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Aquatic Plant Biodiversity: Biological Indicator for Monitoring and Assessment of Water Quality

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Abstract

The present case study covers the concept of water pollution, its cause and effects on plant diversity of an aquatic ecosystem. An alteration in the diversity of plants and the disappearance of aquatic plants has been noted in the majority of the world's water bodies as a result of water pollution. In polluted aquatic ecosystems, plant diversity was studied as a strong bioindicators ofwater quality. Numerous studies on phytoplankton and aquatic macrophytes have been incorporated as an indicator of water pollution. Water pollution leads to changes in species composition, declines in overall plant species diversity and the loss of rare and uncommon species. A perturbation in aquatic ecosystems causes succession of macrophytes with complete loss of submerged vegetation and dominance of phytoplankton's and weeds. Monitoring, assessment and measurement of plant diversity through density, frequency, abundance and diversity indices are also integrated in this paper.

Keywords: Water Pollution, Aquatic Ecosystem , Biodiversity, Biological indicators.

Introduction

Aquatic ecosystems are very rich sources of biodiversity. Macrophyte richness is a vital parameter directly related to altitude, nutritional status and water quality. Mechanisms regulating species diversity in aquatic ecosystems have been studies very little, compared to terrestrial and benthic ecosystems. The species diversity of various water bodies has been explored, where the water quality parameters showed a direct impact on the dynamics of plant diversity. Anthropogenic forcing supports a higher diversity of non-indigenous species as compared to the indigenous species. When there is degradation of an ecosystem by pollution or over-exploitation, the dominant species are eliminated or debilitated, which shows a causal connection between loss in biodiversity and changes in ecosystem structure and function. The anthropogenic stresses and open water habitat increase the abundance of exotic species and lead to vegetation removal and plant invasion, causing perturbation in the aquatic ecosystem. Many physical processes like nutrient cycling, dynamics in temperature, pH, dissolved oxygen, carbon dioxide and light are the important limiting factors for the growth and development of aquatic flora.

The plant species composition showed significant correlations with nutrient concentrations, water level and depth of water body. Aquatic plant diversity is directly influenced by pH, the concentrations of Cl–, organic carbon and NH4 +, and water temperature. Algal diversity was studied in Najafgarh drain (River Sahibi) in Delhi, India. The drain receives agricultural, industrial and domestic effluents. The species recorded from the drain were found to be highly tolerant to water pollution caused by these organic compounds and have been suggested as suitable for bio-monitoring and phytoremediation. The growth responses of common duckweeds Lemna minor and Spirodelapolyrrhiza were reported to be directly correlated with the aquatic environment. Aquatic biodiversity is an underestimated component of global biodiversity and its estimation acts as a model for basic researches in evolutionary and experimental biology and ecological studies.

Therefore, aquatic organisms signal water quality, and can thus be used for monitoring and assessment of different kinds of water pollution and its influence on ecosystem health. The emerged, free-floating and submerged macrophytes have always been considered important in long-term monitoring and assessment of water quality in lentic and lotic aquatic ecosystems, as they are very sensitive to the water pollution. However, the submerged macrophytes are reported to be the most suitable for the assessment of lotic water ecosystems.

Water Pollution

The contamination of water bodies results in the degradation of the aquatic environment when pollutants are directly or indirectly discharged. The entire biosphere, plants and animals living in these water bodies are affected by the water pollution. In most cases, the effect is harmful, not only to individual species and population, but also to the natural biological communities. The most common sources of water pollution are nutrients, fertilizers (industrial and household), acid rain, heavy metals, pesticides, oil, and many other industrial chemicals. One of the major forms of water pollutants comes through run-offs as a result of rain. The nitrates and phosphates in the water result in eutrophication, causing algal blooms. As a result of the increase in algae, a reduced amount of sunlight is able to reach other aquatic plants, leading to their death. The algae themselves also eventually die and bacteria then begin to break down the dead plant material and algae, using up oxygen, resulting in the death of fish and other organisms. The composition and total amount of algae species can indicate the amount of organic pollution. In recent decades, a significant effort has been put forward around the globe for environmental monitoring and assessment of water pollution based not only on chemical parameters (nutrients, metals, pesticides, etc.), but also on biological indicators. It is difficult to draw a conclusion in an intermediate situation about the quality of water without further evaluation.

Biological Indicators

The species whose presence, absence or abundance reflects a specific environmental condition such as habitat or community and health of an ecosystem or pollution, is considered an indicator species. An indicator species provides a forecast for any changes in environmental conditions as they are the most sensitive species of an ecosystem. The biological indicators respond very rapidly to environmental changes and are widely used for the assessment and monitoring of different types of normal and perturbed ecosystems.

For the management and monitoring of pollution levels, the bioindicators are one of the important tools.

Plant species of different groups serve as a reliable index for biological monitoring of pollution load in an aquatic habitat. The aquatic macrophytes are well known for their great potential to indicate quality of water. They can tolerate and accumulate high concentration of toxic substances in their tissues, and on their biochemical analysis, the presence of any environmental contaminant can be determined, even when in very low concentration. In several susceptible species, morphological and structural changes induced by metal may also be indicative of changes which are specific to metals. The nutrient fortification effect is indicated by the disappearance of vulnerable species, leading to the change of species composition. These may be effectively used as ecological indicators (bioindicators) for assessing and predicting environmental changes. To determine the concentration of pollutants, especially heavy metals in rivers and oceans, biological markers have attracted a great deal of scientific interest.

The main idea behind the biomarker approach is to perform the analysis of an organism's metal content and comparison with background metal levels. Indicator species represent a particular environment, and they are easy to adapt and harvest.

Biological Indicators and Bio monitoring Programme

Biological monitoring, or bio-monitoring, is the use of biological responses to assess changes in environmental conditions. Biomonitoring programmes, which may be qualitative, semi quantitative or quantitative, are an important tool for assessing water quality in all types of monitoring programmes. There are two types of biomonitoring: first, surveillance before and after a project is complete, or before and after a toxic substance enters the water; second, biomonitoring to ensure compliance with regulations or guidelines, or to ensure maintenance of water quality. Biomonitoring involves the use of indicator species/communities: aquatic plants are used for various pollutants and nutrients (Feminella and Flynn, 1999). Stream organisms have been reported as the base for pollution detection and water quality monitoring when stressors are unknown and/or less is known about species tolerance levels, multiple level assessment and more intensive and expensive studies will be required. Behavioural changes of organisms may also be considered as indicators for assessment and monitoring. Biochemical, genetic, morphological, physiological and behavioural changes, populations and community dynamics could also be studied through an indicator species. Some other attributes or changes are also considered as indicators for the health of an aquatic ecosystem; for example: genetic mutations, reproductive success, physiology metabolism, oxygen consumption, photosynthetic rate, disease resistance, tissue/organ damage, bioaccumulation, population survival/mortality, sex ratio abundance/ biomass, behaviour (migration), predation rates, population decline/increase in community abundance ('evenness') of an organism, etc.

Plant Diversity as a Biological Indicator

Any structural and functional change in species, population, community, relative density, frequency and abundance may indicate pollution. Presence or absence of a particular species may indicate favourable or unfavourable changes to its ecosystems. The response of a single indicator species may not provide sufficient data for the assessment of an ecosystem's health, and further investigations may be required to reach any conclusion. Many migratory species can also indicate the environmental condition: fish and algal species associated with the same food chain have been used in stream biological monitoring and assessment programmes (Feminella and Flynn, 1999). There is the relative influence of local- and landscape-level habitat on aquatic plant diversity, but local habitats are more influential than the landscape. Several plants from different divisions of the plant kingdom, such as chlorophyta, bryophyta, pteridophyta and angiosperms, can be used for the monitoring and assessment of water quality in freshwater or marine, lentic or lotic, wetlands and coastal aquatic ecosystems.

Macrophytes as an Indicator of Water Pollution

Aquatic plants such as Otteliaalismodes, Fimbristylispauciflora and Blyxamalayana are reported sensitive to zinc, copper, cadmium, lead, nickel, and iron and chromium concentration. Metal enrichment was found to be dependent on the plant species and metal type. All plants showed their potential to remove copper, zinc and cadmium more rapidly than chromium and nickel. These plants were found to be sensitive to the aquatic environment and may be used as biological indicators of water pollution. Lemna minor, freefloating duckweed, is highly sensitive to a number of environmental factors, and has been determined as an indicator of water quality. Various Potamogeton species have also been reported as indicators of water pollution, typically P. filliforms and P. polygonifolius. Many other species like P. alpinus, P. lucens, P. praelongus, P. zooterifolius, P. aqualifolius, P. colourates (P. coloratus), P. densus and P. ratilus are slow growing but also act as water quality indicators. Aquatic macrophytes are photosynthetic and large enough to see with the naked eye. They grow actively submerged or free floating through the water surface.

There are seven plant divisions: Cyanobacteria, Chlorophyta, Rhodophyta, Xanthophyta, Bryophyta, Pteridophyta and Spermatophyta for the aquatic macrophytes. Species richness, composition and distribution of aquatic plants in the more primitive divisions are less known than vascular macrophytes in the divisions Pteridophyta and Spermatophyta, of which 2614 aquatic species have been reported and represent only a small fraction (1%) of the total number of vascular plants. They are included in 33 orders, 88 families and 412 genera. Aquatic macrophytes play an important role in the structure and function of aquatic ecosystems. Many of the threats to fresh water result in reduced macrophyte diversity, which, in turn, affects the faunal diversity of aquatic ecosystems and supports the introduction of exotic species at the expense of native species. Various macrophytes such as Potamogeton sp. have been considered strong indicators of Cu, Pb and Zn pollution in aquatic systems.

Algae as a Biological Indicator

Most algae that grow on the surfaces of rocks in a slippery layer are called periphyton and if they remain suspended in the water are called phytoplankton. The algal population increases at a faster rate when the water is enriched with nutrients that algae need for their growth (Philadelphia Water, 2015). Lower plants are considered as strong indicators of pollution and algae have been extensively used as indicators of water quality. Scenedesmus obliquus has been reported as an indicator of cadmium and lead pollution. Brown algae have also been used as biological indicators of heavy metal pollution. Variation in species diversity of phytoplankton strongly indicates pollution in aquatic ecosystems. Morphological changes, cellular malformation, chlorosis and significant increase in heterocyst frequency in Anabaena cylindrica indicate cadmium pollution. An induction of abnormally long filaments and loss of cellular contents has been reported in A. inequalis as a result of cadmium pollution. A notable decrease in zygospore germination in Chlamydomonas has also been reported in response to some herbicides and insecticides.

Diatoms: An Indicator of Water Quality

Diatoms are a single-celled, microscopic algal species with a siliceous covering called a frustule. They occur in a variety of shapes, and are either planktonic (living suspended on the water), benthic (growing associated to a substrate), or both planktonic and benthic. The algal species that develop in an area are very sensitive to different environmental factors like salinity, temperature, pH, water velocity, shading, depth, substrate availability and water chemistry. Thus, the species that can be found in a water body indicate the physico-chemical properties of the water. Algae are considered good indicators for the monitoring of water quality. Diatoms have the benefit of being easily identifiable at the species level, and are very simple to collect and store due to their hard frustule. The ecological requirements of many diatom species are known and, therefore, many diatom-based indexes of water quality have been developed. The diatoms may remain in their location until or unless there is a disturbance in the aquatic ecosystem: they reflect the characteristics of the water from the area in which they live. Protocols must be followed at the time of sampling, treatments and analysis of diatoms to avoid the risk of using the indexes alone, as there are some situations which can lead to incorrect conclusions about the health of an ecosystem.

Measurements and Evaluation of Biodiversity

The diversity index of a community is the ratio between the number of species and the number of individuals in that community. The species richness index, Palmer's generic index and Margalef's index are useful for the assessment of water quality parameters. The diversity and density index of planktons are generally applied for the monitoring of water pollution by organic contaminants. Population dynamics is the study of how and why population size changes over a time period. Plant populations can be estimated by their size, density, structure, number of individuals of different age groups. To understand the patterns of population dynamics, observations, experiments and mathematical models are used by plant population ecologists. Plant populations are controlled by densitydependent forces, interspecies and intraspecies competition for various resources. Demographic differences among individuals also affect the potential of contribution to population dynamics. Transition matrix models are the most important mode commonly used to study plant populations and guide the management of harvested populations and species of conservation concern. For predicting environmental perturbations, plants are increasingly being used as highly effective and sensitive tools. Due to industrialization and urbanization, water pollution has become an acute problem. Aquatic plants are progressively being used to provide information on the status of the aquatic environment because they do not migrate from one place to another and they quickly attain equilibrium with their ambient environment. Also, they provide cumulative information of preceding and present environmental conditions, as compared with chemical analytical methods, which provide only the current status of the environment. Although a lot of information is available on the bioindicators of air pollution, information on pollutionindicator plants in the aquatic environment is rather inadequate.

Conclusion

Water pollution is a worldwide problem,most commonly associated with the discharge of effluents containing various contaminants from sewers or sewage treatment plants, drains, factories and households. Various types of water bodies are under the direct threat of water pollution. An increase in water acidity influences lake pH levels, as well as heavy metals discharged fromindustrial areas, which may affect the composition of tolerant species. Analysis of water-quality parameters of water bodies determines the diversity and density of algal species and provides a forecast of deteriorating conditions. Plant diversity is a strong bioindicator for aquatic ecosystems of different types and responses.

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