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Using mathematical modeling in predicting the economic efficiency of lake-commercial fish farming in cross-border areas of northern Kazakhstan

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Abstract. On the basis of the developed mathematical forecasting model, the prospects for developing the lake commercial fish farming. Also, its effectiveness in the cross-border regions of northern Kazakhstan is considered in details.

1. Introduction

In the Republic of Kazakhstan, the Program for the Development of the Agro-Industrial Complex in the Republic of Kazakhstan for 2013-2020, Agribusiness 2020 was adopted for the development of the agro-industrial complex, including the commercial fish industry [1]. This Program envisaged the creation of lake-commercial fish farms whose goal is to achieve sustainable economic and social development. One of the main ways of rational, highly efficient use of biological resources of inland waters is to organize commercial fish farming on their basis. This method of farming is caused by the violation of the natural conditions for the reproduction of fish stocks, which include the destruction of spawning grounds due to shallowing of water bodies, the overlapping of rivers by hydraulic structures, etc. To determine the annual increase in fish stocks, we developed a mathematical model to determine the ability of the reservoir to provide such an increase.

2. Material and Methods

To determine the possible production of fish products from water bodies, we rely on the data given in [2], which uses a set of formulas to calculate the annual production of herbivorous fish, planktophages, benthophages, and crustaceans [3]: $P_{rast}=0,006P_1$; $P_{planktofagov}=0,10P_{zoopl}$; $P_{bentofagov}=0,2P_{bentos}$; $P_{rakoobr}=0,04P_{rakooobr}$, where P is the annual fish production, P_1 is the production of aquatic vegetation, P_{zoopl} is the production of zooplankton, P_{bentos} is the benthos products. To determine the annual production of predatory ichthyophages, the formula was proposed [4]:

$$X_{isch} = (P - P_1) / 3, \tag{1}$$

where X_{isch} is the products of ichthyophage predators, kg / ha, P – a calculated production of non-predatory fish, kg / ha, P_1 – desirable commercial production of non-predatory fish, kg / ha, 3 – a feed coefficient for ichthyophages. Based on the data, we have developed a mathematical model.

3. Results

For practical use of the model, we used the data obtained in the study of the Lake of Bolshoy Tarangul. Knowing the main morphometric characteristics of the reservoir, as well as the results of hydrobiological analyzes, determining an annual increase in ichthyomass is possible. Consequently, according to the state of the predicted data, not only those species provided with food in the reservoir can be identified, but also the maximum number of fish necessary for stocking can be determined.

The Lake of Bolshoy Tarangul is located in the North-Kazakhstan region of the Republic of Kazakhstan, 100 meters north-west of the village of Korneevka. The pond has an oval shape and stretches from northwest to southeast. The length of the lake is 9.4 km, the width is 4.6 km, the maximum depth is 5 m, with an average depth of 3 m. The volume of water is 102 million m^3. The water surface area is 3400 ha.

The temperature of summer water fluctuates in open and coastal parts within 22-24°C. Transparency was 0.7-1.0 m, which according to the complex classification, corresponds to the indicator "a quite clean water." The water color on the Forel scale belongs to the XII category. The reaction is medium/slightly alkaline, pH = 8.4. Electrical conductivity corresponded to $PEEP_B$, and it is 1.73-1.74 mCm / cm. The concentration of dissolved oxygen satisfied $PEEP_B$ and was 9.6 mg/dm^3. BOD_5 was lower than the $PEEP_B$ and amounted to 1.6 mg O_2/dm^3, which corresponds to the category of "sufficiently clean" waters [5].

According to the magnitude of mineralization (2148 mg/dm^3), the lake waters are the β-mesogalin brackish. Water salinity exceeds $PEEP_B$. According to the ionic composition in the classification of O. A. Alekin, this water belongs to sodium chloride type II. Chlorides prevail among anions (318 mg/dm^3). Concentrations of these ions do not exceed $PEEP_B$ (350 mg/dm^3 according to GOST 4245-72). The water hardness is average, exceeded $PEEP_B$ and amounted to 32 mol/dm^3. In 2012, the first hydrobiological studies of the lake were carried out by the "Ecosphere" Ltd. In 2018, data was updated as a result of our summer field research [6].

According to the quantitative development of zooplankton, the Lake of Bolshoy Tarangul is medium fodder, and it is characterized as β-mesosaprobic. Also, according to the quantitative development of zoobenthos, the studied water body belongs to mesotrophic. All calculated indicators relating to the annual increase in ichthyomass are calculated by the method of V. N. Abrosov [4]. The results of the calculation are shown in Table 1, calculations are made in Excel.

Based on these calculations, it is found that in terms of a feed base, the Lake of Bolshoy Tarangul is able to provide an annual increase in ichthyomass of non-predatory fish up to 60 tons (or 17.8 kg/ha). In this regard, in order not to undermine the natural forage base, we recommend catching no more than 60.5 tons of fish products annually. However, it should be borne in mind that this value is not the total biomass of non-predatory fish, but only their annual increase. According to the adopted legislation, the generally accepted optimal amount of withdrawal does not exceed 30%. Consequently, the total biomass of non-predatory fish is 200 tons, and the assessment of predator biomass growth could be calculated. Hence, the annual production of predator ichthyophages in the Lake of Bolshoy Tarangul can be 47.1 tons. The annual increase in fish stocks in polyculture can be 107.6 tons.

However, in addition to the annual increase in fish stocks, the proposed model calculates a number of other indicators that are important for commercial fish farming. Namely, according to hydrobiological data and on the basis of the above recommendations [7, 8], biological standards for stocking fish of different fish species are also calculated according to the nature of nutrition.

Table 1. Mathematical model of the Lake of Bolshoy Tarangul.

Reservoir	Bolshoy Tarangul		
Square, ha	3400		
Average depth, m	3		
Degree of growth, %	15		
Feed base of the investigated reservoir			
Sampling point	Phytoplankton Biomass, mg / m^3	Zooplankton Biomass, mg / m^3	Zoobenthos Biomass, mg / m^3
Coastal area	9.8	1.79	2.82
Open zone	6.9	1.72	0.71
Average	8.85	1.76	1.77
This reservoir is able to provide an annual increase in ichthyomass, kg			
Herbivorous fish	30605		
Planktophage	17901		
Benthophagous	12002		
Predatory fish	47062		
The total increase in ichthyofauna can be, t			
107.6			

4. Discussion

Thus, as a kind of water resources, the lakes play an important role in economic development of a region. In order to make rational use of these resources and obtain maximum economic profit, it is advisable to use models that make it possible to predict the effectiveness of lake-commercial fish farming.

The main direction of increasing fish productivity in inland freshwater reservoirs is the transition from the simple exploitation of fish stocks to the creation of highly efficient regulated fishery in lakes and reservoirs. By their potential, small and medium-sized lakes can produce significantly more fish and better quality if there is the creation of intensive-type managed lake farms.

5. Conclusion

Transition to the forms of lake-commercial fish farming for the northern transboundary areas of the Republic of Kazakhstan will contribute to the sustainable economic and social development of the agro-industrial complex, and hence the economy as a whole.

The proposed model will allow to calculate the economic effect of the fisheries reservoir, taking into account various conditions and factors, during its transition to the forms of lake-commercial fishery. The Lke of Bolshoy Tarangul is one of the promising water bodies of Northern Kazakhstan, and its fish stocks are confirmed by means of a mathematical model created by us.

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