

Distribution and Taxonomy of the *Aulacoseira distans* Species Complex Found in Japanese Harmonic Artificial Reservoirs

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Abstract To examine the distribution of the *Aulacoseira distans* species complex in Japanese artificial reservoirs, surface water samples from 109 reservoirs were observed. *Aulacoseira pusilla* and *Aulacoseira tenella* were found in many reservoirs. No other taxon from this species complex was found. The *A. distans* species complex, with the exception of *A. pusilla* and *A. tenella*, may not exist in Japanese harmonic artificial reservoirs.

Key words : *Aulacoseira distans*, distribution, Japan, taxonomy.

Introduction

Small species of *Aulacoseira* are commonly found in harmonic lakes (Haworth, 1988; Tuji and Houki, 2001). However, the taxonomy of these species in Japan is still confused, especially in the bio-monitoring field.

Hustedt's European flora (1930) is widely used by Japanese diatomists (Tuji, 2009). In this flora, Hustedt described *Melosira distans* (Ehrenb.) Kütz. with three varieties: var. *alpigena* Grunow, var. *lirata* (Ehrenb.) Bethge and var. *pfaffiana* (Reinsch) Grunow; and two forms: *M. distans* var. *lirata* f. *seriata* O.Müll. and f. *lacustris* (Grunow) Bethge; all of these have small valves (diameter is 4–20 µm) and having areolae on valve face (Hustedt, 1930: 92–93).

Krammer and Lange-Bertalot (1991), Haworth (1988) and Krammer (1991), are also used for the identification of the *A. distans* species complex. However, it still remains difficult to identify Japanese specimens in this complex. Denys *et al.* (2003) pointed out that '*Aulacoseira subboREALIS* (Nygaard) L.Denys *et al.* is widely distributed in rivers and lakes in W-Europe ..., but has been reported only rarely because of confusion

with other taxa. It appears to develop especially well in more alkaline and rather eutrophic, highly turbid fresh water'; this species has also been reported from Japan (Tsugeki *et al.*, 2006). Tuji and Houki (2004) and Tuji and Williams (2006b) examined type material of *Melosira pusilla* F.Meister and proposed the new combination *Aulacoseira pusilla* (F.Meister) Tuji et Houki. Tuji and Williams (2006b) also made *A. subREALIS* a synonym of *A. pusilla*. This synonymy has since been accepted (Houk and Klee, 2007).

I have also tackled other members of the *Aulacoseira distans* species complex (Tuji, 2006, 2010b; Tuji and Williams, 2006a, 2007; Watanabe *et al.*, 2005). With the exception of *A. pusilla*, the *Aulacoseira distans* species complex should be found in humic rather than harmonic lake. However, these species have been reported from Japanese artificial reservoirs. Because of the importance of biological monitoring in artificial reservoirs, the taxonomy and distribution of the *Aulacoseira distans* species complex needs to be clear.

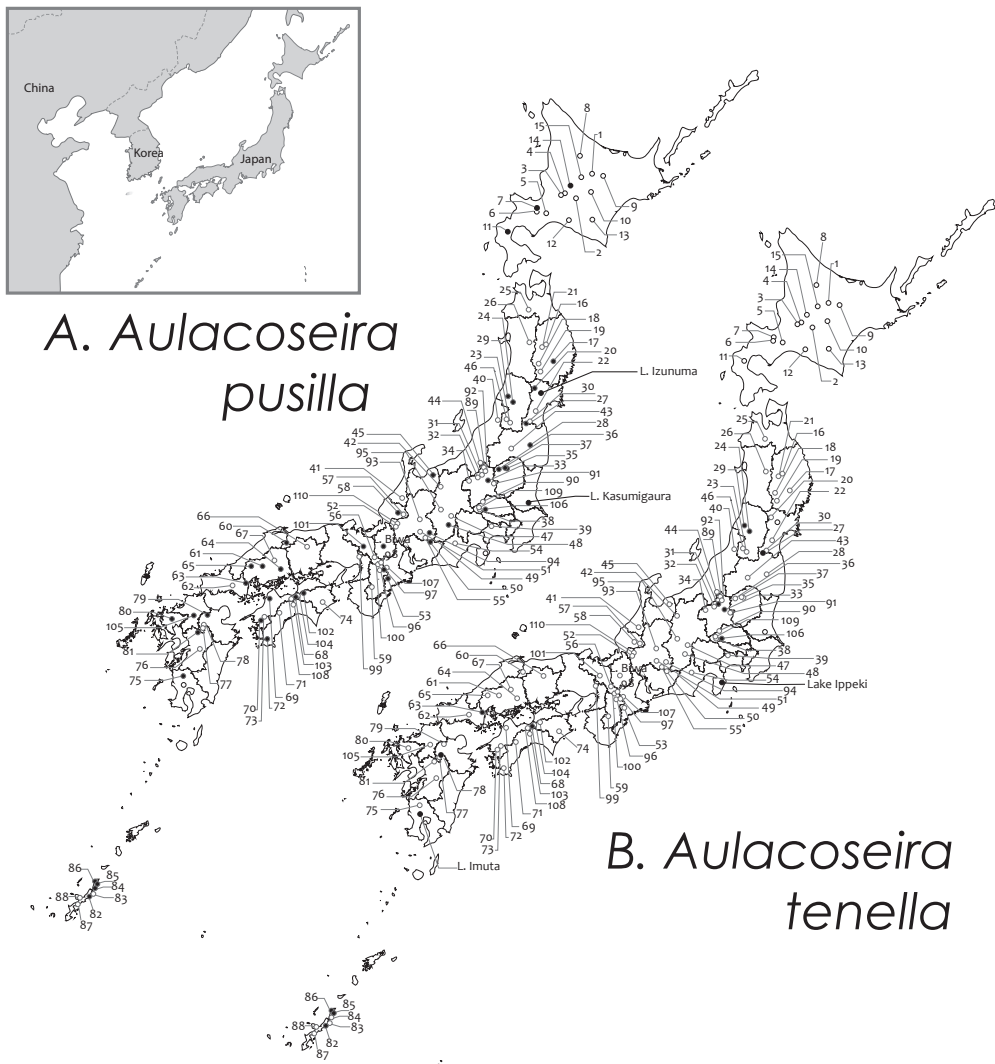


Fig. 1. Site map of Japanese reservoirs (Res.) examined in this study, and existence of a. *Aulacoseira pusilla* and b. *Aulacoseira tenella*. black dot: present; white circle: absent. 1: Taisetsu. 2: Kanayama. 3: Katsurazawa. 4: Ashibetsu. 5: Izarigawa. 6: Hoheikyo. 7: Jozankei. 8: Iwaonai. 9: Kanoko. 10: Tokachi. 11: Pirika. 12: Nibutani. 13: Satsunaigawa. 14: Takisato. 15: Chubetsu. 16: Shijushida. 17: Tase. 18: Yuda. 19: Ishibuchi. 20: Naruko. 21: Goshu. 22: Kamahusa. 23: Shirakawa. 24: Sagae. 25: Aseishigawa. 26: Tamagawa. 27: Shichikashuku. 28: Miharu. 29: Gassan. 30: Surikamigawa. 31: Fujiwara. 32: Aimata. 33: Sonohara. 34: Shinaki. 35: Ikari. 36: Kawamata. 37: Kawaji. 38: Futase. 39: Miyagase. 40: Oishi. 41: Tedorigawa. 42: Omachi. 43: Okawa. 44: Sagurigawa. 45: Unazuki. 46: Yokokawa. 47: Miwa. 48: Koshibu. 49: Shintoyone. 50: Yahagi. 51: Maruyama. 52: Yokoyama. 53: Hachisu. 54: Nagashima. 55: Origawa. 56: Amagase. 57: Kuzuryu. 58: Managawa. 59: Sarutani. 60: Sugawara. 61: Haji. 62: Shimajigawa. 63: Yasaka. 64: Hattabara. 65: Nukui. 66: Tomata. 67: Haizuka. 68: Yanase. 69: Ishitegawa. 70: Nomura. 71: Odo. 72: Nakasujigawa. 73: Kanogawa. 74: Nagayasuguchi. 75: Tsuruda. 76: Midorikawa. 77: Shimoke. 78: Matsubara. 79: Yabakei. 80: Kyuragi. 81: Ryumon. 82: Fukuji. 83: Arakawa. 84: Aha. 85: Fungawa. 86: Benoki. 87: Kanna. 88: Haneji. 89: Yagisawa. 90: Shimokubo. 91: Kusaki. 92: Naramata. 93: Iwaya. 94: Agigawa. 95: Misogawa. 96: Muro. 97: Shorenji. 98: Takayama. 99: Hitokura. 100: Nunome. 101: Hiyoshi. 102: Ikeda. 103: Sameura. 104: Shingu. 105: Terauchi. 106: Urayama. 107: Hinachi. 108: Tomisato. 109: Takizawa. 110: Tokuyama.

Materials and Methods

About 18 liters of surface water samples from 109 Japanese artificial reservoirs were collected in August 2009 (summer), and sent to our laboratory by refrigeration within three days (mostly two days) without fixation (Table 1, Fig. 1). Additionally, samples from 50 selected sites within the 109 total sites 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 $1.0\mu\text{m}$ openings (JAWP04700, Millipore) and dried up with an incubator (ITD-20E, ALP) at 60°C .

The membrane filters were 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 LaB₆ gun, JEOL).

We have also examined specimens from Lake Kasumigaura (collected monthly during 2012 to 2014 by M. Nakagawa), Lake Kitaura (see Tuji, 2010a: nos41), L. Ippeki (TNS-AL54289, Coll. 19 Feb. 2004 by A. Tuji), Lake Izunuma (stub Ak438, Coll. 21 Aug. 2012 by A. Tuji) and Lake Imuta (TNS-AL-10153, Coll. 6 Feb. 1985 by T. Watanabe) for comparison with artificial reservoirs' samples.

All samples, SEM stubs and photographs are housed in the micro-algal herbarium in National Museum of Nature and Science (TNS) (Table 1).

Results and Discussion

1. *Aulacoseira pusilla* (F.Meister) Tuji et Houki, Bull. Nat. Sci. Mus., ser. B. 30: 38.

(Figs 2–16)

Basionym: *Melosira pusilla* F.Meister, Arch. Hydrobiol. 8: 306. pl. IV, f. 2. 1913.

Lectotype (designated in Tuji & Houki 2004): Slide numbered "A3/61" with Meister's label in BRM!

Isotype: Slide in Tempère et Peragallo (1913,

no. 801, 2nd edition), BM69152 in BM!

Type locality: Lake Suwa, Nagano Prefecture, Japan.

Synonym: *Aulacoseira subborealis* (Nygaard) L.Denys, Muylaert et Krammer, Nova Hedwigia 77: 410.

≡ *Melosira italica* var. *subborealis* Nygaard, Folia Limnologica Scandinavica 8: 74. pl. 1. f. 8. pl. 2. f. 13–19. pl. 6. f. 24–25. 1956.

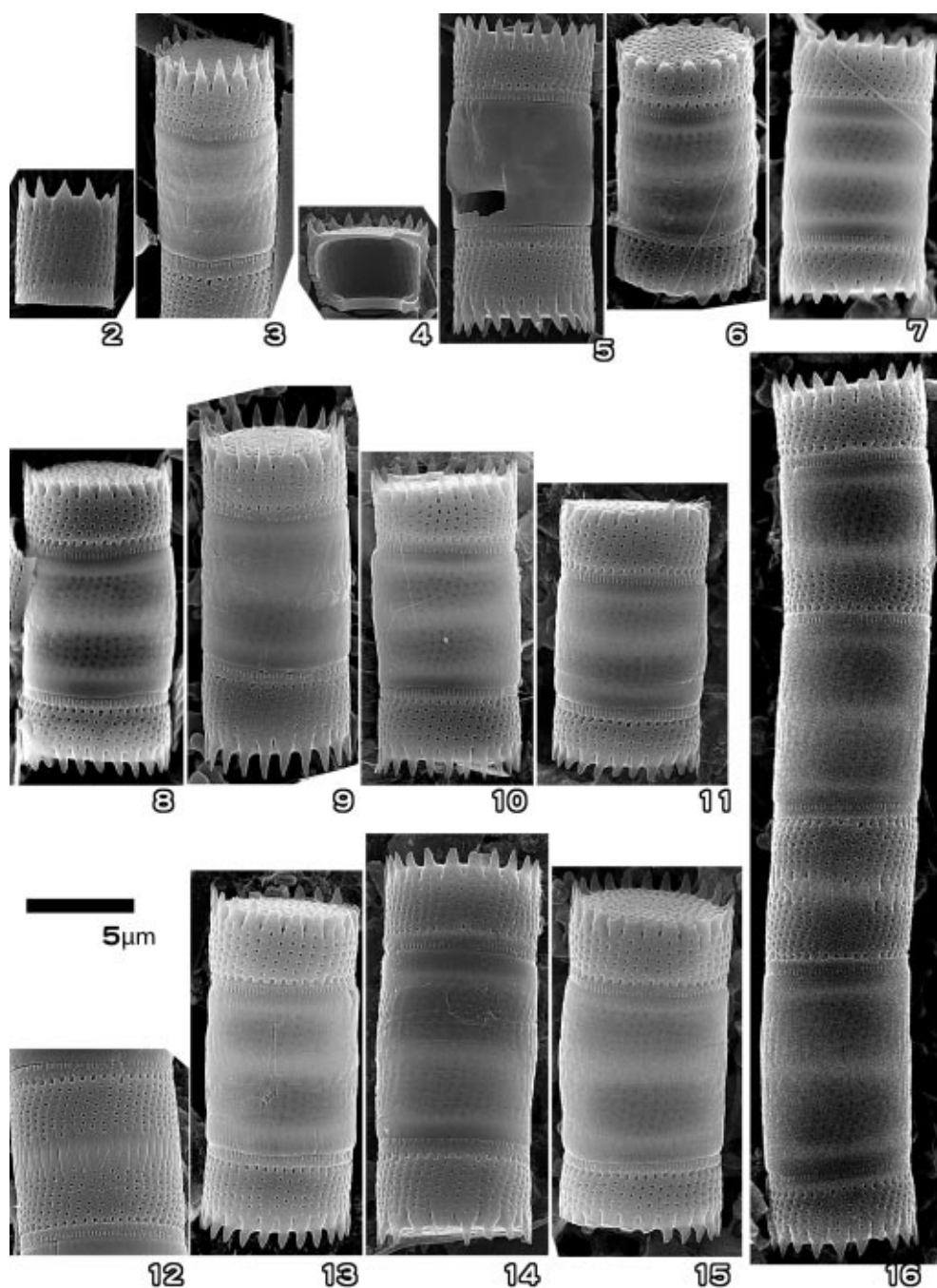
Aulacoseira pusilla was found in 25 of the 109 reservoirs from the summer 2009 samples, in 20 of the 49 spring 2010 samples, in 7 of the 22 autumn 2011 samples and in 44 of the 109 total (Table 1, Figs. 2–16). Though this taxon is found during the winter in Lake Biwa and its Naiko lagoons (Lake Katata, Tuji and Houki, 2001), it was commonly found in the summer 2009; grazing pressure may cause this difference, as Denys *et al.* (2003) have pointed out, this species is found frequently 'in more alkaline and rather eutrophic, highly turbid fresh water'. I have checked the COD, total nitrate and total phosphate of these reservoirs, but no clear relationship was found. *A. pusilla* was also found in Lake Izunuma (Figs. 4, 5) and Lake Kitaura (Fig. 2).

In the artificial reservoir, the valves of *A. pusilla* are $5\text{--}7.5\mu\text{m}$ in diameter, with a mantle height of $3\text{--}4\mu\text{m}$. The ratio of the mantle height to valve diameter is $0.4\text{--}0.7$, and the ratio of the cell length to cell diameter is $0.8\text{--}1.5$. The valve face is flat. The circular areolae on the mantle run in a spiral with $20\text{--}26$ pervalvar striae/ $10\mu\text{m}$ and $25\text{--}30$ areolae/ $10\mu\text{m}$. A Lake Kitaura individual (Fig. 2) had a narrow valve diameter ($4.5\mu\text{m}$) and relatively high mantle height to valve diameter ratio value (0.9). Since Potapova (2010) reported the ratio of mantle height to valve diameter close to 1 or <1 for this taxon in North America, it may fall within the morphological variation reported for this taxon.

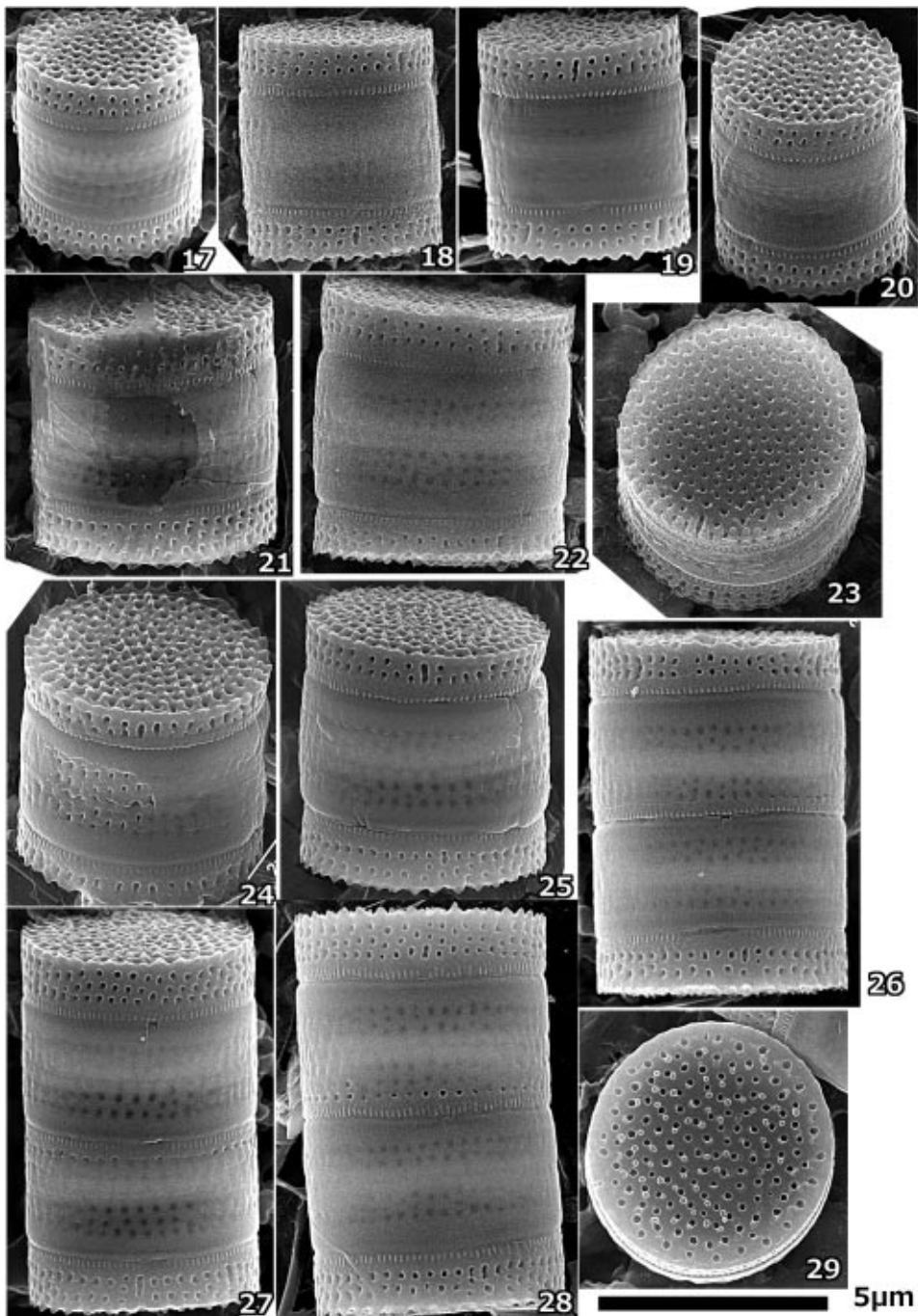
2. *Aulacoseira tenella* (Nygaard) Simonsen, Bacillaria 2: 63. 1979.

(Figs. 17–29)

Basionym: *Melosira tenella* Nygaard, Folia



Figs. 2–16. *Aulacoseira pusilla*. SEM. 2. Lake Kitaura (nos 41), stub ak405. 3. Takayama Res. stub ak488. 4–5. L. Izunuma, stub ak438. 6. Fuji Res. stub ak346. 7. Ryumon Res. stub ak. 345. 8. Ikeda Res. stub ak366. 9. Shorenji Res. stub ak487. 10. Kyuragi Res. stub ak344. 11. Nukui Res. stub ak329. 12. Agigawa Res. stub ak486. 13. Kawamata Res. stub ak300. 14. Miharu Res. stub ak456. 15. Kawaji Res. stub ak301. 16. Kawaji Res. stub ak458.



Figs. 17–29. *Aulacoseira tenella*. SEM. 17. Benoki Res. stub ak483. 18. Fukuji Res. stub ak481. 19. Sonohara Res. stub ak509. 20. Fukuji Res. stub ak346. 21. Sagae Res. stub ak288. 22–23. Yasaka Res. stub ak471. 24. Gassan Res. stub ak293. 25. Yanase Res. stub ak068. 26. Yagisawa Res. stub ak353. 27. Ikari Res. stub ak299. 28. Fujiwara Res. stub ak295. 29. Gassan Res. stub ak293.

Limnologica Scandinavica 8: 76. pl. 1. f. 12–15. pl. 1. f. 1–12. 1956.

≡ *Aulacoseira distans* var. *tenella* (Nygaard) R.Ross in Hartley, J. Mar. Biol. Ass. U.K. 66: 606. 1986.

≡ *Melosira distans* var. *tenella* (Nygaard) M.Florin, Proc. Sixth Symp. Diat. 50. 1981.

Aulacoseira tenella is a unique taxon, having a very small mantle height to valve diameter ratio, very short triangle spines and its valve face covered with evenly spaced areolae; it is found in many reservoirs. Since these characters agree with the descriptions given in Florin (1981), Eloranta (1986) and Siver and Kling (1997), it is identified here as *A. tenella*.

A. tenella was found in 9 of the 109 reservoirs in summer 2009 samples, in 3 of the 49 in spring 2010 samples, in 2 of the 22 autumn 2011 samples, and in 12 of the 109 total (Table 1, Figs. 17–29). Since it was not found in Hokkaido, and only found in western Japan in spring, *A. tenella* may prefer high water temperature. It is defined as an acidophilous taxon (Nygaard, 1956; Florin, 1981; Camburn and Kingston, 1986), but we cannot assess it using the reservoir samples. *A. tenella* was also found in Japanese natural lakes, Lake Ippeki and Lake Imuta, where the pH of both were under 7 (6.2 and 6.5).

In artificial reservoirs, the valves are 6.5–9 µm in diameter, with a mantle height of 1.5–2.3 µm. The ratio of the mantle height to valve diameter is 0.18–0.25, and the ratio of the cell length to cell diameter is 0.45–0.5. The valve face is flat. The circular to ellipse areolae on the mantle, run straight and 21–25 areolae/10 µm with 2–3 (rarely 1) areolae in each row. Two to three-celled colonies were commonly found.

3. Other *Aulacoseira distans* species complex.

We also found *Aulacoseira granulata* (Ehrenb.) Simonsen, *A. ambigua* (Grunow) Simonsen f. *ambigua* and *A. ambigua* f. *japonica* (F.Meister) Tuji et D.M.Williams from these reservoirs. However, other *A. distans* (Ehrenb.) Simonsen species members, such as *A. pfaffiana* (Reinsch) Krammer and *A. nivalis* (W.Sm.) Eng-

lish et Potapova, were not found in this study.

Examination of type material for *Melosira pfaffiana* Reinsch (≡ *A. pfaffiana*) and *Melosira nivalis* W.Sm (≡ *A. nivalis*) were undertaken by Tuji and Williams (Tuji, 2010b, Tuji and Williams, 2006a). Tuji (2010b) proposed *A. pfaffiana* as a synonym of *A. nivalis*. *A. nivalis* is found in high moor in Yaku-shima (Tuji and Williams, 2006a, recorded as *A. pfaffiana*) and Kama-numa (Tanaka and Nagumo, 2007). Since *A. nivalis* also has a low ratio of mantle height to valve diameter and areolae on valve face, *A. tenella* has been mis-identified as *A. nivalis*. *A. distans* species complex members, with the exception of *A. pusilla* and *A. tenella*, may not exist in Japanese harmonic artificial reservoirs.

A. pusilla and *A. tenella* can be understood as members of the *A. distans* species complex due to their small size and areolae on the valve face. However, *A. distans* var. *distans* is an extinct species, and its species complex, with the exception *A. pusilla* and *A. tenella*, are found in humic water-bodies. Thus it is important to distinguish *A. pusilla* and *A. tenella* from other members of the *A. distans* species complex and it is important to avoid the usage of *A. distans sensu lato* which would include both species.

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