Four new species from the diatom (Bacillariophyceae) genus *Adlafia* Moser, Lange-Bertalot & Metzel tin from waterbodies of Vietnam

Anton M. Glushchenko¹, John Patrick Kociolek²,³, Irina V. Kuznetsova¹, Maxim S. Kulikovskiy¹

¹ K. A. Timiryazev Institute of Plant Physiology RAS, IPP RAS, 35 Botanicheskaya St., Moscow, 127276, Russia ² Museum of Natural History, Boulder, Colorado, USA ³ Department of Ecology and Evolutionary Biology, University of Colorado, Boulder, Colorado, 80309, USA

Corresponding author: Anton M. Glushchenko (gluschenkoam@studklg.ru)

Academic editor: K. Manoylov | Received 16 August 2020 | Accepted 2 September 2020 | Published 7 October 2020

Citation: Glushchenko AM, Kociolek JP, Kuznetsova IV, Kulikovskiy MS (2020) Four new species from the diatom (Bacillariophyceae) genus *Adlafia* Moser, Lange-Bertalot & Metzeltin from waterbodies of Vietnam. PhytoKeys 162: 13–27. https://doi.org/10.3897/phytokeys.162.57657

Abstract

Four species of the diatom genus *Adlafia* were found from waterbodies of Vietnam and described as new to science. Their formal descriptions are presented herein and they are illustrated by light and scanning electron micrographs. These new species are: *A. lamdongiensis* Glushch., Kulik. & Kociolek, sp. nov., *A. babeiensis* Glushch., Kulik. & Kociolek, sp. nov., *A. vietnamensis* Glushch., Kulik. & Kociolek, sp. nov. and *A. dauiensis* Glushch., Kulik. & Kociolek, sp. nov. These species are then compared to other similar taxa. Our new findings add to the number of species in this interesting genus and contribute to our understanding of the unique diatom flora found in Vietnam.

Keywords

*Adlafia*, diatoms, morphology, new species, Southeast Asia, Vietnam

Introduction

The genus *Adlafia* was proposed by Moser et al. (Moser et al. 1998). According to the original description, the genus is overwhelmingly represented by small-cell species (less than 25 µm in length). The raphe is naviculoid; external distal ends are smoothly...
bent and slightly extend to the mantle externally while the external proximal ones are drop-shaped, slightly bent to the opposite side from the distal ends (Kulikovskiy et al. 2016). On the inside, the raphe is located on a raised sternum, the distal ends with small helictoglossae, the proximal ends are straight and bent to one side (Morales and Le 2005). A distinctive feature of the genus is the presence of large, often square areolae, closed externally with a hymen and a continuous silica layer (Moser et al. 1998; Lange-Bertalot 2001). Species of the genus are distinguished from those in the genus Kobayasiella Lange-Bertalot in Lange-Bertalot and Genkal (1999) by lacking an “umbilicus”, a deflection or nick in the raphe system on the exterior. Currently, the genus belongs to taxa with an unclear taxonomic position (incertae sedis). Molecular studies of the genus require the involvement of more strains (Kulikovskiy et al. 2016).

The genus includes 27 species and infraspecific taxa (Guiry and Guiry 2020). Species of the genus are distributed around the world. Most species are aerophilous, being found mainly on mosses, but others prefer oligotrophic streams and lakes with a slightly higher or lower pH value, but are rare in large rivers (Spaulding and Edlund 2009; Kulikovskiy et al. 2016; Cantonati et al. 2017). Species are also known from fossil sediments (Lange-Bertalot and Metzeltin 1996; Benson and Kociolek 2012). Southeast Asia is a floristically interesting region, from which many new genera and species of centric and pennate diatoms have been described recently (see Gusev and Kulikovskiy 2014; Glushchenko et al. 2016, 2017, 2018, 2019; Kapustin et al. 2017, 2019; Liu et al. 2018; Kulikovskiy et al. 2019, 2020; Rybak et al. 2019). Several Adlafia species have been recorded previously from Southeast Asia. In Indonesia, for example, Adlafia bryophila (J. Petersen) Lange-Bertalot in Moser et al. 1998 and Adlafia minuscula (Grunow) Lange-Bertalot in Lange-Bertalot and Genkal 1999 have been reported (Bramburger et al. 2004). Adlafia sinensis Liu & Williams in Liu et al. 2017 was described from south-central China. They also provide a comparison of many Adlafia species. In Vietnam, Adlafia minuscula var. muralis (Grunow) Lange-Bertalot in Lange-Bertalot and Genkal 1999 was reported from reservoirs, but without an image to document the determination (Duong et al. 2006).

The aim of our work was to identify the species diversity of the genus Adlafia in freshwater ecosystems of Vietnam.

**Materials and methods**

A list of all samples examined in this study with their geographic positions is presented in Table 1. The samples were treated with 10% hydrochloric acid to remove carbonates and washed several times with deionized water for 12 h. The samples were subsequently boiled in concentrated hydrogen peroxide (≈37%) to dissolve organic matter. They were then washed four times with deionized water at 12 h intervals. After decanting and refilling with up to 100 ml deionized water, the suspension was spread onto coverslips and left to dry at room temperature. Permanent diatom preparations were mounted in Naphrax. Light microscopic (LM) observations were performed
Four new species of genus *Adlafia* from Vietnam

15

with a Zeiss Axio Scope A1 microscope equipped with an oil immersion objective \((\times 100, \text{n.a. 1.4, differential interference contrast [DIC]})\) and Axiocam ERc 5s camera (Zeiss). Valve ultrastructure was examined by means of a JSM-6510LV scanning electron microscope (IBIW, Institute for Biology of Inland Waters RAS, Borok, Russia). 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 Au in an Eiko IB 3 sputter coater. Samples and slides are deposited in the public collection of Maxim Kulikovskiy at the Herbarium of the Institute of Plant Physiology Russian Academy of Science, Moscow, Russia. The number of examined valves is indicated in each description of the species. The average value of the valve length, width and striae density, as well as standard deviation were calculated using Microsoft Excel 2020. Terminology of the valve follows Moser et al. 1998; Lange-Bertalot 2001; Morales and Le 2005; Kulikovskiy et al. 2016; Tusset et al. 2017 and Ciugulea et al. 2019.

Results

**Division:** Bacillariophyta Haeckel  
**Class:** Bacillariophyceae Haeckel  
**Naviculaceae incertae sedis**  
**Genus:** *Adlafia* Moser, Lange-Bertalot & Metzeltin in Kulikovskiy et al. (2016)

*Adlafia lamdongiensis* Glushch., Kulik. & Kociolek, sp. nov.  
Figs 1, 2

**Holotype.** Slide no. 00269 in collection of Maxim Kulikovskiy at the Herbarium of the Institute of Plant Physiology Russian Academy of Science, Moscow, Russia, represented here by Fig. 1A.

| Sample/Slide | Locality | Habitat | Coordinates | Altitude, m | Temperature, °C | pH | Conductivity, µS cm\(^{-1}\) | Coll. date |
|--------------|----------|---------|-------------|-------------|-----------------|----|--------------------------|-----------|
| 00269        | Lâm Đồng Province, Đa Tien Reservoir | benthos | 11°58.816’N, 108°26.987’E | 1503 | 21.5 | 6.4 | 81 | 21.06.2012 |
| 00321        | Khánh Hòa Province, Hồ Bà Nature Reserve, Đâu River | wet moss | 12°06.768’N, 108°59.888’E | 275 | 24 | 6.7 | 92 | 28.05.2012 |
| 00325        | Khánh Hòa Province, Suối Tiên River | benthos and periphyton | 12°12.199’N, 109°01.694’E | 68 | 26 | 6.9 | 101 | 02.07.2012 |
| 02168        | Bắc Kạn Province, Ba Bể Lake | benthos | 22°23.605’N, 105°36.856’E | 163 | 26 | 8.5 | 174 | 19.04.2015 |
| 03593        | Khánh Hòa Province, Khe River | periphyton | 12°16.735’N, 105°36.856’E | 34 | 26.8 | 6.9 | 84 | 08.07.2010 |
| 04633        | Khánh Hòa Province, Hồ Câu Đôi Reservoir | periphyton | 12°15.750’N, 109°04.012’E | 9 | 29 | 6.8 | 110 | 14.09.2010 |

| Sample/Slide | Locality | Habitat | Coordinates | Altitude, m | Temperature, °C | pH | Conductivity, µS cm\(^{-1}\) | Coll. date |
|--------------|----------|---------|-------------|-------------|-----------------|----|--------------------------|-----------|
| 00269        | Lâm Đồng Province, Đa Tien Reservoir | benthos | 11°58.816’N, 108°26.987’E | 1503 | 21.5 | 6.4 | 81 | 21.06.2012 |
| 00321        | Khánh Hòa Province, Hồ Bà Nature Reserve, Đâu River | wet moss | 12°06.768’N, 108°59.888’E | 275 | 24 | 6.7 | 92 | 28.05.2012 |
| 00325        | Khánh Hòa Province, Suối Tiên River | benthos and periphyton | 12°12.199’N, 109°01.694’E | 68 | 26 | 6.9 | 101 | 02.07.2012 |
| 02168        | Bắc Kạn Province, Ba Bể Lake | benthos | 22°23.605’N, 105°36.856’E | 163 | 26 | 8.5 | 174 | 19.04.2015 |
| 03593        | Khánh Hòa Province, Khe River | periphyton | 12°16.735’N, 105°36.856’E | 34 | 26.8 | 6.9 | 84 | 08.07.2010 |
| 04633        | Khánh Hòa Province, Hồ Câu Đôi Reservoir | periphyton | 12°15.750’N, 109°04.012’E | 9 | 29 | 6.8 | 110 | 14.09.2010 |

Table 1. List of samples examined in this study. Geographic locality of samples and measured parameters indicated.
**Type locality.** Vietnam. Lâm Đồng Province, Đa Tien Reservoir, benthos, 11°58.816’N, 108°26.987’E, 1503 m elev., leg. E.S. Gusev, 21.06.2012.

**Description.** LM (Fig. 1A–G). Valves linear with weakly convex margins. Ends are distinctly narrowly-rostrate. Length 9.7–13 µm (11.4 ± 0.9; n = 16), breadth 2.5–2.8 (2.7 ± 0.1; n = 16) µm. Striae and areolae not resolved in LM.

**SEM, external view** (Fig. 2A–C). Valve face flat. Axial area linear. Central area absent. Raphe filiform, weakly lateral. Proximal raphe endings slightly expanded. Distal raphe endings positioned on valve mantle, hooked and curved in same direction, terminating at valve face-mantle junction. Striae uniseriate, radiate, becoming abruptly convergent approaching apices, Striae 45–50 in 10 µm (47.5 ± 1; n = 16). Areolae rounded or rectangular, hymenes not preserved during specimen preparation. Slit-like opening of apical areolae arranged in one row onto valve apex. Areolae 40–50 in 10 µm (45 ± 1.8; n = 16).

**SEM, internal view** (Fig. 2D–F). Raphe slightly lateral, lies in a prominent and raised raphe-sternum. Proximal raphe endings deflected towards primary side of valve. Distal raphe endings terminating in small helictoglossae. Striae continuing onto valve mantle. Short striae alternate with longer striae at valve center. Areolae rounded or rectangular. Openings of apical areolae apically elongated.

**Etymology.** Epithet refers to the province of Vietnam (Lâm Đồng Province) where the specimens were found.

**Distribution.** Vietnam. Type locality (slide no. 00269) and slide no. 03593.

---

**Adlafia babeiensis** Glushch., Kulik. & Kociolek, sp. nov.
Figs 3, 4

**Holotype.** Slide no. 02168 in collection of Maxim Kulikovskiy at the Herbarium of the Institute of Plant Physiology Russian Academy of Science, Moscow, Russia, represented here by Fig. 3A.

**Type locality.** Vietnam. Bắc Kạn Province, Ba Bể Lake, benthos, 22°23.605’N, 105°36.856’E, 163 m elev., leg. E.S. Gusev, 29.04.2015.

**Description.** LM (Fig. 3A–L). Valves lanceolate with rostrate ends. Length 11.5–14.0 µm (12.8 ± 0.6; n = 21), breadth 4.0–4.5 µm (4.3 ± 0.1; n = 21). Axial area
Four new species of genus *Adlafia* from Vietnam

narrow, almost linear. Central area weakly expressed or absent. Raphe filiform. Striae indistinct in LM, weakly radial at the central area, convergent towards to the ends. Areolae not resolved in LM.
SEM, external view (Fig. 4A–C). Valve face flat. Axial area linear. Central area absent. Raphe filiform, weakly lateral. Proximal raphe endings slightly expanded, deflected. Distal raphe endings positioned on the valve mantle, hooked and curved in the same direction, and terminating at the junction valve face-mantle. Striae uniseriate, radiate, becoming abruptly convergent approaching apices, Striae 36–40 in 10 µm (38 ± 0.1; n = 21). Areolae rounded or rectangular, occluded by hymenes. Slit-like opening of apical areolae invisible. Areolae 65–70 in 10 µm (67.5 ± 0.8; n = 21).

SEM, internal view (Fig. 4D). The raphe straight, lying in a prominent and raised raphe-sternum. Proximal raphe endings deflected towards primary side of valve. Distal raphe endings terminating in small helictoglossae. Striae continuing on to valve mantle. Short striae alternate with longer striae at the center of the valve. Areolae rounded. Openings of apical areolae apically elongated.

**Etymology.** Epithet refers to the lake of Vietnam where the new species was found.

**Distribution.** Vietnam. Known only from the type locality.

**Adlafia vietnamensis** Glushch., Kulik. & Kociolek, sp. nov.

Figs 5, 6

**Holotype.** Slide no. 00325 in collection of Maxim Kulikovskiy at the Herbarium of the Institute of Plant Physiology Russian Academy of Science, Moscow, Russia, represented here by Fig. 5G.

**Type locality.** Vietnam. Khánh Hòa Province, Suối Tiên River, benthos and periphyton, 12°12.199’N, 109°01.694’E, 68 m elev., leg. E.S. Gusev, 02.07.2012.

**Description.** LM (Fig. 5A–K). Valves linear-elliptical with capitate to subcapitate ends. Length 15–22 µm (18.5 ± 1.6; n = 20), breadth 3.5–5.0 µm (4.3 ± 0.4; n = 20). Axial area narrow, almost linear. Central area weakly expressed. Raphe filiform. Striae radiate, becoming abruptly convergent approaching apices, 32–34 in 10 µm (33 ± 0.4; n = 20). Areolae not resolved in LM.

**SEM, external view** (Fig. 6A–C). Valve face flat. Axial area linear. Central area weakly expressed. Raphe filiform. Proximal raphe endings slightly expanded, deflected.
Four new species of genus *Adlafia* from Vietnam

**Figure 4.** *A–D* *Adlafia babeiensis* Glushch., Kulik. & Kociolek, sp. nov. *A–C* SEM, external views *D* internal views. Sample no 02168. Scale bars: 2 µm (*A, C*), 1 µm (*B, D*).
Distal raphe endings positioned on the valve mantle, hooked and curved in the same direction, and terminating at the junction valve face. Striae uniseriate. Areolae rounded or rectangular, occluded by hymenes. Slit-like opening of apical areolae invisible. Areolae 50–55 in 10 µm (52.5 ± 1.0; n = 20).

**SEM, internal view** (Fig. 6D–F). Raphe straight, lying in a prominent and raised raphe-sternum. Proximal raphe endings deflected towards primary side of valve. Distal raphe endings terminating in small helictoglossae. Striae continuing onto valve mantle. Short striae alternate with longer striae at the center of the valve. Areolae rounded or rectangular. The openings of apical areolae apically elongated.

**Etymology.** Epithet refers to the country where the new species was found.

**Distribution.** Vietnam. Slides no. 00325 (type locality) and no. 04633.

*Adlafia dauiensis* Glushch., Kulik. & Kociolek, sp. nov.

Figs 7, 8

**Holotype.** Slide no. 00321 in collection of Maxim Kulikovskiy at the Herbarium of the Institute of Plant Physiology Russian Academy of Science, Moscow, Russia, represented here by Fig. 7C.

**Type locality.** Vietnam. Khánh Hòa Province, Hòn Bà Nature Reserve, Dầu River, wet moss, 12°06.768’N, 108°59.888’E, 275 m elev., leg. E.S. Gusev, 2.07.2012.

**Description.** LM (Fig. 7A–K). Valves linear to linear-elliptical with subcapitate ends. Length 19.0–26.5 µm (22.8 ± 2.3; n = 20), breadth 4.5–5.5 µm (5.0 ± 0.2; n = 20). Axial area narrow, almost linear. Central area weakly expressed. Raphe filiform. Striae radiate, becoming abruptly convergent approaching apices, 32–34 in 10 µm. Areolae not resolved in LM.

**SEM, external view** (Fig. 8A–C). Valve face flat. Axial area linear. Central area weakly expressed. Raphe filiform. Proximal raphe endings slightly expanded, deflected. Distal raphe endings positioned on the valve mantle, hooked and curved in the same direction, and terminating at the junction valve face-mantle. Striae uniseriate. Areolae

---

**Figure 5.** A–K *Adlafia vietnamensis* Glushch., Kulik. & Kociolek, sp. nov. LM, DIC, size diminution series. Slides no 00325 (B–K) and 04633 (A). Holotype (G). Scale bar: 10 µm.
Four new species of genus *Adlafia* from Vietnam

**Figure 6.** A–F *Adlafia vietnamensis* Glushch., Kulik. & Kociolek, sp. nov. SEM, sample no 00325 A–C external views. D, E internal views A whole valve B central area C valve end D whole valve E central area F valve end. Scale bars: 2.5 µm (A, D), 1 µm (B, C, E), 0.5 µm (F).
rounded or rectangular, occluded by hymenes. Slit-like opening of apical areolae invisible. Areolae 55–60 in 10 µm (57.5 ± 1.1; n = 20).

**SEM, internal view** (Fig. 8D–F). Raphe straight, lying in a prominent and raised raphe-sternum. Proximal raphe endings deflected towards primary side of valve. Distal raphe endings terminating in small helictoglossae. Striae continuing onto valve mantle. Short striae alternate with longer striae at the center of the valve. Areolae rounded or rectangular. The openings of apical areolae apically elongated.

**Etymology.** Epithet refers to the river of Vietnam where the new species was found.

**Distribution.** Vietnam. Known only from the type locality.

**Discussion**

The four new species described here from Southeast Asia are morphologically similar to each other, but can be differentiated on the basis of valve shape, valve ends and striae density. All species share the morphological features typical for the genus *Adlafia*. A comparison of species to each other and with previously-described taxa shows that the new species from Southeast Asia are easily distinguished, unique taxa (Table 2).

*Adlafia lamdongiensis* sp. nov. resembles specimens identified by Lee as *Kobayasiella venezuelensis* Metzeltin & Lange-Bertalot (2007, p. 155, pl. 141, figs 10–23) specimens as illustrated with light micrographs (Lee 2012, fig. 15, K–M) on the basis of valve outline. Moreover, the valve identified by Lee in the SEM (Lee 2012, fig. 15, N) would appear to belong to the genus *Kobayasiella*, since there is a characteristic break of the raphe (the “umbilicus”) inherent to representatives of this genus. The valve has noticeably convex edges (Lee 2012, fig. 15, N), while in our material, and the light micrographs of Lee, valves are slightly convex. In our opinion, the light micrographs and a scanning image of Lee (2012) belong to species from different genera.

*Adlafia babeiensis* sp. nov. resembles *Adlafia multnomahii* Morales & Le (2005, p. 151, figs 1–38), differing from it mainly by having valves that are more lanceolate in shape and rostrate valve ends (Table 2). In *A. multnomahii*, on the other hand, the valve ends
Four new species of genus *Adlafia* from Vietnam

are capitate to rostrate. The density of striae in both species is similar (35–40 at 10 µm in *Adlafia babeiensis* sp. nov. in comparison with 37–45 at 10 µm in *A. multnomahii*). Our species also resembles *Adlafia detenta* (Hustedt) Heudre, Wetzel & Ector in Heudre et
Table 2. Morphometric features of new *Adlafia* species and comparison with similar taxa.

| Taxon                    | Outline                  | Valve ends                        | Valve length, µm | Valve width, µm | Striae in 10 µm | Areolae in 10 µm | References                  |
|-------------------------|--------------------------|-----------------------------------|------------------|----------------|-----------------|------------------|------------------------------|
| *A. lamdongiensis* sp. nov. | linear with weakly convex margins | distinctly narrowly-rostrate       | 9.7–13.0         | 2.5–2.8        | 45–50           | 40–50            | This study                  |
| *A. babeiensis* sp. nov. | lanceolate                | rostrate                          | 11.5–14.0        | 4.0–4.5        | 36–40           | 65–70            | This study                  |
| *A. vietnamensis* sp. nov. | linear-elliptical         | capitate to subcapitate           | 15–22            | 3.5–5.0        | 32–34           | 50–55            | This study                  |
| *A. dauiensis* sp. nov.  | linear to linear-elliptical | subcapitate                       | 19.0–26.5        | 4.5–5.5        | 32–34           | 55–60            | This study                  |
| *Adlafia multnomahii* Morales & Le | lanceolate                | capitate to rostrate              | 9–16             | 4–5            | 37–45           | 65–70            | Morales and Le 2005         |
| *A. detenta* Heudre, Wetzel & Ector in Ector et al. | elliptic to linear-elliptical | capitate                          | 15–18            | 4.5–6.0        | 28–33           | 30–35            | Heudre et al. 2018          |
| *A. neoniana* Cantonati in Ciugulea et al. | elliptic-lanceolate      | rostrate to subcapitate           | 9.4–18.5         | 3.7–5.1        | 30–32           | 45–50            | Ciugulea et al. 2019        |
| *A. decorai* Tusset, Tremarin & Ludwig | linear-lanceolate        | rostrate                          | 18.2–26.2        | 4.6–5.7        | 24–32           | 50–54            | Tusset et al. 2017          |
| *Kobayasiella venezuelensis* Metzeltin & Lange-Berlati *sensu* Lee | Linear with weakly convex margins | subcapitate                       | 12.7–13.8        | 2.7–2.8        | no data         | no data           | Lee 2012                    |

*Data obtained from illustrations.

awl. (2018, p. 273), differing from it by the rostrate, rather than bluntly capitate, ends of the valves, striae that are more radiate in their orientation, higher density of striae (36–40 in our species versus 28–33 in 10 µm in *A. detenta*), and higher density of areolae (65–70 at 10 µm in our species versus 30–33 at 10 µm in *A. detenta*) (Table 2).

*Adlafia vietnamensis* sp. nov. resembles *Adlafia neoniana* Cantonati in Ciugulea et al. (2019, p. 381, figs 1, 2), by having more pronounced capitate ends, as well as less convex valves, in general, with a higher striae density (32–34 at 10 µm for our material compared to 30–32 at 10 µm for *Adlafia neoniana*) (Table 2). The density of the areolae of our species is also slightly higher (50–55 at 10 µm in *Adlafia vietnamensis* sp. nov. versus 45–50 at 10 µm in *A. neoniana*). *Adlafia vietnamensis* sp. nov. has a linearly elliptical shape of valves and valve ends from rostrate to subcapitate; *A. neoniana* is characterized by elliptical-lanceolate valves and rostrate to subcapitate ends. Our species is also similar to *Adlafia dauiensis* sp. nov. (see below) from which it differs mainly by a lower density of striae (50–55 in 10 µm in *A. vietnamensis* sp. nov. versus 45–50 at 10 µm in *A. neoniana*). *Adlafia vietnamensis* sp. nov. has a linearly elliptical shape of valves and valve ends from rostrate to subcapitate; *A. neoniana* is characterized by elliptical-lanceolate valves and rostrate to subcapitate ends. Our species is also similar to *Adlafia dauiensis* sp. nov. (see below) from which it differs mainly by a lower density of striae (50–55 in 10 µm in *A. vietnamensis* sp. nov. versus 55–60 in 10 µm in *A. dauiensis* sp. nov.). *A. vietnamensis* sp. nov. is slightly narrower than *A. dauiensis* sp. nov. (3.5–5.0 µm versus 4.5–5.5 µm). Valve ends of *A. vietnamensis* sp. nov. are capitate to subcapitate in shape while in *A. dauiensis* sp. nov. the ends are subcapitate. The outline of *Adlafia vietnamensis* sp. nov. is linear-elliptical, while *Adlafia dauiensis* sp. nov. has a linear to linear-elliptical outline (Table 2).

*Adlafia dauiensis* sp. nov. resembles *Adlafia decora* Tusset, Tremarin & Ludwig (2017, p. 261, figs 1–18), differing from it in having capitate, but not rostrate ends, as well as having less convex valves, with a slightly higher striae density (32–34 in 10 µm in our material in comparison with 24–32 to 10 µm in *A. decora*). The areola density is also different between the two species (50–54 at 10 µm in *A. decora* versus 55–60 at 10 µm in *A. dauiensis* sp. nov.) (Table 2).

These new species were found in different water ecosystems of Vietnam that show this genus is widespread in this country, especially in acidic ecosystems.
Morales and Le (2005) suggested *Adlafia* is a monophyletic group but they did not perform any formal analysis or present data to support their conclusion. Based only on a single species, Thomas et al. (2016) suggested *Adlafia* is part of a monophyletic group that could be considered the Cymbellales. No other analysis was forthcoming on this taxon, so this work did not address whether *Adlafia* is a monophyletic genus. Several authors, including in the original description of *Adlafia*, have made comparisons with *Kobayasiella* Lange-Bertalot in Lange-Bertalot and Genkal 1999 (as *Kobayasia* Lange-Bertalot, 1996, non *Kobayasia* S. Imai & A. Kawamura, 1958; see also Morales and Le 2005; Monnier et al. 2012; Van de Vijver et al. 2017). The two genera have fine striae, external distal raphe ends that are distinctly curved and external hymenate occlusions on the areolae. The difference between the two genera is usually suggested to be the absence (in *Adlafia*) or presence (in *Kobayasiella*) of a deflection (umbilicus) in the raphe system. However, this distinction has not always been applied consistently. For example, Le Cohu and Azémar (2010, figs 12, 13) showed specimens of *K. jaagi* (Meister) Lange-Bertalot, 1999 without the umbilicus. Liu et al. (2017) highlighted areas of the girdle that might help diagnose *Adlafia* as a monophyletic group, but these observations await formal analysis.

**Acknowledgements**

Authors are grateful to the staff of the Centre of Electron Microscopy of the Papanin’s Institute for Biology of Inland Waters, RAS, for technical assistance. Samples were collected during expeditions organized and permitted by the Joint Russian-Vietnam Tropical Centre, Ecolan 3.2 theme. Publication is based on research carried out with financial support by Russian Science Foundation (19–14–00320) for LM, SEM, sample investigation and by framework of the state assignment (theme AAAA–A19–119041190086–6) for finishing the manuscript.

**References**

Benson ME, Kociolek JP (2012) Freshwater diatom floristics of the Late Eocene Florissant Formation, Clare’s Quarry site, central Colorado, USA. Bibliotheca Diatomologica 58: 1–136.

Bramburger AJ, Haffner GD, Hamilton PB (2004) Examining the distributional patterns of the diatom flora of the Malili Lakes, Sulawesi, Indonesia. In: Poulin M (Ed.) Proceedings of the 17th International Diatom Symposium. Biopress Limited, Bristol, 11–25.

Cantonati M, Kelly MG, Lange-Bertalot H (2017) Freshwater Benthic Diatoms of Central Europe: Over 800 Common Species Used in Ecological Assessment. Koeltz Botanical Books, Germany, 942 pp.

Ciugulea I, Burroughs S, De Francesco C, Spitale D, Charles DF, Lange-Bertalot H, Cantonati M (2019) *Adlafia neoniana* (Naviculaceae), a new diatom species from forest streams in Puerto Rico. Plant Ecology and Evolution 152(2): 378–384. https://doi.org/10.5091/plecevo.2019.1616

Duong T, Coste M, Feuertet-Mazel A, Dang D, Gold C, Park Y, Boudou A (2006) Impact of urban pollution from the Hanoi area on benthic diatom communities collected from
the Red, Nhue and Tolich rivers (Vietnam). Hydrobiologia 563(1): 201–216. https://doi.org/10.1007/s10750-005-0005-z

Glushchenko AM, Genkal SI, Kulikovskiy MS (2016) Aulacoseira konstantinovii sp. nov. and Aulacoseira krylovii sp. nov. – two new centric diatoms from South East Asia. Diatom Research 31(4): 367–378. https://doi.org/10.1080/0269249X.2016.1253617

Glushchenko AM, Kociolek JP, Kuznetsova IV, Kezlya EM, Kulikovskiy MS (2019) Prestauroneis genkalii – a new diatom species (Bacillariophyceae: Stauroneidaceae) from Southeast Asia. Phytotaxa 414(4): 156–164. https://doi.org/10.11646/phytotaxa.414.4.1

Glushchenko AM, Kulikovskiy MS, Dorofeyuk NI, Kociolek JP (2018) New species and combinations in the genus Eunotia Ehrenberg 1837 (Bacillariophyceae: Eunotiaceae) from waterbodies of Southeastern Asia. Nova Hedwigia. Beiheft 147: 69–103. https://doi.org/10.1127/nova-suppl/2018/009

Glushchenko AM, Kulikovskiy MS, Okhapkin AG, Kociolek JP (2017) Aneumastus laosica sp. nov. and A. genkalii sp. nov. – two new diatom species from Laos (Indochina) with comments on the biogeography of the genus. Cryptogamie. Algologie 38(3): 183–199. https://doi.org/10.7872/crya/v38.iss3.2017.183

Guiry MD, Guiry GM (2020) AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org [accessed: 18 August 2020]

Gusev ES, Kulikovskiy MS (2014) Centric diatoms from Vietnam reservoirs with description of one new Urosolenia species. Nova Hedwigia. Beiheft 143: 111–126.

Heudre D, Wetzel CE, Moreau L, Ector L (2018) Sellaphora davoutiana sp. nov.: a new freshwater diatom species (Sellaphoraceae, Bacillariophyta) in lakes of Northeastern France. Phytotaxa 346(3): 269–279. https://doi.org/10.11646/phytotaxa.346.3.6

Imai S, Kawamura A (1958) On the Japanese species of Protubera. Science Reports of the Yokohama National University Section II 7: 1–6.

Kapustin DA, Kociolek JP, Glushchenko AM, Kulikovskiy MS (2019) Four new species of Cymbella (Bacillariophyta) from the ancient Malili lakes (Sulawesi Island, Indonesia). Botanicheskij journal 104(5): 766–780. https://doi.org/10.1134/S0006813619050065

Kapustin DA, Kulikovskiy MS, Kociolek JP (2017) Celebesia gen. nov., a new cymbelloid diatom genus from the ancient Lake Matano (Sulawesi Island, Indonesia). Nova Hedwigia. Beiheft 146: 147–155. https://doi.org/10.1127/1438-9134/2017/147

Kulikovskiy MS, Chudaev DA, Glushchenko AM, Kuznetsova IV, Krivova ZV, Kociolek JP (2020) Navicula gogorevii – a new, large-celled diatom species from Vietnam (Southeast Asia). Phytotaxa 428(1): 60–66. https://doi.org/10.11646/phytotaxa.428.1.6

Kulikovskiy MS, Glushchenko AM, Genkal SI, Kuznetsova IV (2016) Identification book of diatoms from Russia. Filigran, Yaroslavl, 804 pp.

Kulikovskiy MS, Maltsev Yel, Andreeva SA, Glushchenko AM, Gusev ES, Podunay YuA, Ludwig TV, Tisset E, Kociolek JP (2019) Description of a new diatom genus Dorofeyukea gen. nov. with remarks on phylogeny of the family Stauroneidaceae. Journal of Phycology 55(1): 173–185. https://doi.org/10.1111/jpy.12810

Lange-Bertalot H (1996) Kobayasia bicuneus gen. et spec. nov. Iconographia Diatomologica 4: 277–287.

Lange-Bertalot H (2001) Navicula sensu stricto. 10 Genera separated from Navicula sensu lato. Frustulia. Diatoms of Europe 2, 526 pp.
Four new species of genus *Adlafia* from Vietnam

Lange-Bertalot H, Genkal SI (1999) Diatoms from Siberia I. Islands in the Arctic Ocean (Yugorsky-Shar Strait). Iconographia Diatomologica 6: 1–271.

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

Le Cohu R, Azémard F (2010) Les genres *Adlafia*, *Kobayasiella*, *Fallacia*, *Microcostatus* et *Naviculadicta* (Bacillariophycées) recensés dans quelques lacs des Pyrénées françaises. Bulletin de la Société d’histoire naturelle de Toulouse 146: 5–13.

Lee JH (2012) Chrysophyta: Pennales: Raphidineae: Naviculaceae: 20 genera including *Navicula*. Freshwater Diatoms VIII. Algal Flora of Korea 3(10): 1–74.

Liu Y, Kociolek JP, Glushchenko AM, Kulikovskiy MS, Fan Y (2018) A new genus of Eunotiales (Bacillariophyta, Bacillariophyceae: Peroniaceae), *Sinoperonia*, from Southeast Asia, exhibiting remarkable phenotypic plasticity, and evidence for another lineage of monoraphid diatoms. Phycologia 57(2): 147–158. https://doi.org/10.2216/17-21.1

Liu B, Williams DM, Ou Y (2017) *Adlafia sinensis* sp. nov. (Bacillariophyceae) from the Wuling Mountains Area, China, with reference to the structure of its girdle bands. Phytotaxa 298(1): 43–54. https://doi.org/10.11646/phytotaxa.298.1.4

Metzeltin D, Lange-Bertalot H (2007) Tropical diatoms of South America II. Iconographia Diatomologica 18: 1–876.

Monnier O, Ector L, Rimet F, Ferréol M, Hoffmann L (2012) *Adlafia langebertalotti* sp. nov. (Bacillariophyceae), a new diatom from the Grand-Duchy of Luxembourg morphologically similar to *A. suchlandtii* comb. nov. Nova Hedwigia. Beiheft 145: 131–140.

Morales EA, Le M (2005) A new species of the diatom genus *Adlafia* (Bacillariophyceae) from the United States. Proceedings. Academy of Natural Sciences of Philadelphia 154(1): 149–154. https://doi.org/10.1635/0097-3157(2004)154[0149:ANSOTD]2.0.CO;2

Moser G, Lange-Bertalot H, Metzeltin D (1998) Island of endemics New Caledonia – a geobotanical phenomenon. Bibliotheca Diatomologica 38: 1–464.

Rybak M, Solak CN, Noga T, Glushchenko AM, Williams DM, Kulikovskiy MS (2019) *Nupela brevistriata* sp. nov. – a new, terrestrial diatom species from Southeast Asia. Diatom Research 34(4): 251–258. https://doi.org/10.1080/0269249X.2019.1698467

Spaulding SA, Edlund M (2009) *Adlafia*. Diatoms of North America. https://diatoms.org/genera/adlafia [accessed: 18 August 2020]

Thomas EW, Stepanek JG, Kociolek JP (2016) Historical and current perspectives on the systematics of the ‘enigmatic’diatom genus *Rhoicosphenia* (Bacillariophyta), with single and multimolecular marker and morphological analyses and discussion on the monophyly of ‘monoraphid’ diatoms. PLoS One 11(4): 1–20. https://doi.org/10.1371/journal.pone.0152797

Tusset EA, Tremarin PI, Straube A, Ludwig TAV (2017) Morphology of *Adlafia* taxa (Bacillariophyta, Cymbellaceae), with proposition of two new species from Brazil. Phytotaxa 306(4): 259–274. https://doi.org/10.11646/phytotaxa.306.4.2

Van de Vijver B, Lange-Bertalot H, Wetzl CE, Ector L (2017) *Michelcostea*, a new diatom genus (Bacillariophyta) from the sub-Antarctic Region. Nova Hedwigia. Beiheft 146: 125–136. https://doi.org/10.1127/1438-9134/2017/125