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Assessment of the ecological status of transitional waters in Sicily (Italy): First characterisation and classification according to a multiparametric approach

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ABSTRACT

A 1-year cycle of observations was performed in four Sicilian transitional water systems (Oliveri-Tindari, Cape Peloro, Vendicari and Marsala) to characterise their ecological status. A panel of variables among which trophic and microbial (enzyme activities, abundance of hetetrophic bacteria and of bacterial pollution indicators) parameters, were selected. Particulate organic carbon (POC) and nitrogen (PON) and chlorophyll-*a* (Chl-*a*) contents defined the trophic state, while microbial hydrolysis rates and abundance gave insights on microbial community efficiency in organic matter transformation and on allochthonous inputs. To classify the trophic state of examined waters, the synthetic trophic state index (TRIX) was calculated.

Microbial hydrolysis rates correlated positively with POC and Chl-a, which increased along the eutrophication gradient. The significant relationships among TRIX, trophic and microbial parameters suggested the use of leucine aminopeptidase, alkaline phosphatase and POC as suitable parameters to implement the Water Framework Directive when assessing the ecological status of transitional water systems.

1. Introduction

Transitional water systems, such as lagoons, estuaries and coastal lakes, are very complex ecosystems located at the interface between land and sea, characterised by confined circulation and weak hydrodynamism, shallow depth, strong variations in temperature and light regimes, high productivity, high potential biodiversity, high vulnerability to anthropic pressure. The assessment of the health status of these water systems is a major issue for accurate management and preservation of their integrity. The Water Framework Directive (WFD, 2000/60/CE Directive) requires Member States to classify their water bodies according to a number of indicators or "quality elements", including physico-chemical, hydromorphological and biological elements. However, as recognised by recent studies (Devlin et al., 2007), the monitoring criteria indicated in the WFD fail to accurately describe the ecological status of all the different typologies of water bodies. For this reason one of the most technically challenging issues in the implementation of the WFD concerns the development of innovative classification tools and approaches for ecological quality status assessment. Great research efforts are being made across Europe with this aim, with an increased interest in the revision of the indicators of trophic state and environmental quality currently in use (Dell'Anno et al., 2002; Pusceddu et al., 2003). The need to implement the WFD is particularly urgent for transitional environments, due to the inadequacy of the ecological descriptors currently used (Fabiani, 2005). In fact, despite their economical and ecological importance as natural microcosms suitable for studying ecological processes, little attention has been given to the development of indicators and indices for assessing trophic status and quality in transitional water systems (Basset et al., 2006). Zaldívar et al. (2008) reported a comprehensive review on indicators and tools for assessing eutrophication; nevertheless, microbial processes which act at the basis of the food web should not be neglected in this context, in order to obtain a more comprehensive scenario of natural dynamics.

In Italy, Sicilian inland areas are still poorly known in their physical, chemical and biological features, as well as in terms of trophic inputs and anthropic pressure. The little existing data concerns only some water systems such as Oliveri-Tindari and Marsala, where both the trophic and biological characteristics were investigated during previous studies (Caruso et al., 2005; Crisafi et al., 1981; Leonardi et al., 2000; Leonardi and Giacobbe, 2001; Sarà et al., 1999).

In 2005 the Regional Agency for Environmental Protection (ARPA Sicily) started a multidisciplinary program aimed at the first characterisation of Sicilian water bodies; in this framework, a comparative study of Cape Peloro, Oliveri-Tindari, Vendicari and Marsala water systems was undertaken as representative of the second cluster of Italian lagoons, e.g., xero-Mediterranean lagoons

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(Tagliapietra and Volpi Ghirardini, 2006), also in the perspective of establishing quality criteria.

The aim of this study was to assess the ecological status of the main transitional areas of Sicily through the use of a new integrated approach based on measurements of both trophic (suspended organic matter, particulate organic carbon and nitrogen, chlorophyll-*a*, nutrients) and microbial (enzyme activity and bacterial abundances) parameters in parallel with the main physico-chemical ones (temperature, salinity, and dissolved oxygen). Here the results of a 1-year cycle of observations (2005–2006) are reported.

2. Materials and methods

2.1. Description of the study areas

The four areas examined during this study, Cape Peloro, Oliveri-Tindari, Vendicari and Marsala, are transitional water systems between terrestrial and marine environments (Fig. 1). Their detailed description is given by Mazzola et al. (2010). According to their geomorphological characteristics, Cape Peloro (which includes two water bodies, Ganzirri and Faro) and Oliveri-Tindari (which consists of four water bodies, Marinello, Mergolo, Porto and Verde) can be classified as coastal brackish areas. The Vendicari area consists of three shallow water bodies (Roveto, Grande and Piccolo) and Marsala is a semi-enclosed area under hydrodynamic exchange with the adjacent open sea (Fabiano et al., 2001).

2.2. Samples collection

From June 2005 to May 2006, surface water samplings were performed monthly in each of the 10 water bodies belonging to the four analysed water systems. For every water body, only one station, located at the deepest point of each site, was sampled and this was considered representative for the whole area (Fig.1). Due to the larger spatial extension of the Marsala area, three points (northern, central and southern) were sampled instead of one.

All samples were taken using sterile Niskin bottles, which were kept at +4 °C until laboratory analysis. A conductivity, temperature and depth (CTD) probe Sea-Bird 19*plus* were used to provide *in situ* measurements of conductivity and temperature. Salinity values were calibrated through comparison with laboratory measurements made with an induction salinometer AutoSal Guildline Model 8004B. Dissolved oxygen (O_2) content was estimated through Winkler's method.

2.3. Trophic parameters

Nutrient concentrations (nitrite, NO_2, nitrate, NO_3, and orthophosphate, PO_4, ions) were determined according to Genovese and Magazzù (1969); ammonia (NH_4) concentrations according to Aminot and Chaussepied (1983). Total N and P were measured according to Strickland and Parsons (1972).

Particulate organic carbon (POC) and nitrogen (PON) amounts were estimated by filtering 500 ml of water samples on precombusted Whatman GF/F filters. After a 6-h HCl fumes exposition to eliminate the inorganic carbon, the filters were processed at 980 °C in a Perkin–Elmer CHN-Autoanalyzer 2400, using acetanilide as the standard (Iseki et al., 1987).

Chlorophyll-*a* (Chl-*a*) concentration was measured after water filtration on Whatman GF/F filters and extraction in 90% acetone of the recovered material; readings were carried out in a Varian Eclypse spectrofluorometer, previously calibrated with serial standard dilutions of Chl-*a* from *Anacistis nidulans* (Sigma) (Lazzara et al., 1990).

2.4. Microbial parameters

Microbial enzyme activity rates (leucine aminopeptidase, LAP; alkaline phosphatase, AP) as markers of the potential ability of the microbial community to decompose peptides and organic

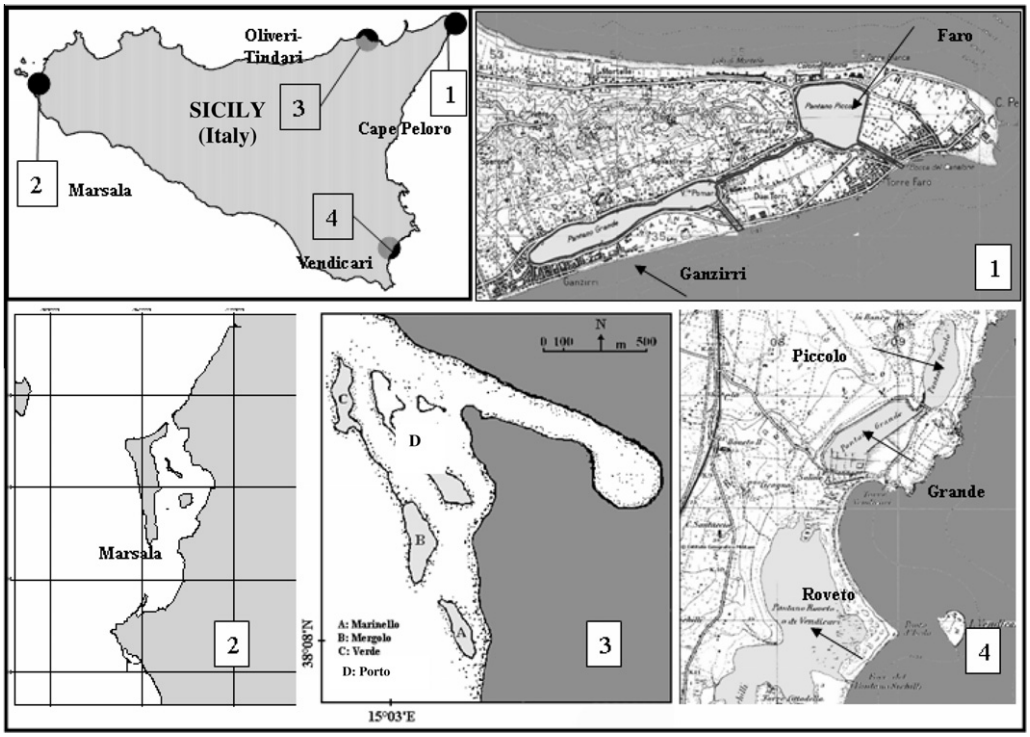

Fig. 1. Sicilian transitional water systems and sampling stations.