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A process-driven sedimentary habitat modelling approach, explaining seafloor integrity and biodiversity assessment within the European Marine Strategy Framework Directive

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ABSTRACT

The Marine Strategy Framework Directive (MSFD) seeks to achieve good environmental status, by 2020, for European seas. This study analyses the applicability of a process-driven benthic sedimentary habitat model, to be used in the implementation of the MSFD in relation to biodiversity and seafloor integrity descriptors for sedimentary habitats. Our approach maps the major environmental factors influencing soft-bottom macrobenthic community structure and the life-history traits of species. Among the 16 environmental variables considered, a combination of water depth, mean grain size, a wave-induced sediment resuspension index and annual bottom maximum temperature, are the most significant factors explaining the variability in the structure of benthic communities in the study area. These variables are classified into those representing the 'Disturbance' and 'Scope for Growth' components of the environment. It was observed that the habitat classes defined in the process-driven model reflected different structural and functional characteristics of the benthos. Moreover, benthic community structure anomalies due to human pressures could also be detected within the model produced. Thus, the final process-driven habitat map can be considered as being highly useful for seafloor integrity and biodiversity assessment, within the European MSFD as well as for conservation, environmental status assessment and managing human activities, especially within the marine spatial planning process.

1. Introduction

Increasing pressure induced by human activities in the marine environment has triggered the necessity for new management requirements. Amongst others, new initiatives towards marine management, *e.g.* Marine Spatial Planning (MSP) (Douvere and Ehler, 2009; European Commission, 2010b) and Ecosystem-Based Management (EBM) (or the Ecosystem-based MSP (Foley et al., 2010; Katsanevakis et al., 2011)), have highlighted the need for the best available scientific knowledge both of the marine environment and ecosystem functioning. For example, benthic habitat maps have been identified as being the basic knowledge to permit scientists and managers to understand the distribution of living and non-living resources on the seafloor (Shumchenia and King, 2010) together with their characteristics (vulnerability, sensitivity, etc.). Such information needs to be taken into account in managing human activities to optimize the exploitation of marine goods and services, at the same time minimizing the environmental impact of the related uses and activities. Unfortunately, scientific knowledge on the extent, geographical range and ecological functioning of benthic habitats is still poorly established. Consequently, it is difficult to manage resources effectively, protect ecologically important areas and establish legislation to safeguard the oceans.

In order to address this management requirement, there is an urgent need to develop robust methods for mapping marine ecosystems, to establish their geographical location, extent, and condition (Brown et al., 2011). Specifically, in the European Marine Strategy Framework Directive (MSFD, (Council Directive, 2008/56/EC, 2008), two important descriptors used in assessing environmental status of marine waters are seafloor integrity and biodiversity. 'Sea Floor' is interpreted as including both the physical parameters of the seabed – bathymetry, roughness (rugosity),

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substratum type, etc.; and biotic composition of the benthic community. 'Integrity' is interpreted as both covering spatial connectivity, such that the habitats are not fragmented unnaturally, whilst having the natural ecosystem such processes functioning in characteristic ways. 'Biodiversity' includes, together with species, population and ecosystem structure, other indicators related to habitat distribution, extent and condition (European Commission, 2010a). Areas of high habitat integrity in both of these standards are resilient to perturbations. As such, human activities can cause some degree of perturbation without serious and lasting harm to the ecosystems (Rice et al., 2010; Van Hoey et al., 2010; Borja et al., 2011; Rice et al., 2012).

The environmental variables that describe a species fundamental niche can be grouped broadly into: resource gradients, *e.g.* chemicals or energy consumed by a species; direct gradients of variables, with a physiological influence on a species but not consumed by it, *e.g.* sediment grain size or temperature, and indirect gradients of variables, correlated with direct and resource gradients but with no physiological connection to the species, *e.g.* depth and latitude (Meynard and Quinn, 2007). Considering the aforementioned assumptions, habitat modelling methods have been used to statistically link field observations of biological data to a set of environmental variables or spatial predictors, reflecting some key characteristics of the niche (Guisan and Zimmermann, 2000; Hirzel and Guisan, 2002; Hirzel and Le Lay, 2008). Physical disturbance and available food supply are known to be important in structuring benthic communities (Kube et al., 1996). Thus a benthic habitat model should take these into account, together with other information on physical processes occurring on the seafloor and oceanographic information pertaining to the near-bottom water column (Gogina et al., 2010b). Consequently, the process-driven habitat template (Kostylev and Hannah, 2007), takes into consideration the aforementioned assumptions, when formulating the habitat model. The process-driven habitat template is a conceptual model, used to relate species life-history traits to the properties of the environment, transforming maps of the physical environment into a map of benthic habitat types. Such an approach has been applied to benthic marine habitat in Atlantic Canada (Kostylev et al., 2005); it was also applied elsewhere in assessing how the resulting classification corresponded to distributions of a number of species, including corals, sponges and commercially important bottom fish (Gregr, 2008). More recently, the capacity of this model to explain the spatial distribution of fish species diversity has been demonstrated (Fisher et al., 2011).

Within this context, the present study aimed to test the applicability of a process-driven benthic sedimentary habitat model, in the implementation of the European MSFD, in relation to the biodiversity and seafloor integrity descriptors for sedimentary habitats (Rice et al., 2010; Van Hoey et al., 2010; Borja et al., 2011) and the MSP approach. A case study, the Basque continental shelf (Bay of Biscay) has been adopted. To accomplish this aim, the following sequential approach was applied: (1) near-bottom oceanographic and sedimentological parameters that determine species assemblages were identified; (2) the most important environmental parameters were selected and fitted within the process-driven habitat model template; (3) a process-driven habitat model map was produced; (4) the structural parameters and life-history traits of species were analysed within the process-driven habitat model template, and, finally, (5) benthic habitats were characterized in terms of species assemblages and environmental characteristics.

2. Material and methods

The study area is located on the continental shelf of the Basque Country, in the southeastern part of the Bay of Biscay, northern Spain (Fig. 1).

2.1. The process-driven habitat model template

The process-driven marine benthic habitat mapping approach, as proposed by Kostylev and Hannah (2007), is based upon ecological theory that relates species life-history traits to the properties of the environment (Southwood, 1977; Margalef et al., 1979; Huston, 1994; Reynolds, 1999), transforming maps of the physical environment into those of benthic habitat types. This approach is based upon the aggregation of sets of environmental selective factors, on two axes. The 'Disturbance' axis reflects the intensity of habitat alteration or destruction, or the durational stability of habitats, including only natural seabed processes responsible for the selection of species life history traits, on the evolutionary time-scale. The 'Scope for Growth' (SfG) axis describes the amount of energy available for growth and reproduction after adjusting the available food supply by environmental stressors that pose a cost for the physiological functioning of organisms. This latter factor could be related also to the metabolic theory of ecology (Brown et al., 2004). Thus, the habitat model constructed according

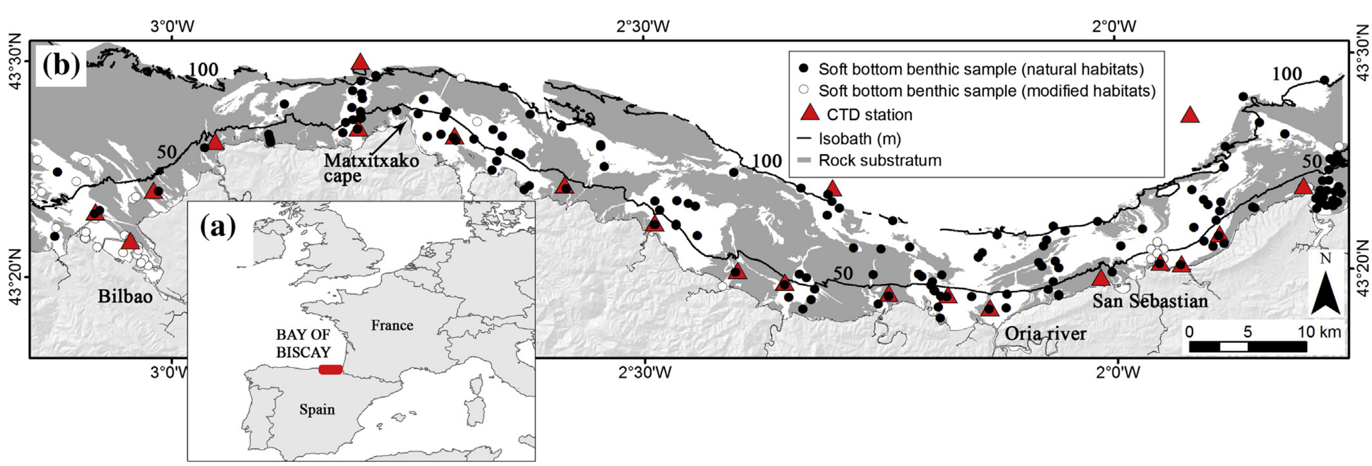

Fig. 1. (a) Study area location within the Bay of Biscay; and (b) study area and CTD stations and soft bottom benthic sample locations for "natural habitats" and "modified habitats". Note: grey shadows shows the rocky bottom substratum.