Lake Baikal (East Siberia) – an ancient ecosystem under change

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Lake Baikal is one of the most famous lacustrine ecosystems of the globe. Why do we think so?: (1) Baikal is the oldest extant lake on the planet, its age being about 25–30 Mya (Mats 2001); (2) Baikal is the deepest lake of the planet (1740 m); (3) Baikal is storing nearly 20 % of all of Earth's fresh surface water, the water volume of Baikal is larger than the combined volume of all the five American Great Lakes, and even by its surface area of 31,500 km^2 it ranks to the 7–8th place among world's large lakes; (4) Baikal represents the most unusual lake ecosystem in terms of the number of recorded species: 2595 animal and more than 1000 plant taxa are known so far (*ca.* 56 % of the animal taxa are endemic including about 10 endemic families among sponges, flatworms, molluscs, crustaceans and fishes), and the lake has even been considered as a separate zoogeographical province (Berg 1931, Starobogatov 1970); (5) Baikal has extraordinarily thick layers of sediments (locally exceeding 7 km), which preserve not only the history of the lake proper but the palaeontological, climatic etc. "chronicles" of the whole Asian continent; and (6) Baikal is the deepest continental depression on the Earth (water column depth + sediment layer thickness).

Special attention in the lecture was paid to biodiversity, evolution and ecology of this magnificent ecosystem. Along with comparative analysis of the major groups of Baikal fauna, such as Porifera, Turbellaria, Amphipoda, Cottoid fishes, the presentation was illustrated with examples of the newest discoveries in taxonomy, community ecology and biogeochemistry. Special attention was paid to the recently described enigmatic Turbellarian family Rhynchokarlingiidae, which consists of more than 60 endemic species in 12 genera (Timoshkin 2004) demonstrating unusual morphological diversity of proboscis, digestive and reproductive systems. Baikal is a lake where a biologist can find not only abundant species, genera and families new for science, but even new freshwater communities like ciliopsammon, hydrovent

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and cryophilic communities. Ecologically, the lake represents a peculiar and enigmatic ecosystem (according to the opinion of the late Finnish crustacean specialist, Prof. Heikki Salemaa, the Baikalian benthonic communities are so abundant and species rich, that by the first glance, they might seem as an "ecological chaos"...). Despite of abundant data and long-term observations, benthos ecology is still very poorly understood in Lake Baikal.

The second half of the lecture was dedicated to the questions of elaboration of a universal monitoring system for lacustrine ecosystems. The approaches to monitoring are as diverse as the ecosystems themselves. Even within the same ecosystem scientists of different generations or persuasions may use different monitoring methods that give results not strictly comparable. The need for universally applicable methods has often been expressed. For example, Younes (1999) stated: "Inventorying and monitoring of biodiversity is being carried out in numerous countries, sometimes with considerable international funding. However, different taxonomic groups, with different sampling methods and monitoring intervals, are usually chosen by different countries. It is difficult to predict the result of these exercises, even for those nations currently involved. Certainly, no useable output will emerge for the understanding of global biodiversity dynamics. *Countries should use pre-designed and universally accepted frameworks for interchanging results for acceptable comparability*" (author's italics). Do such fundamental compatible criteria exist, from which universally applicable methodological approaches or methods could be derived, not only to freshwater, marine but to terrestrial ecosystems as well? Approaches, based on the concept of landscape, were discussed in the lecture. In general summary, landscape is a historically developed and universal structural unit of nature, composed of different elements of litho-, hydro-, atmo- and biosphere. The landscape concept unites atmosphere, lithosphere, hydrosphere and biosphere; but landscapes nevertheless tend to have defined boundaries and can be effectively separated. As examples, for land, see the Baikal basin landscapes (Galazy 1993); for rivers the so-called "riverscape" (Ward 1998); for lakes Karabanov *et al.* (1990); for seas Berg (1931), Panov (1950), Guryanova (1959), Lindberg (1959) and Petrov (1974, 1975). Additionally, this criterion has a significant socio-ecological aspect. What should be monitored at the landscape level? Monitoring of abiotic parameters should include the topographic relief and physico-geographical and chemical factors. Broad spectrum remote sensing, e.g. satellite, photo-, video-, and other indirect methods of measurement, as well as computer data base systems, should be applied where possible. Anthropogenic impacts may influence the biota at all levels of organization: **communities → populations → organisms → cells → molecules**, and the biotic monitoring should cover each level. In practice, this scheme can be realized as follows: **1)** the cytogenetic monitoring (chromosomal aberrations and the mutagenic effects) (very promising results have been received on the gastropods and chironomids of Lake Baikal; for review, see Ostrovskaya *et al.* 1983, 1984; Ostrovskaya & Poberezhny 1987; Proviz, pers. comm.); **2)** monitoring of abnormal and deformed organisms and/or of their embryos/eggs (example for Baikal see Sitnikova *et al.* 1997); **3)** monitoring of the populations of (dominant) species (including the *in situ* and *in vitro* investigations of the life cycles for examples, see Shirokaya & Roepstorf 2003, Maximova 2003, Maximova *et al.* 2003, Zaitseva *et al.* 2006); **4)** monitoring of communities (ecosystems) (including, for example, their trophic relations by means of the analyses of the stomach contents and C/N stable isotope ratio investigations).

Optimal monitoring should include both **short-term (status)** and **long-term (dynamics) observations**. The first may include rapid methods and surveys (e.g. abiotic parameters, indicator species, "biological pollution", and analyses of integrated parameters like chlorophylls and other pigments). The second one should follow the sequence: a) subdivision into landscapes (= landscape zonation; for giant lacustrine ecosystems see Karabanov *et al.* 1990); b) selection of characteristic, vulnerable or unique landscapes; c) establishment of natural reserves that include such landscapes, or selection of such landscapes within existing reserves (e.g. Coulter 1999, 2003; Coulter *et al.* 2006); d) development of standard sets of transects (or ecological test-sites, "polygons") to enable repeatable long-term monitoring (e.g. Timoshkin 2001, Timoshkin *et al.* 2003a). If the reserves already exist (for example, on Baikal), the scheme of the monitoring, complex of methods and necessary equipment should be given to the reserve's staff. Special attention shall be paid to the establishment of multi-year observation schemes, developed on similar types of intra-lacustrine landscapes or similar natural water complexes (e.g. elaboration of GIS based on landscape-ecological mapping). An attempt to create such a scheme on Lake Baikal has been described in detail earlier (Timoshkin *et al.* 2005). Several interesting phenomena, such as the strict interrelations in the development of planktonic and benthonic communities (Timoshkin *et al.* 2000), the preferences of microorganisms, diatoms, Gastropoda and Porifera to specific types of rock, enabling them to break up the minerals of the rocky littoral for life and growth (Suturin *et al.* 2003, Timoshkin *et al.* 2003b), have been found and described during our 5-years long observations.

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References

Berg L.S. 1931. Landscape-geographical zones of the USSR. Vol. 1, USSR Acad. Sci. Publ., Moscow-Leningrad, 401 p. (In Russian)

Bykov B.A. 1988. Dictionary of Ecology. Nauka Press, Alma-Ata, 246 p. (In Russian)

Coulter G.W. 1999. Sustaining both biodiversity and fisheries in ancient lakes: The cases of Lakes Tanganyika, Malawi/Nyasa, and Victoria. In: Kawanabe H., Coulter G.W. & Roosevelt A.C. (eds) Ancient Lakes. Their Cultural and Biological Diversity. Kenobi Productions, Ghent, pp. 177–187.

Coulter G.W. 2003. "Sustainability" or survival?: Dilemma of the world's ancient lakes. Berliner Palaeobiol. Abh. 4: 7–13.

Coulter G., Langenberg V., Lowe-McConnel R., Riedel F., Roest F., Sarvala J. & Timoshkin O.A. 2006. The problems confronting survival of biodiversity in ancient lakes. Verh. Internat. Verein. Limnol. 29(3): 1178–1181.

Galazy G.I. (ed.) 1993. Baikal. Atlas. Federal Russian Service of Geodesy and Cartography, Moscow, 160 p. (In Russian)

Guryanova E.Ph. 1959. Theoretical bases for the creation of the underwater landscape maps. In: Proc. III Session of the All-Union Paleontol. Soc. USSR Acad. Sci. (Questions of Biostratigraphy of Continental Thickness), Moscow, pp. 35–48. (In Russian)

Isachenko A.G. 1982. System of the main terminology in the modern science on landscapes. In: Geography and Modernity, Leningrad State Univ. Press, Leningrad, pp. 17–49. (In Russian)

Karabanov E.B., Sideleva V.G., Izhboldina L.A., Melnik N.G., Zubin A.A., Zubina L.V., Smirnov N.V., Parfenova V.V., Fedorova O.A., Gorbunova L.A. & Kulishenko Yu.L. 1990. Underwater landscapes of Lake Baikal. Nauka Publ, Novosibirsk, 183 p. (In Russian)

Lindberg G.U. 1959. Underwater landscape's mapping for investigation of the peculiarities of animal distribution. In: Proc. III Session of the All-Union Paleontol. Soc. USSR Acad. Sci. (Questions of Biostratigraphy of Continental Thickness), Moscow, pp. 49–52. (In Russian)

Mats V.D. (ed.) 2001. The Cenozoic history of the Baikal rift basin. PH SB RAS, Novosibirsk, 252 p. (In Russian)

Maximova N.V. 2003. Distribution and age structure of the endemic Baikalian gastropod *Maackia herderiana* (Lindholm, 1909). Berliner Palaeobiol. Abh. 2: 78–80.

Maximova N.V., Nepokrytyh A.V., Shirokaya A.A., Rozhkova N.A. & Sitnikova T.Ya. 2003. Gastropoda and Trichoptera in biocenoses of the stone littoral of Southern Baikal. In: Mikheyeva T.M. (ed.) Proc. II Intern. Sci. Conf. Lake ecosystems: biological processes, anthropogenic transformation, water quality. Belarussian State Univ. Press, Minsk, pp. 468–471. (In Russian)

Nakashizuka T. & Stork N. (eds) 2002. Biodiversity research methods. IBOY in Western Pacific and Asia. Kyoto University Press & Trans Pacific Press, Kyoto, Melbourne, 216 p.

Ostrovskaya R.M. & Poberezhny E.S. 1987. Polyploydy in Baikalian molluscs and its role in their reaction on anthropogenic influence. In: V All-Union Symp. N.V. Vavilov's Geneticists and Selectioner's Society, 3. Nauka Publ., Moscow, pp. 152–153. (In Russian)
Ostrovskaya R.M., Poberezhny E.S. & Petrenko N.K. 1983. Baikal molluscs as an object for cytological monitoring. In: Molluscs. Systematics, ecology, distribution peculiarities. Proc. All-Union Symposium on Mollusc Investigations, Nauka Publ., Leningrad, pp. 70–71. (In Russian)
Ostrovskaya R.M., Poberezhny E.S., Razvoszhaev M.S., Voronina A.V. & Pavlova M.E. 1984. Mutation process control in the natural populations of Baikal endemic mollusks in connection with anthropogenic influence. In: Test-systems for estimation of the mutagenic potential of the environmental pollutants. Irkutsk State Univ. Press, Irkutsk, pp. 32–33. (In Russian)
Panov D.G. 1950. On underwater landscapes of the world ocean. Proc. USSR Acad. Sci. Geograph. Soc. 82(6): 582–606. (In Russian)
Petrov K.M. 1974. Theoretical bases of the landscape mapping of the marine shallow water bottom. In: Shelf's mapping. Leningrad, pp. 6–30. (In Russian)
Petrov K.M. 1975. Unit's system of the physical-geographical zonation of marine shallow water bottoms. Proc. USSR Acad. Sci. Geograph. Soc. 107(2): 97–104. (In Russian)
Shirokaya A.A. 2003. Post-embryonal growth and feeding of Baikal endemic limpets (Gastropoda, Pulmonata, Acroloxidae). Berliner Palaeobiol. Abh. 2: 104–105.
Shirokaya A.A. & Roepstorf P. 2003. Morphology of syncapsules and the duration of embryogeny of Baikalian endemic limpets (Gastropoda, Pulmonata, Acroloxidae). Berliner Palaeobiol. Abh. 4: 183–192.
Sitnikova T.Ya, Ostrovskaya R.M., Poberezhny E.S. & Roepstorf P. 1997. Occurrence of abnormal shells and frequency of chromosomal aberrations in embryonic cells of *Benedictia baicalensis* (Gerstfeldt) from different regions of Lake Baikal. Ruthenica 7(1): 31–37.
Starobogatov Ya.I. 1970. Mollusc fauna and zoogeographical demarcation of the continental waterbodies. Nauka Publ., Leningrad, 372 p. (In Russian)
Suturin A.N., Timoshkin O.A., Paradina L.Ph, Kravtsova L.S., Rozhkova N.A.A, Kulikova N.N., Saibatalova Ye.V. & Semiturkina N.A. 2003. Biogeochemical processes on the stony littoral – unlimited element and nutrient source for Baikal ecosystem. Berliner Palaeobiol. Abh. 4: 129–139.
Timoshkin O.A. 2001. Lake Baikal: biodiversity of fauna, the problems of its "immiscibility" and origin, ecology and "exotic" communities. In: Timoshkin O.A. (ed.) Index of animal species inhabiting Lake Baikal and its catchment area. Nauka Publ., Novosibirsk, pp. 16–113.
Timoshkin O.A. 2004. Rhynchokarlingiidae – a new enigmatic group of Turbellaria Kalyptorhynchia (Platyhelminthes, Neorhabdocoela) from Lake Baikal (East Siberia) with emendation of nine species, description of twelve genera and fifty new species: example of «non-Darwinian evolution»? In: Index of animal species inhabiting Lake Baikal and its catchment area. Nauka Publ., Novosibirsk, Siberian branch, Vol. 1(2): 1344–1491.
Timoshkin O.A., Bondarenko N.A., Obolkina L.A., Melnik N.G., Kravtsova L.S., Sitnikova T.Ya., Izhboldina L.A., Mazepova G.F., Afanasyeva E.L., Mekhanikova I.V., Slugina Z.V., Rozhkova N.A., Proviz V.I., Evstigneeva T.D., Sheveleva N.G., Zubina L.V., Novikova O.A., Roepstorf P. & Naumova T.V. 2000. Pelagic and benthic communities of Baikal: correlation of the cycles in their development? In: Third International Vereshchagin Baikal Conference, Irkutsk, pp. 232–233.

Timoshkin O.A., Wada E., Coulter G., Yuma M., Bondarenko N.A., Kravtsova L.S. & Karabanov E.B. 2003a. Landscape-ecological approach in lacustrine ecosystems: towards establishment of the universal pattern of the ecosystem's monitoring. In: DIWPA Symposium Perspectives of the Biodiversity Research in the Western Pacific and Asia in 21st Century, Kyoto, pp. 52–53.

Timoshkin O.A., Suturin A.N., Maximova N.V., Semiturkina N.A., Galkin A.N., Kulikova N.N., Khanaev I.V. & Roepstorf P. 2003b. Rock preferences and microdistribution peculiarities of Porifera and Gastropoda in the shallow littoral zone of Lake Baikal (East Siberia) as evidenced by underwater macrophotograph analysis. Berliner Palaeobiol. Abh. 4: 193–200.

Timoshkin O.A., Coulter G., Wada E., Suturin A.N., Yuma M., Bondarenko N.A., Melnik N.G., Kravtsova L.S., Obolkina L.A. & Karabanov E.B. 2005. Is the concept of a universal monitoring system realistic? Landscape-ecological investigations on Lake Baikal (East Siberia) as a possible model. Verh. Internat. Verein. Limnol. 29: 315–320.

Ward J.V. 1998. Riverine landscapes: biodiversity patterns, disturbance regimes, and aquatic conservation. Biol. Conserv. 83(3): 269–278.

Younes T. 1999. Biological and cultural diversities: challenges and prospects. In: Kawanabe H., Coulter G.W. & Roosevelt A.C. (eds) Ancient Lakes. Their Cultural and Biological Diversity. Kenobi Productions, Ghent, pp. 43–58.

Zaitseva E.P., Mizandrontsev I.B. & Timoshkin O.A. 2006. Postembyonic development and growth dynamics of *Baikalobia guttata* (Gerstfeldt, 1858) (Platyhelminthes): first report on the life cycle of endemic Tricladida from Lake Baikal. Hydrobiologia 568 (Suppl. 1): 239–245.