is another genus described from Lake Baikal, but species from this taxon are known from Holarctic. This genus is like *Platesiberia* gen. nov. valves with uniseriate and biseriate valves, but they occur in opposite placements. In *Skabitschewskia*, biseriate striae are known in the rapheless valves, and uniseriate striae are found on the raphe valves. Moreover, *Skabitschewskia* is characterized by the presence of a cavum on the rapheless valves. The cavum is an important morphological feature and is absent in *Platesiberia* gen. nov. Another genus with a cavum is *Planothidium*, and this genus is also characterized by having multiseriate striae on both valves [9,44,45].

Another genus having a cavum is *Gliwiczia*, but unlike the condition seen in *Skabitschewskia* and *Lemnicola*, the cavum is present on both the raphe and rapheless valves [7]. *Gliwiczia* is characterized by having uniseriate striae on both valves like in other genera without a cavum. These other genera include *Trifonovia*, *Psammothidium*, *Eucocconeis*, *Achnanthidium*, *Gololobovia* and *Gogorevia* [8,10,11].

A very interesting feature of *Platesiberia* gen. nov. is the presence of a stauros that is evident externally and internally. However, this stauros has distinct interstriae in the central part between shorter striae. This structure is evident in raphe valves but less so in rapheless ones. A stauros, seen in *Platesiberica*, is also known in the monoraphid genera *Gliwiczia*, *Lemnicola*, *Gololobovia* and *Gogorevia* [7,9,10,38].

The stauros is much more evident in the genus *Gogorevia*, which is closely related to *Lemnicola* on the basis molecular data [10]. We can postulate that a stauros is not common among monoraphid freshwater diatom genera and that the morphology of this structure in the genus *Platesiberia* gen. nov. is unique. We need more molecular phylogenetic investigations to understand evolution of this feature between monoraphid diatoms. *Gogorevia* and *Lemnicola* are phylogenetically close genera, and we can postulate that the stauros arose once in this group.

Table 1. Comparison of *Platesiberia* gen. nov. with *Platessa* and related monoraphid genera.

	***Platesiberia* gen. nov.**	***Platessa***	***Platebaikalia***	***Gogorevia***
Type species	*P. rhombicolanceolata* (Kulikovskiy & Lange-Bertalot) Kulikovskiy, Glushchenko, Genkal & Kociolek comb. nov.	*P. bavarica* Lange-Bertalot & Hofmann 2004	*P. elegans* Kulikovskiy, Glushchenko & Kociolek	*G. renatii* Kulikovskiy, Glushchenko, Maltsev & Kociolek
Striae in RV	biseriate	biseriate	multiseriate	uniseriate
Striae in RLV	uniseriate	biseriate	biseriate	uniseriate
Interstriae in RV externally	flat, the same width as striae	flat, equal or broader than striae	flat, more narrow than striae	flat, broader than striae
Interstriae in RV internally	very prominent on striae, the same width as striae	flat, equal or broader than striae	very prominent on striae, more narrow than striae	prominent, broader than striae
Interstriae in RLV externally	flat, the same width as striae	flat, equal to or broader than striae	flat, equal to or narrower than striae	flat, broader than striae
Interstriae in RLV internally	very prominent on striae, the same width as striae	flat, equal to or broader than striae	very prominent, more narrow than striae	prominent, broader than striae
Pore occlusions	silica membrane	hymenes	silica membrane	hymenes
Distal raphe ends externally	tear-shaped, extending slightly onto valve mantle; turned in opposite directions	linear and straight on valve face	tear-shaped, straight on valve face	deflected to opposite sides, terminating in drop-like pores on the valve face
Distal raphe ends internally	in small helictoglossae; curved in the opposite directions	in small helictoglossae; curved in the opposite directions	in small helictoglossa; straight	in small helictoglossae; turned in different directions
Central raphe ends externally	tear-shaped, straight	tear-shaped, straight	tear-shaped, straight	tear-shaped, straight
Central raphe ends internally	linear, straight, slightly curved in opposite directions	straight; turned in opposite directions	linear, straight, slightly curved in opposite directions	slightly curved in opposite directions
Axial area in RV, externally	flat, narrow and linear	flat, narrow and linear	narrow and linear, slightly widened into central area, sternum detected	very narrow, linear, opening rather abruptly to the central area
Axial area in RV, internally	enough broad and widened to central area, sternum evident and elevated	flat, narrow and linear	narrow and linear, slightly widened to central area, sternum	slightly raised above the surface of the striae
Axial area in RLV, externally	narrow and linear, slightly widened to central area	very broad, flat	narrow and linear, slightly widened to central area, sternum, deep on valve face	flat, narrow sternum is evident
Axial area in RLV, internally	broad rhombic sternum	very broad, flat	wide lanceolate, sternum-like prominent on the striae level	flat, narrow sternum is evident
Central area in RV externally	bowtie-shaped, narrow, slightly raised	small, circular	flat, moderately transapically enlarged	more or less symmetrical, narrow, rectangular to wedge-shaped fascia reaching in some species the valve margins
Central area in RV internally	narrow, bowtie-shaped due to shorter two or three striae, elevated, stauros-like	small, circular	prominent, moderately transapically enlarged	forming a raised stauros
Central area in RLV externally	small, flat	absent due to broad axial area	flat, transapically enlarged	asymmetrical, narrow, wedge-shaped fascia reaching in some species the valve margins
Central area in RLV internally	small	absent due to broad axial area	prominent, transapically enlarged	more or less expressed, asymmetrical, wedge-shaped
References	This investigation, [8]	[37,46]	[8,9]	[10]

Table 2. Comparison of *Platesiberia* gen. nov. with some monoraphid genera.

	***Platesiberia* gen. nov.**	***Gololobovia***	***Achnanthidium***	***Skabitschewskia***	***Gliwiczia***	***Lemnicola***
Type species	*P. rhombicolanceolata* (Kulikovskiy & Lange-Bertalot) Kulikovskiy, Glushchenko, Genkal & Kociolek comb. nov.	*G. mariae* Kulikovskiy, Glushchenko, Genkal & Kociolek sp. nov.	*A. microcephalum* Kützing 1844	*S. dispersipunctata* Kulikovskiy & Lange-Bertalot 2015	*G. tenuis* Kulikovskiy, Lange-Bertalot & Witkowski 2013	*L. hungarica* (Grunow) Round & Basson 1997
Striae in RV	biseriate	uniseriate	uniseriate	uniseriate	uniseriate	biseriate
Striae in RLV	uniseriate	uniseriate	uniseriate	biseriate	uniseriate	biseriate
Interstriae in RV externally	flat, the same width as striae	flat, equal to striae	flat, equal or broader than striae	flat, equal to striae	flat, slightly broader than striae	flat, wider than striae
Interstriae in RV internally	very prominent on striae, the same width as striae	flat, equal to striae	flat, equal or broader than striae	Prominent, equal to or broader than striae	slightly prominent, slightly broader than striae	slightly raised, narrower than striae
Interstriae in RLV externally	flat, the same width as striae	flat, equal to striae	flat, equal to or broader than striae	prominent, equal to or broader than striae	flat, equal to or broader than striae	flat and broader than striae
Interstriae in RLV internally	very prominent on striae, the same width as striae	flat, equal to striae	flat, equal to or broader than striae	very prominent (rib-like), connected with sternum, close areolae by silica layer (alveoli), narrower than striae; in some species with reduced striae the interstriae are longer and broader	slightly raised, narrower than striae	evidently raised, narrower than striae
Pore occlusions	silica membrane	hymenes	hymenes	silica membrane	silica membrane, below the occlusion a pair of foramina lips	hymenes
Distal raphe ends externally	tear-shaped, extending slightly onto valve mantle; turned in opposite directions	curved, terminate to opposite sides of the apices, extending onto valve mantle	straight or slightly curved on valve face or extending slightly going onto valve mantle; turned to the same direction	straight or slightly curved on valve face or extending slightly onto valve mantle; turned in opposite directions	straight and extending slightly onto mantle, slightly deflected in opposite directions	extending onto mantle; curved in opposite directions
Distal raphe ends internally	in small helictoglossae; curved in the opposite directions	in small helictoglossae; turned in different directions	in small helictoglossae; turned in different directions	in small helictoglossae; turned in different directions	helictoglossae almost undeveloped; slightly turned in opposite directions	in small helictoglossae; slightly curved in opposite directions
Central raphe ends externally	tear-shaped, straight	tear-shaped, slightly curved to the same direction	slim or tear-shaped, straight or slightly curved to the same direction	tear-shaped, straight	tear-shaped, straight	straight and curved to the same direction
Central raphe ends internally	linear, straight, slightly curved in opposite directions	linear; tear-shaped, slightly curved in opposite directions	straight or in small hook; turned to the different direction	straight; turned to the different direction	straight; evidently turned in different directions	straight; slightly curved in opposite directions
Axial area in RV, externally	flat, narrow and linear	narrow and linear, sternum detected	narrow and linear or widened to form central area	narrow and linear, sternum detected	narrow and linear, sternum detected	linear, narrow, sternum evident

Table 2. *Cont.*

	Platesiberia **gen. nov.**	*Gololobovia*	*Achnanthidium*	*Skabitschewskia*	*Gliwiczia*	*Lemnicola*
Axial area in RV, internally	enough broad and widened to central area, sternum evident and elevated	narrow and linear or widened to central area, sternum evident	narrow and linear or widened to central area, sternum evident	sternum well-developed, narrow and linear	sternum well-developed, narrow and linear	linear, narrow, in well-developed sternum
Axial area in RLV, externally	narrow and linear, slightly widened to central area	narrow and linear, deep on valve face	narrow and linear or slightly wider to central area	narrow and linear or slightly wider to central area, in many species deep on valve face	narrow and wider to central area, almost rhombic	flat, linear
Axial area in RLV, internally	broad rhombic sternum	has the axial rib elevated near the unequal central area only	narrow and linear or slightly wider to central area	narrow lanceolate, raised on valve face in middle	broad rhombic sternum	linear, well-developed sternum
Central area in RV externally	bowtie-shaped, narrow, slightly raised	unequal in width, with the widest side extending to the margin and having no short striae, the opposite, narrower side with short striae evident at the margin	absent or present by fascia, flat	circle or bowtie-shaped, flat or slightly raised in center	stauros elevated, central nodule evidently raised	stauros
Central area in RV internally	narrow, bowtie-shaped due to shorter two or three striae, elevated, stauros-like	thickened, is unornamented but not a stauros	absent or present by fascia slightly raised on valve face	circle or bowtie-shaped, raised in center	stauros strongly elevated with cavum on one side	stauros
Central area in RLV externally	small, flat	unequal in width, with the widest side extending to the margin and having no short striae, the opposite, narrower side with short striae evident at the margin	absent or present by fascia, flat	flat, fascia in one cavum side of valve	stauros elevated	slightly circle or not evident
Central area in RLV internally	small	distinct, thickened, unequal	absent or present by fascia, flat	cavum	stauros strongly elevated with cavum on one side	slightly circular or not evident
References	This investigation, [8]	[11]	[47–50]	[8]	[8], own data	[51,52]

Areolae are closed internally in our new genus *Platesiberia* gen. nov. by silica cover. Mostly, areolae are covered by hymenes as pore occlusions. SEM did not allow us to observe pore occlusions with hymenes. Hymenes as morphological feature are characterized by a slim silica plate with many tiny pores that are differently shaped [53]. In *Gliwiczia*, pore occlusions are presented additionally by a pair of foramina lips below the silica membranes [8].

We discussed differences of pore occlusion between monoraphid genera when we described the genus *Gololobovia* [11]. We referred to Shi et al. [52] who indicated 'convex hymenes' and show them to be present in *Lemnicola* and in our investigation for *Gololobovia*. This structure covers every areola internally and is found in *Lemnicola*, *Gogorevia* and *Gololobovia*. Further investigation will be important for understanding these peculiarities and needs the combination of morphological analysis with transmission electron microscopy, scanning microscopy with high magnification and molecular phylogenetic investigations. We note here the importance of this work for the future.

We acknowledge here that this work is based on valve morphological features only, and some of these features are only evident with scanning electron microscopy. More recent studies on the delineation and description of taxa take what has been termed a "polyphasic" approach, utilizing a variety of features, morphological and molecular, to characterize new taxa (e.g., [31,54]). Of course, having a broader understanding of a wider range of features to better understand a taxon, and its phylogenetic relationships, is a highly desirable goal. Due to timing of collections and whether the taxon is extant or extinct help define what can be known at any one time. We also do not have in place yet a formal analysis of relationships and whether each of these freshwater monoraphid genera are monophyletic [55]. Formal phylogenetic analyses of some monoraphid diatom genera have affirmed, however, that morphologically diagnosable groups of monoraphid diatoms are monophyletic (e.g., [10]). Further research is necessary to more fully understand the taxon described herein and to assess its systematic position among the freshwater monoraphid diatoms.

This investigation increases our understanding of the diversity of monoraphid freshwater genera that were previously assigned to the old catch-all genus *Achnanthes* Bory. Description of new genera is related to our investigation of morphology from different monoraphid taxa and combining morphological features together with molecular data for some genera where possible. This work is based on a larger investigation of biodiversity from different poorly studied areas or hotspots of diatoms. Lake Baikal is a unique place, existing for 25–30 million years [56], thus allowing a long time for the evolution of diatoms and resulting in very high species diversity. We believe that diversity of monoraphid diatoms in this ancient lake will be investigated in the future more carefully and many new species and possibly new genera will be described. Our previous investigation of monoraphid diatoms [8,36] from Lake Baikal showed very high diversity between monoraphid and biraphid genera with interesting and shared unusual morphology. It is important for us to combine new morphological information about freshwater diatoms not only from Lake Baikal but also from Southeast Asia, Australia, Africa and South America. These areas have also been poorly studied up till now.

Author Contributions: Conceptualization, M.S.K.; methodology, A.M.G. and M.S.K.; validation, A.M.G., M.S.K. and J.P.K.; investigation, A.M.G., M.S.K. and J.P.K.; resources, M.S.K.; writing—original draft preparation, A.M.G. and M.S.K.; writing—review and editing, A.M.G., M.S.K. and J.P.K.; visualization, M.S.K., I.V.K., S.I.G. and A.M.G.; supervision, M.S.K.; funding acquisition, M.S.K. All authors have read and agreed to the published version of the manuscript.

Funding: Publication is based on research carried out with financial support by Russian Science Foundation (19-14-00320П) for LM and SEM and by framework of state assignment of the Ministry of Science and Higher Education of the Russian Federation (theme 122042700045-3) for finishing manuscript.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Hustedt, F. Bacillariophyta (Diatomeae). In *Die Süßwasser-Flora Mitteleuropas*; Pascher, A., Ed.; Zweite Auflage, Heft 10, Gustav Fischer: Jena, Germany, 1930; 466p.
2. Patrick, R.; Reimer, C.W. The diatoms of the United States exclusive of Alaska and Hawaii. Volume 1: Fragilariaceae, Eunotiaceae, Achnanthaceae, Naviculaceae. *Monogr. Acad. Nat. Sci. Phila.* **1966**, *13*, 1–688.
3. Krammer, K.; Lange-Bertalot, H. Bacillariophyceae. 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. In *Süßwasserflora von Mitteleuropa*; Ettl, H., Gerloff, J., Heynig, H., Mollenhauer, D., Eds.; Gustav Fisher Verlag: Stuttgart, Germany, 1991; 576p.
4. Round, F.E.; Bukhtiyarova, L.V. Four new genera based on *Achnanthes* (*Achnanthidium*) together with a re-definition of *Achnanthidium*. *Diatom Res.* **1996**, *11*, 345–361. [CrossRef]
5. Bukhtiyarova, L.V.; Round, F.E. Revision of the genus *Achnanthes* sensu lato. *Psammothidium*, a new genus based on *Achnanthidium marginulatum*. *Diatom Res.* **1996**, *11*, 1–30. [CrossRef]
6. Wojtal, A.Z. Species composition and distribution of diatom assemblages in spring waters from various geological formation in southern Poland. *Bibl. Diatomol.* **2013**, *59*, 1–436.
7. Kulikovskiy, M.S.; Lange-Bertalot, H.; Witkowski, A. *Gliwiczia* gen. nov. a new monoraphid diatom genus with a description of four species new for science. *Phytotaxa* **2013**, *109*, 1–16. [CrossRef]
8. Kulikovskiy, M.S.; Lange-Bertalot, H.; Kuznetsova, I.V. Lake Baikal: Hotspot of endemic diatoms II. *Iconogr. Diatomol.* **2015**, *26*, 1–657.
9. Kulikovskiy, M.S.; Glushchenko, A.M.; Genkal, S.I.; Kuznetsova, I.V.; Kociolek, J.P. *Platebaikalia*—A new monoraphid diatom genus from ancient Lake Baikal with comments on the genus *Platessa*. *Fottea* **2020**, *20*, 58–67. [CrossRef]
10. Kulikovskiy, M.S.; Maltsev, Y.I.; Glushchenko, A.M.; Kuznetsova, I.V.; Kapustin, D.A.; Gusev, E.S.; Lange-Bertalot, H.; Genkal, S.I.; Kociolek, J.P. *Gogorevia*, a new monoraphid diatom genus for *Achnanthes exigua* and allied taxa described on the basis of an integrated molecular and morphological approach. *J. Phycol.* **2020**, *56*, 1601–1613. [CrossRef]
11. Kulikovskiy, M.S.; Glushchenko, A.M.; Kuznetsova, I.V.; Genkal, S.I.; Kociolek, J.P. *Gololobovia* gen. nov.—A new genus from Lake Baikal with comments on pore occlusion in monoraphid diatoms. *Phycologia* **2020**, *59*, 616–633. [CrossRef]
12. Kociolek, J.P.; You, Q.-M.; Yu, P.; Li, Y.-L.; Wang, Y.-L.; Lowe, R.L.; Wang, Q.-X. Description of *Gomphothidium* gen. nov., with light and scanning electron microscopy: A new freshwater monoraphid diatom genus from Asia. *Fottea* **2021**, *21*, 1–7. [CrossRef]
13. You, Q.; Wang, Y.L.; Yu, P.; Kociolek, J.P.; Pang, W.T.; Wang, Q.X. Four new species of monoraphid diatom from Western Sichuan Plateau in China. *Phytotaxa* **2021**, *47*, 257–274. [CrossRef]
14. Monnier, O.; Lange-Bertalot, H.; Hoffmann, L.; Ector, L. The genera *Achnanthidium* Kützing and *Psammothidium* Bukhtiyarova et Round in the family Achnanthidiaceae (Bacillariophyceae): A reappraisal of the differential criteria. *Cryptogam. Algol.* **2007**, *28*, 141–158.
15. Kociolek, J.P.; Williams, D.M.; Stepanek, J.; Liu, Q.; Liu, Y.; You, Q.-M.; Karthick, B.; Kulikovskiy, M.S. Rampant homoplasy and adaptive radiation in pennate diatoms. *Plant. Ecol. Evol.* **2019**, *152*, 131–141. [CrossRef]
16. Jasnitsky, V.N. Neue und interessante Arten der Diatomeen aus dem Baikalsee. *J. Bot. L'Urss* **1936**, *21*, 689–703.
17. Jasnitsky, V.N. Gigantism in Lake Baikal flora. *Proc. Biol. Geogr. Inst. Irkutsk. Univ.* **1952**, *13*, 3–11.
18. Skvortzow, B.W.; Meyer, C.I. A contribution to the diatoms of Baikal Lake. *Proc. Sungaree River Biol. Stn.* **1928**, *1*, 1–55.
19. Skvortzow, B.W. Bottom diatoms from Olhon gate of Baikal Lake, Siberia. *Philipp. J. Sci.* **1937**, *62*, 293–377.
20. Skabichevsky, A.P. New and interesting diatoms from Northern Baikal. *Bot. J. USSR* **1936**, *21*, 706–722.
21. Skabichevsky, A.P. On the taxonomy of the Lake Baikal diatoms. *Not. Syst. Acad. Sci. URSS Inst. Bot. Sect. Cryptogam.* **1952**, *8*, 36–42.
22. Skabichevsky, A.P. New species of diatomeae from overgrowths of the Baikal sublittoral. *Ukr. Bot. J.* **1975**, *32*, 268–271.
23. Skabichevsky, A.P. Species *Gomphonematis* Ag. (Bacillariophyta) Lacus Baical. *Nov. Sist. Nizshikh Rastenii* **1984**, *21*, 51–62.
24. Skabichevsky, A.P. About two species of *Gomphonema* Ag. (Bacillariophyta) from Lake Baikal. *Bull. Mosc. Soc. Nat. Biol. Ser.* **1985**, *90*, 92–103.
25. Skabichevsky, A.P. Materies ad floram Bacillariophytprum zonae sublitoralis Lacus Baical. *Nov. Sist. Nizshikh Rastenii* **1987**, *24*, 72–79.
26. Kulikovskiy, M.S.; Lange-Bertalot, H.; Khursevich, G.K.; Kuznetsova, I.V. New diatom species of the genus *Eolimna* (Bacillariophyceae) from Lake Baikal. *Nov. Sist. Nizsh. Rast.* **2012**, *46*, 46–51. [CrossRef]
27. Kulikovskiy, M.S.; Kociolek, J.P. The diatom genus *Gomphonema* Ehrenberg in Lake Baikal. I. Morphology and taxonomic history of two endemic species. *Nova Hedwig. Beih.* **2014**, *143*, 507–518.
28. Kulikovskiy, M.S.; Lange-Bertalot, H.; Witkowski, A.; Kuznetsova, I.V. Description of four species belonging in *Cavinula* D.G. Mann & Stickle from Lake Baikal with notes on family Cavinulaceae D.G. Mann in Round et al. 1990. *Nova Hedwig.* **2014**, *99*, 487–499.

29. Kulikovskiy, M.S.; Lange-Bertalot, H.; Witkowski, A.; Khursevich, G.K.; Kociolek, J.P. Description of *Eunotia* species (Bacillariophyta) new to science from Lake Baikal with comments on morphology and biogeography of the genus. *Phycologia* **2015**, *54*, 248–260. [CrossRef]
30. Kulikovskiy, M.S.; Kociolek, J.P.; Solak, C.N.; Kuznetsova, I.V. The diatom genus *Gomphonema* Ehrenberg in Lake Baikal. II. Revision of taxa from *Gomphonema acuminatum* and *Gomphonema truncatum-capitatum* complexes. *Phytotaxa* **2015**, *233*, 251–272. [CrossRef]
31. Kulikovskiy, M.S.; Lange-Bertalot, H.; Annenkova, N.V.; Gusev, E.S.; Kociolek, J.P. Morphological and molecular evidence support description of two new diatom species from the genus *Ulnaria* in Lake Baikal. *Fottea* **2016**, *1*, 34–42. [CrossRef]
32. Glushchenko, A.M.; Maltsev, Y.I.; Kociolek, J.P.; Kuznetsova, I.V.; Kulikovskiy, M.S. *Cymbopleura natellia*—A new species from Transbaikal area (Russia, Siberia) described on the basis of molecular and morphological investigation. *PhytoKeys* **2021**, *183*, 95–105. [CrossRef]
33. Kezlya, E.M.; Glushchenko, A.M.; Maltsev, Y.I.; Gusev, E.S.; Genkal, S.I.; Kociolek, J.P.; Kulikovskiy, M.S. Three new species of *Placoneis* Mereschkowsky (Bacillariophyceae: Cymbellales) with comments on cryptic diversity in the *P. elginensis*-group. *Water* **2021**, *13*, 3276. [CrossRef]
34. Kociolek, J.P.; Kulikovskiy, M.S.; Solak, C.N. The diatom genus *Gomphoneis* Cleve (Bacillariophyceae) from Lake Baikal, Russia. *Phytotaxa* **2013**, *154*, 1–37. [CrossRef]
35. Kulikovskiy, M.S.; Lange-Bertalot, H.; Witkowski, A.; Khursevich, G.K. *Achnanthidium sibiricum* (Bacillariophyceae), a new species from bottom sediments in Lake Baikal. *Algol. Stud.* **2011**, *136/137*, 77–87. [CrossRef]
36. Kulikovskiy, M.S.; Lange-Bertalot, H.; Metzeltin, D.; Witkowski, A. Lake Baikal: Hotspot of endemic diatoms. I. *Iconogr. Diatomol.* **2012**, *23*, 7–608.
37. Krammer, K.; Lange-Bertalot, H. Bacillariophyceae 4. Teil: Achnanthaceae, Kritische Erganzungen zu *Navicula* (Lineolatae), *Gomphonema* Gesamtliteraturverzeichnis Teil 1–4 [second revised edition] [With "Ergänzungen und Revisionen" by H. Lange Bertalot]. In *Suβsswasserflora von Mitteleuropa*; Ettl, H., Gärtner, G., Heynig, H., Mollenhauer, Eds.; Spektrum Akademischer Verlad: Heidelberg, Germany, 2004; Volume 2, 468p.
38. Kulikovskiy, M.S.; Maltsev, Y.I.; Andreeva, S.A.; Glushchenko, A.M.; Gusev, E.S.; Podunay, Y.A.; Ludwig, T.; Kociolek, J.P. Description of a new diatom genus *Dorofeyukea* gen. nov. with remarks on phylogeny of the family Stauroneidaceae. *J. Phycol.* **2019**, *55*, 173–185. [CrossRef]
39. Kulikovskiy, M.S.; Maltsev, Y.I.; Glushchenko, A.M.; Gusev, E.S.; Kapustin, D.A.; Kuznetsova, I.V.; Frolova, L.A.; Kociolek, J.P. Preliminary molecular phylogeny of the diatom genus *Nupela* with the description of a new species and consideration of the interrelationships of taxa in the suborder Neidiineae D.G. Mann sensu E.J. Cox. *Fottea* **2020**, *20*, 192–204. [CrossRef]
40. Tseplik, N.D.; Maltsev, Y.I.; Glushchenko, A.M.; Kuznetsova, I.V.; Genkal, S.I.; Gusev, E.S.; Kulikovskiy, M.S. *Achnanthidium gladius* sp. nov. (Bacillariophyceae)—A new monoraphid diatom species from Indonesia. *PhytoKeys* **2021**, *187*, 129–140. [CrossRef]
41. Tseplik, N.D.; Maltsev, Y.I.; Glushchenko, A.M.; Kuznetsova, I.V.; Genkal, S.I.; Kociolek, J.P.; Kulikovskiy, M.S. *Achnanthidium tinea* sp. nov.—A new monoraphid diatom (Bacillariophyceae) species, described on the basis of molecular and morphological approaches. *PhytoKeys* **2021**, *174*, 147–163. [CrossRef]
42. Tseplik, N.D.; Glushchenko, A.M.; Maltsev, Y.I.; Kuznetsova, I.V.; Genkal, S.I.; Kociolek, J.P.; Kulikovskiy, M.S. A new monoraphid diatom species from the genus *Karayevia* sensu lato (Bacillariophyceae: Stauroneidaceae) with remarks on taxonomy and phylogeny of the genus. *Diatom Res.* **2022**, *37*, 39–50. [CrossRef]
43. Liu, Y.; Kociolek, J.P.; Wang, Q.; Fan, Y. Two new species of monoraphid diatoms (Bacillariophyceae) from the south of China. *Phytotaxa* **2014**, *188*, 31–37. [CrossRef]
44. Kulikovskiy, M.S.; Glushchenko, A.M.; Genkal, S.I.; Kuznetsova, I.V. *Identification Book of Diatoms from Russia*; Filigran: Yaroslavl, Russia, 2016; 804p.
45. Jahn, R.; Abarca, N.; Gemeinholzer, B.; Mora, D.; Skibbe, O.; Kulikovskiy, M.S.; Gusev, E.S.; Kusber, W.-H.; Zimmermann, J. *Planothidium lanceolatum* and *Planothidium frequentissimum* reinvestigated with molecular methods and morphology: Four new species and the taxonomic importance of the sinus and cavum. *Diatom Res.* **2017**, *32*, 75–107. [CrossRef]
46. Romero, O.E. Study of the type material of two *Platessa* Lange-Bertalot species, formerly *Cocconeis brevicostata* Hust. and *Cocconeis cataractarum* Hust. (Bacillariophyta). *Diatom Res.* **2016**, *31*, 63–75. [CrossRef]
47. Lange-Bertalot, H.; Ruppel, M. Zur Revision taxonomisch problematischer, ökologisch jedoch wichtiger Sippen der Gattung *Achnanthes* Bory. *Algol. Stud.* **1980**, *26*, 1–31.
48. Lange-Bertalot, H.; Krammer, K. *Achnanthes*, eine Monographie der Gattung mit Definition der Gattung *Cocconeis* und Nachträgen zu den Naviculaceae. *Bibl. Diatomol.* **1989**, *18*, 1–393.
49. Potapova, M.; Hamilton, P.B. Morphological and ecological variation within the *Achnanthidium minutissimum* (Bacillariophyceae) species complex. *J. Phycol.* **2007**, *43*, 561–575. [CrossRef]
50. Novais, M.H.; Jüttner, I.; Van de Vijver, B.; Morais, M.M.; Hoffmann, L.; Ector, L. Morphological variability within the *Achnanthidium minutissimum* species complex (Bacillariophyta): Comparison between the type material of *Achnanthes minutissima* and related taxa, and new freshwater *Achnnathidium* species from Portugal. *Phytotaxa* **2015**, *224*, 101–139. [CrossRef]
51. Round, F.E.; Basson, P.W. A new monoraphid diatom genus (*Pogoneis*) from Bahrain and the transfer of previously described species *A. hungarica* and *A. taeniata* to new genera. *Diatom Res.* **1997**, *12*, 71–81. [CrossRef]

52. Shi, Y.; Wang, P.; Kim, H.K.; Lee, H.; Han, M.S.; Kim, B.H. *Lemnicola hungarica* (Bacillariophyceae) and the new monoraphid diatom *Lemnicola uniseriata* sp. nov. (Bacillariophyceae) from South Korea. *Diatom Res.* **2018**, *33*, 69–87. [CrossRef]
53. Mann, D.G. Sieves and Flaps: Siliceous Minutiae in the Poresof Raphid diatoms. In Proceedings of the 6th Symposium on Recent and Fossil Diatoms, Budapest, Hungary, 1–5 September 1980; Ross, R., Ed.; Koeltz: Koenigstein, Germany, 1981; pp. 279–300.
54. Komárek, J. A polyphasic approach for the taxonomy of cyanobacteria: Principles and applications. *Eur. J. Phycol.* **2015**, *51*, 346–353. [CrossRef]
55. Kociolek, J.P.; Williams, D.M. How to define a diatom genus? Notes on the creation and recognition of taxa, and a call for revisionary studies of diatoms. In Proceedings of the 8th Central European Diatom Meeting, Zagreb, Croatia. *Acta Bot. Croat.* **2015**, *74*, 195–210. [CrossRef]
56. Bukharov, A.A. *Baikal in Numbers (Quick Reference)*; Publishing House of IP "Makarov S.E.": Irkutsk, Russia, 2001; 72p.