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A comparison of phytoplankton communities between the ancient Lakes Biwa and Baikal

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Abstract

As a result of comparative analysis of phytoplankton population structures between the ancient lakes Biwa and Baikal, we found floristic similarities and differences; but the former were minor. Both lakes had highly original algal florae due to presence of endemic, relict and rare forms. The richest in species number in the lakes were green algae and diatoms; *Scenedesmus*, the most diverse genus in Chlorococcales and *Cyclotella*, *Stephanodiscus*, *Aulacoseira* and *Synedra* in diatoms. The chief distinction between the lakes was that desmids appeared abundantly in the pelagic zone of Lake Biwa, whereas they were observed only in shallows and bays in Lake Baikal. The Sorensen's coefficient calculated for the planktonic florae was very low. This suggests that the algal florae of these lakes are significantly diverse.

Introduction

Lake Biwa, located in the central part of Japan, is one of the oldest lakes in the world (2–5 million years). The lake being 680 km^2 in the surface area consists of two basins, the north basin, oligo-mesotrophic (mean depth 44 m, maximum 104 m) and the south basin, eutrophic (mean depth 3 m). It is a characteristic of Lake Biwa that there are many endemic species including six species of fishes and 20 of molluscs. However, the ecosystem structure seems to have changed since the 1960's through progressive eutrophication, chemical pollution, physical alteration of habitats and invasion of alien organisms.

Lake Baikal is located in East Siberia, in an active rift zone. The lake is the oldest, ca. 25–30 million years, and deepest, 1637 m deep, in the world. It consists of three basins. The water is low mineralised, about 100 mg l^{-1} total ions (Votintsev, 1961). Baikal is not only a natural laboratory for understanding evolutional processes of lacustrine systems but also practically important as a huge reservoir of ca. 20% of the Earth's freshwater. The lake is rich in its biodiversity including 2500 species of animals, 82% endemic (Timoshkin, 1995), and about 1000 species of plants, 30% endemic.

The purpose of the present work is to make a comparison between the phytoplankton communities of the ancient Asian lakes Biwa and Baikal from a taxonomic point of view.

Results

Lake Biwa

Taxonomic studies on phytoplankton in Lake Biwa have been developed by late Professor Neg-

oro. Negoro (1968, 1971) and Ichise & Wakabayashi (1982) described many species of planktonic algae through their regular surveys in Lake Biwa. Mori (1980) and Mori & Miura (1980, 1990) compiled algal species in the fauna and flora lists on the basis of data by Negoro. Recently, much taxonomic information on European and American phytoplankton species has been introduced (Krammer & Lange-Bertalot, 1991; Patrick & Reimer, 1966, 1975) and made it possible to reassess the taxonomic positions of phytoplankton taxa in Lake Biwa. As a result, many new records have been described from Biwa. Ito (1988) reported 39 species of chrysophytes as new records – only four taxa in Mori & Miura (1980). Tuji & Houki (2001) reported nine centric taxa in diatoms as new records and ten taxa as misidentification – 13 taxa in Mori & Miura (1980). Shiga prefecture (1995, 2000) also reported many new records.

Tuji et al. (in preparation) and Tuji (in preparation) compiled a new flora list of planktonic algae on the basis of these recent studies. To understand fully the biodiversity of the Biwa phytoplankton community further, taxonomic work is required.

After Tuji et al. (in preparation), phytoplankton in Lake Biwa consists of 574 taxa, including 276 taxa of green algae, 91 of diatoms, 89 of chrysophytes and 63 of blue-green. Most of the taxa are cosmopolitan. Only three species of Bacillariophyta, namely *Stephanodiscus suzukii* Tuji et Kociolek, *Stephanodiscus pseudosuzuki*i Tuji et Kociolek and *Aulacoseira nipponica* (Skvortzow) Tuji, are regarded as endemic (Tuji & Kociolek, 2000; Tuji, in preparation). *S. suzukii*, *S. pseudosuzukii* and *A. nipponica* have been identified previously as *S. carconensis* Grunow var. *carconensis*, *S. carconensis* var. *pusilla* Grunow and *Melosira solida* Eulenstein (*Aulacoseira solida* (Eulenstein) Krammer) respectively. These endemic taxa are very similar to those from western United States, and seem to be sister taxa (Tuji & Kociolek, 2000). These endemic diatoms are observed in the north basin of Lake Biwa in winter (ca. 7 °C) and inhabit oligotrophic, cold water (Tuji & Houki, 2001).

Pediastrum biwae Negoro and its variety were described as endemic species, but Barrientos (1979) modified these taxa as synonyms of *P. simplex* Meyen. Though other several taxa have been described also as endemic, taxonomic positions of these are uncertain. *Staurastrum planctonicum* Teiling and *Staurastrum pseudosebaldii* Wille, which have been identified as *S. dorsidentiferum* W.-G.S. West var. *ornatum* (Gontcharov et al., 1999), are very important and unique to Lake Biwa. These taxa are observed abundantly from late summer to autumn in the pelagic zone of the north basin of Lake Biwa. Though many other species of desmids are found, their habits are restricted to the littoral zone.

Phytoplankton flora in Lake Biwa has changed somewhat since the 1970's. A "red tide" by sudden propagation of *Uroglena americana* Calkins occurred in 1977 and has been observed annually ever since (Nakanishi, 1984; Nakanishi & Sekino, 1996). Further, populations of *P. biwae* (*P. simplex*) and *M. solida* (*Aulacoseira nipponica*) tended to decrease around 1985, while *Anabaena* spp. and *Microcystis* spp. increased (Nakanishi & Sekino, 1996). Recently, *S. suzukii* has been decreasing in abundance, too. *A. nipponica* and *S. suzukii* are regarded as endangered species (Tuji & Houki, 2001).

Lake Baikal

Lake Baikal phytoplankton have been intensively studied during the 20th century (Meyer, 1930; Yasnitsky, 1930; Yasnitsky & Skabichevsky, 1957; Kozhova, 1959, 1987; Antipova, 1963; 1974; Votintsev et al., 1975; Popovskaya, 1987; and others). The last systematic list of baikalian planktonic algae numbers 299 species and subspecies belonging to 111 genera, 56 families and eight phyla (Bondarenko, 1995). In species diversity, green algae are most numerous, having 112 taxa, blue-green 66, diatoms 63, and chrysophytes 37. The phytoplankton differ in species numbers between the pelagic and shallow zones of Lake Baikal, pelagic species numbering only 158. However, pelagic diatoms are the most numerous, comprising 34% of the total algal composition, but no representatives of Euglenophyta and Xantophyta have been observed. Cryptophytes are represented by the same species both in pelagic and shallow waters. The two epiplanktonic algae *Chrysosphaera melosirae* K. Meyer of chryso-

Table 1. Phytoplankton taxonomic structure of Lakes Biwa and Baikal

Phylum, class, order	Species and subspecies number		Number of common taxa
	Lake Baikal	Lake Biwa*	
Cyanophyta	66	63	20
Chrysophyta	37	89	19
Cryptophyta	8	14	5
Dinophyta	9	19	2
Raphydophyta	–	1	–
Euglenophyta	3	16	2
Xanthophyta	1	5	–
Bacillariophyta:	63	91	21
Centrophyceae	43	32	11
Pennatophyceae	20	59	10
Chlorophyta:	112	276	47
Volvocales	4	53	4
Tetrasporales	–	7	–
Chlorococcales	68	176	38
Zygnematales	–	2	–
Ulotrichales	5	5	2
Desmidiales	35	32	3
Oedogoniales	–	1	–
Total	299	574	116

* for Lake Biwa were accounted also attached forms being abundant in plankton.

phytes and diatom *Synedra cyclopum* Brutschy inhabit the plankton.

In the Lake Baikal phytoplankton, 13 of the 56 families are rich in species and subspecies. They number 132 taxa, ranged lower than genus, that is 40% of the total list. The richest genera are 14 (of 111), which include 55% of the total species composition. Among these, most diverse are the 7 genera *Anabaena* Bory (13 species and subspecies), *Cyclotella* Kützing (14), *Stephanodiscus* Ehrenberg (9), *Aulacoseira* Thwaites (9), *Dinobryon* Ehrenberg (9), *Scenedesmus* Meyen (9), *Mallomonas* Perty (8). So, the Lake Baikal phytoplankton tend to concentrate species diversity into a limited number of genera, i.e. 14 round the lake and three within the pelagic zone, as well as into 13 families. At the same time, there are many genera and families, poor in species number. According to Skabichevsky (1974), species richness in a limited pool of genera and families, mentioned above, and the low species number in most genera and families reflect complicated processes in their genesis. This trend suggests that allochthony was important in the formation of the Lake Baikal algal flora. An autochthonous origin was important in genesis of the genera *Anabaena*, *Dinobryon*, *Scenedesmus*, *Mallomonas*, *Aulacoseira*, *Cyclotella*, *Stephanodiscus*. Only among the last three, are there endemic taxa. Species of these listed genera, except *Scenedesmus* dwelling in shallows, dominate in the pelagic zone.

Most algae of Lake Baikal plankton are cosmopolitan (62%). Also there are 14% boreal forms, 3% arctic-alpine ones, and 15% of unidentified nature. Of the planktonic algae, 5% have been found to be endemic, being mostly numbered among diatoms by seven taxa, principally *Aulacoseira baicalensis* (K. Meyer) Simonsen, *Cyclotella baicalensis* Skvortzow, Meyer, *C. minuta* (Skvortzow) Antipova, *Stephanodiscus binderanus* var. *baicalensis* Popovskaya et Genkal. Except in the genus *Crateriportula* Flower, Hakansson, planktonic algae express their endemism at species and subspecies level. In Baikal phytoplankton, there are relict forms also, described as endemic but later found elsewhere; for example, *Gymnodinium coeruleum* Antipova. Among baikalian plankton, there are forms that are globaly rare, namely the diatom *S. cyclopum*, the chrysophyte *Mallomonas vannigera* Asmund and the green alga *Pediastrum privum* (Printz) Hegew.

Comparative analyses

In comparing the phytoplankton communities of the ancient Asian lakes Baikal and Biwa, it is apparent both lakes have endemic, relict and rare forms. Endemic forms have been found in diatoms, dinoflagellates and chrysophytes in Baikal but only in diatoms in Biwa. The richest in species number are green algae and diatoms.

A difference between the lakes is that desmids, especially *S. planctonicum* and *S. pseudosebaldii*, appear abundantly in the open water of Biwa, while they are observed only in shallows and bays in Baikal. Volvocales have been found to similarly spread.

Though diatom numbers are higher in Lake Biwa (91 spp.) than in Baikal (63 spp.), most of small centric species, including *Stephanodiscus* spp.

and *Cyclotella* spp., are observed in the littoral zone, as are the potamoplankton in Biwa. Some of these species prefer brackish and/or eutrophic water. Another difference between the lakes is that 16 species of euglenophytes are described in Biwa but only three species in Baikal. This seems to reflect a difference in the trophic status of the lakes.

Species common to both the lakes number 116 (Table 1). The Sorensen's coefficient (Sorensen, 1948) is a low 27%, indicating that the algal florae of the lakes are more diverse than similar.

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