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Research on the Impact of Resource Availability: A Case Study of Lamprey

Haixiang Liang, Caihua Qiu *, Qihan Huang, Fengyi Chen, Zhuang Jin

Guangdong University of Science and Technology, Dongguan, Guangdong, China

*** Corresponding author:** Caihua Qiu (Email: 32320062@qq.com)

Abstract: The changes in resource availability significantly affect the development of one's own population. This article aims to study the availability of lamprey resources, which affects the reproductive success rate and sex ratio of lamprey, and further affects the lamprey population, other populations, and even the entire ecosystem. In order to achieve our research objectives, we used a reproductive success model and a resource utilization efficiency model to simulate the population density changes of lampreys under different resource conditions, and analyzed the specific impact of resource availability on population density, other species diversity, and ecosystem stability.

Keywords: Lamprey; Resource Availability; Resource Utilization Efficiency Model.

1. Introduction

The ocean is a fundamental component of the global life support system. The sustainable development of marine resources and environment is an important foundation for supporting social and economic development [1]. The lamprey is known as a "living fossil" [2] and represents the primitive type of vertebrate, playing an important role in the evolutionary history of vertebrates[3]. According to relevant literature, the resource of Chinese lampreys has sharply declined and has been listed as a vulnerable species in the Red List of Chinese Species. It is one of the rare and endangered aquatic animals in China. At the same time, there is little research on lampreys in China, so the protection of lampreys resources is urgent[4]. To understand the impact of the biological abundance of lamprey [5], this article aims to explore the resource availability of lampreys and analyze their effects on ecosystems, populations, and other organisms to ensure the sustainable use of lampreys resources.

2. Technology

To explore the effect of resource availability on lamprey, the reproductive success model was used to predict prey reproductive success [6]. a b This article defines reproductive success rate as the independent variable, resource quantity as the dependent variable, and a and b as weight coefficients used to regulate the impact of resource quantity and gender ratio on reproductive success rate. In addition, we conducted data collection, integration, and analysis to study the impact of different resource levels on the reproductive success rate of lampreys. Definition formula:

$$P = aR + bf(x) \tag{1}$$

Among them, P represents the success rate of reproduction; R represents the amount of resources; $f(x)$ represents the gender ratio.

By comparing the resource utilization efficiency of male and female lampreys, we used a resource utilization efficiency model to analyze the impact of their sex ratio on resource utilization efficiency, and examined the effects on their population density and ecosystem under this influence. Definition formula:

$$E = cf(x) + d \tag{2}$$

c and d are parameters of the regression model, representing the degree and baseline level of the impact of gender ratio on resource utilization efficiency.

Because the population density of lampreys is influenced by their sex ratio, and resource availability is also constrained by their population. Definition formula:

$$S(t) = X(t) + Y(t) \tag{3}$$

$X(t)$ represents the number of female individuals in the population of lampreys; $Y(t)$ represents the number of male individuals in the population of lampreys.

According to the change in the sex ratio between females and males, the formula is defined as:

$$f(x) = \frac{X(t)}{Y(t)} \tag{4}$$

Among them, x represents the resource availability coefficient.

By exploring the impact of resource availability on the reproductive ability of female individuals and the survival ability of male individuals. Definition formula:

$$\frac{dX(t)}{dt} = f(R(t)) \bullet X(t) \tag{5}$$

$$\frac{dY(t)}{dt} = g(R(t)) \bullet Y(t) \tag{6}$$

$R(t)$ represents the variable of resource availability at time t; $f(R(t))$ represents the impact of resource availability on the reproductive ability of female individuals; $g(R(t))$ represents the impact of resource availability on the survival

ability of male individuals; $\frac{dX(t)}{dt}$ and $\frac{dY(t)}{dt}$ represent the rate of change in the number of female and male individuals over time, respectively.

Based on the search and analysis of the gender ratio of lampreys caused by the abundance of environmental food, a differential equation is established through the impact of resource availability on the gender ratio, and the formula is defined as follows:

$$f(R(t)) = \frac{b}{1 + A \cdot \exp(-r \cdot R(t))} \tag{7}$$

$$g(R(t)) = ae^{cR(t)} \tag{8}$$

And b is the maximum value of reproductive ability; A is the function value at the inflection point of the growth curve; r is the growth rate, a represents the survival ability when there are no resources, and c represents the growth rate of the impact of resource availability on survival ability.

Based on the changes in resource availability, the reproductive success model and resource utilization efficiency model are used to evaluate the changes in different resource quantities, in order to analyze the gender ratio of lampreys and the impact of changes in reproductive success rate. Based on the impact of resource utilization on the reproductive success rate and sex ratio of the lamprey population, we established a corresponding mathematical model and used Python to analyze the dynamic changes in resource quantity and lamprey population, and drew corresponding relationship diagrams. Through data analysis, we found that changes in the food resources of the lamprey population can affect its sex ratio, and as the resources increase, the lamprey population also increases. The changes in population density and growth rate indirectly affect the entire ecosystem.

3. Methods

The availability of resources can affect the male to female ratio of the lamprey population, and there may be changes in the population size, which in turn can lead to changes in the ecosystem in which the lamprey is located. Therefore, under different resource utilization rates, PIT telemetry technology was used to monitor the movement activity of juvenile lampreys in an artificial stream at the Hammond Bay Biological Station in Milsburg [7] , Michigan. As shown in **Fig.1**.

Tagging_Date	Release_Date	Recovered	Died	Detected	Source	Length	Weight	Surgeon	Surgery_Notes
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	182	8.7	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	155	5.9	EL	Bleeding
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	150	4.7	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	159	6	EL	NA
10/23/2014	10/27/2014	2/6/2015	0	0	Morpion	152	4.6	EL	protruding viscera
10/23/2014	10/27/2014	2/6/2015	0	1	Morpion	164	5.6	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	171	6.8	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	163	6.6	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	156	5.2	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	172	7.3	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	164	6.8	EL	NA
10/23/2014	10/27/2014	NA	NA	1	Morpion	170	6.7	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	152	4.8	EL	small, bleeding
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	163	5.3	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	170	7	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	0	Morpion	167	6.9	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	151	4.9	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	160	5.7	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	156	5	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	0	Morpion	162	6.2	EL	NA
10/23/2014	10/27/2014	2/6/2015	0	1	Morpion	165	6.3	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	170	6.8	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	172	7.4	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	176	8.5	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	182	8.4	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	165	6.3	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	158	4.8	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	158	5.6	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	173	7.1	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	168	6.5	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	176	7.6	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	0	Morpion	152	4.6	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	163	5.8	EL	bleeding
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	179	8.1	EL	NA
10/23/2014	10/27/2014	2/6/2015	0	1	Morpion	162	5.8	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	185	9.1	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	167	6.4	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	164	6.9	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	162	5.3	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	157	5.6	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	145	6.4	EL	stumpy tail
10/23/2014	10/27/2014	1/6/2015	0	1	Morpion	175	7.4	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	157	5.9	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	168	6.1	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	172	7.2	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	155	4.9	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	163	5.6	EL	NA
10/23/2014	10/27/2014	2/3/2015	0	1	Morpion	168	6.4	EL	NA

Fig 1. Artificial flow of lamprey data

Due to the varying availability of this resource in different environments, the population abundance of lampreys may also be affected. Based on experimental data, a comparative analysis was conducted on the population size and expected situation of lampreys in different regions [8]. As shown in Table 1.

Table 1. The changes of lamprey in different regions

lake	Lamprey Compared to that expected	Abundances index
Superior	Above target	Flat
Michigan	Meeting target	Flat
Huron	Above target	Flat
Erie	Meeting target	Flat
Ontario	Meeting target	Flat

4. Results Analysis

4.1. Impact on the Population

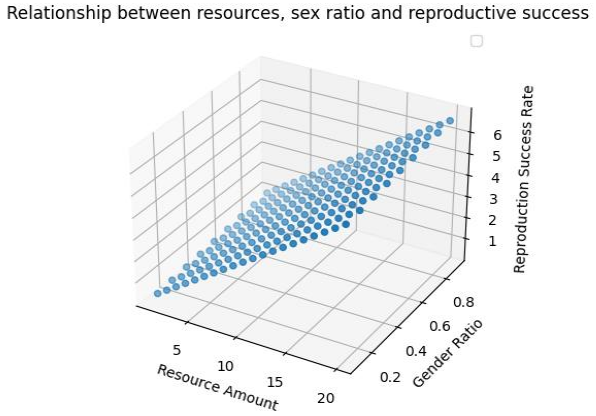


Fig 2. The relationship between resource quantity, sex ratio rate and reproductive success rate

Draw a relationship diagram using formula (1) to illustrate the impact of different resource levels on the reproductive success rate of lampreys. Analysis shows that resource abundance and gender ratio have a significant impact on the reproductive success rate of lampreys. As shown in **Fig. 2**, under different resource conditions, the change in sex ratio plays an important role in reproductive success rate. Specifically, when the sex ratio approaches 0.5 (i.e. the number of males and females is roughly equal), the reproductive success rate of lampreys is relatively high. The adaptation of this gender ratio is believed to be beneficial for lampreys to better utilize their resources and environment, thereby increasing their population size and growth rate. In the case of reduced resources, the number of male lampreys decreases while the number of females increases. This change is seen as an adaptive strategy that helps promote population development and improve overall reproductive capacity.

4.2. Impact Effects on Other Organisms

As shown in **Fig. 3**, the increase in resources leads to a tendency for juvenile lampreys to develop into females. As the number of female lampreys increases, the population of lampreys also increases accordingly. This directly affects the number of preys. If the prey source is sufficient, the population of lampreys can grow steadily; On the contrary, if the source of prey is insufficient, the population of lampreys will decrease. This will provide more food sources for natural enemies, which is beneficial for increasing their numbers and expanding their breeding space. In summary, the changes in the population size of lampreys are closely related to the number of female lampreys and the abundance of resources. At the same time, these changes indirectly affect the number and breeding space of natural enemies that feed on lampreys.

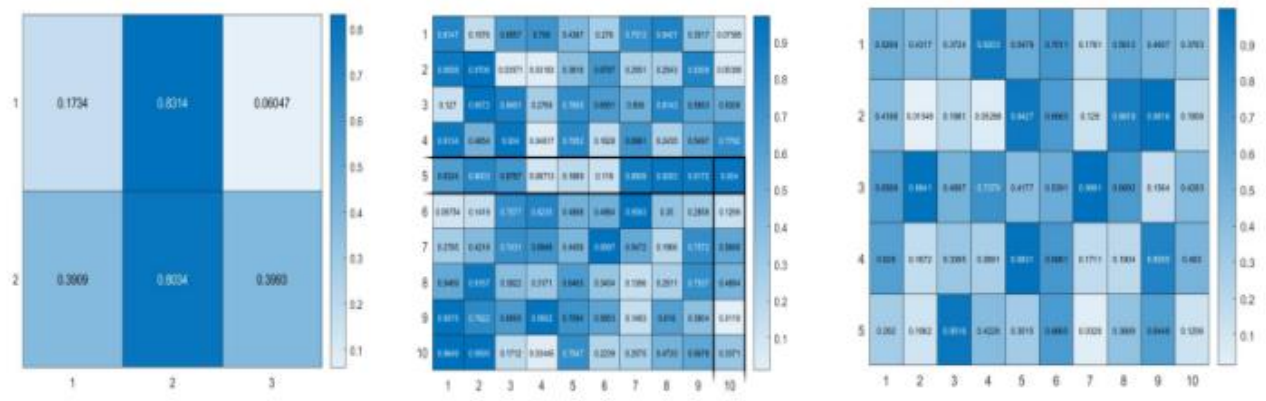


Fig 3. Plot of factors between male and female and species dynamics

4.3. Impact on the Ecosystem

According to the trend shown in Fig. 4, we can see that population growth is significantly limited under limited resource conditions. In the early stages of population development, due to the relatively small population size and abundant resources, the growth rate of the population is relatively fast. However, as the population gradually increases, the consumption of resources also increases, leading to a decrease in the availability of resources. At this point, competition within the population begins to intensify, and the survival pressure between individuals increases, gradually slowing down the growth rate of the population. When the competition for resources reaches a certain level, the growth rate of the population will drop to its lowest point, and may even stop growing, forming a relatively stable equilibrium state. This phenomenon clearly indicates that resource availability is a key factor limiting the population growth of lampreys.

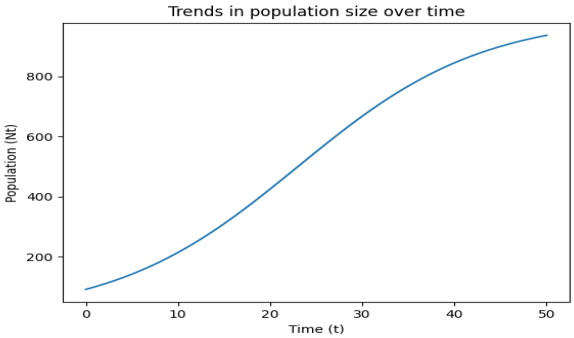


Fig 4. Trend plot of population number over time

Therefore, in resource limited environments, the growth of lamprey populations will be directly affected by resource availability. From an ecosystem perspective, changes in the population of lampreys will affect the structure and function of the entire ecosystem. As a link in the food chain, changes

in the number of lampreys will directly affect the number of predators and prey, and the activities and behaviors of lampreys may also have indirect impacts on the environment of ecosystems.

5. Conclusion

The changes in resource availability are crucial for the balance of lamprey populations, other populations, and ecosystems. With changes in resource availability, the reproductive success rate and sex ratio of lampreys will show different trends. Resource availability, as a key factor limiting the growth of the lamprey population, combined with relevant models and formulas, we found that resource availability further affects the structure and function of the lamprey population, other populations, and even the entire ecosystem by influencing their reproductive success rate and sex ratio. This article aims to reveal the potential impact of the complex relationship between the availability of lamprey resources and population growth, sex ratio, and ecosystem structure, and promote sustainable management of lamprey resources to ensure the balance and long-term development of the ecosystem.

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