Coastal waters classification based on physical attributes along the NE Atlantic region. An approach for rocky macroalgae potential distribution

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A B S T R A C T

According to requirements for intercalibration of assessment methods of vegetation quality elements along the North East Atlantic region, within the scope of the European Water Framework Directive (WFD), a better classification system of coastal regions is needed. To accomplish that goal, a quantitative classification approach was launched in order to establish common typologies for assessment of this biological quality element. This was preliminarily based on a physical classification of the coastal waters that included two consecutive steps, a first one devoted to the establishment of “biotypes” (large areas), and a latter one dealing with recognition of the variability within biotypes (“subtypological variants”). The NEA region coastline was subdivided into 550 consecutive stretches (40 km long). Then, physical variables (sea surface temperature, photosynthetically active radiation, wave exposure, tidal range and salinity) were calculated in reference points of each stretch, 5 km from the coast. This information was based mostly on satellite acquired data, using specific procedures proposed in this work. Physical typologies of NEA coastal waters were obtained by statistical analyses. Five different biotypes were selected (i.e. coastal sectors of the European coast) by national experts as baseline information to be used on intercalibration of assessment methods for vegetation within the WFD. Variability of environmental conditions on those biotypes was also analyzed and compared with previous classifications carried out at the national scale. Results from this study showed the feasibility of this methodological approach as a useful tool for assessment of the actual homogeneity of coastal environments.

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1. Introduction

The European Water Framework Directive (WFD; 2000/60/EC) establishes the aim of achieving by 2015 a “good ecological status” for all bodies of surface water, including transitional and coastal ones. For this purpose, Member States (MS) have to assess the Ecological Status (ES) of water bodies, assigned through the evaluation of biological, physico-chemical and hydromorphological
quality elements. One of the biological quality elements (BQE) in coastal and transitional waters is the vegetation (macroalgae and angiosperms), for which MS have proposed different methodologies for the assessment of ES. In order to enable the consistency of the national assessment systems with the normative definitions (WFD) and the comparison of those between MS, it is then necessary to perform an intercalibration (IC) exercise. Hence the essence of the intercalibration is to ensure that good ecological status represents the same level of ecological quality everywhere in Europe (Annex V WFD). To reduce dissimilarities due to spatial gradients, the intercalibration exercise is performed in a first step inside each Geographical Intercalibration Groups (GIGs) (European Commission, 2009a).

The North East Atlantic (NEA) GIG is a very heterogeneous region, with coastal waters which present diverse vegetation composition, including zones as diverse as the Canary Islands and Norway. In fact, the final results of the first phase of the IC exercise (2005–2008) showed the great difference within the NEA GIG and the difficulty of the establishment of common standardized assessment methods and reference conditions for the vegetation quality elements within the NEA intercalibration area (European Commission, 2009a). At present, common intercalibration types inside the NEA GIG are agreed for both coastal and transitional water bodies. For coastal waters these have been based on the obligatory factors (salinity and tidal range) plus optional factors (depth, current velocity, exposure, mixing and residence time). This resulted on the adoption of six coastal water body types (CW–NEA): 1/26, 3/4, 7, 8, 9 and 10 (European Commission, 2009b). These general types try to integrate the heterogeneity of coastal environments recognized at a lower scale within the coastal classifications developed by MS (Moy et al., 2003; Roger et al., 2003; Bettencourt et al., 2004; Spanish Environmental Ministry, 2008; Leonardsson et al., 2009; Ministry of Housing, 2009; Ministère, 2010; NLWKN, 2010).

A general problem in the implementation process of the WFD is the need to find a balance between typologies being too specific (too many types) and being too general (types do not sufficiently reflect natural variability) (Hering et al., 2010). In the case of the NEA GIG, because of the broad nature of some typologies (CW–NEA1/26), further subdivisions seemed to be necessary in order to produce results. The recognition of suitable “common types” is an urgent need and a preliminary task before intercalibration of classification methods can be finalized (European Commission, 2009c). Therefore, in the second phase of the IC exercise (2008–2011) further work in this field was proposed by experts in order to review the common intercalibration types defined in the first IC phase.

The intercalibration exercise is carried out within “common intercalibration types”, but compositional differences in biological communities still remain within a common type. Therefore, an adjustment is needed to remove the effects of such biogeographical discrepancies that can make comparability difficult (Guinda et al., 2008). Partly, the biogeographical variation is due to the climatic gradient across countries, being temperature one of the most important parameters (van den Hoek, 1982a,b; Breeman, 1988). The important role of the temperature is therefore recognized as one of the most important environmental factors directly responsible for differences in the geographical distributions of marine organisms resulting in the delimitation of large biogeographical regions. But other variables determining the geographical seaweed distribution may be found, such as salinity, water movement and light (Lüning, 1990; Rinne et al., 2011; Spatharis et al., 2011). There is considerable literature showing that populations and communities are strongly correlated with those abiotic characteristics (Roff and Taylor, 2000). Furthermore, it could be advantageous to use these physical factors in large scale classifications, due to the possibility of a continuous data acquisition against the lack of homogeneous reliable biological information all around a large area. Based on such assumptions it is possible to consider that physical characteristics might be used as surrogate indicators of ecological processes. The development of classification systems based on those proxies would allow for the establishment of different geographical zones for IC macroalgae purposes in NEA region.

Globally there have been fewer such attempts, mainly due to difficulties in acquiring data on that scale. Of the existing biogeographic classifications, the Large Marine Ecosystems (LMEs) are perhaps the most widely used for management purposes. These “large regions” are characterized by distinct bathymetry, hydrography, productivity and trophically dependent populations, and they were devised through expert consultation. On the other hand, the European Community and International Conventions have elaborated different classifications along the European coast, as the WFD ecoregions for transitional and coastal waters, the Marine Strategy Framework Directive subregions (MSFD; 2008/56/EC), the OSPAR regions and the EUNIS system (Davies et al., 2004). Apart from that, several approaches have been developed to classify national coastal waters, being the most commonly used variables: exposure to wave action, temperature, current velocity, tidal range, depth, substrate type, topography, salinity and solar radiation (e.g. Dethier, 1990; Roff and Taylor, 2000; Connor et al., 2004; Lombard et al., 2004; Snelder et al., 2006; Mount et al., 2007; Madden et al., 2009; Verfaille et al., 2009). However, main results of these classifications are represented as habitat patches instead of continuous coastal areas, as necessary for the IC exercise.

For river vegetation elements, an interesting approach that considers “subtypological variants”, characterized by distinct physical features and biological communities, has been developed (European Commission, 2009a). The proposal tries to deal with diverse patterns of species dispersal, climatological gradients or regional specificities within a common intercalibration type.

Bearing this in mind, as the main goal of the work, it was tried to provide suitable information to justify the establishment of physically homogeneous coastal zones for potential distribution of macroalgae under the NEA GIG coastal area. The physico-chemical characteristics were used to establish such a quantitative classification, the “biotypes”, which, after a more detailed analysis reflecting the variability at this lower scale (biotypes), should be able to identify likely “subtypological variants” for these coastal areas.

The integration of current technical advances from this research field, and following a four-steps procedure (Fig. 1), constituted the starting point for the establishment of suitable biotypes along the NEA intercalibration region.

Fig. 1. Summary of the main steps proposed for the establishment of common IC types.
2. Methodology

2.1. Study area

The study was carried out in the European NEA coast. This region extends from the longitude 39° W to 31° E and from the latitude 27° N to 71° N, including parts of the coastline of the following countries: Belgium, Denmark, France, Germany, Ireland, Netherlands Norway, Portugal, Spain, Sweden and United Kingdom. Because of its wide extension, the NEA region has a very heterogeneous climate, from desert climate (BW) in Canary Islands to continental subarctic (Dfc) and even tundra climate (ET) in Norway, according to Köppen classification (1936).

In order to apply a uniform procedure for the division of the entire coast, sections of equal length were established by cutting a smooth digital coastline at global scale every 40 km using ArcGis (ESRI). This length for the coastal stretches was considered the optimum, taking into account the global scale of the entire study area. The boundaries of the 530 stretches obtained were projected to a parallel line to the coastline (5 km away from the coast) and physical variables were calculated in the central point of each of these offshore sections. Thus, a serial number, beginning at the Strait of Gibraltar (Iberian Peninsula), was assigned to each section as well as to the points where the variables were calculated (reference points hereinafter) (Fig. 2).

2.2. Data

Taking into account the results obtained from preliminary analyses, which were carried out for the classification of this coastal area, five global variables and a total of 10 different indicators were selected: sea surface temperature (annual mean, maximum, minimum and standard deviation values), photosynthetically active radiation (annual mean, maximum and minimum values), salinity (annual mean), tidal range (annual mean) and significant wave height (annual mean). These variables fulfill the following criteria: (1) they are included in the WFD, (2) they are used in other regional classifications (e.g. Roff and Taylor, 2000; Connor et al., 2004; Lombard et al., 2004; Snelder et al., 2006; Mount et al., 2007), (3) they may be related to the geographical distribution of vegetation communities, (4) it is possible to obtain quantitative data at global scale within the study area and (5) indicators of the variables did not showed mutual influence (intercorrelation coefficient lower than 0.9).

For the study of the seasonal and interannual variability of those variables affecting the ecosystems, a combination of satellite and in situ data was used (Table 1). To estimate the variations of sea surface temperature (SST), remotely sensed Advanced Very High Resolution Radiometer (AVHRR) data from the Jet Propulsion Laboratory Physical Oceanography Distributed Active Archive Center (JPL PODAAC) were used. These data were processed in JPL within the NASA/NOAA AVHRR Oceans Pathfinder 5 project. The SST data series was composed by monthly estimates collected between 1982 and 2009. Only images from the ascending passes (night-time) were used in order to avoid daylight heating. During daytime, solar heating may lead to the formation of a very thin warm layer, particularly in regions with low wind speed. The data presented a spatial resolution of 4 km, which constitutes a compromise between the high spatial variability of the coastal regions and the data limitation due to cloud cover.

Estimates of Photosynthetically Active Radiation (PAR), derived from 9.3 km Sea-viewing Wide Field of-view Sensor (SeaWIFS) Level 3 data, were provided by the NASA Goddard Space Flight Center, Distributed Active Archive Center. The data used is daily integrated, which takes into account the number of daylight hours and cloud coverage. The exposure to wave action was obtained from the significant wave height records of five different satellite missions: TOPEX, TOPEX 2, Jason, Envisat, and Geosat Follow-On (GFO). The Atlantic basin was divided into a 1° × 1.5° grid (degrees latitude by degrees longitude), seeking a compromise between a representative number of data per cell and the highest spatial resolution. The tidal range was calculated from harmonic analysis computed using sea level observations of the TOPEX/Poseidon altimeter.

Finally, in situ salinity values were used in this study due to the lack of long temporal series of remotely sensed data. Vertical profiles of water salinity measurements were provided by the “World Ocean Database 2009” (WOD) of the National Oceanic and Atmospheric Administration (NOAA)-NESDIS National Oceanographic Data Center (NODC) (Boyer et al., 2006). The procedures for data quality control and data fusion are described at the address: ftp://ftp.nodc.noaa.gov/pub/WOA09/DOC/woa09_vol2_text.pdf. The salinity profiles used in this study were acquired between 1990 and 2009, and only data within the 0–10 m layer were considered.

According to the different spatial resolution of each data series (Table 1), SST, PAR and tidal range variables were obtained from the nearest point with satellite information to the reference points (cf. Fig. 2). On the other hand, wave height and salinity were estimated as the average of all data points within a circle of 0.5 km radius around the reference points. This method avoids problems due to the sparse available data of these two variables.

2.3. Classification procedure

Following the procedure shown in Fig. 1, two different steps were carried out for the establishment of the physical classification. First, a classification into broad geographic regions was developed, taking into account only SST (mean, maximum, minimum and standard deviation) and PAR (mean, maximum and minimum). These large regions (“biotypes” hereinafter) were obtained by hierarchical agglomerative clustering with complete linkage as the amalgamation rule, being this a suitable method to look for discontinuities in data (Legendre and Legendre, 1998). Previously, data series were normalised and used to construct a similarity matrix using Euclidean distances, since this is the appropriate distance measure for physico-chemical variables. These analyses were carried out using STATISTICA v.6.0.

A second step in the classification was accomplished in order to recognize and summarize the variability of environmental

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conditions within each biotype (i.e., subtypological variants). For this task the whole set of selected variables (SST, PAR, salinity, tidal range and significant wave height) was used to develop a cluster analysis similar to that of the first step. This hierarchical approach of further clustering within individual clusters is effective if a combination effective a more extensively divided classification is desired (Buddemeier et al., 2008). In order to give more weight to temperature in the final classification, three SST indicators were included (average, maximum and minimum), but only the average of the other four variables.

Finally, in order to make a preliminary analysis of the suitability of the subtypological variants identified, these have been compared with coastal zones previously established by MS in their national classification systems (Moy et al., 2003; Roger et al., 2003; Bettencourt et al., 2004; Spanish Environmental Ministry, 2008; Leonardsson et al., 2009; Ministry of Housing, 2009; Ministère, 2010; NLWKN, 2010).

The indicator used was the percentage of stretches integrated in each coastal zone at the national level that were also included in the same subtypological variant. In case more than one national type existed for each coastal stretch, the closest to the coast and/or with rocky substrate was selected. The global value for each MS was calculated as the average of “agreement” for the different estimated national types, according to the weighted length (number of stretches) of coast cover by each type.

3. Results

3.1. Data series

The basic information underlying classifications of the coastal area is the geographic distribution of each individual variable. A representation of data series, corresponding to the average of each variable divided into five equal interval classes can be observed in Fig. 3. Sea surface temperature (Fig. 3a) presented values between 5 and 21 °C, progressively increasing from North to South. Waters along the English Channel (extending southward into France), Southern Ireland and a small area in the northwest of the Iberian Peninsula showed medium SST values. Radiation followed the same trend (Fig. 3b), except in the Skagerrak and Kattegat zones, where PAR was slightly higher.

On the other hand, as shown in Fig. 3c the average wave height was maximum (around 3 m) in the West of Ireland, Northwest England and localized points in Norway and the Iberian Peninsula. All these coastal areas are very exposed to the Atlantic Ocean with a long fetch which permits the development of large waves. On the other hand, the Kattegat Strait coasts experience minimum wave conditions (around 0.5 m) due to the clear protected nature of this area. At the same time, the English Channel zone exhibited a high tidal range, typical of the restricted coastal configuration and shallow-water regions (Fig. 3d). Finally, salinity did not change very much throughout the study area, except in the Kattegat and Skagerrak coasts, a transition area between the brackish Baltic Sea and the saline North Sea (Fig. 3e).

3.2. Physical classification

NEA coastal waters were classified in biotypes taking into account the results of the cluster analysis. Depending on the cut-off Euclidean distance considered (Fig. 4, top), several classification schemes, including an increasing number of theoretical biotypes, could be obtained, as indicated in Fig. 4(a–f). Taking into account the first threshold (linkage distance of 9.6) established in the cluster, a first general division was made in Brittany (France), distinguishing between a southern warm region (A) and a northern cold region (B) (Fig. 4a). The second threshold (linkage distance of 7, Fig. 4b) defined the difference between Canary Islands and Madeira (A1) and the rest of the southern region (A2). These islands present very specific conditions that make them a singular group (high SST and PAR, 20 °C and 42 E m⁻² day⁻¹ on average, respectively). Furthermore, this group was characterized by a very low value of SST standard deviation (1.7 °C).

The next two subgroups refer to the northern area. The first one (Euclidean distance 4.8) subdivided group B into B1, Southern North Sea and the area of influence of the Baltic Sea, and B2, including the rest of the northern region (Fig. 4c). A further division (Fig. 4d, cut-off Euclidean distance of 4.64) distinguished the coastal region closer to the Arctic (B22, Trøndelag, and Northern Norway regions) with average SST ca. 11 °C, from the rest, the English Channel and the Northern area of the Bay of Biscay, Ireland, United Kingdom and Western Norway.

The final two divisions established from the cluster were related with much more specific gradients at a national scale. First (Fig. 4e), the southern part of the Iberian Peninsula and the Azores were segregated from the group A2. Secondly, according to regional differences in temperature, with a cut-off Euclidean distance of 3.8 seven subgroups are obtained (Fig. 4f).

From these classification schemes a preliminary agreement on the suitability of five different biotypes (Fig. 4d) within the NE Atlantic region was considered in this paper (cf. Discussion). Thus, the results from the second step of physical classification can be observed in Fig. 5. The five groups obtained with a cut-off Euclidean distance of 4.64 have been reclassified in order to identify potential subtypological variants within each. In this analysis a large variability is observed originating from the recognition of different environmental coastal conditions within each biotype.

The boreal areas (A1 and B22) seemed to be those with less intravariability, especially the small region of Canary Islands and Madeira (Fig. 5a). In the case of Norway, the theoretical subtypological variants were marked by latitude (Fig. 5e). The other three biotypes considered (A2, B1 and B21) showed higher variability. As for Norway, the Iberian Peninsula (A2) was marked by latitude, following the gradient of SST (Fig. 5b). However, in the case

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**Table 1**

Source and data series characteristics for each of the five variables selected (see text for the full name of acronyms).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Source</th>
<th>Data series</th>
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<tr>
<td>SST</td>
<td>AVHRR Pathfinder v.5.0.project</td>
<td>1981–2009 Monthly average 4 km</td>
</tr>
<tr>
<td>PAR</td>
<td>SeaWIFS sensor</td>
<td>1997–2009 Monthly average 9.28 km</td>
</tr>
<tr>
<td>Wave height</td>
<td>TOPEX, TOPEX 2, Jason, Envisat, and GFO missions</td>
<td>1992–2009 Monthly average 1° × 1°</td>
</tr>
<tr>
<td>Tidal range</td>
<td>TOPEX/POSEIDON mission</td>
<td>2007–2008 Minute 7 km</td>
</tr>
<tr>
<td>Salinity</td>
<td>NODC (NOAA data center)</td>
<td>1900–2010</td>
</tr>
</tbody>
</table>

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Random data distribution.
of group B1 (Fig. 5c) a greater variability occurred along the salinity gradient influenced by proximity to the Baltic Sea. Finally, the highest variability was observed in the UK, Ireland and English Channel area (Fig. 5d), in agreement with the complex coastal configuration of those islands (exposure conditions, tidal range, etc).

The comparison between theoretical subtypological variants and national types is shown in Table 2. For all MS the total agreement was higher than 70%. The higher “pondered agreement” occurred in the cases Germany, Sweden and Portugal. In addition, in the case of Portugal each national type corresponded almost perfectly to each potential subtypological variant. The lower agreement was found in UK, where two national types match only with a half of the potential subtypological variants.

4. Discussion

Results presented in this work are taken to demonstrate the global suitability of the methodological approach applied for the objective definition of possible biotypes along the NEA GIG with homogeneous and standardized available data. This approach intends to remove any ambiguity in the use of subjective classification schemes, ensuring that results are reliable and provide a sound foundation for ascertaining statistically different biotypes.

In spite of this global agreement with the main goal of this paper, several questions, both methodological and conceptual, arise for debate. Some of the most likely reservations on technical terms refer to obtaining quality information throughout a large
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biogeographic area (i.e. the NE Atlantic) with the sufficient precision for detecting the most significant regional singularities.

A crucial aspect in the development of a classification system based on physical descriptors is to quantify those variables in a homogeneous way and with an adequate level of accuracy. Nowadays, the advance produced in generating oceanographic and meteorological data from satellite sensors provides a tool of enormous potential for the objectives raised in this study. In this sense, it should be noted that the data series obtained demonstrated that this is a valid method for quantifying the selected variables, reflecting the same patterns as those described by other authors, regarding for instance global tidal range and wave height (Briggs et al., 1997), Atlantic sea temperatures (van den Hoek, 1982a, b), the sea surface temperatures along the Iberian Peninsula (Fraga, 1981) and salinity gradient in the Kattegat and Skagerrak areas (Jakobsen, 1997). In addition, the selected satellite sensors (AVHRR Pathfinder, TOPEX/Poseidon, SeaWIFS, etc.) have been widely used providing validated and reliable data (Yu and Emery, 1996; Smith et al., 1998; Hooker and McClain, 2000; Li et al., 2001).

In the same way, this similarity between the present results and previously described patterns along the same study area confirms that the procedure used to quantify variables 5 km away from coast was appropriated for analyzing the variability of the main coastal physical features at the scale as wide as the NEA GIG. If the location of reference points (where the variables were estimated) had been situated closer to the coastline, it would not have been possible to obtain continuous and homogenized information throughout the NEA coast. Otherwise, the measurement of variables in points situated further than 5 km offshore would have shown oceanographic characteristics instead of coastal ones. Moreover, data information thus obtained could be used for multiple analyses of the area (classification of other systems related to the marine environment as transitional waters, prediction of potential habitats for a wide range of flora and fauna, etc.).

From a conceptual point of view, the identification of significant differences in environmental conditions is a problem of the working scale and the specific objective of the study. The eastern Atlantic coasts of Europe may be considered either as a whole aquatic system or as a complex mosaic of regional seas (e.g. WFD), whose borders are not real but either administratively defined or scientifically justified. For intercalibration purposes, a classification system seems to be required in order to improve the quality of
comparisons between assessment results of the vegetation quality element. So the methodological proposal applied in this study is an iterative approach for rocky macroalgae potential distribution, Estuarine, Coastal and Shelf Science (2012), doi:10.1016/j.ecss.2011.11.041

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Table 2

<table>
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<tr>
<th>MS</th>
<th>National type</th>
<th>Number of stretches</th>
<th>Subtypological variant</th>
<th>Percentage of common stretches</th>
<th>Pondered agreement</th>
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<td>Spain</td>
<td>12</td>
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<td>A2b2</td>
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<tr>
<td>14</td>
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<td>Portugal</td>
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<td>9</td>
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<tr>
<td>A7</td>
<td>3</td>
<td>A2a2</td>
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<td>France</td>
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<td>B1a2b</td>
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<tr>
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a National types considered the closest to the coast and/or these with rocky substrate.

b Including only the exposed coast.

areas, establishing groups inside which vegetation communities can be compared, and intercalibration performed in a safer way. However, it should be considered that as a flexible proposal that must take into account possible regional or local singularities. Specific analyses of possible particular characteristics are always needed (e.g. salinity in Skagerrak and Kattegat areas).

This classification on five biotypes presents a study scale equivalent to other previously developed schemes that include the European coast, as OSPAR regions, the Water Framework Directive ecoregions for transitional and coastal waters, LME ecological regions, the Marine Strategy Framework Directive subregions or the NEA coastal water types for the intercalibration exercise. In fact, there is no objective information (data) that explains or justifies the procedure carried out for the establishment of those classifications, as has been evidenced in the work of the Geographical Intercalibration Groups. For example, in the NEA coastal water types, the division of the type 1/26 in five subtypes (a–e) for phytoplankton quality analyses was explained by the different influence of the upwelling, but without objective data that could put in evidence the divisions made (European Commission, 2009b). Hence, the approach used in this paper offers a considerable advance in this sense.

Anyway, some information should be in the technical base of those classification schemes since there are obvious cases of large areas that coincide with the quantitative results obtained in this study. Such is the case of those classifications that identify the physical singularity of the Norwegian Sea (northern part of Norway = biotype B22). On the other hand, the extension of continental Southern Region of OSPAR and MSFD (“Bay of Biscay and Iberian Coast”) is very similar to that of the A2 biotype, with a limit slightly further south in our case.

Following the debate on the conceptual meaning of the obtained biotypes and their geographical limits, the importance of the biological validation (Fig. 1, steps 3 and 4) must be stressed as a basic support for the final interpretation of specific relationships between the actual distribution of aquatic communities and their physical environment. Furthermore, the implementation of “predictive tools” based on physical descriptors would improve the management capacity of these ecosystems. In this way, the spatial—temporal delimitations of gradient zones (e.g. establishment of the northern limits for the A2 biotype in the Brittany coast) or the justification for a more precise assignment of biotypes of certain coastal areas (e.g. Celtic and North Sea related areas from the UK or the Skagerrak area) should be further considered.

Another aspect that is necessary to rise in relation to the procedure proposed is the necessity or not to divide the physical classification in two steps in order to apply a sort of hierarchical classification (Fig. 1). In this sense, previous trials showed how the use of all variables in a single classification analysis resulted in the aggregation of regions as diverse as Norway and the Iberian Peninsula in the same group. Moreover, hierarchical approaches have been long used to classify coastal areas, supporting the advantage of this type of technical procedures (e.g. Dethier, 1990; Connor et al., 2004; Davies et al., 2004; Madden et al., 2009).

Going into detail, confirming the distribution of biotypes as a gradient and the difficulty of establishing borders in a continuous environment, some coastal zones could be distinguished, where stretches of two different groups appear interspersed (see Fig. 4d). For instance, that was the case of the coastal area between groups A2–B21 (Brittany in France) and B21–B21 (Nord-Pas-de-Calais in France and Belgium). The first gradient zone (A2–B21) could be attributed to the gradual change from a warm temperate region to a cold one (Dinter, 2001). This diffuse border is also marked by macroalgae distributions, with Brittany being the southern distributional limit for many northern species (OSPAR, 2010). On the
other hand, the second gradient area (B21–B1) could be explained by the change in the average salinity registered in the area (Fig. 3e). Therefore, it seems to be appropriated to justify the location of the boundaries between biotypes in a more flexible way.

The five biotypes proposed for the present WFD intercalibration exercise have been slightly homogenized according to MS expert knowledge to obtain continuous coastal sections (Fig. 6). These continuous biotypes have been the ground for the development of the second physical classification. So, the objective of the second phase was not directed to the establishment of new subtypes but to recognize the coastal areas that may reflect the variability of environmental conditions within each biotype (subtypological variants). Such information is very useful for either the development of the WFD intercalibration exercise or the development of a further study on the appropriated adjustment of the current environmental conditions within each biotype (subtypological variants). These changes are very important (as shown in the lower scale study (biotype), being more variable in those areas situated in the temperate region. An important aspect in the recognition of this variability (subtypological variants) is to compare how the general analysis performed in this work fits with the boundaries established by each MS for their coastal zones. Results of this basic analysis showed a generally good agreement between both approaches, regarding the integration of most of national typologies within only one of the subtypological variants established. However, such concordance depended very much on the scale of work at the national level and the specific criteria used for the classification. For instance, the agreement is higher in the coastal zones of Portugal than in UK. It could be due to coastline shape, as stated before. The shape allows the sheltered and exposed coasts to exist, and the approach here used may put in evidence homogeneity from regular coastlines. Countries where sheltered shores are not so frequently intercalated with exposed ones, found in national classifications a higher agreement with this one. Sheltered shores are less influenced by offshore environmental conditions (as used in this study) than more exposed ones. So, countries where the presence of sheltered shores is more frequent, is expected a higher disagreement between results from this work and national classifications. This way, it seems that the physical classification would be able to reflect the general variability of the system at the biotypes scale, although some national classification systems have gone further in this analysis.

In conclusion, the methodological approach proposed in this paper allows, firstly, to establish a classification system of the coast environment (biotypes) that is in agreement with the main goal previously described and, secondly, to recognize the variability associated with each of these biotypes. For this purpose, the quantification of variables by means of satellite sensors presently offers a useful approximation and promises a great future because of its unique viability dealing with global scale studies. Furthermore, according to other authors (Roff and Taylor, 2000) it is possible to assume that the proposed classification would be able to represent the distribution of marine species along the NE Atlantic region. However, after the theoretical verification of the physical classification system, it seems clear that its use as the basis to carry out an ecological typification of the study area requires a validation to establish its real ecological meaning. It is therefore necessary to know the relationship between the actual distributions of the different features of macroalgae communities along this huge region. The comparison of the groups obtained in the physical classification and the information of the populations colonizing coastal areas is very important, given that it would allow, first, to properly interpret and to identify potential habitats and species communities and, second, to establish the different reference conditions. This basic procedure constitutes part of the second phase presented in Fig. 1, including the detection of the representative macroalgal taxa along the study area, the selection of those which may define biogeographic differences and the validation with macroalgae distribution in order to check the ecological suitability. Due to the difficulties for the generation of homogeneous standardized data all along the NE region, this study is currently in progress.

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References


