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The Characteristics of Phytoplankton Community Based on Ecological Simulation

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Abstract: In recent years, computer technology has entered a period of rapid development, and it has become more and more important to use water ecological models to simulate the ecological changes of water bodies and the impact of pollutants on ecosystems. The purpose of this paper is to study phytoplankton community characteristics based on ecological simulation. Firstly, the principle and main simulation process of the AQUATOX model are expounded in detail, and then on the basis of collecting the data of various water quality indicators and phytoplankton measured in M Lake, the model simulation area and parameters are determined, and the M Lake ecological model is established. The model was used to simulate the seasonal succession law of three kinds of large aquatic plants (Eyes serrata, algae, chara) and three kinds of algae (cyanobacteria, green algae, diatoms) and the change law of the main zooplankton in the lake area, In the simulation of aquatic plant and algal biomass in the lake area, it is found that the simulation effect of green algae and cyanobacteria is better, and the average relative error is within 20%, while the average relative error of diatom simulation is larger, which is 30%.

1. Introduction

From an ecological point of view, a lake is a complete ecosystem. It is composed of two major sub-systems, the organisms in the lake (including producers, consumers and decomposers) and the environment with water as the main body, and they are inseparable, organically linked and interact with each other [1- 2]. Therefore, lakes have a variety of functions and are endowed with a large number of abundant natural resources. It has become very urgent to protect water resources, improve the water environment, and study the characteristics of phytoplankton communities [3-4]. At present, water ecological models have been widely used in water pollution control and water quality prediction [5].

Phytoplankton is an important part of aquatic ecosystems and biological resources [6]. Gaëlle Speeckaert studied strong seasonal variations in the concentrations of these compounds associated with phytoplankton succession, with high DMS(P,O) producers (mainly brown algae) occurring in spring and low DMS(P,O) producers occurring earlier (various diatom species) spring and autumn. The spatial gradient of DMS and DMSP is related to the spatial gradient of phytoplankton biomass itself, which is related to nutrient input from the Scheldt estuary [7]. Bharathi MD conducted time series observations in the upper, middle and lower reaches of the mouth of the Godavari. Changes in salinity in estuaries depend on freshwater discharge and tidal exchange. River discharges bring a lot of nutrients, and the contribution of diatoms to total phytoplankton abundance increases with decreasing salinity, and vice versa for blue-green algae. The relationship between phytoplankton abundance and salinity and nutrients indicated that low salinity and high N:P ratio favored the growth of cyanobacteria, while high salinity and low N:P/N:Si favored diatoms [8]. Therefore, it is feasible to use ecological models to study the changes of phytoplankton community characteristics [9].

Based on the investigation of the phytoplankton community in Lake M, this paper uses the AOUATOX ecosystem model to simulate the seasonal variation and succession of important macrophytes and phytoplankton in the water for phytoplankton species composition and biomass. It was concluded that the green algae were higher in spring every year, the biomass decreased in September, and the biomass increased slightly in winter. Cyanobacteria have higher biomass in spring and summer. The variation law of diatom biomass is not obvious, and the fluctuation of biomass throughout the year is relatively large.

2. Research on the Characteristics of Phytoplankton Community Based on Ecological Simulation

2.1 Phytoplankton

Phytoplankton is an ecological concept that refers to microscopic plants that live in water with phytoplankton, usually phytoplankton refers to phytoplankton. Phytoplankton are tiny plants that vary widely in size and shape. Most phytoplankton are invisible to the naked eye and can only be clearly seen with a microscope or electron microscope [10].

The self-regulation of phytoplankton is very simple, all organisms can absorb nutrients to produce organic matter, and do not need as much energy as higher plants to support organisms [11]. In addition, the reproduction method is simple, usually dominated by cell division, and when the environmental conditions are favorable and nutrient-rich, the number of phytoplankton individuals increases rapidly. In addition, phytoplankton are widely distributed and abundant in freshwater and oceans [12-13].

2.2 AQUATOX Model

The AQUATOX model can simulate the fate of organic compounds, nutrients and other pollutants in the aquatic ecosystem in the aquatic environment system, and their impact on various ecosystem elements such as fish, invertebrates and aquatic plants [14]. The AQUATOX model includes five parameter libraries. Therefore, the model contains numerous model parameters, which provide the relevant coefficients for the process function. When inputting parameters, the user can use the default value of the model itself or manually specify it according to the specific situation of the simulated object. The AQUATOX model can establish a causal chain between biological responses, water quality, and water biological utilization [15].

The AQUATOX model includes five parameter libraries, namely chemical substance library, animal library, plant library, site library and mineralization library. Substance characteristics and fate data of chemical substances, etc.; animal bank refers to relevant parameters of fish and invertebrates, mainly including animal names, toxicity records, animal classification and animal data, etc.; plant bank refers to parameters related to algae and macrophytes, mainly including plant names, toxicity records, plant classification and plant data, etc.; site library refers to parameters related to simulated objects, including site name and site data, etc.; mineralization library refers to debris and nutrients related to research objects Substance parameters, most of which will not change with the change of the research object. Therefore, the parameters involved in the AQUATOX model cover many aspects, with a large number, reaching hundreds of [16-17].

2.3 Plant Simulation Process

The plants of the model are divided into four types: planktonic algae, sessile algae, macrophytes, and bryophytes. Among them, planktonic algae and sessile algae can be divided into four types: cyanobacteria, green algae, diatoms, and other algae. Macroplants can be divided into submerged algae. There are three types of plants, emergent plants and floating plants. Different types of plants simulate different processes and influencing factors [18].

The change of plant biomass is expressed by ashless dry weight, the biomass unit of planktonic algae is mg/L, and the biomass unit of sessile algae is g/m2. The biomass of planktonic algae and sessile algae is a function of factors such as nutrient concentration in water, photosynthesis, respiration, photorespiration, natural death, feeding pressure, and sedimentation. The diffusion between them also affects their biomass. In the model, the photosynthesis of algae is determined by its own maximum photosynthesis rate, organic toxicants, nutrient element limitation, habitat adaptability, light radiation intensity, temperature, water flow and other influencing factors; algal respiration can increase the biomass of plants. In the model, the respiration loss of algae is a function of temperature; the photorespiration loss of algae is a function of photorespiration coefficient, light limitation and photosynthesis; the factors that determine the death rate of algae include the mortality caused by organic poisons, and the mortality of themselves., high temperature effects, nutrient stress, light limitation, the settlement of planktonic algae and the shedding of sessile algae, etc. The death of algae in the model will release nutrients into the water and accelerate the mineralization of the water body; Or thermal stratification thickness, water flow, physiological stress and other factors; the erosion and shedding of algae are determined by factors such as biological volume, water flow, and the amount of shedding caused by organic toxic agents [19-20]. The model does not directly simulate the concentration of chlorophyll in the water body, but estimates the biomass and chlorophyll content of different types of algae.

The biomass unit of macrophyte and bryophyte is dry weight g/m2, and the biomass change is calculated by influent load, photosynthesis, respiration loss, photorespiration loss, death, ingestion, and damage. The simulation processes of photosynthesis, respiration, temperature limitation, and light limitation of macrophytes and bryophytes are similar to those of algae, but submerged plants and emergent plants are regarded as absorbing nutrients from the sediment, while floating plants and Bryophytes, like algae, absorb nutrients from water. In addition, emerging plants and floating plants are not affected by the reduction of light by the water body because the plants are higher than the water surface, but the floating plants are greatly affected by the water flow speed because the whole plants are on the water surface, and their size is related to the environmental load of the plants.

3. Investigation and Research on the Characteristics of Phytoplankton Community Based on

Ecological Simulation

3.1 Simulation Area and Parameter Determination

In order to simplify the simulation, it is reasonable to consider the simulation area as a whole lake basin. Most of the water depths in the lake area are less than 2m, and the average water depth is about 1.95m. Therefore, it can be considered that the water body in the vertical direction of the lake is relatively uniform, so the water body is not stratified. Boundary conditions are extremely important when modeling water bodies under study. Collect meteorological data (average air temperature, evaporation, solar radiation, wind speed, etc.), hydrological data (water entering the lake, water leaving the lake, water level) from 2018 to 2021, as well as water quality data and phytoplankton data under simultaneous monitoring. In the parameter calibration process, a normal distribution model was selected, its standard deviation was set to 60% of the parameter value, and the number of iterations was set to 10.

3.2 Algal Biomass Equation

The cycle process of algal biomass is a function related to nutrient load in water, self-photosynthesis, respiration, excretion and photorespiration, natural death and predation pressure, etc. The calculation formula is as follows:

$$\begin{aligned}\frac{dBiomass_{phyto}}{dt} &= Loading + Photosynthesis - \mathrm{Re}\,spiration - \\ &Excretion - Mortlity - \mathrm{Pr}\,edtion \pm Sinking \pm Floating - Washout + \\ &Washin \pm TurbDiff + Diffusion_{seg} + \frac{Slough}{3}\end{aligned} \tag{1}$$

$$\begin{aligned}\frac{dBiomass_{\mathrm{peri}}}{dt} &= Loading + Photosynthesis - \mathrm{Re}\,spiration - \\ &Excretion - Mortlity - \mathrm{Pr}\,edtion + Sed_{\mathrm{peri}} - Slough\end{aligned} \tag{2}$$

Among them, BiomassIdt: algal biomass, Loading: algal biomass load, Sinking: loss and increase between water layers caused by sedimentation, Slough: shedding loss, Predation: predatory death.

4. Analysis and Research of Phytoplankton Community Characteristics Based on Ecological Simulation

4.1 Community Structure Characteristics of Phytoplankton

The identified phytoplankton species are listed in Table 1.

Table 1. Phytoplankton species identified in the Haihe River Basin from 2018 to 2021

years	Cyanobacteria	Cryptophyta	Dinophyta	Chlamydomonas	Diatoms	Chlorophyta
2018	20	0	2	4	10	11
2019	17	0	1	1	11	15
2020	16	0	3	0	20	12
2021	18	2	6	2	22	14

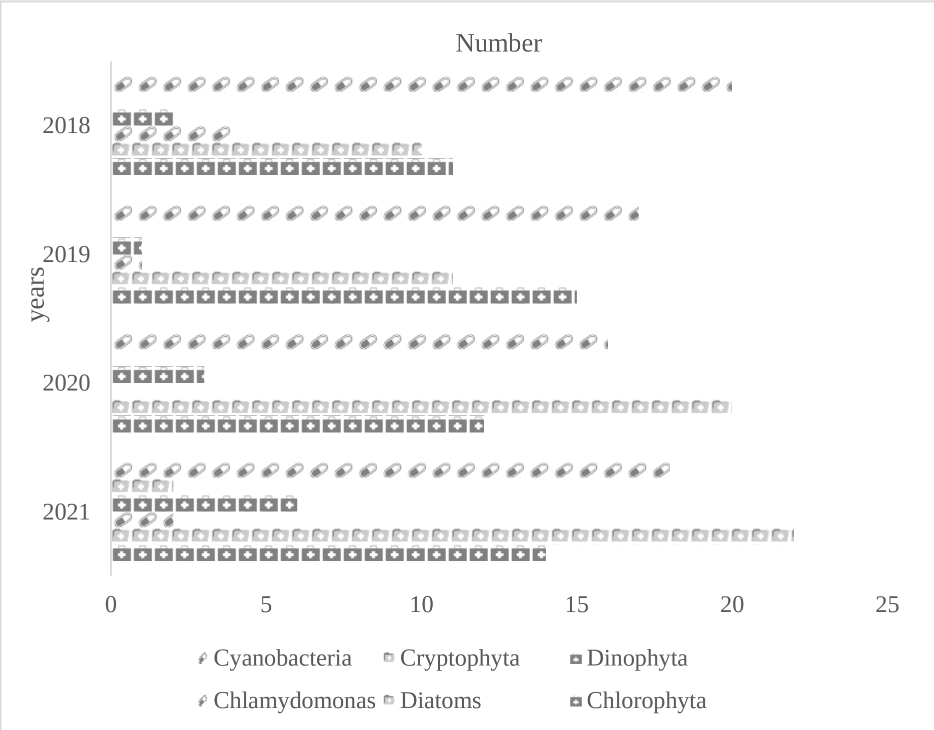

Figure 1. Phytoplankton species

As can be seen from Figure 1, in terms of the number of phytoplankton categories: 6 in 2018 and 2021, indicating that the Haihe River Basin is rich in phytoplankton species in these two years; 5 in 2018 and 2019, and 2020 in 2020 There were 4 phyla, indicating that individual species were missing in these years due to low species richness or no samples were collected. From the perspective of species composition: the number of Chlorophyta species is the largest from 2018 to 2021, while the number of Diatomaceous species is the largest in 2021, which shows that the ecological structure of phytoplankton in the Haihe River Basin has changed.

4.2 Simulation of Large Aquatic Plants and Algae

In this paper, the succession law of S. eucalyptus, algae and chara was simulated, as shown in Table 2. The seasonal succession laws of the three macrophytes are not consistent, mainly due to the different adaptability of different plants to the environment. In spring, the temperature is low in May, and the plants with lower optimum temperature of the algae and chara begin to recover and grow. With the increase of temperature, the algae and charophyte grow faster, and the biomass reaches the peak in early summer and July., With the drop of temperature, the algae and Charoella withered and died in September, and the biomass decreased sharply. However, the growth of A. chinensis lagged behind that of the algae and charoalgae, and the biomass basically reached its peak in September every year. The biomass of three aquatic plants was the lowest in winter in December.

Table 2. Aquatic Plant Simulation Results (g/m2 dry)

month	You Xuyanzi	Foxtail algae	Chara
May	105	92	88
July	88	152	132
September	268	62	50
December	40	15	6

The algae in the simulated lake area are mainly composed of green algae, cyanobacteria and diatoms. Therefore, this model only simulates the seasonal succession process of these three groups of algae. The simulation results and error analysis are shown in Figure 2 and Table 3. Among them, the simulation results of green algae and cyanobacteria are better, the average relative error is within 20%, while the average relative error of diatom simulation is larger, which is 30%. The biomass of green algae was higher in spring every year, then the biomass gradually decreased, and the lowest value was in September, and the biomass increased slightly in winter. The biomass of cyanobacteria was higher in spring and summer, which was also in line with the growth characteristics of cyanobacteria adapting to higher temperature. The variation law of diatom biomass is not obvious, and the fluctuation of biomass throughout the year is relatively large.

Table 3. Simulation Results and Errors

algae	Simulation results	absolute error (%)
green algae	1.85	12
Cyanobacteria	1.06	15
Diatoms	1.58	30

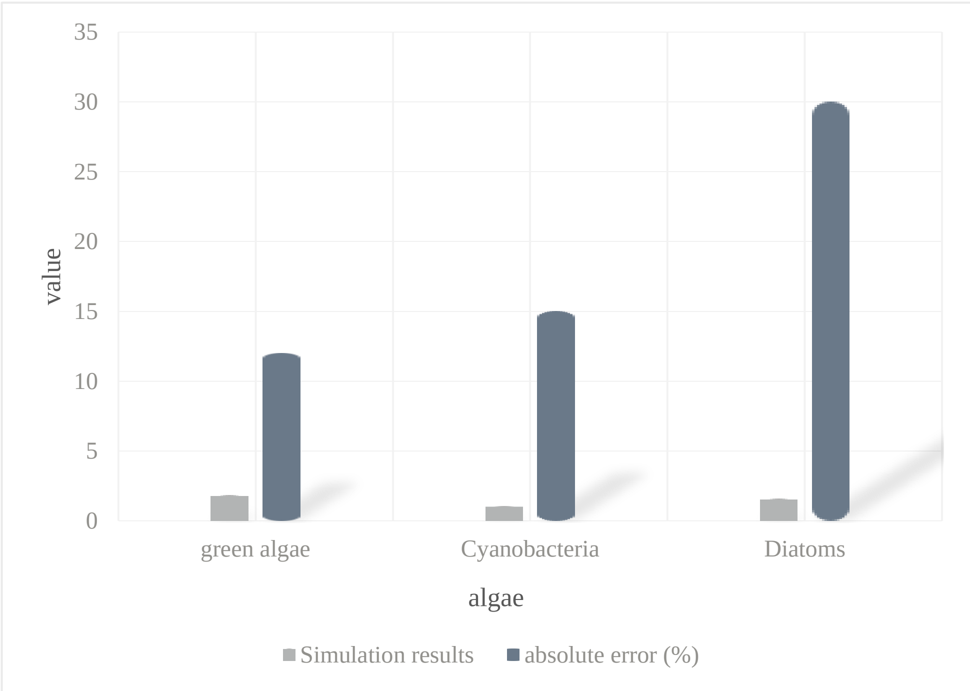

Figure 2. Algae simulation results

5.Conclusions

Although the research on the water ecological model of water body cannot contain all the contents of the dynamic of the water body ecosystem, it also reflects the changes of the water body ecosystem greatly, and provides a theoretical basis and research method for the simulation research of lakes. But the current research also has some imperfections. One is the limitation of the software itself, including the lack of support for the spatial distribution of plants, the unrealistic calculation method for the absorption and release of nutrients in higher plants, and the inability to calculate the human disturbance to plants, which limits the application scope of the software and the accuracy of the simulation results. Second, due to the constraints of manpower, material resources and time, it is impossible to track and detect related sites for a long time and correct the model.

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