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Algae as Biological Indicators of Water Pollution

Codruța Mihaela Dobrescu[1], Anca Turtureanu[2], Leonard Magdalin Dorobăț[3]

Abstract: Water pollution is a major environmental problem that has existed for decades, perhaps even longer, and is becoming more and more serious, necessitating the need for efficient, accurate and if possible inexpensive methods of monitoring and evaluating its impact on aquatic ecosystems. Algae, as photosynthetic organisms, have gained considerable attention as reliable biological indicators of water pollution due to their high sensitivity to environmental changes and their wide distribution in all categories of aquatic habitats. The unique characteristics of algae, a wide variety of species and their ubiquity in different types of water make them suitable candidates for such indicators. Algae respond rapidly to changes in water chemistry, temperature and nutrient levels, making them sensitive to various types of pollution including heavy metal pollution, organic pollutants and excess nutrients, various methods and techniques can be used to measure and assess algae responses to water. Pollution, determining both quantitatively and qualitatively the level of pollution. These techniques range from traditional microscopy-based identification and enumeration to more advanced molecular methods such as DNA barcoding and high-throughput sequencing. In addition, the use of bioindicators derived from algal communities, such as algal and biotic indices, is discussed as a valuable tool in water quality assessment. The potential of algae to detect and monitor pollution events, assess the ecological health of water bodies, and evaluate the effectiveness of pollution control measures is high and incompletely exploited in Romania and beyond. Factors such as natural variability, species-specific responses, and the need for standardized protocols, emphasizing the importance of considering these factors when interpreting algal data, are crucial issues and still need to be well established. Continuing research in

[1] Senior Lecturer, PhD, University of Pitesti, Faculty of Science, Physical Education and Informatics, Romania, Address: Str. Targu din Vale 1, Pitesti, Arges, Romania, Tel./Fax: +4 0348453260, E-mail: codrutza_dobrescu@yahoo.com.

[2] Professor, PhD, Danubius University of Galati, Faculty of Economic Sciences, Romania. Address: 3 Galati Blvd, Galati 800654, Romania. Tel.: +40372 361 102, fax: +40372 361 290. Corresponding author: ancaturtureanu@univ-danubius.ro.

[3] Senior Lecturer, PhD, University of Pitesti, Faculty of Science, Physical Education and Informatics, Romania, Address: Str. Targu din Vale 1, Pitesti, Arges, Romania, Tel./Fax: +4 0348453260, E-mail: coltanabe@yahoo.com

this field is crucial for perfecting the use of algae as indicators and developing standardized protocols at the international level (EU and not only) for their application in water quality assessment.

Keywords: bioindicators; algae; water pollution; water quality; pollution monitoring

1. Introduction

“Bioindicator” is a term that refers to any source that reacts to ecological changes, indicator taxa being used both to detect changes in the natural environment and assess the health of the environment, and to indicate the impact of biogeographical changes that have place in the environment, be they negative or positive. Plankton responds quickly to changes that occur in the environment and is an important biomarker in the aquatic environment for the assessment of water quality and/or the degree of pollution, a phenomenon closely related to aquatic biodiversity and beyond. It also has the advantage of acting as an early warning signal.

Against the background of industrialization and intensive urbanization, the problems related to water contamination and pollution have intensified, determining the need for efficient, accurate and, if possible, cheap methods of monitoring and evaluating its impact on ecosystems. Monitoring of all taxonomic groups is necessary to quantify the current state of Earth’s aquatic resources in order to assess the effectiveness of measures taken to rehabilitate damaged ecosystems.

In addition to the use of bioindicators, biological monitoring also incorporates data on past aggravations and the impact of various variables and anthropogenic stressors to address viable restoration, remediation, or reintroduction measures (Hosmani, 2013). Although all species can be considered biomonitors to some extent, algae can be a first choice in water pollution studies (Singh *et al*., 2013). Algal communities can even provide historical water quality benchmarks for characterizing the biological status of many disturbed ecosystems.

Emphasis is now placed on the state of ecosystem integrity and monitoring programs for key biological characteristics rather than simply comparing local water quality conditions to standard criteria obtained from bioassays conducted under controlled conditions. The bioindication method reflects real changes in natural conditions.

Modern informational means can analyze and integrate the complex information obtained from the monitoring process so that with the economic aspects allow a holistic approach to environmental management.

The principles of bio-indication of algae and biomonitoring in the environment, both for fresh waters (streams, rivers, lakes, reservoirs) and for marine ecosystems, consider both groups and species of pelagic algae as well as benthic ones or sediments; bioassay procedures and techniques are being developed for both field natural assemblages and laboratory cultures (Dokulil, 2003).

2. Discussions

Algae are characterized by diversity and abundance in most aquatic ecosystems (freshwater and marine) and wide distributions among ecosystems and geographic regions, even greater than most species of higher organisms, making them applicable to all aquatic habitats and several environmental stressors. In general, each algal class exhibits tolerance to various nutrient concentrations.

The main reason for including algal indicators in environmental monitoring programs is their key role in mediating energy flow in aquatic ecosystems. In dam lakes, algae formations participate directly, by gradually increasing the amount of organic matter in the ecosystem, in the development of the natural eutrophication process, a process also related to the aging of the lake. As a result of this process, gradually changing living conditions, the composition and quantity of phytoplankton also changes: in general, there is an enrichment of phytoplankton in species indicative of eutrophic conditions, the biomass and primary production of phytoplankton increase. On the other hand, as a result of eutrophication, there is a strong quantitative development of phytoplankton, which can reach the level of "blooming" of the water in the lakes. This phenomenon is increasingly common today, and the problem arises of finding effective and economical ways to combat it. Even in aquatic ecosystems where energy input from terrestrial sources is considerable, algal biomass can support a substantial secondary production (Mayer & Likens, 1987).

Many eutrophic environments are dominated by cyanobacteria, chlorophyceae, flagellates, and excessively developed diatoms because of the penetration, directly or indirectly, of fertilizers such as nitrogen, carbon, or phosphorus compounds; each species may have a different response to nutrient enrichment. Tracking dynamic changes in phytoplankton biomass and algal community structure has been recognized early on as a useful indicator of trophic status and environmental quality in aquatic ecosystems (Padisák *et al*., 2006) as long as on the hydrological map of the world the eutrophication of has become the main problem of water quality and an extremely complex phenomenon followed by a series of effects whose impact on the environment cannot be ignored. For example, cyanophyta constitutes a particularly powerful bioindicator that indicates the rapid eutrophication of water bodies through this blooming phenomenon (Thakur *et al*., 2013).

In a large combined study of personal research and review research from over 150 references published from 1951 to 2017, Barinova & Fahima (2017) reported 8475 freshwater indicator taxa, of which 8125 are algae, the difference being represented by other plant species – Bryophyta (6), Polipodiophyta (6), Magnoliophyta (83) or aquatic invertebrates. Each group of indicators can be evaluated separately according to its significance for the bioindication.

Table 1. Taxonomic Categories of Indicator Algae Species (Modified After Barinova & Fahima, 2017)

Taxa	No. of indicator taxa
Cyanophyta	834
Euglenophyta	1241
Pyrrophyta (Dinoflagellata)	150
Cryptophyta	42
Chrysophyta - Chrysophyceae	533
Chrysophyta - Xanthophyceae	67
Chrysophyta - Bacillariophyceae	**2652**
Rhodophyta	50
Chlorophyta	1127
Charophyta	1429

The species contained in the database of Barinova & Fahima (2017) were grouped into 12 ecological categories according to the predictable response to these variables, thus, 6308 species can be considered indicators for habitat preferences (Habitat preferences), 5678 of them – for degree of saprobity, 5644 - Self-purification zone, 2898 – for Water pH, 2615 – Salinity, 2440 – Trophy, 1953 for rheophilicity and oxygenation, 480 – pH range, 413 – Temperature, 13 for H2S, and others.

Any species that responds predictably to these variables can be used as a bioindicator, reflecting the reactions of aquatic ecosystems to eutrophication, acidification, organic pollutants, etc. (Kumari & Paul, 2020).

Results obtained from field research (McCormick and Cairns, 1994; Rath *et al*., 2018) recommend the development of taxonomic indicators, the best studied group in this regard being diatoms (Bacillariophyceae class). Both population and algal community indices have strengths, and even if there are limitations to one or the other level of biological organization, their use in tandem can be standardized for monitoring ecosystem change. The problems associated with the standardization of parameters between watersheds or other geographical units with different types of algal communities can be overcome due to the large-scale distribution of most species, which ensures the spatial continuity of indicators for national or regional monitoring programs.

State-of-the-art biomonitoring applications consist of metabarcoding combined with high-throughput sequencing (HTS). The DNA extraction method influences molecular inventories, and extraction protocols require testing to select the best extraction method for HTS metabarcoding. In this sense, applications are known for diatoms (Vasselon *et al*., 2017; Rimet *et al*., 2018a, Baricevic, *et al*., 2022; Kulaš, 2023) and for other phytoplankton groups (Gao *et al*., 2018; Rimet *et al*., 2018b).

Rimet *et al*. (2018b), following a survey of littoral benthic samples from 56 clean alpine lakes, by comparative analysis of diversity indices with microscopy and metabarcoding, conclude that HTS can detect morphologically cryptic species and to detect better rare taxa and even free-floating extracellular DNA.

Metabarcoding combined with high-throughput sequencing (HTS) has great potential for biomonitoring applications but requires standardization.

There are few studies on the actual costs of the monitoring process with the help of indicator algae (Vasselon *et al*., 2019), but the benefits recommend them for the improvement of their use as indicators and the development of internationally standardized protocols (EU and not only) for their application in water quality assessment.

3. Conclusions

Phytoplankton and bioassay methods are promising tools for assessing water pollution and aquatic ecosystem health when combined, physicochemical, biological, and molecular quantifications are used to obtain detailed information for sustainable management of aquatic ecosystems.

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