An Investigation of The Relationship Between Metamorphosable Characteristics and The Environment of The Lamprey (Anguilla Anguilla) Based on The Lotka-Volterra Model

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Abstract. In the face of the dual challenges of global economic growth and ecological damage, ecological protection and biodiversity maintenance are particularly urgent. Studies have shown that the sex ratio of lampreys is an important indicator of ecological health. To this end, this paper develops an integrated system that combines the Lotka-Volterra model, sex ratio function, and food web model for predicting the interactions between the sex ratio of the lamprey and the ecological environment. The Lotka-Volterra model was optimized to incorporate a sex ratio function for the female-to-male ratio and the number of lampreys, and the data were analyzed for recent years and years. It was shown that changes in sex ratio had a significant effect on population dominance, especially under resource-rich conditions, and that increasing the proportion of females may be beneficial to population growth. In addition, a food web model was constructed to investigate the effects of changes in the sex ratio of lampreys on the structure of predator and prey populations.

Keywords: Food web modeling, Sex ratio adjustment function, Lotka-Volterra modeling.

1. Introduction

The sex ratio of the lamprey plays a key role in its ecosystem, profoundly influencing population survival, reproduction and predator-prey relationships. Changes in sex ratio may be an adaptation to environmental changes, reflecting the survival strategies of the species. Environmental factors such as food resources, habitat quality and pollution status can affect sex ratio, so the conservation of the lamprey and its ecosystem is crucial for biodiversity.

Studying and predicting the impact of sex ratio on ecosystems the impact of sex ratio on ecosystems is the key to ecological management and conservation and helps to develop rational conservation measures. It is of great practical significance to realize the sustainable development of ecosystems. Biodiversity and ecosystems are related to the sustainable development of human beings, and the effectiveness of their conservation depends largely on what kind of environmental ethics human beings uphold. This paper provides an overview of the major schools of environmental ethics, analyzing the main views of classical and enlightened anthropocentric ethics, animal liberation and animal rights ethics, biocentric ethics, ecocentric ethics, environmental synergism ethics and other western schools of environmental ethics, as well as their implications for the conservation of biodiversity and ecosystems. It also analyzes the environmental ethics in the context of traditional Chinese culture, showing that the environmental ethics of Confucianism belongs to the enlightened anthropocentric ethics, while the environmental ethics of Taoism is closer to the environmental synergism ethics. Research shows that the loss of biodiversity and the degradation of ecosystems are ostensibly the product of the contradiction between economic development and environmental protection, but essentially the result of the deviation of environmental ethics in regulating the relationship between human beings and nature over a long period of time. Only by establishing a correct concept of environmental ethics can we fundamentally curb the momentum of biodiversity loss and ecosystem degradation, realize the sustainable development of "heaven, earth, man and nature" from the mechanism, and truly achieve the goal of "all things are brought into being by their own harmony, and all things are brought into being by their own nourishment" [1].

Lotka-Volterra model was established in the 1940s by the scholars A.J. Lortka and V. Volterra, who believed that there existed a variety of relationships between populations within the same environment, including a mixture of competition, parasitism, and symbiosis, etc. Lotka-Volterra model is a general term that contains three types of models. Volterra model is a general term that encompasses three types of models. The first is the competition model, which is used to study the competitive relationship between two populations or systems, i.e., the presence of one population will have an inhibitory effect on the growth of the other population. The second is the predator-bait model, which means that one population is the bait for the other, and if the bait population dies out, the predator population will also die out, which is used to represent the dependence of the predator population or system on the bait population or system. Third, the reciprocal cooperation model, i.e., the existence of one population or system will promote the growth of another population or system.The Lotka-Volterra model is a methodological tool for mining the evolution of inter-population relationships, which is mainly used for solving the interactions in ecosystems under the framework of multi-modal relationships. As the model has been improved and applied, its scope of application has gradually expanded from ecology to sociology and management to analyze the interactions among different populations.

The article "Response mechanism and ecological effect of plankton on the water environment of Weihe River" In order to investigate the response mechanism and ecological effect of plankton on the water environment of the Shaanxi section of Weihe River, a total of 14 sampling points were set up and 14 water samples were collected from the Shaanxi section of Weihe River as the study area in April 2021, to analyze the characteristics of the spatial distribution of the plankton community structure; when assessing the homogeneity, species richness, and diversity of the plankton community The Pielou index, Margalef index and Shannon-Weiner index were commonly used, and the quality of the water environment at the cross section was evaluated; the degree of influence of environmental factors on the spatial distribution of phytoplankton and zooplankton communities was identified using canonical correspondence analysis (CCA) and redundancy analysis (RDA). The results showed that there were 55 species of phytoplankton in 7 phyla in the Shaanxi section of the Weihe River, with the highest number of species in the diatom phylum (49.09%) and 6 dominant species. 0.890, 0.446-1.099, and its index of zooplankton varied from 0.811 to 2.459, 0.754 to 1.000, and 0.126 to 0.542, respectively; the CCA analysis showed that the environmental factors affecting the changes in the spatial distribution of the phytoplankton community were mainly TP, NH3-N, and pH; according to the results of RDA analysis, the main influence factor on the structure of the phytoplankton community, chemical demand, and the main influence factor of the zooplankton community structure were TP, NH3-N, and pH. According to the results of RDA analysis, chemical oxygen demand (COD) and water temperature (WT) played a key role for the main influencing factors of zooplankton community structure. Conclusions: The changes of zooplankton index in the Shaanxi section of Weihe River showed that the study area was in a clean-moderately polluted state; according to the water pollution indicator species of phytoplankton and zooplankton in the "Chinese Freshwater Algae-Systems, Classification, and Ecology", "Environment and Indicator Organisms (Watersheds Subchapters)", the environmental quality of water environment could be judged, and compared with the diversity indexes of the present study, the zooplankton's influence on the water environment quality could be assessed. environment quality and concluded that the results of zooplankton response to water quality evaluation were more accurate. By constructing a comparative judgment model of water environment-zooplankton and selecting more accurate evaluation indexes in the region, it helps to improve the accuracy of the indicator role of zooplankton on water ecosystems, and then reveals the response mechanism of zooplankton on water ecosystems [2].

2. Research methodology

2.1. Data Acquisition and Preprocessing

2.1.1 Data source: open-source websites

2.1.2 Pre-processing of data

(1) Data collection:

Collect historical data on the size of the lamprey population, often including time-series data, documenting the size of the population at different points in time.

Collect data on environmental factors that may affect the population size of the lamprey, such as water temperature, water quality parameters (e.g., dissolved oxygen, nutrient salt concentrations), habitat quality, predator abundance, and food resource availability.

(2) Data cleansing:

Dealing with missing values: for missing data, methods such as deletion, interpolation (e.g., using the mean, median, or prediction by modeling) can be used.

Handling outliers: Identify and handle outliers, either using statistical methods or based on expert knowledge judgment.

(3) Standardization: If the scales of different variables are not consistent, they may need to be standardized, using z-score standardization or normalization.

(4) Variable selection: according to the purpose of the study and modeling needs, select the environmental factor variables that have a significant effect on the population size of the seven-gill eel.

(5) Data validation:

Check the consistency and reliability of the data to ensure the accuracy and scientific validity of the data sources.

(6) Data integration:

Integration of cleaned and transformed data into a format suitable for model inputs, e.g., time series data alignment, variable merging, etc.

2.2. Introduction to the methodology

The Lotka-Volterra model, sex ratio function and food web model are combined in the model developed in this paper to form a comprehensive analytical framework.The Lotka-Volterra model is a classical ecological model describing the interactions between predators and prey, and is commonly used to simulate the population dynamics of two species (a predator and a prey). In this model, the growth of the predator population depends on the availability of prey, while the growth of the prey population is limited by the predator's feeding pressure. In this paper, the sex ratio function is introduced to optimize the traditional Lotka-Volterra model so that it can take into account the effect of sex ratio on population dynamics. The sex ratio function can be expressed as sex ratio-dependent fecundity or survival, or any parameter that has a significant effect on population dynamics. Meanwhile food web modeling can be used to describe the complex interactions between multiple species in an ecosystem, including predation, competition and other ecological relationships. Through food web modeling, this paper can explore how changes in sex ratio affect species diversity, population size stability, and the stability of food chain relationships throughout the ecosystem. Not only can it adapt to environmental changes and reflect the adaptive strategies of lamprey populations to environmental changes, but it can also predict the effects of sex ratio changes on lamprey reproduction rates, which in turn affects the stability and health of the entire ecosystem. --The change characteristics of surface soil heat flux in the wetland of eel beach at the estuary of Minjiang River in Fujian Province from March 2019 to February 2020 were studied to analyze the effects of major environmental factors on soil heat flux and its change characteristics. The results showed that the annual average daily and seasonal daily changes of soil heat flux in the wetland of Minjiang River estuary eel beach were in the shape of "S". Under the influence of tidal inundation, the annual mean daily change curve of soil heat flux in the wetland of the Minjiang River estuary was flatter than that of the dryland, and the nighttime was more moderate than the daytime, and the maximum difference of the annual mean daily change was 2439 W-m-2, and there was a delay in the feedback of soil heat flux to the net radiation in the daily change characteristics. Due to monsoon and coastal air flow activities, the average daily amplitude was more intense in spring and summer than in fall and winter, with a maximum difference in the daily amplitude of heat flux of 11108 W-m-2 throughout the year. Throughout the year, soils in the region mainly behaved as a heat source, and in all season's heat fluxes showed heat sinks during the daytime and heat sources at night, with a maximum occurring at midday. The heat flux peaks were largest and positive for the longest time in summer, and the opposite was true in winter. Gross solar radiation, net radiation, 6 m air temperature and relative humidity were the main factors affecting the variation of soil heat flux, among which net radiation had the strongest influence on the average daily soil heat flux throughout the year, and the contribution was higher in spring and summer [3].

3. Modeling and solving

3.1. Modeling

3.1.1 Lotka-Volterra model-based analysis of sex ratio dynamics and ecosystem response of the lamprey (Anguilla anguilla)

Historically used to elucidate population dynamics in predator-prey systems, the Lotka-Volterra model provides a framework that goes beyond its traditional application to encompass the exploration of population dynamics in a variety of ecosystems. This includes the intricate interactions between sex ratios and environmental factors. In this case, the model describes fluctuating population dynamics, characterizing one population as predator and the other as prey.

Empirical data suggest that the environment affects the sex ratio of lampreys, so the model can be adapted by dividing the population into females (denoted by a) and males (denoted by b) and introducing a variable (denoted by c) to represent the sex ratio. This augmented model helps to gain insight into the mechanisms of sex determination in aquatic ecosystems and predict the effects of environmental perturbations on sex ratios. By incorporating additional parameters, such as growth rate and environmental stress, the model provides insight into how external factors may distort sex ratios, which is critical for developing strategies to protect species that are highly sensitive to ecological change, such as lampreys. --This was also shown in the article "Advances in genes regulating male sex differentiation and spermatogonial development in fish". Fish sex is regulated by both the environment and genes, both of which can influence gonadal differentiation and development, but how the environment influences gonadal developmental genes to regulate fish However, how the environment affects the gonadal development genes to regulate fish sex is not clear. Existing research suggests that high expression of upstream genes sox9 and amh can induce the differentiation of fish primitive gonads into spermatogonia, sox9 promotes spermatogonia proliferation, and amh inhibits spermatogonia proliferation, while elevated expression of downstream genes ar and er can induce spermatogonia splitting, differentiation, spermatogonia proliferation, and spermatogenesis; exogenous estrogen inhibits the expression of sox9 and amh, and low levels of ar and er can induce spermatogonia splitting, differentiation, spermatogonia proliferation, and spermatogenesis, er was induced by low concentration and inhibited by high concentration. In summary, male sex differentiation in fish is jointly regulated by sox9, amh, ar and er, and changes in environmental factors can affect this differentiation process. Therefore, this paper reviews the upstream major regulatory genes sox9 and amh, the downstream major regulatory genes ar and er, their relationship with spermatheca development, and the effects of environmental factors on these genes and spermatheca organization and structure, in order to explore the development of spermatheca in fish and the role of environmental factors in the regulation of the development of the developmental process [4]. The following modeling equations were constructed in this paper:

(1) Female population dynamics

$$\frac{\mathrm{da}}{dt} = r_a a\left(1 - \frac{a+b}{K}\right) - \alpha ab - \gamma acc \tag{1}$$

(2) Male population dynamics

$$\frac{\mathrm{db}}{\mathrm{d}t} = r_b b\left(1 - \frac{a+b}{K}\right) - \beta ab - \zeta ac \tag{2}$$

(3) Dynamics of the sex ratio

$$\frac{dc}{dt} = \varepsilon c(1-c)\left(p - \frac{a+b}{K}\right) \tag{3}$$

The model meticulously incorporates the intricate predatory and competitive relationships between the two sexes of lanternfish and examines the effects of sex ratios on population dynamics. The model reveals that the dynamics of these sex ratios are influenced by external environmental forces. The effects of lamprey sex ratios on population dynamics were investigated by manipulating model parameters such as predation intensity and sex ratio dynamics during simulations. Examining the impact of lamprey sex ratio fluctuations on the broader ecosystem. This nuanced approach allows for a more comprehensive understanding of the ecological consequences of changes in lamprey sex ratios. This paper contributes to strategic planning for biodiversity conservation and ecosystem management through this powerful framework for modeling predictions of ecosystem responses to environmental change. Strategic Planning for Biodiversity Conservation and Ecosystem Management.

3.1.2 Modeling of lamprey population dynamics and resource fitness analysis based on sex ratio adjustment function.

An increase in the proportion of males may exacerbate intraspecific competition and population density. Conversely, a surge in the number of female lampreys suggests that they are better adapted to their environment. In order to explore the strengths and weaknesses of lamprey populations, this paper introduces an innovative sex ratio adjustment function to refine the Lotka-Volterra model, which helps to provide a comparative assessment of population dynamics in different habitats, and population dynamics in different resource landscapes. In addition, this paper uses genetic algorithms to model and optimize genotype frequencies in response to environmental challenges in order to elucidate the impact of sex ratio changes.

The strengths and vulnerabilities of lamprey populations can be comprehensively assessed from multidisciplinary perspectives such as ecology, physiology and ethology [5]. The strengths and vulnerabilities of lamprey populations can be comprehensively assessed from multidisciplinary perspectives such as ecology, physiology and ethology. The effect of sex ratio on population dynamics can be investigated by extending the Lotka-Volterra model developed in the previous paper. The approach of this study consists of optimizing the traditional Lotka-Volterra equations to encompass a wider range of species interactions and ecological complexities such as interspecific competition, food web dynamics, and population dynamics. competition, food web dynamics, and species invasions in multi-species ecosystems. These refined equations will synthesize multifaceted species interaction terms, and variables related to environmental factors [6]. As an innovation, this study chose to incorporate a sex ratio adjustment function into the Lotka-Volterra framework. This function can be expressed as a sex-ratio dependent fertility or survival rate, or as any parameter that has a significant effect on population dynamics, thus introducing a new aspect to the mathematical modeling of ecosystems. Assumptions can be made:

$$\begin{aligned} \frac{dR}{dt} &= \mathbf{r}_R - \boldsymbol{\lambda}_R RF\Phi\left(S, \frac{R}{F}, \alpha_R, \beta_R\right) \\ \frac{dF}{dt} &= \boldsymbol{\alpha}_F RF - B_F F\Phi\left(S, \frac{R}{F}, \alpha_F, \beta_F\right) \end{aligned} \tag{4}$$

These include.

$$\Phi\left(S, \frac{R}{F}, \alpha_R, \beta_R\right) \tag{5}$$

is a sex-ratio adjusted function, with availability denoted as S, and the prey-to-predator ratio as $\frac{R}{F}$.

R represents the number of female individuals F represents the number of male individuals α, B, γ and λ are model parameters. The model fully considered the interaction between predator and prey, and the parasitic behavior of the seven-gill eel was also considered in this paper. The above system of equations leads to

$$\frac{d(R+F)}{dt} = r(R+F)\left(1 - \frac{R+F}{K}\right)\alpha(R+F)^2 \tag{6}$$

3.1.3 Analysis of the temporal evolution of the sex ratio and population dynamics of the lamprey (Anguilla anguilla)

By solving this system of equations, changes in the population size of male and female lampreys under different environmental conditions, as well as changes in the sex ratio over time, can be obtained. By programming and plotting, graphs of the changes in female and male population size over time were obtained.

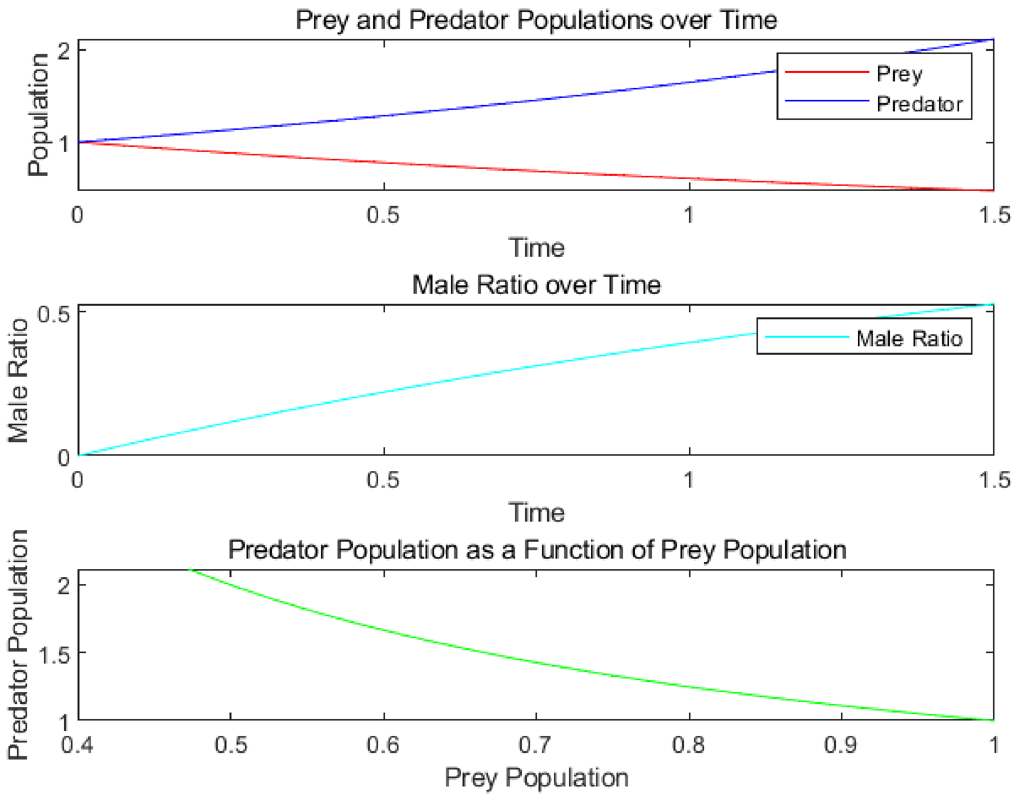

Figure 1: Temporal dynamics of prey and predator populations

Figure 1 includes three different dynamics: fluctuations in prey numbers, predator numbers, and sex ratio. The model parameters were carefully fine-tuned to simulate the results to gain a deeper understanding of the critical role of lampreys in the ecosystem. Changes in lamprey sex ratios were found to have profound effects on ecological dynamics, population fluctuations and stability. Sex-based dichotomies in predation and prey behavior may alter their ecological niche and distribution, which in turn affects coexisting species. Changes in sex ratios can lead to oscillations in lamprey populations, and an increase in the proportion of females may increase reproductive frequency and success, catalyzing population change and triggering a range of responses in dependent species [7]. In addition, drastic changes in sex ratios can adversely affect the balance of the ecosystem, complicate the maintenance of population balance, and have a knock-on effect on species interactions, ultimately jeopardizing the stability of the ecosystem [8]. Therefore, protecting the lamprey and its habitat and stabilizing its sex ratio are crucial to maintaining the integrity of the ecosystem and its prosperous evolution.

3.1.4 Ecological impacts and risk assessment of changes in the sex ratio of lampreys

By debugging the code, the positive and negative ratio situations were obtained as shown in Figure 2 below:

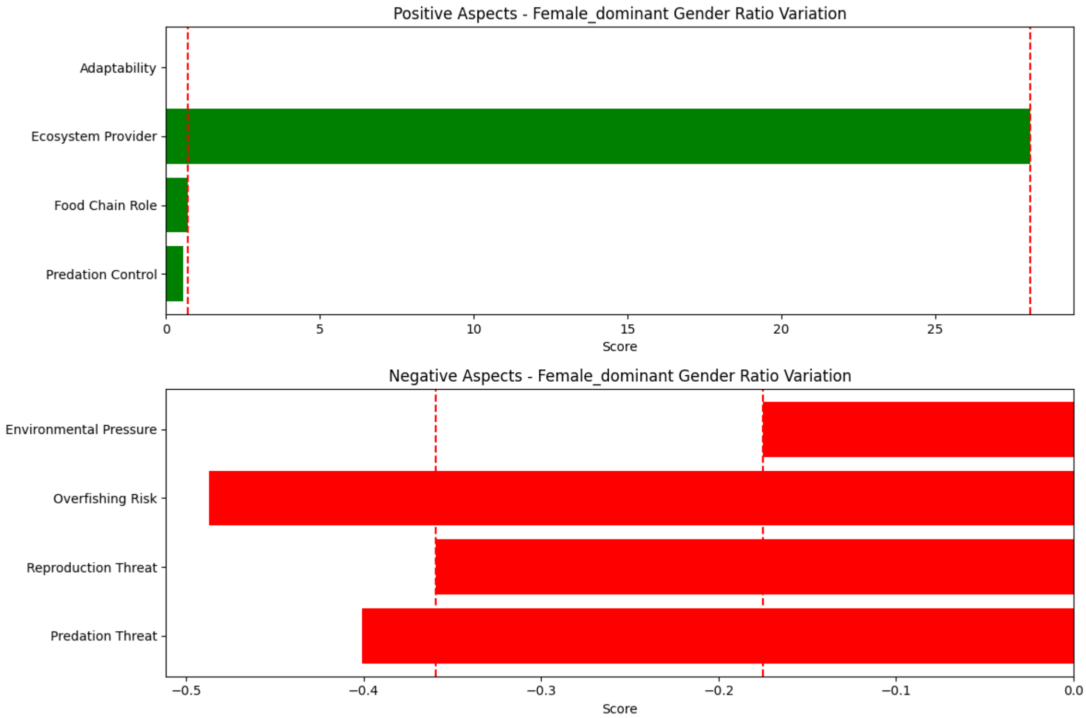

Figure 2: Impact of sex ratio differences on ecosystem roles and risks

The advantages and disadvantages of changing the sex ratio of lampreys for lamprey populations can be concluded as shown in Figure 2. Advantage: In lamprey populations, especially in resource-rich environments, an increase in the proportion of female lampreys contributes to rapid population expansion through mass reproduction when food is plentiful. Females have the potential to reproduce more offspring, thus rapidly expanding the population size in a short period of time [9]. The ability of lamprey sex ratios to adapt to different environmental conditions provides the species with a flexible mechanism to minimize competition for scarce resources. By regulating sex ratios, lampreys can optimize resource allocation and, in the event of food scarcity, increase the production of males to reduce competition for limited food. Cons: Lamprey sex ratio imbalance can have profound effects on the balance and health of the ecosystem. Not only does this disparity erode the genetic diversity of the population, it also reduces overall reproductive rates. Even when food resources are adequate, a reduced female ratio can slow population growth, thus constraining the size and distribution of the population in the long term.

In addition, since seven-gill eels are an important food source for predators, changes in their sex ratio may affect the abundance and distribution of predators, thereby affecting the balance of the entire food web [10]. These knock-on effects highlight the intricate and subtle ecological interdependencies in nature and emphasize the importance of understanding and protecting them. In essence, subtle changes in lamprey sex ratios not only reflect adjustments within populations but are also indicators of ecosystem balance. Such changes warrant close monitoring and highlight the complexity of ecological conservation efforts.

4. Conclusion

In this study, the effects of changes in the sex ratio of lampreys on ecosystem stability were analyzed in depth through the integrated use of the Lotka-Volterra model, the sex ratio function and the food web model, revealing the important role of the sex ratio in resource utilization, population dynamics and food chain structure. The results emphasize the importance of sex ratio balance in maintaining ecosystem health and point out the necessity of monitoring and regulating sex ratio in ecological conservation and management. Despite the limitations of the model in predicting complex ecological dynamics, this study provides new perspectives for understanding the ecological significance of sex ratio changes in the lamprey and provides scientific support for the development of effective ecological conservation strategies. Future studies should further consider the effects of environmental change on sex ratios and how these findings can be applied to broader ecosystem and species conservation. Taking the Fuhu River, which has water entering Baiyangdian all year round, as the study object, we carried out the investigation and evaluation of the water ecological environment quality status of the Fuhu River during the flood season in terms of river plankton, benthic organisms, fishes, and large vascular plants. The results of FEQI showed that the quality status of the water ecosystem of the Fufu River is good in the upper reaches, medium in the middle reaches and medium in the lower reaches. It was found that there were local differences in the density and biomass of aquatic organisms under different hydrological conditions; the biodiversity of the Fu River tends to be stable. Overall, the quality status of the water ecosystem of the Fuhu River in Baoding City is between moderate and good, with the upstream section being good and the middle and downstream sections having moderate water quality. Biology and environment are an organic whole, we can judge the quality of the environment through the biological situation, similarly, we can judge the biological activity through the environment of a region.

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