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Editorial

Editorial for the Special Issue on Aquatic Ecosystems and Water Resources

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Water is essential for *all* life, as the age-old universal adage holds. Nevertheless, humanity is drifting increasingly further away from the recognition and understanding of how riparian and aquatic ecosystems maintain and sustain water availability and quality. For millennia, riparian ecosystems such as floodplains and wetlands have been regulating the flow and seasonal availability of water. Gallery forests trap sediments in runoff entering streams and rivers, whose aquatic ecosystems further maintain water quality by decomposition and nutrient cycling. Native functioning ecosystems also provide mankind with fisheries, wildlife, and recreation, among other services. Recognizing the vital importance of preserving naturally flowing rivers and the role of intact native vegetation such as forests, grasslands, and wetlands in maintaining the natural flow regime, a plethora of traditional perspectives across Asia, Africa, Australia and the Americas have regarded rivers and forests as sacred, thereby preserving these ecosystems until recently. Acknowledgement among naturalists of the importance of these features led to the development ecological studies on rivers and streams in Europe in the early 20th century. There is a profusion of literature, including the comprehensive publication Rivers and Stream Ecosystems of the World [1], that details connections between hydrology, water quality, aquatic ecosystems, services provided to humanity and the management of watersheds to sustain these water bodies and their ecosystems.

However, over the past century, the rapidly escalating human demand for water is exerting tremendous pressure on aquatic ecosystems, largely through the over-extraction of water, altered flow regimes, channelization of rivers and untreated wastewater discharges. This is ongoingly resulting in the degradation of biodiversity and ecosystem services provided to mankind. As far back as in 1968, the proceedings of an international conference titled “The Careless Technology: Ecology and International Development” [2] documented the unintended catastrophic consequences of development schemes that ignored the aquatic and riparian ecosystems, their dependence on the natural water regime and their role in maintaining water quality, controlling waterborne disease vectors and fishery services to humanity.

Unfortunately, in much of the world, there remains a dearth of regional scientific literature on managing and/or restoring local aquatic ecosystems in the context of water resource management. Furthermore, whatever limited amount of information exists is most often unavailable to water managers, policymakers and other stakeholders, especially in Africa, Asia, South America and the Caribbean. This results in a widespread lack of detailed awareness, of the links between hydrology, water quality and the life in these water bodies, leading to statements from stakeholders such as “we should not let the freshwater in a river go to waste by flowing into the sea”. In order to ensure the sustainable management of water resources and thereby ascertain water security, it is absolutely imperative to identify, protect and restore the structure and function of aquatic ecosystems throughout the river basin, from headwater streams, wetlands, lakes and rivers all the way downstream to estuaries.

This Special Issue, titled “Aquatic Ecosystems and Water Resources”, collates a dozen publications from around the world that are focused on various aspects of understanding and managing water (and watersheds) to sustain aquatic ecosystems. These aspects include

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research approaches for determining hydrology–water quality–ecosystem links, the evaluation and application of management guidelines for monitoring/managing aquatic ecosystems and stakeholder perspectives of the reasons behind declining aquatic ecosystem services.

A number of publications focus on the development of mechanistic models and field studies to quantify hydrological and water quality processes. The knowledge attained can be used to quantify biogeochemical features of the aquatic environment that are experienced by plants, invertebrates, amphibians, reptiles and fish.

Starting from the farm or pasture level, de Filippis et al. describe the development of an open-source module simulating the physical processes of the nitrogen cycle in unsaturated soils and thence quantify nitrate leaching into groundwater. This module can be coupled with spatial models to forecast the fate and transport of nitrate at the watershed scale, and thus enable the prediction and management of eutrophication, for instance. Although it was calibrated in Italy, the module can be re-calibrated elsewhere, and the use of an open-source platform aids its adoption and development in under-represented areas of the world.

Soria et al. describe the process of determining the residence times of water in a lagoon in coastal Spain, given the limited hydrological data and changing land use conditions. The natural hydrological zonation in the lagoon's wetland system is related to the difference in residence times in the respective zones, which in turn influence aquatic communities.

Landmeyer et al. describe a tracer-based hydrogeologic approach to demarcate the basin areas that recharge streams comprising the habitat of an endemic and threatened bottom-dwelling darter fish species in the southeastern USA. They also determine the residence time of groundwater that supplies baseflow recharging these streams; the finding that it could take decades for a packet of infiltrated rainwater to travel underground before entering streams illustrates that land use change can have a delayed effect on streamflow in this region.

Paddeda et al. describe a study that examines the connection between anthropogenic activities that decrease inflow and simultaneously increase nonpoint nutrient pollution in the biggest lake in Sardinia, which rapidly undergoes eutrophication in the summer. They recommend watershed-level actions to decrease nutrients in the runoff, from the best management practices to the establishment of constructed wetlands and riparian buffers.

Chomba et al. review the literature on coupled hydrological–hydraulic models for floodplain assessments across Africa. In so doing, they provide a succinct overview of floodplain ecosystems, the services they provide humanity and the role of seasonal and interannual flows in maintaining these ecosystems. Furthermore, the review also serves as a reference for undertaking similar modeling efforts in areas lacking hydrological data and information, with a focus on using freely available global datasets.

Multi-decadal hydrological and water quality datasets are needed to understand the extent of interannual variability in flows caused by climate teleconnections such as ENSO and changing land use. In addition, species life cycles and fish migration are intimately dependent on the flow regime, especially flood pulses and dry season baseflows. This information is not available in most parts of the world. While a general understanding of the importance of flows exists, quantifying the amount of flows/water depths is necessary given the reality of an increasing freshwater demand from the agricultural, municipal and industrial sectors. This has led to the concept of environmental flows in rivers.

Saha et al. detail the process of determining the minimum freshwater inflows required to sustain aquatic and riparian ecosystems in a hitherto protected Tanzanian river estuary with increasing water demands from various sectors. There is a paucity of hydrological discharge data concerning this estuary and almost no knowledge of the dependance of different floral and faunal assemblages in Sadaani National Park on the seasonality of water flow and salinity. A yearlong field data collection campaign followed by a series of multi-stakeholder workshops were used to develop environmental flow recommendations, that provided monthly river water level benchmarks in years of average and below-average rainfall. Such a study can be adapted to data-poor areas worldwide.

Moving on to the application of methodologies with which to monitor and assess the ecological condition of aquatic ecosystems, Costa et al. report on the implementation of the River Habitat Survey (RHS), a generic methodology recommended by the Water Resources Framework Directive of the European Union. Using a case study in Portugal, the authors describe how the RHS was used to assess the riverine habitat condition, identify causes of degradation and suggest possible remedial actions to restore habitat heterogeneity.

Latsiou et al. describe the use of the RHS as well as another qualitative assessment tool, the Qualitat del Bosc de Ribera (QBR) index, together with drones in assessing the condition of riparian vegetation in rivers across Greece. Correlational relationships of a riparian habitat condition with fluvial morphological and watershed land use changes were then observed. Rapid assessments indicated that further research needs to include developing more effective, locally relevant tools for monitoring riparian ecosystems.

Similarly rapid assessment survey methodologies (such as RHS and QBR) need to be developed for other parts of the world; however, this would require detailed knowledge of the local aquatic ecosystems and their links to water flow and quality regimes. Arrighi et al. highlight the importance of this knowledge of local ecosystem–water links in their study, which indicated a poor correlation between the widely used EU Water Framework Directive ecological quality indicators and water levels in a river in Italy. The indicators used in Arrighi et al.'s study were based on dissolved oxygen and nutrient concentrations and the presence/abundance of macrophyte vegetation and diatoms. Other widely used indicators of aquatic ecosystem and watershed health are based on aquatic macroinvertebrates such as mayflies, stoneflies and caddisflies (EPT taxa), whose presence in streams indicates both low sedimentation as well as the existence of the natural flow regime. Because ecosystems differ from region to region, these indicators need to be fine-tuned for a specific region, taking into account the structure of aquatic communities and their links with flow and water quality, which are in turn influenced by the land use in the watershed. Changing land use and a lack of documentation of the natural pre-alteration ecosystems are challenges that confound the straightforward application of generic high-level ecosystem assessment methods. Acknowledging these challenges and developing place-specific assessment methods can be considered essential in monitoring the effects of hydrological and watershed management/restoration on riparian and aquatic ecosystems.

As mentioned earlier, healthy aquatic ecosystems provide many services to humanity, the most widely known being fisheries from lakes, rivers and seas. Most fisheries are unfortunately in decline across the world, the reasons for which range from overexploitation and habitat loss/destruction to changes in water availability and quality driven by anthropogenic water diversions, extraction and land use change. Now, climate change has added another dimension via the increased unpredictability of precipitation and extreme weather events such as hurricanes interspersed by long droughts. Sustainable fishery management thus requires a distinction between the various stressors.

In a landmark long-term socio-ecological study on the Ganga River in India, Kelkar et al. compiled the perspectives of fisherfolks and fishmongers; these groups identified overfishing as the main reason for declining fish yields. At the same time the authors also examined the hydroclimatic variables driving flood pulse variability and dam operations/water diversions leading to altered flows in the river. They concluded that while it is easy to ascribe declining fish yields to overfishing, changes in the natural historical river flow from hydropower dams, water abstractions, land use change, climate teleconnections and climate change are invisible factors but have a very significant impact. This recognition once again emphasizes the necessity of incorporating flow–ecology relationships in basin-level water resources management. This paper also represents a reference source for freely available global hydroclimatic datasets and their use.

Finally, to conclude the Special Issue, two papers describe the inclusion of hydrology–ecology relationships in sustainable resource management. In a Greek Mediterranean setting, Papadimitriou et al. investigate the role of prevailing sea currents influencing mussel growth and conclude with recommendations of aligning mussel farming longlines to the direction of documented dominant currents.

Gophen describes a study quantifying seasonal water quality and identifying the sources of nutrient pollution of an Israeli lake, thereby providing scientific input for conflict resolution between agriculture and a waterbird sanctuary. Agriculturalists, aggrieved due to crop-raiding by birds, attributed the eutrophication in the lake to guano from migratory cranes, identifying this as the main source. The study identified peat loss from wetland drainage for agriculture as a significant source of soil erosion, apart from waterbirds. Such endeavors of conflict resolution can therefore allow the coexistence of multiple land uses in the lake's watershed, and pave the way for the sustainable management of nutrient losses and pathways.

It is anticipated that this Special Issue will contribute to the body of knowledge references for water management agencies, research institutions and other stakeholders to consult in order to ensure water security and the health of aquatic ecosystems; hence, it addresses one of the most pressing challenges facing humanity.

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