

## Risk-based management of Mediterranean water resources under multiple stressors

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Water has become a precious resource on which the well-being and survival of future generations critically depends. Around the world, there are many warnings that human water use exceeds supportable levels. Groundwater depletion, low or non-existing river flows, and worsening contamination are among the more palpable indicators. Consequently, issues relating to water, such as quality, quantity, availability, planning and management, must be confronted, now and in the future.

Most freshwater systems in Europe are threatened by a variety of stressors, including organic and inorganic pollution, geomorphological alterations, changes in land use, climate variability and change, water abstraction, invasive species, and presence of pathogens. Despite their diverse nature, all of these stressors adversely impact organisms and ecosystems, and ultimately threaten the quality and biological diversity of European water bodies. In addition to the environmental consequences, there are important economic ones as well. Most ecosystems are exposed simultaneously to several stressors. In some cases, stressors act independently of each other whereas in others their interactions lead to synergistic/antagonistic effects, either directly (acting on the same target) or indirectly (acting on different targets). Although multiple-stress scenarios can have deleterious effects on freshwater ecosystems, most studies have examined only the effects of single stressors on the chemical and ecological status of water bodies and on ecosystem functioning. These studies include investigations of so-called emerging contaminants, which have been detected in most rivers and, with their negative effects on water quality, degrade both biodiversity and ecosystem services.

Some stressors, such as water scarcity, can limit biodiversity and economic activities in entire regions. In addition to being a stressor on its own, water scarcity can drive the effects of other stressors acting upon river ecosystems. The intermittency in water flow has negative implications for hydrologic connectivity, biodiversity, water quality, and river ecosystem functioning. Water scarcity can amplify the effects of water pollution by reducing the natural diluting capacity of rivers. Interactions between stressors also may be exacerbated by climate change. For instance, warmer temperatures and reduced



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river flows will likely increase the physiological burden of pollution on the aquatic biota, and biological feedback between stressors (e.g., climate change and nutrient pollution) may produce unexpected outcomes. The degradation of drainage basins, the destruction of natural habitats, the over-exploitation of fish populations and other natural resources, and the establishment of invasive species may give rise to synergistic effects, especially during periods of water shortage. The effects of these stressors are very relevant for the chemical and ecological status of water bodies, as well as for the sustainability of the ecosystem services they provide.

Water scarcity is a key stressor in the Mediterranean basin, which is characterized by highly variable river flows and the periodic occurrence of low flows and even no-flows. Climate change will increase the frequency and magnitude of extreme events. Although extremes are part of the normal hydrologic behavior of Mediterranean rivers, in many of them there is already a consistent trend towards decreased discharge.

In this special issue of CONTRIBUTIONS TO SCIENCE we have compiled nine different articles covering the most relevant issues concerning stressors in Mediterranean river basins. One of the articles refers to the Spanish-funded project SCARCE and to the EU-funded project GLOBAQUA, which addresses water scarcity in Europe. These two projects inspired the current issue. To solve problems related to water scarcity, they assess and predict the effects on water quantity and quality in European river basins under various global climate change scenarios. The continuous exchange of information between scientists and river basin authorities will allow the findings of the two projects to be put into practice.

A second article focuses on the Llobregat River, as a clear example of a Mediterranean river suffering from multiple stressors, such as nutrient excess, organic pollution as well as

water scarcity. The Llobregat is under constant stress due to a low a mean water flow of 14 m<sup>3</sup>/s and the relatively large population of 3 million people living in the vicinity of its highly industrialized basin. Four different articles cover the issue of emerging contaminants, including perfluorinated chemicals, pharmaceuticals, and pesticides, with respect to Mediterranean water resources. The joint contributions of authors from Catalonia and Greece, and Catalonia, Valencia, and Italy provide a Mediterranean assessment of the risk to river waters posed by emerging contaminants. In another article, the prioritization of organic pollutants in Mediterranean waters is addressed.

Finally, there are two articles from well-established water-research institutes in the Mediterranean region: the Catalan Institute for Water Research (ICRA), and the International Water Research Centre (Nireas-WRC); the latter being based in Cyprus. The mission of both institutes is to solve Mediterranean water problems, including water scarcity, water treatment and reuse, desalination, and impacts on a multi-stressed ecosystem.

The information provided in the nine articles should be of interest to a broad readership, as a Mediterranean-like climate also prevails in much of California, in parts of Western and South Australia, in southwestern South Africa, in sections of Central Asia, and in parts of central coastal Chile. These geographic regions are similarly confronted with water scarcity and its associated risks.

Last but not least, I would like to thank the authors for their contributions, which have made this special issue of CONTRIBUTIONS TO SCIENCE a very remarkable and fruitful compilation of the latest scientific knowledge on water research in the Mediterranean. I would also like to express my gratitude to the Institute for Catalan Studies for funding this (special) thematic issue. 