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Defining benchmark values for nutrients under the Water Framework Directive: Application in twelve Portuguese estuaries

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ABSTRACT

The Water Framework Directive requires the assessment of physicochemical parameters supporting the biological quality elements. To achieve this evaluation, water samples were collected in 89 sites located at 42 water bodies (WB) from 12 transitional systems in Portugal. Nitrate, nitrite, phosphate, ammonium and silicate concentrations were measured in surface and near-bottom water samples collected at high- and low-tide. The influence of salinity, biological consumption, morphology and river basin inputs was examined. Results showed that nutrient variability is estuary and site specific. To overcome this inter-specificity complexity, benchmark values for nutrients were estimated based on Portuguese estuaries previously classified with good ecological status for the phytoplankton quality element. This methodology allowed classifying the chemical status for nutrients in the WBs of the surveyed systems. Water bodies from Cávado, Ave, Douro, Tagus and Sado showed "Low" status due to ammonium that was often above the benchmark value. Comparatively, nutrient concentrations in all WBs of Minho, Ria of Aveiro, Mira and Guadiana were lower than the benchmark values and therefore a classification of High was given.

1. Introduction

Estuaries are ecosystems where freshwater, including dissolved substances and suspended particles from natural processes and anthropogenic activities meet seawater. The fate of solutes and particles is driven mainly by the water circulation and biogeochemical processes. Understanding the nutrient dynamics is of primary importance because they may determine estuarine systems ecology (e.g. Hilton et al., 2006; Mainstone and Holmes, 2010). Commonly, mixing diagrams are used to assess the relationship of nutrients with salinity. The linear decrease of nutrient concentration with salinity indicates that dilution is the driving factor. Otherwise, negative or positive shifts suggest that biological consumption, internal inputs or regeneration superimpose to dilution (Olausson and Cato, 1980). Excess of nutrients may have indirect effects on water quality, biodiversity and ecosystem services (Brito et al., 2012). In UK, freshwater nutrient concentrations were considered the major cause of failures to achieve European legislative goals (Carvalho and Moss, 1995).

The application of the Water Framework Directive (WFD; Directive 2000/60/EC, 2000) requires the assessment of the chemical status of water bodies using nutrients among other parameters. The threshold values for nutrients in transitional waters have not been considered in this directive and are established by each member state (Devlin et al., 2011). The distinction of the anthropogenic pressures from the natural signal is crucial for the implementation of measures that prevent deterioration of water quality. However, no standard procedure is established for the determination of background levels (Tueros et al. 2008). According to these authors, two main approaches have been adopted: (i) sampling of pristine areas; and (ii) long-term monitoring programs or sampling at a large number of sites, then applying statistical analysis to establish a benchmark value or range (Bettencourt et al., 2004; Tueros et al., 2008). The first approach it is difficult to apply since the uncontaminated areas with different water typologies do not exist across Europe. Although the second has the advantage of broad application no general agreement exists on the statistical methodologies to be applied. Several water modeling systems have been proposed for Portuguese estuaries (e.g. Saraiva et al., 2007; Simas and Ferreira, 2007), but they have restrictions associated with short-term variations in estuary topography, changes on velocity currents, dimension of intertidal areas and hydrodynamics in low depth areas (0.2–1 m). Furthermore, the variability of light penetration in the water column and nutrient exchange across the sediment-water interface associated with advection and seepage processes in intertidal areas are not usually considered. Moreover, data of nutrients and primary production in Portuguese

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estuarine systems is scattered and derived mainly from research projects or short-term monitoring programs performed in few estuaries. The 90th percentile estimates the benchmark value for chlorophyll *a* (Borja et al., 2012; OSPAR, 2002; ECOSTAT, 2003). The same methodology is proposed for nutrients since the percentile-based approach will provide a more robust analysis of variability. Exceptionally high and low nutrient concentrations may occur occasionally but they are not considered using this approach. This means that there is less risk of a system being wrongly classified due to outliers. To respond for WFD demands a wide study was performed in the main Portuguese estuaries. Thus, the variability of nutrient concentrations in the water column of 12 estuaries was investigated. Nitrate, nitrite, ammonium, phosphate and silicate concentrations were measured in 42 water bodies of single-channel to broad inner-bay systems. A methodology for nutrient benchmark values was established based on the 90th percentile and applied to all estuarine water bodies. This methodology was used to classify the chemical status of nutrients on the 42 water bodies of the surveyed transitional waters.

2. Material and methods

2.1. General description of study areas

The main estuaries from continental Portugal, classified as transitional waters according to the WFD, were surveyed (Fig. 1). Accordingly to their typology the selected estuaries are characterized as (i) narrow channel (Minho, Lima, Cávado, Ave, Douro, Mondego, Mira, Arade and Guadiana); (ii) coastal-lagoon type estuary (Ria of Aveiro, hereafter named Aveiro); and (iii) semi-enclosed estuarine areas (Tagus and Sado). Table 1 presents the main water basin characteristics of these estuaries. Estuarine systems located in the south of Portugal (Tagus, Sado, Mira, Arade and Guadiana) are submitted to prolonged dry seasons and

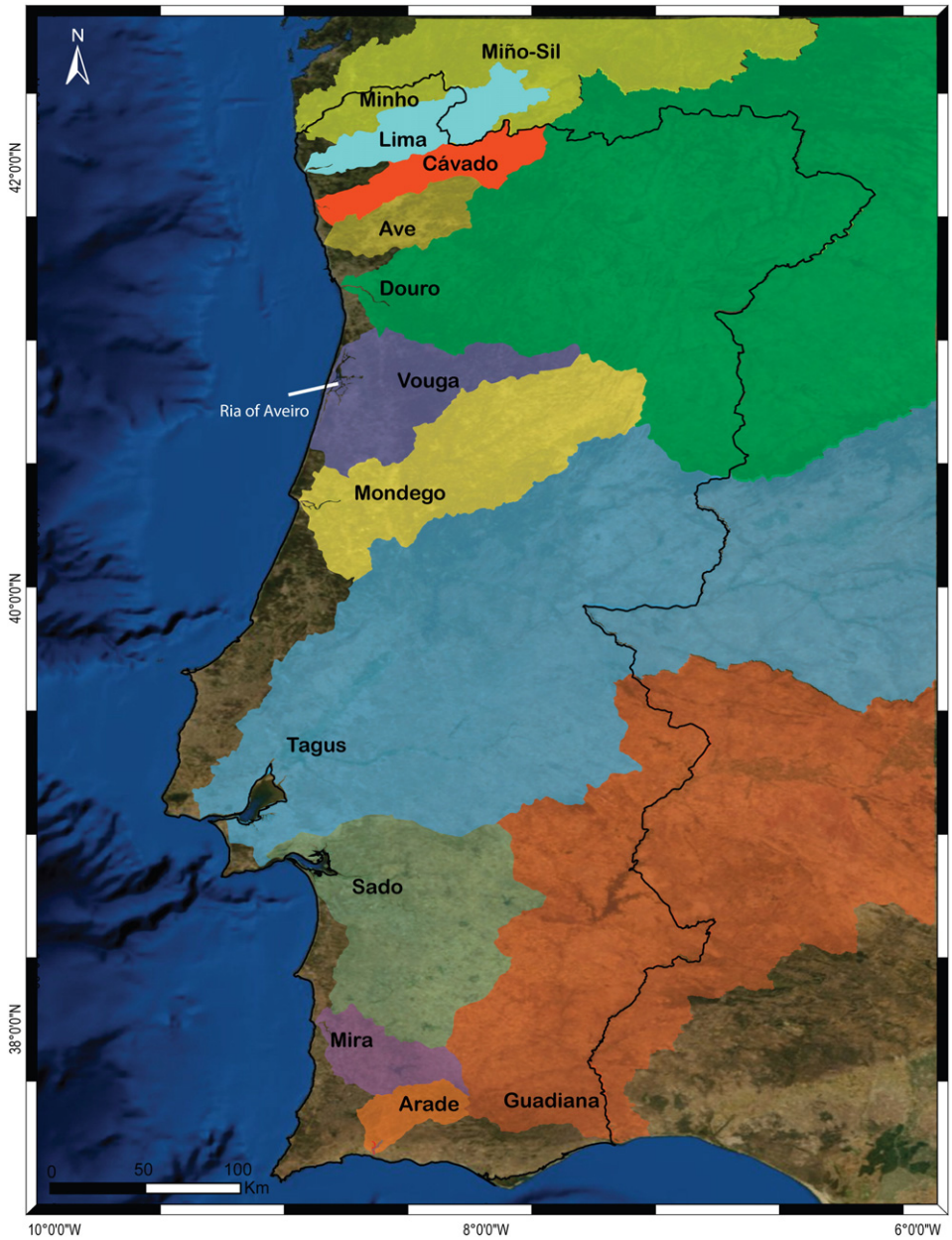

Fig. 1. Location of the twelve studied estuaries (Minho, Lima, Cávado, Ave, Douro, Ria of Aveiro, Mondego, Tagus, Sado, Mira, Arade and Guadiana) in the Iberian Peninsula (Southwest Europe). Limits of the drainage basins are represented by confined areas.