EUTROPHICATION INDICATORS IN THE NORTHWEST COAST OF THE ALBORAN SEA: A MULTISCALAR TIME ANALYSIS

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Abstract
A time series of hydrology, nutrients and chlorophyll a during 1992-2007 was analysed to study the influence of the hydrological dynamics and nutrient pollution on the trophic state of a coastal station located at the bay of Málaga. The results indicate that water quality has improved during the last decade.
Keywords: Alboran Sea, Eutrophication, Phytoplankton, Nutrients, Time Series

Introduction
The link between anthropogenic sources of nutrients and eutrophication symptoms in coastal areas is generally accepted. However, the analysis of time series reveals that the coastal systems respond in various different ways to nutrient enrichment. This variety of responses is due to physical and/or biological attributes that together act as a filter to modulate the response to the signal of change in nutrient loading. Furthermore, the simultaneous operation of other stress factors (including the climate system) influences all the signals and the filters. The availability of nutrients in the northwest sector of the Alboran sea is strongly influenced by quasi-permanent upwelling of enriched deep water associated to the hydrological structures generated by the Atlantic jet that penetrates through the Strait of Gibraltar. Additionally, the wind regime regulates the intensity of the upwelling. The objective of this work is to study how these hydrological constrains may contribute to modulate the response to nutrient enrichment of the coastal ecosystem in the bay of Malaga .

Methods
One station located close to the bay of Málaga was sampled each three months from october-1992 to february-2007. During each visit, the Secchi disc depth was determined and vertical profiles of temperature and salinity were obtained. Additionally, water samples for nutrients and chorophyll a (chl a) analysis were collected at 0, 10 and 20 m depth. Nitrate and phosphates and chl a concentrations were analysed according to the methods detailed in [1]. TRIX index was calculated according to [2]. The seasonal variability patterns were tested by determining the statistical significance of the differences among seasonal means. An exponential smoothing of the seasonally adjusted series was performed in order to remove high-frequency component of variability (residuals series). Inter-annual change patterns and linear trends over time were examined by analysing the smoothed series. The significance of the monotonous trends over time was tested by fitting the smoothed series to a linear model.

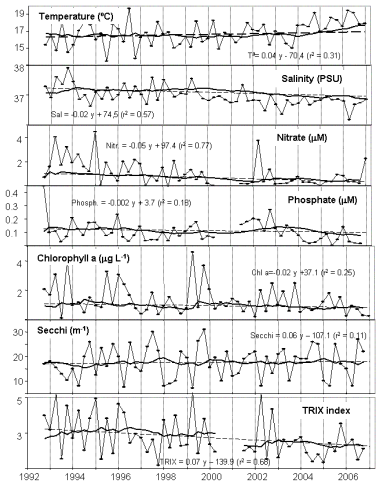

Fig. 1. Seasonally adjusted and smoothed time series of different measured variables. The dotted line indicates the linear trend calculated by least square fit of the trend component time series.

Results
The annual maxima of temperature were obtained in summer, and salinity and nitrate peaked in spring. Nitrate concentration averaged for summer-period was reduced 5-fold with respect to the spring period. In contrast, phosphate concentration did not follow a defined seasonal cycle. The temperature described a linear monotonous increase trend over time (Fig. 1). The linear time trends for the salinity, nitrate and phosphate were also significant although negative. The residuals series of temperature and salinity were significantly correlated ($r = -0.55$, $p < 0.05$). However, there was not correlation between residuals series of salinity and nitrate or phosphate. Chl a concentration and Secchi disc depth did not describe any clear seasonal variation pattern, although normally higher chl a values were obtained in spring. Both variables experienced a monotonous decrease trend over the study period. Residuals of chl a were positively correlated with nitrate concentration ($r=0.35$ $p < 0.05$), however the correlation with phosphate was non-significant statistically. As obtained for nutrient concentrations and Chl a, TRIX index decreased over time.

Discussion
The study area is characterised by the presence of surface Atlantic water (AW) that is more or less modified depending on the degree of upwelling of deep Mediterranean water (MW). Therefore, the salinity decrease trend over time denotes a progressively lesser influence of the MW, as previously showed by [2] in other locations of the Alboran sea for the period 1992-2002. Atlantic water is usually depleted in nutrients. Consequently, the increasing influence of the AW produced a reduction of the nutrient concentration. Coincidently, chl a trended to decrease over time, indicating that the stock standing of phytoplankton at decadal scale was mainly controlled by the availability of nitrate. The high-frequency variability of chll a appears to be also controlled by the nitrate availability, as residuals series of both variables were significantly correlated. However, residuals series of nutrients were not correlated with salinity, probably indicating that the local peaks of nitrate and phosphate (which were especially conspicuous in 1992, 1994 and 2002) were not related with hydrological dynamics. It could be hypothesized that this high-frequency variability is due to nutrient discharge from terrestrial sources. The decrease trend over time of the TRIX index is a consequence of both the reduction of the nutrient and chl a concentrations (oxygen concentration did not experience any decadal variation pattern).

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