

# *Fragilaria asterionelloides*, A New Planktonic Species of *Fragilaria* from Japanese Reservoirs That Forms Star-Shaped Colonies

Akihiro Tuji<sup>1,\*</sup> and David Williams<sup>2</sup>

<sup>1</sup>Department of Botany, National Museum of Nature and Science,  
Amakubo 4-1-1, Tsukuba, Ibaraki 305-0005, Japan

<sup>2</sup>Department of Life Sciences, the Natural History Museum,  
Cromwell Road, London SW7 5BD, UK

\*E-mail: tuji@kahaku.go.jp

(Received 17 February 2017; accepted 22 March 2017)

**Abstract** A new species of *Fragilaria*, *Fragilaria asterionelloides*, is described. It is found in Japanese reservoirs. *Fragilaria asterionelloides* forms a characteristic star-shaped colony and is easily distinguished from most other species of *Fragilaria* because of this feature. *Fragilaria asterionelloides* is most similar to *Fragilaria tenera* var. *lemanensis* but differs in the outline of the frustule, the fine density of striae and the swollen central area. *Synedra acus* var. *ostenfeldii* also forms a star-like colony but has no central area. The frustule (valves and girdle) of *Fragilaria asterionelloides* also resemble those of *Fragilaria crotonensis* but differ from these by the fine density of striae and the swollen central area.

**Key words**: *Fragilaria tenera* var. *lemanensis*, *Synedra acus* var. *ostenfeldii*, *Fragilaria crotonensis*, plankton, reservoir.

## Introduction

The freshwater planktonic diatom flora in Japanese reservoirs and lakes has been studied by a number of researchers (e.g. Kobayasi and Inoue, 1985; Watanabe and Kanechika, 1986) and the taxonomy of some species has been clarified (e.g. Tuji and Houki, 2001, 2004; Tuji and Williams, 2006, 2007).

In August 2009, the phytoplankton flora from 109 Japanese artificial reservoirs (Tuji, 2015) was examined and a very large and assumed unknown 'araphid' species which formed a characteristic star-like colony was found. It was dominant in Kanayama reservoir, Hokkaido, Japan (Figs. 1, 2). Similar specimens were found in Takisato reservoir, Hokkaido (2009 summer) and Moniwakko reservoir, Fukushima Prefecture (Surikamigawa-dam, 2011 autumn).

In this paper, the unknown 'araphid' species is

described as new and named *Fragilaria asterionelloides*.

## Materials and Methods

The same material and methods as described in Tuji (2015) were used for this report. About 18 litres of surface water samples from 109 Japanese artificial reservoirs were collected in August 2009 (during the summer) and sent to the laboratory, after refrigeration, within three days (mostly two days) and without fixation. In addition, samples from 50 selected sites from the 109 total were collected from March to May 2010 (spring) and 22 sites were collected from September to October 2011 (autumn), were examined.

About one liter of surface water sample was filtered using PTFE membrane filters having 1.0 µm openings (JAWP04700, Millipore) and dried with an incubator (ITD-20E, ALP) at 60°C. The mem-

brane filters were then cut into small pieces (about 5 mm square) and attached to an SEM stub using carbon adhesive tape. These stubs were sputtered coated with platinum and examined using a SEM (JSM-6390 with LaB<sub>6</sub> gun, JEOL).

One drop of formalin fixed specimen was placed on a coverslip and then placed on a grass plate (Laboratory protection plate, Schott). The plate was put on a stove burner and baked for 30 minutes. The coverslip was carefully washed using distilled water and then mounted with Zrax (Microlife services, Somerset, U.K.). The perma-

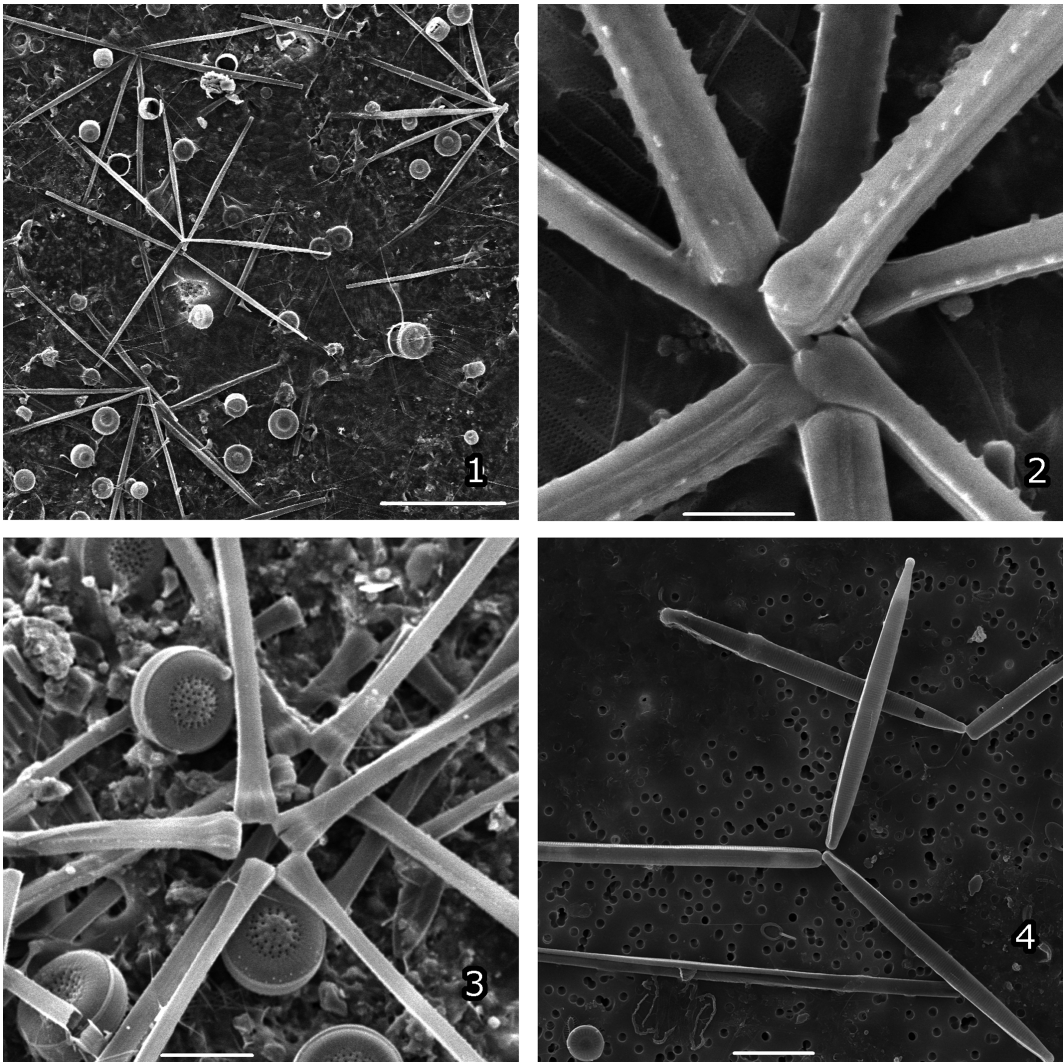
nent slides were examined and photographed using an Axiophot, Zeiss microscope.

All samples, SEM stubs and photographs are housed in the micro-algal herbarium in National Museum of Nature and Science (TNS).

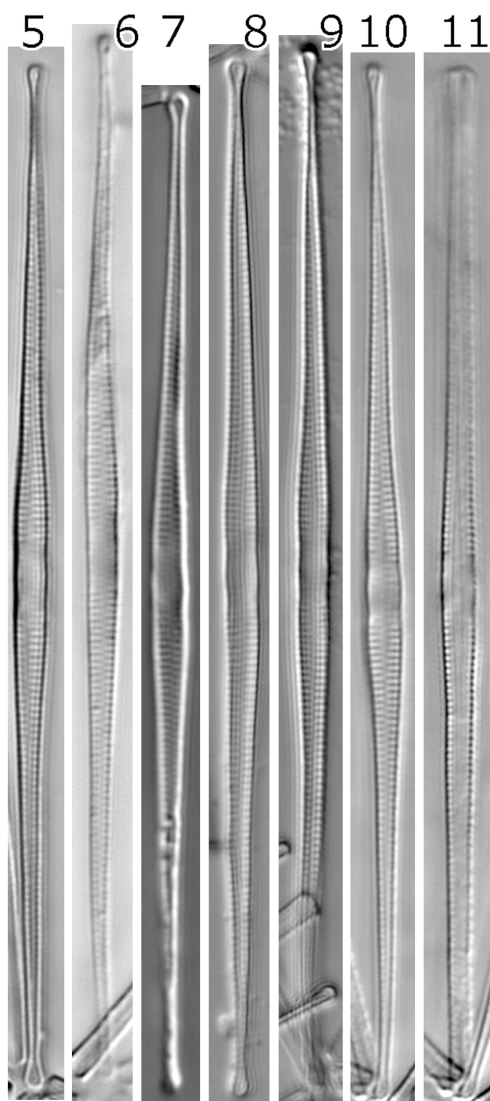
#### Taxonomic description

*Fragilaria asterionelloides* Tuji et D.M.Williams sp. nov. (figs. 1, 2, 5–18)

Holotype: A colony in a slide TNS-AL-58931 in TNS (Department of Botany, National Museum of Nature and Sciences = Fig. 12)



Figs. 1–4. Scanning electron microscopy. 1–2. *Fragilaria asterionelloides*, 1. bar = 50  $\mu$ m, 2. bar = 2  $\mu$ m. 3. *Asterionella formosa*, bar = 10  $\mu$ m. 4. *Nitzschia fruticosa*, bar = 10  $\mu$ m.



Figs. 5–11. *Fragilaria asterionelloides*, light microscopy, bar = 10  $\mu\text{m}$ , TNS-AL-58931.

Type locality: Kanayama reservoir, Hokkaido, Japan.

Other localities: Takisato reservoir, Hokkaido, Moniwakko reservoir (Surikamigawa-dam), Fukushima Prefecture, and Lake Ashi, Kanagawa Prefecture, Japan.

In situ, frustules connected in star-shaped colonies; frustules overlap at poles. Valves lanceolate, tapering towards round to capitate poles. Each valve with expanded central area; valve

length 60–70  $\mu\text{m}$ , breadth 2  $\mu\text{m}$ . Small spines located at valve at face—mantle junction, most situated on a virga, some across a pair of virgae. Spines short, taper towards tips; spines at valve centre mostly bifurcate; spines at poles not bifurcating, but tilting towards respective pole. Some spines occur above each polar ocellulimbus (Figs. 15–18); ocellulimbus composed of three rows and three columns of pores (Figs. 17, 18). Striae alternate, in single rows, parallel throughout valve, not all opposite either side of central sternum, 22–23 per 10  $\mu\text{m}$ . Sternum relatively thin, 1/5 of valve width. One rimoportula per frustule, situated on valve face (Figs. 15, 16). Girdle of 3+ (?) bands, appear open although not clearly so (Figs. 17, 18).

### Results and Discussions

A few planktonic ‘araphid’ species are known to have star-shaped colonies. For example, *Asterionella formosa* Hassall (and some of its varieties and forms: *Asterionella formosa* var. *acaroides* Lemmermann 1903 and *Asterionella formosa* var. *tatrica* Woloszynsaka 1934, amongst others) form these kinds of colonies (see also Körner, 1970a, b) (Fig. 3). The connecting part of the colony of *Fragilaria asterionelloides* is, however, irregular and closely fitting (Fig. 2), so can be easily distinguished from those seen in *A. formosa* when using SEM and LM (Fig. 3). The robust diatom *Nitzschia fruticosa* Hust. also makes similar colonies (Fig. 4), but is quite a different diatom; a number of other diatoms also form these colonies but few could be confused with any ‘araphid’ species. Thus, *Fragilaria asterionelloides* is easily distinguished from other known Japanese planktonic diatoms.

As the specimens have one rimoportula per frustule (Fig. 15), small spines, alternate striae consisting of single rows, and open girdle bands, it should, at present, belong in the genus *Fragilaria* (see Williams and Round, 1987, Round, 1991).

There are two taxa that have a star-shaped colony that are worth comparison. One has been placed in *Fragilaria* the other in *Synedra* sensu

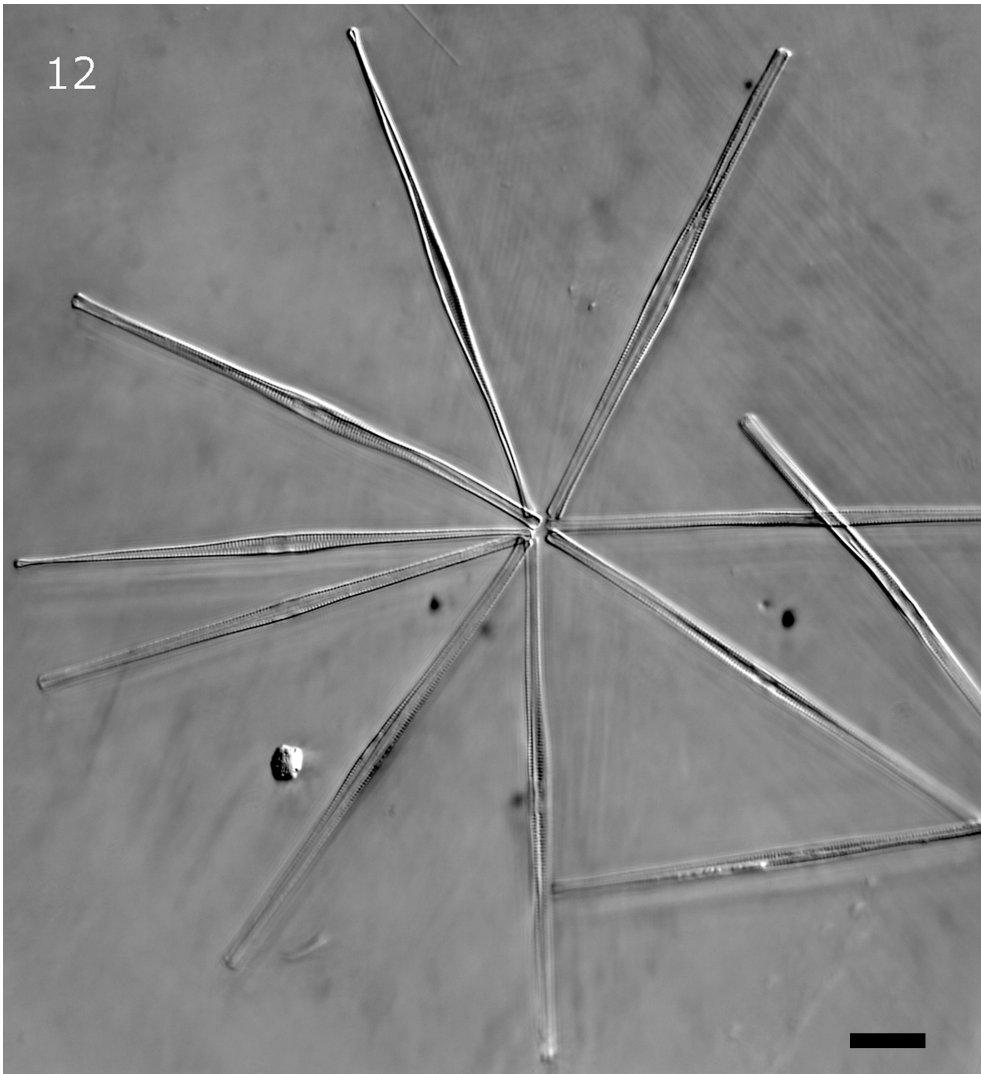
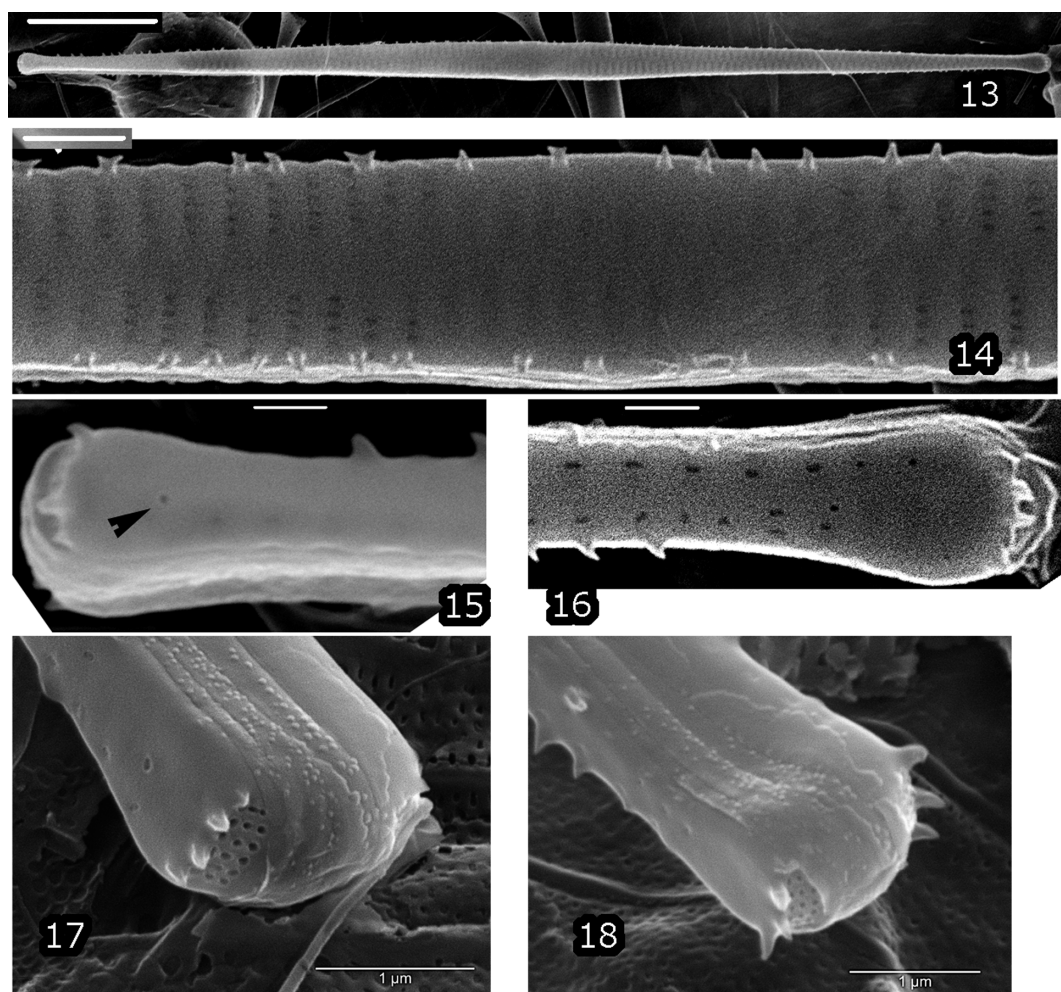


Fig. 12. *Fragilaria asterionelloides*, light microscopy, bar = 10  $\mu\text{m}$ , TNS-AL-58931. Holotype individual.

lato. *Fragilaria tenera* var. *lemanensis* Druart, Lavigne et Robert was recently described from Lake Geneva, Switzerland (Druart *et al.*, 2007: 284). The taxon was illustrated with only three light micrographs, but later Lange-Bertalot and Ulrich documented it in much greater detail using specimens from Lake Constance, Germany; they provided a lengthy discussion of *Fragilaria tenera* and its varieties (Lange-Bertalot and Ulrich, 2014: 9–15). *Fragilaria asterionelloides* has a swollen and clear central area allowing it to be distinguished from *F. tenera* var. *lemanensis*. The den-

sity of valve striation differ as well: 18–20 str. per 10  $\mu\text{m}$  for *F. tenera* var. *lemanensis*; 22–23 str. for *Fragilaria asterionelloides*.

The second relevant taxon that has been reported with star-shaped colonies is *Synedra acus* var. *ostenfeldii* Krieger, which has a similar striae density to *Fragilaria asterionelloides* (22–24 str. per 10  $\mu\text{m}$ ). Inspection of Krieger's original illustration shows that the valves do not have a central area and hence differs from *Fragilaria asterionelloides*, although the illustrations are difficult to interpret and Krieger's material has not been



Figs. 13–18. *Fragilaria asterionelloides*, scanning electron microscopy. 13. Whole frustule, bar = 10  $\mu$ m. 14. Slightly swollen central area with small spines positioned at the margin and on a virga, bar = 1  $\mu$ m. 15. Valve poles with apical pore field (ocellulimbus) and rimportula, bar = 0.5  $\mu$ m. 16. Valve apices with apical pore field (ocellulimbus) but lacking any rimportula, bar = 0.5  $\mu$ m. 17–18. Valve apices with open bands, bar = 1  $\mu$ m.

examined or yet to be traced (Krieger, 1927: taf. 3, fig 29b, after Ostenfeld, 1905: Pl. II, Figs. 16, 17).

The valve outline (Figs. 5–13) is similar to that recorded for *Fragilaria crotonensis* Kitton (e.g. Crawford *et al.*, 1985), although the form of its colony is very different. There are a number of SEM images of specimens named as *Fragilaria crotonensis* (see listing in Gaul *et al.*, 1993, Henderson *et al.*, 2003) and a number of varieties and forms of *Fragilaria crotonensis* have been described. With respect to the SEM images, most are hard to evaluate as they do not

show sufficient detail to determine anything other than the basic characters, with the exception of the images in Lange-Bertalot and Ulrich (2014). One constant is that the colonies are formed by the central portion being attached by spines.

With respect to the many named varieties and forms, these too are hard to evaluate as most are either illustrated with just simple line drawings, not illustrated at all or are apparently published in obscure items difficult to find.

The density of striae in *Fragilaria asterionel-*

*loides* is 22–23 in 10  $\mu\text{m}$ , finer than recorded for most descriptions of *F. crotonensis* (e.g. 15–18 in 10  $\mu\text{m}$  by Patrick and Reimer, 1966). *Fragilaria asterionelloides* also has a slightly swollen central area, which distinguishes it from *F. crotonensis*. However, morphological variation in *F. crotonensis* is very high and will possibly include several cryptic taxa (Tuji pers. obs.), so it is important to distinguish *Fragilaria asterionelloides* from *F. crotonensis* by an examination of its colony. Since the type material also include specimens of *F. crotonensis*, only colony forming valves were examined with valves not yet studied.

### Acknowledgments

A.T. would like to thank Dr. Hidetaka Ichiyanagi, Water Resources Environment Center. We also wish to extend my thanks to Dr. Yuko Niiyama and Dr. Kaoru Ogane for helping the filtration of so much samples, and Mrs. Yuri Inami for taking many SEM photographs presented in this study. Part of this work was supported by Watershed Ecology Research Group.

### References

- Crawford, R. M., Canter, H. M. and Jaworski, G. H. M. 1985. A study of two morphological variants of the diatom *Fragilaria crotonensis* Kitton using electron microscopy. *Annals of Botany* 55: 473–485.
- Druart, J. C., Lavigne, S. and Robert, M. 2007. *Fragilaria tenera* var. *lemanensis*, une nouvelle variété pour le Léman (France-Suisse). *Cryptogamie Algologie* 28: 283–287.
- Gaul, U., Geissler, U., Henderson, M., Mahoney, R. and Reimer, C. W. 1993. Bibliography on the fine-structure of diatom frustules (Bacillariophyceae). *Proceedings of the Academy of Natural Sciences of Philadelphia* 144: 69–238.
- Henderson, M. V. and Reimer, C. W. 2003. Bibliography on the fine structure of diatom frustules (Bacillariophyceae). II. (+ Deletions, addenda and corrigenda for bibliography I). *Diatom Monographs* 3: 1–377.
- Krieger, W. 1927. Zur Biologie des Flußplanktons. *Pflanzenforschung* 10: 1–64.
- Kobayasi, H. and Inoue, H. 1985. Fine structure and taxonomy of the small and tiny *Stephanodiscus* Bacillariophyceae species in Japan 1. *Stephanodiscus invisitatus*. *Japanese Journal of Phycology* 33: 149–154.
- Körner, H. 1970a. Morphologie und taxonomie der diatomeengattung *Asterionella*. *Mathematisch-Naturwissenschaftlichen Fakultät der Freien Universität Berlin Vorgelegt von Heinz Kömer aus Komotau, 557–724, 8 diagrams, 20 pls.*
- Körner, H. 1970b. Morphologie und taxonomie der diatomeengattung *Asterionella*. *Nova Hedwigia* 20: 557–723.
- Lange-Bertalot, H. and Ulrich, S. 2014. Contributions to the taxonomy of needle-shaped *Fragilaria* und *Ulnaria* species. *Lauterbornia*. 78: 1–73.
- Lehmann, E. 1903. Brandenburgische Algen. II. Das Phytoplankton des Müggelsees und einiger benachbarter Gewässer. *Zeitschrift für Fischerei und deren Hilfswissenschaften*. 11: 73–123.
- Ostenfeld, C. H. 1905. Phytoplankton. In: A regular fortnightly of the plankton of the two Icelandic lakes Thingvallavatn and Myvatn by C. H. Ostenfeld and C. Wesenberg-Lund. *Proceedings of the Royal Society of Edinburgh* 25 (II): 1106–1128.
- Tuji, A. 2015. The distribution and taxonomy of the *Aulacoseira distans* species complex found in Japanese harmonic artificial reservoirs. *Bulletin of the National Museum of Nature and Science, Series B* 41: 53–60.
- Tuji, A. and Houki, A. 2001. Centric diatoms in Lake Biwa. *Lake Biwa Study Monographs* 7: 1–90.
- Tuji, A. and Houki, A. 2004. Type Examination of *Synedra delicatissima* W.Sm. and its occurrence in Japan. *Bulletin of National Science Museum, Tokyo, Series, B* 30: 151–154.
- Tuji, A. and Williams, D. M. 2006. Examination of the type material of *Synedra rumpens* = *Fragilaria rumpens*, Bacillariophyceae. *Phycological Research* 54: 99–103.
- Tuji, A. and Williams, D. M. 2007. Type examination of Japanese diatoms described by Friedrich Meister (1913) from Lake Suwa. *Bulletin of National Science Museum, Tokyo, Series, B* 33: 69–79.
- Patrick, R. M. and Reimer, C. W. 1986. The Diatoms of the United States Exclusive of Alaska and Hawaii. *Monographs of the Academy of Natural Sciences of Philadelphia*, 1, 688 pp., 64 pls.
- Round, F. E. 1991. On stria patterns in *Fragilaria* and *Synedra*. *Diatom Research* 6: 147–154.
- Watanabe, T. and Kanechika, M. 1986. Application of DAIPo (Diatom assemblage index to organic water pollution) to lentic environment to the Muroo Reservoir in Nara Prefecture. *Diatom* 2: 153–162.
- Williams, D. M. and Round, F. E. 1987. Revision of the genus *Fragilaria*. *Diatom Research* 2: 267–288.
- Woloszynska, J. 1934. *Asterionella formosa* Hass. var. *tatrica* n. var. w jeziorach tatrzańskich. (*Asterionella formosa* Hass. var. *tatrica* n. var. in den Tatrseen). *Acta Societatis Botanicorum Poloniae. Warszawa* 11 (Suppl.): 137–151.