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Assessing environmental quality status by integrating chemical and biological effect data: The Cartagena coastal zone as a case

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ABSTRACT

Cartagena coastal zone (W Mediterranean) was chosen for a practical case study to investigate the suitability of an integrated indicator framework for marine monitoring and assessment of chemicals and their effects, which was developed by ICES and OSPAR. Red mullet (*Mullus barbatus*) and the Mediterranean mussel (*Mytilus galloprovincialis*) were selected as target species. Concentrations of contaminants in sediment and biota, and contaminant-related biomarkers were analysed. To assess environmental quality in the Cartagena coastal zone with respect to chemical pollution, data were assessed using available assessment criteria, and then integrated for different environmental matrices. A qualitative scoring method was used to rank the overall assessments into selected categories and to evaluate the confidence level of the final integrated assessment. The ICES/OSPAR integrated assessment framework, originally designed for the North Atlantic, was found to be applicable for Mediterranean species and environmental matrices. Further development of assessment criteria of chemical and biological parameters in sediments and target species from the Mediterranean will, however, be required before this framework can be fully applied for determining Good Environmental Status (GES) of the Marine Strategy Framework Directive in these regions.

1. Introduction

Over the last decade, a large number of studies have demonstrated that the best way to assess the quality of the marine environment and to conduct an environmental risk assessment with respect to hazardous substances is by assessing a suite of chemical and biological measurements (biomarkers and bioassays) in an integrated way (Van der Oost et al., 2005; ICES, 2006; Thain et al., 2008; Lyons et al., 2010; Vethaak et al., 2015). Since 2008, the Marine Strategy Framework Directive (MSFD, Directive, 2008/56/EC) and the gradual application of the ecosystem approach (EcAp) in the Mediterranean region (UNEP/MAP, 2013) has put additional emphasis on the importance of assessing key biological responses for evaluating the health of organisms, linking alterations in these responses to putative contaminant effects.

Working groups have developed guidelines and criteria for biological effect methods within the International Council for Exploration of the Sea (ICES) and Oslo-Paris Commission (OSPAR). A framework has been developed for integrated assessment of contaminant impacts in coastal and offshore areas (Vethaak et al., 2015). In this proposed framework, different components of the ecosystem (water, sediment and biota) have to be jointly monitored. The biota component comprises fish, mussels and gastropods. Chemical (contaminant concentrations) and biological (bioassay and biomarker responses) parameters are measured for

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each matrix. Data obtained for each parameter are assessed against corresponding assessment criteria (ACs). Background assessment criteria (BAC) for contaminants in sediments and biota are defined as the concentration of a substance at a place where no deterioration of the environment can be expected. In the case of biological parameters BAC are defined as the baseline biological condition in healthy organisms. Ecotoxicological assessment criteria (EAC) are defined in sediments and biota as the contaminant concentration or biological response above which significant acute and long-term adverse biological effects are likely to occur. In the case of biomarkers of exposure, only BAC can be determined, whereas for biomarkers of effect both BAC and EAC can be established if appropriate data are available. Within the integrated framework (Vethaak et al., 2015), monitoring observations are first compared to assessment criteria, then, in a second step, an integration of parameters by matrix is performed for a given site before, in a third step, the integration of matrices can be performed for a site assessment. The results for each determinant and matrix carry equal weight in the integration (to scale the sums to a total of 100%). Data can be further integrated across multiple sites to perform a regional assessment. The proposed assessment framework provides a useful tool for assessment of environmental monitoring data to determine whether or not "Good Environmental Status" is being achieved for Descriptor 8 of the MSFD. "Good Environmental Status" (GES) for the site or region will be reached if 95% of the aggregated data are below EAC (Vethaak et al., 2015). Therefore, an essential requirement to perform such an integrated assessment is the availability of ACs for all parameters measured in the different matrices.

The methodology to estimate ACs depends of the nature of the chemical compound/biological response and the environmental matrix under consideration. Furthermore, biogeographical peculiarities between European marine regions may lead to the establishment of different ACs for the same environmental matrices. Unlike contaminant concentrations in sediments, contaminant concentrations and biomarker responses in biota can usually not be assessed against ACs without consideration of possibly confounding biological and environmental factors (such as species, gender, size, age, maturation state, season or ambient temperature). A range of ACs for contaminant concentrations and biological responses have been developed for its use in European waters, with particular reference to the North Atlantic region (OSPAR Commission, 2009; Law et al., 2010; Vethaak et al., 2015). ACs proposed by ICES/OSPAR have been developed using OSPAR database, national data sets, and in some cases, specific research studies, covering a wide geographical range, in which the confounding factors mentioned above were taken into account (for details see Davies and Vethaak, 2012). There is however a scarcity of ACs for biological effect measurements in species from the Mediterranean region, mainly due to the lack of necessary data to validate them (UNEP/MAP, 2011; Benedicto et al., 2012; Martínez-Gómez, 2013; Fernández et al., 2015). ACs obtained from target species in the Mediterranean are restricted to mussel (*Mytilus galloprovincialis*) and red mullet (*Mullus barbatus*). Most of the ACs for these Mediterranean species have been developed using data from organisms sampled at reference sites in Mediterranean Spanish waters with the following characteristics: mussels (size ranging from 3 to 5 cm) sampled in May–June, and red mullet (size ranging from 12 to 18 cm; gonadosomatic index <1) sampled in October (for details see Benedicto et al., 2012; ICES et al., 2013).

In this study, we explore the feasibility of the multi-step process developed by the OSPAR/ICES Study Group on Integrated Monitoring of Contaminants (SGIMC) (Vethaak et al., 2015) to perform an integrated assessment of the environmental status of chemical pollution in Western Mediterranean Regions, using the Cartagena coastal zone (SE Spain, NW Mediterranean) as a study area. A qualitative scoring method to rank the overall assessments into different categories, and an evaluation of the level of confidence of the final integrated assessment score was proposed to facilitate (i) comparisons between areas/countries/regions and (ii) decision-making policy recommendations for management measures to achieve or improve GES for any particular area or region.

The interest of assessing the environmental status of Cartagena coastal zone was based on the fact that this area is subjected to multiple stressors emerging from anthropogenic activities, including an intense commercial and recreational shipping activity, naval military and fishing activities. Moreover, the Cartagena coastal zone is under the influence of urban, harbour, industrial and oil-related activities of Cartagena city, as well as being influenced by the nearby industrial zone of Escombreras Valley (Fig 1), already identified as a priority pollution hot spot in the Mediterranean Sea (UNEP/MAP/MED POL, 2005; Martínez-Gómez et al., 2012). Furthermore, marine sediments from Cartagena are influenced by a legacy of metal inputs (mainly Pb, Zn), due over 30 years of mining waste discharges to the nearby Portmán Bay (Benedicto et al., 2008).

To assess whether or not GES of the Cartagena coastal zone has been achieved with regard to chemical pollution, a selection of core and supplementary parameters were analysed in sediments and biota. Coordinated sampling of key environmental components was performed in the autumn 2008 in the Cartagena marine area. The sampling occasions and target species, red mullet (*Mullus barbatus*) and the Mediterranean mussel (*Mytilus galloprovincialis*), were done as recommended by the MED POL program (UNEP/RAMOGE, 1999). The ACs considered were those available for target species and sediment for the Mediterranean Region. Concentrations of contaminants in sediment and biota, as well as contaminant-related biomarkers of exposure and effect were analysed. Sediment bioassays were performed on elutriates using the sea urchin embryotoxicity test. Chemical and biological effect data were assessed against corresponding ACs available for the target species and sediments. The resulting assessments were then integrated over environmental matrices and across categories. Finally, the assessments were aggregated to provide a single and integrated assessment of the environmental status of Cartagena coastal zone.

2. Materials and methods

2.1. Biota and sediment sampling

Mussels were sampled in May 2008 (pre-spawning period) following the requirements of the Programme for the Assessment and Control of Pollution in the Mediterranean Region (MED POL) (UNEP/RAMOGE, 1999). Due to the scarcity of native populations of mussels in Cartagena coastal zone, resident mussels were sampled from the outer wall of the Escombreras breakwater, close to the industrial area of Cartagena port, and under the influence of shipping traffic and industry (oil refinery). This native population may not be representative enough of the overall chemical quality of Cartagena waters. Therefore, in this study, mussels were transplanted to a location considered as representative of the diffuse contamination of Cartagena coastal waters, near Isla de las Palomas, at a distance of about 3 nautical miles west of native mussels. Mussels were obtained from ropes near a fish farm located in open waters in Fuengirola (Malaga, SE Spain) and they were immersed inside of a cage of polyethylene netting (dimensions 1 × 1 m, with 1 cm mesh size), and deployed in October 2008 for 6 weeks (47 days) (Fig. 1). The caged mussels were deployed at approximately 6 m–8 m below the sea surface (40 m depth), and the system was anchored to the bottom by means of ballast weighing about 50 kg.