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Driver detection of water quality trends in three large European river basins

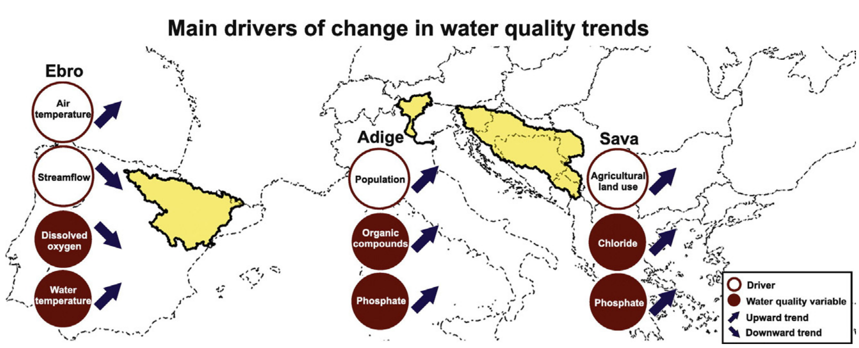
Elena Diamantini [a,*], Stefanie R. Lutz [b], Stefano Mallucci [a], Bruno Majone [a], Ralf Merz [b], Alberto Bellin [a]

[a] University of Trento, Department of Civil, Environmental and Mechanical Engineering, Via Mesiano 77, 38123 Trento, Italy
[b] UFZ Helmholtz Centre for Environmental Research, Department Catchment Hydrology, Theodor-Lieser-Str. 4, 06120 Halle (Saale), Germany

HIGHLIGHTS

- Trend analysis of physico-chemical variables in surface waters and their drivers of change
- Comparison among surficial water quality in three contrasting European river basins
- Highest risk of developing anoxic conditions in Iberian Peninsula
- Agriculture as source of organic compounds and phosphate in the Adige basin
- Increasing trends of chloride and phosphate in the Sava linked with agriculture

GRAPHICAL ABSTRACT



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ABSTRACT

This study analyses how indicators of water quality (thirteen physico-chemical variables) and drivers of change (i.e., monthly aggregated air temperature and streamflow, population density, and percentage of agricultural land use) coevolve in three large European river basins (i.e., Adige, Ebro, Sava) with different climatic, soil and water use conditions. Spearman rank correlation, Principal Component Analysis, and Mann-Kendall trend tests were applied to long-term time series of water quality data during the period 1990–2015 in order to investigate the relationships between water quality parameters and the main factors controlling them. Results show that air temperature, considered as a proxy of climatic change, has a significant impact, in particular in the Adige and Ebro: positive trends of water temperature and negative of dissolved oxygen are correlated with upward trends of air temperatures. The aquatic ecosystems of these rivers are, therefore, experiencing a reduction in oxygen, which may exacerbate in the future given the projected further increase in temperature. Furthermore, monthly streamflow has been shown to reduce in the Ebro, thereby reducing the beneficial effect of dilution, which appears evident from the observed upward patterns of chloride concentrations and electrical conductivity. Upward trends of chloride and biological oxygen demand in the Adige and Sava, and of phosphate in the Adige appears to be related to increasing human population density, whereas phosphates in the Sava and biological oxygen demand in the Ebro are highly correlated with agricultural land use, considered as a proxy of the impact of agricultural practises.

The present study shows the complex relationships between drivers and observed changes in water quality parameters. Such analysis can represent, complementary to a deep knowledge of the investigated systems, a reliable tool for decision makers in river basin planning by providing an overview of the potential impacts on the aquatic ecosystem of the three basins.

* Corresponding author.
E-mail address: elena.diamantini@unitn.it (E. Diamantini).

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1. Introduction

The ecological and chemical status of freshwater has attracted a wealth of attention in the last decades (e.g., Vega et al., 1998; Ahearn et al., 2005). Water bodies hosting important ecosystems are subjected to anthropogenic and climatic stressors often acting in synergy. To assess the effects of actions aimed at improving the ecological status of freshwater ecosystems, monitoring networks have been implemented in most of European basins, which provide a quite extensive database of water quality parameters (Benfenati et al., 2003). Despite this wealth of data, the connection between drivers and water quality parameters has not been fully exploited so far. Little is known beyond the effects of single stressors on the chemical and ecological status of water bodies and on their ecosystem functionality (Navarro-Ortega et al., 2015). This lack of knowledge limits our capability of understanding ecosystem responses to multiple stressors (Friberg, 2010), and as a consequence, the possibility for water and land use managers to determine suitable adaptive strategies for mitigating their effects. Many studies describe observed changes in chemical, ecological or hydrological variables (e.g., Bouza-Deaño et al., 2008), but few studies attempt to attribute causes of pattern variations (López-Moreno et al., 2011). Other works attempt to explain concentration patterns by using measurements of single sampling campaigns without considering long temporal variations (e.g., Kračun-Kolarević et al., 2016). Moreover, few studies assess long-term trends in water quality indicators at single gauging stations or detect alterations in the spatial patterns, chiefly because of data fragmentation and sampling discontinuity (Levi et al., 2015; Vrzel and Ogrinc, 2015).

The present work explores the complex interplay between water quality trends and the main drivers' observable at large scales and affecting surface water quality, by analysing whether observed changes are consistent with the drivers of change. To this aim, three large European river basins among the six included in the GLOBAQUA project (Navarro-Ortega et al., 2015) are studied: Adige, Ebro and Sava. The selection of these basins is made according to differences in hydro-climatic conditions and land use management, and to their contrasting resilience to climate change (Lutz et al., 2016). The main objectives of the present work are (i) to analyse long term water quality trends in each river basin, (ii) to identify links between observed patterns of physico-chemical variables and drivers (i.e., agriculture, streamflow, air temperature and population) in each basin, through quantitative analyses and (iii) to compare the studied basins with respect to their vulnerability and resilience to the identified drivers of change.

2. Study basins

The Adige River Basin is an alpine watershed located in the north-eastern part of Italy (Fig. 1A). With a size of about 12,100 km^2, it is the third largest Italian river basin. The large majority of the basin (91%) is Alpine and belongs to the Trentino Alto Adige region, while the remaining portion is the floodplain and is totally included in the Veneto region. The Adige River has a length of 409 km and drains into the Adriatic Sea (Chiogna et al., 2016). Its main tributaries are: Passirio, Isarco, Rienza, Noce, Avisio, Fersina and Leno. Streamflow shows a typical alpine regime with two maxima, one occurring in spring due to snowmelt and the other one in autumn triggered by cyclonic storms. In the alpine portion of the catchment, elevation ranges from 120 to 3400 m a.s.l. Climate is typically alpine with dry winters, snow and glacier-melt in spring, humid summers and autumns. The long-term annual mean temperature is 3 °C and annual average precipitation is 1456 mm (both evaluated in the time span 1961–1990; Lutz et al., 2016).

The Ebro River Basin is mainly located in the north-eastern part of Spain (Fig. 1B). With a catchment area of 85,362 km^2, the Ebro is the largest river basin of Spain. The basin extends from the Pyrenees and the Cantabrian Range in the north (maximum altitude of more than 3000 m a.s.l.) to the Iberian Range in the South and the Coastal Range in the East (López-Moreno et al., 2011). The Ebro River has a length of 910 km and it drains into the Mediterranean Sea with a mean

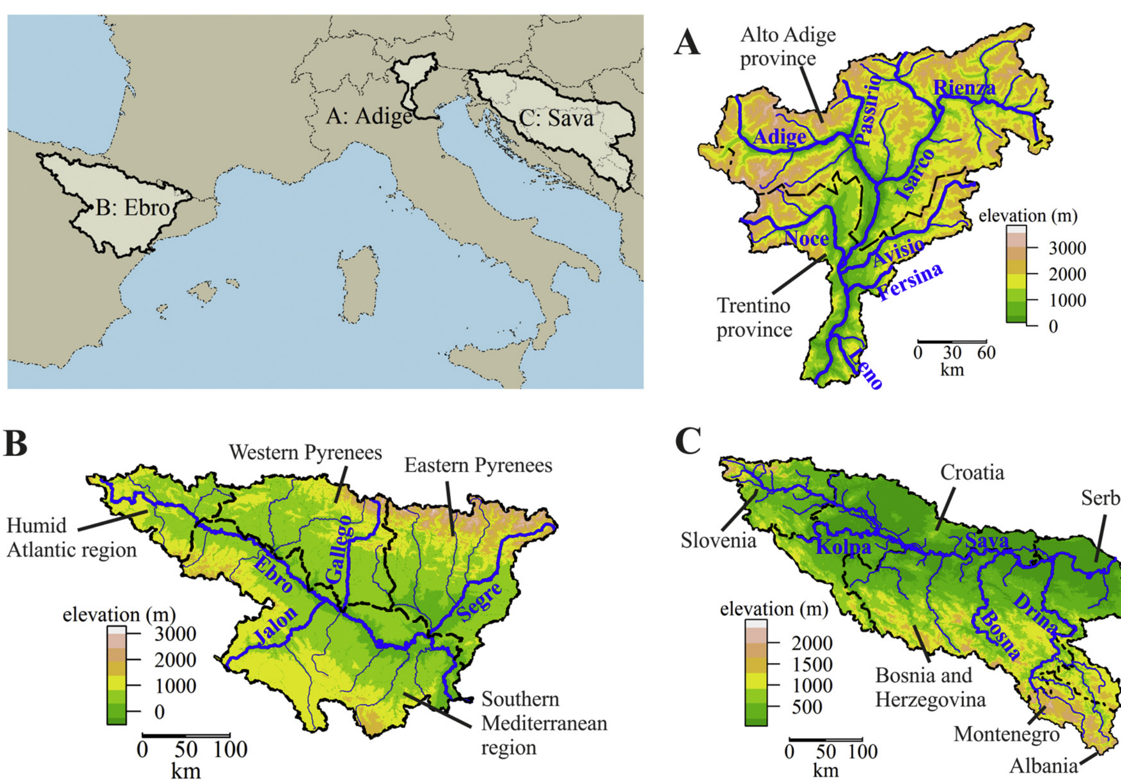

Fig. 1. Southern Europe map with the locations of the investigated river basins. Elevation maps and the river networks (up to the second order streams) are shown in sub-panels (A), (B) and (C) for the Adige, Ebro and Sava, respectively.