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Editorial

Use of Aquatic Biota to Detect Ecological Changes in Freshwater: Current Status and Future Directions

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Abstract: Freshwater ecosystems have been severely damaged worldwide by a multitude of human pressures, such as pollution, nutrient enrichment, damming or overexploitation, and this has been more intense over the past five decades. It is therefore important that the impacts of such stressors can be effectively detected, monitored and assessed in order to provide adequate legislative tools and to protect and restore freshwater ecosystems. The use of aquatic biota to detect, measure and track changes in the environment is often known as freshwater biomonitoring and is based on the premise that the presence or absence of biotic assemblages at a given site reflects its degree of environmental quality. For over a century, since the early pollution-oriented indicators, freshwater monitoring has been developing and testing progressively more complex indicator systems, and increasing the plethora of pressures addressed, using different biological groups, such as benthic macroinvertebrates, macrophytes, fish, phytoplankton and phytobenthos. There is an increasing demand for precision and accuracy in bioassessment. In this Special Issue, five high-quality papers were selected and are briefly presented herein, that cover a wide range of issues and spatial contexts relevant to freshwater biomonitoring.

Keywords: biomonitoring; ecological quality; macrophytes; macroinvertebrates; fish; biotic indices; multimetric indices

1. Introduction

Debuting one century ago, aquatic biota has been increasingly used worldwide to monitor and assess ecological changes in freshwater as a result of environmental stressors, such as pollution, nutrient enrichment, habitat loss or overexploitation [1,2]. This has been more intense over the past five decades, where human pressures developed into unprecedented levels, and policy makers and society in general have become more attuned to environmental issues. The use of aquatic biota to detect ecological changes over time, often known as biomonitoring, is based on the premise that the presence/absence of biotic assemblages at a given site reflects its environmental quality [3], which is needed for the management and conservation of rivers and streams, with the aim of protecting ecosystems, and the services that they supply [4–6].

Since the first biomonitoring assessment more than a century ago—notably the saprobic index to detect organic pollution in Central Europe [7], several other methods have evolved and diversified using different biological groups, such as benthic macroinvertebrates, macrophytes, fish, phytoplankton and phytobenthos. This led to an increasing demand for precision and accuracy requirements and to more sophisticated tools, given the very high number of families (hundreds) and species involved (thousands), that are assessed over large spatial (networks of sites) and temporal (medium- to long-term) scales. A large number of types of biological indicators have arose to express changes in the structure (patterns) and function (processes) of freshwater ecosystems, responding to the needs of important legislative tools, such as the Water Framework Directive, the Habitats Directive or the US Clean Water Act, which require countries to evaluate the ecological status of surface waters using aquatic biota. This in turn generated a large amount of data with respect to recognized standards.

Further, advances in biomonitoring are constantly described in the literature [5]. Among these techniques, taxon-based biotic indices and multimetric approaches are the most frequently used (e.g., [8]), though functional measures have been increasingly applied as a complementary approach to reflect ecological integrity [9,10]. However, biomonitoring has also been criticized by the fact that it can be time-consuming and technically demanding, because it typically relies on morphological criteria for taxonomic identification [11]. Recent advances in molecular techniques, such as environmental DNA and metabarcoding, seem promising to make the assessments faster, more accurate and cost-effective, making them a promising tool to complement and replace morphological identifications [12], nonetheless there is still a long way until genetic-base monitoring is operational, due to present limitations such as geographical coverage, lack of standardized field and laboratory procedures and incompleteness of reference libraries for many taxa [13,14].

Following the experience gathered in the last twenty years, and with the advent of wide-scale biomonitoring, encompassing different ecosystems and biomes, the strongest issues coming to debate are the level of determinism of cause–effect links, the capacity of bioindicators to integrate multi-scaled complex pressures, and the variability of responses of biota under different restoration scenarios and land use changes.

2. Content of the Special Issue

This Special Issue invited fundamental and applied research which follows on from recent developments in biomonitoring of freshwater ecosystems to detect environmental stressors and point out future directions. From the five papers were received, two dealt with macrophytes, other two with macroinvertebrates and one dealt with fishes.

In Europe, Szoszkiewicz et al. [15] evaluated the ability of the Macrophyte Index for Rivers (MIR), developed in Poland upon the demands of the Water Framework Directive, to detect trophic degradation in rivers and compared its efficiency with other macrophyte metrics. Their study area encompassed two European ecoregions (the Central and Eastern Plains) covering a total of 100 river sites, representing a wide gradient of eutrophication from oligotrophic to advanced eutrophic conditions. They found that the MIR system responded strongly to trophic degradation, which is the main problem affecting surface waters in that country, and suggest the need, for the purposes of environment monitoring, to consider local aspects of ecological status assessment to increase the potential for a better identification of threats. Specifically, they recommend the adjustment of indicative plant lists and verification of the ecological sensitivity of particular species in various ecological conditions.

The paper from Vásquez et al. [16] assessed the use of bryophyte communities as indicators of water pollution along a tropical urban river (Zamora River) in Ecuador, Central America. They evaluated the bioaccumulation of eight heavy metals and arsenic by the thallose liverwort (*Marchantia polymorpha* L.) and the changes in bryophyte community structure, as responses to urban pollution. Their study area consisted of three zones within the city limits along the river a control (forest) zone, making up a total of 12 sites, where they registered the presence/absence and bryophytes cover. They found that the concentration of most heavy metals and arsenic were higher in the bryophytes from the urban zone, which also showed a lower species richness and a distinct community structure, when compared to the control zone. They concluded that bryophytes, in particular the thallose liverwort, can be adequate biomonitors of water quality in tropical urban rivers.

Another interesting contribution came from another tropical river in Myanmar (South-East Asia), where country-specific tools for biomonitoring of freshwaters do not exist and are needed to better inform water managers. The study of Ko et al. [17] evaluated the applicability of three internationally accepted rapid macroinvertebrate indices on a Myanmar river basin, the Ayeyarwady: the miniSASS (mini Stream Assessment Scoring System) developed in South Africa (www.minisass.org), the Asia Foundation method developed in Mongolia and Lao PDR (http://asiafoundation.org), and the Australian Waterwatch (www.nswwaterwatch.org.au/resources), all scoring macroinvertebrate families in relation to their sensitivity to anthrop ogenic activities. They found that the Asia Foundation method showed the best fit for Myanmar taxa, though differences were small when compared to the Australian Waterwatch method, which they later modified and suggest that it can be further developed for the country widespread use, in combination with an easier biomonitoring tool for citizens such as miniSASS.

In the USA, Donatich et al. [18] related macroinvertebrate community metrics from 34 headwater streams in Piedmont (NC, USA), with the NC Stream Quantification Tool (SQT) protocol factors and other variables relevant to ecological function in order to test its predictive ability. They hypothesize that the Pyramid Framework, the basis of the SQT, is generalizable, in that hydrologic variables explain the most variance in biological function variables, while other higher-level variables (e.g., hydraulics, geomorphology, and physico-chemistry) explain relatively less variance. They employed three statistical models—stepwise, lasso and ridge regression—to predict the NC Biotic Index (NCBI) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness using two datasets, composed of SQT variables and additional watershed, hydraulic, geomorphic, and physico-chemical variables. Results showed that stepwise and ridge were the best predictive models for the biotic integrity data collected and that the SQT variables can reasonably predict biology metrics. They also reported that the inclusion of additional variables improved model prediction, suggesting that the SQT protocol still lacks important metrics to macroinvertebrates, and that with further refinement, the SQT can be a beneficial tool for practitioners and regulators.

From South America, came a freshwater biomonitoring paper, with the goal of developing a multimetric fish-based Index of Biotic Integrity for an agricultural region within the domains of the Atlantic rainforest. To achieve this goal, Gonino et al. [19] sampled 23 streams in four sub-basins of the upper Paraná river basin (Brazil) and collected large-scale and local environmental variables, including a local physical condition index, to select reference sites and classify the remaining ones in accordance to the disturbance level. The newly developed index, N3S-IBI, is composed of six metrics: (i) the Simpson's dominance, (ii) the number of Characiforme individuals, (iii) the proportion of Characidae species, (iv) the proportion of intolerant insectivorous individuals, (v) the proportion of tolerant species and (vi) the number of non-native individuals, encompassing different attributes (tolerance, composition, abundance, richness, trophic habits, and origin). The index was found to easily discriminate between the least and most disturbed sites, suggesting that it can be a useful tool to monitor restoration actions.

3. Conclusions

All these five papers coming from different parts of the world (all continents except Africa and Oceania) are important to progress the understanding on the use of aquatic biota to detect ecological changes in freshwaters. Such work becomes even more imperative as global change has been a major topic of concern and will continue to be in the next decades, and is expected to magnify the effect of existing human pressures, such as damming, urbanization and nutrient enrichment on river ecosystems [20,21], while the combination of pressures will further confound effects [22].

To sum up, this Special Issue helped to fill gaps in knowledge on the biomonitoring of freshwaters, notably extending biomonitoring to different situations and resolutions. Another important line is the comparison of the accuracy and operational demands when considering traditional taxa-based biomonitoring and advanced molecular techniques, such as environmental DNA and metabarcoding [23,24], notably the compliance checking of the later with the legislative frameworks currently used, as well as its adequate response to pressures. Despite the technological advances there remains inherent limitations in such implementations [14]. There is, thus, scope for a Special Issue to assess the capacity of DNA metabarcoding and high-throughput sequencing methods in current and future freshwater biomonitoring.

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