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Biological validation of physical coastal waters classification along the NE Atlantic region based on rocky macroalgae distribution

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A B S T R A C T

A methodology to classify rocky shores along the North East Atlantic (NEA) region was developed. Previously, biotypes and the variability of environmental conditions within these were recognized based on abiotic data. A biological validation was required in order to support the ecological meaning of the physical typologies obtained. A database of intertidal macroalgae species occurring in the coastal area between Norway and the South Iberian Peninsula was generated. Semi-quantitative abundance data of the most representative macroalgal taxa were collected in three levels: common, rare or absent. Ordination and classification multivariate analyses revealed a clear latitudinal gradient in the distribution of macroalgae species resulting in two distinct groups: one northern and one southern group, separated at the coast of Brittany (France). In general, the results based on biological data coincided with the results based on physical characteristics. The ecological meaning of the coastal waters classification at a broad scale shown in this work demonstrates that it can be valuable as a practical tool for conservation and management purposes.

1. Introduction

Studies of marine ecosystems have been usually focused on local-scale processes (Foster, 1990), which are typically less useful than biogeographic approaches for understanding species distribution patterns and dynamics. Thus, research efforts need to be increased in order to encompass global studies (Lawton, 1996). This search for generalities can be handled through ecological classifications, that permit the collation, unification and synthesis of large scale data, providing an objective basis for analyses and a useful tool for conservation efforts (Snelder et al., 2007).

The emergence of a worldwide environmental management arose in the 1990s, showing the need of integrate pollution control and develop a coordinate ecosystem approach which combines natural and social sciences (Apitz et al., 2006). Through several international conventions and organizations (e.g. the Earth Summits, the Convention of Biological Diversity, the United Nations Environment Programme) countries agreed to achieve environmental sustainability. In Europe, after other proposals, this idea resulted in the European Water Framework Directive (WFD, Water Framework Directive 2000/60/EC), which ultimate goal was to

Abbreviations: IC, intercalibration; MS, member state; NEA, north east Atlantic; PAR, photosynthetically active radiation; SST, sea surface temperature; WFD, water Framework Directive.

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improve the quality of surface waters (Hering et al., 2010). Beside this, the European Community has developed other Directives (the Habitats Directive, HD 92/43/CEE, and the Marine Strategy Framework Directive, MSFD 2008/56/EC) which require that all European countries classify their coastal waters into typologies from an ecological point of view. The WFD involves the intercalibration (IC) of ecological assessment methods within four different Geographical Intercalibration Groups (GIGs). One of them is the North East Atlantic (NEA) GIG, which comprises the area from Northern Norway to the Canary Islands. Additionally to this first broad division, common IC types within GIGs are required in order to remove the effects of geographical differences before comparing assessment methods (European Commission, 2009).

In this context, different methods have been applied to classify coastal waters at regional and larger scales all around the world (Sherman, 1986; Roff and Taylor, 2000; Mount et al., 2007; Madden et al., 2009). Specifically along the NE Atlantic region several classification systems have been developed; these are the European Union Habitats Directive (1992/43/EEC); CORINE (Commission of the European Communities, 1991); the WFD ecoregions for coastal and transitional waters; the Marine Strategy Framework Directive subregions (MSFD; 2008/56/EC); European Palaearctic (Devilliers and Devilliers-Terschuren, 1996); Baltic HELCOM; EUNIS (Davies et al., 2004); the BioMar project (Connor et al., 1997), that encompasses and complements all of them, and the OSPAR regions (Dinter, 2001). Despite the number of classification approaches, these systems greatly vary depending on the region in which they were developed, on the physical and biological heterogeneity, on the data availability and on the scale on which they are based. There was not a harmonized and standardized classification methodology that can be generally used for management and conservation purposes. Taking this into account, a physical classification along the NEA GIG coastal area was developed by Ramos et al. (2012). The physico-chemical characteristics of sea surface temperature (SST) and photosynthetically active radiation (PAR) were used to establish a first classification into five large regions called "biotypes". Then, a second step was carried out in order to recognize and summarize the variability of environmental conditions within each biotype ("subtypological variants"). Thereby, suitable information was provided to justify the establishment of physically harmonized outer coastal zones for the potential distribution of macroalgae. These biotypes were adopted for the IC of macroalgae dividing the common IC type NEA 1/26 into "NEA 1/26 A2" (Iberian Peninsula and Southern France) and "NEA 1/26 B21" (Northern France, Ireland, Norway and UK).

Most of the classification methods based on physical variables do not include biological validation, given the sparseness of biological data and the difficulty of gathering it. If the objective is to understand different physical structures, then these classifications may be sufficient. However, if these classification systems claim to describe biogeographical regions and allow the establishment of ecological typologies, it is necessary to test and validate the biological suitability of the different classes obtained (Gregr et al., 2012). An important criterion is an objective statistical demonstration which proves that the derived classification units are significantly similar or different, based on both environmental and biological characteristics (Valesini et al., 2010). However, this biological criterion is lacking in most of the existing coastal classifications and the establishment of suitable biotypes along the NEA intercalibration region is not yet finished. It is necessary to develop a second step as defined by Ramos et al. (2012): the detection of the most representative macroalgae taxa along the study area and the use of this macroalgae distribution in order to check the ecological suitability of the physical classification system.

Intertidal macroalgae communities associated with intertidal rocky shores are very relevant from an ecological and scientific point of view. From an ecological perspective, it has been shown that despite their small relative representation (i.e. they occupy a small area in relation to other coastal ecosystems), they are vital for the ecological functioning of coastal zones (Lubchenco et al., 1991), as they are an integral component of ecosystems and provide food, habitat and shelter for many marine organisms (Cavanaugh et al., 2010). Scientifically, the composition and distribution of these assemblages have been widely studied. It is therefore well known that intertidal species vary due to natural abiotic influences. Among the most important physico-chemical factors that determine geographical macroalgae distribution are temperature (van den Hoek, 1982; Breeman, 1988), wave exposure (Levin and Paine, 1974), tidal range (Lewis, 1955), solar radiation (Hanelt et al., 1993) and salinity (Wallentinus, 1991). There is also a great variability at small spatial scales, caused by both abiotic features (e.g. substratum, nutrients, etc.) (Lüning, 1990) and biological interactions (Hawkins et al., 1992), although these factors have not been considered in this work because of its global scope. The strong correlation between macroalgae species and abiotic factors shows the utility of these variables as indicators of potential habitats for different communities and, consequently, for the establishment of coastal ecosystem classifications (Roff and Taylor, 2000). Therefore, detailed information about the spatial distribution of macroalgae is a fundamental issue, providing a way of testing the biological suitability of a physical classification.

General distribution patterns of macroalgae species are reasonably well-known along the NE Atlantic coasts (van den Hoek, 1975; Lüning, 1990). However, most studies and compilations analyze species distribution for single locations or countries and not for wider bio-geographical regions, as for example Juanes and Sosa (1998) in Spain; Gaspar et al. (2012) in Portugal; Lewis (1955) in UK; Jaasund (1965) in Norway; van den Hoek and Donze (1966) in France; and Munda and Markham (1982) in Helgoland (Germany). Despite all these studies, a comprehensive single and standardized inventory all along the NEA region does not exist, which hampers an adequate approximation of intertidal macroalgae species distribution for marine management purposes. In addition, the stronger knowledge of species composition and biodiversity around this area is of utmost importance to maintain the long-term suitability of ecosystems, allowing a better evaluation of changing environmental conditions as global warming (Verfaillie et al., 2009).

Considering all these aspects, the development of a suitable ecological classification system is an important feature for different management actions. It will be useful in the implementation of different legislation, as well as for the general assessment of coastal ecosystems. The main goal of this work is the biological validation of the physical classification developed by Ramos et al. (2012). In addition, this work provides homogenous and standardized information about the biogeographical distribution of intertidal macroalgae species along NE Atlantic region, and characterizes common biotypes according to macroalgae data.

2. Methods

2.1. Study area

The study was undertaken from Norway to the southern Iberian Peninsula as delineated by the NEA GIG. Taking into account the intrinsic characteristics of the study area (i.e. the existence of intertidal rocky substratum that enables the development of seaweeds), the coast line of seven countries was included in the analyses (Portugal, Spain, France, Ireland, UK, Germany and Norway).