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ECOLOGICAL AND SOCIO-ECONOMIC SIGNIFICANCE OF THE STUDY OF THE "HABITAT - HYDROBIONTS" SYSTEM IN THE RESERVOIRS

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ABSTRACT

Water occupies a special position among the natural resources of the Earth, meeting the needs of ecological systems, the biosphere and a single biogeochemical cycle as a factor of continuity of life on the earth's surface, as well as the development of the economy and prosperity of mankind, food security and the preservation of humanity as a species on Earth. The ecological problems of the unique Volga basin with its catchment area, which makes up a third of the European territory of Russia, undoubtedly of national importance. The article is devoted to the problems that arose after the creation of reservoirs on the Volga; the main processes that threaten the environmental safety of water and aquatic biological resources of the Volga reservoirs are considered. A special role is played by the expansion of the network of environmental monitoring and research of the "habital – hydrobionts" system as a complex chain of interdependent links that determine the quality of water and aquatic biological resources.

Keywords: environmental safety, reservoirs, environmental monitoring, hydrobiont, system, quality, water

The results of ecological experiments obtained based on a large number of hydrological, hydro-chemical, hydrobiological data by methods of mathematical modelling are considered. The prediction of optimal water levels in different phases of the water regime of the largest Kuibyshev reservoir in Russia and Europe per the environmental requirements for water quality and criteria favorable for the reproduction and conservation of fish stocks. In General, the data obtained indicate the consistency of the optimal level regime of the reservoir both in terms of water

quality requirements and criteria favorable for fish reproduction. The predicted average optimal water level of the Kuibyshev reservoir corresponds to the category of water “moderately polluted”. For the category of “clean” water, the predicted water level exceeds both the normal and forced retaining level and is unrealizable, as it can lead to emergencies at hydroelectric power plants.

The low water period generally contributes to an increase in the level of water pollution in reservoirs. In combination with favorable temperature conditions, it contributes to the development of eutrophication processes and water pollution with a wide range of toxic metabolites - cyanotoxins, dangerous for fish, near-water animals, for humans, which are not taken into account in monitoring programs.

The multilevel system for assessing the status of fish populations of various ecological groups under the conditions of regulated runoff under the RFBR grant and increasing pollution levels, developed by the authors of the article, requires new approaches to the subsystem for monitoring surface water quality, which is the first level of the system for assessing the status of fish populations. The development and implementation of “biologically early warning systems” (BEWS), designed for the rapid detection of emergency and emergency environmental situations, makes it possible to control a greater number of chemical compounds and integrated risk assessment from environmental pollution by unaccounted for chemical compounds, to obtain a direct response biological system for habitat quality, hazard registration at the earliest stages. Of considerable interest is the use of the characteristics of the behavior of fish as biosensor organisms in the prototype of the biological monitoring system TrackTox-Fish, developed at the Department of Applied Ecology, Kazan Federal University.

A general characteristic of the habitat is the first level of the system for assessing the status of fish populations and precedes the next ichthyological analysis, combined with a massive pathological study of individual fish individuals. The creation and implementation of the new “TrackTox-Fish” biologic-electronic water quality registration system to the first level of the system for assessing the status of fish populations using fish as test objects will be useful for prompt response to the current situation in order to prevent a decrease in fish reproduction and the proportion of individuals with anomalies in development in reservoirs.

Water security is one of the basic human needs on Earth. Water occupies a special position among the Earth's natural resources, satisfying the needs of ecological systems, the biosphere and the unified biogeochemical cycle as a factor of “continuity of life on the Earth's surface”, the basis of life on the planet [1, 2], as well as the development of the economy and the prosperity of mankind, ensuring food security and the preservation of humanity as a species on Earth. Consequently, sustainable development, preservation of the biosphere and life on Earth are impossible without understanding in society of the special irreplaceable role of water as one of the greatest values. Therefore, the most important task is to attract the attention of the scientific community to solving problems of improving

the ecological state of aquatic ecosystems, preserving biodiversity and improving the conditions for reproduction of aquatic biological resources, drawing public attention to the special role of water in life on Earth, to the need for its economical and reasonable use, and preventing its pollution. Further ignoring water security issues is a real threat to sustainable development [3].

Russia a special responsibility before humanity for the preservation of this indispensable natural resource. Ecological problems of the unique Volga basin with the catchment area [3], which makes up one-third of the European territory of Russia, are of undoubted national importance. Prevention of pollution of the Volga basin, improvement of the ecological state of the Volga and its tributaries, restoration and improvement of the quality of its waters are envisaged by the priority federal project "Improvement of the Volga" operating in Russia in accordance with the list of instructions of the President of the Russian Federation V.V. Putin dated 05.12.2016 No. Pr-2346. In this regard, the idea [4] of adopting the federal law "On the Protection of the Volga River" (similar to the federal law of 1999 "On the Protection of Lake Baikal") is of great importance for the comprehensive and systematic consolidation of measures aimed at ensuring environmental recovery and preserving unique water Volga river systems.

Beginning in 1935, after the construction of hydroelectric power plants and the conversion of the Volga into a cascade of reservoirs, the usual course of the river was forever violated, its properties radically changed, the quality of water sharply worsened, and the self-cleaning of the Volga decreased. The pressure on the Volga many times exceeded the load on water resources on average in Russia [5]. The pressure on aquatic ecosystems, essentially of the “producers” of natural water, has increased; hydrobionts, including migratory fish populations (sturgeon, salmon), which were blocked from spawning places, and this is direct damage to the country's former wealth.

In connection with the problems arising after the creation of reservoirs on the Volga [5, 6], including Kuibyshevsky, a special role was played by the expansion of the network for monitoring the state of their aquatic and aquatic biological resources [7, 8]. A wealth of experience has been accumulated in scientific and technical support of technical, technological and economic solutions, taking into account the requirements for the quality of aquatic and aquatic biological resources.

The level regime of reservoirs as one of the most important factors determines the quality of surface water resources, leading to increased pollution with a low-level regime [9]. Of interest are two independent environmental experiments carried out by the authors of the report in recent years at the Kuibyshev reservoir - a reservoir of seasonal regulation of the water level [10, 11]. Based on a large array of hydrological, hydro-chemical, and hydrobiological data, the methods of mathematical modeling are used to predict the optimal water levels in different phases of the water regime in accordance with environmental requirements for water quality, on the one hand, and criteria favorable for the reproduction and preservation of fish stocks, on the other.

Based on the forecast model of the influence of the level regime of the Kuibyshev reservoir on the formation of water quality, the optimal level regime of 52,5 – 51,5 m BS (Baltic Height System), as well as the minimum permissible water level (50,5 m BS) under environmental quality requirements are scientifically substantiated water (except in winter due to fewer monitoring data).

Based on many years of comprehensive research, a model of the influence of the level regime on the formation of fish stocks in the Kuibyshev reservoir has been obtained. The optimal level regime of the Kuibyshev reservoir, favorable for fish reproduction, was in the range of 53,4 – 49,0 m BS.

The optimal level regimes of the Kuibyshev reservoir in different phases of the water regime that meet environmental requirements for water quality and are favorable for fish reproduction are shown in the table.

The optimal level regime in different phases of the water regime of the reservoir, meeting environmental requirements for water quality and favorable for fish reproduction, is presented in table 1.

Table 1

The optimal level regime in different phases of the water regime of the reservoir

Phases of the water regime of the reservoir	Level mode *) taking into account the main environmental requirements for the quality of water resources, m BS	Level mode **), favorable for the reproduction of fish, m BS
Spring flood/ high water	avg. 52,0; min 51,0	53,0
Summer-autumn low water level (baseflow)	avg. 52,0; min 50,0	-
Summer period	-	≥ 52,0
Autumn period	-	Early discharge of the water level in the reservoir - up to 51,0
Winter period	51,0*)	The gradual discharge of the water level in the reservoir - ≥ 49,0

Note. *) Since information on monitoring water quality in winter is limited, the result obtained for this time of the year should be considered only as preliminary and requires additional research.

The water quality of the reservoir is most affected by the water level during the flood and summer-autumn low-water periods, while during the winter low-water period, level fluctuations have a weak effect on water quality. Accordingly,

the desired optimal water levels of the Kuibyshev reservoir differ according to the constructed models for different hydrological regimes.

In general, the data obtained indicate the consistency of the optimal reservoir level regime both in terms of water quality requirements and criteria favorable for fish reproduction, i.e. the "habital – hydrobionts" system as a complex chain of interdependent relationships - reacts similarly to the external influence of the same factor (water level) in full accordance with the ecosystem concept.

The predicted average optimum water level of the Kuibyshev reservoir corresponds to the category of "moderately polluted" water. For the category of "clean" water, the predicted water level exceeds both normal and forced support level (FPU) and is unrealizable, because excess FPU can lead to overflow over the crest of the dam and to other emergencies at hydroelectric power stations.

The low water period generally contributes to an increase in the level of water pollution in reservoirs. In particular, in combination with a favorable temperature regime, it contributes to the development of eutrophication processes, an increase in the number and biomass of cyanobacteria, with one or more species dominating in the species composition [12, 13]. The course of these processes contributes to water pollution with a wide range of toxic metabolites - cyanotoxins, dangerous for fish, near-water animals, and also for humans [14, 17, 18]. Cyanotoxins are still not included in the program of extended tests of water quality in eutrophic freshwater water sources [19], as if they do not officially exist, therefore, at present, the content of these unaccounted-for hazardous compounds is determined only for research purposes.

The authors of the report developed a multilevel system for assessing the status of fish populations of various ecological groups under the conditions of regulated runoff RFBR grant and increasing pollution levels require new approaches to the surface water quality monitoring subsystem, making it possible to control a greater number of chemical compounds, including chemicals, information on the content of which is absent in the water, taking into account the integrated assessment of risks from environmental pollution to assess the direct response of biological their systems, including the status of fish populations, and making adequate decisions habitat monitoring is the first level of a system for assessing the status of fish populations.

One of the solutions to this problem may be the development and implementation of "biologically early warning systems" (BEWS), designed for the rapid detection of emergency and emergency environmental situations [20]. In the development of early biological warning systems, the principle of instrumental bio testing is applied, when test organisms, biosensors, serve as operational alarms for the occurrence of a dangerous level of water pollution, and the functional indicators of organisms are recorded automatically in the hardware part of the system without operator intervention. Fish, mollusks and crustaceans are mainly used as bioindicators in early warning systems [21], and the parameters of heartbeat, the optical density of the medium, and movement of organisms or body parts are most often recorded as functional indicators.

Such an approach makes it possible to identify a dangerous situation when traditional methods of physicochemical monitoring are insufficient or may fail. This is because existing approaches are focused on the definition of a regulated limited list of indicators. In the case of the appearance of ingredients in water that are not taken into account in standard control, the level of environmental risks increases, which can lead to harm to ecosystems, aquatic biological resources and human health. Biological monitoring approaches based on an integrated assessment of environmental quality can register a hazard at the earliest stages, for the widest list of pollutants, thus ensuring the possibility of an operational response to the current situation and, as a result, ensuring environmental safety of the environment and lowering the level of environmental risk [22].

Of considerable interest is the use of fish behavior characteristics as biosensor organisms in the prototype of the TrackTox-Fish biological monitoring system (Figure 1), developed at the Department of Applied Ecology, KFU [23]. The system is designed for continuous monitoring of water quality in both flowing and static modes. Organisms are monitored on-line using computer vision technology implemented in a specialized program [24].

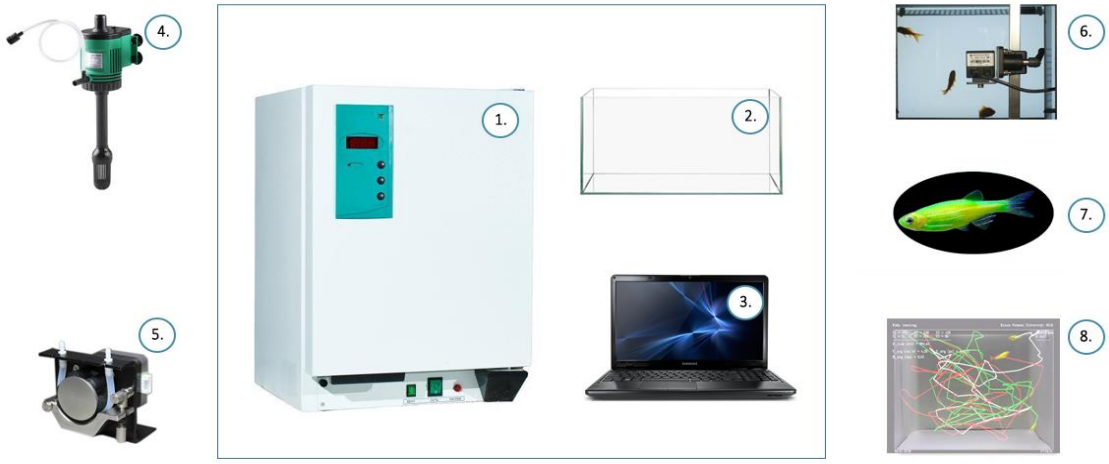


Figure 1 - Components of the TrackTox-Fish bioelectronic water quality registration system

The system consists of a climate chamber (1) providing stability of thermal and light conditions, inside which an aquarium with analyzed water is placed (2), the parameters are controlled from an external computer station (3). The analyzed water, which has undergone initial aeration and filtration (4), is pumped (5) to the aquarium and evaluated by test objects, which are continuously monitored using a video system (6). As organisms-biosensors are fish (7), in our case *Danio rerio* (Cyprinidae), but it is possible to use other species, for example, guppies or aboriginal representatives of ichthyofauna. The behavior of test organisms is evaluated using computer vision technology by an external computer station. The main recorded reaction is the speed of swimming; additionally, the following indicators are estimated: the distribution of fish in the aquarium (coordinates, depth

of swimming), the distance traveled, and the orientation of the fish body in space. Incoming information is automatically processed, water quality assessment is formed and visualized on the screen (8). In case of danger detection, an alarm is triggered.

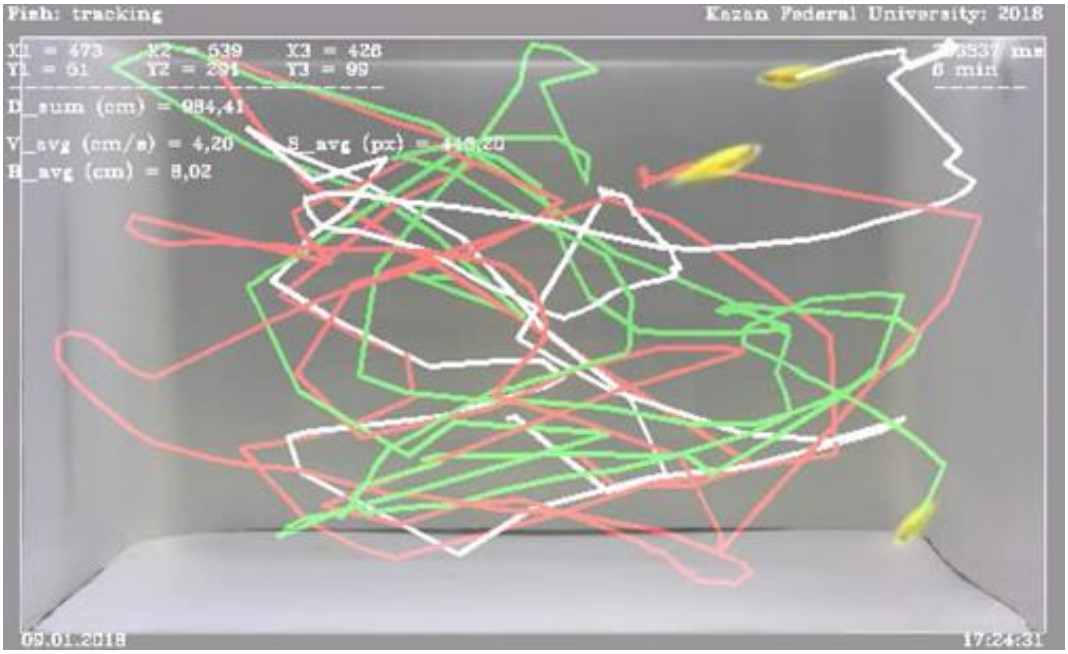


Figure 2 - Visualization of the movement tracks of three zebrafich in control conditions

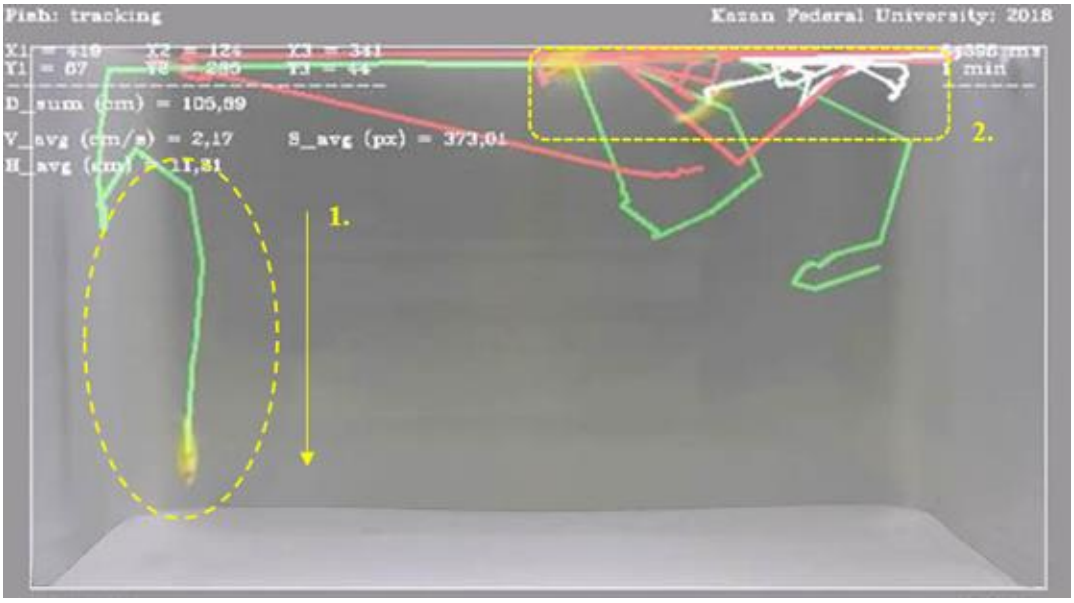


Figure 3 - Visualization of the movement tracks of three zebrafich in conditions with a toxicant (characteristic changes in movement: 1 - “sinking” movements, 2 - concentration at the surface)

As an example, tracks of fish swimming for 1 minute under normal conditions (Figure 2) and under conditions of toxicant entry into the aquatic environment (esfenvalerate pesticide at a concentration of 0,03 mg L^{-1}, Figure 3) are given.

The developed bioelectronic system “TrackTox-Fish” allows you to quickly detect hazardous pollutants (in the above example from the first minutes after the addition of the toxicant) and as a result – to ensure the environmental safety of surface waters by reducing the level of environmental risk

The implementation of the early biological warning system will allow to achieve: increasing objectivity in environmental monitoring; informing about the state of the environment in real time; the possibility of taking into account the danger of unaccounted substances; integrated assessment of risks from environmental pollution, taking into account the multi-component, combinatorial effect between substances; increasing the interpretability of the data, due to the direct response of biological systems to the quality of the environment.

General characteristics of the environment is the first level of the system of assessment of fish populations and is preceded by the following ichthyological analysis, combined with mass autopsy study [25] separate species of fish.

The creation and implementation of the new TrackTox-Fish biologic-electronic water quality registration system at the first level of the fish population assessment system using fish as test objects will be useful for a quick response to the current situation in order to prevent a decrease in fish abundance and the proportion of individuals with anomalies in development in reservoirs.

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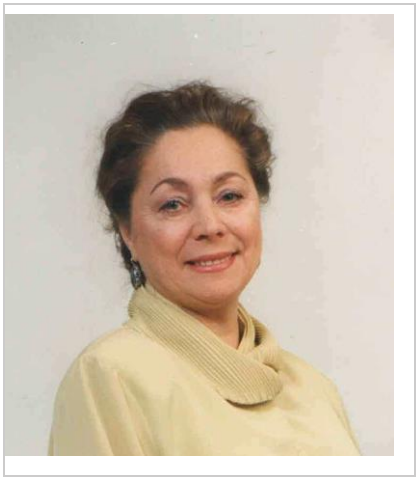
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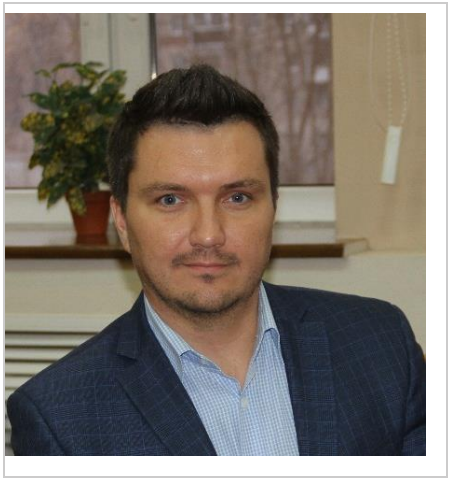
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