ARTICLE IN PRESS

Marine Pollution Bulletin xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Coastal waters environmental monitoring supported by river basin pluviometry and offshore wave data

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ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Coastal waters
Pluviometry
Wave data
Environmental monitoring
WFD

ABSTRACT

Environmental monitoring in the scope of the Water Framework Directive 2000/60/EC (WFD) is usually expensive and requires considerable human effort. In this study, we analyzed data obtained by a WFD coastal waters monitoring network over a three-year period (35 campaigns), with the aim to ascertain is it possible to increase the monitoring efficiency and obtain more accurate results. As the trophic condition of the coastal waters of Valencia is primarily, but not entirely, determined by continental loads and hydrodynamic conditions, additionally we analyzed related river basin pluviometry (daily frequency) and oceanographic (one hour frequency) data. Chlorophyll *a*, salinity, rain and wave data time series were analyzed separately, to identify any possible pattern. Analyzing coastal water bodies integrating all four parameters, it is found strong interactions between coastal waters trophic conditions, sea hydrodynamics and related basin pluviometry. Eight phytoplankton biomass scenarios associated to environmental conditions are identified and finally developed basis for a new efficient monitoring strategy and more accurate coastal waters assessment.

1. Introduction

Coastal waters are very fragile ecosystems and their equilibrium is constantly under pressure from urban growth, restructuring of coastal areas, economic development, agriculture, fisheries and other anthropogenic activities. Degradation of coastal aquatic ecosystems has long been a concern and the European Commission has passed legislation that aims to preserve and restore European waters. The Water Framework Directive 2000/60/EC (WFD) requires member states to achieve or to maintain good ecological status. In order to assess the ecological status of coastal waters and obtain information regarding an ecosystem's condition a system of biological quality elements is used that clearly indicates anthropic pressure. Currently, the research literature on the bioassessment of coastal waters focuses on phytoplankton (e.g. Bianchi et al., 2003; Sagert et al., 2005; Devlin et al., 2007; Pachés et al., 2011; Pereira Coutinho et al., 2012) and other WFD biological quality elements (e.g. Borja et al., 2003; Muniz et al., 2005; Rees et al., 2006; Dauvin, 2007; Blanchet et al., 2008; Pergent-Martini et al., 2005).

Phytoplankton, unlike other WFD bio-indicators, reacts directly to nutrient enrichment and this is shown in alterations in its biomass and variations in its composition (Gasiūnaitė et al., 2005). The dynamics of its growth cycle can provide rapid information on the status of an ecosystem (Reynolds, 2002). Monitoring the composition of the phytoplankton species (and its recounts) requires significant human and financial effort, although using chlorophyll *a* as a surrogate indicator of the phytoplankton biomass is an effective cost/time measure, and one which is widely implemented in environmental monitoring programs under the WFD.

Numerous authors have criticized the WFD sampling frequency requirement (2 times per year) for phytoplankton (de Jonge et al., 2006; Carstensen, 2007; Devlin et al., 2007, etc.) while others point out the need for extensive and frequent monitoring to obtain accurate information (Toompuu and Carstensen, 2003; Heiskanen et al., 2005). In mean time, phytoplankton experts of the Working Group 2.7 on Monitoring within the Common Implementation Strategy of the WFD provide recommendations on increasing the frequency of the campaigns and Monitoring guidance document (EC (2003)) states that WFD minimum frequency can be inadequate for many regions and recommends at least monthly sampling. Nevertheless, even using chlorophyll *a* as an indicator in the assessment of coastal waters, a monthly sampling frequency from more than

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http://dx.doi.org/10.1016/j.marpolbul.2014.12.052
0025-326X/

Please cite this article in press as: Abramic, A., et al. Coastal waters environmental monitoring supported by river basin pluviometry and offshore wave data. Mar. Pollut. Bull. (2015), http://dx.doi.org/10.1016/j.marpolbul.2014.12.052

100 sampling stations along 437 km of the Valencian coast is very costly.

After three years of monthly water sampling, the question has arisen of whether the same results could be obtained with an alternative monitoring strategy. Cost effective solutions, required in this time, can be based on the development of bio-indicators, but we developed research that tries to provide a new efficient monitoring policy on the basis of current methods, obtained data and acquired information.

Until now, analyzing information obtained by the phytoplankton monitoring network, we provide a methodology to reliably determine for which water bodies monitoring frequency can be reduced and the results will be unchanged (Abramic et al., 2012). This method reduce costs for Valencian coastal waters monitoring in the scope of WFD around 10%. Additionally, we developed method to inquire the efficiency of sampling stations distribution in the monitoring programme (as in the water body) and to provide alternative that can reduce sampling and within significantly downgrade financing (Abramic et al., 2014).

In this study, the same information was analyzed and it was considered a possible strategy to increase efficiency of sampling campaigns and provide more accurate results. To achieve this, we are analyzing information obtained by WFD coastal waters monitoring network, but additionally we also report on two environmental factors which can influence the phytoplankton biomass.

The phytoplankton dynamic is determined by various factors, but for this analysis we limited ourselves to a study in our opinion most significant for the Valencian coast; continental loads caused by precipitation events and hydrodynamic conditions forced by waves.

The approach adopted takes the data from three different networks established by different state institutions; one measuring phytoplankton under WFD guidelines for the coastal waters, one measuring off shore oceanographic parameters and one measuring precipitation levels in the river basin.

During periods of rain, usually, in the coastal environment, the rain/plume effect can be easily observed. The rain/plume effect consists of inshore waters having decreased salinity concentrations due to the discharge of continental freshwater from rivers, gullies, groundwater, etc. Usually, the reduction in salinity is accompanied by an increase in nutrient loads which are taken up quickly by phytoplankton (and bacteria), entering the food chain as particulate organic matter, and leading to organic enrichment (Furnas and Mitchell, 1996). This process was managed by the Mediterranean Geographical Intercalibration Group – Phytoplankton (set up as part of implementing the WFD), which established coastal marine system typology, mainly focused on hydrological parameters characterizing water body (w.b.) dynamics and circulation (Carletti and Heiskanen, 2009). Three different types of coastal sites on the Mediterranean Sea were selected, on the basis of the influence of freshwater, for evaluation of their trophic condition.

Pluviometric time series were analyzed separately with the aim of identifying a possible seasonal pattern. It was thought that, in the framework of the coastal ecosystem, a seasonal pattern might have a direct influence on the phytoplankton biomass dynamic.

Wave exposure was used as an obligatory factor in establishing coastal typology (WFD) for the Baltic Sea. The coast of Finland was split into an outer open zone and an inner coastal zone based on mixing conditions and wave exposure, which was derived from the density of islands, openness of water areas and mean water depth (Perus, 2004). Water bodies within Polish marine waters are classified as partly open, protected and partly protected, depending on wave exposure (Krzyminski et al., 2004). Finally, sea layers vertical mixing (due particular hydrodynamic conditions) and its effects on the phytoplankton biomass, composition and dynamic is frequent topic of research (Eslinger and Iverson, 2001; Serra et al., 2003; Perruche et al., 2010) Accordingly it is reasonable to assume and confirm analyzing the available environmental data (hydrodynamics, current patterns, wind regime, etc.) that wave exposure has significant consequences on the trophic conditions in Valencian and Mediterranean coastal waters.

As with the rain data, significant wave height over a time series was analyzed separately as an environmental factor that might influence the trophic state of coastal waters.

Phytoplankton seasonality was a frequent topic of research in the 1980s (e.g. Azov, 1986; Cadee, 1986; Marshall and Lacouture, 1986), but has recently come under scrutiny again (Alcalà et al., 2004, Cermeño et al., 2006, etc.). Equally as environmental parameters, chlorophyll *a* time series were analyzed to identify possible pattern or level of seasonality that can be used to increase sampling monitoring efficiency.

Finally, chlorophyll *a* and salinity time series (phytoplankton network) were analyzed together with pluviometric and oceanographic data to better understand how coastal ecosystem responds on different levels of hydrodynamics and continental load pressures. Developed multi-disciplinary method integrates environmental data with the phytoplankton monitoring results in order to ascertain relations and influence on trophic conditions. With this integrated analysis we will obtain information/knowledge on ecosystem that provides basis for more accurate ecological assessment and potential to decrease cost of WFD monitoring.

2. Method

To analyze how the environmental factors impact on the trophic state of the coastal waters it was necessary to integrate data from different networks that sample different parameters, from different location, with different frequency and so on. To manage all the data a data base was developed and integrated in the geographical information system (GIS) used for a required spatial analysis (networks stations positions and mutual distances, analysis of river basin influence on coastal waters, coastal morphology, fetch length, coastal zone hydrology, etc.).

2.1. WFD coastal waters monitoring network

The WFD monitoring network that surveys 437 km of the Valencian littoral uses more than 100 coastal sampling stations and started functioning in August 2005. The network carries out monthly sampling campaigns, based on the agreement and recommendations done by phytoplankton experts on Common Implementation Strategy of the WFD (EC (2003)), even though the sampling frequency proposed by the WFD for surveillance monitoring of the phytoplankton is once every six months (EC, 2000). The locations of the monitoring stations for the Valencian coastal waters were chosen taking into account the influence of continental waters (rivers, gullies and so on) and of well-known anthropogenic impacts (for example, sea outfalls, geomorphologic changes of the coast).

Each monitoring station in the network, took inshore water sample at a depth of 10 cm in the surf zone (but before the wave collapsing area to avoid the sediment re-suspension that can affect bio-chemical water quality). Taking the water samples inshore makes the survey more efficient and easy, and does away with the need for a vessel. More than 2300 samples were regularly taken and analyzed during the three-year period August 2005 to July 2008 with the exception of September 2005 when the water sampling campaign was cancelled. Chlorophyll *a* and salinity values for this month have been excluded from our analysis. Similarly, technical problems in the laboratory during the summer of 2008 meant