

Freshwater Diatom Flora in the Bottom Sediments of Lake Biwa (South Basin): Part 2: *Gomphonema* Sensu Lato

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Abstract This is the second part of a study on the flora from the bottom sediments of the South Basin of Lake Biwa. In this paper, I identify 24 *Gomphonema* taxa, including one new combination and one new name. The flora in the present study differ greatly from those of the epilithic diatoms of Lake Biwa and some of taxa should be classified as an epipellic taxon.

Key words: *Gomphonema intricatum* var. *clavatum* comb. nov., *Gomphonema insigniturris* stat. nov. nom. nov., sediment, Lake Biwa, endemic.

Introduction

This is the second part of a study on the flora from the bottom sediments of the South Basin of Lake Biwa. Many new *Gomphonema* taxa have recently been described (Kociolek & Stoermer 1991; Reichardt & Lange-Bertalot 1991; Reichardt 1997, 1999; Spaulding & Kociolek 1998; Reichardt 1999) and many of these taxa are thought to be endemic taxa. In the present study, I re-examine the identification of Japanese *Gomphonema* taxa in the light of this new information.

Materials and methods

Bottom sediments were collected at 10 sampling sites in the South Basin of Lake Biwa between May of 2000 and January of 2001. Sediment samples (Materials TNS-AL-54381m–TNS-AL-54470m in TNS (Department of botany, National Science Museum)) were oxidized with H₂O₂ and mounted onto glass slides with Pleurax (Slides TNS-AL-54381s–TNS-AL-54470s in TNS) and observed using a light microscopy (LM) (Axiophot, Carl Zeiss, Germany). Photographs were taken using a CCD camera (DXM-1200, Nikon Co., Tokyo, Japan) and printed after image processing. These materials

and methods follow those described in Tuji (2003).

The genus *Gomphonema* sensu lato includes *Gomphonema* sensu stricto, *Gomphoneis* and *Gomphosphenia*. Due to the very low relative abundance of *Gomphonema* taxa in this study and examination only by LM, these genus name, *Gomphoneis* and *Gomphosphenia*, are not used here. Scanning electron microscopic (SEM) examination is necessary to divide *Gomphoneis* and *Gomphosphenia* from the genus *Gomphonema*.

Results and discussion

Twenty-four taxa are identified in this study. The flora in the present study differ greatly from those of the epilithic diatoms of Lake Biwa (Tuji 1995). Although the *Gomphonema olivaceum* complex, including *G. tetrastigmatum*, is widely observed as an epilithon (Tuji 1995, personal observation), the relative abundance of this complex was very low in this study. On the other hand, *G. grovei* var. *lingulatum* and *G. punctatum*, which are very rare as an epilithon, were found in many of the present samples (Tuji 1995, personal observation). These species have been reported from the sediments of various lakes (Haraguchi, 1997, 1999; Watanabe & Usman, 1987) and springs (Nakai, 1987), and

should be classified as an epipelagic taxon. In this study, several species were found that have been identified in East Asia including Japan (Hustedt, 1927; Okuno, 1952, 1974) but that have not been reported in Europe (Krammer & Lange-Bertalot, 1997), clearly indicating that the monographs on European diatoms do not apply to the identification of Japanese diatoms. The monographs for North American diatom (Patrick & Reimer, 1975), on the other hand, are very useful to the Japanese diatomist. Although in general the descriptions and figures are consistent with Japanese diatom flora, European specimens sometimes differ to the extent that new taxa are needed. Furthermore, there are several diatoms that are endemic to East Asia or Japan (Hustedt, 1927; Okuno, 1974) and that have therefore not been discussed in the research on diatom flora from places other than Japan. As recently as 20 years earlier, many Japanese diatomists had had access only to the limited information presented in the European monographs (Hustedt 1930; Schmidt et al., 1874–1904), and had thus identified Japanese diatoms based on these data, leading to considerable confusion. Several names for example have been used for a single taxon and likewise several taxa have been identified with a single name, making it impossible to evaluate Japanese flora without figures. Under these conditions, new records are of questionable use and therefore have not been included in the present paper.

In the study of endemic taxa, it is critically important to examine the type specimen and variation within a taxon using many individuals. Although the samples used in this study include many taxa, the relative abundance of each taxon is very low, making it difficult to study each taxon in detail. Some species, which were rare in this study, are common as epilithic diatoms and my current research involves an examination of these species using epilithic samples.

LIST OF DIATOM TAXA OBSERVED IN THE PRESENT STUDY:

Gomphonema grovei var. *lingulatum* (Hust.) Lange-Bert., *Biblioth. Diatomol.* **9**: 47. 1985.

Basionym: *Gomphonema lingulatum* Hust., *Arch. Hydrobiol.* **18**: 166. *pl. 5. f. 5.* 1927.

Synonym: *Gomphonema lingulatum* var. *constricta* Hust., *Arch. Hydrobiol. Suppl.* **15**: 443. *pl. 27. f. 19.* 1927.

Synonym: *Gomphonema yatukaensis* Horik. et Okuno in Okuno, *Bot. Mag. Tokyo.* **58**: 10. *f. 5a.* 1944. (Pl. 1, Figs. 1–7)

Hustedt (1927) and Haraguchi (1997) both describe this taxon from Lake Aoki, Japan and the individuals in the present study are consistent with the figures and descriptions in these works. The lectotype of *G. lingulatum* var. *constricta* Hust. described from Lake Toba, Sumatra by Simonsen (1987) should be considered a synonym of this taxon due to the agreement of the larger individuals (Figs. 6–7). *G. yatukaensis* described by Okuno (1944) from the Yatuka deposit, Japan should also be considered a synonym of this taxon using the original drawing. Kociolek et al. (1988) describe *G. herrmanniana* from China, which is similar to the individuals in the present study in its isolated puncta and ghost striae; however, they did not examine *G. grovei* var. *lingulatum* and other varieties, and the taxonomic position of these varieties therefore remains uncertain. The differences between these taxa are very small and direct comparison using SEM is necessary to fully identify this species complex. Lange-Bertalot (1995) recommends that this taxon be transferred to subgen. *Gomphosphenia* of genus *Gomphosphenia*.

Gomphonema punctatum Hust., *Arch. Hydrobiol. Suppl.* **15**: 443. *pl. 27. f. 20.* 1927.

(Pl. 1, Figs. 8–13)

This taxon has been described from Lake Toba, Sumatra (Hustedt, 1927). My present observations are consistent with the photographs of the lectotype presented by Simonsen (1987). Nakai (1980) reports this taxon as *G. grovei* var. *lingulatum* from a spring of Okinawa Island, Japan. This taxon has very clear central and polar terminals and may belong to subgenus *Gomphosphenia* of genus *Gomphosphenia* as described by Lange-Bertalot (1995). In order to clarify the taxonomic position of this taxon, it is

necessary to define the relationship between this taxon and the *G. grovei* species complex using SEM.

Gomphonema olivaceoides Hust., Arch. Hydrobiol. **43**: 397. pl. 37. f. 9–12. 1950.

(Pl. 1, Fig. 14).

Gomphonema tetrastigmatum Horik. et Okuno in Okuno, Bot. Mag. Tokyo. **58**: 10. f. 3e. 1944.

(Pl. 1, Fig. 15)

Okuno (1944) describes this taxon from the Yatuka deposit, Japan. It has also been reported as *G. olivaceum* (Watanabe & Houki, 1988) and *G. quadripunctatum* (Tuji 1995) from Lake Biwa. Negoro & Gotoh (1983) report it from Yura River and discuss the differences between *G. quadripunctatum* var. *quadripunctatum*, *Gomphonema quadripunctatum* var. *hastata* and this taxon. Okuno (1974) presents transmission electron microscopy (TEM) photographs of this taxon, which are consistent with my observations. *G. olivaceum* complex including *G. tetrastigmatum* have been widely observed on the shores of Lake Biwa as an epilithon (Tuji 1995), however the relative abundance of this complex in the present study is very low. This complex is expected to exist on the shore only as an epilithic taxon.

Gomphonema clevei Frie.Fricke in Schmidt et al. pl. 234. f. 44–46. 1902. (Pl. 2, Figs. 1–2)

This taxon has been described in many countries (Krammer & Lange-Bertalot 1997; Foged 1978; Watanabe 1990). Furthermore, many variety have been described for this species (Van Landingham, 1969) and additional study of this species complex is needed.

Gomphonema christenseni R.L.Lowe & Kociolek, Nov. Hedw. **39**: 471. f. 18–20. 1984.

(Pl. 2, Figs. 3–6)

This taxon has been described by Lowe & Kociolek (1984) from the Great Smoky Mountains National Park (TN and NC, USA) and by Gotoh (1986) from the Kumano River, Wakayama, Japan. Fukushima et al. (1997) studied the morphological variability of this taxon using a sample from Kirishima Heights, Kyushu, Japan, and Watanabe & Houki (1988) and Tuji (1995) also

report this taxon from Lake Biwa. However, I suggest that the taxon reported in these papers from Lake Biwa should be considered another new species. The individuals in the present study had relatively long polar terminals and differ from those reported in Lowe & Kociolek (1984) and Fukushima et al. (1997). However, I have not yet examined the information on the morphological variability of the type material for this taxon, and therefore do not yet wish to judge whether these differences may represent variability within a single taxon.

Gomphonema insigne W.Greg., Quart. J. Micr. Sc. **4**: 12. pl. 1. f. 39. 1856. (Pl. 3, Figs. 1–2)

Reichardt (1999) describes the lectotype (BM671) of this taxon. Although these lectotype individuals have a relatively wide foot, this taxon was found to be very rare in the present study and I was therefore unable to examine it in detail.

Gomphonema insigniturris stat. nov. nom. nom.

Basionym: *Gomphonema insigne* fo. *major* Grunow in Van Heurck, Synops. Diat. pl. 24. f. 39. 1880. (Pl. 3, Fig. 3)

This taxon is similar to *G. affine*, but with a narrower foot. *G. turris* sensu Kawashima & Mayama (2001) should be considered a synonym of this taxon. Type examination remains to be done.

Gomphonema turgidum Ehrenb., Mikrogeol. Atlas. 15. pl. 2–2. f. 40. pl. 4–2. f. 34. 1854.

(Pl. 3, Fig. 4)

This taxon was first described by Ehrenberg (1854) in New York. Reichardt (2001) designed its lectotype, with which my observations are consistent.

Gomphonema acuminatum Ehrenb., Phys. Abh. Akad. Wiss. Berlin **1831**: 86. 1832; Infus. 217. pl. 18. f. 4 (1–6). 1838. (Pl. 3, Fig. 5)

Ehrenberg (1832, 1838) first described this taxon in Europe (Berlin, etc.). My observations are consistent with the original figures, and I believe it should be classified as a cosmopolitan taxon.

Gomphonema minutum (C.Agardh) C.Agardh, Consp. Crit. Diat. 34. 1830.

Basionym: *Licmophora minuta* C.Agardh,

Östr. Länd. Gatt. Algen 629. 1827.

(Pl. 5, Figs. 12–13)

Gomphonema minutum fo. *lemanense* Lange-Bert. & E.Reichardt in Lange-Bertalot, Biblioth. Diatomol. **27**: 63. 1993.

Synonym: *Gomphonema minutum* fo. *lemanense* Lange-Bert. & E.Reichardt, nom. Inval., in Krammer & Lange-Bertalot, Süßwasserfl. Mitt. Bacill. **2(4)**: 410. pl. 81. f. 15–15a. 1991.

(Pl. 4, Figs. 1–5)

Gomphonema angustatum (Kütz.) Rabenh., Fl. Eur. Alg. Sect. I. 283. 1864.

Basionym: *Sphenella angustata* Kütz., Kies. Bacill. Diat. 83. pl. 8. f. 4. 1844.

(Pl. 4, Figs. 6–7)

Watanabe & Usman (1987) report this taxon from Central Sumatra as *G. vibrio* var. *pumilum*. *G. pumilum* (= *G. vibrio* var. *pumilum*) as reported by Reichardt (1997) has cuneate ends and therefore differs from this taxon.

Gomphonema intricatum var. *dichotomum* (Kütz.) Grunow in Van Heurck, Synopsis Diat. pl. 24. f. 30–31. 1880.

Basionym: *Gomphonema dichotomum* Kütz., Synopsis Diat. 569. f. 48. 1833.

Synonym: *Gomphonema intricatum* Kütz. sensu R.M.Patrick in Patrick & Reimer, Diat. Unit. Stat. 134. pl. 18. f. 1. 1975.

(Pl. 4, Figs. 8–15)

My observations are consistent with the figure shown in Krammer & Lange-Bertalot (1997) using a Kützing material. Although, Krammer & Lange-Bertalot (1997) consider this taxon to be a synonym of *G. angustatum*, these differ in that the striae of *G. intricatum* are slightly radiate throughout, and in that the polar terminals of *G. angustatum* are short. This species has also been identified as *G. clavatum* (Watanabe & Houki 1988), following the work of Patrick & Reimer (1975). Kawashima & Mayama (2001) also report this taxon as *G. clavatum* from Lake Akan, Japan, however, the individuals from Lake Akan are wider than *G. clavatum* and the striae of *G. clavatum* become more closely spaced towards the ends, a characteristic which is not clearly seen in the individuals reported by

Kawashima & Mayama (2001) nor in those of the present study. *G. intricatum* var. *dichotomum* also differs from *G. clavatum* in its width and form. Additional information of type specimens is needed to accurately identify the individuals of this taxon.

Gomphonema sarcophagus W.Greg., Quart.J. Micr. Sc. 4: 13. pl. 1. f. 42. 1856. (Pl. 4, Fig. 16)

Reichardt (1999) designed the lectotype of this taxon (pl. 30. f. 1–10, BM 670). The individuals of lectotype show two densities of striae (7–8 striae per 10 μ m and 9–10 striae per 10 μ m) though the individuals observed in the present study had only the finer density of striae. The individuals in this study had a wider foot than that indicated in the lectotype; however, there is considerable variation in the width of foot in this lectotype and this may be simply a variation of this taxon.

Gomphonema parvulum (Kütz.) Kütz., Sp. Alg. 65. 1849.

Basionym: *Sphenella parvula* Kütz., Bacill. 83. pl. 30. f. 63. 1844. (Pl. 5, Figs. 1–3)

Gomphonema parvulum var. *exilissima* Grunow in Van Heurck, Synops. Diatom. pl. 25. f. 12. 1880. (Pl. 5, Figs. 4–5)

Gomphonema parvulum var. *parvulum* fo. *saprophilum* Lange-Bert. & E.Reichardt in Lange-Bertalot, Bibl. Diat. **27**: 69. 1993.

Synonym: *Gomphonema parvulum* Lange-Bert. & E.Reichardt, nom. Inval., in Krammer & Lange-Bertalot, Süßwasserfl. Mitt. Bacill. **2(4)**: 400. pl. 76. f. 8–13. 1991. (Pl. 5, Fig. 6–7)

G. parvulum is a cosmopolitan species with many varieties, several of which may be in a single sample. the identification of the *G. parvulum* complex is thus very confusing. Additional study on the morphological variation of this species complex using Japanese samples is essential.

Gomphonema parallelistriatum Lange-Bert. & E.Reichardt in Lange-Bertalot, Bibl. Diat. **27**: 68. pl. 76. f. 11–16. 1993.

Synonym: *Gomphonema parallelistriatum* Lange-Bert. & E.Reichardt, nom. Inval., in Krammer & Lange-Bertalot, Süßwasserfl. Mitt. Bacill. **2(4)**: 408. pl. 80. f. 7–11. 1991.

(Pl. 5, Fig. 8)

Gomphonema pseudoaugar Lange-Bert., Arch. Hydrobiol. Suppl. **56**: 202, 215. f. 11–16. 1979.

(Pl. 5, Fig. 9)

Gomphonema gracile Ehrenb., Infus. Vollk. Org. 217. pl. 18. f. 3. 1838. (Pl. 5, Figs. 10–11).*Gomphonema intricatum* var. *clavatum* comb. nov.Basionym: *Gomphonema parvulum* var. *clavatum* Okuno, Atlas Foss. Diat. Jap. Diat. Dep. 32. pl. 28. f. 16. 1952. (Pl. 5, Figs. 14–19)

Okuno (1952) describes this taxon from Yubari, Hokkaido, Japan and Yufuin, Kyushu, Japan. Since the original figures are those from Yufuin, Yufuin should be designated as the type locality of this taxon. The original description of this taxon is not consistent with the original figure (Okuno 1952). My observations are consistent with the original figure, however the figure is too simple and I am therefore unable to determine the exact identification of this taxon. My current research includes a study of Okuno's specimens for this purpose. Although *G. intricatum* sensu Spaulding & Kociolek (1998) may be a synonym of this taxon, the figures of *G. intricatum* (Krammer and Lange-Bertalot 1997) using Kützing materials show wider individuals than those presented by Spaulding & Kociolek (1998) and those in the present study. Reichardt (1997) also studied the *G. pumilum* complex, which is not included in this taxon. It is possible that *G. intricatum* may exist only in East Asia and North America.

Gomphonema roehringeri E.Reichardt, Iconogr. Diat. **8**: 55. pl. 66. f. 1–12. 1999. (Pl. 5, Fig. 20)*Gomphonema angustivalva* E.Reichardt, Nova Hedw. **65**: 112. pl. 6. f. 1–29. 1997.

(Pl. 5, Fig. 21)

Because these two taxa are small and very rare in the present study, I was unable to examine them in detail. Further study using SEM is needed in this case.

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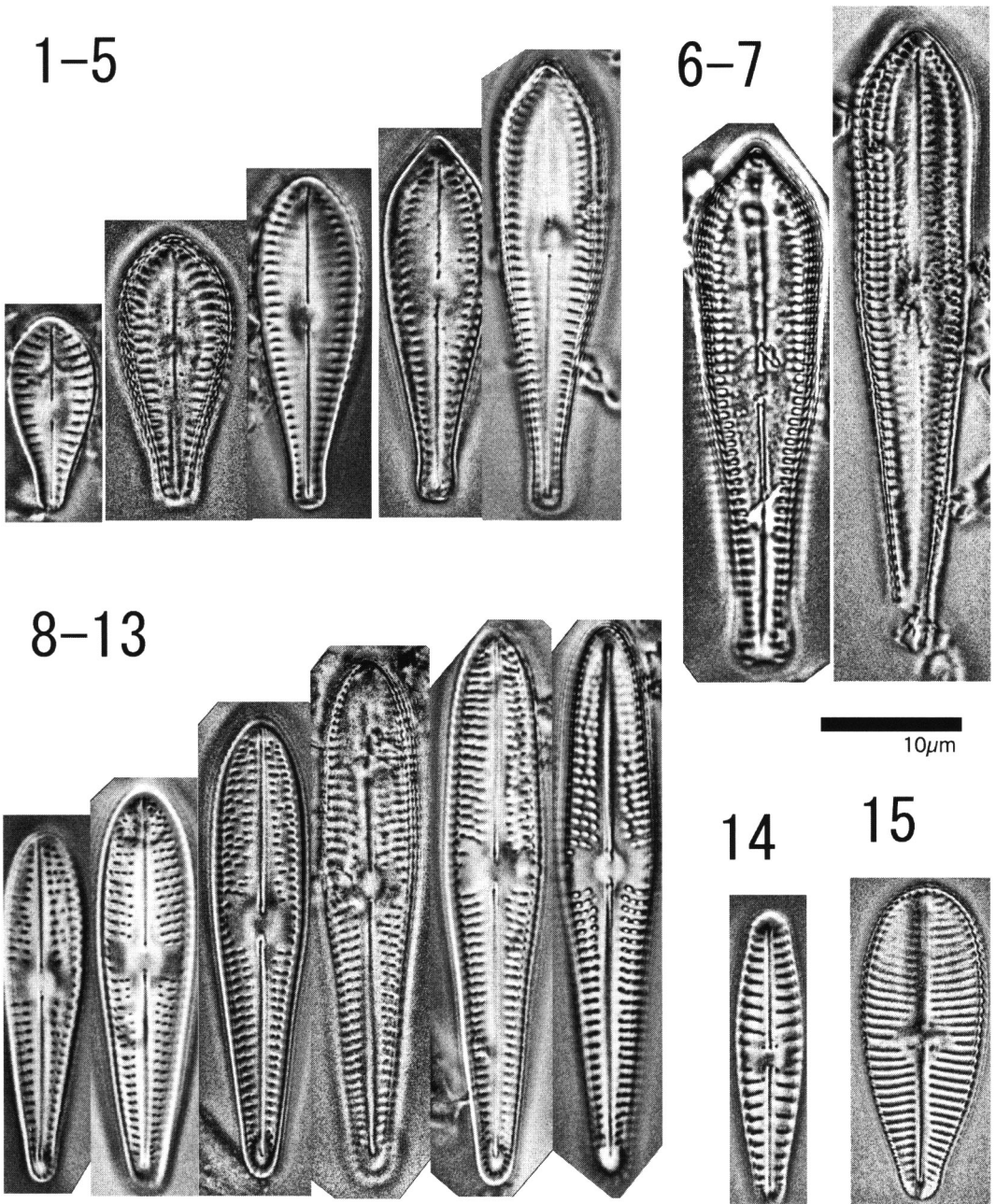


Plate 1. ($\times 2000$). 1-7. *Gomphonema grovei* var. *lingulatum* (Hust.) Lange-Bert., 8-13. *Gomphonema punctatum* Hust., 14. *Gomphonema olivaceoides* Hust., 15. *Gomphonema tetrastigatum* Horik. et Okuno.

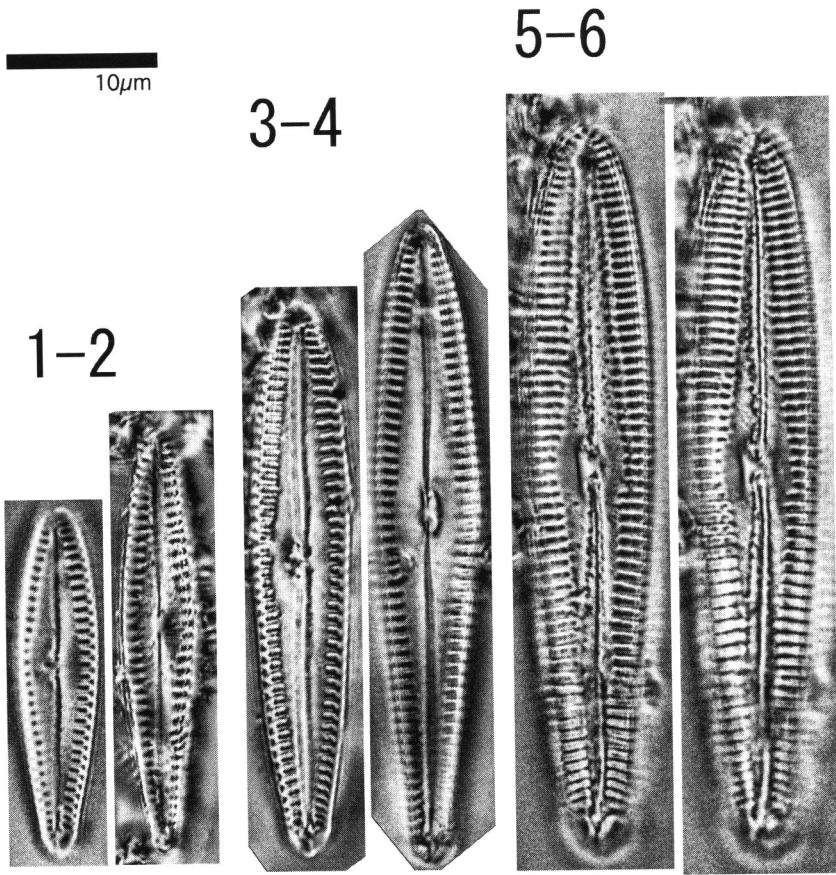


Plate 2. ($\times 2000$). 1-2. *Gomphonema clevei* Fric. Fricke, 3-6. *Gomphonema christenseni* R. L. Lowe & Koci-olek.

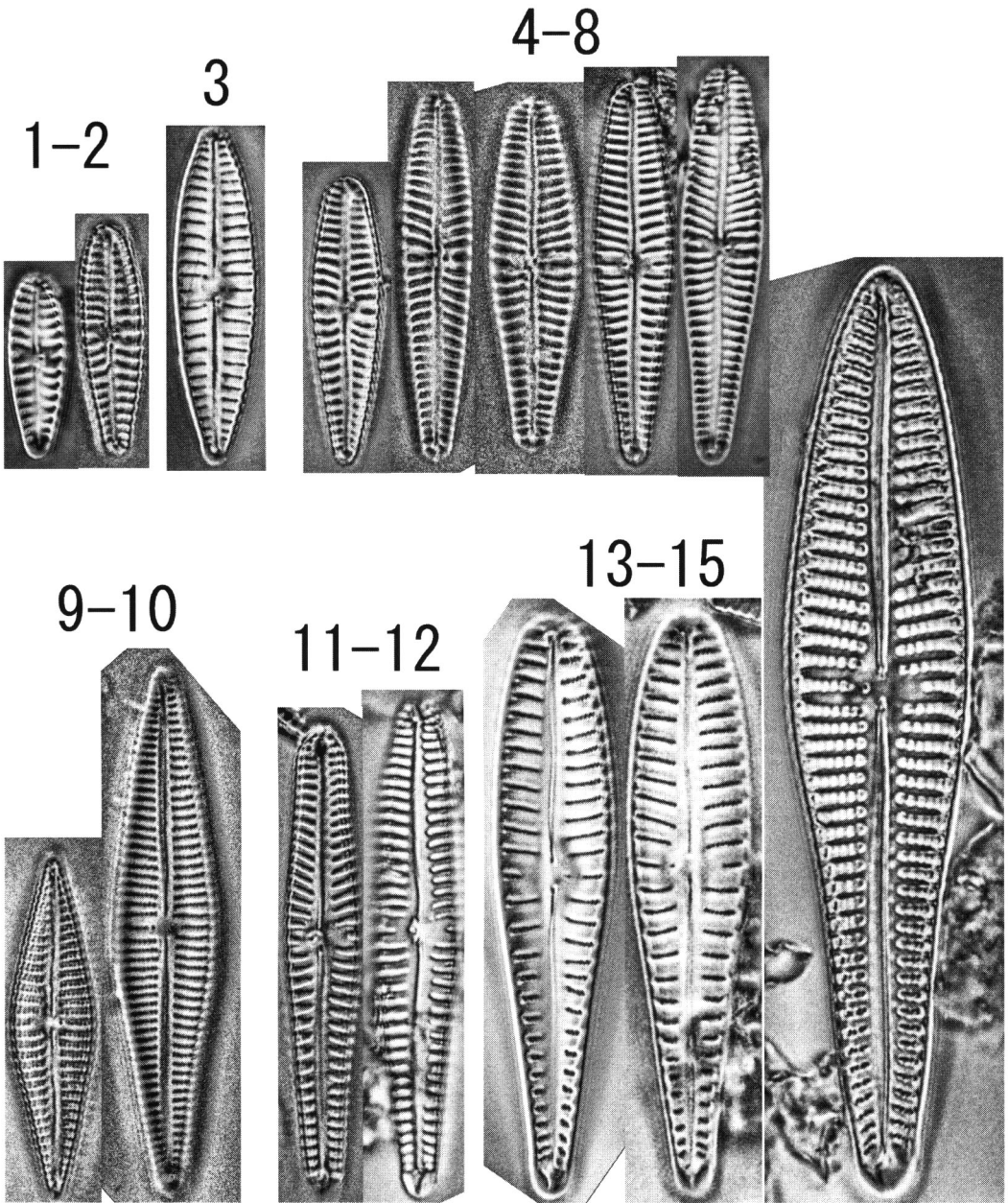


Plate 3. ($\times 2000$). 1-2. *Gomphonema insigne* W. Greg., 3. *Gomphonema insigniturris* stat. nov. nom. nov., 4. *Gomphonema turgidum* Ehrenb., 5. *Gomphonema acuminatum* Ehrenb.

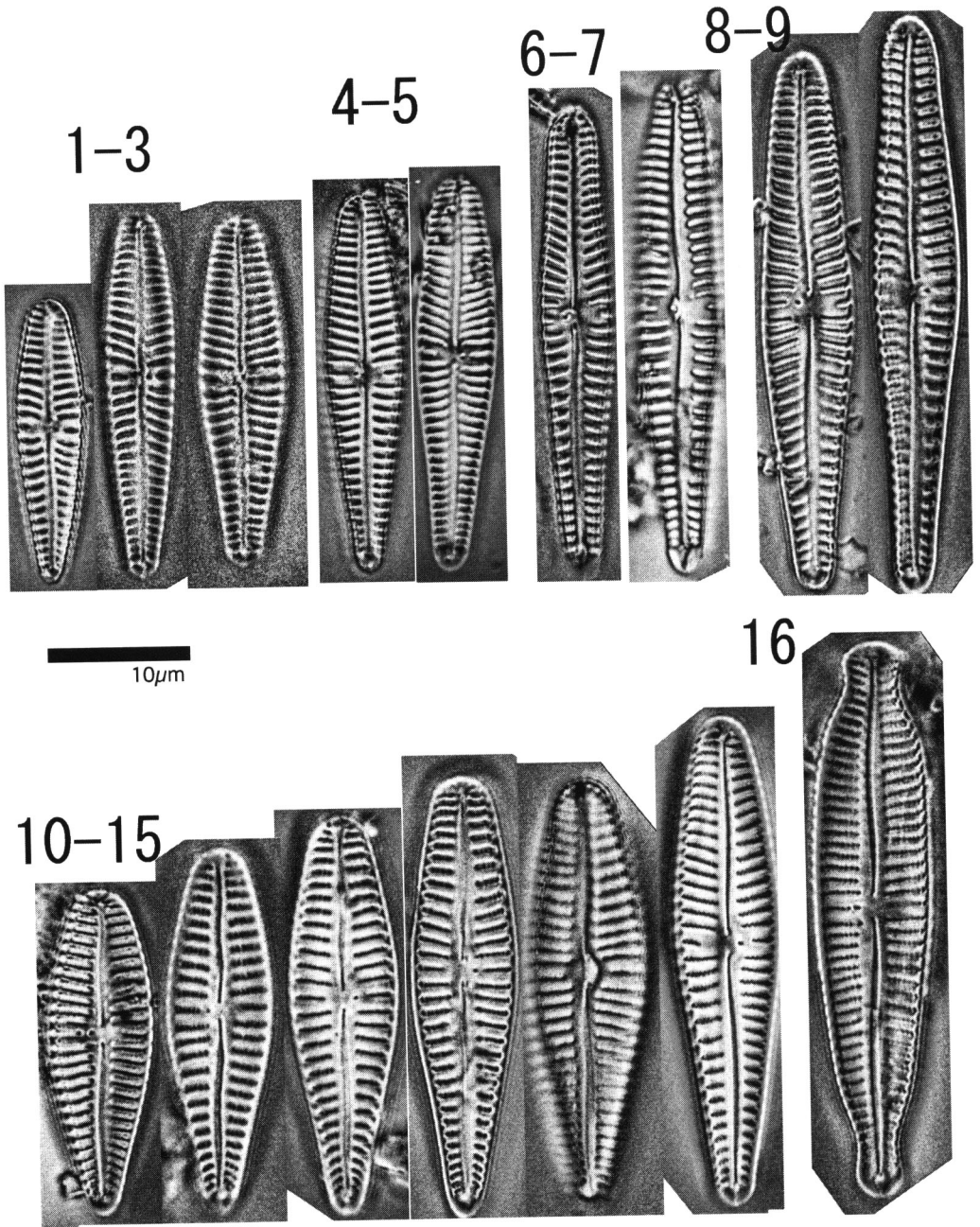


Plate 4. (×2000). 1-5. *Gomphonema minutum* fo. *lemanense* Lange-Bert. & E.Reichardt, 6-7. *Gomphonema angustatum* (Kütz.) Rabenh., 8-15. *Gomphonema intricatum* var. *dichotomum* (Kütz.) Grunow, 16. *Gomphonema sarcophagus* W. Greg.

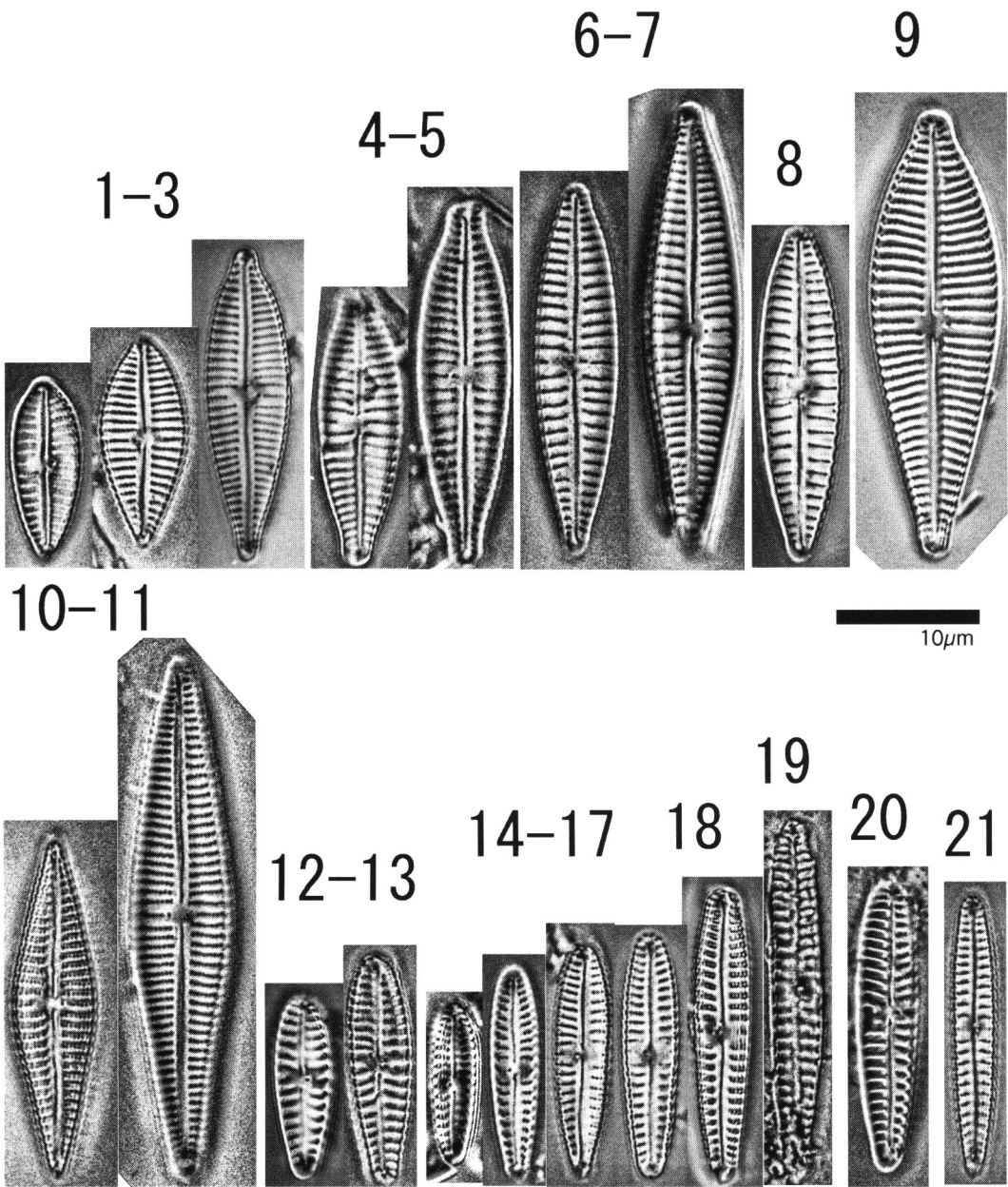


Plate 5. ($\times 2000$). 1-3. *Gomphonema parvulum* (Kütz.) Kütz., 4-5. *Gomphonema parvulum* var. *exilissima* Grunow, 6-7. *Gomphonema parvulum* var. *parvulum* fo. *saprophilum* Lange-Bert. & E. Reichardt, 8. *Gomphonema parallelistriatum* Lange-Bert. & E. Reichardt, 9. *Gomphonema pseudoaugar* Lange-Bert., 10-11. *Gomphonema gracile* Ehrenb., 12-13. *Gomphonema minutum* (C. Agardh) C. Agardh, 14-19. *Gomphonema intricatum* var. *clavatum* comb. nov., 20. *Gomphonema roehringeri* E. Reichardt, 21. *Gomphonema angustivalva* E. Reichardt.

