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Studies on Planktonic Blue-green Algae 6. Bloom-forming Species in Lake Biwa (Japan) in the Summer of 1994

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Abstract Eight species of bloom-forming cyanophytes were recognized in five samples collected from Lake Biwa, Shiga Prefecture, Japan. The algae include one new species, *Anabaena oumiana* M. Watanabe, and one alga which was proposed for a new rank, *Anabaena ucrainica* (Schkorbatow) M. Watanabe for *A. spiroides* var. *ucrainica* Schkorbatow. The alga which was previously recorded in the lake as *Oscillatoria tenuis* Ag. was thought to be *Planktothrix raciborskii* (Wolosz.) Anagn. & Kom.

In 1994 Y. MATSUOKA and S. ICHISE of the Shiga Prefectural Institute of Public Health and Environmental Science brought some plankton samples collected at four sites in Lake Biwa to the author to identify bloom-forming species of cyanophytes. Lake Biwa is the largest lake in Japan and it plays very important role in the local economy. Due to increasing population around the lake, especially in the southern part, eutrophication of the lake water has been accelerating and noxious phytoplankton is increasing year by year. Information on classification, behaviour and productivity of harmful substances for such algal species has been of interest to local lake water managers. Lake Biwa has become one of the most well-known lakes in Japan regarding phytoplankton taxonomy due to the work of Dr. NEGORO (1968, 1991, etc.). In the summer of 1994, the climate of Japan was unusually hot and dry, thus the water level of the lake was lower than that of an ordinary summer. This abnormal climate brought some changes to the phytoplankton flora of Lake Biwa, namely, abnormal growth of *Microcystis* species and the appearance of new *Anabaena* species. In this paper the author will discuss the state and species of blue-green algal bloom in Lake Biwa under abnormal climatic conditions.

Materials and Methods

Samples were collected by the staff of the Shiga Prefectural Institute of Public Health and Environmental Science and brought to the author. The

Table 1. Localities of the materials studied.

Sample no.	Locality	Date of collection
53658	Akanoi harbor, southeast part of the lake	August 22nd, 1994
53659	Nagahama harbor, northeast part of the lake	August 24th, 1994
53660	Okoto harbor, southwest part of the lake	September 9th, 1994
53661	Akanoi harbor	September 13th, 1994
53662	Off Konohama, southeast part of the lake	September 13th, 1994

specimens were fixed with formalin and preserved in the herbarium of the National Science Museum, Tokyo (TNS). Table 1 shows the sources of the materials used in this study.

Results and discussion

Out of the five samples, five species of *Anabaena*, two species of *Microcystis*, and one species each of *Oscillatoria* and *Planktothrix* were detected. Descriptions and taxonomic notes are given below.

1. Anabaena affinis Lemm. (Figs. 1, 2, 11)

In the samples from Akanoi harbor a small number was of trichomes of *Anabaena affinis* observed. Among the single trichomes, only a few bundle-forming trichomes were seen. Two other species of *Anabaena* with straight trichomes have been known in Lake Biwa, namely *A. planctonica* Brunth. and *A. smithii* (Kom.) M. Watan. A solitary trichome of *A. affinis* is distinguished from the other species by its smaller dimensions and by attenuation at the trichome ends (WATANABE 1971, 1992; NEGORO 1991).

2. Anabaena crassa (Lemm.) Kom.-Legn. & Cronb. (Fig. 12)

This alga was originally described as a variety of *Anabaena spiroides* by LEMMERMANN (1898) and was raised to species rank by KOMÁRKOVÁ-LEGNEROVÁ & CRONBERG (1992). The alga is characterized by regularly twisted spring-like coils, elliptical akinetes and larger dimensions than those of *A. spiroides*, and is commonly found in the southern part of Lake Biwa (NEGORO 1968, 1991). A small number of this alga was found in a sample from Akanoi harbor (no. 53658), and it became rare after three weeks at the same location (no. 53661; akinetes 16–18 μm broad, 18–20 μm long).

3. Anabaena flos-aquae Bréb. in Born. & Flah. (Figs. 3, 4, 13)

Trichomes free-floating, irregularly twisted, forming floccose colonies, sometimes forming somewhat irregular coils, without a mucilaginous sheath. Cells spherial or barrel-shaped, with gas vesicles, 5–6 μm broad. Heterocytes spherical,

5–6.5 μm broad. Akinetes remote from heterocytes, cylindrical, with rounded ends, sometimes slightly curved, 9 μm broad, 18 μm long.

Authorities from the Shiga Prefectural Institute of Public Health and Environmental Sciences were especially interested in the toxicity of *A. flos-aquae*, which has been known as a toxic alga (GORHAM *et al.* 1964, CARMICHAEL 1988, PARK *et al.* 1993). The Biwa alga differs taxonomically from the famous toxic strains NRC-44-1 and NRC-525-17 from Canadian lakes, at least as indicated by the two scanning electron micrographs published by CARMICHAEL (1988). *Anabaena flos-aquae* has spherical cells, while, the Canadian strains have cylindrical cells which are characteristic of *A. mendotae* Trelease (Syn.: *A. flos-aquae* var. *treleasii* Born. & Flah.), which was originally described from Lake Mendota, Wisconsin. One of the common properties of the two species is the formation of floccose aggregations. In Japan *A. flos-aquae* is distributed mainly in the central districts, while, *A. mendotae* is found in the northern districts, especially in Hokkaido.

4. Anabaena oumiana M. Watanabe, **sp. nov.** (Figs. 5–7, 14, 15, 19, 21)

Trichomata libere natantia, solitaria, plus minusve regulariter circinata, vaginis crassis mucosis circumcincta. Spirae 28–46 μm in diametro, 10–20 μm distantes. Cellulae vacuolis gaseosis includentes, sphaeroideae vel cupiformes, 6.0–7.1 μm latae, 3.0–6.5 μm longae. Heterocytae sphaerica, 6.8–8.5 μm latae, 6.4–8.0 longae. Akineta sphaerica, 10–12 μm lata, solitaria vel binata, ad heterocytas unilaterale vel utrimque affixa.

Iconotypus: Figurae 5–7.

Locus typicus: in lacu Biwa, Shiga, Japoniae.

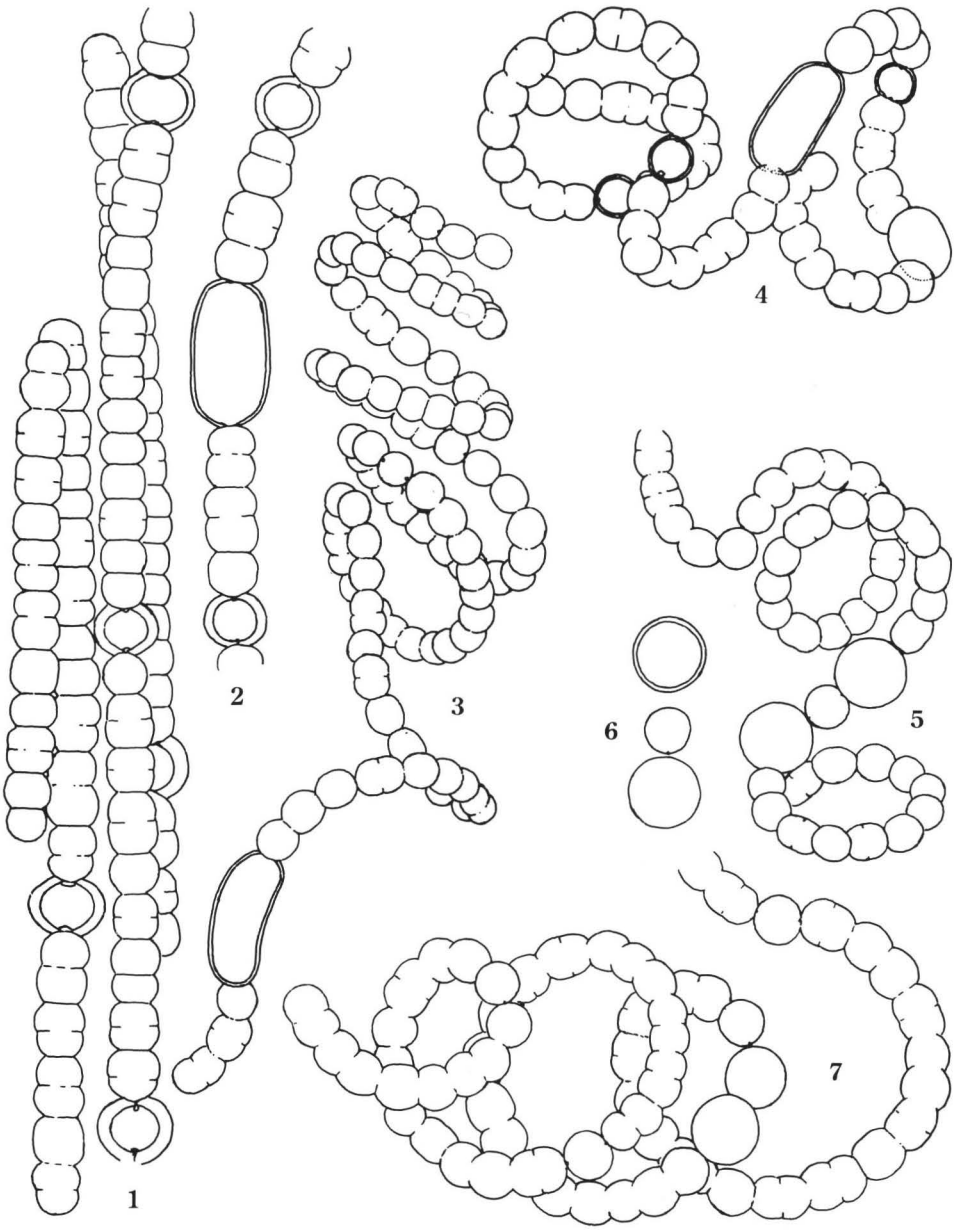
Trichomes free-floating, solitary, more or less regularly coiled, covered with thick mucilage. Coils 28–46 μm broad, 10–20 μm apart. Cells with gas vesicles, subspherical or barrel-shaped, 6.0–7.1 μm broad, 3.0–6.5 μm long. Heterocytes spherical, 6.8–8.5 μm broad, 6.4–8.0 μm long. Akinetes spherical, 10–12 μm broad, solitary or in pairs, attaching at one or both sides of the heterocytes.

The new species resembles *Anabaena spiroides* Kleb. superficially, but differs in producing spherical akinetes. Although the alga approaches *A. ucrainica* in akinete form, it differs in the dimensions of its cells and in the relative location of the akinetes to the heterocytes. In *A. ucrainica*, akinetes develop away from the heterocytes. The new species is closest in many aspects to *A. kisseleviana* (Kissel.) Elenk. except the latter species has straight trichomes.

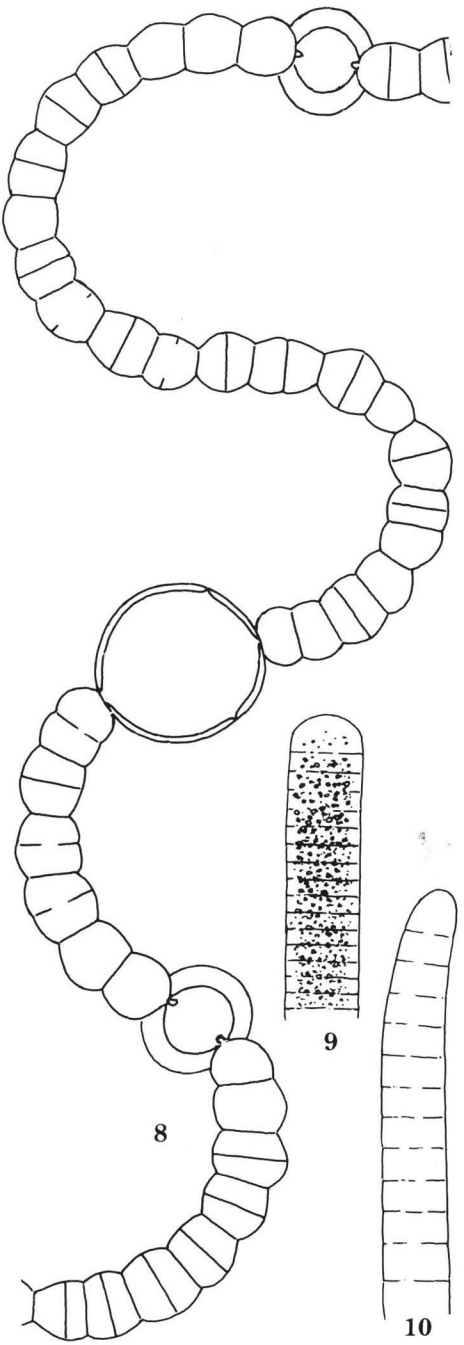
Etymology: Oumi is the old name of Lake Biwa and means "large lake."

5. Anabaena ucrainica (Schkorb.) M. Watanabe, **stat. nov.** (Figs. 8, 16–18)

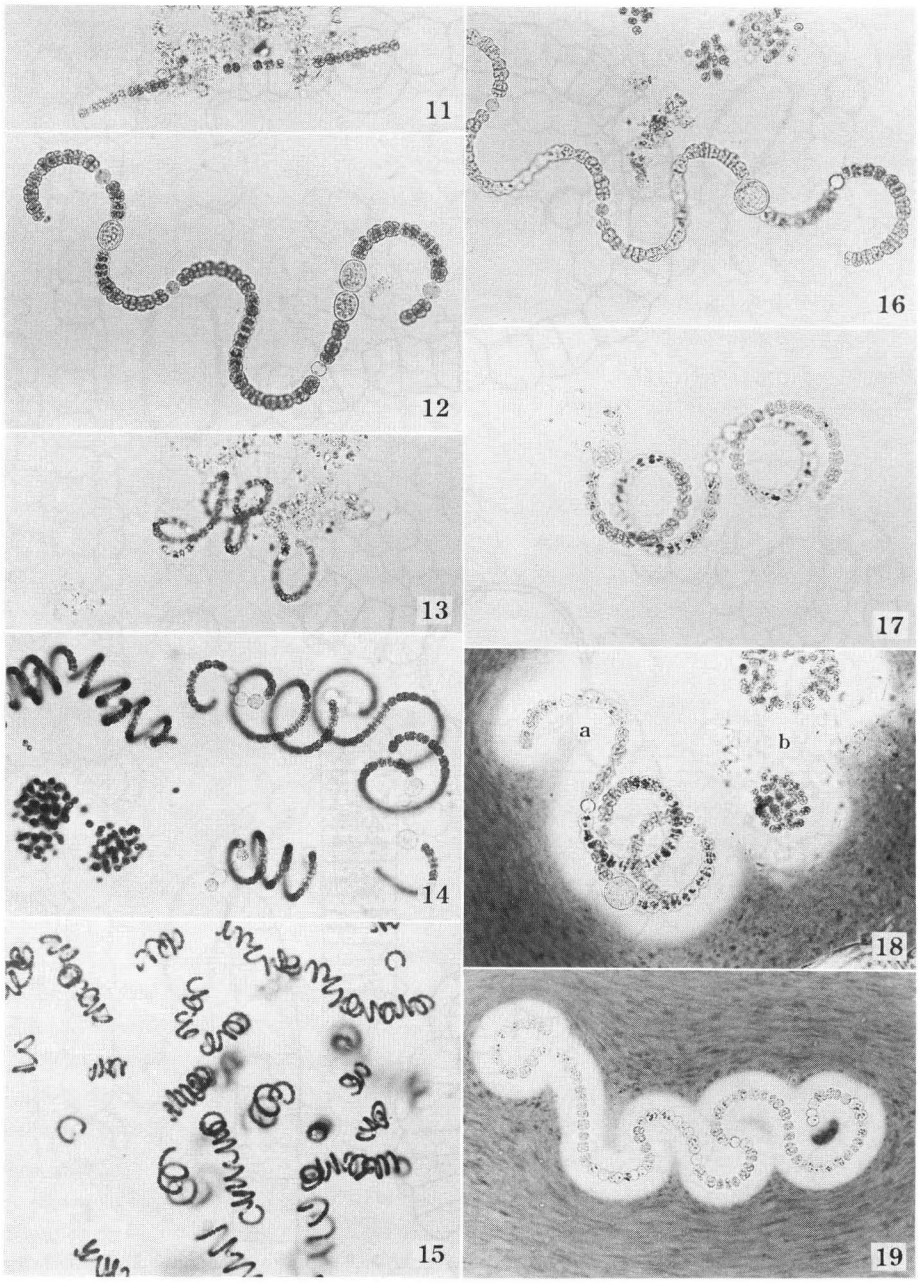
Syn. *Anabaena spiroides* var. *ucrainica* Schkorbatow, Not. Syst. Inst. Crypt. Hort. Bot. Petropol. 2(6): 88 (1923).



Figs. 1–7. 1, 2. *Anabaena affinis.* 3, 4. *Anabaena flos-aquae.* 5–7. *Anabaena oumiana* sp. nov. All: ×1000.



Figs. 8–10. 8. *Anabaena ucrainica.* 9, 10. *Planktothrix raciborskii.* All: ×1000.



Figs. 11–19. 11. *Anabaena affinis.* 12. *Anabaena crassa.* 13. *Anabaena flos-aquae.* 14, 15. *Anabaena oumiana* sp. nov. 16, 17. *Anabaena ucrainica* with spherical akinetes. 18. a: *Anabaena ucrainica*, b: *Microcystis aeruginosa* treated with ink. 19. *Anabaena oumiana* treated with ink. 11–14, 16–19: ×200, 15: ×100.

Trichomes solitary, free-floating, forming regular coils, with a thick mucilaginous sheath. Coils about 60 μm in diameter, 50–70 μm apart. Cells spherical or short barrel-shaped, about 10 μm broad. Heterocytes spherical, about the same size with the cells. Akinetes spherical, 18–23 μm broad, remote from the heterocytes.

This alga was originally described by SCHKORBATOW from Ukraina as a new variety of *Anabaena spiroides*, distinguishing from *A. spiroides* var. *crassa* by spherical akinetes. The present author proposes to give the species rank for the alga, because the relation between var. *crassa* and var. *ucrainica* is comparable with that of *A. planctonica* and *A. smithii* (WATANABE 1992) and var. *crassa* was changed to the species rank by KOMÁRKOVÁ-LEGNEROVÁ & CRONBERG (1992). *Anabaena spiroides* var. *crassa* has been recorded from many places in Japan without any information of akinetes in most cases (UMEZAKI & WATANABE 1994), but at least some of those algae should be identified as *A. ucrainica.* The present author previously noted the presence of *"A. ucrainica"* in Lake Sagami (WATANABE 1994).

6. Microcystis aeruginosa (Kütz.) Kütz. (Figs. 20a, 21b)

Outline of colonial mucilage not visible under a microscope. Cells irregularly arranged, spherical, with gas vesicles, 5.0–6.7 μm broad.

This alga was the most abundant of all the samples examined.

7. Microcystis wesenbergii (Kom.) Kom. in Kondr. (Fig. 20b)

Colonies soft, spherical or irregularly lobated, composed of refractive envelopes and filling mucilage. Cells attached to inside of the envelope in single layer. Among this species, two different types of cell dimensions were observed. Most of the colonies examined had smaller cells about 6 μm broad while the larger ones were 6.9–7.2 μm broad.

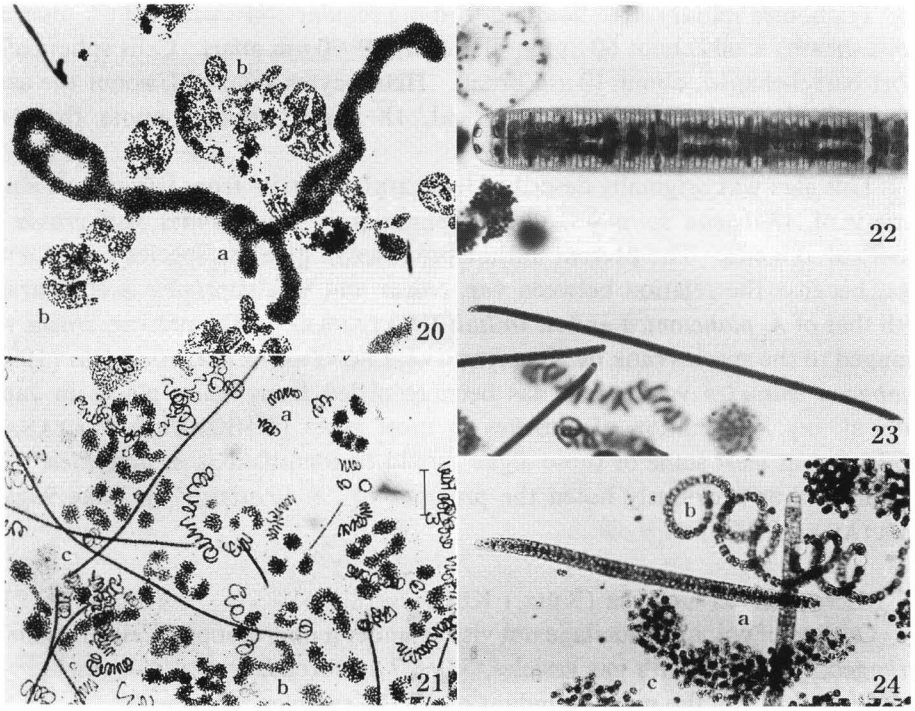
8. Oscillatoria kawamurae Negoro (Fig. 22)

This species was originally described from Manchuria, northwest China by NEGORO (1943), and appeared in Lake Biwa recently (NEGORO 1991). The alga is characterized by very wide trichomes of a maximum breadth of over 70 μm and regularly arranged large gas vesicles. Each discoid cell contains 3 or 4 gas vesicles at periphery which gradually change positions with respect to adjacent cells. Consequently regulary and loosely twisted lines are visible from the surface of the trichomes.

9. Planktothrix raciborskii (Wolosz.) Anagn. & Kom.

(Figs. 9, 10, 21c, 23, 24a)

Syn. *Oscillatoria raciborskii* Wolosz.



Figs. 20–24. 20. a: *Microcystis aeruginos*, b: *M. wesenbergii.* 21. a: *Anabaena oumian*, b: *Microcystis aeruginosa*, c: *Planktothrix raciborski.* 22. *Oscillatoria kawamurae.* 23. *Planktothrix raciborskii.* 24. a: *Planktothrix raciborskii*, b: *Anabaena oumiana*, c: *Microcystis aeruginosa.* 20, 21: ×60, 22, 23: ×100, 24: ×200.

Trichomes straight, several hundreds micrometers long, solitary, free-floating, with gas vesicles, without constriction at the cross-walls, 9.5–11(–12) μm broad, usually attenuated and sometimes bent at the apex.

This species is common in eutrophic lakes in central Japan (WATANABE 1994) and has been recorded as *Oscillatoria tenuis* Ag. in Lake Biwa (NEGORO 1968, 1991). *Oscillatoria tenuis* does not form gas vesicles and is fundamentally a benthic species.

The distribution and appearance of the algal species in the specimens examined are summarized in Table 2. Algae were most at Akanoi harbor and poorest at Nagahama harbor in both quality and quantity. MATSUOKA and ICHISE told the first findings of *Anabaena flos-aquae* and *A. oumiana* in Lake Biwa (in personal comm.).

Table 2. Distribution and appearance of the species in the specimens.

Species \ Locality	Akanoi Aug. 22nd	Nagahama Aug. 24th	Okoto Sept. 9th	Akanoi Sept. 13th	off Konohama Sept. 13th
Anabaena affinis	few	—	—	few	—
Anabaena crassa	few	—	—	rare	—
Anabaena flos-aquae	—	—	—	few	—
Anabaena oumiana	abundant	—	—	few	—
Anabaena ucrainica	few	—	—	few	few
Microcystis aeruginosa	many	many	few	many	many
Microcystis wesenbergii	common	few	many	—	few
Oscillatoria kawamurae	—	—	few	—	few
Planktothrix raciborskii	common	—	—	—	—

—: not detected.

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