Academic Journal of Environment & Earth Science
ISSN 2616-5872 Vol.6, Issue 5: 31-36, DOI: 10.25236/AJEE.2024.060505

Study on Lampreys population and ecosystem based on logistic model

Xiangkai Wang#, Zifan Cao#, Qinsheng Xu#

College of Mechanical and Power Engineering, Shenyang University of Chemical Technology, Shenyang, 110142, China
#These authors contributed equally.

Abstract: *The sex ratio of lampreys has some effect on the ecosystem. To examine the impacts of changing sex ration ecosystem, the paper used logistic model to describe the relationship between sex ratio and food resources. The paper established a comprehensive population dynamics model by adding different niche and food web influence conditions, and then used a weighted scoring model to analyze the impacts on ecosystem. To investigate the strengths and weaknesses of lamprey populations in the ecosystem, data were first collected and analyzed in contrast to the data of lamprey populations from other biological populations. Factors with large differences after comparison of different data were mainly selected as influencing factors. On the basis of the original, the population dynamic model was improved, and the advantages and disadvantages of the population were analyzed by the weighted scoring model. Sorts through the above analysis can understand the advantages and disadvantages of its species change sex ratio ability, and the mutual influence between and ecological system.*

Keywords: *Logistic model, Population dynamics model, Lampreys*

1. Introduction

In the field of ecology and evolutionary biology, population sex ratio has always been one of the research hotspots. Sex ratio changes not only reflect the population of the internal control mechanism, and is closely related to the stability of ecosystem and biodiversity. Lamprey, as a special fish, has a remarkable mechanism of sex determination and sex ratio change. In recent years, a large number of studies have been conducted on the variation[1] of sex ratio of lamprey in an attempt to reveal the underlying biological mechanisms and their effects on the ecosystem. In this paper, we successfully developed models describing the relationship between sex ratio and food resources in lamprey populations by employing logistic models, which not only deepens our understanding of lamprey population dynamics, but also provides new perspectives for ecosystem research. Logistic model in describing the population growth and distribution of food resources application has been widely recognized. This paper study further proves that the model in lampreys applicability in the study of populations, provides reference to similar populations. By comparing data from lamprey populations with those from other biological populations, key factors affecting population dynamics were identified. This data-driven approach improves the reliability and utility of the study and provides a scientific basis for the development of conservation and management strategies. Introducing weighted scoring model for the analysis of population advantage and disadvantage of ecosystem[2] provides a new tool. This model can not only quantify populations within and between species and ecosystem affect each other, also can provide policy makers with intuitive evaluation results. With the deepening of research and the accumulation of data, this model can be further optimized to improve its prediction accuracy and applicability. For example, can consider to introduce more ecological factors, such as climate change, environmental pollution, etc., in order to more fully describe the population dynamics. The results presented here are not only applicable to the study of lamprey populations, but can also be extended to other similar populations and ecosystems[3]. More precise conservation measures can be formulated to promote the protection of biodiversity and the sustainable development of ecosystems.

2. Sex ratio and resource availability analysis

The sex ratio of lampreys can vary depending on the external environment. The rate at which lampreys develop during the larval stage determines whether they are male or female. The growth rate

ISSN 2616-5872 Vol.6, Issue 5: 31-36, DOI: 10.25236/AJEE.2024.060505

of these larvae is affected by the availability of food. In environments where food availability is low, growth rates will be low and males can make up about 78% of the population. In environments where food is more readily available, the proportion of males observed is about 56% of the population.

In the context of considering the changing sex ratio of lamprey, a Logistic model[4] can be used to describe how food availability affects the rate of development at the larval stage and thus the sex ratio. Logistic models are usually used to describe the growth of a population or the change in a particular trait, and the equations have the following form:

$$P(t) = \frac{1}{1 + e^{-r(t-t_0)}} \tag{1}$$

This model is based on a Logistic function[5]with a sigmoid curve and is often used to describe the development or change of a characteristic in a population of organisms. Can therefore be interpreted $P(t)$ larvae into the probability of a female. The parameter r represents the rate of development and t_0 represents the time at which the sex ratio begins to change. Models of sex determination applicable to lampreys may need to consider more complexities, such as the effect of environmental temperature on developmental rates. Therefore, the model can be further extended to account for environmental factors, where the environmental temperature T can be used as a regulating parameter:

$$P(t) = \frac{1}{1 + e^{-r(T)(t-t_0)}} \tag{2}$$

Where $r(T)$ represents the effect of temperature T on the rate of development (not considered).

Setting $r = 0.5$ and $t_0 = 1$ in the model yields the simulated data as shown in the Figure.1.

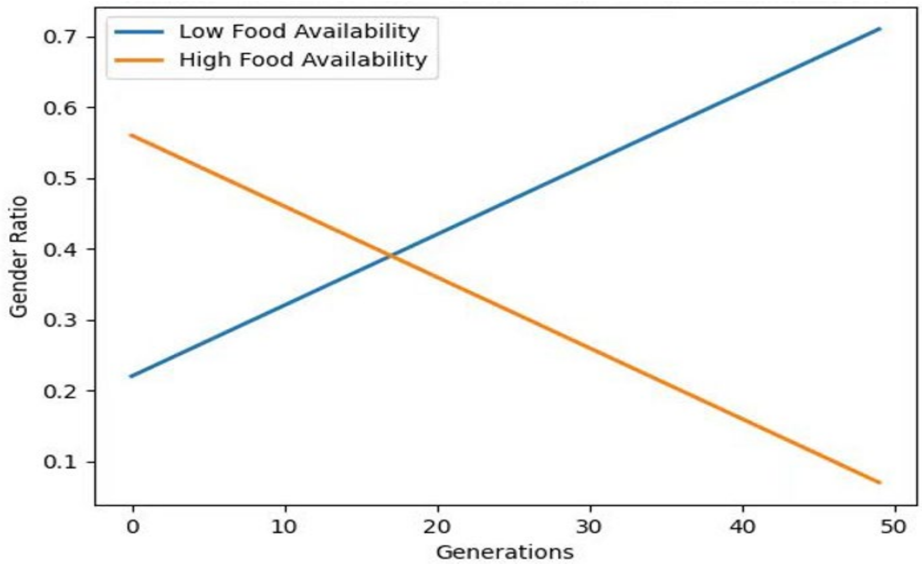

Figure 1: Simulated Gender Ratio in Response to Food Availability

2.1 Model Solving Sex ratio and niche analysis

The paper will use the data in the above model as a surrogate model. The lamprey surrogate model is embedded in the ecosystem dynamics model. Then the simulated breeding of lamprey was carried out, and the breeding success rate was proportional to the sex ratio affected by the sex ratio, and the simulated resources affected the sex ratio, and the average breeding success rate was recorded.

$$\alpha_n = \alpha(n-1) - 0.005 * \left|(\alpha - 0.5)\right| \tag{3}$$

The sex ratio is affected by the availability of resources. With high resource availability, the sex ratio will increase accordingly, but it will not exceed 1 at most. After 100 time steps of iteration, the position

ISSN 2616-5872 Vol.6, Issue 5: 31-36, DOI: 10.25236/AJEE.2024.060505

with the highest reproduction rate is found and marked with a red line to obtain Figure.2.

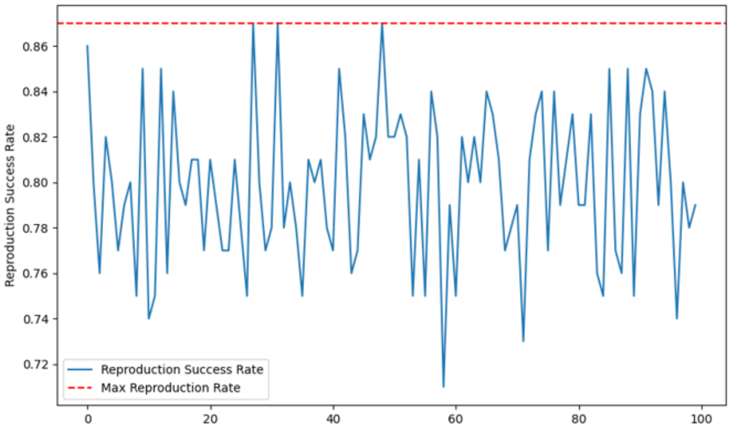

Figure 2: Resource availability and the relationship between the reproduction rate

2.2 Sex ratio and niche analysis

According to the surrogate model, the relationship bet. The paper the sex ratio and the predators in the food The paper was considered. Variation in the proportion of males set in the model depends on food availability. The function sets the initial proportion of males based on food availability and updates the proportion of males at each time step. The specific calculation formula is as follows. In environments with less food, the proportion of males increased:

$$R_m(n) = R_m(n-1) + 0.01 \tag{4}$$

In environments with more food, the proportion of males decreases:

$$R_m(n) = R_m(n-1) - 0.01 \tag{5}$$

Simulating changes in the number of predators: in each time step, based on the availability of food, the number of predators is updated. The specific calculation formula is as follows.

In environments with less food, the number of predators increases:

$$S_n = S(n-1) * (1 + 0.02) \tag{6}$$

The paper predators in environments with more food:

$$S_n = S(n-1) * (1 - 0.01) \tag{7}$$

It is substituted into the population dynamics mode[6]and iterated. As shown in Figure 3.

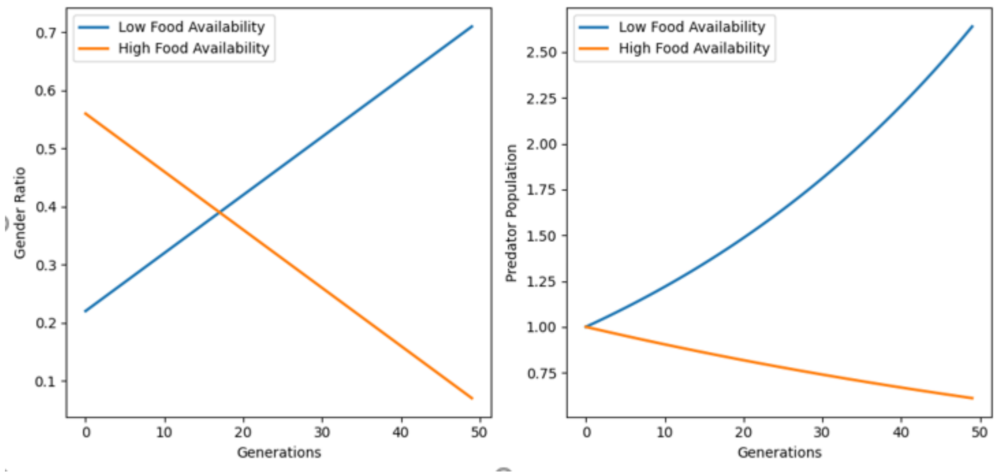

Figure 3: Smooth Composite Indicator in Different Gender Ratios

ISSN 2616-5872 Vol.6, Issue 5: 31-36, DOI: 10.25236/AJEE.2024.060505

Consider the relationship bet The paper sex ratio and food resources.

The change of sex ratio from all-female to all-male was set in the model, and the initial number of food resources was set to one.

$$Fn = F(n-1) - 0.02 \tag{8}$$

It is substituted into the population dynamics model[7]and iterated. As shown in Figure 4.

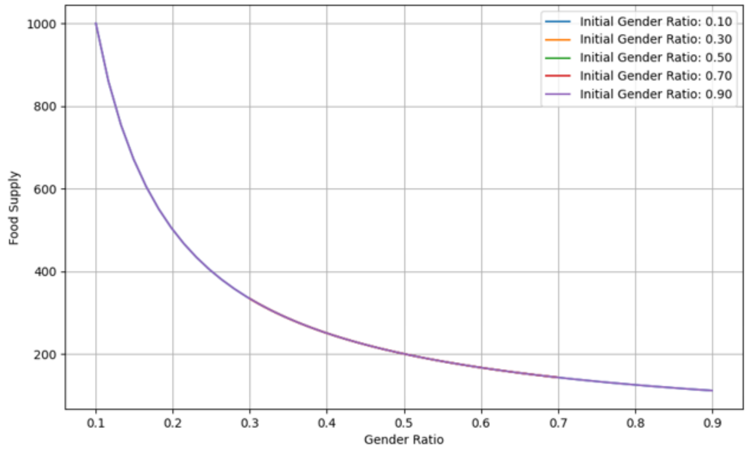

Figure 4: Effect of Gender Ratio on Food Supply

2.3 Comprehensive assessment of ecosystem impacts

Based on these results, the paper can see the impact of changing sex ratios on the food chain and reproductive success, and in general, changing sex ratios can lead to changes in the abundance and division of other biological groups, which has a ripple effect on the entire ecosystem. As shown in Figure 5.

$$C_{1n} = 0.3R + 0.4S + 0.2\alpha + 0.1F \tag{9}$$

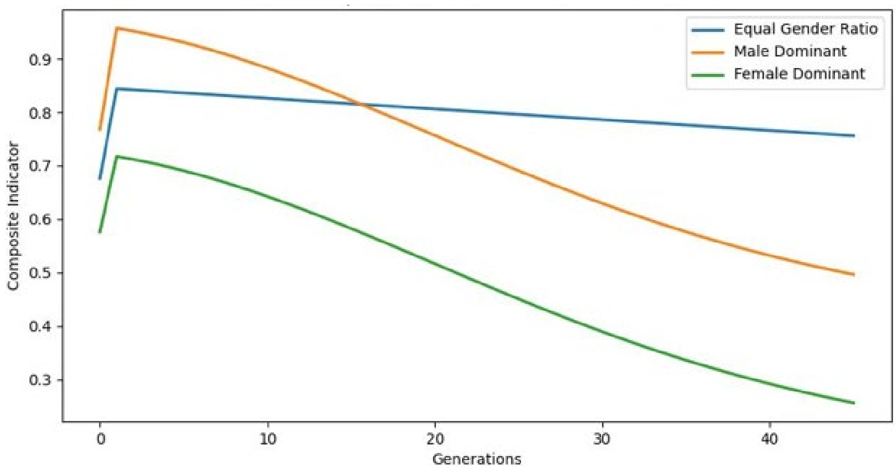

Figure 5: Smooth Composite Indicator in Different Gender Ratios

3. Strengths and The paperaknesses of lamprey populations

Based on the above analysis, an ecosystem model[7] was established from the perspectives of male proportion, reproductive success, predator number, and food resources.

Then they are divided into three groups according to the change of sex ratio[9]: male dominant and female dominant and gender equal, respectively, the change of each generation is simulated in cycles, and a composite index is calculated. At the same time, some negative factors are also simulated, such as the level of threat from predation on other species, the level of threat to reproduction, the level of risk of overfishing, and the level of environmental stress. Computational model for composite indicators: This model[10]calculates a composite indicator by means of The paperighted summation, which is used to assess the state of the lamprey population. The specific formula is as follows. As shown in Figure.6.

$$C_{2n} = 0.4R_s + 0.3S_n + 0.2\alpha_n + 0.1F_n \tag{10}$$

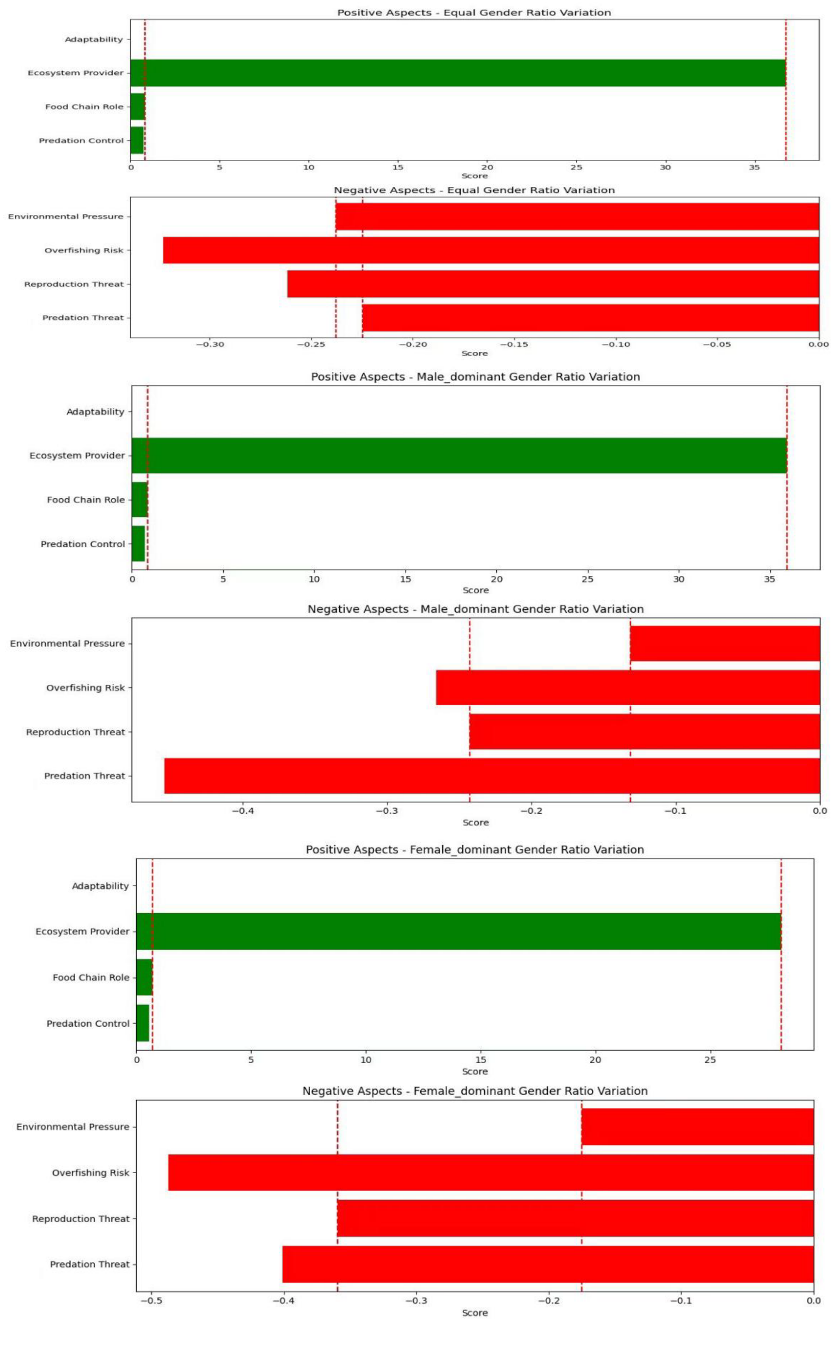

Figure 6: Population status in different environments

According to the above results, the paper can analyze that the population has advantages in parasite control, environmental adaptability and as a provider in the ecosystem. In competition, it is vulnerable to environmental pressure, as the paper as threats from other organisms, and its destruction of ecological balance.

ISSN 2616-5872 Vol.6, Issue 5: 31-36, DOI: 10.25236/AJEE.2024.060505

4. Conclusions

In this paper, we successfully developed models describing the relationship between sex ratio and food resources in lamprey populations by employing logistic models, which not only deepens our understanding of lamprey population dynamics, but also provides new perspectives for ecosystem research. Logistic model in describing the population growth and distribution of food resources application has been widely recognized. This paper study further proves that the model in lampreys applicability in the study of populations, provides reference to similar populations. By comparing data from lamprey populations with those from other biological populations, key factors affecting population dynamics were identified. This data-driven approach improves the reliability and utility of the study and provides a scientific basis for the development of conservation and management strategies. Introducing weighted scoring model for the analysis of population advantage and disadvantage of ecosystem provides a new tool. This model can not only quantify populations within and between species and ecosystem affect each other, also can provide policy makers with intuitive evaluation results. With the deepening of research and the accumulation of data, this model can be further optimized to improve its prediction accuracy and applicability. For example, can consider to introduce more ecological factors, such as climate change, environmental pollution, etc., in order to more fully describe the population dynamics. The results presented here are not only applicable to the study of lamprey populations, but can also be extended to other similar populations and ecosystems. More precise conservation measures can be formulated to promote the protection of biodiversity and the sustainable development of ecosystems.

References

[1] Ali M , Shah S F , Ullah A S F .A study on the consumption of safe drinking water and its determinants using the weighted multinomial logistic model[J].Aqua: water infrastructure, ecosystems and society, 2023, 72(9/12):2422-2445.

[2] Wang Y G , Kong J , Lan L ,et al.Assessing the Gumbel-Logistic Model's performance in modeling long-term rainfall series in a high-latitude plain region[J].Theoretical and Applied Climatology, 2024, 155(5):3891-3905.DOI:10.1007/s00704-024-04859-0.

[3] Chen H , Fan W , Zhang L .Glass classification and identification based on Lasso-logistic model and K-means clustering[J].Highlights in Science, Engineering and Technology, 2023.DOI:10.54097/ hset. v42i. 7100.

[4] Martinussen T , Scheike T .Efficient t 0 -year risk regression using the logistic model[J].Scandinavian Journal of Statistics, 2023.DOI:10.1111/sjos.12658.

[5] Ye Y , Liu Z , Pan D ,et al.Regression analysis of logistic model with latent variables[J].Statistics in medicine, 2023.DOI:10.1002/sim.9647.

[6] Jing-Tian W , Xiao-Yu C , Qiong Z ,et al.FastBiCmrMLM: a fast and powerful compressed variance component mixed logistic model for big genomic case-control genome-wide association study[J]. Briefings in Bioinformatics, 2024(4):4.DOI:10.1093/bib/bbae290.

[7] Mahto A K , Tripathi Y M , Dey S ,et al.Bayesian estimation and prediction under progressive-stress accelerated life test for a log-logistic model[J].Alexandria Engineering Journal, 2024, 101:330-342.DOI:10.1016/j.aej.2024.05.045.

[8] Karakaya H , Kartal S , Ozturk I .Qualitative behaviour of discrete-time Caputo-Fabrizio Logistic model with Allee effect[J].International Journal of Biomathematics, 2023.DOI:10.1142/s 1793524 523500390.

[9] Sawada Y , Takeuchi Y , Dong Y .Dynamics of a two-patch logistic model with diffusion and time delay[J].IOP Publishing Ltd, 2024.DOI:10.1088/1361-6544/ad55a0.

[10] Indu R , Dimri S C .Detecting Spam E-mails with Content and Weight-based Binomial Logistic Model[J].Journal of Web Engineering, 2023(7):22.