Phytotaxa 669 (2): 119–130
https://www.mapress.com/pt/
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Article

ISSN 1179-3155 (print edition)
PHYTOTAXA
ISSN 1179-3163 (online edition)

https://doi.org/10.11646/phytotaxa.669.2.4

Luticola centraloporea sp. nov.—a new diatom (Bacillariophyceae: Diadesmidaceae) species from Europe and North America

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Abstract

Among the diatoms of the genus *Luticola* D.G.Mann, many have elliptical and linear-elliptic valves. Most of these species have been incorrectly identified in the past as the brackish water taxon *Luticola mutica*. In the present work, we describe a new terrestrial species—*Luticola centraloporea sp. nov.* The species has a similar outline to *Luticola mutica* but is distinguished from all other similar taxa in the genus due to the unique position of the isolated pore, which is located practically in the middle of the valves. The new taxon was observed with two populations, one from North America, and a second one from Europe, suggesting that it may actually have a wide distribution in the Northern Hemisphere. The new species is compared with morphologically similar species of the genus.

Key words: Holarctic, bryosphere, terrestrial habitats, Diadesmidaceae

Introduction

The genus *Luticola* D.G.Mann (in Round *et al.* 1990) was distinguished from *Navicula* Bory to accommodate species included in *Naviculae* sect. *Punctatae* (Hustedt 1959). *Luticola mutica* (Kützing 1844: 93) D.G.Mann (Round *et al.* 1990: 532) was designated as the generitype, and additionally, 25 species originally described within the genus *Navicula,* and 4 species originally described as *Stauroneis* Ehrenberg were also transferred to the genus. After the establishment of the genus, more attention began to be paid to species representing *Luticola* in different geographic regions which resulted in the description of new species from all continents. The greatest breakthrough in taxonomic research of this genus was the monography made by Levkov *et al.* (2013) which increased the number of known species to almost 200. Since the publication of the genus monograph, 74 additional taxa (species, variety and morphotypes) have been described or transferred to the genus *Luticola* (see Annex).

Diatoms from *Luticola* genus represent both a large ecological amplitude and also demonstrate significant diversity in their morphology. They can be found in freshwater, brackish, marine and terrestrial habitats (Levkov *et al.* 2013, Rybak *et al.* 2021, Rybak *et al.* 2023) and can also be a part of epizoic biofilm (Wetzel *et al.* 2009, Wu & Bergey 2017). The valve outline ranges from linear-elliptic, elliptical, elliptic-lanceolate, lanceolate, to clearly rombic, moreover valves can be less or more asymmetric. Also valve apices shows great variability form widely rounded, being an integral part of the valve, to clearly distinct (Levkov *et al.* 2013). There is also great variation in the size of the cells themselves. Among the currently known species, the smallest species, *L. minutissima* M.Rybak, Peszek, Skoczylas, T.A.V.Ludwig (Rybak *et al.* 2022: 288), reaches only 5.2 µm length and 3.7 µm in width, while the largest, *L. kraeuselii* (Cholnoky 1954: 284) Metzeltin & Lange-Bertalot (1998: 139), reaches even 96 µm in length and 26 µm in width. This genus also has great diversity in the presence/absence of such morphological structures as longitudinal channels, spines, septa and number of isolated pore and areolae structure (see Rybak *et al.* 2024). However, the advent of newer tools facilitating detailed taxonomic research and questioning of past force-fitting means that many species has resulted in many new taxon descriptions and the idea that there are still many new species to be discovered (Tyler

Accepted by María Luján García: 28 Sept. 2024; published: 22 Oct. 2024

1996). Even in the case of the *typus generis*, there is still much uncertainty regarding the taxa previously identified under this name (Levkov *et al.* 2013).

In this paper we describe a new species, *Luticola centraloporea sp. nov.*, discovered in samples from both North America and Europe, based on its unique morphology and compare it with similar species based on the published literature.

Material and Methods

For the purposes of preparing documentation in light and scanning microscopy, for two distant populations, two samples were used in which the newly described species occurred:

- 2015/12—moss sample collected near lake shore, April 2015, United States of America, Castle Rock Lake, Wisconsin, 43°59'56"N 89°59'33"W.
- 2022/199—moss sample from rock collected in the temperate greenhouse of the Botanical Garden of the University of Warsaw, June, 2022, Poland, 52°13'00"N 21°01'36"E.

In the laboratory, the samples were digested in a mixture of concentrated sulphuric acid [VI] and potassium dichromate to remove organic matter and obtain clean diatom frustules. The material was centrifuged with distilled water at 2500 rpm to remove the sulphochromic mixture. The cleaned diatom material was pipetted onto coverslips and dried, and then mounted on glass slides using Naphrax mounting medium (Brunel Microscopes Ltd, Wiltshire, UK). Light microscope (LM) observations were made with a Zeiss Axio Imager A2 (Carl Zeiss, Jena, Germany) microscope equipped with Differential Interference Contrast (DIC) under a magnification of 1000×. For SEM, a few drops of cleaned material were placed on Whatman Nuclepore polycarbonate membrane filters (Fisher Scientific, Schwerte, Germany). Once dry, the membranes were mounted on aluminium stubs and coated with 20 nm of gold using a turbo-pumped Quorum Q 150 T ES coater (Judges Scientific plc, London, United Kingdom). SEM observations were performed using a Hitachi SU8010 (Hitachi, Ltd, Tokyo, Japan) microscope. The diatom terminology used in this paper largely follows Barber & Haworth (1981), Round *et al.* (1990) and Levkov *et al.* (2013). Following article 8.2 of the ICBN (Turland *et al.* 2018) entire slide was chosen as the type.

Results

Division: **Bacillariophyta** Haeckel
Class: **Bacillariophyceae** Haeckel
Subclass: **Bacillariophycidae** D.G. Mann
Order: **Naviculales** Bessey
Family: **Diadesmidaceae** D.G. Mann
Genus: ***Luticola*** D.G. Mann in Round *et al.*, 1990

Luticola centraloporea M.Rybak, Getler et Kociolek ***sp. nov.***

LM observations (1A–T):—Valves elliptic-lanceolate to linear-lanceolate with rounded apices (Figs 1A–T). Valve length 9.0–21.0 µm, width 4.0–6.0 µm and 20–24 striae in 10 µm (n = 35). Axial area narrow and linear. Central area rectangular to bow-tie shaped and bordered near margin by 2–3 shortened striae (Figs 1A–H). Isolated pore clearly visible in the central part of central area almost between proximal raphe endings (Figs 1A–H). Raphe filiform, with proximal raphe endings clearly curved away from the isolated pore, distal raphe endings barely visible (Figs C, D) elongated, weakly hooked opposite the proximal raphe endings. Striae clearly radiate with 3–4 areolae per striae. No morphological differences were observed between the European and North American populations.

SEM observations (2A–H, 3A–H):—Externally, striae composed by 3–4 areolae per striae, rounded, sometimes enlarged near the valve face margin (Figs 2A–D, 3A, B). Internally, areolae covered by hymen forming continuous strip, separated by not thickened virgae (Figs 3C). Single row of areolae (interrupted on the apices) present also on valve mantle (Figs 2C, D, G, 3A, B, G). Both, valve face and mantle areolae circular in shape. Isolated pore rounded, located in the central part of the central area, almost between proximal raphe endings (Figs 2A–F, 3A, B, E). Raphe branches straight and filiform, with proximal endings pore-like shaped and curved away of isolated pore bearing side

(Figs 2A–F, 3A, B, E). Distal raphe endings pore-like shaped, terminating onto valve face, only slightly bent away of isolate pore bearing side (Figs 2A–D, G, 3A, B, G). Internally, isolated pore opening small, c-shaped, positioned midway between valve margin and the central area (Fig. 3F). Longitudinal channels located along on both sides of valves (Fig 3C). Externally, central area bow-tie shaped with a smooth surface (Figs 2c, 3A, B). Girdle bands with two rows of poroids (Fig 3D). No morphological differences were observed between the European and North American populations.

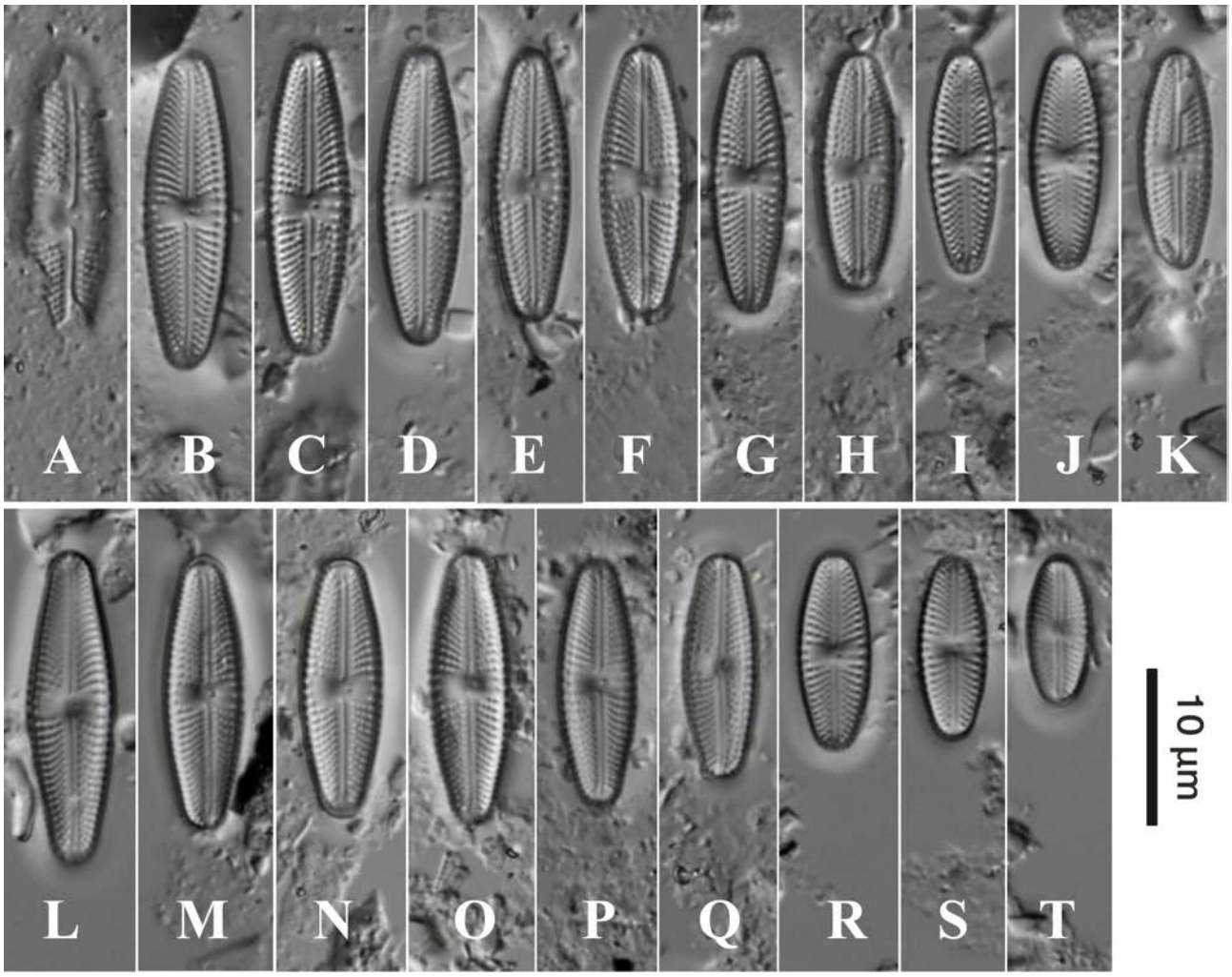

FIGURE 1. LM microphotography of *Luticola centraloporea sp. nov.* from two population in size diminution series. A–K populations from central Europe (sample no. 2021/199), L–T holotype population from United States of America (sample no. 2015/12). Scale bar = 10 µm.

Type:—United States of America, Castle Rock Lake, Wisconsin, 43°59'56"N 89°59'33"W, moss sample from lake shore, collected in April 2015. Holotype: Slide no. SZCZ 29315 at the University of Szczecin, isotype 1 slide no. 2015/12 and unmounted material with the same number at the University of Rzeszów, Poland, isotype 2 slide no. WA0000166879 and unmounted material with the same number at the Herbarium of the Faculty of Biology, University of Warsaw. The holotype population is presented in Figs 1L–T.

Etymology:—Name refers to the position of isolated pore.

Distribution:—Probably widely distributed in the northern hemisphere, observed in Wisconsin (USA) and in Warsaw (Poland).

Ecology and accompanying taxa:—In both analyzed samples the species occurred very rarely (<0.5% share in the community) also in both samples, diatoms were rare and represented only a few species. In sample 2015/12, the most common associated species were *Geissleria decussis* (Østrup) Lange-Bertalot & Metzeltin (1996: 65), *Planothidium* sp., *Skabitschewskia peragalloi* (Brun & Héribaud) Kuliskovskiy & Lange-Bertalot (in Kulikovskiy *et al.* 2015: 85). In sample 2022/199 the most common taxa encountered were *Humidophila delognei* Goeyers & Van de Vijver (2023: 3) and *Luticola micra* Levkov, Metzeltin & A.Pavlov (2013: 156).

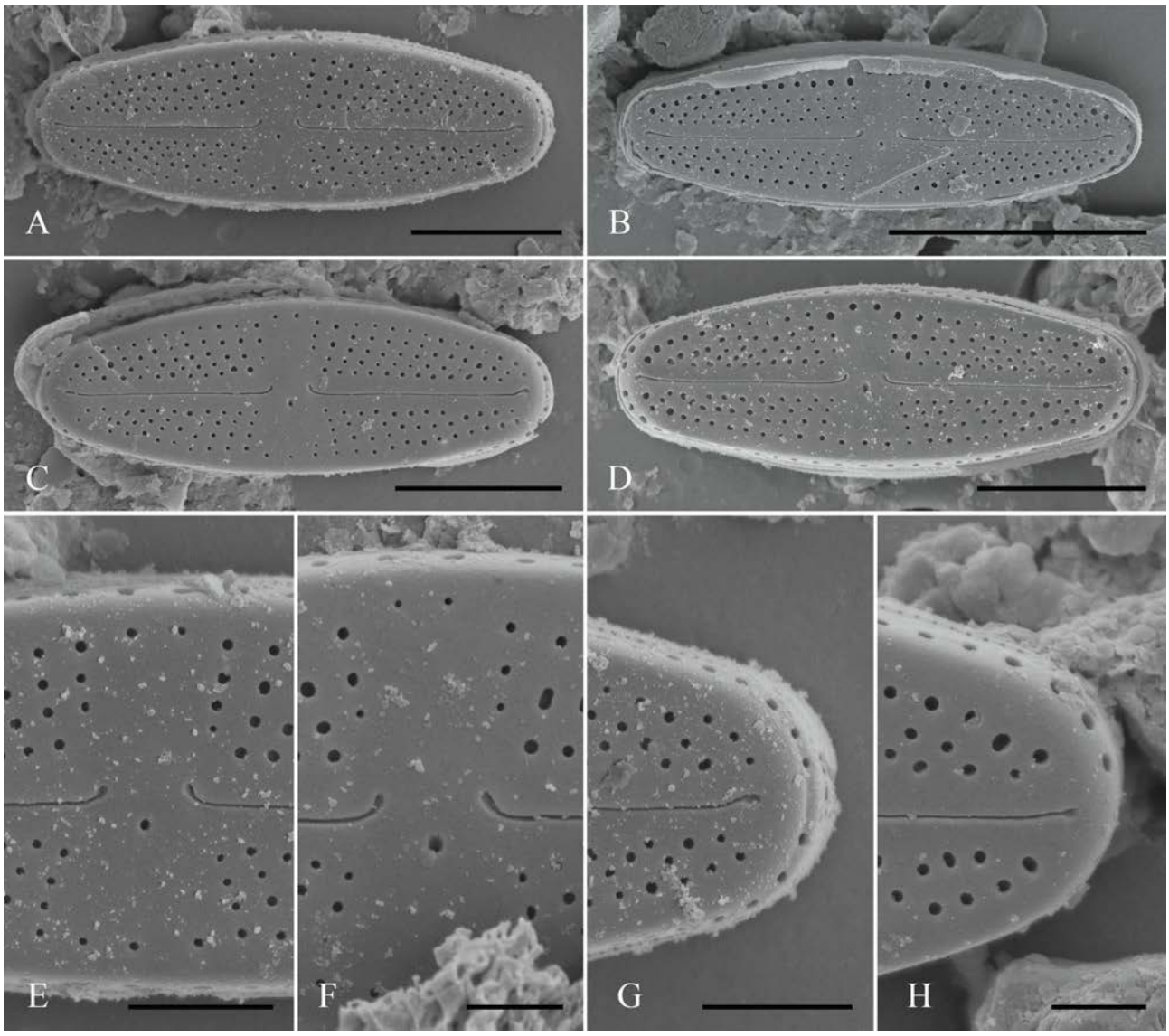

FIGURE 2. SEM microphotography of *Luticola centraloporea sp. nov.* from the type population in USA (sample 2015/12). Scale bars = 5 μm (A–D), 1 μm (E–H).

Similar species:—*Luticola confusa* M.Rybak & Czarnota (in Rybak *et al.* 2023: 8), *L. imbricatiformis* Levkov, Metzeltin & Pavlov (2013: 134), *L. mitis* Levkov, Metzeltin & A.Pavlov (2013: 161), *L. mutica*, *L. rotunda* Solak & Levkov (in Levkov *et al.* 2013: 212).

Discussion

Many *Luticola* taxa worldwide represent a group of small to medium sized species with elliptic-lanceolate to linear-elliptic valves which were been identified previously as *L. mutica* (Levkov *et al.* 2014, Rybak *et al.* 2023). On the one hand, *L. mutica*, as one of the first species transferred in the genus, has so far been reported from many locations around the world (Guiry and Guiry 2024). On the other hand, the "real" *L. mutica* is a brackish species, which means that most of the previous records of this taxon, both from freshwater and terrestrial environments, may refer to other species of similar shape and size (Levkov *et al.* 2013). A similar situation was evident with members of the genus previously reported from Antarctica (e.g. Kellogg & Kellogg 2002; Kohler *et al.* 2015). This may make *L. mutica* the most misidentified species in the genus and its actual distribution requires verification.

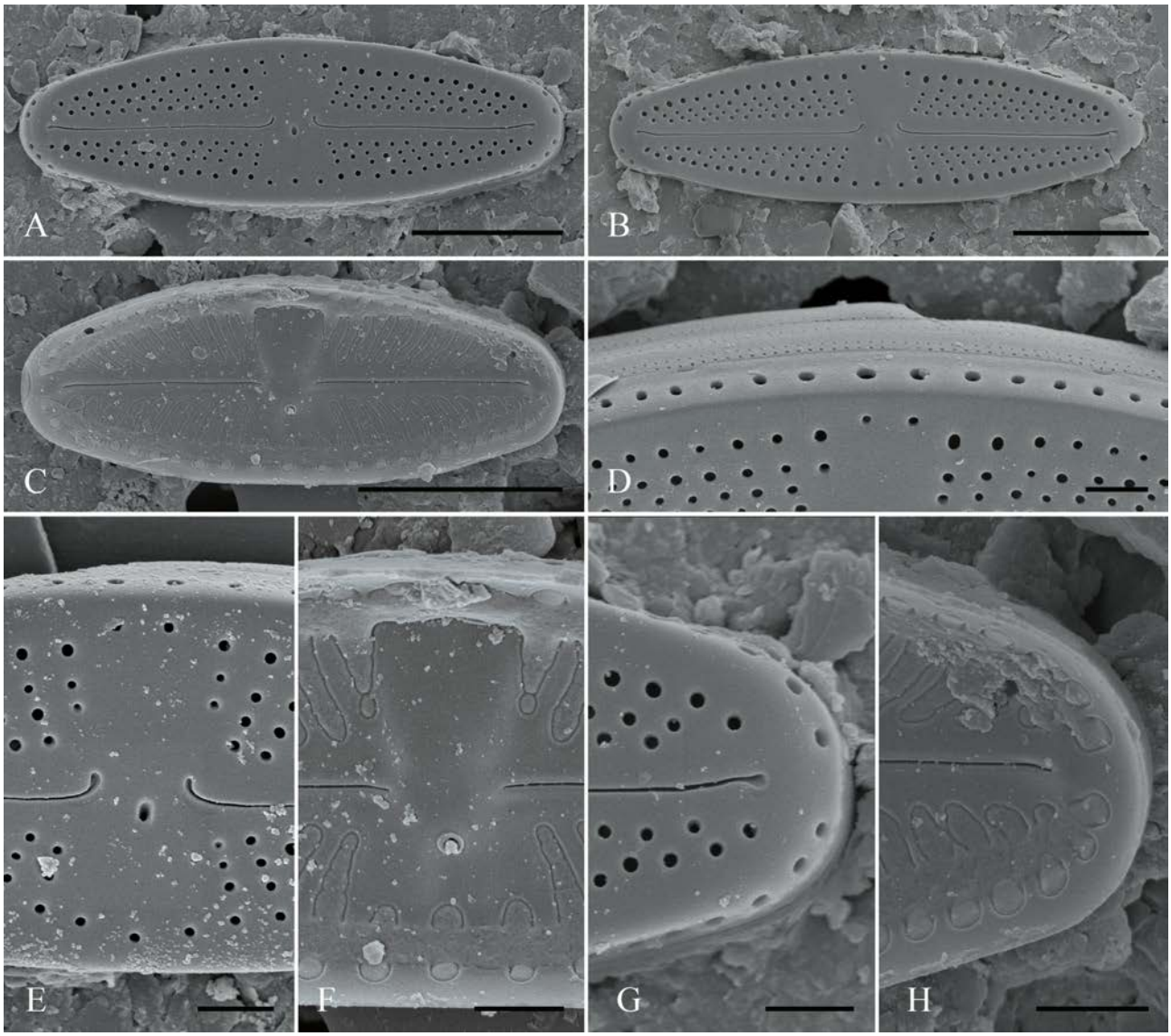

FIGURE 3. SEM microphotography of *Luticola centraloporea sp. nov.* from European population (sample 2021/199). Scale bar = 5 µm (A–C), 1 µm (D–H).

Luticola centraloporea sp. nov. represents a species that may have identified in the past as *L. mutica* due to its similar valve outline and dimensions. In addition to the characteristic location of the isolated pore in *Luticola centraloporea sp. nov.*, both species are also distinguished by a number of other features. The newly described species has significantly higher striae density (20–24 in 10 µm vs. 16-18, see Table 1), shorter distal raphe endings located on the valve face, and proximal raphe endings without thread-like depressions which occurs in *L. mutica* (Levkov *et al.* 2013, pl. 2). Additionally, *L. mutica* shows presence of deeply embedded cribrum in their areolae (Levkov *et al.* 2013, pl. 2, figs 5,6, pl. 3, fig. 3) which is absent in *L. centraloporea sp. nov.*.

Another species showing high similarity to *L. centraloporea sp. nov.* is *L. confusa*. Both species can be easily distinguished by distal raphe endings which terminate on the valve mantle in *L. confusa* (Rybak *et al.* 2023, fig2 Y–AA), not on valve face like in *Luticola centraloporea sp. nov.* Additionally, *L. confusa* has proximal raphe endings with small depressions (Rybak *et al.* 2023, fig2 Y–AA) which are absent in *L. centraloporea sp. nov.* It is in addition *L. centraloprea sp. nov.* shows more radiate striae than *L. confusa* (Rybak *et al.* 2013)(Table 1).

Among *Luticola* species, the external opening of isolated pore is located halfway between the valve center and its valve margin or is more or less shifted towards the margin, while the internal opening is always positioned halfway between the valve center and the margin (Levkov *et al.* 2013). The external opening being located at or very close to the center of the valve, a feature used to diagnose *L. centraloporea sp. nov.*, is also found in *L. imbricatiformis*. Moreover, *L. imbricatiformis* has also similar proximal raphe endings but completely different distal raphe endings; In *L. imbricatiformis* the distal raphe endings are hooked and terminate on valve mantle (Levkov *et al.* 2013, pl. 28, fig.

11). However, *L. imbricatiformis* has a much lower striae density compared to *L. centraloporea sp. nov.* (see Table 1) and a wider central area that can be bordered by up to 5 areolae (Levkov *et al.* 2013, pl. 28, fig 11).

TABLE 1. Comparison of *Luticola centraloporea sp. nov.* with morphologically similar taxa.

	L. centraloporea sp. nov.	*L. confusa*	*L. imbricatiformis*	*L. mitis*	*L. mutica*	*L. rotunda*
Length [µm]	9.0–21.0	9.0–22.0	12.0–34.0	14.5–28.0	11.0–28.0	7.0–19.0
Width [µm]	4.0–6.0	4.5–5.5	5.5–7.0	6.0–8.0	6.0–9.5	4.5–6.5
Striae [in 10 µm]	20–24	20–22	15–19	20–22	16–18	18–22
Areolae per striae	3–4	4	3–4	5–6	3–4	2–3
Proximal raphe endings	teardrop shaped and curved away of isolated pore	deflected to side opposite to stigma with small rounded depressions	deflected to side opposite to isolated pore	Deflected to side opposite to stigma, expanded into small central pores	closely standing, doubly-curved with irregular thread like depressions	slightly curved to side opposite to isolated pore
Distal raphe endings	teardrop shaped, terminating onto valve face, only slightly bent away of isolate pore bearing	hooked, terminated on valve mantle	hooked, terminated on valve mantle	hooked	hooked, terminated on valve mantle	straight to weakly deflected to side opposite to isolated pore
Central area	rectangular to bow-tie shaped bordered by 2–3 areolae	elliptic bordered by 3–4 areolae	wide, transversally elliptic to wedge-shaped, bordered 3–5 areolae	asymmetrical, almost rectangular to transversally elliptic, bordered by 3–5 areolae	narrow , transversally elliptic, bordered by 1–2 areolae	wide, asymmetric, transversally elliptic, bordered by 3–4 areolae
Isolated pore	circular, located almost in the valve center	circular to slightly elongated, located in midway between valve margin and valve center	elongated, close to valve center	round to transapically elongated	elliptic, close to valve margin	round, almost halfway between the valve center and margins
References	This study	Rybak *et al.* 2023	Levkov *et al.* 2013	Levkov *et al.* 2013	Levkov *et al.* 2013	Levkov *et al.* 2013

Luticola rotunda also shows similarity in raphe endings morphology to *L. centraloporea sp. nov.*, but their proximal raphe endings are not expanded forming teardrop-shaped openings (Levkov *et al.* 2013, pl. 34, fig. 3). Moreover, their striae contain mainly two areolae (rarely 3), while in *L. centraloprea sp. nov.* 3–4 areolae are present per striae (see Table 1).

Luticola mitis, despite the general similarity in the shape of the valves, it can be easily distinguished from *L. centraloporea sp. nov.* by wider valves and denser striation (see Table 1). Moreover, in *L. centraloporea sp. nov.* the central area is rectangular and symmetrical, whereas in *L. mitis* the central area is as symmetrical and and more or less transversally elliptic (Levkov *et al.* 2013)

The distribution of the described species is also interesting. Most members of the genus *Luticola* are considered endemic, with significant diversity of the group reported from Antarctica (Kociolek *et al.* 2017). However, it should be noted that many taxa of this genus occur in terrestrial environments that are still undersampled. Many of currently known species from this genus are still known only from their type locality (i.e. *L. andakiesiorum* Simonato, Kociolek & Plata Díaz 2020: 383, *L. minutissima* M.Rybak, Peszek, Skoczylas, T.A.V.Ludwig 2022: 288, *L. moaiorum* Peszek, M.Rybak, A.Witkowski & Lange-Bertalot 2021: 9, *L. rapanuiensis* M.Rybak, Peszek, A.Witkowski & Lange-Bertalot 2021: 7, *L. tenera* Bagmet, Abdullin, A.Y.Nikulin, V.Y.Nikulin & A.A.Gontcharov 2023: 4). This means that the occurrence of many terrestrial species (not only of *Luticola*) may still be underestimated. The species, apart from its type locality in Wisconsin in the United States of America (sample 2015/12), has also been recorded in central Europe (sample 2022/199). In addition, a single valve with a similar valve outline, dimensions and striation pattern, and with a centrally positioned isolated pore as in *Luticola centraloporea sp. nov.* was illustrated in LM from a stream in Japan by Ohtsuka *et al.* (2007, page 38, fig. 73). Further studies may show that *L. centraloporea sp. nov.* to be found from other localities across the Northern Hemisphere.

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Annex

Alphabetical list of diatom taxa described or transferred into genus *Luticola* D.G.Mann since the publication of the monograph of the genus.

taxa	origin	taxonomical status	references
L. andakiesiorum Simonato, J.P.Kociolek & Plata Díaz	South America	new species	Simonato *et al.* 2020
L. areolata V.Lokhande, Lowe, Kociolek & B.Karthick	South Asia	new species	Lokhande *et al.* 2020
L. asiatica V.Lokhande, Lowe, Kociolek & B.Karthick	South Asia	new species	Lokhande *et al.* 2020
L. asymmetrica M.Rybak, Kochman-Kędziora & Peszek	South Africa	new species	Rybak *et al.* 2021a
L. bandanensis M.Rybak & Peszek	SE Asia	new species	Rybak *et al.* 2024
L. bartolomeui Silva-Lehmkuhl, T.Ludvig, Tremarin & D.Bicudo	South America	new species	Da Silva Lehmkuhl *et al.* 2019
L. blancoi Levkov, Tofilovska, C.E.Wetzel, Mitic-Kopanja & Ector	Europe	new species	Levkov *et al.* 2017
L. bogaertsiana Zidarova, Z.Levkov & Van de Vijver	Antarctica	new species	Zidarova *et al.* 2014
L. bolavenensis Glushchenko, Kulikovskiy & Kociolek	SE Asia	new species	Glushchenko *et al.* 2017
L. bradyi T.J.Kohler	Antarctica	new species	Koehler *et al.* 2015
L. bryophila M.Rybak, Czarnota & T.Noga	Europe	new species	Rybak *et al.* 2023
L. caquetensis Kociolek, Simonato & Núñez-Avellanedra	South America	new species	Simonato *et al.* 2020
L. coloradiana Shea, Greifenstein & Kociolek	North America	new species	Seah *et al.* 2022
L. confusa M.Rybak & Czarnota	Europe	new species	Rybak *et al.* 2023
L. contii Zidarova, Levkov & Van de Vijver	Antarctica	new species	Zidarova *et al.* 2014
L. cribriareolata M.Rybak, Witkowski, Risjani & Yunianta	SE Asia	new species	Rybak *et al.* 2021b
L. darwinii Witkowski, Bak, Kociolek, Lange-Bertalot & Seddon	Galapagos Island	new species	Bąk *et al.* 2017
L. dubia Levkov, Tofilovska, C.E.Wetzel, Mitic-Kopanja & Ector	Europe	new species	Levkov *et al.* 2017
L. elegans (W.West & G.S.West) T.J.Kohler & K.kopalová	Antarctica	new combination	Koehler *et al.* 2015
L. elliptica M.Rybak & Peszek	SE Asia	new species	Rybak *et al.* 2024
L. galapagoensis Witkowski, Bak, Kociolek, Lange-Bertalot & Seddon	Galapagos Island	new species	Bąk *et al.* 2017
L. gandhii (H.P.Gandhi) Kale, Levkov & Karthick	South Asia	new combination	Kale *et al.* 2017
L. georgzizkae A.Witkowski, Lange-Bertalot, M.Rybak & Peszek	Rapa Nui Island	new species	Peszek *et al.* 2021
L. gigantea V.Lokhande, Lowe, Kociolek & B.Karthick	South Asia	new species	Lokhande *et al.* 2020
L. glushchenkoia V.Lokhande, Lowe, Kociolek & B.Karthick	South Asia	new species	Lokhande *et al.* 2020
L. halongiana Witkowski, M.Rybak, H-D.Nguyen & D-V.Nguyen	SE Asia	new species	Rybak *et al.* 2021b
L. hunanensis Bing Liu & D.M.Williams	East Asia	new species	Liu *et al.* 2017
L. indica V.Lokhande, Lowe, Kociolek & B.Karthick	South Asia	new species	Lokhande *et al.* 2020
L. insularis M.Rybak & Peszek	SE Asia	new species	Rybak *et al.* 2024

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Annex (Continued)

taxa	origin	taxonomical status	references
L. iporangensis Silva-Lemhkuhl & T.Ludwig	South America	new species	Da Silva Lehmkuhl *et al.* 2019
L. ivetana Chattová & Van de Vijver	Islands on Souther Indian Ocean	new species	Chattová *et al.* 2017
L. jinshaensis L.Yang & Q.X.Wang	East Asia	new species	Yang *et al.* 2022
L. jogensis (H.P.Gandhi) Kale, Levkov & Karthick	South Asia	new combination	Kale *et al.* 2017
L. juliae S.Bustos, M.R.Morales & Maidana	South America	new species	Bustos *et al.* 2017
L. kaweckae Kochman-Kędziora, Noga, Olech, Van de Vijver	Antarctica	new species	Kochamn-Kędziora *et al.* 2022
L. lancettula var. *merguellilae* M.Coste & Riaux	North Africa	new variety	Coste *et al.* 2019
L. laosica Glushchenko, Kulikovskiy & Kociolek	SE Asia	new species	Glushchenko *et al.* 2017
L. lecohui Levkov, Tofilovska, C.E.Wetzel, Mitic-Kopanja & Ector	Europe	new species	Levkov *et al.* 2017
L. levkovii E.Reichardt	Europe	new species	Reichardt 2018
L. levkovii V.Lokhande, Lowe, Kociolek & B.Karthick	South Asia	new species – nom. illeg.	Lokhande *et al.* 2020
L. linearis (Gonzalves & H.P.Gandhi) V.Lokhande, C.Radhakrishnan, J.P.Kociolek, R.Lowe & B.Karthick	South Asia	new combination	Lokhande *et al.* 2020
L. macknightiae T.J.Kohler & K.Kopalová	Antarctica	new species	Koehler *et al.* 2015
L. madagascarensis M.Bąk, Kryk & Peszek	Madagascar	new species	Bąk *et al.* 2019
L. malukuana M.Rybak & J.P.Kociolek	SE Asia	new species	Rybak *et al.* 2024
L. microcephala M.Rybak, Peszek & Kochman-Kedziora	South Africa	new species	Rybak *et al.* 2021a
L. minutissima M.Rybak, Peszek, Skoczylas, T.A.V.Ludwig	South America	new species	Rybak *et al.* 2022
L. moaiorum Peszek, M.Rybak, A.Witkowski & Lange-Bertalot	Rapa Nui Island	new species	Peszek *et al.* 2021
L. mollis Lange-Bertalot & U.Rumrich morphotype 2	South America	new morphotype	Bustos *et al.* 2017
L. moreirae Straube, Tremarin & T.Ludwig	South America	new species	Straube *et al.* 2017
L. neglecta Zidarova, Levkov & Van de Vijver	Antarctica	new species	Zidarova *et al.* 2014
L. nipkowii (Meister) A.M.Glushchenko & M.C.Kulikovskiy	SE Asia	new combination	Glushchenko *et al.* 2015
L. nosybeana Kryk, M.Bak & Peszek	Madagascar	new species	Bąk *et al.* 2019
L. obscura Levkov, Tofilovska, C.E.Wetzel, Mitic-Kopanja & Ector	Europe	new species	Levkov *et al.* 2017
L. olegsakharovii Zidarova, Levkov & Van de Vijver	Antarctica	new species	Zidarova *et al.* 2014
L. orientalis M.Rybak, Peszek, J.P.Zhang & Witkowski	SE Asia	new species	Rybak *et al.* 2021b
L. papilioformis Straube, Tremarin & T.Ludwig	South America	new species	Straube *et al.* 2017
L. poliporea M.Rybak, Peszek, Luthfi, Arsad & A.Witkowski	SE Asia	new species	Rybak *et al.* 2024
L. pseudodistinguenda Glushchenko, Glushchenko & Kociolek	SE Asia	new species	Glushchenko *et al.* 2017
L. pseudolagerheimii (H.P.Gandhi) V.Lokhande, C.Radhakrishnan, J.P.Lociolek, R.Lowe & B.Karthick	South Asia	new combination	Lokhande *et al.* 2020

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Annex (Continued)

taxa	origin	taxonomical status	references
L. puchalskiana Kochman-Kedziora, Zidarova, T.Noga, Olech & B.Van de Vijver	Antarctica	new species	Kochman-Kędziora *et al.* 2020
L. punae S.Bustos, M.R.Morales & Maidana	South America	new species	Bustos *et al.* 2017
L. rapanuiensis M.Rybak, Peszek, A.Witkowski & Lange-Bertalot	Rapa Nui Island	new species	Peszek *et al.* 2021
L. renelecohui Glushchenko, Kulikovskiy & Kociolek	SE Asia	new species	Glushchenko *et al.* 2017
L. robustiformis Glushchenko, Kulikovskiy & Kociolek	SE Asia	new species	Glushchenko *et al.* 2017
L. rojkoviensis Hindáková & T.Noga	Europe	new species	Hindáková & Noga 2021
L. schweickerdtii (Cholnoky) Cocquyt & J.C.Taylor	East Africa	new combination	Cocquyt & Taylor 2022
L. sinchii Sala, J.P.Kociolek & Simonato	South America	new species	Simonato *et al.* 2020
L. spainiae T.J.Kohler & K.Kopalová	Antarctica	new species	Koehler *et al.* 2015
L. stoermeri V.Lokhande, Lowe, Kociolek & B.Karthick	South Asia	new species	Lokhande *et al.* 2020
L. tenera Bagmet, Abdullin, A.Y.Nikulin, V.Y.Nikulin & A.A.Gontcharov	East Asia	new species	Bagmet *et al.* 2023
L. terrestris Kochman-Kędziora, M. Rybak & Peszek	South Africa	new species	Rybak *et al.* 2021a
L. transantarctica T.J.Kohler & K.Kopalová	Antarctica	new species	Koehler *et al.* 2015
L. vancampiana Chattová & B.Van de Vijver	Islands on Souther Indian Ocean	new species	Chattová *et al.* 2017
L. wulingensis Bing Liu & S.Blanco	East Asia	new species	Liu *et al.* 2017