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Research Article

Lake Baikal Ecosystem Faces the Threat of Eutrophication

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Recently there have been reports about large accumulations of algae on the beaches of Lake Baikal, the oldest and deepest freshwater body on earth, near major population centers and in areas with large concentrations of tourists and tourism infrastructure. To evaluate the observations indicating the ongoing process of eutrophication of Lake Baikal, a field study in July 2012 in the two largest bays of Lake Baikal, Barguzinsky and Chivyrkuisky, was organized. The study of phytoplankton using the sedimentary method and quantitative records of accumulations of macrophytes in the surf zone was made. In Chivyrkuisky Bay, we found the massive growth of colorless flagellates and cryptomonads as well as the aggregations of *Elodea canadensis* along the sandy shoreline (up to 26 kg/m^2). Barguzinsky Bay registered abundantly cyanobacterial *Anabaena* species, cryptomonads, and extremely high biomass of *Spirogyra* species (up to 70 kg/m^3). The results show the presence of local but significant eutrophication of investigated bays. To prevent further extensions of this process in unique ecosystem of Lake Baikal, the detailed study and monitoring of the coastal zone, the identification of the sources of eutrophication, and the development of measures to reduce nutrient inputs in the waters are urgently needed.

1. Introduction

Lake Baikal, in southeastern Siberia, is the oldest and deepest freshwater body on earth, containing ca. 20% of the world's liquid freshwater (equivalent to all North American Great Lakes combined). It is known for its specific abiotic characteristics such as high oxygen content throughout the water column and a stable low water temperature with a long seasonal ice cover of the lake surface. The high rate of endemism and the exceptional biotic diversity of this ancient lake contributed to UNESCO's 1996 decision to designate Lake Baikal a World Heritage Site.

Lake Baikal is in one of three areas in the world experiencing the most rapid climate change. Despite the enormous temperature buffering capacity of the large water body, it has already been estimated that global and regional warming has caused a 1.21°C increase in the average surface water temperature in the past 60 years [1], a rate twice that of the global average, and the ice-free season has lengthened by 16.1 days between 1868 and 1995 [2].

In addition to temperature change, industrial pollution and cultural eutrophication are of particular concern for Lake Baikal. The Baikal region, containing an industrial corridor with chemical plants and aging industries, lies within the lake's airshed, and industrial pollutants are carried into the basin of the lake by prevailing winds, affecting the entire ecosystem of the lake [3, 4].

Furthermore, in the past two decades, the tourism industry has developed rapidly on the coasts of Lake Baikal. The number of people visiting Baikal has increased several times. A growing number of pleasure crafts are using the lake. Numerous hotels and tourist centers have been constructed on the banks of the lake. Many beaches are extensively used by individual tourists. Domestic waste effluents and sewage from these territories fall into Lake Baikal.

Researches of rivers Maksimikha and Barguzin, conducted in 2012, show that these rivers enrich the water of Barguzin Bay in nutrients. In the wellhead area of Maksimikha River quite high levels of nitrate (0.26 mg L^{-1}) and phosphate (0.22 mg L^{-1}) were found that significantly increased the value of total mineralization—135 mg L^{-1} (K. S. Mikhalev and G. M. Speiser, personal communication). In the same year in the southern part of Lake Baikal in the west bank (Bolshie

Figure 1: Massive growth of green algae of the genus *Spirogyra* in Barguzinsky Bay of Lake Baikal (shoreline accumulations). Photo by V. Petrov.

Koty village) mineralization amounted to 98.5 mg/L; that is, it almost corresponds to the value registered here 50 years ago. Few literature data also indicate the supply of nutrients from the river Barguzin to the bay, which affects the composition of phytoplankton in the shallow zone [5].

It is well known that addition of organic matter to the aquatic medium is the major cause of eutrophication. A water bloom in a lake occurs when it becomes rich of nutrients (primarily phosphorus and nitrogen) [6].

The main focus of monitoring observations has traditionally been the deepwater pelagic zone of Lake Baikal [1, 7]. The shallow coastal zone has received much less attention. However, shallow zones are the places that are affected by the negative impacts of economic and recreational activity especially.

In recent years, public environmental organizations and local activists have regularly reported about accumulations of algae on the beaches of Lake Baikal near major population centers (Slyudyanka, Severobaykalsk, etc.) [8]. Information about abnormally high growth of filamentous algae of the genus *Spirogyra* in the coastal shallow waters of southern Baikal began to appear in the scientific literature [9, 10]. Local inhabitants have also reported large accumulations of algae on the shores of the largest Baikal bay, Barguzinsky Bay, in recent years during autumn storms. In 2012, we estimated that a number of these algal accumulations consisted primarily of green filamentous algae (Figure 1) [11].

With this background, we carried out investigations to study the status of algal flora and their abundance as measures of eutrophication in the coastal areas of two largest bays of the Lake Baikal.

2. Materials and Methods

2.1. Sampling Sites. The depths and morphometry of Barguzinsky Bay and Chivyrkuisky Bay are different. Both bays are located close but separated from each other and from the open waters of Baikal by the Svyatoy Nos Peninsula and the Svyatonossky Isthmus. Barguzinsky Bay, the largest bay, is located on the southern side of these geographical features. It has an almost-circular shape, with an area of approximately 700 square kilometers. Its length is close to 30 km, and its length exceeds the width by about maximum 5 km. The entrance to Barguzinsky Bay is wide (approximately 20 km) and deep (more than 1000 m), allowing the waters of Baikal to exchange freely with the bay water. The depths then gradually decrease in the direction of the central area of the bay. The largest tributary of the bay, the Barguzin River, empties into the bay in the middle portion of the coast, contributing a significant amount of organic matter. Barguzin is one of the largest tributaries of the Lake Baikal; its length is 480 km, with basin area of 21,100 square miles, and the average annual discharge at the mouth is 130 cu·m/s. In the upper reaches, it is a mountain stream with clean water, but the lower part flows through agricultural areas and quite large settlements (Barguzin, Ust-Barguzin).

The warm Maksimikha Cove, with sandy beaches, is located in the southern part of Barguzinsky Bay. The eponymous village of Maksimikha and the Maksimikha River are also located at this site. In the Maksimikha village, there are many tourist bases and hotels. A review of advertisements of travel companies shows that in summer these facilities are able to accommodate 750 to 1000 people. The number of unorganized tourists is difficult to account for, but probably even more than organized.

Chivyrkuisky Bay is located north of the Svyatonossky Isthmus and is much smaller in size and shallower than Barguzinsky Bay. It has an elongated shape, an area of approximately 270 square kilometers, a width of 6–12 km, and a length of approximately 27 km. Depths in excess of 200 m can only be observed at the entrance of the bay; the average depth does not exceed 20–25 m. The maximum depth in the southern part of the bay rarely exceeds 10 m, and the water is generally warm (more than 20°C in the coves) starting from June. These two bays are among the places that are most affected by the local fishing industry and by recreational activities on the Lake Baikal. In Chivyrkuisky Bay, local fishing industry has well developed. Although there are few stationary tourist camps, a large number of tourists arrive in cars and boats.

In Zmeevaya Cove, there are many hot springs. Preliminary estimates reveal that tourists and fishermen add about 160 tons of liquid waste to the Lake Baikal in one summer season [12].

2.2. Sampling. Field studies were conducted in the summer (July 2012) in the littoral zone of the east coast of Lake Baikal in the two largest bays of the lake, Barguzinsky Bay and Chivyrkuisky Bay (Figure 2). The principal sampling sites were in the southern part of Chivyrkuisky Bay, near Monakhovo village (53°39′53″ N, 109°00′33″ E); in the middle part of this same bay, in the Zmeevaya Cove ("Bay of Serpents," 53°46′00″ N, 109°01′61″ E); and in the southern part of Barguzinsky Bay, near village Maksimikha (53°16′13″ N, 108°42′59″ E). For comparison, we chose another point in the Barguzin Bay, north of the mouth of the Barguzin River at the Svyatonossky Isthmus, near the shore (53°31′45″ N, 108°57′32″ E).

Samples of phytoplankton were obtained by a simple scooping-up of the water near the shore or by the research vessel from the surface layers at a moderate distance (100 m)

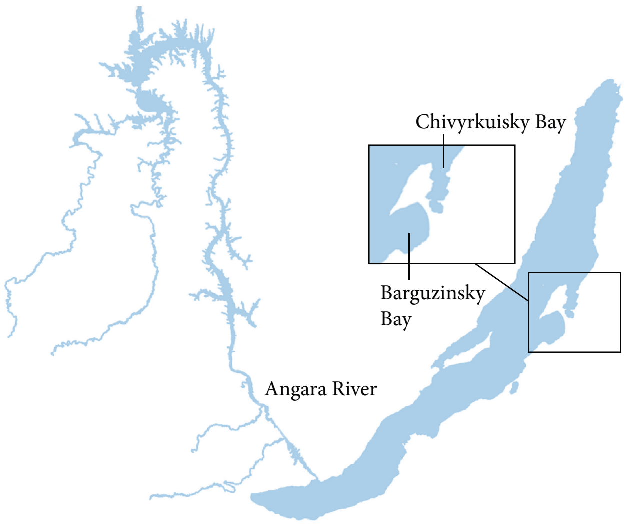


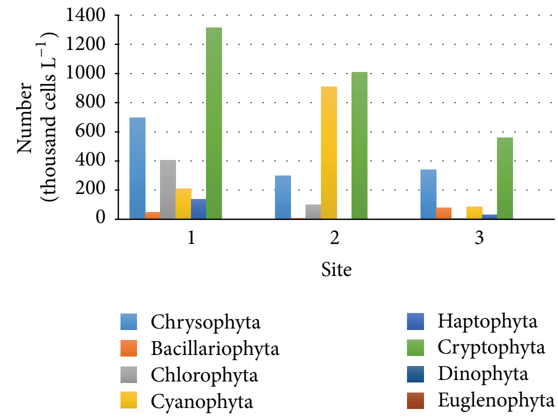
Figure 2: Map of the Lake Baikal sampling sites: Barguzinsky Bay and Chivyrkuisky Bay. The map was created using the "Paint" packages of Windows 7 software (Microsoft, USA).

from the shoreline. Simultaneously with the collection of the water samples, the shoreline zone was monitored to identify the quantity and composition of aquatic plants washed up on the shore by the waves. We filled glass bottles of 0.7 L with water and the samples were fixed with Utermöhl's solution. We processed samples using the sedimentary method [13]. We let them be settled previously for 20 days or more. After this, we drained off the top layer of water and estimated the number and the species diversity of algae in the concentrated samples (V = 10–15 mL) under a Leica DMLB microscope (Germany). Large-cell phytoplankton were counted in 0.1 mL under the microscope with 200x magnification. Small-cell phytoplankton were counted in 0.02 mL at a magnification of 1000. The biomass of dominant species was determined using the volume of their cells. The volume of algae was calculated based on the shape and size of their cells. Specific cells' weight was determined for 1 cm^3 = 1 g. Microphotographs of algae were obtained on the microscope Leica DMLB with a digital camera DC 300 (Germany).

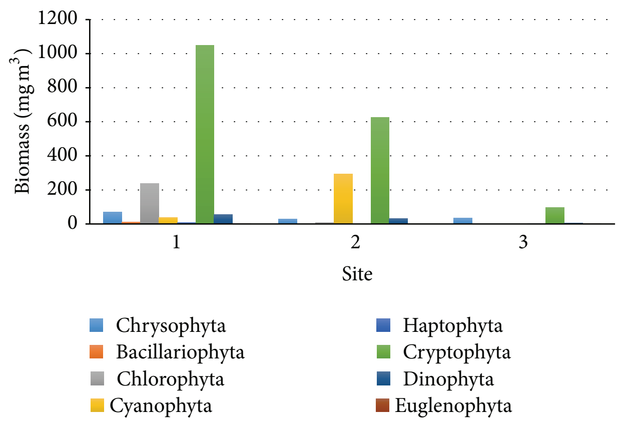
3. Results and Discussion

3.1. Chivyrkuisky Bay. During the season of our study, the weather was generally cloudy, with frequent rain and wind. Thus, the temperature was not sufficiently high to warm the waters of Chivyrkuisky Bay, and the temperature did not exceed 19°C. We expected that the planktonic diatoms might go up from the bottom in the water thickness in such conditions. Planktonic diatoms are typical dominants of the spring and early summer phytoplankton in the Chivyrkuisky Bay [14]. However, the present study showed the dominance of Cryptophyta group in number as well as biomass of the phytoplankton close to Monakhovo village (Figure 3).

We observed a very high species abundance of the genus *Cryptomonas* in Chivyrkuisky Bay: *C. marssonii* Skuja was most abundant followed by *C. reflexa* (M. Marsson) Skuja and



(a)



(b)

Figure 3: The ratio of algal divisions in the phytoplankton composition of the Chivyrkuisky Bay in July 2012: (a) by the number and (b) by the biomass. Sites: 1, Monakhovo near the shore; 2, Monakhovo, 100 m from shore; and 3, Zmeevaya, 100 m from shore.

C. erosa Ehrenberg (Figure 4). The total cells of this genus count exceeded 600000 cells L^{-1}, with a biomass greater than 1.2 g/m^3. This level was 20 times greater than that in the open waters of Baikal, where the average *Cryptomonas* cell counts range from 10000 to 20000 cells L^{-1}. This is the first report of such a massive development of the algal genus *Cryptomonas* in Lake Baikal.

At Chivyrkuisky Bay, we also observed small *Rhodomonas pusilla* (H. Bachmann) Javornicky, belonging to the Cryptophyta, with the highest estimated abundance of 690000 cells L^{-1} and a biomass of 0.07 g/m^3. A small flagellate alga, *Chrysochromulina parva* Lackey (Haptophyta), also reached a high abundance: more than 100000 cells L^{-1}. Besides these, there were a large number of small heterotrophic colorless flagellates and flagellates with chloroplasts from the division Chrysophyta, whose total cell count exceeded 400000 cells L^{-1}.

Thus, the cryptomonads and heterotrophic flagellates dominated in the algal plankton communities of Chivyrkuisky Bay. Intensive growth of these algae indicates that the water contains organic matter. Cyanobacteria (Cyanophyta

Figure 4: Dominant cryptophyte species in the phytoplankton of Chivyrkuisky Bay of Lake Baikal: C*ryptomonas marssonii* Skuja and *Rhodomonas pusilla* (Bachm.) Javor. (small cell). Scale bar: 10 μm.

or blue-green algae) were primarily represented by the genus *Anabaena*, among which *Anabaena lemmermannii* P.G. Richter was the most abundant (with total cell counts of 200000 cells L^{-1} and a biomass of 0.04 g/m^3).

In the coastal waters of Chivyrkuisky Bay, *Elodea canadensis* Michx. was highly abundant. *E. canadensis* first appeared in Lake Baikal in the late 1970s and developed extensively in a number of areas in the late 1980s. In our study, we found that *E. canadensis* now dominates the southern part of the bay, forming massive accumulations in the surf zone near the edge of the water, with a biomass of up to 26 kg/m^2 in wet weight (Figure 5).

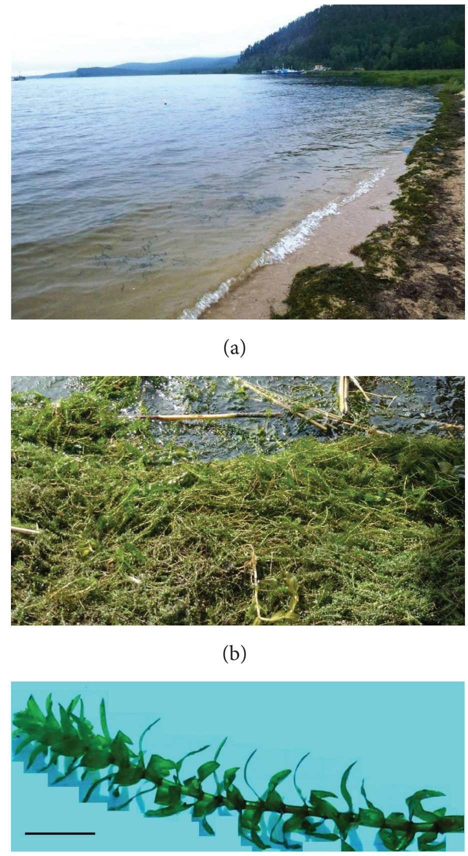
Earlier researchers [15] reported that *E. canadensis* actively developed on soft ground in the shallow waters of Chivyrkuisky Bay and began to displace the native vegetation. We found that black sludge accumulates at the bottom of Chivyrkuisky Bay at a distance of as little as 5–10 m from the water's edge. It should be assumed that *E. canadensis* contributes to the siltation of the littoral zone of the bay, which has developed markedly in recent years.

In certain regions of Chivyrkuisky Bay, for example, in the upper strata of Zmeevaya Cove, we found entire colonies of the planktonic cyanobacterium *Gloeotrichia echinulata* (J.E. Smith) P. Richter. The colonies were shaped like spherical balls (with diameters up to 1.5 mm).

In Zmeevaya Cove, we also found a representative of the Dinophyta, *Peridiniopsis polonicum* (Woloszynska) Bourrelly, 1968, for the first time in Baikal (Figure 6). This is a potentially toxic dinoflagellate.

Euglenophytes were represented by *Trachelomonas volvocina* Ehrenberg, *T. hispida* (Perty) F. Stein emend. Deflandre, *T. ornata* (Svirenko) Skvortzov, and an unidentified *Euglena* species, each with an abundance of 500–1000 cells L^{-1}. All these three *Trachelomonas* are indicators of organic pollution and characterized as beta-mesosaprobionts [16].

Summarizing our observations at Chivyrkuisky Bay, we note clear signals of an ongoing trend of eutrophication. The most important of these signals are the massive development of heterotrophic colorless flagellates as well as the massive development of *E. canadensis* along the sandy shoreline and its contributions to the siltation of the littoral zone. The number of registered dominant species in the bay has increased in comparison with the data for the years 1964–1973 [14]. Flora of summer plankton community was enriched by species of the genera *Cryptomonas*, *Rhodomonas*, and *Chrysochromulina*.



(a)

(b)

(c)

Figure 5: (a, b) Massive accumulations of *Elodea canadensis* Michx. on the shores of the Chivyrkuisky Bay of Lake Baikal. (c) Shoot of *E. canadensis* from the shore accumulation. Scale bar: 1 cm.

3.2. Barguzinsky Bay. In Barguzinsky Bay, near Maksimikha village (Maksimikha Cove), we observed the highest levels of phytoplankton growth, with a total biomass of up to 65 g/m^3. Near the shore, cyanobacteria clearly dominated both in abundance and in biomass (Figure 7); the most numerous cyanobacteria belonged to the genus *Anabaena*. They were dominated by *Anabaena lemmermannii* P. Richter. In open waters of bay, *A. lemmermannii* presented up to 21 million cells L^{-1} and a biomass of 4 g/m^3 (Figure 8). However, maximum growth of *A. lemmermannii* was recorded in a location sheltered from the wind in the waters in Maksimikha Cove with total cell counts up to 650 million cells L^{-1}, with a biomass of 65 g/m^3.

It is interesting to note that *A. lemmermannii* is a common species in lakes at all latitudes, where its massive growth usually produces a bloom of this species in eutrophic waters. The growth of the alga usually occurs during the period

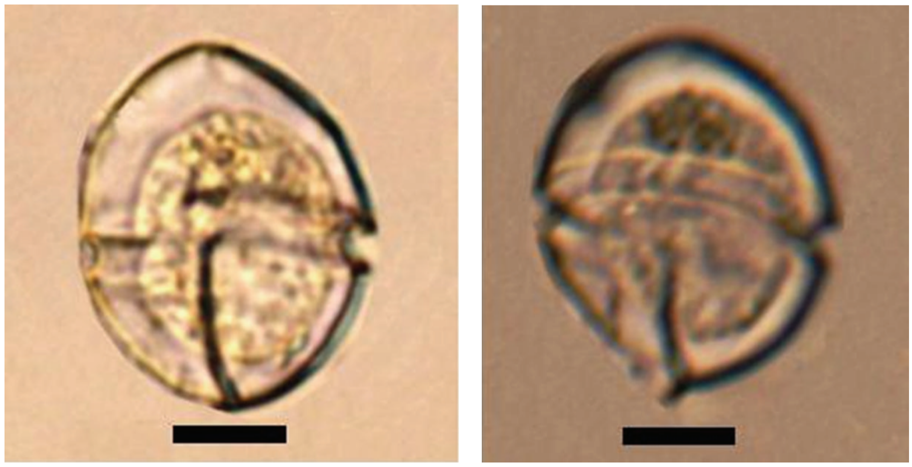
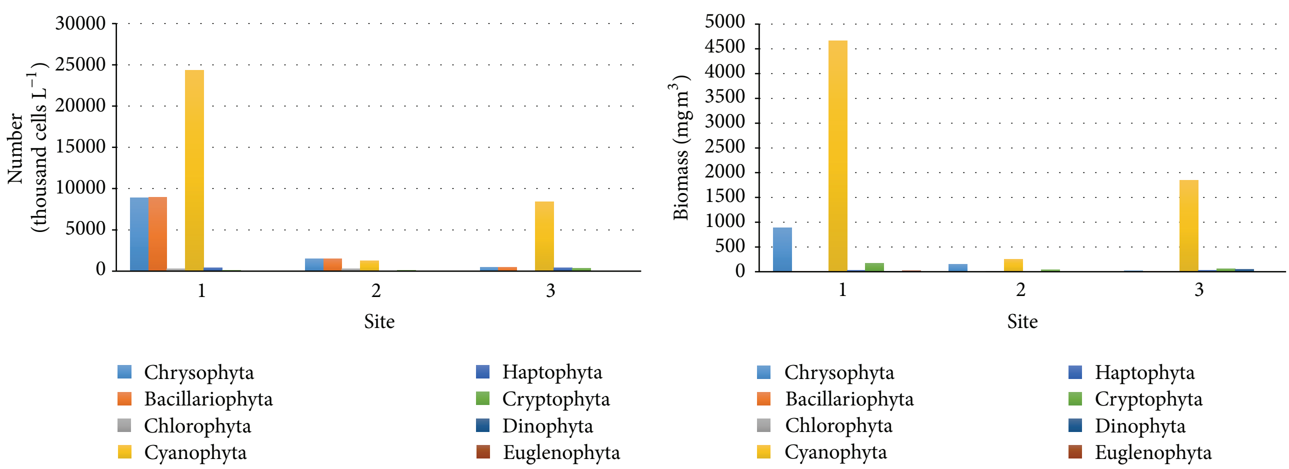


Figure 6: *Peridiniopsis polonicum* (Woloszynska) Bourrelly from the Chivyrkuisky Bay. The same cell in different focus of the microscope. Scale bar: 10 μm.



(a) (b)

Figure 7: The ratio of algal divisions in the phytoplankton composition of the Barguzinsky Bay in July 2012: (a) by the number and (b) by the biomass. Sites: 1, Maksimikha near the shore; 2, Maksimikha, 100 m from the shore; and 3, Svyatonossky Isthmus, near the shore.

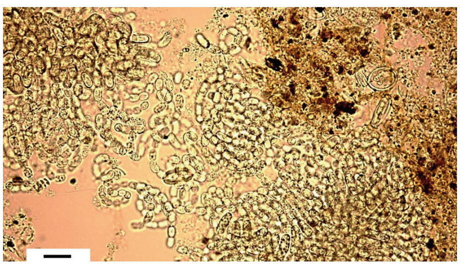
of maximum warming of the water. The species is capable of nitrogen fixation and can grow luxuriantly regardless of the number and forms of mineral nitrogen in the water. This allows the alga to develop during the initial period of eutrophication, when the water is enriched with phosphorus but deficient in inorganic nitrogen [17, 18].

At the shore line, together with cyanobacteria, heterotrophic flagellates were observed in large numbers (up to 8 million cells L^{-1} and a biomass of 0.8 g/m^{3}). The cryptomonad species *Cryptomonas reflexa* (M. Marsson) Skuja, *C. marssonii* Skuja, and *C. erosa* Ehrenberg were also highly abundant (up to 100000 cells L^{-1} and a biomass of 0.22 g/m^{3}).

It is also a matter of interest that the observed composition of the dominant planktonic species communities in Maksimikha Cove is not typical for Lake Baikal. Such a community pattern is, most likely, characteristic of eutrophic aquatic environments with a high content of phosphorus. The extensive development of heterotrophic organisms such as small flagellates and various species of the genus *Cryptomonas* clearly shows that the bay environment is rich in dissolved organic compounds.

In the shallow waters of Maksimikha Cove, we found an extensive growth of periphyton. Numerous cloud-like clusters occurred on the sandy bottom or floated in the water, often at the surface. These clusters were formed by filamentous green algae and dominated by species of the genus *Spirogyra*. We also found species of the genera *Zygnema*, *Oedogonium*, *Cladophora*, and *Mougeotia*. To identify species of the genus *Spirogyra*, it is necessary to examine the zygospore, a product of sexual reproduction that is formed as a result of cell fusion [19]. However, the zygospores had not yet formed during the sampling period, and the *Spirogyra* cells in all analyzed samples were sterile. Only one pair of sexually mature conjugating cells were found, which were in the initial stage of cell fusion (Figure 9). The *Spirogyra* community of filamentous species was characterized by

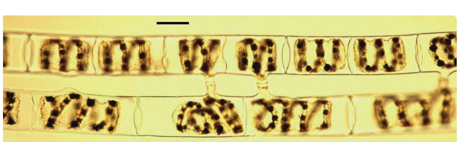
(a)



(b)

Figure 8: Maximal growth of cyanobacterial species *Anabaena lemmermannii* P. Richter near Maksimikha Cove in Barguzinsky Bay of Lake Baikal. (a) The water bloom near shoreline. (b) Colonies of *A. lemmermannii*. Scale bar: 20 μm.

(a)



(b)

Figure 9: (a) Sterile filaments of *Spirogyra* species, dominant in the assemblages of algae in the Maksimikha Cove (Barguzinsky Bay of Lake Baikal, July 2012). Scale bar: 20 μm. (b) Sexually mature conjugating cells of *Spirogyra* species. Scale bar: 40 μm.

a high level of morphological diversity. In view of these morphological characteristics, we suggest that at least four species of the genus *Spirogyra* were present in Maksimikha Cove. All filamentous algae observed were active, in viable condition, and emerald-green in color. These algae have developed rapidly in the bay, where the current conditions are highly favorable for them. The species of *Spirogyra* have been noted previously in the Lake Baikal [20], but they have never been numerous. As already mentioned, only recently these algae have been reported in extreme abundance in the coastal zone, as, for example, near Listvyanka village (southern Baikal) [9, 10]. The current study presents the first report of a massive growth of *Spirogyra* in the largest bay of the Lake Baikal. The biomass of clusters of *Spirogyra* reached extremely high levels, up to 70 kg/m^3 (see Figure 1), with total filaments counts ranging from 17.5 to 25.5 thousand cells L^{-1}. The increased growth of these filamentous algae is a definitive sign of the ongoing changes in the environmental conditions of Barguzinsky Bay.

Figure 10: Colonial cyanobacteria of the *Stratonostoc* species on the coast of the Barguzinsky Bay of Lake Baikal. The diameter of the colonies is 8–20 mm.

It is also interesting to note that on the opposite side from the mouth of the Barguzin River, where there are no permanent tourist facilities, the deposits of algae on the beach were absent. In phytoplankton, cyanobacteria were dominated by the number as well as biomass (see Figure 7, site 3).

In contrast to Chivyrkuisky Bay, Barguzinsky Bay did not yield evidence of *Elodea canadensis* at the time of the study. We found profuse thickets of aquatic plants in a shallow estuary in an extended portion of the Maksimikha River. These thickets were formed primarily by *Equisetum fluviatile* L. and *Sagittaria natans* (Pallas). According to reports by the local inhabitants (fishermen and villagers) these aquatic plants have been intensively colonizing the shallow waters of the river during the past 10 years.

In Maksimikha Cove, the massive growth of filamentous algae was observed, accompanied by the release of these algae from the coastal strip during the autumn storms. Later, in September 2014, for the first time in the Lake Baikal, the massive development of colonial cyanobacteria of the genus *Stratonostoc* on the coast of the bay was reported by local inhabitants (Figure 10).

Occurrence of substantial colonies of *Stratonostoc* species freed from the substrate by the surf was also observed to the south of Barguzinsky Bay on a beach along the shore of the lake near Goryachinsk village (in September 2013). These *Stratonostoc* colonies covered up to 20% of the shoreline area of Maksimikha Cove, an additional clear signal of the ongoing trend of eutrophication. The most important of these signals are the massive growth of cyanobacteria species of the genus *Anabaena*, heterotrophic cryptomonads, and *Spirogyra* species.

4. Conclusion

The data collected in this study indicate the presence of local but significant eutrophication of the two largest shallow bays of the Lake Baikal. We conclude that the results of this field expedition and study clearly confirm that certain regions of the unique ultraclean aquatic ecosystem of this important lake face the threat of eutrophication. To prevent further extensions of this process of eutrophication, detailed study and monitoring of the coastal zone of the Lake Baikal is urgently needed. The identification of the sources of eutrophication and the development of measures to reduce nutrient inputs and organic matter in the waters of the lake should be given special consideration.

Competing Interests

The authors declare that they have no competing interests.

Acknowledgments

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References

[1] S. E. Hampton, L. R. Izmest'eva, M. V. Moore, S. L. Katz, B. Dennis, and E. A. Silow, "Sixty years of environmental change in the world's largest freshwater lake—Lake Baikal, Siberia," *Global Change Biology*, vol. 14, no. 8, pp. 1947–1958, 2008.

[2] J. J. Magnuson, D. M. Robertson, B. J. Benson et al., "Historical trends in lake and river ice cover in the Northern Hemisphere," *Science*, vol. 289, no. 5485, pp. 1743–1746, 2000.

[3] H. Ishibashi, H. Iwata, E.-Y. Kim et al., "Contamination and effects of perfluorochemicals in baikal seal (*Pusa sibirica*). 1. Residue level, tissue distribution, and temporal trend," *Environmental Science and Technology*, vol. 42, no. 7, pp. 2295–2301, 2008.

[4] A. A. Mamontov, E. A. Mamontova, E. N. Tarasova, and M. S. McLachlan, "Tracing the sources of PCDD/Fs and PCBs to Lake Baikal," *Environmental Science & Technology*, vol. 34, no. 5, pp. 741–747, 2000.

[5] T. Katano, S.-I. Nakano, H. Ueno et al., "Abundance and composition of the summer phytoplankton community along a transect from the Barguzin River to the central basin of Lake Baikal," *Limnology*, vol. 9, no. 3, pp. 243–250, 2008.

[6] J. B. Shukla, A. K. Misra, and P. Chandra, "Modeling and analysis of the algal bloom in a lake caused by discharge of nutrients," *Applied Mathematics and Computation*, vol. 196, no. 2, pp. 782–790, 2008.

[7] M. V. Moore, S. E. Hampton, L. R. Izmest'eva, E. A. Silow, E. V. Peshkova, and B. K. Pavlov, "Climate change and the world's "sacred sea"-lake Baikal, Siberia," *BioScience*, vol. 59, no. 5, pp. 405–417, 2009.

[8] O. Timoshkin, M. Sakirko, V. Annenkov et al., "Baikal: ecology of the coastal zone. About the emergency sityation in the area of Severobaikalsk," *Eastern Siberia: The Arguments of the Week*, vol. 9, no. 401, pp. 16–17, 2014.

[9] L. S. Kravtsova, L. A. Izhboldina, I. V. Khanaev et al., "Nearshore benthic blooms of filamentous green algae in Lake Baikal," *Journal of Great Lakes Research*, vol. 40, no. 2, pp. 441–448, 2014.

[10] O. A. Timoshkin, N. A. Bondarenko, Y. A. Volkova, I. V. Tomberg, V. S. Vishnyakov, and V. V. Malnik, "Mass development of green filamentous algae of the genera *Spirogyra* and *Stigeoclonium* (Chlorophyta) in the littoral zone of the southern part of Lake Baikal," *Hydrobiological Journal*, vol. 51, no. 1, pp. 13–23, 2015.

[11] G. I. Kobanova, "The mass growth of filamentous macroalgae in the Barguzinsky Ba y of Baikal," in *Ecological Safety of the Coastal Regions (Seaports, Coastal Protection, Recreation, Mariculture): Proceeding of the International Scientific Conference Dedicated to 150-Years Anniversary of N.M. Knipovich. Rostov-on-Don*, pp. 115–118, SSC RAS, 2012.

[12] G. I. Kobanova, G. M. Speiser, M. P. Rikhvanova, K. S. Mikalyev, and E. A. Voronkova, "The results of the assessment of the ecological state of bays of Lake Baikal obtained during the Baikal social-science expedition in 2012," in *Materials of the VIII International Scientific-Practical Conference "Rivers of Siberia and the Far East", Irkutsk, June 2013*, pp. 108–110, Baikal Environmental Wave, Irkutsk, Russia, 2013.

[13] H. Utermöhl, *Zur Vervollkommung der Quantitativen Phytoplankton-Methodik*, vol. 9, Mitteilungen der Internationale Vereinigung für Theoretische and Angewandte Limnologie, 1958.

[14] G. I. Popovskaya, "The phytoplankton of coastal-lakes zone," in *Limnology of the Coastal-Lakes Zone of Baikal*, pp. 156–175, Nauka, Novosibirsk, Russia, 1977 (Russian).

[15] B. B. Bazarova and N. M. Pronin, "Spatial distribution of *Elodea canadensis* Michx. (Hydrocharitaceae) in Chivyrkuisky bay, Lake Baikal," *Inland Water Biology*, vol. 2, pp. 49–54, 2007.

[16] K. Wołowski and M. Grabowska, "Trachelomonas species as the main component of the euglenophyte community in the Siemianówka Reservoir (Narew River, Poland)," *Annales de Limnologie*, vol. 43, no. 3, pp. 207–218, 2007.

[17] I. S. Trifonova, *Ecology and Succession of Lacustrine Phytoplankton*, Nauka, Leningrad, Russia, 1990.

[18] C. Callieri, R. Bertoni, M. Contesini, and F. Bertoni, "Lake level fluctuations boost toxic cyanobacterial 'oligotrophic blooms'," *PLoS ONE*, vol. 9, no. 10, Article ID e109526, 2014.

[19] L. A. Rundina, *The Zygnematales of Russia (Chlorophyta: Zygnematophyceae)*, Nauka, St. Petersburg, Russia, 1998.

[20] L. A. Izhboldina, *Guide and Key to Benthonic and Periphyton Algae of Lake Baikal (Meio-and Macrophytes) with Short Notes on Their Ecology*, vol. 248, Nauka-Center, Novosibirsk, Russia, 2007.