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Monitoring of the ecological state of the city lake of Chita

V. V. Zvyagintsev, O. Yu. Zvyagintseva, V. K. Chernyshov
Transbaikal State University (Chita, Russian Federation)

Introduction. The paper presents the results of the studies on assessing the quality of the aquatic ecosystem of a lake located within the city. The European perch (Perca fluviatilis L.) and the Gibel carp (Carassius gibelio) were used as an indicator for determining the quality of the aquatic ecosystem by the method of fluctuating asymmetry.
Problem Statement. The aim of the work was to conduct monitoring with the subsequent assessment of the quality of the ecosystem of the city lake using the method of fluctuating asymmetry (hereinafter FA).
Theoretical and Practical Part. The quality of the urban lake aquatic ecosystem was assessed using the FA method (indicators: the European perch (Perca fluviatilis L.), 1758 and the Gibel carp (Carassius auratus Bloch), 1783). To identify the reasons for the high PFA values, a chemical analysis (in an accredited laboratory) of the gills of the Gibel carp for heavy metals was performed.
Conclusions. As a result of the research, the FA indicators values for these indicators were obtained. According to the results of a laboratory study of the content of heavy metals in the gill arches of the Gibel carp, an excess of the maximum permissible concentration of 8 out of 10 analyzed elements was revealed. It has been established that the ecosystem of the city lake Kenon is experiencing a significant anthropogenic load (5 points — the critical quality of the aquatic environment) and it continues to increase towards the deterioration of the habitat.

***Keywords*:** aquatic ecosystem, heavy metals, ecological state, environmental quality, fluctuating asymmetry (FA).

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Introduction. In the modern world, the problem of environmental pollution is becoming more and more urgent, since technological progress does not stand still. Both of these processes are inextricably linked with each other. With the growth of industry, the need for energy and raw materials is also growing, which are the main factors of negative impact on the environment. In this regard, the accumulation of heavy metals in soil, water bodies and living organisms is becoming more intense and dangerous. There are seven large thermal power stations located directly on the Trans-Baikal Territory, which are serious sources of pollution, including heavy metals. The largest producer of electricity and heat on the Trans-Baikal Territory is Chita TPS-1, located on the shore of Lake Kenon. It is also the only thermal power station that has been using a natural lake as a heat sink for 55 years. In addition, it is planned to complete the construction of the next stage of the TPS, which will undoubtedly worsen the ecological condition of Kenon Lake.

Problem Statement. The purpose of this work was to conduct monitoring with subsequent assessment of the quality of the ecosystem of the urban lake by the method of fluctuating asymmetry. The object of research is the natural lake Kenon, located within the city of Chita (Fig. 1).

Theoretical and Practical Parts. The object of research and over 50% of its catchment area are located within the boundaries of the urban area (western outskirts). The lake is located in the central part of the Chita-Ingoda intermountain forest-steppe basin. From the west, the Kadalinka River flows into Kenon Lake (27 km) with a catchment area of 94.2 km^2, from the north — the Zastepinsky stream, which originates from the Yablonovy Mountains [1].

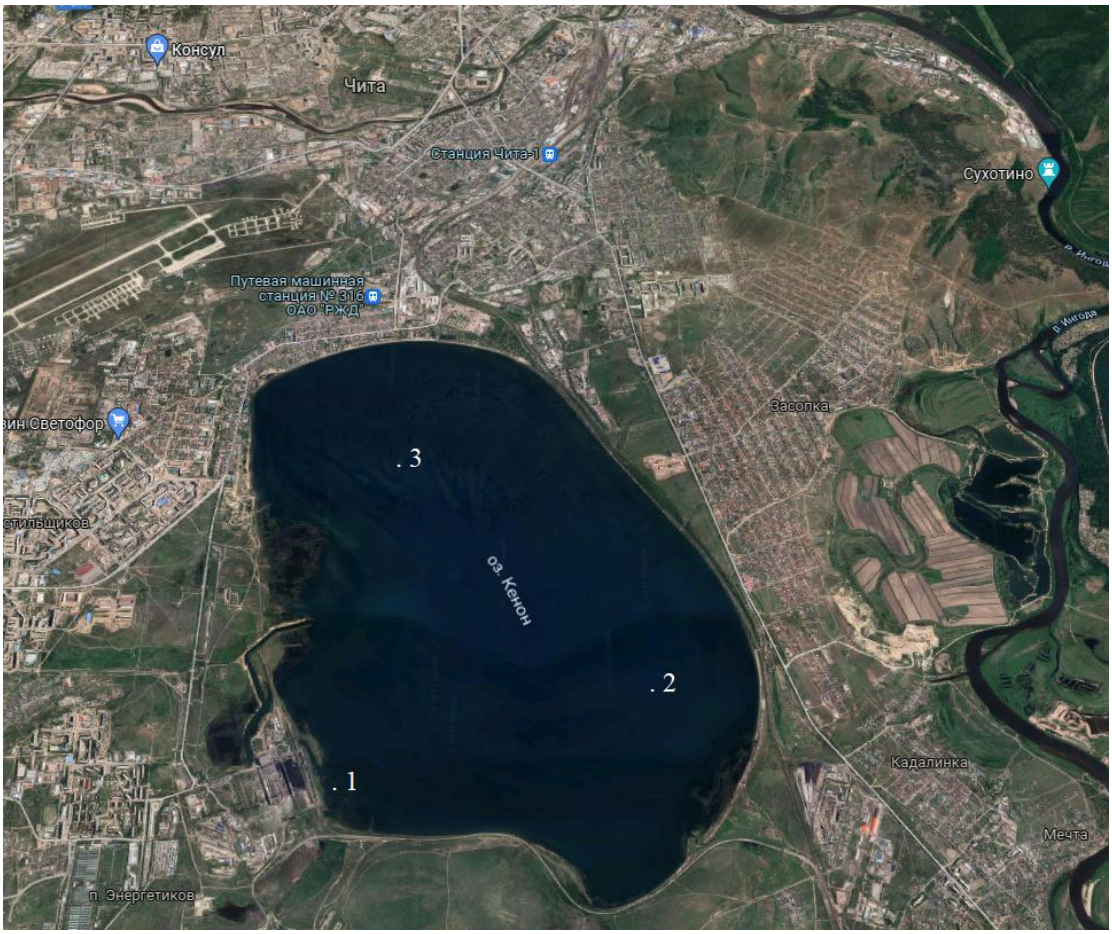

Fig. 1. Location of Kenon Lake

Kenon Lake is a heat sink for the thermal power station TPS-1, and is also used by the population as a place of rest mainly in the summer. The lake is unique, it is a natural water body located within the city and has a water surface area of about 16,200 m^2. It is the only lake in Siberia and the Far East located within the administrative center. In previous periods, the lake's water area was actively used for fishing purposes, since it was rich in large fish (pike, white amur, Siberian Roach, Amur catfish, carp, bighead, crucian carp, perch) [2]. Later, some fish species disappeared.

In 2010, a city beach was equipped on the eastern shore of the lake, which is currently functioning, which attracts more tourists and tourists here.

The hydrological features of the lake's water regime include the fact that it is fed mainly by groundwater, precipitation and small streams, in addition, water is periodically pumped from the outside through a pipeline laid from the Ingoda River in order to maintain the absolute level of 653 m to ensure the efficiency of the TPS.

The freezing period on the lake ranges from 180 to 215 days only in the southeastern part, since part of the water area located near the discharge of warm waters in the northwestern part does not freeze. This leads to intensive evaporation of water, as well as to a decrease in the ice cover in this part of the lake. As the lake is heat sink, the thermal balance of the water masses of the reservoir is disturbed, which certainly affects the state of aquatic organisms and aquatic vegetation.

A white amur and a Bighead carp were introduced into the city lake; the water level was raised in it by almost a meter [2, 3]. Because of this, the settlement areas were rapidly reduced, and in the central part of the lake, the Potamogeton crispus population disappeared [4].

Since some species of fish, including the Bighead carp and the white amur, have disappeared, there is currently a tendency for active development of aquatic vegetation, especially in places where warm waters are discharged, since the development conditions in them are most favorable.

The peculiarity of the bottom sediments of Kenon Lake is that it is covered with a small layer of dark gray and sometimes black mud. Its capacity in the western part of the research object is up to 0.3 m, and in the eastern part — up to one meter. Pollution of bottom sediments is modern and cannot be relict. The uneven distribution of bottom sediments was to some extent facilitated by the extraction of sandy soil from the bottom of the lake with the help of a dredger in the north-western part when the base was washed under the site of TPS-1 in the early sixties of the last century. According to the results of research in 2013, the excess of MPC for several chemical elements in various places of the water area was revealed [5]. The excess was recorded for the following elements: lead (Pb), arsenic (As), zinc (Zn), selenium (Se). In addition, an excess of the standards for benzapyrene was detected directly near the TPS and from the village of Kadala, as well as a tendency to its accumulation from the eastern part of the water area [5, 6].

The authors have assessed the quality of the aquatic ecosystem of the urban lake using the following methods:

— according to the FA method of European perch (Perca fluviatilis L.), 1758 and Gibel carp (Carassius auratus Bloch), 1783;

— optical method (atomic absorption spectrometry) was used to determine the quantitative index of heavy metals in fish tissues and organs (Gibel carp).

The low-cost method of fluctuating asymmetry (recommended by the Ministry of Natural Resources of the Russian Federation) makes it possible to determine the quality of terrestrial and aquatic environments [7]. The essence of this method is the determination of morphological features (symmetry) of plants and living organisms to assess the state of the environment. Except for the European perch the Gibel carp was additionally selected as a bioindicator for this method, which, according to the results of research in 2016, was recommended by the authors for bioindication purposes [3].

The researches using the above methods were carried out in the period from 2019 to 2020. Each sample of material (point) for the aquatic environment was 20 individuals of fish. The material was selected at three points (Fig. 1). Point No. 1 is located directly near the TPS-1. The material for the study was selected in the channel of warm technical waters discharge. Point No. 2 is located on the side of the southern shore of the lake, near the place of water supply from the Ingoda River. Point No. 3 is located in the northeastern part of the lake, near the recreational area.

After completing the measurements using the FA method of the Gibel carp caught in the winter-spring period of 2020, all the gill arches in each fish were removed and dried, after which an analysis was performed in the laboratory using one of the optical methods for the content of heavy metals in them. Using the MGA-915 atomic absorption spectrometer, the following heavy metals were determined in the gills of the Gibel carp: arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), zinc (Zn).

The comparative analysis and data processing were carried out on a computer using the Microsoft Office Excel program.

Results and Discussion. The results of studies using the FA method of the European perch and the Gibel carp, shown in Table 1, confirm that the ecosystem of the urban Kenon Lake is experiencing significant anthropogenic stress (refers to the fifth point).

Table 1

Assessment of the aquatic environment quality (the level of deviation from the norm)

Year	PFA of perch (Perca fluviatilis L.)	Score	Environment quality	PFA of carp (Carassius auratus Bloch)	Score	Environment quality
2019	**0.61±0.001**	5	Critical	-	-	-
2020	**0.6±0.001**	5	Critical	**0.47±0.001**	5	Critical

In addition, the FA index of perch (Perca fluviatilis L.) has significantly increased compared to the data of the study conducted in 2009-2012 (0.46±0.001), which indicates a deterioration of the habitat [8, 9].

To identify the causes of high PFA, a chemical analysis was performed (in an accredited laboratory) of the gills of the Gibel carp for the content of heavy metals, as organs that are most susceptible to their accumulation. According to the results of this laboratory study, an excess of MPC was detected in 8 out of 10 analyzed elements (Table 2). Table 2 reflects the content of heavy metals in the gill arches of the Gibel carp in absolute (mg/kg) values. MPC of heavy metals in fish are established in accordance with the current document [10].

Table 2

The content of heavy metals in the gill arches of the Gibel carp

No.	Name of the element	Content, mg/kg	MPC, mg/kg
1	Cadmium	0.69	0.2
2	Nickel	3.7	0.5
3	Chrome	2.4	0.3
4	Zinc	544.9	40
5	Manganese	22.2	10
6	Copper	8.8	10
7	Iron	214.9	30
8	Lead	2.1	1.0
9	Arsenic	0.3	1.0
10	Cobalt	0.7	0.5

The content of cadmium was 3.45 MPC, nickel — 7.4 MPC, chromium — 8 MPC, zinc — 13.62 MPC, manganese — 2.22 MPC, iron — 7.16 MPC, lead — 2.1 MPC and cobalt — 1.4 MPC, the content of copper and arsenic in the gill arches of the Gibel carp does not exceed MPC. The results obtained indicate that the level of heavy metal pollution of fish in Kenon Lake is very high. First of all, this may be due to water leaks from the hydraulic ash dump, with the discharge of recycled water from the TPS-1, as well as with the watercourse formed as a result of leaks and discharges from the second lift pumping station [5].

According to the results obtained, it is clear that Kenon Lake is experiencing a strong anthropogenic load due to the complex impact of adverse factors. The entry of heavy metals into the reservoir is undoubtedly connected with the production process of the Chita TPS-1, since a large amount of solid fuel is burned during the operation of the thermal power station.

Kenon Lake needs systematic environmental monitoring, restoration of the ecosystem by reducing the anthropogenic load. Only strict quality control of discharged industrial waters, emissions of burned solid fuel, as well as a well-equipped hydraulic ash dump will reduce the negative impact on the reservoir.

As an object for comparing the values obtained by the FA method, the lakes Arachley and Shakshinskoye, located on the territory of the natural park, were selected. In the summer of 2019, the authors conducted a sample of the European perch in these lakes in order to assess the quality of the environment by the FA method. Table 3 shows the obtained results.

Table 3

The quality of the aquatic ecosystem of some lakes according to the FA indicator

Name of the lake	PFA of perch (Perca fluviatilis L.)	Score	Environmental quality (level of deviation from the norm)
The Arachley	**0.32 ±0.001**	**2**	Initial deviations
The Shakshinskoye	**0.25 ±0.001**	1	Conditionally normal

When comparing the results obtained, it can be seen that the environmental quality of Kenon Lake is significantly lower than that of the lakes of the natural park. Although both of these lakes experience a significant recreational load, they are located far enough from the city and industrial enterprises, so the level of anthropogenic load on their ecosystem is small [11].

Conclusions. The studies using the FA method revealed that the Kenon Lake water area has a high score of deviations assessment in the state of the organism from the conditional norm in terms of the PFA of developmental stability for fish. For the first time in the conditions of Eastern Trans-Baikal, the Gibel carp (Carassius auratus Bloch) was used as an indicator of the quality of the aquatic environment by the FA method, which showed good bioindicative properties.

In a comparative analysis of the results obtained during the research in the summer of 2019 and in the winter-spring period of 2020, it was found that the tendency to reach a critical level of the ecosystem of the reservoir has persisted. A comparative analysis of the environmental quality of Lake Kenon and Lakes Arakhlei and Shakshinskoye of the Ivano-Arakhleisk Nature Park revealed that the Arakhlei and the Shakshinskoye have a much better PFA. The results of the analysis of the content of heavy metals in the gill arches of the the Gibel carp showed an excess of the MPC for 8 out of 10 determined metals.

Thus, monitoring of the ecological state of urban Kenon Lake in the city of Chita showed that the quality of its ecosystem, determined by the method of fluctuating asymmetry, is assessed as critical. This is confirmed by a very high level of heavy metal contamination of fish (according to the results of a laboratory study of the gill arches of the Gibel carp). It is necessary to carry out regular comprehensive monitoring of this facility and work to improve the ecology of Kenon Lake.

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About the authors:

Zvyagintsev, **Vladimir V.,** Head, Department of Technosphere Safety, Transbaikal State University (30, Aleksandro-Zavodskaya st., Chita, RF, 672039), Cand. Sci., Associate professor, ORCID: https://orcid.org/0000-0001-6587-4524, zchst@mail.ru

Zvyagintseva, **Olga Yu.,** Associate Professor, Department of Water Management, Environmental and Industrial Safety, Transbaikal State University (30, Aleksandro-Zavodskaya st., Chita, RF, 672039), Cand. Sci., ORCID: https://orcid.org/0000-0002-0691-5901, zchst@mail.ru

Chernyshov, **Vadim K.,** Master's degree student, Department of Technosphere Safety, Transbaikal State University (30, Aleksandro-Zavodskaya st., Chita, RF, 672039), ORCID: https://orcid.org/0000-0002-7340-4239, zchst@mail.ru

Contribution of the authors

V. V. Zvyagintsev — formulation of the main concept, goals and objectives of the study, conducting research, preparation of the text, formulation of the conclusions; O. Y. Zvyagintsev — analysis of the research results, revision of the text, correction of the conclusions; V. K. Chernyshov — collection of ichthyological material, conducting research, analysis.