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ASSESSMENT OF FISH POPULATION DYNAMICS IN LAKE ZAISAN USING A COHORT APPROACH

Abstract

This paper proposes a new approach for estimating changes in the abundance and biomass of fish populations in water reservoirs based on sample data from research and commercial fishing. The developed approach takes into account the age structure and dynamics of changes by cohort, without requiring additional information on absolute fish abundance. To reduce the influence of fluctuations and uncontrolled factors, preprocessing of the data using third-degree polynomial regression is used. A mechanism for conditionally accounting for sex composition in biomass calculations is also implemented, allowing for increased estimation accuracy. The presented formulas provide a flexible and adaptive analysis method suitable for conditions with limited or incomplete data. The new assessment approach provides reproducible and comparable results, enabling monitoring of population status and tracking trends in the abundance and biomass of fish resources. The proposed mathematical model is an alternative cohort method for estimating fish populations and their biomass, which should be considered in conjunction with other approaches to stock assessment and applied jointly to management decision-making in fisheries.

Keywords: mathematical modeling, cohort analysis, fish resources, biomass, abundance, scientific fishing, sex structure, data preprocessing, population dynamics.

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ЖАЙСАН КӨЛІНДЕГІ БАЛЫҚТАРДЫҢ САНДЫҚ ДИНАМИКАСЫН КОГОРТТЫҚ ТӘСІЛМЕН БАҒАЛАУ

Аңдатпа

Жұмыста су қоймаларындағы балық популяцияларының сандық мөлшері мен биомассасының өзгерісін бағалаудың жаңа әдісі ұсынылады. Құрылған әдіс балықтардың жастық құрылымын және когорталар бойынша динамикасын ескереді, сонымен қатар олардың абсолюттік саны туралы қосымша ақпаратты қажет етпейді. Ауытқулар мен бақыланбайтын факторлардың әсерін азайту үшін деректер үшінші дәрежелі полиномиалдық регрессия әдісімен алдын ала өңделеді. Сонымен бірге биомассаны есептеу кезінде жыныстық құрамды шартты түрде ескеретін механизм енгізілген, бұл бағалаудың дәлдігін арттыруға мүмкіндік береді. Ұсынылған формулалар шектеулі немесе толық емес деректер жағдайында да икемді әрі бейімделгіш талдау әдісін қамтамасыз етеді. Жаңа бағалау тәсілі популяцияның жай-күйін бақылауға және балық ресурстарының сандық мөлшері мен биомассасының өзгеру үрдістерін қадағалауға мүмкіндік беретін қайта өндіруге болатын және салыстырмалы нәтижелер береді. Ұсынылған математикалық модель балық популяциясы мен оның биомассасын бағалауға арналған когорттық әдіске балама болып табылады және ол басқа тәсілдермен кешенді түрде қарастырылып, балық шаруашылығын басқару шешімдерін қабылдау кезінде олармен бірге қолданылуы тиіс.

Түйін сөздер: математикалық модельдеу, когортты талдау, балық ресурстары, биомасса, саны, ғылыми балық аулау, жыныстық құрылым, деректерді алдын ала өңдеу, популяция динамикасы.

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ОЦЕНКА ДИНАМИКИ ЧИСЛЕННОСТИ РЫБ В ОЗЕРЕ ЖАЙСАН С ИСПОЛЬЗОВАНИЕМ КОГОРТНОГО ПОДХОДА

Аннотация

В настоящей работе предлагается новый подход оценки изменения численности и биомассы рыбных популяций в водоёмах на основе выборочных данных научно-исследовательского и промыслового лова. Разработанный подход учитывает возрастную структуру и динамику изменений по когортам, при этом не требует дополнительной информации об абсолютной численности рыб. Для снижения влияния колебаний и неконтролируемых факторов применяется предварительная обработка данных методом полиномиальной регрессии третьей степени. Также реализован механизм условного учёта полового состава при расчёте биомассы, позволяющий повысить точность оценки. Представленные формулы обеспечивают гибкий и адаптивный способ анализа, пригодный для условий с ограниченными или неполными данными. Новый подход оценки обеспечивает воспроизводимые и сопоставимые результаты, позволяющие производить мониторинг состояния популяции и отслеживать тенденции изменения численности и биомассы рыбных ресурсов. Предложенная математическая модель является альтернативным когортным методом для оценки популяции рыб и ее биомассы, которая должна рассматриваться в комплексе с другими подходами при оценке запасов и применяться совместно с ними при принятии управленческих решений в области рыбного хозяйства.

Ключевые слова: математическое моделирование, когортный анализ, рыбные ресурсы, биомасса, численность, научный лов, половая структура, предварительная обработка данных, динамика популяций

Introduction

Assessing the status of fish populations in water reservoirs is of key importance for the management and planning of fisheries activities. However, in these conditions, researchers often consider limited or incomplete data obtained during research and/or commercial fishing. These data, as a rule, represent sample values, successive turns of fluctuations, transitions with variability of fishing conditions, seasonal factors, changes in sex structure and other sources of uncertainty.

Models based on control catch data are often used for Central Asian countries, including Kazakhstan. These models demonstrate high efficiency in predicting seasonal fluctuations of populations and take into account both natural and anthropogenic factors [1,2].

One of the reliable methods for assessing the current state of a population and forecasting its size is the analysis of the age structure based on scientific fishing data. Such a structure allows us to trace cohort transitions between age groups by year and model demographic dynamics even with limited information on external biotic and abiotic factors [3,4].

Paper [5] examines how the formation of the adult part of a fish population depends on environmental conditions and juvenile (cohort) dynamics. The authors compare two types of models: Internal state distribution models (e.g. partial differential equations) and Internal state configuration models (computer simulations that track the behavior of many individuals individually). Analytical solutions were obtained for three PDE models and compared with equivalent individual-based simulation models. The results showed that both approaches can give similar results, which allows them to be used interchangeably in many cases. However, if random fluctuations in fish growth are temporally correlated (e.g. if a fish grows faster than average one day, it tends to grow faster the next day), then the differences between the models become significant.

Mathematical modeling of fish population dynamics is an important tool in the study of aquatic ecosystems and fisheries management. Such models allow us to predict changes in population numbers, develop sustainable fishing strategies and assess the impact of external factors, including climate and anthropogenic changes. [6-10].

In the current situation, it is necessary to develop robust mathematical approaches that allow extracting useful information even from noisy samples. The aim of this study is to propose a methodology that provides an assessment of changes in the abundance and biomass of fish by species and age groups, taking into account the cohort structure, relative changes and pre-processed data.

In this article, we develop a model that allows tracking population dynamics without the need for absolute indicators. Particular attention is paid to the issue of adjusting the average fish weight taking into account the sex composition, which significantly increases the accuracy of biomass assessment. The developed methodology is oriented towards application in conditions of limited availability of detailed data and has a universality that allows it to be used for analyzing various types of water reservoirs.

In Kazakhstan, several established approaches based on different principles and input data are used to estimate fish populations. Each of these methods has its own advantages and limitations, is based on certain assumptions and is sensitive to the quality of the input information. Depending on the chosen approach, significant differences in results are possible, which complicates the adoption of scientifically based decisions in the field of fisheries management.

An additional complication is the limited observational data, information on commercial catches is often fragmentary, irregular and noisy, and scientific research is not conducted in all age groups or years. This significantly reduces the reliability of traditional population estimates.

Thus, there is a need for alternative models that can take into account the incompleteness, uncertainty and variability of data. In this study, a cohort approach is proposed as a dynamic model for assessing changes in fish abundance by age groups. The model does not require a full volume of information and is focused on identifying general trends and structural changes, complementing existing methods of analysis and assessment.

Research methodology

In accordance with the approved methodological guidelines, researchers in the Republic of Kazakhstan have at their disposal data on the quantity and weight of fish caught by species and age groups. This information was obtained as a result of scientific research fishing, and in some cases - on the basis of observations of commercial catch in different years.

Let us introduce the following notations:

x_{ij}^k is an amount of individuals of the i -th fish species of the j -th age in the k -th year caught by the method of scientific and/or commercial fishing;

w_{ij}^k is an average weight of one individual of the i -th fish species of the j -th age in the k -th year caught by the method of scientific and/or commercial fishing;

where $i = \overline{1, I}$ is fish species, $j = \overline{j_{i0}, J_i}$ is age, $k = \overline{1, T}$ is year of observation (j_{i0} Minimum age estimated for the i -th species).

The initial data are sample values characterizing the structure of the fish population by species, age and years of observation. However, they are subject to the influence of a number of factors: uneven fishing intensity, seasonal fluctuations, variability of the sex composition and other random effects. In this regard, to increase the reliability and analytical value of the information, a preliminary processing stage is required, which allows eliminating noise and stabilizing statistics. Based on the purified data, a mathematical model is then built to assess the dynamics of the number and biomass of the water reservoir.

1.1. Data preprocessing

Due to the fact that data obtained from research and/or commercial fishing demonstrate high variability and random nature, they require preliminary processing.

Let us introduce the notation ξ_{ij}^k for observed data (noisy data).

In order to reduce the influence of random fluctuations and stabilize the sample, data are grouped according to relevant characteristics, such as age categories or catch share.

There are many methods for preprocessing $f(x)$ data, the choice of which depends on the amount and quality of available information. In this study, given the limited source data, various approaches were tested: Bayesian, k-nearest neighbors, linear and polynomial regression.

The best results in approximating dependencies were shown by third-degree polynomial regression, which ensured stable smoothing and preservation of characteristic trends. As a result, the following function was constructed:

$$\bar{\xi}_{ij}^k = f_{ij}(k) \quad (1)$$

where, $f_{ij}(k)$ is a data preprocessing function used to calculate the estimated value $\bar{\xi}_{ij}^k$, $\bar{\xi}_{ij}^k$ is an estimated value of ξ_{ij}^k , obtained as a result of scientific fishing, after preliminary processing.

1.2. Construction of a mathematical model

In this study, only research and/or commercial fishing data are used as initial information. The lack of comprehensive data obtained by other methods does not allow for a reliable assessment of the absolute number of fish populations.

In this regard, the main emphasis is placed on assessing the dynamics of population change by age cohorts. This approach allows tracking trends in the population structure, despite the lack of information on absolute values.

The cohort approach is adopted as the basis for modeling, in which the transition of individuals from one age class to the next is described using a generalized form of the Baranov equation [11]:

$$N_{ij+1}^{k+1} = N_{ij}^k e^{-Z} \quad (2)$$

where, N_{ij}^k is an amount of individuals of the i -th fish species of the j -th age in the k -th year; Z is a mortality coefficient.

Since absolute values of abundance are unknown and the model is based on data obtained as a result of scientific fishing, the transition between age classes and years is carried out on the basis of relative ratios of estimated values formed after preliminary processing. Taking into account equation (2), the dynamics of abundance can be represented as the following ratio:

$$N_{ij}^{k\pm l} = \frac{\bar{x}_{ij}^{k\pm l}}{\bar{x}_{ij}^k} N_{ij}^k \quad (3)$$

where, \bar{x}_{ij}^k is an estimated value of the quantity x_{ij}^k , obtained as a result of scientific and/or commercial fishing, after data preprocessing from (1);

l is the number of years for which the population is restored based on relative changes.

This approach allows us to take into account relative changes in the sample, while maintaining the cohort logic of the transition between ages, despite the lack of absolute data.

Based on expression (3), it is possible to reconstruct the values of abundance by age, after which the total number of individuals of the i -th fish species in the k -th year is determined as the sum of all age groups:

$$N_i^k = \sum_{j=j_{i0}}^{J_i} N_{ij}^k \quad (4)$$

where, N_i^k is the amount of individuals of the i -th fish species in the k -th year, summed up for all age groups.

The change in the number of a given species for each subsequent year, according to equation (4), is calculated using the following formula:

$$\frac{N_i^{k+1}}{N_i^k} = \frac{\sum_{j=j_{i0}}^{J_i} N_{ij}^{k+1}}{\sum_{j=j_{i0}}^{J_i} N_{ij}^k} \quad (5)$$

In this way, the dynamics of the population of each species over time is determined, which creates the basis for subsequent generalization of the results at the level of the entire population.

1.3. Estimation of the total amount of fish in a water reservoir

To analyze the general state of the population, the total number of fish is calculated for all species and age groups in each year of observation. This indicator is determined by the formula:

$$N^k = \frac{1}{I} \sum_{i=1}^I \frac{N_i^k}{\bar{p}_i^k} \quad (6)$$

where, N^k is an amount of total fish stock in the k -th year of observation;

\bar{p}_i^k is the proportion of the i -th fish species from the total amount of fish caught from scientific fishing in the k -th year, obtained as a result of scientific fishing, after data preprocessing from (1).

This calculation method allows us to recalculate the amount of each species taking into account its proportion in the total catch obtained from scientific and commercial fishing. Scientific fishing data is rarely proportional to the real population structure: some species are caught more often, others less often, and this creates a bias. Dividing N_i^k by \bar{p}_i^k corrects this bias, allowing us to imagine what the number of a given species would be if the catch reflected the true population structure.

Summing over all species yields the total fish abundance, and dividing by the number of species I yields an average estimate that smooths out the effects of disproportions between species. This is especially important when working with limited and heterogeneous data, where one or more dominant species may distort the final outcomes.

Based on expression (6), it is possible to determine the relative change in the total amount of fish in a reservoir between two consecutive years. This allows tracking population growth or decline trends regardless of absolute values, which is especially important when working with sample data. The relative change in population is calculated using the following formula:

$$\frac{N^{k+1}}{N^k} = \frac{\sum_{i=1}^I \frac{N_i^{k+1}}{\bar{p}_i^{k+1}}}{\sum_{i=1}^I \frac{N_i^k}{\bar{p}_i^k}} \quad (7)$$

This approach allows us to generalize information on species and obtain an integral characteristic of the state of the population, smoothing out the impact of the irregular distribution of species in catches.

1.4. Estimation of total biomass in a water reservoir

Data on average fish weight obtained as a result of research and/or commercial fishing do not contain separate information by sex from year to year, which significantly complicates the analysis. Let us consider the following expression:

$$\bar{q}_{i,j}^k = \alpha_{ij}^k \bar{q}_{i,j}^{(f)k} + (1 - \alpha_{ij}^k) \bar{q}_{i,j}^{(m)k} \quad (8)$$

where, $\bar{q}_{i,j}^{(f)k}$, $\bar{q}_{i,j}^{(m)k}$ are the average weight of females and males respectively;

α_{ij}^k is the proportion of females in the catch of a given age group.

Since the proportion of sexes varies from year to year, the average mass may be biased by changes in the catch structure rather than biological factors. To eliminate this bias, the study implemented a conditional reconstruction of the average mass by sex. Based on the known proportions and the accepted assumptions, the values of the mass of males and females were reconstructed. This made it

possible to reduce the influence of variations in the sex composition and ensure comparability of data between years.

Based on expression (8), the average mass is further used to perform calculations:

$$\bar{q}_{i,j}^{(avg)k} = \frac{1}{2} \left(\bar{q}_{i,j}^{(f)k} + \bar{q}_{i,j}^{(m)k} \right) \quad (9)$$

Taking into account (9), the total biomass in the k -th year is determined:

$$W^k = \sum_{i=1}^m W_i^k = \frac{1}{m} \sum_{i=1}^m \frac{1}{p_i^k} \sum_{j=j_{i0}}^{n_i} \bar{q}_{i,j}^{(avg)k} N_{ij}^k \quad (10)$$

where, W^k is a biomass of the total fish stock in the k -th year of observation;

W_i^k is a biomass of the total stock of the i -th fish species in the k -th year of observation;

$\bar{q}_{i,j}^k$ is a mass of caught fish of the i -th species of the j -th age in the k -th year, after data preprocessing from (1).

Based on equation (10), the dynamics of changes in the biomass of each individual is calculated, similar to the assessment of its numbers:

$$\frac{W_i^{k+1}}{W_i^k} = \frac{\sum_{j=j_{i0}}^{J_i} \bar{q}_{i,j}^{(avg)k+1} N_{ij}^{k+1}}{\sum_{j=j_{i0}}^{J_i} \bar{q}_{i,j}^{(avg)k} N_{ij}^k} \quad (11)$$

The dynamics of changes in the total biomass in a water reservoir is calculated as:

$$\frac{W^{k+1}}{W^k} = \frac{\sum_{i=1}^I W_i^{k+1}}{\sum_{i=1}^I W_i^k} = \frac{\frac{1}{I} \sum_{i=1}^I \frac{1}{p_i^k} \sum_{j=j_{i0}}^{J_i} \bar{q}_{i,j}^{(avg)k+1} N_{ij}^{k+1}}{\frac{1}{I} \sum_{i=1}^I \frac{1}{p_i^k} \sum_{j=j_{i0}}^{J_i} \bar{q}_{i,j}^{(avg)k} N_{ij}^k} \quad (12)$$

This approach allows us to eliminate distortions arising from changes in the sex composition of the sample and to obtain a more stable and comparable estimate of the fish biomass in the reservoir.

Based on equations (5) and (11), the dynamics of changes in the amount of each individual and its biomass by year are calculated. Equations (7) and (12) allow us to determine the aggregate indicators reflecting changes in the total amount and biomass of fish at each time step. These dependencies serve as indicators of the state of the population, allowing us to track trends and identify changes in the studied water reservoir. Below are the results obtained on the basis of a mathematical model constructed using research and commercial fishing data.

Results of the study

Since the data obtained as a result of research and commercial fishing are stochastic in nature and characterized by high variability, they are largely subject to the influence of random fluctuations caused by both biological factors (differences in sex composition, heterogeneity of fish distribution in the water area, seasonal migrations) and technical features of the fishing process itself (location and time of setting gear, sampling intensity, weather conditions). In this regard, at the first stage of the analysis, special attention was paid to the procedures of preliminary data processing aimed at eliminating noise distortions and stabilizing time series. In this study, third-degree polynomial regression ($k = 3$) was used as a basic tool for smoothing and restoring the patterns of the population age structure. This choice is due to its ability to simultaneously ensure the stability of the approximation with a limited volume of observations and preserve key trends characteristic of population dynamics. As a result of the processing, reconstructed series of fish numbers by age groups were obtained, which made it possible to increase the reliability of the analysis and create a basis for further construction of cohort models.

The study focused on the five most typical fish species for the ichthyofauna of Lake Zhaisan: bream, pikeperch, perch, roach, ide and pike. These species represent both mass commercial objects and important elements of the trophic structure of the ecosystem, which makes them indicative for analyzing the general state of populations in the studied reservoir. Data processing for the remaining species was carried out using a similar method, but due to their large volume, they are not included in this section. In Figure 1 (a, b, c, d, e, f), the red dots represent the original results of the scientific catch, the blue line corresponds to the smoothed curve obtained from the regression analysis, and the dotted lines illustrate the general trends in abundance in age cohorts.

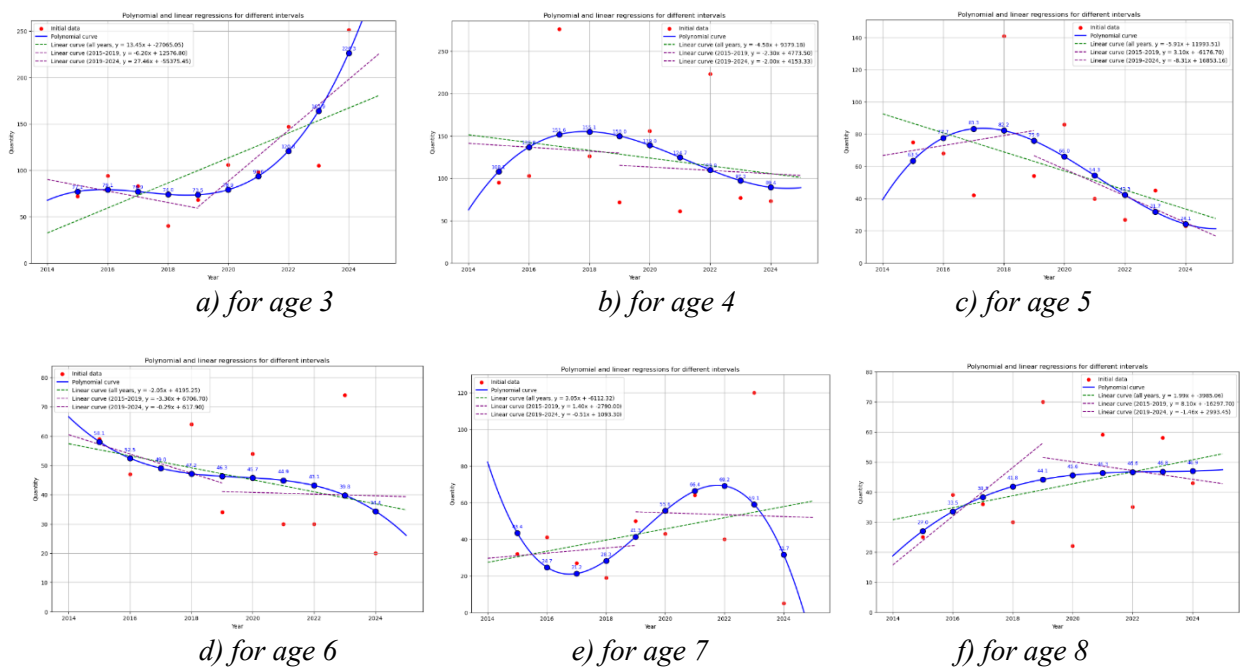


Figure 1. Input data trends for ages 3-8 (for bream species)

Let us proceed to discuss the results obtained on the basis of the developed mathematical model. Figure 2 (a) shows the dynamics of changes in the bream population for the period from 2015 to 2024, showing a gradual increase in numbers throughout the entire observation period. In the first years of observations, a gradual increase in numbers is noted, which subsequently becomes more pronounced. The highest growth rates occur in the middle of the study period, when the number increased especially quickly, reflecting the entry of numerous generations into the population. In subsequent years, growth continued, but its rate slowed down somewhat, which may be due to natural limitations caused by the capacity of the ecosystem and intrapopulation competition. Figure 2 (b) shows the dynamics of the population biomass, which also demonstrates a steady increase throughout the observation period.

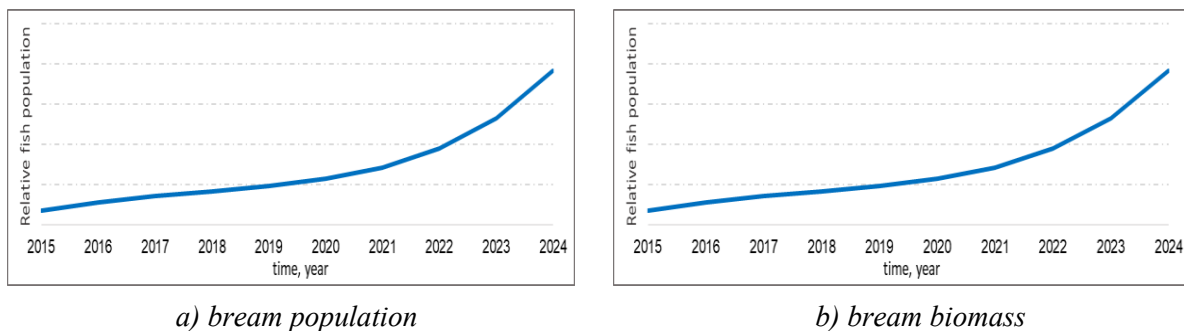


Figure 2. Dynamics of changes in the population and biomass of bream by year

In the first years, the increase was moderate, but with the accumulation of older age groups, the rate of increase increased, and the maximum values were reached in the final years. Thus, the modeling results confirm the positive trend in both numbers and biomass, which indicates population stability.

Further, Figure 3 (a, b) shows changes in the dynamics of the population size and biomass of the pikeperch in the period from 2015 to 2024. Unlike bream, the dynamics of the pikeperch population is more oscillatory. At the beginning of the period under review, a decrease in the indicator was observed, reaching minimum values by 2017–2018. In subsequent years, the number began to gradually recover: the growth became especially noticeable after 2019, when the values stably increased until 2022–2023. By the end of the period, a slight decrease in numbers is noted, which may be due to natural population fluctuations and the impact of external factors.

The change in pikeperch biomass generally follows the dynamics of abundance. After a decline in the first years, the indicators remained at a relatively low level, but starting in 2019, there was a steady increase, reaching a maximum by 2022–2023. In 2024, a slight decrease was recorded, coinciding with a decrease in abundance.

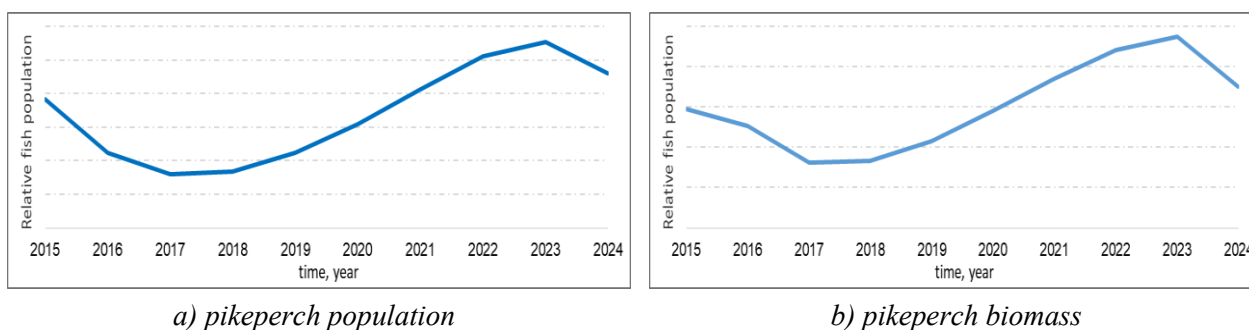


Figure 3. Dynamics of changes in the population and biomass of pikeperch by year

Figure 4 (a, b) shows changes in the dynamics of the population size and biomass of the perch population from 2015 to 2024. The population dynamics are characterized by progressive growth throughout most of the period under review. Initially, the growth was moderate, but starting in 2018, the rate of increase increased significantly, and by 2022–2023, the population reached its maximum values. In 2024, a decrease in the indicator was recorded, which may be due to natural population fluctuations and a decrease in the proportion of older age groups.

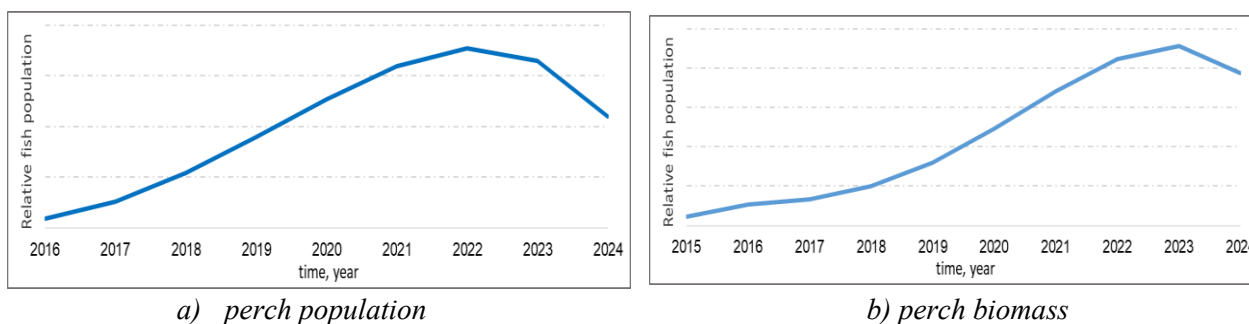


Figure 4. Dynamics of changes in the population and biomass of perch by year

The change in biomass generally follows the identified trends in numbers. Throughout the period, there was an increase, most pronounced from the end of the second decade, when a greater number of adults began to predominate in the population. The maximum values are in 2022–2023, after which a slight decrease is noted in 2024.

Figure 5 (a, b) shows changes in the dynamics of the abundance and biomass of the roach population in the period from 2015 to 2024. In the first years of observation, the population showed

a downward trend, reaching minimum values in 2017. Later, the situation changed: starting in 2018, there was a steady increase that continued until 2022. By 2023, the population remained relatively high, but in 2024 there was a noticeable decrease, which reflects the oscillatory nature of the dynamics of this species.

The change in biomass generally corresponds to the identified trends. After moderate fluctuations at the beginning of the period, a consistent increase in values was observed until 2022–2023, when a maximum was recorded. In 2024, the indicators decreased significantly, which coincides with a decrease in the population.

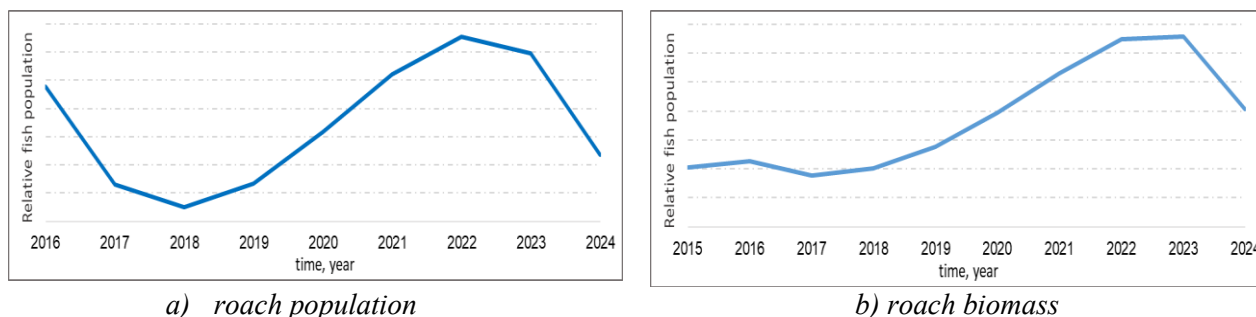


Figure 5. Dynamics of changes in the population and biomass of roach by year

Figure 6 (a, b) show changes in the abundance and biomass of the pike population in the period from 2015 to 2024. The population dynamics are characterized by a decrease in the first years of observations, when the indicators reached minimum values by 2018–2019. The situation gradually improved: starting in 2020, there was a steady increase, which continued until the end of the period, reaching a maximum in 2024. The change in biomass generally follows these trends. After a noticeable decrease in the first half of the period, the values remained low until 2019. Since 2020, a gradual recovery has been outlined, accompanied by an increase in biomass, which led to maximum values in 2024.

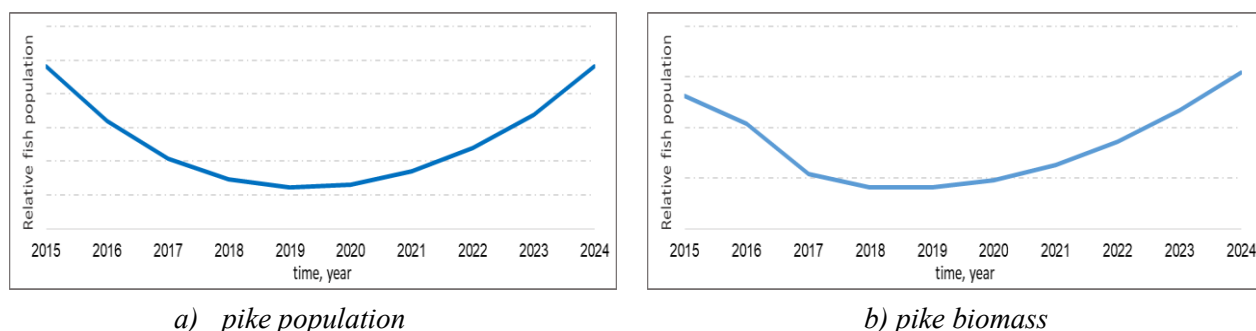


Figure 6. Dynamics of changes in the population and biomass of pike by year

To assess changes in the total fish population in a reservoir, it is necessary to track how the shares of individual species and age groups in the community structure change. Based on previously calculated indicators for each species, an integrated assessment of the total fish population was made for the period 2015–2024. Figures 7 and 8 show the dynamics of population change for all species considered, as well as the corresponding changes in their total biomass.

Based on the calculations of the population dynamics for five fish species (bream, pikeperch, perch, roach, pike) for the period 2015–2024, a steady upward trend is observed. A particularly pronounced increase is observed after 2020, indicating an improvement in the state of fish resources. The bream population made the greatest contribution to the growth of relative abundance. Thus, Figures 8 and 9 reflect the overall picture of the positive dynamics of the abundance and biomass of fish in Lake Zhaisan.

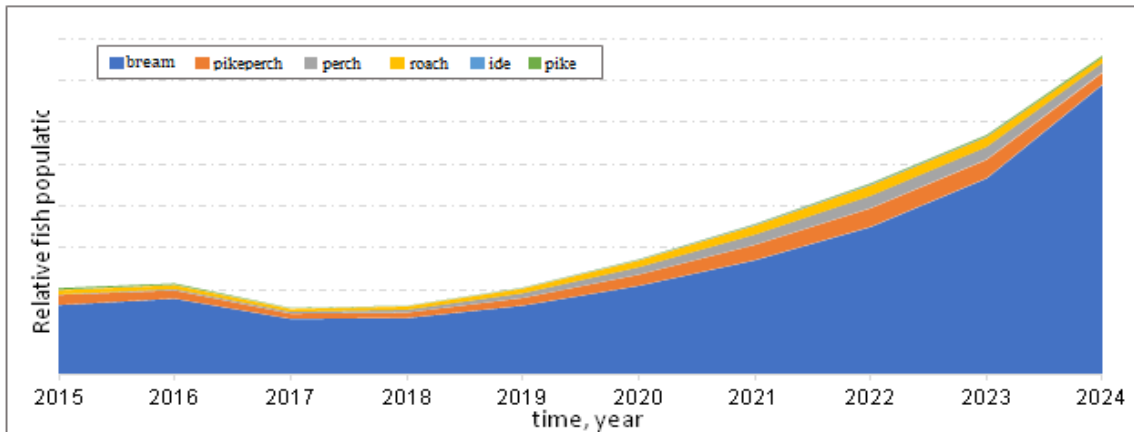


Figure 7. Dynamics of total abundance of all species

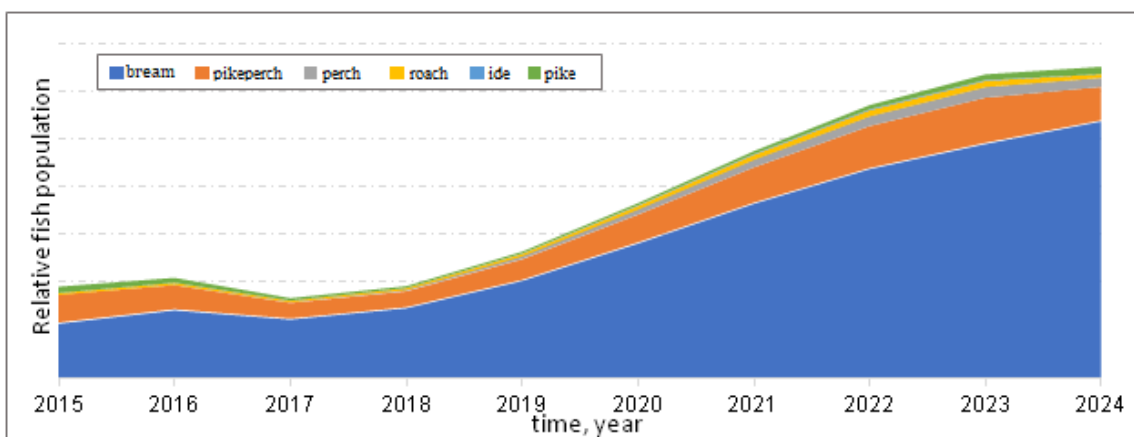


Figure 8. Dynamics of total biomass of all fish species

Discussion

The results obtained during the study demonstrate the high practical significance of the proposed cohort approach for assessing the abundance and biomass of fish populations in conditions of limited and fragmentary initial data. The use of smoothing methods based on polynomial regression made it possible to significantly increase the reliability of calculations and eliminate the influence of random fluctuations characteristic of research and commercial fishing data.

Analysis of the dynamics of changes in the fish population and biomass of the five main fish species of Lake Zhaisan revealed a stable positive trend, especially pronounced in the period after 2020. This may be due to a number of factors, including changes in the water regime, a decrease in fishing pressure, or other ecological and economic conditions. The most significant contribution to the growth of the total abundance and biomass was made by bream, which is consistent with its dominant position in the catch structure.

The advantage of the proposed model is its adaptability to incomplete and irregular data, as well as the possibility of application in the absence of information on sex composition, absolute abundance and biomass. This approach can be useful in the analysis of poorly observed or hard-to-reach water bodies, where traditional methods do not provide sufficient accuracy and completeness.

Conclusion

In this study, an approach to assessing the dynamics of changes in fish population and biomass based on cohort analysis and regression smoothing of sample data from scientific and commercial fishing was developed and implemented.

The application of this methodology to fish populations in Lake Zhaisan allowed us to identify a steady increase in relative abundance and biomass indicators over recent years, as well as to determine species-specific features of changes in age structure.

The proposed approach is a universal tool that allows assessing the state of aquatic bioresources in conditions of limited information. It can be recommended for further use in monitoring systems and scientific substantiation of management decisions in the field of protection and rational use of fish stocks, including within the framework of existing fisheries regulation programs in the Republic of Kazakhstan.

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