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Algae in Fresh Water Ecosystem

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Abstract

The phytoplankton study is a very useful tool for the assessment of water quality in any type of water body and also contributes to understanding of the basic nature and general economy of the aquatic system. Changes in season, temperature, wind, precipitation patterns, and nutrient cycles influence the dominance of algae. Mostly algae were abundant in early spring and summer seasons. Phosphorus (P) is often considered as the principal limiting nutrient for aquatic algal production due to their short supply compared to cellular growth requirements. Rapid increase or accumulation in the population of algae in a water system is referred as algal blooms which are harmful in nature. Algal population can be measured by estimating chlorophyll a concentration, Secchi depth measurements and total phosphorus concentrations. Excess algae can be controlled by chemical, physical and biological methods. Bioindices of species diversity can be derived from species counts, which are species richness (Margalef index, Menhinick's index), species evenness/dominance (Simpson index) and a combination of richness and dominance (Shannon–Wiener index), Pielou's evenness index (E), Berger-Parker dominance index is the number of individuals in the dominant taxon. The algal abundance can be used to determine the trophic status of an aquatic ecosystem.

***Key words*:** Algal blooms, Bioindices, Chlorophyll a, Limiting nutrients, Margalef index ,Phosphorus , Phytoplankton, Secchi depth, Simpson index , Trophic status.

Introduction

Most aquatic systems around the world, including rivers, lakes and reservoirs, have undergone changes because of human–induced disturbances from land-use activities (Kuang *et al,* 2004). Among the freshwater organisms phytoplankton, as primary producers forms the vital energy source at the first trophic tier (Gayathri *et al.,* 2011).They also have an important role in the material circulation in aquatic ecosystems by controlling the growth, reproductive capacity and population characteristics of aquatic biota (Anjana *et al*., 1998). Phytoplankton are important in environmental impact study in as much as they are extremely responsive to change in the environment and thus indicate environmental changes and fluctuations that may occur (Ingole *et al.,* 2010). They have a short life span and respond quickly to environmental changes (Zebek, 2004 ; Kawecka and Eloranta, 1994). Phytoplankton are very useful tool for the biomonitoring of a water body with regard to its pollution status (Stoermer, 1977). However excessive growth of algae may interfere with our enjoyment of aquatic resources and may even be harmful. Because of their importance to aquatic ecosystems and susceptibility to changes in the environment, algal measurements are often key components of water quality monitoring programs. This paper describes algae and their role in aquatic ecosystems; characterize algal succession; describe how algal levels are measured and what these measurements indicate; and discuss how algal populations, especially nuisance algal blooms, may be controlled.

Algae come in an amazing number of sizes and shapes which are actually adaptive strategies to prevent them from sinking away from the sunlight in the upper portion of the water column. These anti-sinking adaptations include flat, wide cell shapes and spines which increase friction and lessen gravitational influences. Some phytoplankton have developed mechanisms to move actively (Caduto, 1990). Tail-like extensions, flagella of some algae can move them through the water. Some phytoplankton adjusts the size of gas-filled sacs, vacuoles to move through the water column. Some algae reproduce via asexual reproduction, where the parent splits into two or more cells, while other algae are capable of sexual reproduction (St. Amand, 1995). Some even adapt reproduction rates in response to water flow rates. For example, an alga may reproduce faster in turbulent waters, to replace cells swept downstream, than in still waters where algal biomass can accumulate (Caduto, 1990)

Factors influencing algal growth

Increase in phytoplankton cell numbers are affected by seasons, amount of sunlight penetrating the water column, available inorganic nutrients, competition from other algae and aquatic plants, and the residence time of water in the acquatic system (Simpson, 1991). Aken (2008), Stenseth *et al.,* (2004) and Tsuchida *et al.,* (1984) reported that temperature was the limiting factor for controlling the multiplication rate and standing stock of natural population density of phytoplankton. Phosphorus (P) and Nitrogen (N) are often considered as the principal limiting nutrients for aquatic algal production (Cecilia, 2011 and Hutchinson, 1967). Generally aquatic ecosystems receive excess of this nutrient through untreated domestic sewage and agriculture runoff (Shinde *et al.*, 2010). In aquatic systems whose course takes those through terrains made up of agricultural and residential areas, phosphates can be expected to be found in higher concentrations than those that drain non-agricultural areas (Cecilia, 2011 and Reid, 1961). Higher phosphate content during summer is due to high temperature (Patil *et al.*, 2013; Subhabrata *et al*., 2012). The phosphate concentration decreased quickly with the increase of phytoplankton abundance, and in most cases, phosphate concentration was lower than the level at which the growth of phytoplankton is limited (Gao and Song, 2005). Blue green algae assimilate phosphate at a faster rate than green algae and accumulated large amount of reserve phosphate for extended growth periods at low phosphate concentration (Lam and Silvester, 1979). The presence of inorganic phosphorus at 0.03 mg/L concentration is sufficient to cause dense, smelly algal mats referred to as an algal bloom (Sheela *et al*., 2011).

Seasonal Changes in Algae

Throughout the year, however, algal species dominance of lakes changes in a yearly cycle, known as algal succession (Kortmann and Henry 1990). This natural succession of algae occurs in response to changes in season, temperature, wind, precipitation patterns, and nutrient cycles (Moore and Thornton 1988). Mostly in reservoirs of Asia, minimum phytoplankton can be observed during the monsoon (Silva, 2005). According to Sugunan (2000) most of the reservoirs in India have three plankton pulses coinciding with the post-monsoon (September to November), winter (December to February) and summer (March to May) seasons. It has been pointed out that the amount of rainfall plays a significant role in regulating the various seasonal biological rhythms and the raise the level of aquatic systems with the concentration of certain chemical substances which in turn influence the fluctuations in the quantity and quality of phytoplankton (Hulyal and Kaliwal, 2009). The temporal variations of phytoplankton in tropical systems are related to differences in rainfall (Subhabrata, 2012; Chellappa *et al*., 2008 ; Dantas *et al.,* 2008 andMelack, 1979). The high temperature, bright sunlight and rapid tropholytic activities could render to decrease in water level and bring the deep nutrient-rich areas into the fold of tropholytic zone, which increase phytoplankton biomass during summer dry month of March to May (Janjua, 2009; Kelly and Linda, 1996). In winter, due to the reduction in the amount of light energy, the abundance and biomass of algae decreased (Kozak, 2005). Significant dilution of essential growth nutrients for biotic communities is usually witnessed during annual episodic flooding periods at the peak of rainfall, between August and November (Dike and Adedolapo, 2012; Oduwole, 1997). Freshwater discharges from the river causing turbidity and less availability of light during rainy season decreasing algal biomass (Gnanamurthy *et al*., 2013; Bhoyar and Tamloorkar, 2012, Krishnamoorthy *et al.,* 2007).

Harmful Algal Blooms

Extremely high levels of algae can generate enough shade to prevent sunlight from reaching macrophytes, limiting their plant growth or even causing them to die. Also, as more algae grow within the lake, there are more dead algae to be decomposed. Decomposition by bacteria consumes oxygen and may decrease or even completely deplete dissolved oxygen contents of some lakes during the summer. Complete lack of oxygen is a condition known as anoxia which can cause death of fish. High levels of algae may raise the pH of waterbodies. Higher pH levels may be noted late on sunny summer afternoons after photosynthesis has consumed carbon dioxide throughout the day. After sunset, pH levels may fall noticeably since photosynthesis has ended. These extreme fluctuations in pH stress sensitive aquatic life. There is also concern that excessive amounts of algae may form the organic matter base of a reaction with the chlorine used at many water treatment facilities. This generates trihalomethanes (Moore and Thornton, 1988). Trihalomethanes may be associated with cancer risks.

Phytoplankton species have the ability to liberate some “toxic” or “allelopathic” agents (Cembella, 2003; Arzul *et al.,* 1999). In general the number of toxic-phytoplankton species is remarkably smaller than the number of other phytoplankton that are non-toxic so far, only 30–50 species of phytoplankton have been identified as toxic (Cembella, 2003). The presence of toxic species has a significant impact on the overall plankton dynamics (Roy *et al.,* 2006; Kozlowsky-Suzuki *et al.,* 2003; Nielsen *et al.,* 1990 and Ives, 1961). Some genera of phytoplankton, such as *Microcystis, Anabaena, Nostoc* and *Aphanizomenon,* usually breakout and stand stably, leading to problems with hypoxia, toxins and changes in the structure of biological communities (Carmichael, 2001). Lake management emphasis should be geared towards maintaining healthy, natural levels of algae within waterbodies.

Measurement of Algal Concentrations

Measurement of chlorophyll a concentration is considered a reasonable estimate of algal concentrations (Simpson, 1991). To measure chlorophyll a concentration, a lake water sample is taken. A known quantity of water from this sample is passed through a glass fiber filter disk. The filter catches the algal cells from the sample. The filter is stored in the cold and dark to minimize additional algal growth or degradation. Chlorophyll a is extracted with an acetone solution. Concentrations are determined by analysis with a fluorometer or a spectrophotometer. A way to measure algal concentrations indirectly is by taking Secchi depth measurements, a measure of water clarity. The degree of water clarity is a result of the amount of suspended materials in the water column. In areas of low sediment inputs to lakes, there is a strong relationship between Secchi depth measurements and chlorophyll a concentrations. Total phosphorus concentrations may also be used to estimate the potential amount of algae in a lake (Kelly and Linda, 1996).

Control of Algal Populations

Due to the growing concern about nuisance algal growth in many lakes, mechanisms have been explored to limit algal growth (Mc Comas, 1993). Mechanical control involves the use of filters, pumps, and barriers (e.g., curtains, floating booms) to remove or exclude blooms from impacted waters. Physical, chemical (Copper sulfate, Buffered alum and/or calcium compounds are sometimes added to bind up phosphorus and make it unavailable for algal use) and biological control (pathogens that can kill algal blooms) measures have been used in freshwater systems for small and large-scale control of algal blooms due to their significant public health, economic, and ecosystem impacts (Chorus and Bartram, 1999).

Determinants of Trophic Status of aquatic system

Algal concentrations can be used to determine the trophic status of a lake. Oligotrophic waters are clear to great depths and have few algae. Waterbodies with abundant algae are described as eutrophic; these are often turbid. In the middle of the spectrum, with moderate algal levels, are mesotrophic waterbodies (Kelly and Linda, 1996). Trophic status can be estimated from chlorophyll a concentrations, Secchi depth measurements, or total phosphorus concentrations. The overall trophic state index (TSI) of a lake is the average of the TSI for phosphorus, the TSI for chlorophyll-a and the TSI for secchi depth. These parameters help to create a complete picture of a lake's water quality and the relationship between water quality and algal growth.

Bioindices of Phytoplankton Communities

Diversity indices can serve as a good indicator of the overall pollution of water. Bioindices of species diversity can be derived from species counts and are of three main categories, which are species richness (Margalef index), species evenness/dominance (Simpson index) and a combination of richness and dominance (Shannon–Wiener index) (Sigee, 2004). These diversity indices have been developed by taking into account the number of species and their relative abundances, which means the higher the values of these diversity indices, the more the oligotrophic state of water bodies. Wilhm (1975) implied that a high value of diversity index (H') suggests a more healthy ecosystem, while a low value suggests a less healthy or degraded ecosystem. Dash (1996) reported that higher the value of Shannon's index (H') the greater is the phytoplankton diversity. Margalef index (Margalef, 1958) relates the number of species to the total number of individuals. The fall in the value of Margalef index shows the rise in the level of pollution. Mukherjee (1997) reported that higher species richness (R_1 and R_2) is characterized by larger food chain. The higher value of Shannon's index (H') indicated greater species diversity. The greater species diversity means larger food chain and more cases of inter-specific interactions and greater possibilities for negative feedback control which reduced oscillations and hence increases the stability of the community (Ludwick and Reynold, 1998). Pielou's evenness index (E) (1967) states that species evenness is a measure of diversity that quantifies how equal the community is numerically. Species evenness decreased with increasing size of the plankton population (Shinde *et al.,* 2011; Adesalu and Nwankwo, 2008). Berger-Parker dominance index (1970) is the number of individuals in the dominant taxon divided by number of individuals (n). It is the largest species proportion of all species in a community. This index is most strongly influenced by evenness of the indices (Shannon and Weiner, 1949).

Various diversity measures have potential applications in aquatic ecosystems, mainly in conservation. It is often understood that species rich communities are better than species poor communities. Secondly, in environmental monitoring, it is assumed that the adverse effects of pollution will be reflected in the reduction of diversity or change in the composition of species abundance. Rosenberg (1976) and Patrick (1973) are of the opinion that enriched or polluted ecosystems display a reduction in diversity. Platt et al. (1984) used the Simpson's index in bio monitoring. Stoermer (1984) discussed the role of phytoplankton species and assemblage as bio-indicators. Maguran (1983) comments that ecologists should be able to ask the question and formulate the hypothesis to help them understand and sensitively manage the natural ecosystem.

It is generally believed that ecosystems high in diversity are more stable. Since the Earth Summit held in Rio de Janeiro, Brazil, in 1992, interest in species diversity has been increasing, especially in terms of conserving natural ecosystems (Tamiji and Gen, 2004). However, the factors producing and maintaining species diversity have not yet been well documented. As stated by Hutchinson (1961), the reason why many plankton species coexist in an apparently homogeneous and isotropic environment is still in question.

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