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Editorial

Ecological Monitoring, Assessment, and Management in Freshwater Systems

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Abstract: Ecological monitoring and assessment is fundamental for effective management of ecosystems. As an introduction to this Special Issue, this editorial provides an overview of "Ecological Monitoring, Assessment, and Management in Freshwater Systems". This issue contains a review article on monitoring surface waters, and research papers on data management, biological assessment of aquatic ecosystems, water quality assessment, effects of land use on aquatic ecosystems, etc. The papers in this issue contribute to the existing scientific knowledge of freshwater ecology. They also contribute to the development of more reliable biological monitoring and assessment methods for sustainable freshwater ecosystems and ecologically acceptable decision-making policies, and establishment of practices for effective ecosystem management and conservation.

Keywords: freshwater ecosystem monitoring; freshwater ecosystem assessment; freshwater ecosystem management; biological indicators; biological assessment

1. Introduction

The reliable monitoring and assessment of water resources is fundamental for effective management of water quality and aquatic ecosystems [1]. Traditionally, physicochemical parameters have been used to assess the quality of water resources. However, they have a limitation in grasping the wholeness of water systems, particularly with reference to ecosystem health and integrity [2]. Various approaches are applicable to ecosystem health assessment at different levels of the biological hierarchy, from genes to ecosystems.

Many countries conduct nationwide monitoring programmes on aquatic organisms for effective freshwater ecosystem management. For example, in Europe, such programmes are carried out under the Water Framework Directive (WFD) [3]. The WFD monitoring programme aims at collecting data for status assessment and controlling the efficiency of the applied water protection measures [4]. In the USA, two major national biomonitoring programmes exist which are funded through the US Environmental Protection Agency (National Aquatic Resources Survey; NARS (previously called EMAP)) and the US Geological Survey (National Water Quality Assessment; NAWQA) [5]. In China, there are three national monitoring programmes supported by the Ministry of Water Resource (National River and Lake Health Program), Ministry of Environment Protection (Watershed Health Condition Assessment), and Chinese Major Science and Technology Program for Water Pollution Control and Management (Ten Important Rivers and Lakes Health Assessment) [6]. In Korea, the National Aquatic Ecological Monitoring Program (NAEMP) is conducted to assess the ecological health status of stream ecosystems based on biological indices, using benthic diatoms, macroinvertebrates, fish, and aquatic plants. The NAEMP funded by the Ministry of Environment was established in

2007, and since then, the number of sampling sites has increased from 540 to 960, covering the entire nation [7,8]. By 2018, the total number of monitoring sites will gradually increase to 3000.

We designed this special issue to improve the scientific understanding for monitoring, assessment, and management of freshwater aquatic ecosystems. The following section summarises the individual contributions.

2. Contributions

The WFD, established in 2000, provides the current basis for monitoring surface waters and ground water in the countries of European Union. Arle et al. [4] reviewed the monitoring of surface waters in Germany under the WFD. They considered monitoring methods, selection of monitoring sites, and monitoring frequencies. Furthermore, they examined the changes in water monitoring in Germany over the past 16 years and summarised the monitoring results from German surfaces waters under the WFD.

The datasets obtained in the monitoring programmes provide many opportunities for various advanced comparative and synthetic studies, policy-making, and ecological management [9]. In order to realise the potentials and opportunities, Jiang et al. [9] developed a RESTful API-based data management system called OSAEM (the Open, Sharable, and Extensible Data Management System for Aquatic Ecological Monitoring).

Choi et al. [10] presented the transferability of monitoring data from neighbouring streams in a physical habitat simulation. They examined similarities in the data related to channel geometry and in the observed distribution of the target species, and constructed habitat suitability curves using the gene expression programming model. They performed the physical habitat simulations with the proposed generalised habitat suitability curves. Their results indicated that the use of data from a neighbouring stream in the same watershed could result in large errors in the prediction of composite suitability index, and the proposed generalised habitat suitability curves increased the predictability of the composite suitability index in the physical habitat simulation.

Li et al. [11] implemented a self-organizing map (SOM) to detect outlier loci in the amplified fragment length polymorphism band presence/absence data, and demonstrated that genetic diversity adaptively responds to environmental constraints. Specifically, they characterised overall loci composition patterns according to the SOM, revealed environmental responsiveness according to altered input data based on SOM recognition, and addressed associations between outlier loci and environmental variables.

Benthic macroinvertebrates are commonly used for biological assessment of aquatic ecosystems owing to their taxonomic diversity, sedentariness in habitat range, and suitable lifespan [12,13]. Jun et al. [14] studied nationwide distribution patterns of benthic macroinvertebrates and important environmental factors affecting their spatial distribution using the data obtained from the NAEMP. They classified 720 sampling sites into five clusters according to the pollution levels from fast-flowing, less-polluted streams with low electrical conductivity to moderately or severely polluted streams with high electrical conductivity and low water velocity. Their analysis revealed that altitude, water velocity, and streambed composition are the most important determinants for explaining the variation in macroinvertebrate assemblage patterns.

Grygoruk et al. [15] studied the effects of dredging on the benthic macroinvertebrates in agricultural rivers. They demonstrated that the total abundance of riverbed macroinvertebrates in the dredged stretches of the rivers analysed was approximately 70% lower than that in non-dredged areas, and concluded that the dredging of small rivers in agricultural landscapes seriously affects their ecological status by negatively influencing the concentrations and species richness of benthic macroinvertebrates.

Mountainous and headwater streams are characterised by diverse microhabitats that help protect macroinvertebrates from competition, predation, and natural disturbances, and therefore support a rich regional biodiversity [16,17]. Lee et al. [18] examined the water chemistry data collected at headwater streams on different timescales to establish a monitoring programme optimised for identifying potential risks to stream water quality arising from rainfall variability and extremes. Their results suggested that routine monitoring, based on weekly to monthly sampling, is valid only in addressing general seasonal patterns or long-lasting phenomena such as drought effects.

Wang et al. [19] quantified the impacts of the run-of-river scheme on the instream habitat and macroinvertebrate community in a mountain river. They demonstrated that flow diversion at the 75% level and an in-channel barrier, due to the run-of-river scheme, are likely to lead to poor habitat conditions and decrease both the abundance and the diversity of macroinvertebrates in reaches influenced by water diversion.

Bae et al. [17] studied the structure and function of benthic macroinvertebrate communities in four headwater streams at two different spatial scales over three seasons of the year. They showed that the differences between samples were accounted for by seasonal variation more than spatial differences at the individual stream scale, and site differences became more important when performing an ordination within a single season.

Kim et al. [20] examined the effects of land use types on community structure patterns of benthic macroinvertebrates in streams of urban areas. They found that species composition patterns are mainly influenced by both the gradient of physicochemical variables such as altitude, slope, and conductivity, and the proportion of forest area. Community structure patterns were further correlated to the proportion of urbanisation and to biological indices such as diversity and number of species.

Hwang et al. [21] examined the relationships between urban land use and water quality in Korea. They analysed the data derived from NAEMP by using linear and generalised additive models. Their results showed that the generalised additive models had a better fit and suggested a non-linear relationship between urban land use and water quality.

Yun and An [22] assessed the influence of land use patterns on nutrient contents and N:P ratios in stream ecosystems, and determined the empirical relationships between N:P ratios and nutrients and sestonic algal biomass. Their results indicated that land use patterns in the study watersheds are a key factor regulating nutrient contents and N:P ratios in ambient water, and influenced empirical relationships between N:P ratios and sestonic chlorophyll.

An et al. [23] examined the non-stationary relationship between the ecological condition of streams and the proportions of forest and developed land in watersheds by using geographically weighted regression (GWR). They found that the GWR model had superior performance compared with the ordinary least squares method model.

Kim and An [24] evaluated the ecological health of Nakdong River in Korea by using an integrated health responses model based on chemical water quality, physical habitat, and biological parameters. They found that the key stressors were closely associated with nutrient enrichment (N and P) and organic matter pollutions from domestic wastewater disposal plants and urban sewage.

Glińska-Lewczuk et al. [25] evaluated the influence of habitat connectivity and local environmental factors on the distribution and abundance of functional fish groups in 10 floodplain lakes. Their results indicated that the composition and abundance of fish communities are determined by lake isolation gradient, physicochemical parameters, and water stage, suggesting that lateral connectivity between the main channel and floodplain lakes is of utmost importance.

Kim et al. [26] investigated the effectiveness of the nature-like fishway installed at a weir on the Nakdong River in Korea by using traps and passive integrated transponder telemetry. Moreover, they presented measures to improve the efficiency of the fishway by analysing the correlation between the upstream water level and fishway use data.

Drapper and Hornbuckle [27] presented a field evaluation of a stormwater treatment train with pit baskets and filter media cartridges. Their results were significantly different for the filters, but not the pit baskets. In addition, they identified the significant influence of analytical variability on performance results, specifically when influent concentrations are near the limits of detection.

3. Conclusions

We believe that the papers in this special issue contribute to scientific knowledge of freshwater ecology concerning the monitoring, assessment, and management of freshwater ecosystems. They also contribute to developing more reliable biological monitoring and assessment methods for sustainable freshwater ecosystems, and ecologically acceptable decision-making policies, and establishing practices for effective ecosystem management and conservation.

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