A New and Three Rare Species of Planktonic *Anabaena* (Nostocales, Cyanophyta/Cyanobacteria) from Japan

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Abstract A new species of planktonic *Anabaena*, *A. tsugaruensis*, is described from Lake Higurashi-no-ike of the Tsugaru-Juniko lakes in Aomori Prefecture, northern Japan. Further, three rare species of planktonic *Anabaena*, *A.* cf. *heterospora* Nyg., *A. levanderi* Lemm., and *A.* cf. *solitaria* Kleb., are added to the Japanese cyanophyte flora with taxonomic notes.

Key words: new species, new records, *Anabaena*, plankton, Cyanophyta, Japan.

Since Professor Okamura recorded planktonic Anabaena, A. flos-aquae and A. spiroides var. crassa from Japanese waters for the first time (Okamura 1916), 25 planktonic species of the genus Anabaena have been recorded up to now. The present author has recorded 20 planktonic species of Anabaena including five new species (A. akankoensis, A. citrispora, A. minispora, A. oumiana, and A. pseudocompacta) from Japan and proposed two new combinations (A. smithii and A. ucrainica) for the Japanese populations (Watanabe 1985, 1992, 1996, 1996a, 1998, 2003, and Watanabe et al. 2004). Further, the author adds a new and three rare planktonic species of Anabaena to the Japanese cyanophyte flora in this paper.

Materials and Methods

The sources of the materials used in this study are shown in Table 1. One specimen collected from a shallow pool along the Shirarutoro River in the Kushiro marsh land in July, 1967 has been lost and only data with measurements and drawings remain now. The other specimens were deposited in the herbarium of the Department of Botany, National Science Museum in Tokyo (TNS).

Results and Discussions

Anabaena cf. heterospora Nygaard, 1949

(Figs. 1–5)

Trichomes free-floating, straight, constricted at the cross walls, delicately attenuated at the apices. Cells barrel-shaped or shortly cylindrical, 3.2–3.8 μ m wide, 2–6 μ m long. Heterocytes spherical or cylindrical, 4.5–5 μ m wide, 5–7 μ m long. Akinetes cylindrical, with rounded ends, 5–6 μ m wide, 10–23 μ m long, usually near the both side of the heterocytes.

The author collected this alga at Lake Shupunto (Oonuma), Wakkanai, Hokkaido in July, 1970 for the first time. In a specimen he could merely observe immature akinetes, and then identification was impossible (Fig. 5). In July 1991 Mr. Yutaka Iikura of the Tokyo Metropolitan Waterworks Bureau brought an Anabaena culture isolated from the waters of Watarase flood control zone in Tochigi Prefecture to the present author for identification. The Anabaena culture produces enough akinetes to identify and it is found to most closely resemble Anabaena heterospora Nyg. (Figs. 1–4). But it differs in discontinuously smaller dimensions in all of vegetative cells, heterocytes and akinetes respectively (Table 2). Anabaena heterospora Nyg. was characterized originally as producing spores of a double origin.

	Collector	M. Watanabe M. Watanabe S. Tateishi Y. Iikura
	Date of collection	July, 1971 Sept., 1984 May, 2000 July, 1991
Table 1. Specimens used in this study.	Locality	Lake Shupunto, Wakkanai, Hokkaido Lake Suigetsu-ko, Mikatacho, Fukui Pref. Lake Higurashi-no-ike, Tsugaru-juniko lakes, Aomori Pref. a pond in Watarase flood controling zone, Tochigi Pref.
	Specimen no.	AL-50735 AL-52806 AL-55688 AL-55700
	Species	Anabaena cf. heterospora Anabaena levanderi Anabaena tsugaruensis Anabaena cf. heterospora

Namely the species produces two different types of akinetes in maturity. One is cylindrical with rounded ends and the other one is long ellipsoidal. The present alga produces cylindrical akinetes only, the same as the alga recorded from Finland (Komárková-Legnerová and Eloranta 1992). As mentioned above the alga deviates in some morphological characteristics from *A. heterospora* sensu auct. but seems most similar to this species among the known relatives.

Specimen examined: AL-55700. Locality: Lake Shupunto, Hokkaido; Watarase flood control area, Tochigi Pref.

Anabaena levanderi Lemmermann, 1906

(Figs. 6–7)

Trichomes free-floating, straight, slightly constricted at the cross walls. Cells cylindrical, $3.5-4 \mu m$ wide, $5.5-15 \mu m$ long, with gas vesicles. Heterocytes spherical, about $5 \mu m$ wide. Akinetes ellipsoidal, $10.5-11 \mu m$ wide, $11-15 \mu m$ long, solitary or sometimes in pairs.

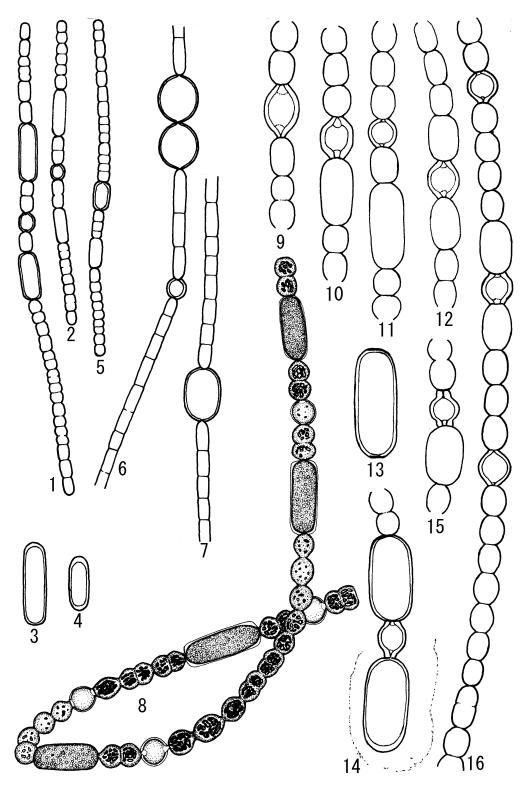
Anabaena levaderi Lemm. was characterized by its long cylindrical cells. The dimensions of the vegetative cells and the akinetes of the present alga correspond to the minimum dimensions shown in the original description of the species. After Lemmermann (1906) described this species Smith (1920) recorded the species in Chain lake, Wisconsin, Frémy (1930) from Equatorial Africa, and Geitler (1932) from Europe, however they cited intact the original measurements.

Specimen examined: AL-52806. Locality: Lake Suigetsu-ko, Fukui Pref.

Anabaena cf. solitaria Klebahn, 1895 (Fig. 8)

Trichomes straight or irregularly bent in rare cases. Cells spherical or lemon-shaped, about 5.2 μ m wide, slightly longer or shorter than wide, with gas vescicles. Heterocytes almost spherical, 6.5–7 μ m wide. Akinetes usually at one or both sides of heterocytes, usually including two cells between akinete and heterocyte, cylindrical, abruptly rounded ends, 5.8–6.6 μ m wide, 15.5–20 μ m long.

The present author recorded this alga in 1971



Figs. 1–16. 1–5: Anabaena cf. heterospora Nyg., 6, 7: Anabaena levanderi Lemm., 8: Anabaena cf. solitaria Kleb. (after Watanabe 1971), 9–16: Anabaena tsugaruensis sp. nov. (×1000)

length widt min max min 2.0 6.0 4.5 4.0 6.5 6.0	ngth widt max min 6.0 4.5 6.5 6.0
Heterr Heterr	Vegetative cells width length width min max min 3.2 3.8 2.0 6.0 4.5 5.0 6.0 4.0 6.5 6.0 4.5 5.7 4.5 5.0 5.5
length min max 2.0 6.0 4.0 6.5	Vegetative cells width length min max min max 3.2 3.8 2.0 6.0 5.0 6.0 6.5 6.5 4.5 5.7 4.5 7.0
	min 3.2 5.0

(Watanebe 1971) from shallow water along the Shirarutoro river flowing through the Kushiro marsh land for the first time as Anabaena sp. (? A. solitaria). After this publication, written in Japanese, no corresponding alga has been found, so the author has tried to record again the existence of this alga with additional taxonomic notes. The alga is discontinuously smaller in dimensions than the known Anabaena solitaria reported in Europe (Klebahn 1895, Skuja 1956, and Komárková-Legnerová and Eloranta 1992), nevertheless it is the nearest to A. solitaria systematically because of its appearance in trichomes, and especially in the arrangement among cells, heterocytes and akinetes.

The specimen of the alga has been lost, but an original line drawing and measurements are available.

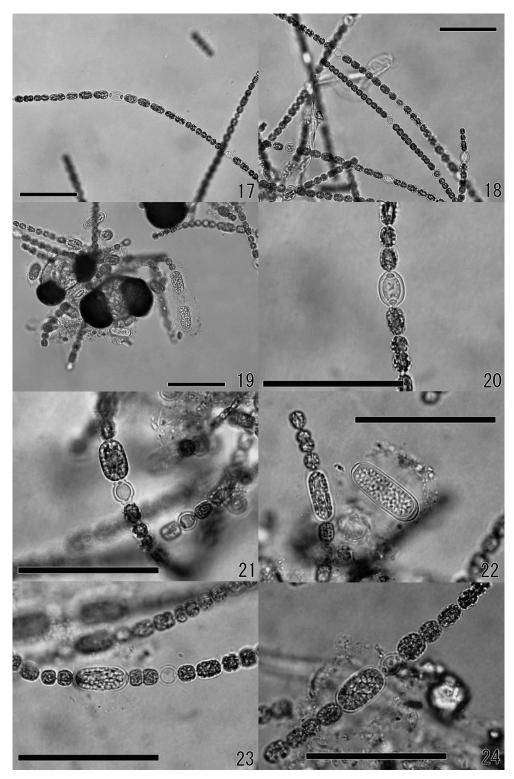
Anabaena tsugaruensis sp. nov. (Figs. 9–24)

Trichomata stricta, cum vagina mucosa densa circumdantia. Cellulae sphaericae, leviter elongata vel cupiformes, $5.1-7.0 \mu m$ latae, $3.8-10.1 \mu m$ longae. Heterocytes sphaericae, leviter elongatae vel interdum breviter cylindricae, 6.4–8.6 μm latae, $6.5-11.7 \,\mu\mathrm{m}$ longae. Akineta cylindrica, apice rotundata, vulgo ad latera utrique vel raro ad unilaterus heterocytis affixa, plerumque e heterocytis in uni- vel bi-cellulis distantia efferentia, $8.1-11.6 \,\mu\text{m}$ lata, $15.1-28.1 \,\mu\text{m}$ longa, 1.6-2.6-pro longiora quam latiora.

Iconotypus: Figurae 9–16.

Locus typicus: in lac Higurashi-no-ike, Aomori, Japoniae.

Trichomes straight, with thick mucilaginous sheath. Cells spherical to slightly elongated or barrel-shaped, $5.1-7.0 \,\mu\text{m}$ wide, $3.8-10.1 \,\mu\text{m}$ long, with gas vesicles. Heterocytes spherical to slightly elongated or sometimes short-cylindrical, $6.4-8.6 \,\mu\text{m}$ wide, $6.5-11.7 \,\mu\text{m}$ long. Akinetes cylindrical, with rounded ends, attached at one or both sides of the heterocyte, or one to two cells distant from the heterocyte, $8.1-11.6 \mu m$ wide, $15.1-28.1 \,\mu\text{m}$ long, 1.6-2.6 times longer than wide.



Figs. 17–24. Anabaena tsugaruensis sp. nov. Scale bar=50 μ m

Table 3. Differences in dimensions (μm) of vegetative cells, heterocytes, akinetes among Anabaena isugaruensis sp. nov. and related taxa.

	\[\]	Vegetative cells							Heter	Heterocytes				
Species	width		length				width				leı	length		
	min max mean sd	mim	max mean	ps	=u	mim	max m	mean	m ps	min rr	max m	mean	ps	= u
A. tsugaruensis sp. nov. A. akankoensis M.Watan. A. fusca Hill	5.1 7.0 6.0 0.4 7.4 10.5 9.0 1.1 5.5 6.5	4 3.8 10.1 1 6.5 11.3 6.0 10.0	.1 6.9 .3 9.2 .0	1.1	50	6.4 9.7 6.0	6.4 8.6 7.6 0.5 6.5 11.7 7.9 1.2 20 9.7 11.4 10.7 0.5 9.5 12.3 10.8 0.9 12 6.0 8.5 6.5 9.0	0 9.7	5. 6 8	\(\delta \de	1.7 2.3 10 0.0	9.8	0.9	20
A. solitaria Klebahn A. solitaria Klebahn A. cf. solitaria Klebahn	8 8.5 10 ca 5.2	ca. 8 8 11				8 bis 10. 6.5	9 5 μ, von 7	ähnlich	9 em Aus	1(sehen) wie die	vegeta	tiven Z	Cellen
Table 3. (continued)														
		Akinetes												
Species	width		length						Sou	Sources				
	min max mean sd	mim	max mean	ps	=u									
A. tsugaruensis sp. nov. A. akankoensis M. Watan.	8.1 11.6 9.7 0.9 10.8 13.0 12.0 0.7	9 15.1 28.1 7 23.3 42.3	.1 22.5 .3 28.1	3.0	20		present study, Tsugaru-juniko lakes, Japan Watanabe 2003, Lake Akan, Japan	study, 7 be 2003	sugaru, Lake	-junikc Akan,	lakes,	Japan		
A. fusca Hill A. solitaria Klebahn		16.0 52. 28 35	0.				Hill 1976, Minesota lake, USA Klebahn 1895, Uklei See, Germany	76, Minσ 1 1895,	sota la Uklei S	ke, US ee, Ge	A rmany			
A. solitaria Klebahn A. cf. solitaria Klebahn	10 13.5 5.8 6.6	(25-)35-40 15.5 20	09-				Skuja 1956, Hallaren, Sweden Watanabe 1971, Kushiro marsh-land, Japan	956, Ha be 1971	llaren, Kushi	Sweder ro mar	n sh-land	l, Japan	_	

This alga was collected by Miss Sizuka Ishida in May, 2000 for Master course studies of Mr. Shinichi Wada (Diversity of Anabaena in Lake Higurashi-no-ike of the Tsugaru-Juniko lakes) supervised by Dr. Professor Shoichi Saito at the Faculty of Education, Hirosaki University (Wada et al. 2005). The present author saw the alga to be Anabaena solitaria Kleb. or an allied species at first microscopical observations. Precise observations and measurements reveal the alga did not correspond to any known Anabaena species (Table 3), so it should be given a new taxonomic name, A. tsugaruensis after its locality name. Comparing the new species with other systematically related ones, they have cylindrical akinetes with rounded ends, akinetes formed at or close to the both sides of heterocytes, and cells with gas vesicles. The new species corresponds to A. fusca in cell demensions, but they differ in cell shape from each other. Namely, the trichomes in the former species are not so constricted at the cross walls as those of the latter ones. In other words, connecting spaces at the cross walls of A. tsugaruensis are wider than those of A. fusca. Incidentally A. tsugaruensis has straight trichomes and A. fusca has twisted ones. Average ratio of akinete diameter/cell diameter are reliable for taxonomic characters among Anabaena species. Those are 1.1-1.3 in A. solitaria, 1.3 in A. akankoensis, 1.6 in A. tsugaruensis, 1.5–1.8 in A. planctonica, 1.6–1.8 in A. viguieri, 1.6–2.0 in A. fusca, 2.0 in A. citrispora, and 2.4 in A. macrospora respectively. The new species corresponds to A. planctonica and A. viguieri in the above mentioned character, but differs from the latter species in which akinetes are not formed at or near both sides of heterocytes.

Specimens examined: AL-55688. Type locality: Lake Higurashi-no-ike of Tsugaru-juniko lakes, Aomori Prefecture.

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