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Broad-scale mapping of seafloor habitats in the north-east Atlantic using existing environmental data

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A B S T R A C T

If marine management policies and actions are to achieve long-term sustainable use and management of the marine environment and its resources, they need to be informed by data giving the spatial distribution of seafloor habitats over large areas. Broad-scale seafloor habitat mapping is an approach which has the benefit of producing maps covering large extents at a reasonable cost. This approach was first investigated by Roff et al. (2003), who, acknowledging that benthic communities are strongly influenced by the physical characteristics of the seafloor, proposed overlaying mapped physical variables using a geographic information system (GIS) to produce an integrated map of the physical characteristics of the seafloor. In Europe the method was adapted to the marine section of the EUNIS (European Nature Information System) classification of habitat types under the MESH project, and was applied at an operational level in 2011 under the EUSeaMap project. The present study compiled GIS layers for fundamental physical parameters in the northeast Atlantic, including (i) bathymetry, (ii) substrate type, (iii) light penetration depth and (iv) exposure to near-seafloor currents and wave action. Based on analyses of biological occurrences, significant thresholds were fine-tuned for each of the abiotic layers and later used in multi-criteria raster algebra for the integration of the layers into a seafloor habitat map. The final result was a harmonised broad-scale seafloor habitat map with a 250 m pixel size covering four extensive areas, i.e. Ireland, the Bay of Biscay, the Iberian Peninsula and the Azores. The map provided the first comprehensive perception of habitat spatial distribution for the Iberian Peninsula and the Azores, and fed into the initiative for a pan-European map initiated by the EUSeaMap project for Baltic, North, Celtic and Mediterranean seas.

1. Introduction

The demand for accurate and reliable maps describing the seafloor habitats of Europe has increased dramatically in recent years with the implementation of legislation such as the Habitats Directive (92/43/EEC) and the Marine Strategy Framework Directive (MSFD; 2008/56/EC). Such information is crucial for the production of broad-scale maps of human impact on the marine environment (Andersen et al., 2013; Halpern et al., 2008). Marine spatial planning also demands reliable and comprehensive spatial data that includes the characteristics of coastal and ocean environments based on habitat types (e.g. Douvere et al., 2007; Gilliland and Laffoley, 2008).

Habitat mapping typically relies on the application of multiple survey techniques such as single- and multi-beam sonar, LiDAR, grab sampling and other physical groundtruthing, to derive data that can be integrated to produce a map (Brown et al., 2011). To date, numerous international protected area programmes (e.g. Natura 2000 network established under the Habitats Directive) as well as other local initiatives (e.g. Ehrhold et al., 2006; Galparsoro et al., 2013; Gorman et al.,

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2013; Todd and Kostylev, 2011) have used these different approaches to produce spatially explicit maps. These methods allow detailed maps to be developed: the boundaries between adjacent habitats are accurately delineated, and both the abiotic characteristics and the associated biological communities are described. Their drawback is that they are costly, resource-intensive and time-consuming, typically taking around three years from the first survey to full map completion. Therefore it is impractical to apply such an approach to all points on the seafloor in order to achieve full spatial coverage across Europe.

Broad-scale mapping represents an alternative to the piecemeal approach described above, the benefits of extended map coverage at reasonable cost. The concept relies on the assertion that benthic communities are strongly influenced by the physical characteristics of the seafloor (e.g. type of sediment, or slope) and the water column (e.g. temperature or water movement; Glémarec, 1973). Acknowledging this, Roff et al. (2003) proposed overlaying mapped physical variables using a Geographical Information System (GIS) to produce an integrated map of the physical characteristics of the seafloor, which they termed 'seascapes'. This method, which was successfully tested for the entire Canadian coastline (Roff et al., 2003), can be used to produce maps that, while less detailed, are of greater spatial extent and considerably less costly as they are based on existing information.

The capacity to rapidly augment spatial data in a very cost effective way is leading to a profound and rapid uptake of broad-scale mapping approaches. The approaches have been widely adopted, particularly in Australia (Harris et al., 2008; Huang et al., 2011) and in Europe, where it was first investigated at a continental scale as part of the INTERREG MESH project, which adapted the method to the European EUNIS (European Nature Information System) classification scheme (Coltman et al., 2008). Following on from this, the EUSeaMap project successfully put the method into practice for the western Mediterranean, Celtic, North and Baltic Seas (Cameron and Askew, 2011). Simultaneous national initiatives, in France (Hamdi et al., 2010) and in the United Kingdom (UKSeaMap 2010 project, McBreen et al., 2011), also applied this method successfully.

The present study was carried out within the framework of the MeshAtlantic project funded by the INTERREG 'Atlantic Area 2007–2013' programme. A key output of the project was a broad-scale map for four extensive areas around Ireland, the Bay of Biscay, the Iberian Peninsula and the Azores islands. The goal of this output was clearly to feed into the initiative for a pan-European map initiated by the EUSeaMap project. In order to be compatible with the results of EUSeaMap, the same methodology for generating a broad-scale map was used. A particular effort was dedicated to the selection of ecologically significant thresholds for the categories considered by the EUNIS classification using groundtruthing data.

2. Material and methods

2.1. Study area

The region covered is an area of about 2 million km^2 which includes the Atlantic waters of continental Europe and the Portuguese archipelago of the Azores (Fig. 1). It specifically includes the Iberian Peninsula, the Bay of Biscay, the Irish Sea, the Celtic Sea, and the seas surrounding the Azores islands. Although the Western Channel Sea and western part of the Irish sea were within the geographic bounds of the EU's 'Atlantic Area 2007–2013' programme (http://www.seupb.eu/programmes2007-2013/interreg-overview/transnational/atlanticareaprogramme.aspx) which funded the present project, they were not specifically targeted in this project as they had already been mapped within the framework of the EUSeaMap project (Cameron and Askew, 2011), and no improvement of the data for those areas had been identified since that time.

The area includes a diverse range of environmental conditions. At the scale of the entire area sea temperature and water depth are the main features determining seafloor species geographical distribution. Dinter (2001) separates the shelf and upper slope (for depth up to 1000 m) into three biogeographic zones, from North Shetlands Isles southward (i) the Boreal Lusitanean which comes down to a parallel across the English Channel, (ii) the Lusitanean Boreal extending downwards to roughly the Gironde Estuary in the Bay of Biscay and (iii) the Lusitanean extending to Gibraltar. The latter is divided into a warm subprovince covering the Aquitaine and the Basque Country in the north of Spain and an area in the south composed of the southern Portuguese coast and the Gulf of Cadiz. Due to the presence of strong upwelling, the central part of the Iberian Peninsula from Cantabria to Cape St Vincent is referred to as the cool Lusitanean subprovince. In this province, where the inshore area is dominated by rocky substrate, cold nutrient-rich water induces the presence of invertebrates and macroalgae usually found more to the north (e.g. Martins et al., 2013). Shelves and upper slopes in the Azores archipelago are put into a category of their own belonging to the Macaronesia province.

At finer scales the influence on community composition/species distribution of more specific water quality parameters along with seafloor topography, substrate and exposure to water movement become significant. Broad areas of shallow waters (light grey tones in Fig. 1) occur all around Ireland (west of the Porcupine Bank and in the southern part of the Celtic Sea) and in the western Bay of Biscay (French continental shelf), while off the coasts of northern Spain, the Iberian Peninsula and the Azores, deep-sea areas (dark grey tones in Fig. 1) are much more extensive nearshore. The Azores, a volcanic archipelago straddling the Mid-Atlantic Ridge, are noteworthy for the complexity of their geomorphology with nine islands and numerous seamounts, as well as for the prevalence of deep-sea grounds. Another deep-sea zone is the offshore Rockall Trough, which is located to the northeast of Ireland and in some places extends over 300 km in width and to depths of over 3000 m. From an oceanographic perspective, current-induced flows are generally weak except in the shallow, semi-enclosed Irish Sea, in local areas of the Northeastern French coast and near the Gibraltar Strait. The northeast Atlantic is known for its rough seas due to large storms that occur during the winter months.

2.2. Method overview

2.2.1. Classification scheme

The term 'habitat' is now generally accepted to mean "a place where plants or animals normally live, characterised primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality etc.) and secondarily by the communities of plants and animals that live there" (Davies et al., 2004). A habitat description must be based on a common habitat classification system, the function of which is to provide a common language and ensure cross-boundary consistency (i.e. particularly when spanning different countries). A number of habitat classifications schemes have been developed at regional or local scales. Most published examples of broad-scale mapping have also proposed their own classification (see e.g. Huang et al., 2011; Roff et al., 2003; Zacharias et al., 1999), but rarely were these reused by other authors.

In Europe, the EUNIS (European Nature Information System) classification, which provides a common European reference set of habitat types for terrestrial, freshwater and marine habitats (Davies et al., 2004), facilitates reporting of habitat data in a comparable manner, for use in nature conservation (e.g. inventories, monitoring and assessments), habitat mapping and environmental management. It is thus considered today as a reference tool within a European context. The current structure of the marine section of EUNIS covers a wide range of habitat types; even though it was first derived from the BioMar classification developed for Britain and Ireland (Connor et al., 1997a,b, 2004), substantial efforts have been made to include information on marine benthic habitats from different regions, aiming to provide a comprehensive geographical coverage of European seas (Galparsoro et al., 2012). It