Long-term dynamics of hydrobiont communities in Kenon Lake

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Abstract: Long-term researches of Kenon Lake, that exploited the lake as a cooling reservoir of the Chita thermoelectric plant-1, have revealed that composition of the dominating system of hydrobiont and fish communities of the lake has no significant variations. Maintenance of the lake level at the expense of pumping water from Ingoda River leads to flatness of processes taking place in the ecosystem and possibilities for the ecosystem state regulation.

1. Introduction

Lake Kenon is situated within Chita City (Zabaikalsky Kray). Hydrological regime of the lake is exposed to influence of natural and climatic factors (humidification cycling), and anthropogenic factors as well. Since 1965 the lake has being used as a reservoir-cooler of the Chita thermoelectric plant-1 (TEP-1). For the period of the lake exploitation it’s thermic, hydrological and hydrochemical regimes have been changed [1, 2, 3]. The first studies of Kenon Lake biota were conducted in 1946 [4]. Comprehensive research of the lake ecosystem was performed in the first years of the lake exploitation as a reservoir-cooler [5]. In the mid of 1980ths the water ecosystem laboratory of Institute of Natural Resources Ecology and Cryology Siberian, Branch of Russian Academy of Sciences proceeded with the research [2]. In the 90-ths the works were performed on specific branches of hydrobiology. The current reservoir (2010-2015) started because of occurring the invasive species Elodea [6, 7] in the lake. The purpose of this paper is to trace the long-term dynamics of hydrobiont communities in the Kenon Lake ecosystem, against the background of changing the level regime of the lake.

2. Materials and methods

To obtain comparable results of long-term research, commonly accepted hydrobiological methods were used. Samples are collected using common methods and recommendations in 2010-2015 [6, 7, 10, 11]. Phytoplankton samples were taken from the surface and bottom water layers using a Patalas bathometer. Zooplankton samples were carried out totally by the Juday net (mesh size = 64 μm). The zoobenthos sampling was performed at seven sampling sites located in the more than four meters depth zone. Sampling was performed in one replicate at each sampling sites by a modified Petersen grab with a sampling area of 0.025 m². The sediment was washed through a nylon sieve with a mesh size of 0.270 mm. The zoobenthos diversity was estimated using Shannon-Weaver index calculated from zoobenthos biomass. Samples were fixed in 4% formaldehyde solution. Observations of a primary production are executed using the oxygen method. Researches of macroalgae and aquatic
plants are conducted using conventional methods and techniques. To measure ichthyofauna, along with standard seining of the lake sections with stake gill nets with mesh sizes 12–40 mm, a minnow seine with 5 mm mesh in wings is used [7]. Literature data have been used for analysis of the long-term dynamics of hydrobiont communities [1, 2, 5, 8–15].

Data on water level and precipitation were obtained in the Trans-Baikal administration for Hydrometeorology and environmental monitoring.

3. Results

Dynamics of the level regime. Lake Kenon is closed, with two tributaries (rivers Kadalinka and Ivanovka). It locates in the Upper Amur basin, and has a smoothly outlined coastline. The absolute mark of the lake bottom is 647.5 m by Baltic system (BS). Long-term cyclic fluctuations of the water level are specific for this lake [2]. From the beginning of instrumental observations the interannual average level of water changed in the following way: 1951-1955 – 654.36±0.24 m; 1956-1960 – 653.89±0.08 m; 1961-1964 – 654.19±0.009 m; 1965 - 1969 – 653.58±0.279 m; 1970-1974 – 654.362±0.248 m, 1975-1977 – reduction to 653.54±0.17 m. Since 1978 for supporting water level in the lake required for needs of thermoelectric plant 1, swapping of water from Ingoda-river has started. Since that year and up to 2003 water level in the lake was maintained at the level above 645.5 m (654.74±0.25 m). In the period from 1990 till 2003 the average volume of swapped waters was 12520±4910.108 ths. m$^3$, from maximum 23100 ths.m$^3$ in 1993 and minimum 5664 ths.m$^3$ in 1998. In the period from 2004 till 2017 the volume of swapped water reduced to 8384±2294.491 ths. m$^3$, with maximum 11294 ths.m$^3$ in 2008 and minimum 4381 ths.m$^3$ in 2012. Reduction of swapping amount coincided with the period of air precipitation reduction in the region.

Dynamics of hydrobiont communities in Kenon Lake. Long-term dynamics of dominants’ composition in communities of phytoplankton, zooplankton, hydrophytes is presented in table 1.

Table 1. Long-term dynamics of hydrobiont communities in the Kenon Lake on summer.

| Phytoplankton | 1969-1967 [8] | 1969-1972 [5] | 1985-1987 [2] | 2010-2015 [11] |
|---------------|--------------|--------------|--------------|--------------|
| Gomphosphaeria lacustris | 42 species | 159 species | 129 species | 110 species |
| Chodat f. lacustris | Gomphosphaeria lacustris | Chodat | Lacustris Chodat | Snowella lacustris (Chodat) |
| Gomphosphaeria lacustris var. compacta | Microcystis palveera (H.C.Wood) Forti | Holopedia irregularis (Chodat) | Lacustris Chodat | Komárek & Hindák (=G. lacustris) |
| Lemmermann | Cyclotella comta | Kützing | Gloeocapsa minuta (Kützing) | Asterionella formosa Hassall |
| Cyclotella comta Kützing | Cyclotella comta | Kützing | Holterbach in Elenkin | Lindavia comta (Kützing) |
| Cyclotella sp. | Synedra ulna (Nitzsch) | Ehrenberg | Synedra ulna (Nitzsch) | Nakov, Gullory, Julius, |
| Peridinium sp. | Gomphosphaeria lacustris | Ehrenberg | Ehrenberg | Theriot & Alversion (=C. comta) |
| Ceratium hirundinella (O.F.Müller) Dujardin | Tetraëdron minimum (A.Br.) Hansgirg | Kützing | Cyclotella comta | Peridinium sp. |
| Tetraëdron triangulare Korshikov | (Chodat) | Hansgirg | Ehrenberg | Ceratium hirundinella |
| Tetraëdron minimum (A. Br.) Hansgirg var. minimum | (O.F.Müller) Dujardin | Hansgirg | Xenococcus kerner | Tetraëdron minimum (A.Br.) Hansgirg |
| | | | | Scenedesmus quadricauda (Turpin) Brébisson in |
| | | | | Brébisson & Godey |
| | | | | Lemmermannia komarekii (Hindák) C.Bock & Krienitz in |
| | | | | Bock et al. |
For the period of research the following changes have been noticed. In *phytoplankton* community the share of Bacillariophyta increases, at considerable reduction of cyanobacteria the share of green algae is stable. In *hydrophyte* community the change of dominants in tangles of helophytes has been marked, a girdle of neustophytes disappeared. In the 70ths of the 20th century, in the result of installing the herbivorous fish and sharp artificial rise of water level, tangles of *P. crispus* significantly reduced, and *Beicirinatum* community started to develop. In the period from 1982 to 1998 communities of *M. sibiricum* were extensively developing. Since 2010 *E. canadensis* has appeared. By data of L.N. Zolotaryova, in the 90ths years, among the higher aquatic vegetation *Mougeotia* sp. developed, in the thermal zone of *Cladophora fracta* (Müll. ex Vahl) Kütz [2] was abundant. In 2010-2015 11 species of filamentous macro-algae were registered in the lake. *Cl. fracta* dominates in epibioses by its greatest phytomass up to 4.5 kg/m² in green weight in channels of thermoelectric plant – 1. In August 2014 *Spirogyra sp.* ster. extensively developed in the area of swapping waters from Ingoda-river, while that in 2010 *Ulothrix zonata* Kütz [7] vegetated here.

Reduction in the number of zooplankton organisms’ large forms (Neutrodiatomus, Cyclops, Daphnia) and growth of small species’ share (especially rotifers) is observed in *zooplankton*. In *zoobenthos* community the share of amphipods has increased (up to 51%). In 1985 and 1986 their share did not exceed 1% of the zoobenthos average annual biomass. Similarity of zoobenthos by Shennon’ diversity index is observed. In the central station it was 1.9-2.1 bits per specie in March 2013-2015, that is slightly less than in 1986 (2.5 bits per specie). In zoobenthos of the Kenon Lake depth area, 27 taxa were found in March 2012 and 2015, 15 of them were common in those years. Taxonomic diversity was at the same level on the whole – 19 species were noted in 2013, and 23 species in 2015. By diversity Chironomidae family dominated in that period – 53-57% of the total number of species in 2015 and 2013 respectively. Range of zoobenthos species (in the area 1/40 m²) and its Shennon species diversity index was slightly higher in the depth area in 2015 than in 2013 (table 3). Frequent representatives of zoobenthos in 2013 were *Chironomus gr. annularis*, *Chironomus gr. Plunmosus* и larvae pp. *Propsilocerus* with frequency of occurrence 71 – 86%. Occurrence of the
rest zoobenthos representatives was below 57%, in particular, *Gmelinoides fasciatus* – 42%. In 2015, *Gmelinoides fasciatus*, *Procladius* *choreus*, *Propilocerus paradoxus* and *Chironomus* gr. *Plumosus* were found in all stations. *Tanytarsus batophilus* (88%) and *Chaoborus crystallinus* (75%) also differed by high frequency of occurrence. Data of lake Kenon fish fauna had been still available before 1919. In that period there were 9 species in the lake, *Leuciscus waleckii* (Dybowski, 1869) and *Esix reicherti*ii Dybowski, 1869, were dominant. In 1919 and 1920 *Perca fluviatilis* Linnaeus, 1758, *Carassius auratusgibelio* (Bloch, 1758) and *Cyprinus carpio* Linnaeus, 1758 were brought in the lake [13]. In the 1970ths, *Ctenopharingodon idella* Valenciennesin Cuvierand Valenciennes, 1844, and *Hypophthalmichthys nobilis* (Richardson, 1845) were settled into the lake for obliteration control, subsequently they disappeared. In 2010-2015 the alien species *Gnathopogon strigatus* (Regan) appeared in the lake. Long-term dynamics of quantitative indexes of Kenon Lake hydrobiont communities is given in table 2.

| Parameter                      | 1960-70-ths | 1980-ths | 2010-2015 |
|--------------------------------|-------------|----------|-----------|
| Phytoplankton                  | N, 10⁶ cells/L | B, mg/L | N, 10⁶ cells/L | B, mg/L | N, 10⁶ cells/L | B, mg/L |
| The ratio of products (A) to destruction (R) | 0.01-0.34 | 0.04-0.7 | 6.9-423 | 6.7-964.2 | 0.1-0.001 | 0.5-3.3 |
| Macrophytes (charophyta/gidatophyta) | 393/511 | Phytomass, g/m² | 598/346 | 719-815/521-589 |
| Zooplankton (average for July-August) | 89-424 | 0.56-3.39 | 74-151 | 0.91-2.18 | 89-288 | 0.79-2.87 |
| Fish                           | 60-65 [9] | Fish productivity, kg/ha | 15 [14] | 57 [15] |

Analysis of long-term changes of phytoplankton communities’ quantitative indexes testifies of the current reduction of algae number and biomass. The greatest number and biomass of algae were noted in 1985-1987 and in comparison with 1967 it was much higher. By 2010-2015 the average annual quantitative indexes of algae had significantly decreased. Cyanophyta was developing for the most part in 1985-1987 decreased the area of spreading and intensity of development. In 2010-2015 cyanobacteria *A. spiroides* was marked in water depth by single filaments. Plankton output was 122-178 g/C/m³ [1, 2] in the center of the lake in 1970ths. In 1985-1987 daily average values of primary production and destruction of organic matters were 411-738 g/C/m³ and 1683-3042 g/C/m³ [2]. Intensification of processes for formation of organic matters by 2.6 times occurred, destruction increased by 5 times. Research in summer of 2010-2011 showed that organic matter production was 90-255 g/C/m³, the maximum production was in August. Destruction exceeded production processes and was about 410 g/C/m³. The obtained results testify of reducing production and destruction processes in the lake compared to the 1980ths. Compared to 1998, reduction of the quantitative development of filamentous algae is observed. In the background of reduction of quantitative indexes of algae, growth of the projective cover (from 40 to 70%) and hydrophyte phytomass (table 2) are noted.

Long-term dynamics of zooplankton development indexes shows that level of plankton development is rather stable – the total number and biomass are comparable with the state being in 1969-1971, in the period of starting the thermoelectric plant-1 operation (table 2). Comparison of materials on Kenon Lake zoobenthos obtained in 2013-2015 with results of research for 1985-1991 [2] is rather difficult, however, there is similarity of zoobenthos by Shennon index of diversity, total
bass and domination of larvae pp. *Chironomus*. In 2013-2015 the zoobenthos biomass was at the level of the average value in 1986 (33.03 g/m$^3$) on the central part of the lake. Quantitative indexes of zoobenthos were high in 2013 and 2015 (table 3), at the level of eutrophic reservoirs. The total biomass of zoobenthos was at the same level. There are differences in structure of dominant species against this background. In 2013 72% of zoobenthos biomass formed larvae of *Chironomus*, 41% of them were *Chironomus* gr. *annularis*. In 2015, 51% of zoobenthos biomass was formed by amphipod *Gmelinoides fasciatus*, and only 19% - by *Chironomus* larvae. In 2015 importance of other pacific midges significantly increased, 11.5 % of them were *Propsilocerus paradoxus* larvae, and 8.7% of the total zoobenthos biomass were *Tanytarsus batophilus* larvae.

### Table 3. Benthos community structure in the ice period 2013 and 2015 in the depths of more than 4 m.

| Taxa                        | 2013          | 2015          |
|-----------------------------|---------------|---------------|
|                             | N±SD (n=7)    | B±SD (n=7)    | N±SD (n=7)    | B±SD (n=7)    |
| *Chironomus juv*            | 1177±1764     | 3.8±5.7       | -             | -             |
| *Ch. gr. plumosus*          | 491±689       | 7.2±11.0      | 354±351       | 6.66±5.98     |
| *Ch. gr. annularis*         | 669±791       | 15.0±19.0     | -             | -             |
| Other peaceful Chironomidae | 720±678       | 1.7±1.53      | 4994±3246     | 7.10±2.51     |
| Predatory Chironomidae      | 246±279       | 0.3±0.41      | 760±578       | 1.18±0.61     |
| *Gm. fasciatus* (Stebb.)    | 526±682       | 5.2±6.70      | 2914±5235     | 17.77±25.82   |
| *G. lacustris* (Sars, 1863) | 6±15          | 0.1±0.30      | 11±30         | 0.15±0.39     |
| Gastropoda                  | 29±60         | 1.3±3.37      | 11±20         | 0.44±1.01     |
| Oligochaeta                 | 771±1019      | 1.0±1.29      | 200±266       | 0.17±0.23     |
| Coleoptera                  | -             | -             | 11±30         | 0.04±0.11     |
| Lepidoptera                 | -             | -             | 17±45         | 0.04±0.11     |
| Odonata                     | 6±15          | 0.1±0.36      | -             | -             |
| Trichoptera                 | 11±20         | 0.1±0.09      | 114±182       | 0.46±0.74     |
| Chaoboridae                 | 131±144       | 0.6±0.70      | 160±229       | 0.78±1.11     |
| Total                       | 4783±1395     | 36.3±20.5     | 9549±6648     | 34.78±21.51   |

Note: N – ind./m$^2$; B – g/m$^2$; SD – standard deviation.

It should be noted that zoobenthos of the central part of shallow lakes is rather changeable in time. Investigations of 2013-2015 show essential participation of litoral communities’ components in formation of the lake Kenon depth area zoobenthos. In 2015 their influence strengthened that is proved by growth of occurrence and high indexes of litoral amphipod *Gmelinoides fasciatus* abundance. Ichthyocoenosis dynamics: 60-70ths years – *Perca fluviatilis* Linnaeus, 1758; 80-90ths – *Leuciscus waleckii* (Dybowski, 1869) – *P. fluviatilis*; 2000ths – *P. fluviatilis* – *Carassius auratus gibelio* (Bloch, 1758). Long-term analysis of the perch age structure has shown decrease of the age series: in the 60ths – to 17+; in the 80ths – to 8+; in 2010-2015 – 6+.

### 4. Discussion

Long-term researches of Kenon Lake, that exploited the lake as a cooling reservoir of the Chita thermoelectric plant–1 (TEP–1), have revealed that composition of the dominating system of hydrobiont and fish communities has no significant variations. Increase of water level in winter after starting the thermoelectric plant (TEP) operation resulted in mass development of *P. crispus* that was a bio-obstacle for TEP operation. Installation of herbivorous fish decreased competitive ability of macrophytes that provoked the mass development of phytoplankton in the 1980-90ths. As the result, the reservoir ecosystem transferred to “turbid water”. The stability element of this phase was consistently high water level (above 645.5 m by BS) in the lake, artificially maintained by TEP–1 for 25 years (1978-2003) at the expense of large amount of waters pumped from Ingoda River.
Period from 2004 to 2017 is characterized by decrease of water level in lake Kenon up to 653.13±0.32 m that coincided with the period of low moisture of the area and decrease of water amounts pumped from Ingoda River (8 384 ±2292 ths. m³). Decrease of nutrients inputs from the catchment area and quantitative indicators of plankton resulted in increase of water transparency, area of macrophytes overgrowth and productivity. Macrophytes, forming the dense cover in the bottom, decrease the flow of nutrients from the bottom to the water column on reducing account the resuspension of bottom sediments. Overgrowth of the reservoir bottom by macrophytes affected all hydrobiont communities. The reservoir ecosystem transferred to “clear water”.

Comparative analysis of water level in terms of time has shown that water level in 2010-2015 was close to the level of 1969-1971 (653.585±0.279 m), when the level mode was conditioned only by climatic fluctuations and characterized by 4-6 year fluctuations. By G.L. Karasyov [9], in the 1970ths the lake was abundantly overgrown and supposedly the lake ecosystem characterized as “clear water”. Thus, maintenance of the lake level at the expense of pumping water from Ingoda River leads to some flatness of processes taking place in the ecosystem and possibilities for the ecosystem state regulation. On the whole, this conforms to idea of alternative equilibrium [16, 17, 18], on the base of which there are competitive interrelations between phytoplankton and macrophytes, and which became important in the meaning of functioning shallow lakes.

5. Conclusion
Long-term researches of Kenon Lake, that exploited the lake as a cooling reservoir of the Chita TEP-1, have revealed that composition of the dominating system of hydrobiont and fish communities of the lake has no significant variations. Inter-annual dynamics of aquatic organisms communities depends on the inter-annual variations of natural and anthropogenic factors. The nutrient inflow from the catchment area in natural conditions depends on the moisture content of territory and coincides with the water level dynamics in the lake. This confirms the hypothesis put forward by B. A. Shishkin in the early 1960-ies on secondary (morphological) nature of productivity in the Trans-Baikal basin lakes [19]. Regulation of the lake level by pumping water from the Ingoda River leads to the smoothness of the processes taking place in the lake ecosystem and makes it possible to manage the ecosystem. From 2004 to the present time, maintaining the average annual water level in the lake at 653.13±0.32 m above sea level contributed to the increase in the area of littoral due to the overgrowth of the bottom of the reservoir with macrophytes and the transition of the lake ecosystem to the "clear water" phase.

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