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The Effects of Environmental Factors on the Growth and Competition of Algae

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Abstract In order to study the effect of environmental factors on the algae growth and competition, the author summarized overseas and domestic related researches in recent years. Most of the researches are about the influence of single factor on growth of algae. However, there is insufficient investment on the interaction of different factors and the competition between algae growth. This paper briefly introduced the classification of algae and the role they played in ecological system and focused on the influence which included temperature, illumination, nitrogen, phosphorus and pH on the growth and competition of algal. In the end, the author proposed key questions which were still needed to be studied in order to know more about the relationship between environment effects and growth and competition of algae. Therefore, people could better improve the community structure of algae and water ecological environment, and improve water primary productivity.

Key words pH, Illumination, Temperature, Nitrogen and phosphorus, Algae

As the primary producer of ecological system, algae not only can produce organics and reduce oxygen, but also impose positive influences on some environmental pollution. People's consumption of water rises amid the industrial and agricultural development and increasing population, thus the eutrophication of water is getting worse and worse. Eutrophication has become a world-wide problem. At present, many lakes, rivers and reservoirs in China are at high eutrophication level. Eutrophication can lead to red tides and bring great loss to the marine and agricultural production, and aquaculture. All-round and deep cooperation is needed to improve the environment and adjust the alga structure. Therefore, the influences of important environment factors such as temperature, sunshine, phosphorus, nitrogen and pH on the growth of alga were summarized so as to provide bases for the relevant study research.

1 Alga categories

There are various kinds of alga. So far, 30 thousand kinds of alga have been identified. Early botanists consider alga and fungi as the same kind of plants, namely thallophyte. With the better understanding of alga, especially after the speech of parallel evolution, alga is not considered as a natural category group, and various independent phyla are set up according to the element, content, compound, flagellum and reproduction method. Although alga is a kind of plant that carries Chlorophyll and it does not have root and leaves. Its reproductive organ is unicellular^[1]. There are different opinions on the categories of phyla. Some people think there should be twelve categories, namely *Cyanophyceae*, *Rhodo-*

phyceae, *Cryptophyta*, *Pyrrophyta*, *Chrysophyceae*, *Xanthophyta*, *Bacillariophyta*, *Phaeophyta*, *Euglenophyta*, *Prochlorophyta*, *Chlorophyta*, and *Charophyta*. However, others think there should be nine categories, including *Cyanophyceae*, *Euglenophyta*, *Chrysophyceae*, *Xanthophyta*, *Bacillariophyta*, *Phaeophyta*, *Chlorophyta*, *Rhodophyceae*, and *Phaeophyta*.

2 Influences of algae on aquatic ecosystem

Algae is the foundation of biological resources in the aquatic ecosystem and the basis of material circulation and energy movement in the entire aquatic ecosystem. Whether in the pale water or ocean, algae is the essential preliminary producer in aquatic ecosystem^[2] and a key link in the aquatic food chain. As an important bait to zooplankton and aquatic animals, Algae exerts an important role in maintaining ecological balance. As water covers most part of the earth, it is estimated that nearly half organics produced by photosynthesis are from microorganisms such as algae, and those organics are essential constituents of oceanic grass. Through photosynthesis algae can fix inorganic carbon and turn it into carbohydrates so as to provide basis for the production of waters. In the transformation of food chain, from 100 to 1 000 kg of plankton algae is needed to produce 1 kg of fish or meat. Therefore, most of world-renowned fishing grounds lie in waters with abundant algae resources, and the output of planktonic algae has become the indicator to evaluate the preliminary produce of waters.

Algae can absorb nutrient salt such as nitrogen and phosphorous in waters. For algae which is conducive to the digestion of aquatic animals such as fish, its reproduction in waters can reduce the nitrogen and phosphorous, and provide resources for the growth of economic agents so as to improve the preliminary produce of waters. Studies suggest that *Chlorella vulgaris* can remove the N, P and COD^[3–4] in waste water efficiently. However, under

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certain conditions, the abnormal increase of algae results in algae bloom and red tide, which would deteriorate the quality of water^[5], and kill lots of fishes and shrimps, especially poisonous algae, such as microcystin which can produce toxin that could make people die. The unnatural reproduction of harmful algae brings critical hazards to both aquatic animals and human beings.

3 Influences of major environmental factors on the growth of algae

3.1 Temperature The growth and reproduction of algae is markedly influenced by temperature. The temperature of water imposes influences on the growth of algae in two ways: the biological activity of algae, and the nutrition utilization efficiency. Studies by Shen Zhemin *et al.*^[6] suggested that the annual mean temperature increased by 1.0 °C, and the annual mean algae biomass rose by 0.145 times. Besides, they believed that the more outstanding the eutrophication, the more influences of rising temperature on the growth of algae. Researches by Chen *et al.*^[7] indicated that temperature could influence the size of Chlorella vulgaris and the peculiarity of cells. Studies by Yuan Li'na^[8] *et al.* proved that when the temperature was lower than 25 °C, the algae cell reproduced rapidly, and it was concluded that the temperature affected the growth speed and ultimate growth of algae. There were remarkable differences among the effects at the temperature of 10 °C, 18 °C and 25 °C, and 10 °C can restrain the growth of algae distinctively. Zhao Jianyin *et al.*^[9] studied the optimum growth rate and competition of *Microcystis aeruginosa* and *Scenedesmus obliquus*. Results suggest the optimum temperature for the *Scenedesmus obliquus* to grow was 25 °C, which is lower than the optimal temperature for the growth of *Microcystis aeruginosa* 35 °C. The algae which is cultivated with other plants grew worse than the one being cultivated alone, which proves that there were restraining effects between different algae and such inhibiting effect either intensified or abated due to the changes of temperature. Studies by Zhu Wei *et al.*^[10] proved that when there was competition, the quality concentration of nitrogen and phosphorus was higher than that in *Microcystis aeruginosa* if the temperature was high, and the quality concentration of nitrogen and phosphorus was lower than that in *Microcystis aeruginosa* if the temperature was low. High temperature was conducive to the growth of *Microcystis aeruginosa*, while low temperature was detrimental to the growth of *Microcystis aeruginosa*. Mild temperature was especially beneficial to the growth and reproduction of *Scenedesmus obliquus*. Studies by Casazza *et al.*^[11] suggested that the temperature rose from 20 °C to 25 °C and the fat content rose by one times. Studies by Ouyang Zhengrong^[11] proved that the temperature for the Chlorella to grow was between 25 and 42.5 °C and the optimal temperature was 37.5 °C. Although various algae grow best at different temperatures, generally speaking, 25 °C is the suitable temperature for most algae to grow^[13].

3.2 Sunshine Phytoplankton can produce organics through photosynthesis to maintain its' growth and reproduction. The sea-

sonal changes of phytoplankton output are directly linked with the seasonal variations of sunshine conditions^[14]. The photosynthesis intensity of phytoplankton depends on the sunshine intensity and light quality. Favorable sunshine intensity and optimum wavelength are the foundation for the growth of algae. Because different kinds of algae have varying optimal intensities of natural light, their competence varied even under the same condition of sunshine level^[15]. Studies by Tamburic *et al.*^[16] revealed that light can change the amount of H₂ being released to the air by algae. Studies proved that shades can decrease the concentration of algae^[17]. Sunshine can increase the synthesis of chlorophyll, but once it passed certain amount, the increasing sunshine level would restrain the synthesis of chlorophyll^[18]. Guo Yanqin^[19] studied the influences of five kinds of sunshine intensities on algae and found that the higher the sunshine intensity, the faster the cell divides and the higher the biomass. Along with the addition of light intensity, the total photosynthesis kept increasing. When the sunshine intensity reached to a certain amount, the speed of photosynthesis reduced and even stopped.

3.3 Nitrogen and phosphorus The preliminary produce of waters is influenced by nutritional elements N and P in waters. Those nutritional elements are the material foundation of photosynthesis and synthesized organics of phytoplankton, among which N and P are considered as restrictive factors for the breakout of phytoplankton bloom^[20–22]. Influences of N and P on the growth of algae include the morphology and the concentration of N and P. Their morphology affects the absorption speed and utilization of N and P, while the N and P concentration influences the growth of algae cell and accumulation of materials in the cell.

3.3.1 Influences of the morphologies of nitrogen and phosphorus on the growth of algae. The nutrient salt can be divided as inorganic source and organic source. Studies by Zhang *et al.*^[23] suggest that the optimum nitrogen and phosphorus ratio for the growth of algae differs to different morphologies of nitrogen. Algae uses nitrogen to synthesize protein, but first of all, amino acids are necessary. The nitrogen in inorganic nitrogen is oxidized. Zhang Qingtian *et al.*^[24] studied the influences of three different kinds of nitrogen sources on the reproduction of *Microcystis aeruginosa* on ammonium nitrogen, nitrate nitrogen, and blood urea nitrogen. They found that the optimal ammonium nitrogen concentration for the growth of *Microcystis aeruginosa* should be 0.5 mmol/L, the optimal concentration of nitrate nitrogen for the growth of *Microcystis aeruginosa* should be 1.5–5.0 mmol/L, and the optimal concentration of blood urea nitrogen for the growth of *Microcystis aeruginosa* should be 0.5–1.5 mmol/L.

Phosphorus which can be directly absorbed by Algae is dissolved organic phosphorus and dissolved inorganic phosphorus^[25]. Jing Jiabo^[26] used K₂HPO₄ · 3H₂O as the source of inorganic phosphorus and studied its influence on the growth of *Microcystis aeruginosa*. Study showed that when there was little phosphorus, phosphorus restrained the growth of *Microcystis aeruginosa* and the growth speed quickened with the increase of phosphorus concentra-

tion. Qian Shanle *et al.*^[27] used 1-phosphate-glucose, c-AMP and ATP as the source of soluble phosphorus source, and studied the application of *Microcystis aeruginosa* and *Chlorella pyrenoides* and their growth. Therefore, *Microcystis aeruginosa* is more competitive in the eutrophicated water.

3.3.2 Influences of nitrogen and phosphorus concentration on the growth of algae. Generally speaking, nitrogen and phosphorus are restraining the growth of algae in natural waters in two ways. The first one is the absolute concentration of nutrient salt, which would affect the growth of phytoplankton when the absolute concentration of nutrient salt is lower than the threshold value. The second one is the relative concentration ratio of nutrient salt, which can be higher than the threshold value to satisfy the demand for the growth of phytoplankton^[28]. Zheng Xiaoyu *et al.*^[29] used BG-11, NaNO₃ and K₂HPO₄ to control the initial nitrogen and phosphorus concentration in the experiment. Study indicated that cells may need more nitrogen rather than phosphorus and the optimal concentration of nitrogen and phosphorus for the growth of algae were 16.0–32.0 mg/L and 2.0–5.40 mg/L respectively. Kong *et al.*^[30] used yeast to absorb N and P to control the growth of *Microcystis aeruginosa*. Study by Ruangsomboon *et al.*^[31] indicated the concentration of N, P and Fe would affect the growth of lipids in algae. Meng Shunlong *et al.*^[32] studied the growth and competition of *Microcystis aeruginosa* and *Oscillatoria princeps*, and results proved that *Microcystis aeruginosa* grew best at the ratio of nitrogen and phosphorus of 4.5, and the *Oscillatoria princeps* grew best at the ratio of 0.45. Aslan *et al.*^[33] concluded that the algae dissolved more nitrogen than phosphorus under the condition of pH 7.0, indoor temperature (20±2) °C, sunshine 4100 1x, and the ratio of nitrogen and phosphorus. Dong Juan *et al.*^[34] calculated that amount of algae cell, DGGE monitoring, and the typical corresponding CCA analysis to study the influences of different nitrogen and phosphorus concentration and the relations among influences of N/P on the algae–fungus structure. Results suggested that the nitrogen and phosphorus concentration and N/P ratio would affect the algae; N/P=12 being the optimal condition for algae to grow; N/P=3 and N/P=48 would restrain algae to grow.

3.4 pH The pH of water affects algae in two ways. Firstly, pH would change the acidity and alkalinity of the water. Too strong acid or too alkaline would harm the algae cell. Only within suitable acid and alkaline range can the algae grow normally. Secondly, pH would affect the carbonate balance system and the distribution of different forms of inorganic carbon. Study found that alkaline water was more likely to grow blue-green algae^[35]. pH in the reservoir was mostly determined by the amount of CO₂, while the CO₂ amount would be influenced by many factors, such as water temperature, microorganisms and soluble ion *etc*. Therefore, when there was certain amount of algae, its number and living activity played leading roles in the changes of pH in waters^[36]. Wang *et al.*^[37] proved that pH would affect the growth of blue algae when pH was 5.5, 6.0 and 6.5, and algae would die when pH was 5.5

and 6.0. Yuan Lina^[8] concluded that low pH was detrimental to algae. Zhao Na^[38] studied the influence of different pH conditions on the growth of *Chlorella* and *Scenedesmus obliquus*, and revealed that *Chlorella* grew best at the pH of 7.0 and *Scenedesmus obliquus* grew best at the pH of 9.0. Liu Shufeng *et al.*^[39] proved that the pH value and the number of algae correlated with each other and ΔpH reached the maximum value at the density of 105–106. Ouyang Zhenrong^[12] concluded that *Chlorella* can grow normally at the between pH 6.5 and 9.0 and grew best at the pH of 7.0.

3.5 Other environmental factors Temperature, sunshine, nutrient salt, and pH are major factors influencing the growth of algae. Besides, aerated methods, hydropower and microelements would affect algae^[40–44]. Aerated air can change the constituents of O₂ and CO₂ in the water and affect the pH in the water. Meanwhile, stirring water can improve the transmission of oxygen and intensify the effects of aerated air on algae^[45]. Wang Yunzhong *et al.*^[46] concluded that water circle has distinct influences on algae growth and replacement of advantageous species. Water cycle and soil cycle inhibit the growth of algae, and within 49 days, water cycle and soil cycle reduced algae cell amount by 41% and 91% respectively. Meanwhile, mixing is one of the major physical factors which would affect "water–sediment" interface^[47]. Besides, mixing would make the particles float. The quicker the disturbance is, the greater the energy released from the sediment.

4 Conclusions

Algae is the foundation of biomass in marine ecological system and the material cycle and energy movement in the entire ecological system. Suitable algae structure not only increase the oxygen amount in the water, but also can form efficient food chain as a kind of food source for aquatic animals so as to improve water environment. Therefore, adjustment of environmental factors can restrain the growth of algae. Current study often focus on influences of sunshine, temperature, nutrient salt and pH on algae, while environment influences algae in many ways. Therefore, it is necessary to study the combined influences of sunshine, temperature, nitrogen, phosphorus, and pH on the growth of algae, and adjust the group structure of algae in waters, which will be the focus for future study.

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ternational community increasingly^[16]. LEDAPS based on Landsat image uses the radiation change detection method, to obtain forest vegetation information, and provide surface reflectivity products for estimating the carbon stock of a large area of forest ecosystem. With the development of remote sensing technology, the traditional serial LEDAPS preprocessing can not meet the needs of massive remote sensing image. On the basis of in-depth analysis of the principles and features of LEDAPS processing, this paper proposes a parallel computing method for LEDAPS massive image preprocessing based on MPI, considering the problem of time-consuming process of original serial image preprocessing of LEDAPS. The method uses a master-slave mode focuses on the irrelevance between the Landsat data processing, and carries out circular classification of Landsat data, to achieve data parallelization and at the same time achieve the load balancing processing of the task. The experimental results show that when 8 MPI processes run the program, the speedup after load balancing is 7.37. With the increase of computing nodes, the MPI speedup is increased linearly. At the same time, the test results also show that LEDAPS after transformation has good scalability, and is able to minimize the communication between nodes on the basis of load balancing. This parallel method is easy to use, robust and scalable. On the basis of substantially increasing the computing speed and saving the computing time, it realizes the scalability of computing nodes. This will help to apply LEDAPS to the processing of Landsat massive data, form large-scale application of corresponding surface reflectivity products, and accelerate the application of remote sensing technology to forest biomass and carbon stock.

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(From page 89)

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