

Observations on and typification of *Gomphonema auritum* A.Braun ex Kützing (*Gomphonemataceae*, *Bacillariophyta*)

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Gomphonema auritum A.Braun ex Kützing was originally described in 1849 in Kützing's *Species Algarum* (Kützing 1849: 68) based on material that the latter had received from Alexander C.H. Braun (1805–1877), who collected it from the Titisee (Titi Lake) near Freiburg in southwestern Germany. The original description, “*G. habitu Gomph. intricati, sed ad angulos terminales auribus binis spiniformibus instructum, a latere secundario lanceolatum; stipite demum dichotomo. - Long. bacill. 1/60'''*, *lat. 1/300'''*. - *In lacu “Titisee” ad plantas aquaticas florae Badens. detexit cl. A. Braun!*” (*G[omphonema]*, with the complex outline of *Gomphonema*, but at the terminal edges equipped on each side with a spiniform projection, lanceolate, on the secondary side; eventually as dichotomous stipe. Length 42 µm, width 8 µm. - In the lake “Titisee”, on aquatic plants of the Baden flora. Found by A. Braun!). No illustration was provided. Rabenhorst (1853: 59, pl. VIII: fig. 3 a–e) refined the description not only by adding a length range (20–35 µm), but also by a more precise description of the valve outline (lanceolate, with broadly rounded ends lacking striae, margins broadly rhombical). He also described in more detail the two horn-like, hyaline, mucilage projections from which the species derives its name. The locality of the sample, Titisee, was also better defined as being taken from *Nuphar spenneriana* Gaudin (as ‘*spennerianum*’). Other samples with the species were collected from *Myriophyllum alternifolium* J. Macoun and from a meadow ditch near Giessen (Germany). Rabenhorst also added a few illustrations (reproduced here as Fig. 2) detailing the two horn-like projections. A clear drawing of the species, however, was not provided. Van Heurck (1880: pl. 24, fig. 17; 1885: 125) recombined the species as a variety of *G. gracile* Ehrenberg, *G. gracile* var. *auritum* (A.Braun ex Kützing) Van Heurck and illustrated for the first time a valve together with a new drawing showing the ear-like projections (Van Heurck 1880: pl. 24, fig. 17 b).

Type material of the species has not been examined in the time of Van Heurck. Reichardt (2015: 379) added some details of the morphology of the taxon, illustrating several populations from Switzerland, Austria and Germany, unfortunately broadening the original species concept as it is clear that not all the populations he illustrated can be considered belonging to *G. auritum sensu stricto*. A search of recent literature revealed a lack of a consistent morphological description due to the absence of an analysis of the type (see discussion below) and subsequent species-concept drift and force-fitting to the name.

During an analysis of the original material of *Fragilaria gloiophila* (Grunow) Van de Vijver *et al.* (2020) found in the Kützing collection housed in Meise Botanic Garden (**BR**), Belgium and the Natural History Museum (**BM**), London, UK, from the Titisee (sample 867), a relatively large population of *G. auritum* was observed. The latter was sent to Kützing by A. Braun together with several other samples from the Titisee. One of these samples, sample 873, was collected by A. Braun, probably in August 1847, from *Nuphar spenneriana*, *Myriophyllum alternifolium* and several other aquatic plants. In the handwritten Kützing catalogue kept at **BR**, a short list is added to the diatom flora of the sample (Fig. 1: *Tabellaria fenestrata* & *flocculosa*, *Cocconema cymbiforme*, *Gomphonema constrictum*, *G. subramosum*, *Achnanthidium minutissimum* und andere Diatomeen) together with a brief description of *Gomphonema auritum* detailing the presence of the horn-like

projections. Combining this handwritten description with the note in Rabenhorst (1853) about the sample, it is clear that this sample 873 should contain the type material of *G. auritum*.

In this contribution, we detail observations on specimens of *G. auritum* from sample 873 using light and scanning electron microscopy. Sample 873 is therefore formally designated as lectotype for this species in accordance with ICN Art. 9.3 (Turland *et al.* 2018).

Gomphonema auritum A.Braun ex Kützing (Figs 2–55)

Original description: *Gomphonema auritum* A.Braun ex Kützing, *Species Algarum* p. 68, no fig., 1849.

Lectotype (here designated): **BR** 4596 (Meise Botanic Garden, Belgium). Fig. 11 represents the lectotype.

Isolectotype (here designated): **BM** 18697 (Natural History Museum, London, UK)

Type locality: Titisee (Lake Titi), Baden-Wurttemberg, Germany, sample 873 from the Kützing collection, housed at **BR** and **BM**.

Etymology: Latin, adjective, *auritus*, -a, -um, having long or large ears; having the form of an ear.

Description: Frustules in girdle view weakly clavate to almost rectangular (Figs 3, 4). Girdle composed of several open copulae (Fig. 48). Valvocopula bearing one row of rounded pores (Fig. 49). Valves naviculoid but still distinctly heteropolar, narrowly rhombic-lanceolate with acutely rounded head- and footpoles. Valves tapering gradually from valve middle towards headpole, more abruptly narrowing towards footpole followed by gradual tapering to latter. Valve dimensions (n=50): valve length 15–45 µm, width 4–6 µm. Largest width above middle of valve towards headpole. Axial area moderately broad, linear throughout its entire length, only weakly narrowing near poles. Irregular series of shallow depressions present along axial area. Central area asymmetrical, bordered by curved striae. One marginal stria shortened at one side, at other side only weakly shortened. One isolated pore present at the end of least shortened stria (Figs 50, 52), small, rounded. Raphe clearly lateral. External raphe branches undulating (Fig. 50). Central raphe endings close to each other, weakly deflected, inflated (Fig. 52). Terminal raphe fissures elongated, hooked, continuing onto valve mantle at footpole (Fig. 51), ending abruptly at head pole (Fig. 53). Apical pore field at footpole bisected by terminal raphe fissure, composed of a dense complex of several rows of very small, rounded areolae, continuing onto mantle (Figs 48, 51), giving the impression in LM of a hyaline footpole. At head pole, several striae denser and irregularly organised, composed of small, c-shaped areolae, giving the impression of a second head pole (Figs 49, 53). Striae uniseriate composed of c-, e- to kidney-shaped areolae, almost parallel to radiate throughout entire valve, 13–15 in 10 µm, almost not with increasing density towards poles. Internally, terminal raphe endings terminating onto well-developed helictoglossae (Fig. 54). Clear pseudosepta present at both poles (Fig. 54). Central raphe endings distinctly unilaterally hooked with reversed ending. Internal isolated pore slit-like (Fig. 55), terminating with one central stria (Fig. 54). Striae weakly sunk between virgae.

Vimines separating areolae often interrupted (Fig. 55). Silica struts never present.

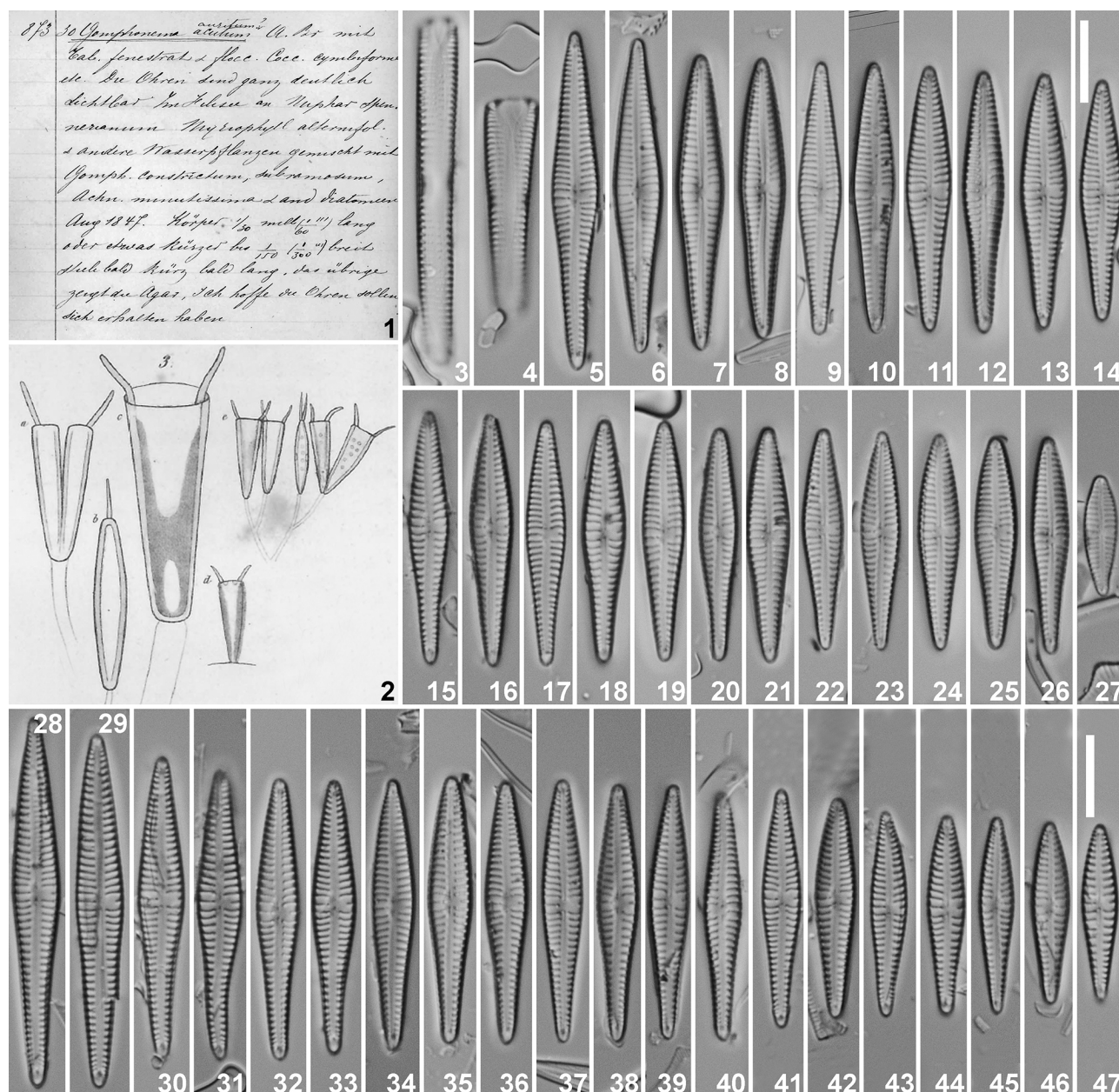
The horn-like projections that gave the species its epithet were not observed as the original material had been prepared prior to conservation in the glass tubes.

Gomphonema auritum is often erroneously reported in literature which has serious consequences for determining its distribution. Subsequent to the original description, the species was associated with a species complex centred around *G. gracile* Ehrenberg, an opinion held by Cleve (1894: 182), Mayer (1928: 118, pl. 4: fig. 7), Hustedt (1930: 376) and Patrick & Reimer (1975: 132), who even considered the species as a heterotypic synonym of *G. gracile*. This association has led to numerous misidentifications with records on almost every continent on earth. Blanco *et al.* (2017) examined the possibility of using morphometric data to disentangle species complexes using five *Gomphonema* taxa including *G. auritum* (Blanco *et al.* 2017: fig. 1 m-o); unfortunately, the illustrated valve most likely represents *G. gracile* or a related taxon based on its more convex valve

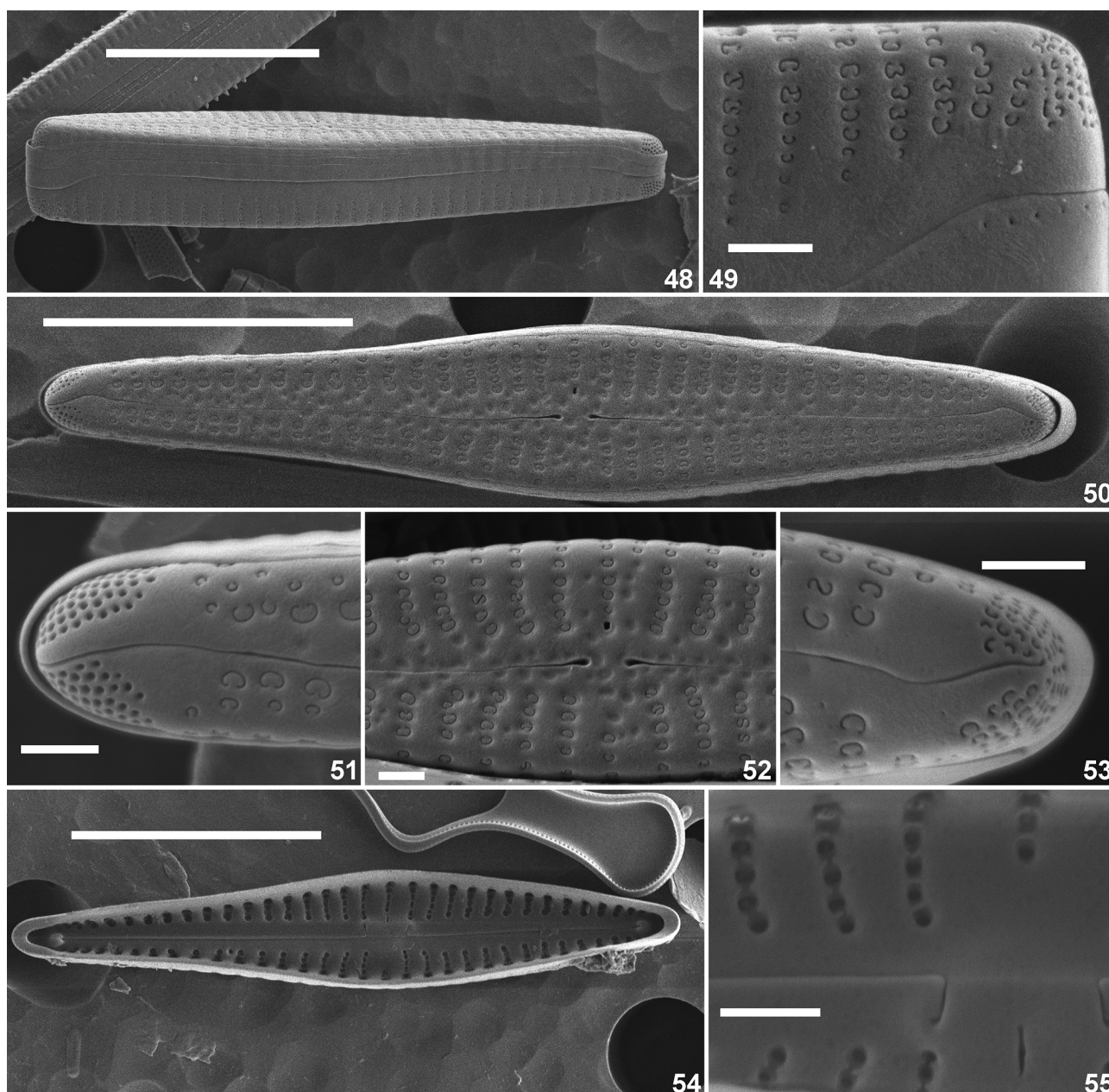
outline. Bahls *et al.* (2018: pl. 8: fig. 11, pl. 45: figs 22–23) recorded the species in western Canada, but the illustrated valve shows more affinity to the *G. exilissimum*-group. The same applies also, for instance, to Rumrich *et al.* (2000, Chile), Tobias & Gaiser (2006: 388, figs 21–25, United States), Buczko *et al.* (2009: 52, pl. 7: fig. 134, Hungary), Ge *et al.* (2013: 2133, pl. 1: figs 6–7, China), Marquardt & Bicudo (2014: 231, figs 81–83, Brazil), Chudaev & Gololobova (2016: 52, pl. 100: figs 1–26; pl. 101: figs 1–6, Russia), Costa *et al.* (2017: 564, figs 100–102, Brazil) and Oğuz *et al.* (2020: fig. 75, Turkey). All these records most certainly represent other taxa, often distantly related to *G. auritum*. The only confirmed records are found in Reichardt (2015: figs 102–105 only) and Lange-Bertalot *et al.* (2017: 300, pl. 100: figs 16–20). Most likely, *Gomphonema auritum* has a restricted distribution, limited to lakes and rivers in central and possibly northern Europe; the occurrence of the species has been confirmed from Swedish rivers (Van de Vijver, pers. obs.).

- Bahls, L., Boynton, B. & Johnston, B. (2018). Atlas of diatoms (Bacillariophyta) from diverse habitats in remote regions of western Canada. *PhytoKeys* 105: 1–186, 132 pls.
- Blanco, S., Borrego-Ramos, M. & Olenici, A. (2017). Disentangling diatom species complexes: does morphometry suffice? *PeerJ* 5: e4159, 7 fig., 1 table.
- Buczko, K., Magyari, E., Stenger-Kovács, Cs. & Korponai, J. (2009). The Holocene diatom flora of Zalavári pond (Lake Balaton system, Hungary). *Algological Studies* 132: 35–73, 258 fig., 1 table.
- Chudaev, D.A. & Gololobova, M.A. (2016). [*Diatoms of the Glubokoe lake (Moscow region)*]. pp. [1]–446, 266 pls. Moscow. [in Russian]
- Cleve, P.T. (1894). Synopsis of the naviculoid diatoms. Part I. *Kongliga Svenska Vetenskapsakademiens Handlingar, series 4* 26(2): 1–194, 5 pls.
- Costa, L.F., Wengrat, S. & Bicudo, D.C. (2017). Diatoms from distinct habitats of a highly heterogeneous reservoir, Billings Complex, southeastern Brazil. *Hoehnea* 44(4): 559–579, 167 fig., 1 table.
- Ge, L., Liu, Y., Kociolek, P.J. & Fan, Y. (2013). Newly recorded species of Cymbellaceae and Gomphonemataceae (Bacillariophyta) from Xingkai Lake, China. *Acta Botanica Boreali-Occidentalia Sinica* 33(10): 2131–2135, 1 pl., 10 figs. [in Chinese]
- Hustedt, F. (1930). Bacillariophyta (Diatomeae) Zweite Auflage. In: *Die Süßwasser-Flora Mitteleuropas. Heft 10.* (Pascher, A. Eds), pp. [i]–vii, [1]–466. Jena: Verlag von Gustav Fischer.
- Kützing, F.T. (1849). *Species algarum*. pp. [i]–vi, [1]–922. Lipsiae [Leipzig]: F.A. Brockhaus.
- Lange-Bertalot, H., Hofmann, G., Werum, M. & Cantonati, M. (2017). *Freshwater benthic diatoms of Central Europe: over 800 common species used in ecological assessments*. English edition with updated taxonomy and added species (Cantonati, M. et al. eds). pp. [1]–942, 135 pls. Schmitt-Oberreifenberg: Koeltz Botanical Books.
- Marquardt, G.C. & Bicudo, C.E.M. (2014). Criptógamos do Parque Estadual das Fontes do Ipiranga, São Paulo, SP. Algas 36: Bacillariophyceae (Cymbellales). *Hoehnea* 41(2): 209–246, 194 fig.
- Mayer, A. (1928). Die bayerischen Gomphonemen. *Denkschriften der Königlich-Baierischen Botanischen Gesellschaft in Regensburg* 17: 83–128, 5 pls.
- Oğuz, A., Kaleli, A., Akçaalan, R., Köker, L., Dorak, Z., Gaygusuz, Ö., Aydın, F., Çetin, T., Karaaslan, Y. & Albay, M. (2020). Composition and distribution of benthic diatoms in different habitats of Burdur River Basin. *Turkish Journal of Water Science & Management* 4(1): 31–57, 85 fig., 4 tables.
- Patrick, R. & Reimer, C.W. (1975). *The diatoms of the United States exclusive of Alaska and Hawaii*. Vol. 2, Part 1. Entomoneidaceae, Cymbellaceae, Gomphonemaceae, Epithemiaceae. pp. [i]–ix, [1]–213, 28 pls. Philadelphia: The Academy of Natural Sciences of Philadelphia.

- Rabenhorst, L. (1853). *Die Süßwasser-Diatomaceen (Bacillarien.): für Freunde der Mikroskopie*. pp. [1]–xii, [1]–72, 10 pls. Leipzig: Eduard Kummer.
- Tobias, F.A.C. & Gaiser, E.E. (2006). Taxonomy and distribution of diatoms in the genus *Gomphonema* from the Florida Everglades, U.S.A. *Diatom Research* 21(2): 379–405, 76 fig., 4 tables.
- Reichardt, E. (2015). *Gomphonema gracile* Ehrenberg sensu stricto et sensu auct. (Bacillariophyceae): A taxonomic revision. *Nova Hedwigia* 101(3/4): 367–393, 174 fig.
- Rumrich, U., Lange-Bertalot, H. & Rumrich, M. (2000). Diatomeen der Anden. Von Venezuela bis Patagonien/Feuerland. Diatoms of the Andes. From Venezuela to Patagonia/Tierra del Fuego. *Iconographia Diatomologica* 9: 1–649, incl. 197 pls.
- Turland, N.J., Wiersma, J.H., Barrie, F.R., Greuter, W., Hawksworth, D.L., Herendeen, P.S., Knapp, S., Kusber, W.-H., Li, D.-Z., Marhold, K., May, T.W., McNeill, J., Monro, A.M., Prado, J., Price, M.J. & Smith, G.F., editors (2018). *International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code)* adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017. *Regnum Vegetabile*, Vol. 159. pp. [i]–xxxviii, 1–253. Glashütten: Koeltz Botanical Books.
- Van de Vijver, B., Ector, L., Schuster, T.M. & Walter, J. (2020). Observations on and typification of *Synedra gloiophila* Grunow (Fragilariaceae, Bacillariophyta) and its transfer to the genus *Fragilaria* Lyngbye. *Notulae Algarum* 145: 1–6, 42 figs.
- Van Heurck, H. (1880). *Synopsis des Diatomées de Belgique. Atlas*. pls I–XXX. Anvers: Ducaju et Cie.
- Van Heurck, H. (1885). *Synopsis des Diatomées de Belgique. Texte*. pp. 1–235. Anvers: Martin Brouwers & Co.



Figs 1–42. *Gomphonema auritum* A. Braun ex Kützing. **Fig. 1.** Extract of sample 873 from the handwritten Kützing catalogue of the samples kept in Meise Botanic Garden (BR), Belgium. **Fig. 2.** Original drawings of *Gomphonema auritum* in Rabenhorst (1853, fig. 3a–e). **Figs 3–27.** Cell cycle of *Gomphonema auritum* A. Braun ex Kützing showing the lectotype material (Titisee, Kützing sample 873). Figs 2–3 show frustules in girdle view. Fig. 11 represents the lectotype specimen. **Figs 28–47.** Cell cycle of *Gomphonema auritum* A. Braun ex Kützing from a second sample in the Kützing collection taken by A. Braun (Titisee, Kützing sample 867). Scale bar represents 10 μ m.



Figs 48–55. *Gomphonema auritum* A.Braun ex Kützing. SEM micrographs of the lectotype material (Titisee, Kützing sample 873). **Fig. 48.** SEM external view of an entire frustule in girdle view showing the open girdle bands. **Fig. 49.** SEM external detail of the head pole in girdle view showing the perforated valvocopula and the dense striation at the headpole. **Fig. 50.** SEM external view of an entire valve with the typical markings in the axial area. **Fig. 51.** SEM external detail of the footpole with the apical pore field bisected by the terminal raphe fissure. **Fig. 52.** SEM external detail of central area with the shortened central stria and the rounded isolated pore. **Fig. 53.** SEM external detail of the head pole with the dense irregular striation resembling an apical pore field. **Fig. 54.** SEM internal view of an entire valve with the typical pseudosepta. **Fig. 55.** SEM internal detail of the central area with the central raphe endings and the slit-like internal opening of the isolated pore. Note the interrupted vimines. Scale bars represent 10 µm except for figs 49, 51, 52, 53 & 55 where scale bar = 1 µm.