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A review of hydrological and chemical stressors in the Adige catchment and its ecological status

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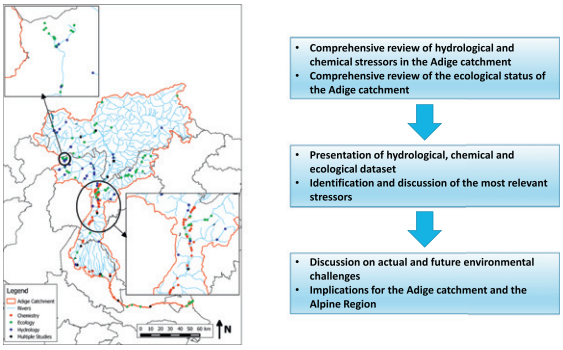
HIGHLIGHTS

- Comprehensive review of hydrological and chemical stressors in the Adige catchment.
- Comprehensive review of the ecological status of the Adige catchment
- Future challenges to characterize the feedback between stressors are discussed.

GRAPHICAL ABSTRACT



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ABSTRACT

Quantifying the effects of multiple stressors on Alpine freshwater ecosystems is challenging, due to the lack of tailored field campaigns for the contemporaneous measurement of hydrological, chemical and ecological parameters. Conducting exhaustive field campaigns is costly and hence most of the activities so far have been performed addressing specific environmental issues. An accurate analysis of existing information is therefore useful and necessary, to identify stressors that may act in synergy and to design new field campaigns. We present an extended review of available studies and datasets concerning the hydrological, chemical and ecological status of the Adige, which is the second longest river and the third largest river basin in Italy. The most relevant stressors are discussed in the light of the information extracted from a large number of studies. The detailed analysis of these studies identified that hydrological alterations caused by hydropower production are the main source of stress for the freshwater ecosystems in the Adige catchment. However, concurrent effects with other stressors, such as the release of pollutants from waste water treatment plants or from agricultural and industrial activities, have not been explored at depth, so far. A wealth of available studies address a single stressor separately without exploring their concurrent effect. It is concluded that a combination of extended experimental field campaigns,

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focusing on the coupled effects of multiple stressors, and modeling activities is highly needed in order to quantify the impact of the multifaceted human pressures on freshwater ecosystems in the Adige river.

1. Introduction

The anthropogenic pressure on water resources is growing worldwide, and reducing its effects on the ecosystem is one of the major societal challenges to address in the near future (Ludwig et al., 2011; Navarro-Ortega et al., 2015; Vörösmarty et al., 2010; Kolditz et al., 2013; Barceló and Sabater, 2010). Knowledge of the complex feedback existing between hydrological (e.g., hydropeaking, water scarcity, flooding), geochemical (e.g., chemical pollution and erosion) and ecological (e.g., occurrence of invasive species, decrease in biodiversity) stressors in large river basins (e.g., 10,000 km^2 or more) is still patchy and additional research is needed to support informed decisions about water resources management at the catchment scale (Rodríguez-Iturbe et al., 2009; Ceola et al., 2014; Aristi et al., 2012; Widder et al., 2014). Even more complex can be to prioritize appropriate intervention strategies, considering economical and societal constraints (Boithias et al., 2014; Valle et al., 2014). For example, climate and land use changes are expected to impact the hydrological cycle to an extent that depends on the resilience of the catchment and on the spatial distribution of these changes (Botter et al., 2013; Destouni et al., 2013; Santos et al., 2014).

Furthermore, additional effort is required to better understand and quantify the fate of contaminants at the river basin scale (Grathwohl et al., 2013; Rinaldo et al., 2006; Botter et al., 2010). In the same way, the investigation, within a coherent framework, of the impact of micro and emerging pollutants (Medina et al., 2007), diffused sources of pollution (e.g., nutrient fluxes as shown in Rinaldo et al. (2005)) and particle facilitated transport (Rügner et al., 2014) on freshwater ecosystems, is a challenging task.

Modeling the impact of hydrological (e.g., water scarcity as described in Acuña et al. (2014) and chemical stressors (Holmstrup et al., 2010) on freshwater ecosystems is also an open issue for large river basins. In particular, the inclusion of the feedback mechanisms, which relate ecosystem functioning and anthropogenic activities to water resources management and chemical fluxes (Heathwaite, 2010), represents a challenge.

In order to investigate these three issues, i.e., changes in the hydrological behavior of large scale catchments, the fate and transport of pollutants in the environment and the interaction with the ecosystem (comprising human activities), it is important to have access to all available information. In particular, it is beneficial and in some cases absolutely necessary, for gaining a global perspective, to integrate data collected by water authorities and environmental protection agencies operating in the river basin, with results published in both peer-reviewed journals as well as in technical reports and other types of gray-literature (e.g., Uhlemann et al., 2013).

In the present work, we provide a review of available hydrological, chemical and ecological data for the Adige catchment, a large Alpine catchment located in Northeastern Italy (Fig. 1). The location of the sites targeted in the peer-reviewed studies are reported in the map shown in Fig. 2 with additional details provided in the Supporting Information. The Adige catchment has been selected as a case-study in the FP7 project GLOBAQUA (Navarro-Ortega et al., 2015), because representative of the variety of stressors encountered in the Alpine region: i) hydropeaking and thermopeaking caused by hydropower production (Zolezzi et al., 2009, 2011); ii) emerging and regulated pollutants released by waste water treatment plants (WWTPs) effluents, which are expected to show significant temporal variations due to seasonal touristic fluxes; iii) climate change, which is expected to impact the hydrological cycle by reducing winter snowfall with the consequent reduction of late spring and summer runoff (Majone et al., 2015; Carturan et al., 2013; Beniston and Stoffel, 2014); iv) pollutants transported by atmospheric circulations and stored in retreating glaciers which are released at low concentrations as an effect of increasing temperatures as observed in the Italian Alps (Villa et al., 2006a) and in other Alpine regions (Bogdal et al., 2010).

The structure of the paper is as follows: the second section provides a general description of the catchment, while the third focuses on the main hydrological stressors. The fourth section reviews the available data on the chemical status of the catchment. The fifth section deals with the ecological investigations focusing on macro-invertebrates. In the sixth section, identification of the most relevant stressors is discussed, and finally, the last section delineates the major scientific challenges in assessing hydrological functioning and water quality dynamics beyond the requirements of the Water Framework Directive.

2. Study site

2.1. Hydrology

The Adige river rises from a spring in proximity of the Resia lake at the elevation of 1586 m a.s.l. and after 409 km it ends in the Adriatic

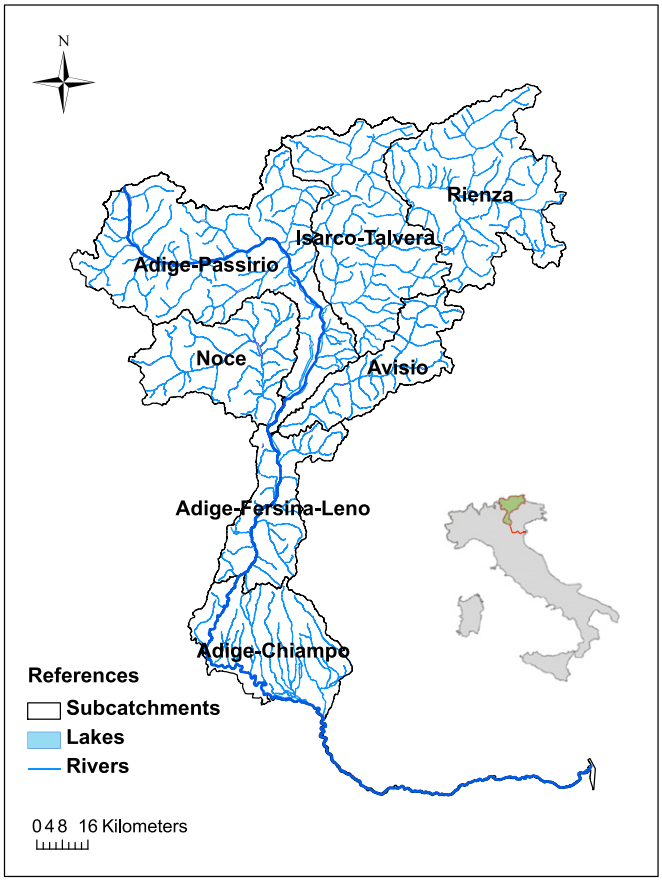

Fig. 1. Map of the Adige basin. Black polygons indicate the main sub-basins, the dark blue line highlights the Adige River, whereas the light blue lines represent the tributaries. The lower right inset shows the location of the Adige catchment within the Italian territory.