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Using phytoplankton and macrophytes to assess the trophic and ecological status of some Italian transitional systems

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ABSTRACT

Assessment of aquatic ecosystems and their recovery became mandatory with the enactment of the Water Framework Directive (WFD, 2000/60/EC). In this framework, the socio-economic value of transitional waters and their role as natural heritage are particularly important. To improve our knowledge of the ecological status and ecosystem functioning of transitional waters, investigations were carried out in Italian lagoons in the Po Delta and elsewhere (Marano-Grado, Goro, Comacchio, Pialassa Baiona, Lesina and Orbertello), applying the same procedures in accordance with National and International protocols. Nutrient concentrations were measured in water and top sediments and the taxonomic composition of phytoplankton and macrophytes was determined so that the trophic and ecological status could be described also by applying the Macrophyte Quality Index. Although the nutrient load was, on average, similar to that of other lagoons with better status, the overall conditions of Po Delta lagoons were found to be poor or bad, as highlighted by the absence of seagrasses and sensitive macroalgal species. Comparing all considered lagoons, the main factors affecting ecosystem recovery seem to be episodic high nutrient inputs, resulting from changes in river outflows, and huge sediment resuspensions caused by human activities. The studied transitional ecosystems displayed a wide range of conditions from bad to high, highlighting the possibility of ecosystem recovery especially by favouring nutrient regulation and angiosperm proliferation.

1. Introduction

The coastline of the Mediterranean Sea has more than 200 transitional systems with an area >0.25 km^2. The highest number of wetlands is located in Italy and on the coast of the North-western Adriatic Sea in particular. Coastal transitional systems play a significant ecological role for many flora and fauna species, but since ancient times they have also represented a considerable resource for numerous human activities. Human attempts to colonise, modify and control wetlands, mainly by means of land reclamation for agricultural proposes, have led to the loss of important natural features and progressive artificialisation.

As an example, in France, the lagoons of both Berre and Thau have long been affected by human activities. The former has been characterised by heavy freshwater discharges from a hydroelectric power plant since 1966 (Gouze et al., 2008). This continuous freshwater input has generated large quantities of suspended matter (27,100 ton) and nutrients ($N–NO_3$: 275 ton, $P–PO_4$: 36 ton, total N: 680 ton and total P: 130 ton) and led to the disappearance of various marine organisms (e.g., zoobenthos taxa, *Zostera* sp. and macroalgae) (Becker, 1986; Bernard et al., 2007). In the latter lagoon the ecological status has been altered by both shellfish farming, with estimated nitrogen biodeposition of ca. 500 kg ha^{-1} yr^{-1} (De Casabianca, 1977, 1996), and urban and agricultural sewage (Nitrogen: 30 kg ha^{-1} yr^{-1}; Phosphorus: 10 kg ha^{-1} yr^{-1}; Agence De l'Eau, 1981). In the same way, in Spain, the Mar Menor lagoon has long been affected by agriculture and urban development in its surroundings (Conesa and Jiménez-Cárceles, 2007)

Although the importance of protecting and planning the sustainable use of wetlands is well established (see Ramsar Convention, 1971), it is only with the need to implement the requirements of the Water Framework Directive (WFD, 2000/60/EC) that the investigation of previously neglected areas has become mandatory.

Recently, Cecere et al. (2009) drew up an inventory of information on Italian transitional systems, with particular attention to flora. It was found that only some of these systems are well studied, such as the lagoon of Venice and the Mar Piccolo of Taranto, whereas for the other transitional areas knowledge is scarce or lacking completely, especially regarding trophic status evaluation and macrophyte studies. This is the case of the Po Delta, a heterogeneous and

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dynamic complex of lagoons and ponds originating from the deposition of sediment transported by the Po River. Its morphological and ecological development, always in progress, is closely linked to both natural and anthropogenic factors. The Po river flows 652 km through northern Italy and its drainage basin, excluding the delta system, has an area of 71,057 km^2, with about 16 million inhabitants (Cozzi and Giani, 2011). A significant proportion of Italian production is concentrated in this area: 37% of industry, 55% of livestock and 35% of agriculture. There is significant annual and interannual variation depending on river discharge: from 1995 to 2007 the annual nitrate load flowing towards the Adriatic Sea varied between 52 and 100×10^3 ton N yr^{-1}, and the reactive phosphorus transport was $1.4–4.0 \times 10^3$ ton P yr^{-1} (Cozzi and Giani, 2011). Such a huge trophic load entering from the river drainage basin, together with human activities related to agriculture, aquaculture and urban development within the Po Delta, have significantly affected the environmental equilibrium of the transitional area (Simeoni and Corbau, 2007). Specifically, nutrient enrichment and fluctuations in sediment transport can change ecosystem conditions and have direct impacts on one or several components, conditioning others and leading to changes in structure and functioning. However, there are few data on nutrient concentrations in the water and surface sediments and no papers dedicated to this topic have been published.

This paper aims to fill this gap, supplying information on the trophic state of the Po Delta (Veneto region area) by analysing phytoplankton in the water column, macrophyte assemblages and physico-chemical parameters and nutrient concentrations in both the water column and surface sediments at 17 sites. A full description is given for the Po Delta system because it is the less known, but, in the same framework with the same protocols and the common aim to describe trophic conditions, data were also collected in other Italian coastal lagoons (the lagoons of Marano-Grado, Goro, Comacchio, Pialassa Baiona, Lesina and Orbetello), in order to supply a complete picture of the ecological state of transitional ecosystems in accordance with the requirements of the Water Framework Directive (2000/60/EC, WFD). The main aim of the WFD is to achieve “good ecological and chemical status” for all surface waters by 2015, giving a significant role to Biological Quality Elements (BQEs: phytoplankton, macrophytes, macrozoobenthos and fish) in the assessment of water body conditions. Implementation of Ecological Indices has thus become mandatory for EU Member States and common guidelines have been established in order to steer research towards shared assessment protocols. Indices for phytoplankton (Brito et al., 2012; Vadrucci et al., 2013; Facca et al., 2014), macrophytes (Orfanidis et al., 2003; Sfriso et al., 2009), macrobenthos (Borja et al., 2000; Munari et al., 2009) and fish (Franco et al., 2009) have been proposed for transitional waters. At the moment, considering Mediterranean transitional waters, the intercalibration exercise (WFD, Annex V section 1.4.1), whose objective is to harmonise the understanding of “good ecological status” in all Member States and to ensure that this common understanding is consistent with the definitions of the Directive, has been completed only for the BQE macrophytes. The Macrophyte Quality Index (MaQI, Sfriso et al., 2009; Sfriso, 2010), the Ecological Evaluation Index (EEI-c, Orfanidis et al., 2003) and the EXamination tool for Coastal Lagoon Macrophyte Ecological status (EXCLAME, Derolez et al., 2013) were intercalibrated (Commission Decision of September 20th, 2013 in the Official Journal of the European Union, issued on October 8th, 2013). This means that the results achieved by these three assessment tools are comparable and accepted by the European Commission. Considering this, MaQI was applied to furnish an assessment of the ecological status of all these lagoons, which is comparable between each other and with other Mediterranean coastal lagoons.

2. Study areas

The Po Delta is an extensive area mainly in the Veneto Region (North-western Adriatic Sea, Italy) which covers about 400 km^2 and extends seaward for about 25 km (Simeoni and Corbau, 2007) (Fig. 1). It is the result of natural evolution over thousands of years. However, in recent times, human intervention, including river diversion, land reclamation and regulation of water flows for aquaculture purposes, have interfered with its natural development, producing the delta's present day morphology (Gandolfi et al., 1982). Water bodies account for ca. 200 km^2 of the delta but only ca. 100 km^2 is subject to tidal influence. The mean depth of these water bodies ranges from 0.5 to 2.5 m, meaning that biogeochemical cycles are very fast and thermal equilibrium between the air and the water column is achieved rapidly with little water column stratification.

The main river course (the Po di Venezia) is divided into five active branches: the Po di Maestra, Po di Pila, Po di Tolle, Po di Gnocca (or di Donzella) and Po di Goro, which correspond to a series of alluvial plain systems and deltaic fronts. An additional branch, the Po di Levante, regulated by a dam, is no longer truly active (Simeoni and Corbau, 2007). The lagoons considered in this study (Caleri, Marinetta, Vallona, Barbamarco, Canarin, and Scardovari) show a range of geomorphological and environmental features, varying mainly in terms of salinity, depending on river inflows and seawater exchanges, and depth, which can range from 0.5 to 1 m or from 1.5 to 2.5 m depending on the basin.

Samplings were carried out on May 13th–15th and October 13th–15th 2008, at 17 sites: two each in Marinetta and Vallona, three each in Caleri, Canarin and Barbamarco and four in Scardovari (Fig. 1). The sampling strategy was designed to collect the highest number of macrophyte species using the Italian monitoring protocol “El-Pr-TW-Protocolli Monitoraggio-03.05” (ISPRA, 2008).

Data collected in May using the same procedures were also available for (a) Marano-Grado lagoon (2007) in the North-western Adriatic, (b) Goro lagoon (2009), which completes the Po Delta system, (c) Comacchio and Pialassa Baiona ponds in the western Adriatic (2009), (d) Lesina lagoon (2004) in the Southern Adriatic and (e) Orbetello lagoon (2005) on the coast of the Tyrrhenian Sea (Fig. 2). All these basins, together with the Po Delta lagoon system and Venice lagoon (whose ecological status was already published, Sfriso et al., 2009), represent the bulk of Italian transitional ecosystems, being ca. 60% of their total surface. They were chosen in relation to typologies (choked and restricted) and anthropogenic pressures (i.e. nutrient and contaminant inputs, aquaculture). All samples were collected in late spring in agreement with the MaQI requirement (Sfriso et al., 2009; Sfriso, 2010).

The Marano-Grado lagoon covers an area of 160 km^2 with a shoreline of ca. 32 km. The average depth varies between 0.66 and 1.15 m, depending on the sub-basin. The lagoon is affected by industrial activities, fishing and aquaculture (Ferrarin et al., 2010 and references therein).

The Sacca di Goro is a shallow coastal lagoon with a surface area of 26 km^2, an average depth of 1.5 m and a volume of ca. 39 million m^3, as well as time-variable bathymetry. This basin receives waters from a branch of the Po (Po di Volano) and at present is an important site for Manila clam production (Zaldívar et al., 2003).

The Comacchio ponds (Valli di Comacchio) are a complex of shallow water lagoons (ca. 110 km^2) with an average depth < 1 m, which are surrounded by earthen dikes and separated from the sea by the highly modified Spina spit. The limited seawater exchanges through two channels, freshwater input from the Reno River and anthropogenic impacts have resulted in a shift from a macrophyte-based system to a phytoplankton-based system characterised by