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Cyanobacterial dominance in lakes

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Abstract

Cyanobacterial dominance in lakes has received much attention in the past because of frequent bloom formation in lakes of higher trophic levels. In this paper, underlying mechanisms of cyanobacterial dominance are analyzed and discussed using both original and literature data from various shallow mixed and deep stratifying lakes from temperate and (sub)tropical regions. Examples include all four ecotypes of cyanobacteria sensu Mur et al. (1993), because their behavior in the water column is entirely different. Colony forming species (*Microcystis*) are exemplified from the large shallow Tai Hu, China. Data from a shallow urban lake, Alte Donau in Austria are used to characterize well mixed species (*Cylindrospermopsis*), while stratifying species (*Planktothrix*) are analyzed from the deep alpine lake Mondsee. Nitrogen fixing species (*Aphanizomenon*) are typified from a shallow river-run lake in Germany. Factors causing the dominance of one or the other group are often difficult to reveal because several interacting factors are usually involved which are not necessarily the same in different environments. Strategies for restoration, therefore, depend on both the cyanobacterial species involved and the specific causing situation. Some uncertainty about the success of correctives, however, will remain due to the stochastic nature of the events and pathways leading to cyanobacterial blooms. Truly integrated research programs are required to generate predictive models capable of quantifying key variables at appropriate spatial and temporal scales.

Introduction

The phytoplankton of many lakes, especially those of higher trophic levels, is dominated by large, colony-forming species of cyanobacteria (formerly referred to as blue-green algae) such as *Microcystis, Planktothrix, Limnothrix, Anabaena*, or *Aphanizomenon.* Permanent cyanobacterial dominance is, therefore, regarded as the ultimate phase of eutrophication occurring world-wide (e.g. Robarts, 1985; Jones, 1994; Pizzolon et al., 1999). Despite considerable research summarized in Schreurs (1992), the reasons for such outbreaks largely remain unclear. Excessive abundance or 'blooming' of cyanobacteria generally has detrimental effects on the domestic, industrial and recreational uses of water bodies and is in many cases a direct motivation for restoration measures.

Because of their success and ubiquity in freshwater systems, cyanobacteria are probably the best studied group of phytoplanktonic micro-organisms (Stanier & Cohen-Bazire, 1977; Bryant, 1994). Several of their prokaryotic properties such as gas-vesicles, low CO_2/high pH optimum and nitrogen-fixation bear special ecological significance. These and further molecular characteristics of cyanobacteria are described in more detail in Schreurs (1992), Mur et al. (1993) and Bryant (1994).

Not all features are present in all cyanobacterial forms. The extent to which certain characteristics are expressed is dependent on the form and the size of the organism. For instance, the formation of colonies or aggregates is of decisive importance for the physiology and behavior of cyanobacteria.

In practice, the planktonic cyanobacteria can be divided into four ecotypes according to their behavior in the water column (Schreurs, 1992; Mur et al., 1993):

1. Species able to fix N_2 (e.g. *Aphanizomenon flos-aquae, Cylindrospermopsis raciborskii*).
2. Stratifying species (e.g. *Planktothrix rubescens*). This ecotype flourishes in a certain 'optimal'