Research progress and ideas of Influence of hydrological regimes on river primary productivity of algae

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Abstract. The algae, as the primary producer of the water ecosystem, are the basic part of food chain in aquatic ecosystem. The flow pattern and hydrological process of the river have been significantly changed by the construction of the high dams. Not only the natural hydrological characteristics and physical and chemical conditions of the river were changed by the obstacle of the dams, but also the habitat environment on which the phytoplankton live, and its community structure, biomass and primary productivity of the water further were affected. In this paper, the research on the effect of river hydrological regime change on the primary productivity of water body were summarized and summarized. In the future, further research can be carried out in these aspects: (i) the analysis of the key factors affecting the primary productivity; (ii) clarifying the mechanism of the influence of hydrological situation change on the primary productivity and its distribution of algae in the reservoir area and downstream channel; (iii) establishing the coupling relationship between the change of hydrological regime and the primary productivity of phytoplankton.

1. The role and primary productivity of phytoplankton

Phytoplankton (algae) is a very important component of freshwater ecosystem, which has very important environmental, economic and social values [1]. The algae, as the primary producer in the water ecosystem, are the basis of material circulation and energy flow in the whole water ecosystem. Phytoplankton, as the basic part of food chain in aquatic ecosystem, can provide many heterotrophic organisms in rivers with necessary food and oxygen sources for their survival [2,3]. If without phytoplankton using inorganic carbon for photosynthesis, many aquatic organisms in the river that do not have the ability of capturing light energy will disappear [4].

The primary productivity refers to the amount of organic compounds synthesized by algae in water body in unit time and unit space through photosynthesis. In natural water, the algae, as the energy base of the whole ecosystem, restricts the productivity of aquatic organisms through the food chain [5]. At the same time, the algal community structure can fully reflect the nutritional status of water body, and is also one of the important indicators applied to water environment monitoring [6-7].

Since the “black-and-white bottle method” for the determination of primary productivity of algae was first proposed by Garrder and Gran in 1927, a lot of work has been carried out by many researchers...
at home and abroad. However, there are few studies on the impact of hydrological regime change on the algal community structure and primary productivity, especially under the effect of the interception and regulation by dams.

2. Influencing factors on algae community and primary productivity

The flow pattern and hydrological process of the river have been significantly changed by the construction of the high dams. Consequently, the flow velocity above the dam slowed down, while the seasonal flood and dry process under the dam became less obviously. It is embodied in the change of water exchange, water temperature stratification, transparency and so on. After the completion of the dam, the flow pattern of the river changes, the water level of the reservoir area on the dam increased, and the stratification of dissolved oxygen and temperature appeared in the reservoir area [8]. With the flow velocity in the reservoir area decreased and the flow pattern tending to be stable, the sediment is continuously deposited, as the source of organic matter and inorganic matter, which greatly changes the original water quality and self-purification capacity [9]. Nutrients were continuously accumulated and the salinity of the water body increased in the reservoir area above the dam. The river gradually transited from the flowing water environment to the still water lake environment [10] and the transformation of algae from adapting to flowing water environment to liking still water environment happened. It is easy to touch off algal blooms out breaking in the water body of the reservoir area, and even lead to the eutrophication of the water body [11,12].

2.1. Effect of flow and velocity changes on primary productivity

Different flow and velocity have different effects on different kinds of algae and the effect on primary productivity is complexed. Due to the decrease of the flow velocity and water exchange volume caused by the dam construction, the nutrient input and accumulation in the upstream section of the dam often lead to the increase of water primary productivity, even the formation of water bloom [13-15]. However, under the influence of the water discharge from the reservoir, the primary productivity in the lower reaches of the river is varied in different seasons. On the whole, due to the increase of algae species and biomass, the primary productivity may also show an upward trend [16, 17].

2.2. Effect of water temperature stratification on primary productivity

The effect of water temperature on primary productivity is mainly to change the enzyme activity of organisms involved in primary production. There may be a quantitative relationship between primary production and water temperature. Generally, in a certain range, the higher the water temperature is the higher the primary productivity is. The annual and multi-year regulation reservoirs were prone to water temperature stratification due to the small amount of water exchange, which will affect the temporal and spatial distribution of algae community, thus affecting the distribution of primary productivity [18-20]. For the lower reaches of the reservoir of the high dams, due to discharge of the low temperature water of the bottom layer, the temperature in the lower reaches of the dam is lower than that in the same period of history [21], which may be to lead to some extent the reduction of the primary productivity of the water body.

2.3. Impact of transparency change on primary productivity

Light energy is the foundation of primary productivity. In the natural water, with the increase of water depth, the radiance will decrease exponentially according to Bill's law. For some specific phytoplankton population, the intensity of photosynthesis changes with the intensity of illuminance of light radiation. Therefore, the distribution of phytoplankton primary productivity in depth is determined by the transparency. After the construction of the dam, the suspended matter of the water body reduced in the upstream section and the transparency increased due to the decrease of water flow velocity, which slows down the attenuation of light intensity in the water and greatly improves the primary productivity. The primary productivity of the lower river reaches is related to the reservoir operation mode and regulation, the amount and the temperature of discharged water.
2.4. Other factors affecting primary productivity

A large number of studies have demonstrated that the change of plankton community structure was mainly affected by the physical and chemical conditions of water body and hydrological conditions [22-24]. Phytoplankton carried by the discharge water body of the upstream reservoir was the main source of phytoplankton in the downstream [25-26]. Different types of reservoirs have different hydraulic retention times, which not only affect the abundance and community structure of phytoplankton in the reservoir, but also affect phytoplankton in the downstream reach [27]. The change of water velocity caused by the dam was also another important factor affecting the community structure of phytoplankton in water [28-29], such as the inter-annual change of natural flow situation including flow intensity, occurrence frequency, duration, occurrence time and variation rate [30]. In addition, the factors include physical, chemical, hydrological and biological competition could have an impact on the distribution of phytoplankton in aquatic ecosystems [31, 32].

The changes of physical and chemical factors and hydrological conditions could be the two key factors that lead to the decrease of phytoplankton quantity in the monitoring stations of the downstream reach. It was shown that the discharge of the upstream reservoir had a great influence on the community structure of phytoplankton in the downstream river [33]. It was found that the water quality and algae community structure of the downstream had been affected by the discharge of upstream reservoir in the study on the rivers located in southwest Australia by Baldwin et al. [34]. Bovo et al. also confirmed that the upstream reservoir would affect the distribution of phytoplankton in the main stream and flood plain lakes in the downstream [35].

3. Prospect

To sum up, the hydropower development not only changes the natural hydrological characteristics and physical and chemical conditions of the river, but also further affects the habitat environment on which the phytoplankton live, and its community structure and biomass. In the future, further research can be carried out in the following aspects: i) the change rule of plankton community structure and primary productivity in the reservoir area and downstream river channel under the influence of the dam construction and operation; ii) a quantitative study of the influence of hydrological situation change on the primary productivity and its distribution in the key reaches of the reserve, and analysis of the key factors affecting the primary productivity; iii) establishing the coupling relationship between the change of hydrological regime and the primary productivity of algae in the key research reaches; iv) clarifying the mechanism of the influence of hydrological situation change on the primary productivity and its distribution of algae in the reservoir area and downstream channel. The relevant research results can provide scientific basis for the hydrological ecological restoration and combined operation of reservoirs system.

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