ECOPHYSIOLOGICAL PERSPECTIVES OF BLUE-GREEN ALGAL BLOOMS

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ABSTRACT

Blue-green algae (cyanobacteria) have had a profound and unparalled impact onthe aquatic environment because of the phenomenon of bloom formation. In many countries, water management is threatened with extensive and persistent noxious blooms of blue-green algae in surface and near-furfacemesotrophic and eutrophic waters.

In view of this, ecological and physiological factors responsible for blue-green algal dominance are discussed. The implications of cyanobacterial blooms are highlighted and recommendations made to combat this menace.

INTRODUCTION

Phytoplankton communities are an essential component of all aquatic environments because primary production by phytoplankton forms the base of the food chain in water. At moderate standing crops, phytoplankton are beneficial as net producers of dissolved oxygen and assimilators f ammonia as a nitrogen source for growth. Despite these beneficial aspects, most water quality problems are the result of unmanaged growth of phytoplankton communities (Smith 1988).

In many countries, regular blooms of toxic algae occur and these have a significant impact on the utilization of aquatic resource (Graneli et. al., 1990). The major groups of phytoplankton responsible for bloom formation are dinoflagellates and blue-green algae.

What are blue-green algae?

Blue-green algae are prokaryotes which lack a membrane-bound nucleus and other membrane-bound organielles. They are unique in their ability to fix free nitrogen inthe atmostphere. In some genera such as Anabaena, Aphaizomenon, Nostoc and Nodularia nigrogen fixatin is confined to metabilically specialize thick-walled cells known as heterocysts. Several non-heterocystous genera are also capable of nitrogen fixation.

Blue-green algae possess differentiated cells referred to as akinetes which are perennating structures that can accumulate storage polymers and encyst. Thus, they aid in survival of the species under adverse environmental conditions (Fogg et al., 1973). All bloom forming cyanobacteria have intracellular gas vacuoles which are involved in regulating cell buoyancy (Fig. 1). They are widely distributed and include at least 22 genera and over 90 species (Gibson and Smith, 1982). They can be separated into unicellular, colonial and filamentous forms.

Factors Favouring Algal Bloom Formation

Despite the ubiquity and persistence of algal blooms, there is little information linking the physical, chemical and biological conditions in the environment with physiological adaptations that such algae have evolved to optimize growth and persistence during bloom periods. Ecophysiological factors responsible for blooms are numerous and complex (Table 2). However, physical factors are frequently of overriding importance in determining which genera and species become established and dominant in specific ecosystems (Paerl and Tucker, 1995).

Implications of Bloom Formation

Cyanobacterial blooms lead to some of the most ominous symptoms of water quality degradation including bottom water anoxia and hypoxia; odour, taste and toxicity problems; destruction of the aesthetic and recreational values of water and structural shifts in plankton communities. However, the most economically important consequence of bloom formation involves mortality and morbidity in fisheries resources (Van der Ploeg and Boyd, 1991).

Generally, cyanobacteria are k-selected organisms with relatively slow growth rates but high competitive ability for limited resources (Kilham and Hecky, 1988). Hence, he low biomass-specific rates of net carbon fixation translates into reduced fish yields. The efficiency of food transfer may be further reduced when blooms are present because they are poorly utilized as food (Paerl 1988b). The slow growth rates of blue-green algae also means that they are poor oxygenators of water on a per unit biomass basis compared to other phytoplankton species. In addition, surface bloom communities reduce net input of dissolved oxygen to water because oxygen production is restricted to the upper few centimetres. massive die-offs of cyanobacterial communities results in oxygen depletin as dead algal cells are decomposed. Fish kills in tropical lakes as a consequence of blooms occur but are rarely reported (Belay and Wood, 1982; Ochumba, 1990).

The production of highly odourous and/or toxic metabolites by some species causes great economic loss in fisheries. Two metabilites of blue-green algae geosmin and 2-methylisoborneol cause earthy-musty odours and off-flavours in pond-cultured fish (Van der Ploeg et al., 1992). Several blue-green algae produce toxins which have poten cyto-hepato - and neuro-toxic effects on fish, shellfish, invertebrates, birds and mammals (Carmichael, 1986; Haney et al., 1995).

Blue-green algal dominance in aquatic environments results in a structural shift in the plankton community structure and hence in the dynamics of the ecosystem.

Control

In proposing control strategies against algal blooms, water column turbulanece of mixing asumes a prominent role. This realization has fostered the application of artificial mixing strategies in reducing and eliminating bloom populations. However, to be effective mixing must operate more or less continually during favourable bloom growth periods.

Close monitoring of the ambient nutritive conditions in water bodies is necessary. Decreased phosphate availability can lead to declines in algal bloom potentials particularly for nitrogen-fixing genera.

There is the possibility of biological control using amoeboid protozoans which are active grazers on blue-green algae even when higher-ranked crustacean zooplankton find such cyanobacteria either inedible, distasteful or toxic (fulton & Paerl 1988). However, bloom eradication and mitigation

Table 2: Factors influencing algal bloom formation

{PRIVATE }ECOLOGICAL FACTORS	EFFECTS OR IMPACTS
Physical	
Temperature	Generally warm water temperatures accompanied by a stratified water column and high nutrient loading rates promote blooms.
Large Scale Vertical Mixing	Prevents surface bloom accumulations and forces competition for light and nutrients with non-buoyant eukaryotic taxa
Small Scale turbulence	May disrupt filaments, colonies and mutualistic associations with other micro-organisms.
High water transparency	Promotes bloom formatin because unlike other eukaryotic phytoplankton bloom-forming genera can withstand long periods of exposure to high photosynthetically active radiation (PAR).
Low hydraulic retention time/flushing	Prevents bloom establishment or removes bloom if flushing rate exceeds growth rate of bloom taxa.
Chemical	
Eutrophication/Nutrient input	Favours bloom formatin especially if the ratio of N to P loading is low.
Salinity	Salinity in excess of a few ppt may be an effective barrier to the development and persistence of blooms.
Environmental pH Trace metals	Generally high pH favours blue-green algal growth. Under high N and P loading, restricted availability of Fe may favour cyanobacteria.
Biological	Absence or scarcity of herbivorous zooplankton and larger filter feeding species that can ingest blue-green algae.

SOURCE: Paerl and Tucker, 1995.

Approaches utilizing biological control measures require careful and critical evaluation prior to deployment on thenatural community.

More recently advancements in biotechnology offer prospects for the use of "bloom" species. It has been discovered that many micro-organisms are a promising new source of bioactive substances which could be used int he manufacture of industrial chemicals, marine biomedicals and non-polluting energy sources. Notable among these, is the discovery of antileukaemia activity in blue-green algae of the family Oscillatoriacea. Thus in the near future, blue-green algal blooms may be harvested and exploited for the production of novel compounds (Ninewe, 1995).

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