Bull. Natl. Mus. Nat. Sci., Ser. B, 41(2), pp. 53–60, May 22, 2015

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

Akihiro Tuji

Department of Botany, National Museum of Nature and Science,
Amakubo 4–1–1, Tsukuba, Ibaraki 305–0005, Japan
E-mail: tuji@kahaku.go.jp

(Received 17 February 2015; accepted 25 March 2015)

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 4–20μm) 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.

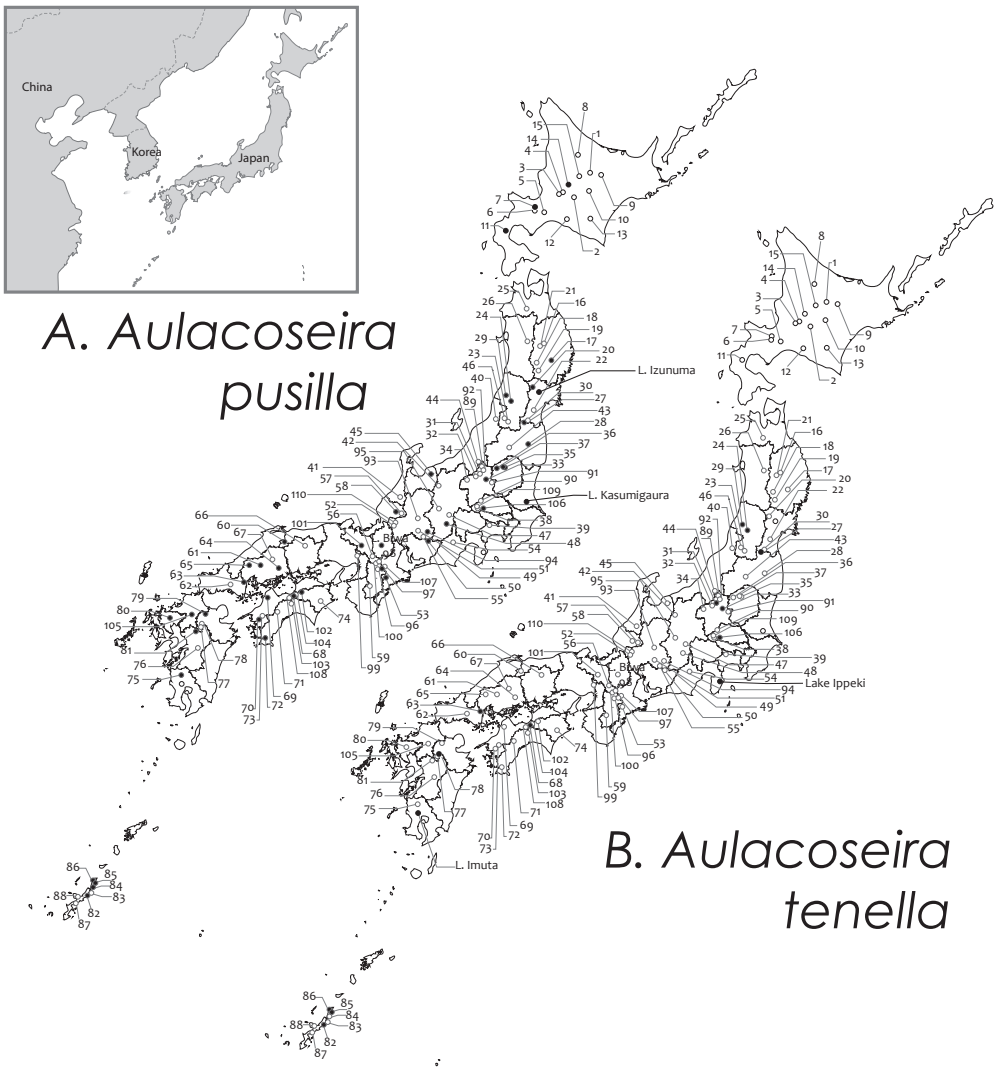


Fig. 1. Site map of Japanese reservoirs (Res.) examined in this study, and existence of a. *Aulacoseira pusilla* and b. *Aulacoseira tenella*. black dot: present; white circle: absent. 1: Taisetsu. 2: Kanayama. 3: Katsurazawa. 4: Ashibetsu. 5: Izarigawa. 6: Hoheikyo. 7: Jozankei. 8: Iwaonai. 9: Kanoko. 10: Tokachi. 11: Pirika. 12: Nibutani. 13: Satsunaigawa. 14: Takisato. 15: Chubetsu. 16: Shijushida. 17: Tase. 18: Yuda. 19: Ishibuchi. 20: Naruko. 21: Gosho. 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: Sugesawa. 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 μm 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 LaB_6 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 5–7.5 μm in diameter, with a mantle height of 3–4 μm. The ratio of the mantle height to valve diameter is 0.4–0.7, and the ratio of the cell length to cell diameter is 0.8–1.5. The valve face is flat. The circular areolae on the mantle run in a spiral with 20–26 pervalvar striae/10 μm and 25–30 areolae/10 μm. A Lake Kitaura individual (Fig. 2) had a narrow valve diameter (4.5 μm) 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.

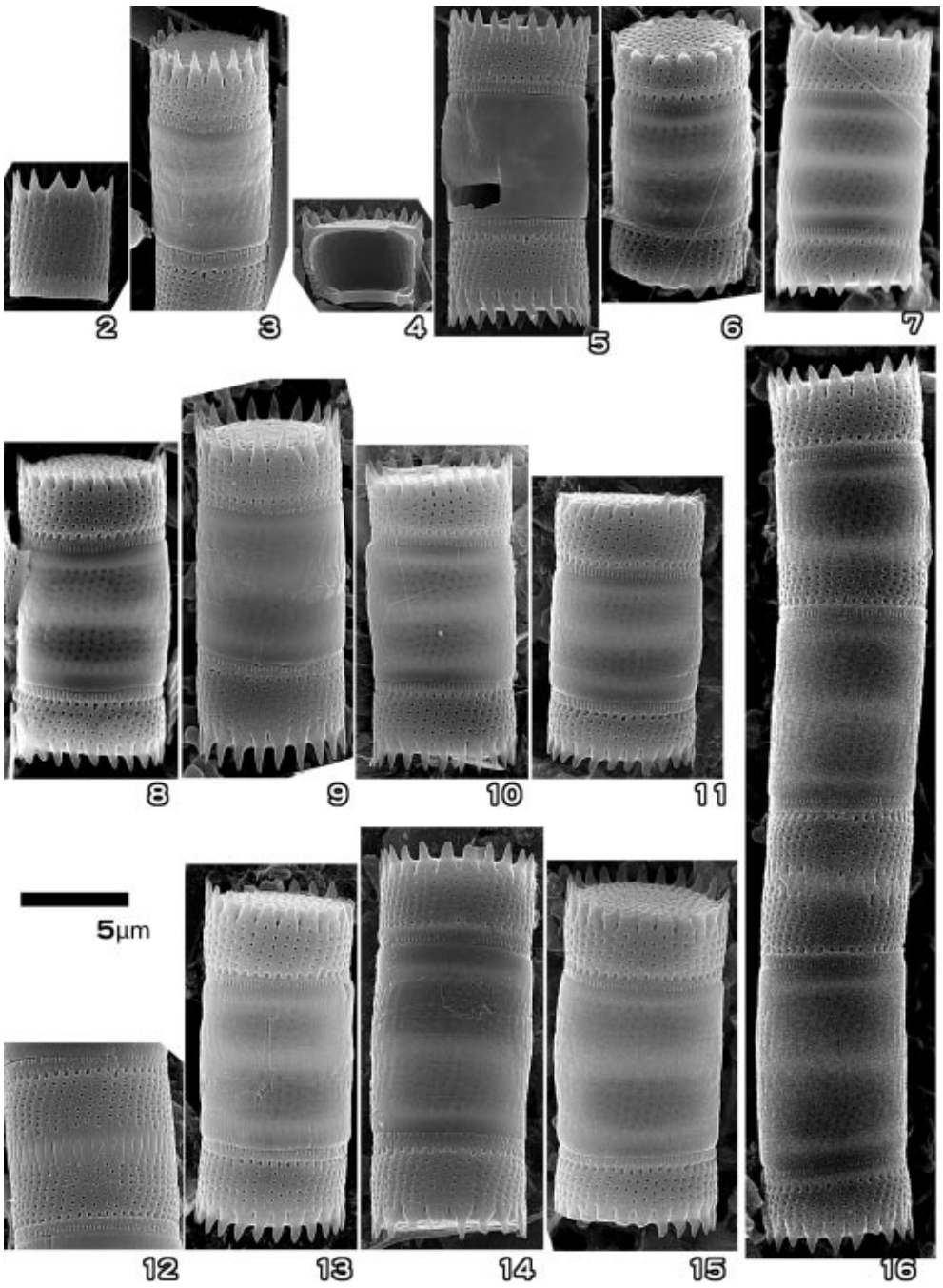
2. ***Aulacoseira tenella*** (Nygaard) Simonsen, Bacillaria 2: 63. 1979.

(Figs. 17–29)

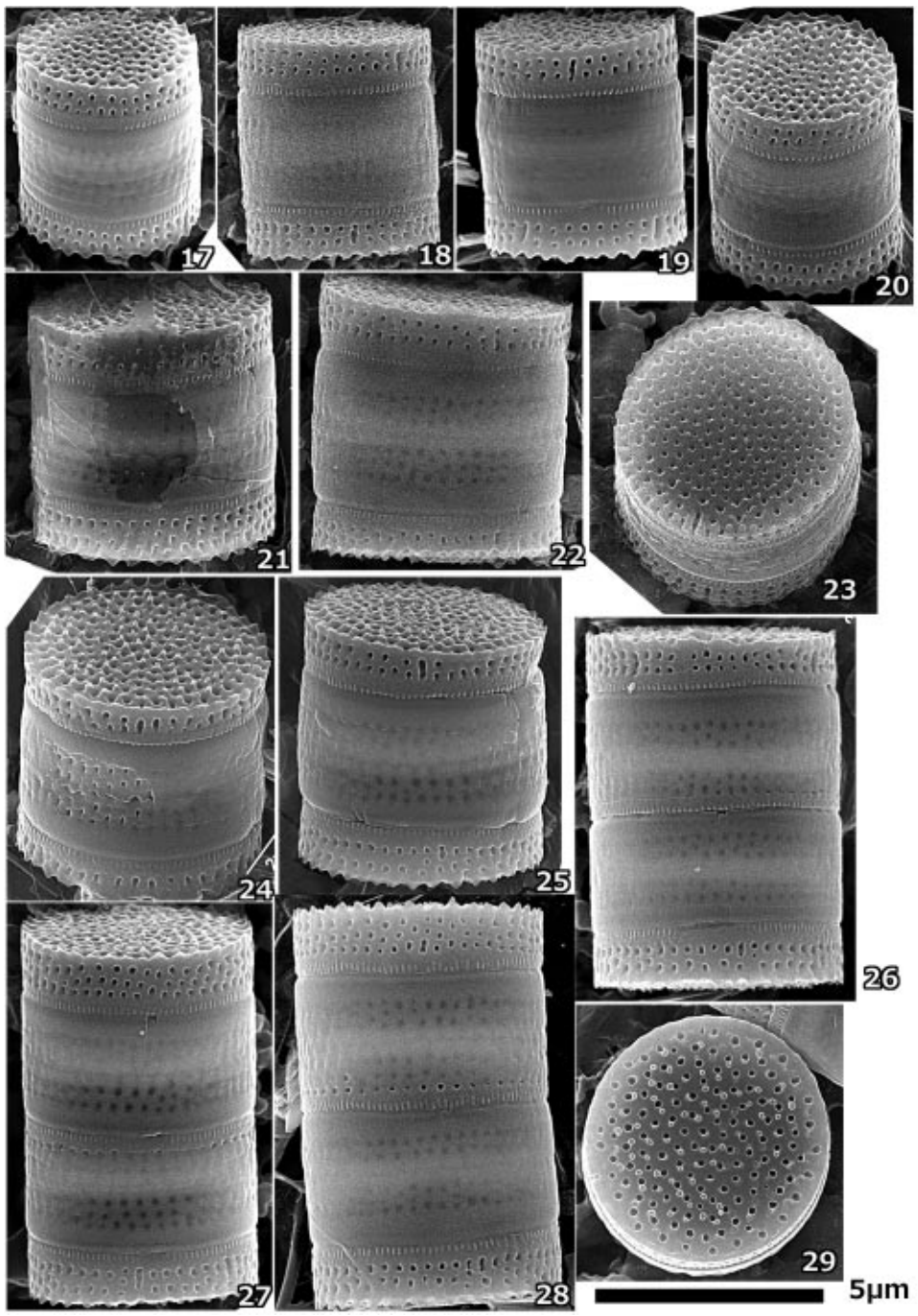
Basionym: *Melosira tenella* Nygaard, Folia

Table 1. List of Japanese reservoirs examined in this study, sampling date and voucher SEM stub specimens (Stab) and photograph numbers (Photo). All SEM stubs and photographs are housed in TNS

			Sampling date			*Aulacoseira pusilla*						*Aulacoseira tenella*					
	Dam name	Reservoir name	2009 Summer	2010 Spring	2011 Autumn	2009 Summer Stab	Photo	2010 Spring Stab	Photo	2011 Autumn Stab	Photo	2009 Summer Stab	Photo	2010 Spring Stab	Photo	2011 Autumn Stab	Photo
1	Taisetsu	Taisetsu-Ko	12 Aug.														
2	Kanayama	Kanayama-Ko	11 Aug.														
3	Katsurazawa	Katsurazawa-Ko	6 Aug.														
4	Ashibetsu	Ashibetsu-Ko	6 Aug.		16 Sep.												
5	Izangawa	Eniwa-Ko	26 Aug.														
6	Toyodairakyo	Jozan-Ko	17 Aug.	May	30 Sep.												
7	Jozankei	Sapporo-Ko	18 Aug.			271	dy0130										
8	Iwaonai	Iwaonai-Ko	11 Aug.	19 May													
9	Kanoko	Oketo-Ko	5 Aug.														
10	Tokachi	Higashitaisetsu-Ko	12 Aug.		21 Sep.												
11	Pirika	Pirika-Ko	3 Aug.	May	Sep.	275	dy0303			504	dy2770						
12	Nibutani	Nibutani-Ko	20 Aug.														
13	Satsunaigawa	Tokachinyutan-Ko	11 Aug.	May													
14	Takisato	Takisato-Ko	12 Aug.	May	28 Sep.			449	dy1876								
15	Chubetsu	Chubetsu-Ko	13 Aug.														
16	Shijushida	Nanbukatafuji-Ko	19 Aug.														
17	Tase	Tase-Ko	19 Aug.	May	14 Sep.					506	dy2628						
18	Yuda	Kinshu-Ko	Aug.	May													
19	Ishibuchi	Ishibuchi	12 Aug.														
20	Narugo	Arao	26 Aug.	19 May	14 Sep.	284	dy2182			507	dy2653						
21	Gosho	Gosho	12 Aug.														
22	Kamafusa	Kamafusa	30 Sep.														
23	Shirakawa	Shirakawa	19 Aug.														
24	Sagae	Gassan	26 Aug.	May		288	dy1535					288	dy1554				
25	Asaseishikawa	Nijino	19 Aug.	May													
26	Tamagawa	Hoeen	19 Aug.	May													
27	Shichikashuku	Shichikashuku	4 Aug.														
28	Miharu	Sakura	19 Aug.	19 May		292	dy1101	456	dy1995								
29	Gassan	Asahigassan	26 Aug.			293	dy1762					293	dy1771				
30	Surikamigawa	Moniwa	5 Aug.		9 Sep.					508	dy2670	294	dy0922				
31	Fujiwara	Fujiwara	5 Aug.									295	dy1449				
32	Aimata	Akaya	5 Aug.														
33	Sonohara	Sonohara	5 Aug.	3 Mar.	14 Sep.			457	dy1973							509	dy2893
34	Shimagi	Joshuyunoko	5 Aug.														
35	Ikari	Ikari	5 Aug.			299	dy0744										
36	Kawamata	Kawamata	5 Aug.			300	dy1732	458	dy1907								
37	Kawaji	Yashio	5 Aug.	3 Mar.		301	dy1480										
38	Nise	Chichibu	5 Aug.														
39	Miyagase	Miyagase	6 Aug.	3 Mar.													
40	Oishi	Oishi	19 Aug.														
41	Tedori	Tedori	5 Aug.	May													
42	Omachi	Rhujin	17 Aug.														
43	Okawa	Wakasato	5 Aug.														
44	Sangokugawa	Shakunage	19 Aug.	19 May	Sep.												
45	Unazuki	Unazuki	20 Aug.	19 May				462	dy2050								
46	Yokokawa	Shiroimorioguni	19 Aug.														
47	Miwa	Miwa	5 Aug.														
48	Koshibu	Koshibu	4 Aug.	3 Mar.		312	dy0892	463	dy2055								
49	Shintoyone	Midori	18 Aug.	4 Mar.													
50	Yahagi	Okuyahagi	19 Aug.	Mar.				465	dy2092								
51	Maruyama	Maruyamasosui	12 Aug.														
52	Yokoyama	Okuibi	19 Aug.														
53	Hasu	Okukahada	19 Aug.	9 Mar.				466	dy2269								
55	Kozato	Origawa	19 Aug.														
56	Amagase	Hoo	6 Aug.														
57	Kuzuryu	Kuzuryu	6 Aug.	1 Mar.													
58	Managawa	Manahime	3 Aug.		2 Sep.	322	dy1694										
59	Sarutani	Sarutanidamu	3 Aug.														
60	Sugesawa	Nichinan	4 Aug.	3 Mar.				468	dy2301								
61	Doshi	Yachiyo	5 Aug.	11 Mar.				469	dy2310								
62	Shimazigawa	Takase	4 Aug.	3 Mar.													
63	Yasaka	Yasaka	11 Aug.	2 Mar.		327	dy1719							471	dy2337		
64	Yadawara	Ashida	5 Aug.	3 Mar.	7 Sep.	327	dy2687			511	dy2965						
65	Nukui	Ryuki	5 Aug.			329	dy1556										
66	Tomata	Okutsu	25 Aug.	2 Mar.	13 Sep.												
67	Haizuka	Haizuka	25 Aug.														
68	Yanase	Kinsha	4 Aug.			332	dy1819					332	dy1823				
69	Isidegawa	Shirasagi	5 Aug.	Mar.				474	dy2369								
70	Nomura	Asagiri	17 Aug.	1 Mar.				475	dy2390								
71	Oto	Sagiri	30 Aug.														
72	Nakasujigawa	Hotaru-Ko	18 Aug.			336	dy0560										
73	Kanogawa	Kanogawa	18 Aug.		Sep.												
74	Nagayasuguchi	Nagayasuguchi	16 Aug.	Mar.													
75	Tsuruta	Otsuru	3 Aug.	2 Mar.				477	dy2421								
76	Midorikawa	Higomidorikawa	18 Aug.	4 Mar.													
77	Shimoke	Hachinosu	11 Aug.														
78	Matsubara	Bairin	14 Sep.	10 Mar.	6 Sep.							272	dy0271				
79	Yabakei	Yabakei	12 Aug.	2 Mar.		343	dy1156	480	dy2470								
80	Kyuragi	Sayono	5 Aug.			344	dy0643										
81	Ryumon	Hanjaku	5 Aug.			345	dy1606										
82	Fukuchi	Fukugami	20 Aug.	10 Mar.		346	dy0995	481	dy2490					481	dy2491		
83	Arakawa	Arakawa	20 Aug.	10 Mar.	7 Sep.												
84	Aha	Kuina	20 Aug.			348	dy1085										
85	Fungawa	Funga	18 Aug.			349	dy0777					349	dy0779				
86	Benoki	Ijuno	19 Aug.	3 Mar.	13 Oct.	350	dy1196	483	dy2518	520	dy3409	350	dy1192	483	dy2519	520	dy3385
87	Kanna	Kanna	12 Aug.														
88	Haneji	Saionakemio	12 Aug.	7 Mar.	6 Sep.												
89	Yagisawa	Okutone	6 Aug.														
90	Shimokubo	Kanna	6 Aug.	7 Mar.													
91	Kusaki	Kusaki	3 Aug.														
92	Naramata	Naramata	6 Aug.														
93	Iwaya	Tosenkyokanayama	13 Aug.														
94	Agigawa	Agigawa	4 Aug.	1 Mar.				486	dy2509								
95	Misogawa	Okukiso	19 Aug.														
96	Muro	Muro	24 Aug.														
97	Shorenji	Shorenji	21 Aug.	4 Mar.				487	dy2578								
98	Takayama	Tsukigase	19 Aug.	7 Mar.	26 Sep.	362	dy1110										
99	Ikko	Chimyo	18 Aug.	11 Mar.													
100	Nunome	Nunome	12 Aug.														
101	Hiyoshi	Amawaka	18 Aug.	4 Mar.				490	dy2620								
102	Ikeda	Ikeda	4 Aug.			366	dy1653										
103	Sameura	Sameura	4 Aug.														
104	Shingu		4 Aug.														
105	Terauchi	Minagi	11 Aug.	10 Mar.	13 Sep.			491	dy2623	518	dy3445						
106	Urayama	Chichibusakura	4 Aug.	3 Mar.	Sep.							367	dy1402				
107	Hinachi	Hinachi	21 Aug.		Sep.												
108	Tomisato	Hoo	4 Aug.														
109	Takizawa	Okuchichibumomiji	5 Aug.														
110	Tokuyama	Tokuyama	12 Aug.	3 Mar.													



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. Fukuji 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.) English 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.

Acknowledgments

I would like to thank Dr. Hidetaka Ichiyanagi, Water Resources Environment Center, Mrs. Megumi Nakagawa, National Institute for Environmental Studies and Ministry of Land, Infrastructure, Transport and Tourism, for the sampling at Japanese artificial reservoirs and Lake Kasumigaura. I also with 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

Camburn, K. E. K. J. C. 1986. The genus *Melosira* from soft-water lakes with special reference to northern Michigan, Wisconsin and Minnesota. *In*: Smol, J. P., Battarbee, R. W., Davis, R. B. and Meriläinen, J. (eds), Diatoms and Lake Acidity, pp. 17–34. Dr W. Junk Publishers, Dordrecht.

Denys, L., Muylaert, K., Krammer, K., Joosten, T., Reid, M. and Rioual, P. 2003. *Aulacoseira subborealis* stat. nov. (Bacillariophyceae): a common but neglected plankton diatom. Nova Hedwigia 777: 407–427.

Eloranta, P. 1986. *Melosira distans* var. *tenella* and *Eunotia zasuminensis* two poorly known planktonic diatoms in Finnish Lakes. Nordic Journal of Botany 6: 99–104.

Florin, M. B. 1981. The taxonomy of some *Melosira* species. A comparative morphological study. II. Proceedings of the 6th symposium on recent and fossil diatoms 6: 43–73.

Haworth, E. Y. 1988. Distribution of diatom taxa of the old genus *Melosira* (now mainly *Aulacoseira*) in Cumbrian waters. Algae and the Aquatic Environment Edited by F. E. Round: 138–167.

Houk, V. and Klee, R. 2007. Atlas of freshwater centric diatoms with a brief key and descriptions. Part II. Melosiraceae and Aulacoseiraceae (Supplement to Part I). Fottea 7: 85–255.

Hustedt, F. 1930. Bacillariophyta (Diatomaceae). In: Pascher, A. (ed), Die Süsswasser-flora Mitteleuropas, Heft 10. 466 pp. Gustav Fischer, Jena.

Krammer, K. 1991. Morphology and taxonomy of some taxa in the genus *Aulacoseira* Thwaites (Bacillariophyceae). I. *Aulacoseira distans* and similar taxa. Nova Hedwigia 52: 89–112.

Krammer, K. and Lange-Bertalot, H. (eds.) 1991. Bacillariophyceae. 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. 576 pp. Gustav Fischer Verlag, Jena.

Nygaard, G. 1956. Ancient and recent flora of diatoms and chrysophyceae in Lake Gribsø. Folia Limnologica Scandinavica 8: 32–94, 12 pls.

Potapova, M. 2010. *Aulacoseira pusilla*. In Diatoms of the United States. [cited February 15 2015]. Available from: http://westerndiatoms.colorado.edu/taxa/species/aulacoseira_pusilla

Siver, P.-A. and Kling, H. 1997. Morphological observations of *Aulacoseira* using scanning electron microscopy. Canadian Journal of Botany 75: 1807–1835.

Tanaka, H. and Nagumo, T. 2007. Morphology of *Aulacoseira distans* (Ehrenb.) Simonsen var. *nivalis* (W.Sm.) E.Y.Haw. from Kama-numa, Fukushima Prefecture. Diatom 23: 113–116.

Tempère, J. and Peragallo, H. 1913. Diatomées du Monde Entier, Edition 2. Fascicule 24–28. Arcachon, Grez-sur-Loing (S.-et.M.), pp. 353–448. Paris.

Tsugeki, N., Gotoh, T., Uchiyama, T. and Yoshikawa, S. 2006. Taxonomic list and ecology of diatoms in sediments of the past few centuries of three irrigation ponds in Osaka Prefecture, Japan: Sayama-ike, Hataoike and Kodera-ike ponds. Diatom 22: 35–47.

Tuji, A. 2006. On the forms of rimoportulae and spines of *Aulacoseira distans* (Ehrenb.) Simonsen. Diatom 22: 74–75.

Tuji, A. 2009. The development of applied research on biological indicators and taxonomy of diatoms. Diatom 25: 15–20.

Tuji, A. 2010a. Algae Aquae Dulcis Japonicae Exsiccatae. Fasc. III. nos. 41–60, National Museum of Nature and Science, Tsukuba.

Tuji, A. 2010b. Examination of type material of *Melosira nivalis* W.Sm. (Bacillariophyceae) and its synonymy with *Aulacoseira pfaffiana* (Reinsch) Krammer. Bulletin of the National Museum of Nature and Science, Series B 36: 161–164.

Tuji, A. and Houki, A. 2001. Centric Diatoms in Lake Biwa. Lake Biwa Research Institute, Otsu.

Tuji, A. and Houki, A. 2004. Taxonomy, ultrastructure, and biogeography of the *Aulacoseira subarctica* species complex. Bulletin of the National Museum of Nature and Science, Series B 30: 35–54.

Tuji, A. and Williams, D. M. 2006a. Examination of type material for *Aulacoseira pfaffiana* (Bacillariophyceae) with special reference to the position of its rimoportula. Bulletin of National Science Museum, Series B 32: 117–121.

Tuji, A. and Williams, D. M. 2006b. Type examination of the freshwater centric diatom *Aulacoseira pusilla* (F.Meister) Tuji et Houki. Diatom 22: 70–73.

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, Series B 33: 69–79.

Watanabe, T., Ohtsuka, T., Tuji, A. and Houki, A. 2005. Picture Book and Ecology of the Freshwater Diatoms. 784 pp. Uchida-rokakuho, Tokyo (in Japanese).