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Pseudostaurosira cataractarum comb. nov. (Bacillariophyta): type analysis, ecology and world distribution of a former "centric" diatom

Pseudostaurosira cataractarum *comb. nov. (Bacillariophyta): análisis del material tipo, ecología y distribución mundial de una diatomea inicialmente descrita como "céntrica"*

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Abstract: The transfer of *Melosira cataractarum* Hust. to the genus *Pseudostaurosira* D.M. Williams & Round is presented based on a detailed analysis of the type material from Java (Malay Archipelago) using light and scanning electron microscopy. The species was initially described as a "centric" diatom within the genus *Melosira* C. Agardh and was later transferred to the genus *Aulacoseira* Thwaites. *Pseudostaurosira cataractarum* (Hust.) C.E. Wetzel, E. Morales & Ector *comb. nov.* differs from other species of the genus by its smaller size, typical radiate striae arrangement and absence of apical pore fields. We additionally propose the transfer of *Fragilaria sopotensis* Witkowski & Lange-Bert. to the genus *Pseudostaurosira*, a species that is morphologically similar to *P. cataractarum*.

Keywords: *Aulacoseira*, Bacillariophyta, diatom, *Melosira*, new combination, *Pseudostaurosira*

Resumen: Se transfiere *Melosira cataractarum* Hust. al género *Pseudostaurosira* D.M. Williams & Round a partir de un análisis detallado del material tipo proveniente de Java (Archipiélago Malayo), mediante microscopía óptica y electrónica de barrido. Inicialmente, la especie se describió como una diatomea "céntrica" dentro del género *Melosira* C. Agardh y fue transferida luego al género *Aulacoseira* Thwaites. *Pseudostaurosira cataractarum* (Hust.) C.E. Wetzel, E. Morales & Ector *comb. nov*. se diferencia de las otras especies dentro del género por su tamaño más pequeño, la disposición radial de las estrías y por la ausencia de campos de poros apicales. Adicionalmente, se propone la transferencia al género *Pseudostaurosira* de *Fragilaria sopotensis* Witkowski & Lange-Bert., una especie morfológicamente similar a *P. cataractarum.*

Palabras clave: *Aulacoseira*, Bacillariophyta, diatomea, *Melosira*, nueva combinación, *Pseudostaurosira*

1 Introduction

While investigating type materials of species from the Malay Archipelago (Java, Bali and Sumatra) originally described by Hustedt [11], we observed that one species, *Melosira cataractarum* Hust., formerly ascribed to the centric diatoms (Family Coscinodiscaceae, Subfamily Melosiroideae), might actually be an araphid pennate taxon given the lack of radial symmetry in valve view under light microscopy (LM). Hustedt placed the species among the "Aeröphile Formen" found in the region at the side of *Melosira roeseana* Rabenh., *M. ruttneri* Hust. and *M. dickiei* (Thwaites) Kütz. Simonsen [18] transferred the species *Melosira cataractarum* to the genus *Aulacoseira* Thwaites (misspelled there as "*Aulacosira cataractorum*"), but provided no further taxonomic argumentation or illustrations. Since its original description *Aulacoseira cataractarum* (Hust.) Simonsen has been analyzed in differing details in a number of papers, most of them based only on LM observations [1][20]. To date, only Genkal & Lupikina [5] had presented scanning electron microscopy (SEM) illustrations as basis for an emended diagnosis, but still ascribing the species to *Aulacoseira.* Excepting the report from the type locality (Java), *A. cataractarum* has been reported in several studies from the Holarctic ecozone during the last century [4][6][9][12][17].

In the present paper, we review the current knowledge on this poorly known diatom, summarize the existing world distributional data, and evidence its relationship with other araphid forms, proposing two new combinations within the genus *Pseudostaurosira* D.M. Williams & Round based on detailed LM and SEM observations, as well as on the available literature.

2 Methodology

We used a small subsample of material AS1524 from the Hustedt Collection (Alfred-Wegener-Institut für Polar- und Meeresforshung, Bremerhaven, Germany), material that corresponds to the holotype slide no. A2/27, Tjibeureum Wasserfall, Java TJ2.III.c.

The material was digested using concentrated H_2O_2 and heating for 24 h using a sand bath. The preparation was then allowed to cool and settle (*ca.* 1 cm h^{-1}), and 80 to 90% of the supernatant was eliminated by vacuum aspiration. A volume of 1 mL of HCl (37%) was then added and the mixture and allowed to rest for 2 h followed by three repetitions of rinsing and decanting using deionized water.

For SEM, portions of the oxidized suspension were filtered and rinsed with additional deionized water through a 3 μm Isopore™ polycarbonate membrane filter (Merck Millipore). Filters were mounted on aluminum stubs and coated with platinum using a BAL–TEC MED 020 Modular High Vacuum Coating System for 30 s at 100 mÅ. An ultra-high-resolution analytical field emission (FE) scanning electron microscope (Hitachi SU–70, Hitachi High-Technologies Corporation, Tokyo, Japan) operated at 5 kV and 10 mm distance was used for the analysis. SEM images were taken using the lower (SE-L) detector signal. Images were digitally manipulated and plates containing LM and SEM images were created using CorelDraw X5®.

3 Results

Morphology

Frustules are rectangular in girdle view, joined by interlocking linking spines. Valves are round to slightly elliptical, 5.8-8.2 μm long and 5.4-7.2 μm wide. Valve apices can only be identified by differences in striation pattern, but many individuals do not expose such a difference. The valve face is flat with a sharp transition between valve face and mantle. The abvalvar edge of the mantle is parallel to the valve face/mantle junction. The axial area is irregularly broad, sometimes somewhat elliptical (Figs 1A-AB). Striae are distinct, composed of round to oval areolae decreasing in size from the valve face/mantle edge to both the central sternum and the valve mantle; 15-18 in 10 μm. Striae radiate throughout the entire valve and extend onto the valve mantle, in many cases stopping shortly before the valve mantle abvalvar edge. Costae are broad, wider than striae. Spines are spatulate, solid and located along the valve face edge, including at the apices (Figs 2A-G). These spines interrupt the striae, but also they are sometimes displaced towards costae, presumably due to size reduction. Spicules and flaps are

absent. Apical pore fields are also absent as is the rimoportula. Girdle bands are open and lack perforations.

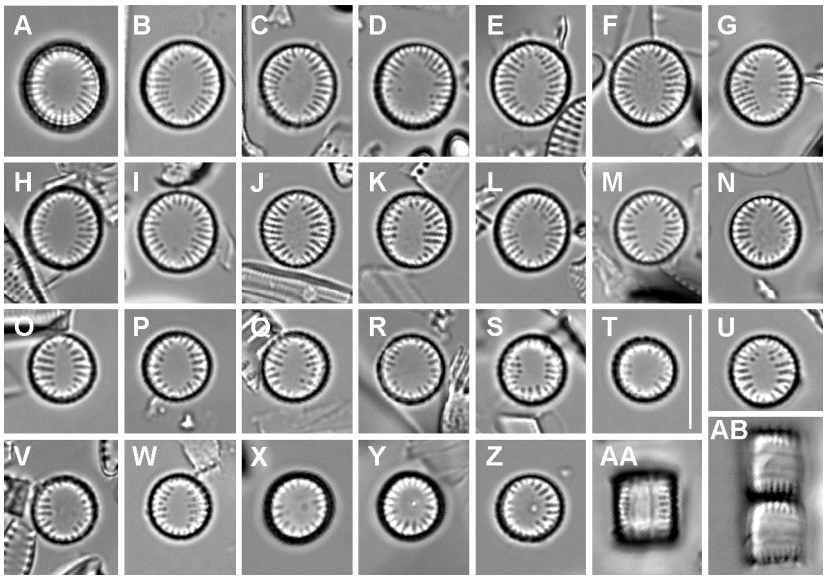

Figura 1: *Pseudostaurosira cataractarum* comb. nov. **A–Z**. Specimens showing size variation in Hustedt's type material (Java, sample AS1524). **AA–AB.** Specimens in girdle view. Scale bar: 10 µm.

Occurrence, distribution and ecology

Melosira cataractarum (or *Aulacoseira cataractarum*) has been infrequently recorded from several countries around the world, namely: Canada, Iceland, Indonesia (Java), Japan, Norway (Svalbard), Portugal (Azores Archipelago) and Russia (several regions) (Fig. 3). Following below are the details of these records.

Canada

Melosira cataractarum was one of the four dominant species (with a relative abundance reaching 9%) in a natural hot spring (water temperature: 42-44° C) from the Hotspring Island, Queen Charlotte Islands (Haida Gwaii), North Coast of British Columbia, Canada [20].

Iceland

Very rare in the natural hot spring Geyser Strokkur (as *Melosira cataractarum*) [20].

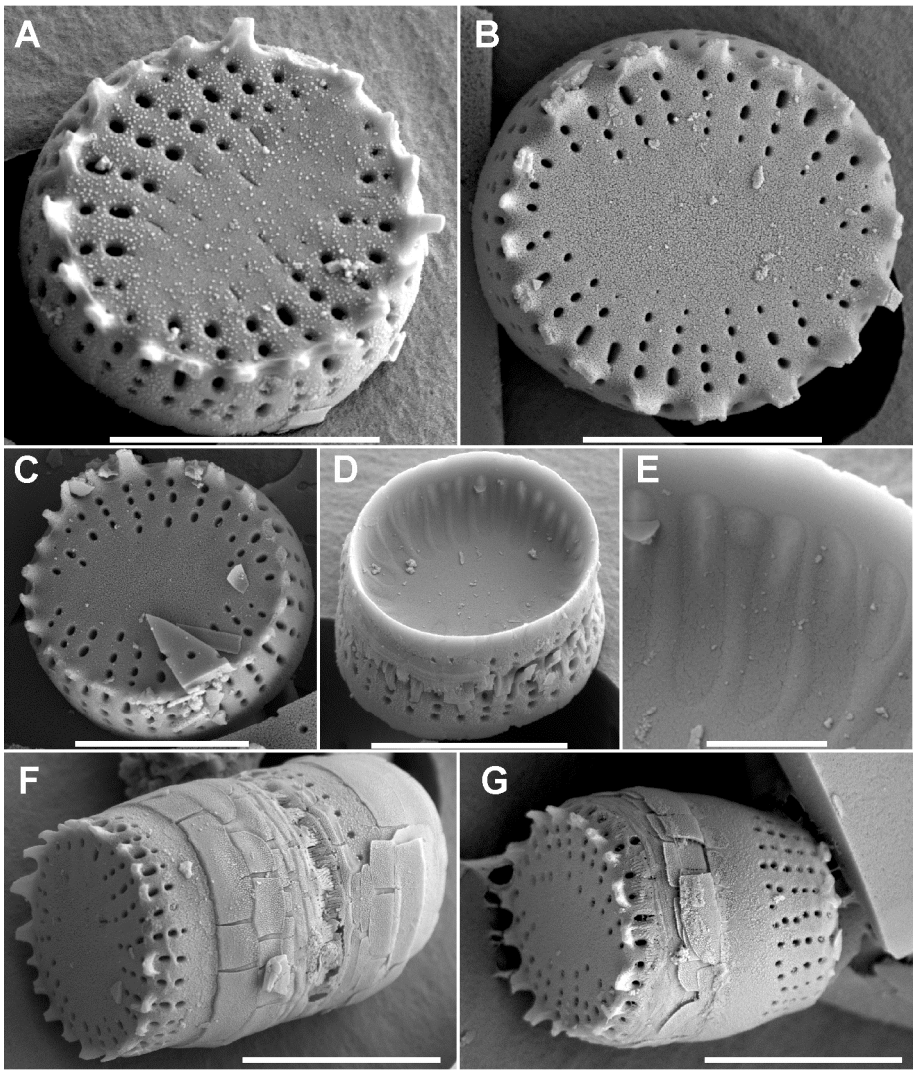

Figura 2: *Pseudostaurosira cataractarum* comb. nov. From Hustedt's type material (Java, sample AS1524). **A–C.** Details of the valve face depicting the shape of the valve, structure of the striae, areolae, and spines. **D**. External and internal aspects of valves joined by linking spines of irregular shape. Valve interior showing striae and areolae structure. **E.** Detail of inner mantle surface showing areolae structure. **F.** Details of the spines, valve face and mantle. Girdle bands, areolae, and silica plates in the valve mantle can be observed. **G.** Valve mantle showing variation in the number of areolae per stria. Scale bars: A–C: 4 µm; D, F–G: 5 µm; E:1µm.

Indonesia (Java)

Type locality: abundantly present in bryophytes in deep shaded, spray water zone of Tjurug Tjibeureum waterfalls (pH: 8.1), southwest of Tjibodas, West Java, Indonesia (as *Melosira cataractarum*) [11].

Japan

Found on wet rocks at Minamiizu, Izu Peninsula, Kamo District, Shizuoka, Honshu Island, Japan (as *Melosira cataractarum*) [1].

Norway (Svalbard)

Fairly common in the warm springs (pH: 6.3-6.6; water temperature: 9.0-23.0° C) at Bockfjord, West Svalbard, Norway (as *Melosira cataractarum* and also *Melosira cataractarum* f. *ovate* Foged) [4].

Portugal (Azores Archipelago)

Abundant on dripping embankment at Ribeira Quente, Povoação, São Miguel Island, Azores Archipelago, Portugal [13] as *Melosira cataractarum* f. *laevis* Manguin, and as *Melosira cataractarum* and *Melosira cataractarum* f. *laevis* [2].

Very rare in plankton, probably accidental, Lagoa das Furnas (pH: above 8), São Miguel Island, Azores Archipelago, Portugal [13], as *Melosira cataractarum* f. *laevis*. Also identified as *Melosira cataractarum* f. *laevis* [2][3].

Identified as *Melosira cataractarum* in São Miguel Island, Azores Archipelago, Portugal [8].

Russia

Species reported as *Melosira cataractarum*, frequent in the springs from Kamchatka (Russia). However, frustules with cell contents were not found [16]. Mentioned as a rare freshwater species from Far East, Russia [17] and from the Khasan district in Primorsky Krai, Russia [22]. Reported as *Melosira cataractarum* as rare in plankton and among fouling organisms of higher plants, unnamed lake in Khakassia region and Pionerskaya River, Russia [12]. Reported as freshwater rare species dwelling in the wet mosses of the hot springs district of Kamchatka, Russia (as *Aulacoseira cataractarum*) [7]. Gontcharov [9] also reports its presence in the Primorsky Krai Region, Russian Far East, Russia (as *Melosira cataractarum* Hust.).

The taxon was also found and illustrated from a swamp peat in the Uzon Caldera, Veselayy Creek, 2.4 m deep, volcanogenic sediments (Holocene) in caldera lakes of Kamchatka, Russia, as *Aulacosira* (*sic*) *cataractarum* (Hust.) Simonsen *emend.* Genkal & Lupikina [5].

Recently, it was registered in the Kuibyshev Reservoir, Russia [6] and from the Primorsky Krai region (lakes and rivers), Russia, as *Aulacoseira cataractarum* [14].

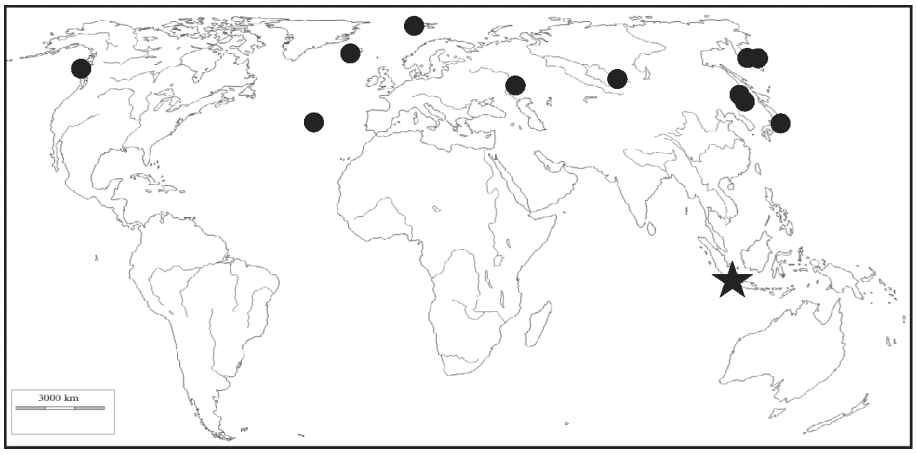

Figura 3: World distribution of *Pseudostaurosira cataractarum* comb. nov. based on literature records (black dots). The type locality (Java) is also indicated (black star).

Illustrations available in the literature

- Hustedt [11] (LM drawing): *Melosira cataractarum*.

- Manguin [13] (LM drawing): *M. cataractarum* f. *laevis*.

- Petersen [16] (LM drawing): *Melosira cataractarum*.

- Proshkina-Lavrenko [17] (LM drawing): *Melosira cataractarum*.

- Foged [4] (LM drawing): *Melosira cataractarum*, Foged [4] (LM drawing): *Melosira cataractarum* f. *ovata*.

- Ando [1] (LM): *Melosira cataractarum*.

- Simonsen [19] (LM): *Melosira cataractarum*.

- Genkal & Lupikina [5] (SEM): *Aulacosira* (*sic*) *cataractarum* (Hust.) Simonsen *emend.* Genkal & Lupik.

- Villeneuve & Pienitz [20] (LM): *Melosira cataractarum* Hust.

4 Discussion and conclusion

The morphological evidence gathered from the type material of *Melosira cataractarum* shows that this diatom is not related to *Melosira* or *Aulacoseira sensu* Houk [10]. *Melosira cataractarum* lacks the radial symmetry characteristic of a centric diatom and its axial area and striation pattern delineate a transapical axis (sternum) typical of an araphid pennate. Also, the complex vela occluding the areolae present in species of *Aulacoseira*, as well as the rimoportulae are absent in *M. cataractarum*.

Melosira cataractarum has all the features of species currently allocated to the genus *Pseudostaurosira*. The characteristics of striae (round to oval areolae bearing branched volae), spines (spatulate, solid and interrupting the striae) and overall construction of the valves are similar to small-sized species of this genus (see detailed comparison below). Therefore, its transfer to *Pseudostaurosira* is proposed as follows:

Pseudostaurosira cataractarum (Hustedt) C.E. Wetzel, E. Morales & Ector *comb. nov*.

Basionym: *Melosira cataractarum* Hustedt 1938, *Archivfür Hydrobiologie, Supplement* 15, p. 142, pl. 9, figs 6-7 [11].

≡ *Aulacoseira* ("*Aulacosira*") *cataractarum* (*cataractorum*) (Hust.) Simonsen 1979, *Bacillaria* 2, p. 57 [18].

= *Melosira cataractarum* f. *laevis* Manguin 1942, *Revue Algologique* 13, p. 119; pl. 1, fig. 1, *syn. nov*. [13].

= *Melosira cataractarum* f. *ovata* Foged 1964, *Tromsö Museums Skrifter* 11, p. 50; pl. 1, figs 2-4, *syn. nov*. [4]

Pseudostaurosira cataractarum differs from other species in its genus by smaller size, typical radiate striae arrangement and absence of apical pore fields. In addition, the variable striae pattern on the valve mantle, sometimes short and composed of a few areolae and sometimes long, with areolae stopping near the abvalvar edge, is characteristic of this species.

The most similar species at the morphological level are *Pseudostaurosira trainori* E. Morales [15] and *Fragilaria sopotensis* Witkowski & Lange-Bert. [21]. *Pseudostaurosira trainori* has longer striae delimiting a much more reduced axial area. These striae vary from parallel towards the valve center to radiate at the apices. Its areolae are wider and contain well-developed volae. Spines are serrate and flaps can be present, especially covering the first areolae on the valve mantle towards its junction with the valve face. These spines always interrupt the striae. Apical pore fields may be present or absent in this taxon.

Fragilaria sopotensis has longer striae on the valve face and their pattern varies from somewhat parallel to slightly radiate in the valve center to strongly radiate toward the apices. Also, spines are always interrupting the striae and are not present at the valve apex. Small flaps are present covering the areolae on the valve mantle [21]. These flaps have been misinterpreted as occlusions of the rota type by Witkowski & Lange-Bertalot [21]. Volae are delicate and can be seen in the transmission electron microscopy image that these authors presented (their fig. n). *Fragilaria sopotensis* has all the features of the genus *Pseudostaurosira*, therefore, the proposal of its transfer to this genus is justified as follows:

Pseudostaurosira sopotensis (Witkowski & Lange-Bert.) E. Morales, C.E. Wetzel & Ector *comb. nov.*

Basionym: *Fragilaria sopotensis* Witkowski & Lange-Bert. 1993, *Limnologica* 23, p. 67, figs 6a-p. [21].

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