Digital models for assessing the impact of aeration processes on reservoir aquaculture

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Abstract. The dissolved oxygen level in a water body is one of the problems affecting all its processes and living organisms. The article identifies the problems associated with insufficient oxygen concentration in water and affecting the ecosystem both within a water body and in the surrounding area. A system dynamics model is developed to predict such changes. The key objects and processes established through structural analysis, observation, synthesis, and mathematical statistics are at the heart of such a model. The application of simulation modeling methods to the obtained results allowed the creation of a model reflecting the dependence of parameters affecting the rate of processes and changes in their states, affecting the population of fish and other living organisms in the reservoir.
Keywords: simulation modeling, system dynamics model, ecology, hydrological processes, hydraulic regime, hydrosphere.

1 Introduction

One of the most critical indicators of water quality in a water body is its dissolved oxygen concentration level [1]. In natural conditions, oxygen enters the water with wind, rain, splashing, and agitation of water from sources flowing into the water body due to the photosynthesis of aquatic plants [2, 3]. The oxygen demand of a water body ecosystem increases with the ingress of objects that require significant resources for decomposing by microorganisms in the bottom layer of water (e.g., polluted sewage, dust, fallen leaves) [4]. Decomposition produces carbon dioxide, organic substances like alcohol, and bad-smelling organic acids [1]. Increasing the efficiency of the decomposition process by adding oxygen to the water through aeration reduces the amount of nutrients for algae blooms and overly rapid plant growth. Aeration can maintain the balance of biological processes in a water body, increasing the proportion of fish, reducing the thermal and chemical stratification of water, creating circulation flows, etc. [4, 5].

In recent decades, the intensification of human domestic, industrial, and economic activities has significantly disrupted natural ecosystem processes. A unified intelligent digital system is required to monitor the state of ecosystems of water bodies, including artificially created ones. The functional capabilities of such a system should include the ability to predict changes in the condition of a water body from human activities, recommendations for correcting problems based on the data received (e.g., from sensors,

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water or soil samples, images of the surface layer of water, objects located along the shoreline, etc.).

Building such a system requires the development of simulation models, which are the digital twin of the real object. In the works of researchers, such models reflect qualitative and quantitative characteristics of all key objects influencing changes in the states of the system processes [6-8].

Thus, **the work aims** to create a formal model describing the changes in the states of processes from the values of indicators. For this purpose, it is required to perform the following **tasks**: to establish key objects influencing the state of the system processes; to determine quantitative and qualitative indicators of the characteristics of such objects; to establish the rules of interaction of objects among themselves; to establish the rules of influence of external factors on the established objects; develop a model of the system based on the obtained results.

The object of the study is closed-type water bodies. **The subject of the study** is the processes affecting the oxygen saturation level of water.

The theoretical significance of the study lies in the systematization of data related to the aeration of water bodies, the establishment of key indicators affecting the state of the processes, and the creation of a unified model unambiguously describing all the processes of the aquatic ecosystem, suitable for use in other studies related to the sustainable development of territories and environmental safety.

The study's practical significance lies in developing a tool that monitors the state of the water body ecosystem, developing recommendations for organizing and carrying out works that maintain a balanced state of the water body, and creating plans for municipalities to spend resources rationally.

2 Materials and methods

The study of literature sources related to the development of simulation models showed that it is required to form a formal description of the object of study [6, 9, 10]. It should reflect all qualitative and quantitative characteristics of the domain elements, their relations among themselves, and the rules of interaction. For this purpose, a set of methods was used, including structural analysis, observation, synthesis, and mathematical statistics.

The system dynamics method, based on the principles of studying complex systems with nonlinear feedback, was used to create the simulation model. This approach has been used in studies related to modeling processes related to agriculture (e.g., in developing techniques for increasing crop yields [7]), ecology (e.g., investigating the effects of airborne concentrations of harmful substances [6]), and the functioning of complex mechanisms [11, 12]. Characterization of the object and subject of the study showed that the modeling of the relevant processes meets the principles of the system dynamics methodology and can be used as a basis for the Forrester model.

3 Results

The study of the application of the aeration method of water resources has shown that it is used for water treatment and water purification for domestic and industrial needs, sewage water treatment, or gas saturation of water bodies of natural and artificial origin [3, 13, 14]. The areas listed are broad and require different techniques and means of applying cleaning methods depending on the end goals. Process modeling for reservoirs will be presented next.

The main purpose of the aeration method in a water body is to provide comprehensive care for it, which, for example, eliminates the possibility of water blooms, creates a current, forces oxygenation, and reduces the accumulation of silt and sediment at the bottom. All this helps to create optimal living conditions for all aquatic life.

Figure 1 shows the results obtained by applying methods that formalize the subject domain and create a simulation model. It shows only a fragment that fits a fish survival model depending on multiple parameters.

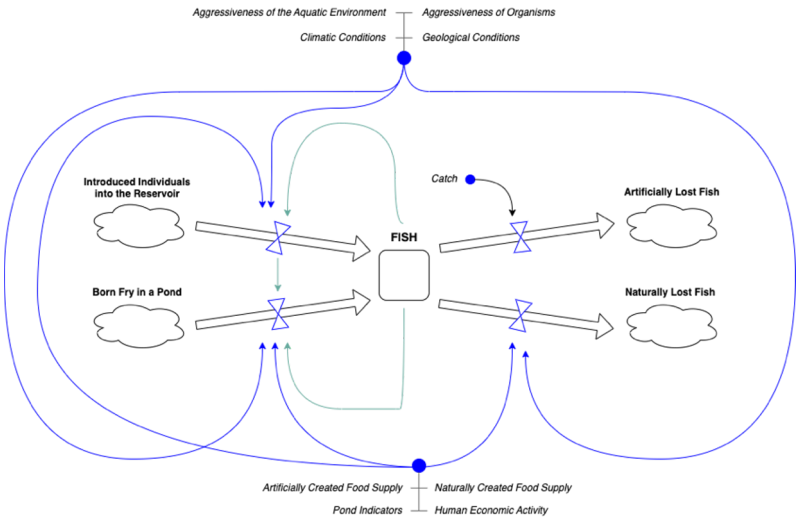

Fig. 1. A model of system dynamics of fish survival in a confined water body using the aeration method.

Many factors influence the fish population; they are thematically grouped for systematization of parameters and reduction of graphic load (without distortion of relations).

Fish can appear in a water body in two ways: by stocking (at any growth stage) and by natural reproduction. Population decline can occur due to natural causes (death due to various reasons) and artificial causes (fishing). Many indicators influence the speed of all these processes. Let us present a description of a part of such indicators:

1. Forage base is divided into natural and artificial. Natural includes all those nutrients that enter a water body without human input (from currents, wind, precipitation), algae, and other living organisms in the aquatic and benthic layers. Artificial feed resources include all those substances that humans contribute (do not include products of domestic or economic activities).

2. Environmental aggressiveness includes all those factors that shorten the life span of fish or lead to fish kills. Such factors include, for example, the presence and size of predator populations, parasites, and the pollution level in a water body from human activities. At the same time, climatic conditions (e.g., temperature, seasonality) and water body characteristics (e.g., flow level, geological structure, light level) are singled out in separate groups, although in terms of meaning, they influence the level of aggressiveness of the environment.

3. Indicators of a water body include a set of indicators that include salinity, acidity, density, odors, etc.

The use of aeration directly affects indicators that change water composition and the pond environment's aggressiveness.

4 Discussion

The nature of the study results is comparable to those obtained in the analyzed papers. In them, the authors highlight the key characteristics of the subject of study that affect the change of its state [4, 7, 8, 15]. The formulated enlarged groups of indicators are valid for the problem domain and allow for the realization of scenarios of system reaction at given time intervals. This approach is implemented in works to develop methodological recommendations for the operational management of the object's state to prevent critical and emergencies or minimize damage from different activities affecting the object of study [2, 5, 6, 12].

The created model can be used to create training digital systems used, for example, in training specialized fishery specialists. As noted in studies related to developing and implementing digital solutions in the educational process, it is necessary to create conditions for implementing practice-oriented tasks that are close to the real conditions of a profile specialist [16].

5 Conclusion

A critical aspect of water aeration is to increase the oxygen content, which is necessary for the respiration of many species of living things and the decomposition of organic matter in the water. This provides a healthy environment for fish, plants, and other organisms to grow and reproduce while reducing water turbidity and odors. At the same time, the ecosystem of the water body itself is formed and maintained, and the general ecological situation around it is improved. Thus, organizing comfortable and functional areas for observation and relaxation is possible.

The use of digital systems capable of analyzing a large number of heterogeneous data to develop effective management decisions aimed at improving certain indicators and reducing the excessive use of resources to preserve the ecological state of the environment is a relevant area of research. The development of simulation models enables the creation of mechanisms for such systems.

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