Research on Sevengill Eel Population and Ecosystem Stability Based on Sex Ratio Changes

Chunsong Li *

School of Computer Engineering, Tongda College of Nanjing University of Posts and Telecommunications, Yangzhou, China, 225127

* Corresponding Author Email: 1847998190@qq.com

Abstract. This study utilizes mathematical modeling, including difference and differential equations, to analyze the impact of gender ratio changes in seven-gill eels on ecosystem dynamics. The model incorporates population growth, gender ratio variations, and interactions with other ecosystem components. The findings reveal that a balanced sex ratio supports optimal population growth and ecosystem stability, while a male-dominated population reduces biodiversity and increases resource competition. Food availability and predator presence significantly affect the sex ratio, influencing the ecosystem's overall health. Using the TOPSIS method, the study determines that a higher proportion of females is most beneficial for ecosystem stability. Maintaining an optimal sex ratio is essential for ecosystem health, providing valuable insights for conservation and management efforts.

Keywords: Gender ratio, Logistic, Sevengill eel, TOPSIS.

1. Introduction

As global ecosystems continue to change, understanding the roles of various species in maintaining ecological balance becomes increasingly important [1, 2]. The seven-gill eel, as a keystone species, has a profound impact on the overall ecosystem dynamics. Particularly, changes in its gender ratio can significantly influence population growth and ecosystem stability [3].

This study employs difference and differential equations to construct and solve a mathematical model of ecosystem dynamics. By analyzing the gender ratio changes, population growth of seven-gill eels, and their interactions with other ecosystem components, we aim to understand the broader impacts of these changes on the ecosystem. Utilizing logistic growth models and Lotka-Volterra equations, this research seeks to reveal the effects of gender ratio changes on food resources, predator populations, and other ecological factors [4, 5].

Additionally, the study uses the TOPSIS method to evaluate the impact of gender ratio changes on the ecosystem [6, 7]. By assessing food supply, the role of parasites, and the quality of the living environment under different gender ratios, this study aims to identify the most favorable gender ratio for ecosystem stability. This research not only enhances our understanding of seven-gill eel population dynamics but also provides a scientific basis for ecosystem management and conservation.

2. Ecological Consequences of Male and Female Proportions in Sevengill Eels

The data for this study is sourced from https://www.comap.com/contests. Because the gender ratio of lampreys changes randomly, we believe it is appropriate to use mathematical knowledge to represent these changes. This study uses difference and differential equations to construct and solve a mathematical model of ecosystem dynamics. The model considers the population growth of lampreys, changes in the gender ratio, and the interactions with other components of the ecosystem. The initial conditions for the gender ratio are shown in Figure 1.

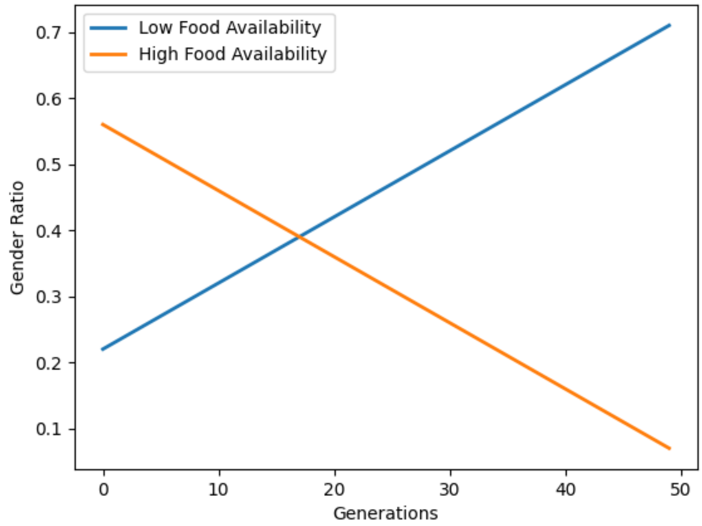

Figure 1. Simulated gender ratio in response to food availability

This study assumes that $N(t)$ the total number of seven gill eels at time t $N_{\mathrm{m}}(t)$ is the number of male seven gill eels, and $N_f(t)$ the number of female seven gill eels. The sex ratio is controlled by a simple logistic function, for example:

$$\alpha(t)=\frac{N_f(t)}{N(t)}=\beta\left(\frac{P_f(t)}{P_f(t)+P_m(t)}\right) \tag{1}$$

Where $P_f(t)$ and $P_m(t)$ are the number of food resources and predator populations at time t, respectively, and β are positive constants. The growth of the seven-gill eel population can be approximated as a Logistic growth model [1]:

$$\frac{dN}{dt}=rN(1-\frac{N}{K}) \tag{2}$$

Where r is the population growth rate and K is the environmental carrying capacity. Furthermore, the analytic solution of the model is:

$$N(t)=\frac{K}{1+(\frac{K-N_0}{N_0})e^{-rt}} \tag{3}$$

This study incorporates the effect of sex ratio into the quest for population growth model and obtains:

$$\frac{dN_m}{dt}=rN_m(1-\frac{N_m}{K}.\alpha(t)) \tag{4}$$

$$\frac{dN_m}{dt}=rN_f(1-\frac{N_f}{K}.\alpha(t)) \tag{5}$$

At the same time, this study believes it is also important to consider changes in food resources and predator populations, which may involve additional differential equations, e.g., changes in food resources can be described by the following equations:

$$\frac{dP_f}{dt}=P_f(a-bN(t)) \tag{6}$$

Where a and b are parameters for the growth and consumption of food resources.

$$\frac{dP_m}{dt} = P_m(c - dN(t)) \tag{7}$$

Where c and d are parameters of predator population growth and depletion. The sex ratio affects food resources as shown in Figure 2:

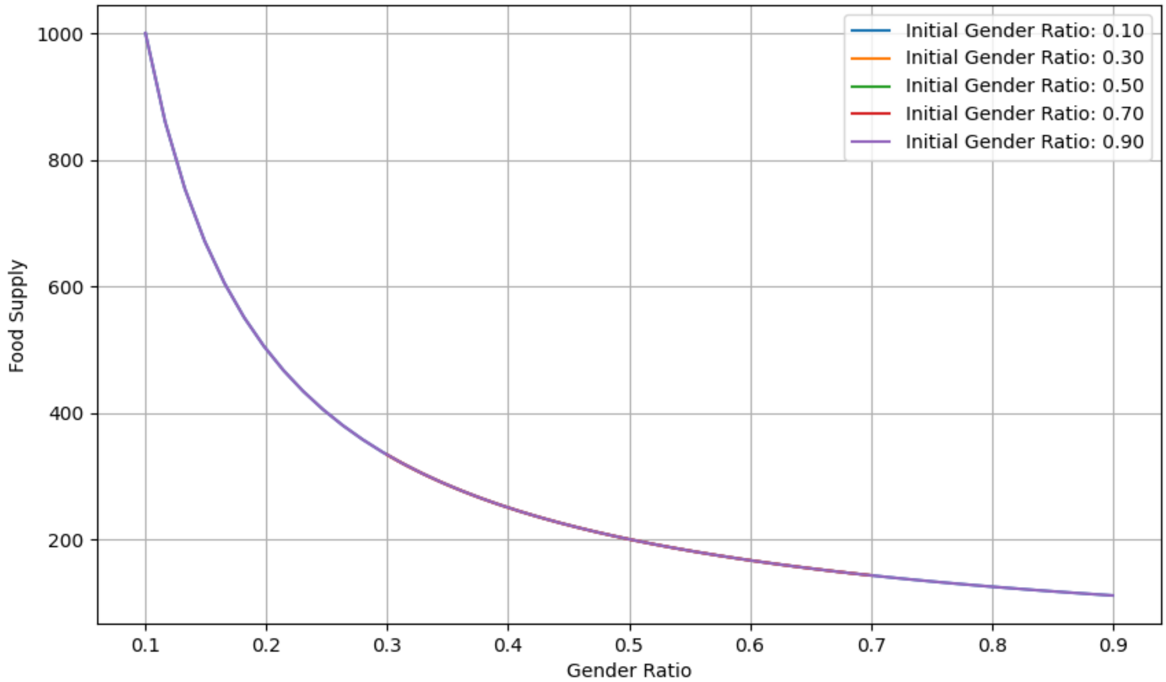

Figure 2. Effect of gender ratio on food supply.

Sex ratio affects the food chain:

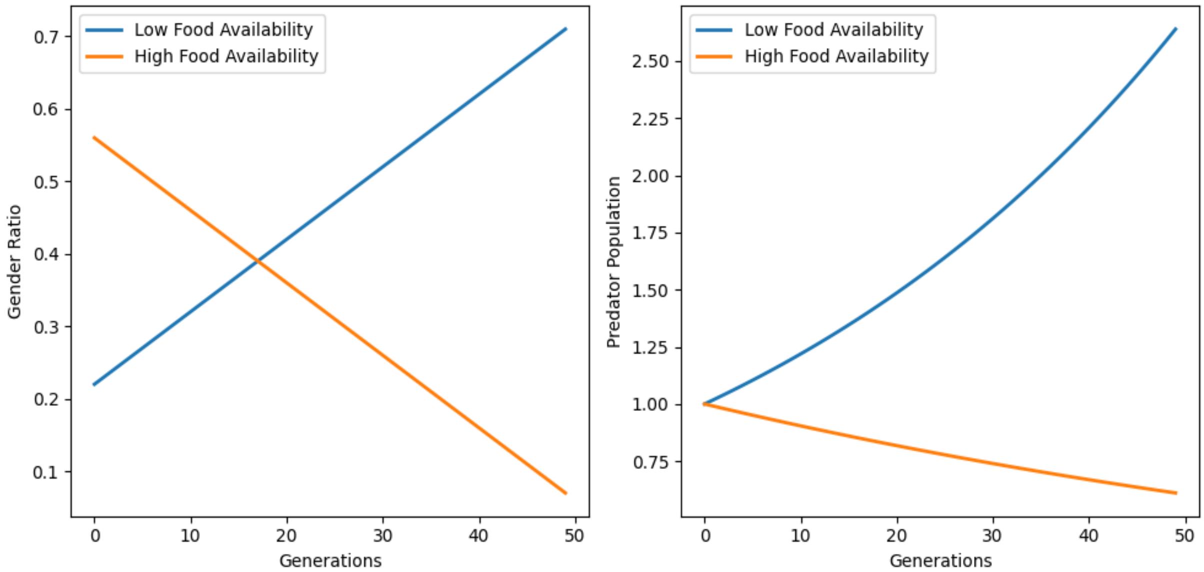

Figure 3. Simulated gender ratio in response to food availability.

In summary, this part constructs a differential equation model to analyze the effects on the larger ecosystem when the population of seven-gill eels can change the sex ratio [2]. This study believes the following impacts on the ecosystem will occur: When the proportion of males outnumbers females, the biodiversity of the ecosystem may be affected. A lack of food in the ecosystem at this point is not conducive to the reproduction of the seven-gill eel population, disturbing the ecological balance, and the seven-gill eels can be viewed as parasites. Conversely, when the proportion of female seven-gill eels is greater than that of males, the ecosystem remains stable and unaffected by the seven-gill eel population.

3. Logistic Growth Model and Its Application to Sevengill Eel Population

The growth of the seven-gill eel population can be described using a logistic growth model. This study used this model to explore the effect of food on population growth.

$$\frac{dN}{dt} = rN(1-S) - CN \tag{8}$$

$$\frac{dS}{dt} = \varphi(F) \tag{9}$$

Where r is the maximum natural growth rate of the population and C is the coefficient of resource competition, which is proportional to the reduction in food supply F. The ratio of dS to dt is a function that expresses the effect of food supply F on the sex ratio S. The ratio of dS to dt *is a* function that expresses the effect of food supply F on the sex ratio S.

From the Logistic growth model, we can learn that the closer the ratio of dS to dt *is to* 1, the more S tends to 1[8]. This indicates that the seven-gill eel population is living in a good environment. People in some areas do not lack food sources. The genetic diversity of the seven-gill eel population helps to improve the adaptability and resistance of the population. Meanwhile, when the sex ratio of the seven-gill eel is appropriate, the growth rate of the population will increase, which is favorable for better reproduction of the population. It also plays an important role in the stability of the ecosystem.

Sevengill eel stockiness can positively affect the food chain throughout the ecosystem. Predator populations are relatively stable.

We believe that an imbalance in the sex ratio can lead to the destruction of the ecosystem. It means that the environment in which the seven-gill-eel population lives is not good. The supply of food is not adequate. When resources are scarce in the living area, there is a lot of competitive pressure between individuals, which is not conducive to the long-term development of the population. The development of the population may also be affected by external factors. For example, damage to the ecosystem by human activities. As shown in Figure 4, the seven-gill eel stock may be at risk from overfishing.

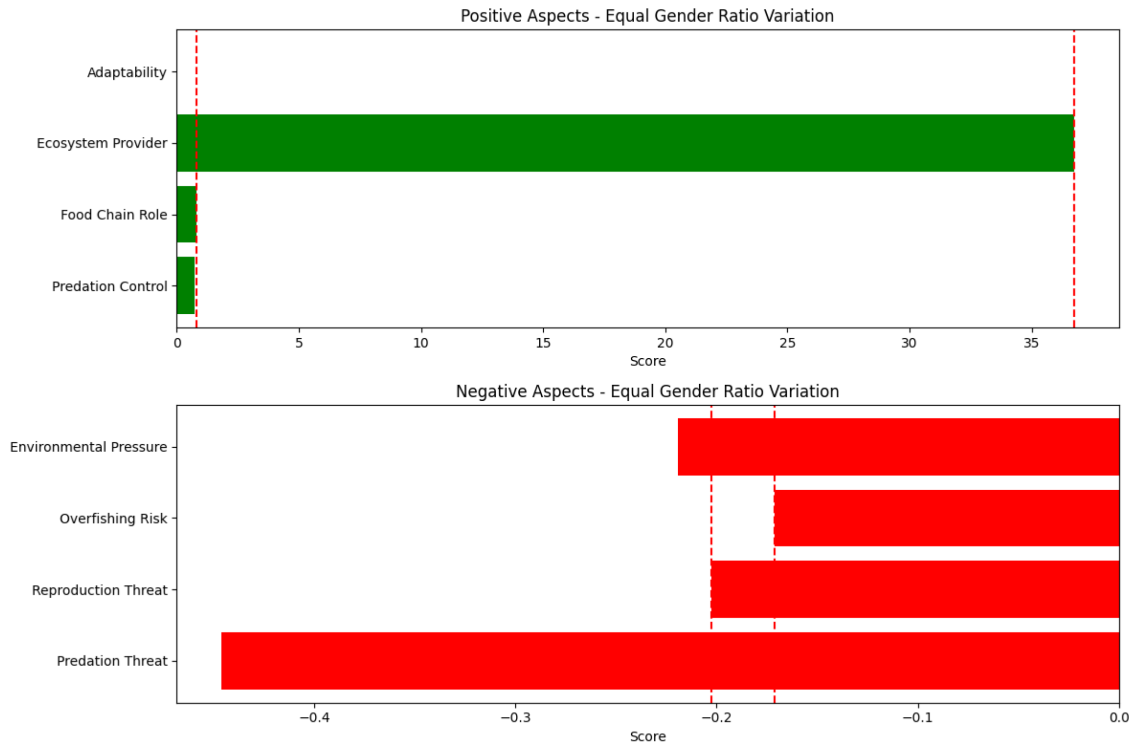

Figure 4. Equal gender ratio variation.

4. Optimal Sex Ratio and Ecosystem Benefits

To develop a mathematical model to address the effects of changes in the sex ratio of the seven-gill eel as a result of ecosystem stability, we believe that some basic assumptions and ecological knowledge need to be considered. For example, it is assumed that changes in the sex ratio affect the birth rate of the population. Other factors are assumed to remain relatively stable. For this purpose, this study collected relevant data about the seven-gill eels. We plan to use the Lotka-Volterra equation to characterize the effect of sex ratio on population size.

$$\frac{dN_m}{dt} = rN_m(1-\frac{N_m}{K}) - \alpha N_m N_f \tag{10}$$

$$\frac{dN_f}{dt} = rN_f(1-\frac{N_f}{K}) - \beta N_m N_f \tag{11}$$

After the study of the equation, we found the effect of the change of the sex of the seven-gill eel on the ecosystem. It is mainly discussed in the following aspects. Sevengill eels may be parasitized by parasites, and if there are too many males, it indicates that the local environmental conditions are not good, which affects the number of parasites, and thus the health status of other aquatic organisms, as shown in Figure 5[9]. The results of the adjustments in the food chain are shown in Figure 6.

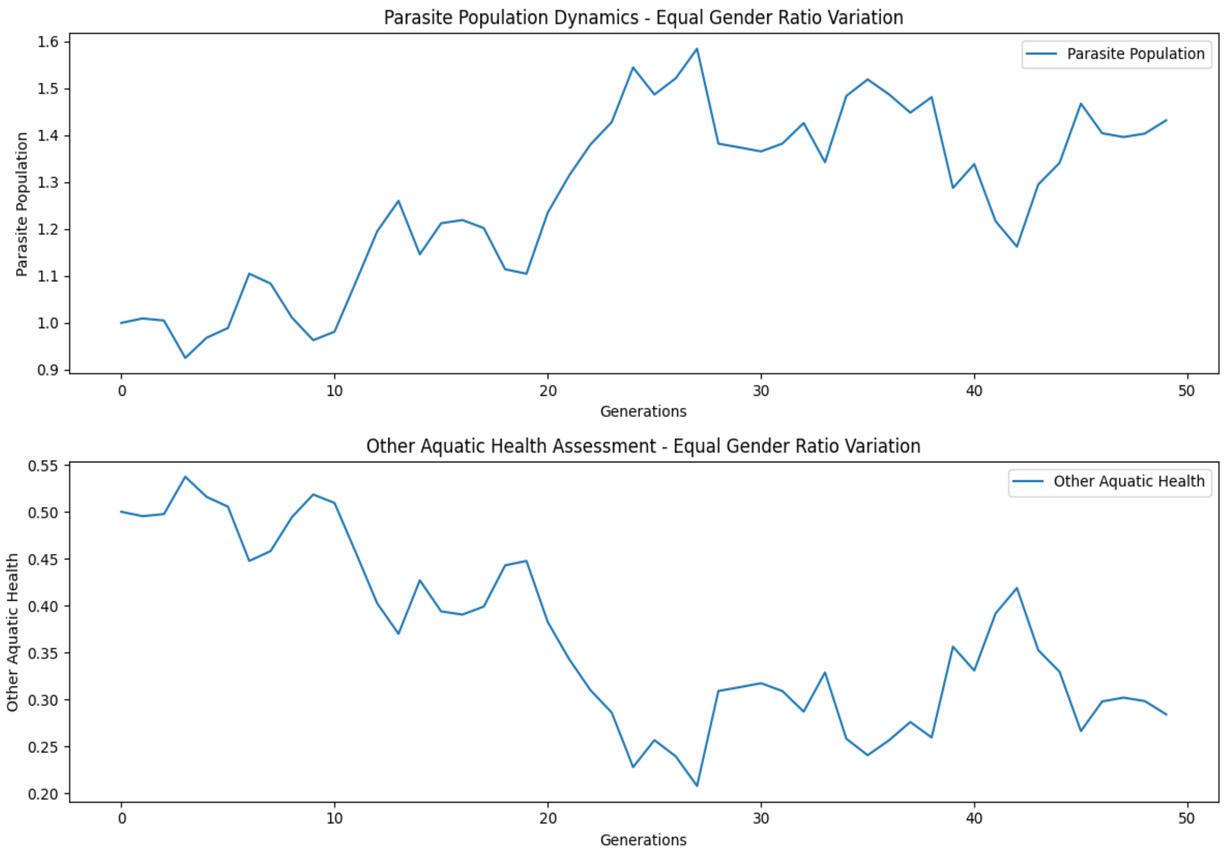

Figure 5: Impact of Equal Gender Ratio Variation on Parasite Population Dynamics and Other Aquatic Health.

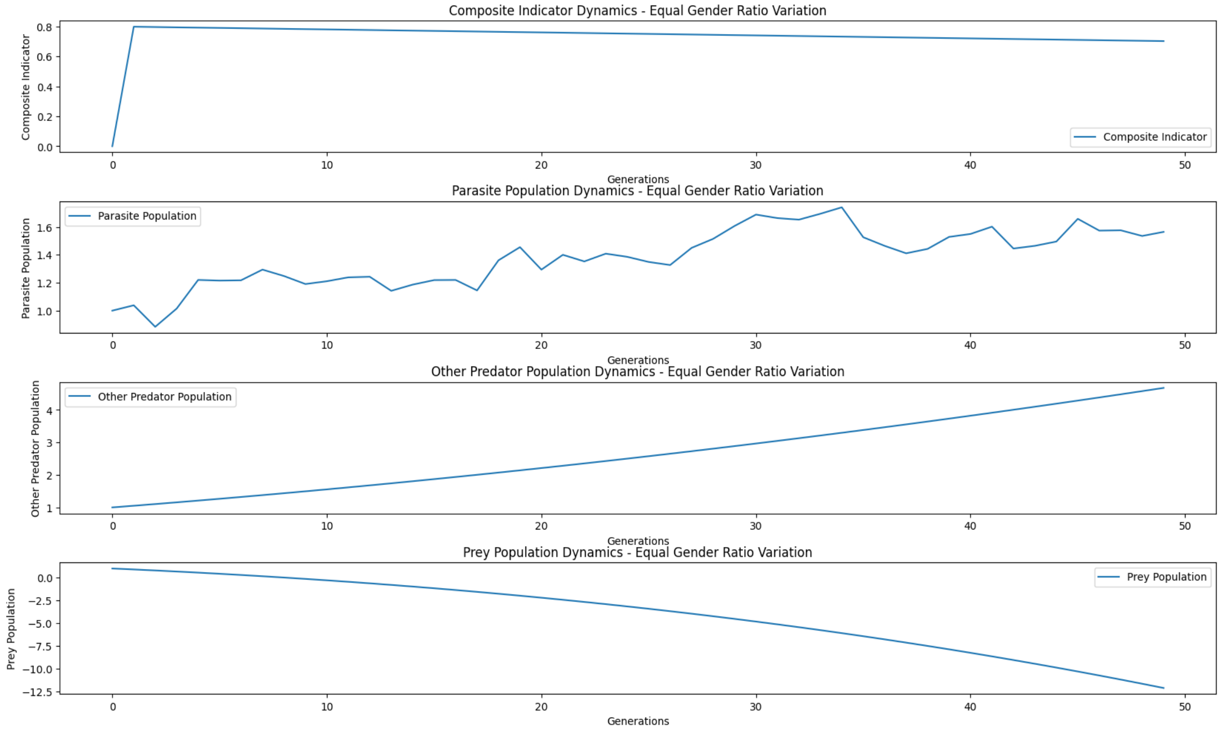

Figure 6. Effects of Equal Gender Ratio Variation on Composite Indicator, Parasite, Predator, and Prey Population Dynamics.

Changes in the sex ratio of the seven-gill eel population may lead to alterations in their feeding habits, which can affect the abundance of prey species and subsequently impact the organisms that parasitize them [10]. Additionally, changes in the sex ratio of the seven-gill eel population may result in other organisms competing with seven-gill eels for food. To further discuss the impacts on the food chain and the changes in competition and cooperation dynamics, this study will use the TOPSIS method for an in-depth analysis.

First, this study identified evaluation attributes. The evaluation attributes include food supply, the role of parasites on seven-gill eels, and the quality of the living environment. We assumed that the degree of impact is expressed as a number. As shown in Table 1, 1 indicates a high degree of impact and 3 indicates a minimal degree of impact. We assumed that the sex ratio is the ratio of male and female seven-gill eels.

Table 1. TOPSIS Evaluation of Gender Ratio Impacts.

Gender ratio	Provision	Effect	Environmental Quality
1	2	3	2
>1	3	3	3
<1	1	3	1

Then, the decision matrix is:

$$\begin{pmatrix} 2 & 3 & 2 \\ 3 & 3 & 3 \\ 1 & 3 & 1 \end{pmatrix} \tag{12}$$

Normalizing the decision matrix, yields the normalized matrix R

$$R_{ij} = \frac{X_{ij}}{\sqrt{\sum_1^3 X_{ij}^2}} = \begin{pmatrix} 0.12 & 0.18 & 0.12 \\ 0.33 & 0.33 & 0.33 \\ 0.09 & 0.27 & 0.09 \end{pmatrix} \tag{13}$$

Next, the decision weights are calculated:

$$\bar{W_i} = \sqrt[3]{\sum_{1}^{3} R_{ij}} \tag{14}$$

$$Y_{ij} = W_j * R_{ij} = \begin{pmatrix} 0.04 & 0.06 & 0.04 \\ 0.14 & 0.14 & 0.14 \\ 0.02 & 0.06 & 0.02 \end{pmatrix} \tag{15}$$

The final calculation yields three relative closeness values: 0.57, 0, and 0.70. In summary, this study believes that the third sex ratio is the most appropriate. The third sex ratio is advantageous for other species in the ecosystem.

5. Conclusions

This study used mathematical modeling to analyze the ecological impact of changes in the sex ratio of seven gill eels. We found that a balanced sex ratio supports optimal population growth and ecosystem stability, while male-dominated populations decrease biodiversity and increase resource competition. Food availability and predator presence significantly influence the sex ratio, affecting overall ecosystem health.

Using the TOPSIS method, we determined that a higher proportion of females benefits the ecosystem most, promoting stability and reducing negative impacts. Maintaining an optimal sex ratio is crucial for ecosystem health, offering valuable insights for conservation and management efforts. Future research should continue to explore these dynamics, incorporating additional environmental factors and long-term data.

References

[1] SAGE R F. Global change biology: a primer [J]. Global Change Biology, 2020, 26(1): 3-30.

[2] HOBBS R J, CRAMER V A. Restoration ecology: interventionist approaches for restoring and maintaining ecosystem function in the face of rapid environmental change [J]. Annual Review of Environment and Resources, 2008, 33(1): 39-61.

[3] CHEN J, ZHU Y, JIN Y. Establishment and application of a population prediction model for lamprey based on gender ratio transformation[C]//. Third International Conference on Biomedical and Intelligent Systems (IC-BIS 2024): SPIE, 2024: 447-452.

[4] DAS S, GUPTA P K. A mathematical model on fractional Lotka–Volterra equations [J]. Journal of Theoretical Biology, 2011, 277(1): 1-6.

[5] ROS V, ROY F, BIROLI G, et al. generalized lotka-volterra equations with random, nonreciprocal interactions: The typical number of equilibria [J]. Physical Review Letters, 2023, 130(25): 257401.

[6] CHAKRABORTY S. TOPSIS and Modified TOPSIS: A comparative analysis [J]. Decision Analytics Journal, 2022, 2: 100021.

[7] WANG Y, LIU P, YAO Y. BMW-TOPSIS: A generalized TOPSIS model based on three-way decision [J]. Information sciences, 2022, 607: 799-818.

[8] SCHOBER P, VETTER T R. Logistic regression in medical research [J]. Anesthesia & Analgesia, 2021, 132(2): 365-366.

[9] ZHANG S. Differential Equation-Based Study on Sex Ratio and Ecosystem Interaction of Seven Gill Eel [J]. Academic Journal of Mathematical Sciences, 2024, 5(2): 84-90.

[10] ZHANG Y, YAO S. Sex Ratio of Seven Gill Eels Based on System Dynamics and Dynamic Generalisation Models [J]. Highlights in Science, Engineering, and Technology, 2024, 93: 109-119.