Ecology & Conservation Science: Open Access
ISSN: 2689-4637

Juniper Publishers
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Review Article
Volume 1 Issue 4 - November 2020
DOI: 10.19080/ECOA.2020.01.555567

Ecol Conserv Sci

Response of Typical Phytoremediation Species Vallisneria to Four Key Factors Under Eutrophic Water Conditions: A Review

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Submission: November 17, 2020; **Published:** November 25, 2020

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Abstract

In China, eutrophication is a major problem in watershed. Phytoremediation is a simple, cheap, and environmentally friendly method. As the main producer of aquatic ecosystems, submerged plants play an important role in phytoremediation. Vallisneria is a representative submerged plant, however, the growth of Vallisneria is mainly affected by many factors. In this article, it investigated four key factors, such as water depth, water movement, benthos and planting method and provided some theoretical support for the maintenance and restoration of submerged plants under ecological restoration.

Keywords: Water depth; Water movement; Benthos; Planting method; Vallisneria

Introduction

According to the Report on the State of the Ecology and Environment in China in 2017, among 109 lakes (reservoirs) whose nutritional status is monitored, 9 were under oligotrophic status, 67 were under mesotrophic status, 29 were under slight eutrophication, and 4 were under intermediate eutrophication. Excessive discharge of nitrogen (N) and phosphorus (P) is the main cause of surface water eutrophication [1,2] which leads to the deterioration of the ecological environment of lakes and rivers [3]. Eutrophication has led to the transformation of lakes from grass-dominated or algae-dominated to cyanobacteria-dominated, resulting in the destruction the ecological balance of the lake [4]. The high phosphorus concentration in the water body is considered to be a key factor in the outbreak of cyanobacteria. The outbreak of cyanobacteria not only reduces the light transmittance of the lake, but also secretes harmful allelochemicals, which leads to the reduction of species in the water ecosystem [5]. Phytoremediation is a simple, cheap, and environmentally friendly method to convert excess nutrients into valuable plant biomass [6], plays an important role in regulating lake functions and maintaining ecological balance [7]. As the main producer of aquatic ecosystem, submerged plants can release allelochemicals to inhibit the growth of cyanobacteria [8-10] They also provide a habitat for fish, reduce the turbidity of water caused by phytoplankton [11], and provide natural substrates for the growth of bacteria, algae and other microorganisms, forming biofilms or epiphytic microbial communities [12], effectively inhibiting the formation of harmful algal blooms [13], Hence, submerged plants has been considered as one of the best options for improving the eutrophication of shallow lakes [14] and has been widely planted to restore the ecological environment of eutrophic water [15,16]. However, the growth of submerged plants is mainly affected by non-biological factors such as water depth, water movement, water temperature, nutrient content, etc. [17]. In addition, the biofilm on the surface of submerged plants will also affect the growth [18]. The combination of biofilm and plants can improve water quality [19]. Vallisneria is one of the submerged plants that exists widely in China and has good nitrogen and phosphorus removal ability [20]. Studies have shown that water depth, water movement, benthos have an important influence on the growth of Vallisneria.

The Effect of Water Depth

Water depth will affect the underwater light, turbidity, distribution of attachments on the surface of aquatic plants and the growth of submerged plants [21,22]. The low light intensity brought by the increase of water depth will result in the winter buds and biomass of Vallisneria decrease sharply [23]. The morphology and structure of the biofilm on the leaf surface, such as the growth of aerobic/anaerobic bacteria and algae on the leaf surface were also affected by water depth. The research of our group showed that water depth affected the biofilm of submerged plants and microbial population structure. Submerged plants were stressed in both shallow and deep water. Thus, the best planting depth was 0.9m-1.2m for vallisneria [24].

The Effect of Water Movement

There will be various changes in the biofilm-water interface under flowing water conditions, including bacterial density, changes in microbial activity through attachment or detachment and production of extracellular polymeric substance [25,26]. As the water flow increases, the thickness of the biofilm decreases, the morphology of the biofilm changes and the diversity of bacteria increases [27]. Water flow affects the biofilm by regulating the growth of aquatic plant leaves to provide an environment for microbial aggregation on the surface of the leaves. Furthermore, the flexibility of plant leaves reduces the rate of water flow and the shear force at the water leaf interface to make the formation of biofilms easier [28]. The research of our group showed that the combination of Vallisneria and its leaf biofilm played a significant role in the removal of total phosphorus from eutrophic water. In addition, the eutrophic water flow could induce the oxidative stress and antioxidant defense system response in plant leaves [29].

The Effect of Benthos

Benthos promote the circulation of nutrients in the water body through absorption and excretion, affecting the growth of submerged plants by preying on submerged plant biofilms [30] The biofilm on the surface of submerged plants plays an important role in the interaction between benthos and submerged plants. Excessive biofilm may have negative effects on submerged plants by reducing light conditions and nutrient utilization [31-33] Some studies have shown that snails can feed on the periphyton layers on the surface of submerged plants, improving the ability of submerged plants to absorb light and nutrients, promoting the growth of submerged plants by regulating the local water environment through metabolism. However, some studies have also shown that snails restrict the growth of submerged plants and cause damage [34]. The research of our group showed that the presence of snails was beneficial to the growth of submerged plants. The increase of snail density was beneficial to the growth of submerged plants when the density of snails was below the medium density condition. There has no significant effect on the growth of submerged plants when the snails change from medium density to high density [35].

The Effect of Planting Method

The planting method of Vallisneria should be determined according to the water conservancy, water quality and the characteristics of planting substrate. Traditional planting methods such as sowing method, cutting method, sinking method have their advantages and disadvantages. The survival rate of the cutting method was higher than that of the sinking method, the sowing method was the lowest, and there was no significant difference among the biomass of individual plants [36]. However, the cutting method requires a lot of manpower and material resources and the operation is difficult. The sowing method is simple but is restricted by environmental conditions and the survival rate is not high. The sinking method causes damage to plants and soil erosion reduces the survival rate of plants. The research of our group shows that the agar-based method effectively improved the photosynthesis of plants, reduced physical damage to plants, weakened the stress response of the antioxidant system and ultimately promoted plant growth. This study indicated that the agar-based method may improve plant performance over existing mud-sinking approaches, which may optimize the restoration of aquatic ecosystems [37].

Conclusion

This review indicated that the water depth, water movement, benthos and planting method could affect vallisneria growth status including shoot height, root height and total chlorophyll. Moreover, the amount of biofilm and the structure of microbial community on vallisneria leaves have also been significantly changed. For water depth, the optimal planting depth of vallisneria for ecological restoration was 0.9-1.2 m below the water surface. For water movement, the combination of periphyton biofilm and vallisneria played an important role in the removal of total phosphorus from flowing eutrophic water. For benthos, the presence of snails was beneficial to the growth of submerged plants. For planting method, the agar-based method promoted plant growth and photosynthesis more effectively than the existing mud-sinking approaches. These above findings provided a better understanding of submerged plants and their biofilms, demonstrating the potential use of biofilm-plant systems in watershed protection.

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How to cite this article: Wenjing S, Zheng Z. Response of Typical Phytoremediation Species Vallisneria to Four Key Factors Under Eutrophic Water Conditions: A Review. Ecol Conserv Sci. 2020; 1(3): 555567. DOI: 10.19080/ECOA.2020.01.555567

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