Elsevier Editorial System(tm) for Journal of Sea Research
Manuscript Draft

Manuscript Number: SEARES-D-14-00022R1

Title: Benthic habitat mapping on the Basque continental shelf (SE Bay of Biscay) and its application to the European Marine Strategy Framework Directive

Article Type: SI: MeshAtlantic

Keywords: Benthic habitat characterization; benthic habitat mapping; EUNIS habitat classification; biological diversity; seafloor integrity; Marine Strategy Framework Directive

Corresponding Author: Dr. Ibon Galparsoro, Dr.

Corresponding Author's Institution: AZTI-Tecnalia

First Author: Ibon Galparsoro, PhD.

Order of Authors: Ibon Galparsoro, PhD.; J. Germán Rodríguez; Iratxe Menchaca; Iñaki Quincoces; Joxe Mikel Garmendia; Angel Borja

HIGHLIGHTS

Benthic habitat map of 2,300 km^2 of the Basque continental shelf was produced.

Benthic habitats were classified according to the European Nature Information System (EUNIS).

Thirteen new EUNIS types are proposed and described.

Seafloor mapping is relevant information within the European Marine Strategy Framework Directive.

Title: Benthic habitat mapping on the Basque continental shelf (SE Bay of Biscay) and its application to the European Marine Strategy Framework Directive

Authors: Ibon Galparsoro[1*], José Germán Rodríguez[1], Iratxe Menchaca[1], Iñaki Quincoces[2], Joxe Mikel Garmendia[1] and Ángel Borja[1]

Affiliations:

[1]AZTI-Tecnalia; Marine Research Division, Herrera kaia, Portualdea z/g, 20110; Pasaia (Spain)

*Corresponding email address: igalparsoro@azti.es

[2]AZTI-Tecnalia; Marine Research Division; Txatxarramendi uhartea z/g; 48395 Sukarrieta (Spain)

ABSTRACT

Benthic habitats on the Basque continental shelf were mapped based on multibeam echosounder surveys, grab sampling, video surveys and oceanographic monitoring. A total area of 2,302 km^2 was classified according to the European Nature Information System (EUNIS) hierarchical classification. Almost 50% of the area corresponded to rock and other hard substrata and the other 50% corresponded to soft bottoms. The biotic composition of several areas was significantly different from the EUNIS habitat classes described previously; therefore, we propose a total of 13 new classes. The habitat mapping has contributed to improving the knowledge and application of several criteria and indicators used to assess environmental status in the European Marine

Strategy Framework Directive in relation to the biological diversity descriptors, such as non-indigenous species and seafloor integrity. It is also useful for other descriptors and for developing the sampling design.

KEYWORDS

Benthic habitat characterization, benthic habitat mapping, EUNIS habitat classification, biological diversity, seafloor integrity, Marine Strategy Framework Directive

HIGHLIGHTS

Benthic habitat map of 2,300 km^2 of the Basque continental shelf was produced.

Benthic habitats were classified according to the European Nature Information System (EUNIS).

Thirteen new EUNIS types are proposed and described.

Seafloor mapping is relevant information within the European Marine Strategy Framework Directive.

1.- INTRODUCTION

Benthic habitats play an important role in some of the key ecosystem processes (i.e., primary production, food webs, recycling, etc.), but they are subjected to many human pressures which put in risk their functionality (Claudet & Fraschetti, 2010). The European Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC) requires European Member States to achieve a Good Environmental Status (GEnS) by 2020 (for more details, see e.g., Borja (2006), Borja *et al.* (2011) and Borja *et al.* (2013)). Achieving a GEnS requires knowing about the marine ecosystems, of which seabed habitats are an integral part (Cogan *et al.*, 2009). Hence, the descriptors considered within the MSFD to assess the environmental status may be directly or indirectly related to habitat distribution, structure and functioning. It is therefore imperative to have good scientific knowledge on seabed habitats in order to carry out the environmental status assessment and be able to propose management plans to ensure the structure and functioning of the seafloor, and thus protect the diversity (see e.g., Borja (2012); Galparsoro *et al.* (2013); Rice *et al.* (2012); and Zampouskas *et al.* (2013). In addition, information on habitat distribution is useful for the identification and protection of ecologically important and representative areas (Baker & Harris, 2012) and can be also used for designing cost-effective monitoring programmes (De Jonge *et al.*, 2006). The characterization of seabed habitats by European Member States has improved greatly over recent years mainly due to the legislative requirements and for conservation purposes (e.g., the European Habitats Directive (92/43/EEC), approved in 1992). Furthermore, important technological developments in methodologies related to acoustic and optical techniques have significantly contributed to this improvement (e.g., Brown *et al.*, (2011)).

The European Union Nature Information System (EUNIS) habitat classification aims to provide a common European reference set of habitat types, within a hierarchical classification to allow the reporting of habitat data in a comparable manner for use in nature conservation (e.g., inventories, monitoring and assessments) (Davies & Moss, 2002). Within EUNIS, habitat classes are ranked into six hierarchical levels for the marine environment. In the first levels (2, 3 and to some extent 4), EUNIS describes the physical (or abiotic) factors of the habitat.

In the Basque coast (SE Bay of Biscay), a first attempt of using EUNIS (Davies *et al.*, 2004) was undertaken within a habitat mapping programme to produce cartographic information for management purposes (Galparsoro *et al.*, 2010)..

That work resulted in a habitat map based on the higher levels of the classification. The classification and mapping of habitats at Level 3 was mainly based on wave energy for hard substrata and sediment types for soft substrata (abiotic habitat map), while classification at Level 4 was based on major epifaunal taxa for rocky habitats and physical and zonal attributes for soft substrata. Due to *in situ* data availability limitations and the difficulties raised when applying the EUNIS habitat classification, it was not possible to reach to lower levels of the classification.

In this context the objectives of this study were: (i) to improve the knowledge regarding to benthic habitats for which there was little information (*i.e.*, rocky habitats and habitats deeper than 100 m); (ii) to improve the EUNIS habitat classification by proposing new habitats of ecological importance to be included if necessary; and (iii) to analyse and evaluate the relevance of benthic habitat maps within the MSFD.

2.- MATERIAL AND METHODS

Study area

The Basque continental shelf is located in the southeastern part of the Bay of Biscay (Figure 1). It is very narrow, ranging from 7 to 20 km, and the total length of the coastline is *c.a.* 150 km (Galparsoro *et al.*, 2010). In relation to its location and orientation, this part of the coast is exposed to large storms from the NW, produced by evolution of the North Atlantic low pressure systems. NW swell waves dominate and are the most common sea state within the study area (Liria *et al.*, 2009; Valencia *et al.*, 2004). Tides are semidiurnal and make a modest contribution to the generation of currents (Fontán *et al.*, 2009). The area shows high geomorphologic diversity from which rocky reefs, sedimentary habitats, and mixed rock and sediment seascapes are dominant. Rocky bottoms are dominant along the shore and they reach the outer part of the continental shelf; meanwhile, sandbanks are distributed from beaches and river mouths down to muddy depths (Galparsoro *et al.*, 2010). Marine habitats along the Basque coast are related to geomorphology and hydrography. The analysis of biological and environmental data shows that wave energy, in the near-bottom, and sedimentary characteristics are the main environmental factors explaining the composition and spatial distribution of sedimentary benthic communities (Galparsoro *et al.*, 2012a).

Bathymetric data

Seafloor mapping was based mainly on two multibeam echosounder (MBES) surveys. The first phase was carried out between 2005 and 2008 down to 100 m water depth, using high-resolution SeaBat 8125 and SeaBat 7125 MBESs (for more details, see Galparsoro *et al.*, (2010)). The second survey was conducted in 2010 and 2011 with an EM3002D MBES to map the seafloor down to 200 m water depth. In both cases MBES records were filtered and a 5 m horizontal resolution Digital Elevation Model (DEM) was produced.

Superficial sediments and oceanographic data

A total of 2,523 grab samples were collected for ground-truthing and sediment characterization (Figure 1). Particle size distribution analyses were undertaken using the dry sieving method and a laser diffraction particle size analyser (for more details, see Rodríguez & Uriarte (2009)).

In terms of wave climatology, the significant wave height, exceeding 12 h per year (Hs12), and period (Tp) were derived from the oceanographic buoy Bilbao-Vizcaya records (period 1996-2006) (Puertos del Estado, 2007). Numerical modelling was used to predict the sediment remobilisation produce by wave action (Harris & Coleman, 1998). The MBES-derived DEM was and wave climatology were used as an input (González *et al.*, 2007; SMC, 2002). The spatial resolution of the resulting grid was 20 m. Wave-induced near-bottom maximum orbital velocities were then derived using linear wave theory and Hs, period (Tp) and mean water depth, for each point of the computational grids (for more details, see Galparsoro *et al.* (2013)).

Biological sampling

The soft-bottom macrobenthos was sampled using Van Veen or Smith-McIntyre grabs at 461 sampling sites (up to *c.a*. 200 m water depth) and sieved using a 1 mm mesh-sized sieve. Besides, the hard-bottom macrobenthos was sampled by divers at 50 locations using 50x50 cm quadrats (up to 25 m depth). The macrobenthos was conserved in 4% buffered formaldehyde and identified to the lowest possible taxonomic level.

Underwater image acquisition

Two techniques were used: (i) a still video camera (Konsberg OE14 model) at 83 locations within a range of 10 to 100 m water depth, in two phases during 2010 and 2011; and (ii) a Remotely Operated Vehicle (ROV) (SeaEye Falcon) at 9 different locations in a depth range from 60 to 260 m water depth recording 1 km length tracks at each site, in 2012 (Figure 1).

Sampling locations were selected according to previous information on seafloor features extracted from MBES records.

Data integration, analysis and mapping

A mixed top-down and bottom-up approach was undertaken (Shumchenia & King, 2010). The bottom-up approach considered the analysis of *in situ* biological samples and environmental data for habitat characterisation. For sedimentary habitats, for which sediment characteristic information and detailed species composition list for each sample was available, sample stations were classified based on BIOENV, SIMPROF and LINKTREE analyses carried out with PRIMER software (Clarke, 1993; Clarke *et al.*, 2008). Hence, most relevant environmental parameters conditioning the species compositions and the determination of the statistically significant threshold values of environmental parameters defining different species compositions were determined. Besides, rocky substratum habitats were classified by taxonomists mainly by interpreting underwater video recordings. Information on physical characteristics and species lists was extracted and linked to the geographic location of the video records.

The top-down approach was then used for map production. Due to the limited number of locations with biological information, maps at physical levels of the marine section of EUNIS; i.e., at Levels 3 or 4, was possible to produce. Thus, the classification was based on the biological zonation (or vertical zonation), the type of seafloor substrate, and the level of exposure to hydrodynamics on rock habitats. High resolution information on bathymetry and topographic features derived from the digital elevation model produced from MBES records was used for the preliminary physiographic and seascapes classification (Roff & Taylor, 2000; Roff *et al.*, 2003). Then, information on the sedimentological and wave energy on the seafloor was included to produce a Level 3 for rock substratum and Level 4 for sedimentary substratum EUNIS habitat map.

Therefore, layers with information on subtratum type distribution, biological zonation, energy levels, were combined within a GIS environment (using ArcGIS 9.3.1), to produce a EUNIS habitat distribution map at physical level (indicating which level for hard and sedimentary habitats). The overall process was carried out in raster mode. The pixel size for the analysis was defined at 5 m, based on the resolution of the previously cited environmental layers (see Vasquez *et al.*, (Accepted) in this Special Issue for an equivalent methodological approach).

3.- RESULTS AND DISCUSSION

Habitat classification

A habitat map covering 2,302 km^2 was produced (Figure 2). According to Level 1 of the EUNIS hierarchical classification, 99.1% of the studied area was classified as “Marine habitats” (A-class) and the remaining 0.9% was classified as “Constructed, industrial and other artificial habitats” (J-class). The J-class area included waste deposits (mainly from dredging activities and old blast furnace slag disposal areas (Borja *et al.*, 2008) and outfall infrastructures (Galparsoro *et al.*, 2010). The J-class area was not possible to classify at higher EUNIS levels because disposal areas of mixed origin are not described for the marine environment (see e.g., Galparsoro *et al.* (2012b)). Since human induced artificial habitats occurs throughout European seabeds, and characterizing and monitoring them is of interest for management purposes (including assessment within the MSFD), further development of this section of the classification is suggested.

Within the A-class, three habitat classes at EUNIS Level 2 where classified: A3 "Infralittoral rock and other hard substrata"; A4 "Circalittoral rock and other hard substrata"; and A5 "Sublittoral sediment", which represented 2.4%, 48% and 49.6% of the studied area, respectively. The relatively small area of infralittoral rock and other hard substrata is due to the steepness of the shallower section of the continental shelf and the limited light penetration in this region (*ca*. 25 m, depth at which most structural algae disappear on the Basque coast (Borja, 1987). This is translated into a highly exposed narrow belt of this habitat along the coastline, which is only interrupted by the main sandbanks at the mouths of estuaries (Galparsoro *et al.*, 2010).

The A3 "Infralittoral rock and other hard substrata" and A4 "Circalittoral rock and other hard substrata" habitats were classified at EUNIS Level 3 according to the wave energy (percentages of each habitat class relative to the total area are given in brackets): A3.1 (high energy; 0.1%); A.3.2 (mid-energy; 1.5%); and A3.3 (low energy; 0.7%); and A4.1 (high energy; <0.1%); A4.2 (mid-energy; 13.9%); and A4.3 (low energy; 33.7%). Higher EUNIS levels were only described when *in situ* biological data from surveys was available (see Supplementary Material 1, for detailed description of habitats). Due to the limited spatial coverage of biological samples, habitats distribution was not mapped. These included the following habitat classes: A3.12 ("Sediment-affected or disturbed kelp and seaweed communities"); A3.13 ("Mediterranean and Pontic communities of infralittoral algae very exposed to wave action"); A3.15 ("Frondose algal communities (other than kelp)"); A3.22 ("Kelp and seaweed communities in tideswept sheltered conditions"); A4.12 ("Sponge communities on deep circalittoral rock"); A4.13 ("Mixed faunal turf communities on circalittoral rock"); A4.121 ("*Phakellia ventilabrum* and axinellid sponges on deep, wave-exposed circalittoral rock"); A4.212 (*Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock"); A4.214 ("Faunal and algal crusts on moderately wave-exposed circalittoral rock"); and A4.22 ("*Sabellaria* reefs on circalittoral rock"). Some of the habitats identified could not be assigned to the EUNIS habitat classes; therefore, proposals for new habitat classes have been made here due to their ecological relevance (see Supplementary Material 1 for detailed descriptions of habitats). Sedimentary habitats (A5-class at EUNIS Level 3) were classified according to their morpho-sedimentary characteristics and water depth. Identified habitats and their corresponding percentage of area were: A5.13 ("Infralittoral coarse sediment"; <0.1%); A5.14 ("Circalittoral coarse sediment"; 2.7%); A5.23 ("Infralittoral fine sand"; 0.2%); A5.25 ("Circalittoral fine sand"; 1.8%); A5.33 ("Infralittoral sandy mud"; 0.9%); and A5.35 ("Circalittoral sandy mud"; 43.5%). In this case also, higher EUNIS Levels were only assigned in those areas where biological information was available. Moreover, sedimentary habitats that were different from the ones included in the EUNIS classification were described (see Supplementary Material 1).

Identification and description of habitats not included in the EUNIS classification

On the Basque coastal platform, the biotic composition of several areas was significantly different from those described in EUNIS. According to the results, a total of 13 potential new classes (or modifications to existing habitat descriptions) were identified.

Four relevant habitat classes were identified for the hard substratum. The following are the proposed names: (i) under the A3.15 class, "*Gelidium corneum* on very exposed infralittoral bedrock and boulders"; (ii) under the A4.12 class, "*Phakellia ventilabrum* and brachiopods on circalittoral rock"; (iii) under the A4.2 class, *"Neopycnodonte cochlear* and other embedded communities on deep circalittoral rock"; and (iv) under the A4.31 class, *"Megerlia truncata* and other communities on circalittoral rock".

Nine new classes were identified for the soft bottom substratum: (i) under the A5.14 class, *"Grania* sp., *Sphaerosyllis bulbosa, Polygordius appendiculatus, Pisione remota* and Nemertina in circalittoral coarse sediment"; (ii) under the A5.25 class, *"Mactra stultorum, Echinocardium cordatum, Magelona johnstoni, Mediomastus fragilis, Owenia fusiformis* and *Spiophanes bombyx* in circalittoral fine sand"; (iii) under the A5.26 class, "*Galathowenia oculata, Chaetozone gibber, Spiophanes bombyx, Pectinaria koreni, Spiophanes kroyeri* and *Prionospio fallax* in circalittoral muddy sand"; (iv) under the A5.35 class, "*Galathowenia oculata, Ampelisca tenuicornis, Terebellides stroemii, Monticellina dorsobranchialis, Thyasira flexuosa* and *Ampharete finmarchica* in circalittoral sandy mud"; (v) under the A5.35 class, "Circalittoral fine sediments with *Epizoanthus incrustatus";* (vi) also under the A5.35 class, "Circalittoral sandy mud with *Callianassa subterranea* and other digger megafauna"; (vii) under the A5.4 class, "Facies with *Leptometra celtica* on sublittoral mixed sediments"; (viii) under the A5.63 class, "*Dendrophyllia cornigera* on deep circalittoral rock"; and (ix) under the A6.53 class, "*Funiculina quadrangularis* and *Ceranthus membranaceus* with other digger megafauna on deep sea mud". A detailed description of the proposed new classes is given as the Supplementary Material 1.

According to our knowledge, most of the habitat classes cited above exist at other locations of the Bay of Biscay, Iberian Atlantic coasts and northern Africa (OSPAR Commission, 2000; Templado *et al.*, 2012). They are considered to be representative and of ecological relevance habitats of the southern Atlantic region and an analysis for their inclusion as new habitats in the EUNIS classification is suggested. Before they are included in EUNIS, scientific consensus should be reached between different research groups and institutions of the region and the European Environment Agency (Galparsoro *et al.*, 2012b).

Benthic habitat mapping within the Marine Strategy Framework Directive

The EU MSFD requires European Member States to manage their seas to achieve or maintain the GEnS by 2020. It contains a number of criteria and associated indicators for assessing GEnS, which are grouped into 11 descriptors (Table 1). For each descriptor, different criteria have been established, which include a set of indicators (Commission Decision 2010/477/EU, see Table in Supplementary Material 2).

Table 1. Qualitative descriptors needed to assess the environmental status, within the Marine Strategy Framework Directive. The references indicate the reports published by each descriptor Task Group (Borja *et al.*, 2011).

Descriptor	Key reference
1. Biological diversity	Cochrane *et al.*, (2010)
2. Non-indigenous species	Olenin *et al.*, (2010)
3. Commercial fish/shell fish	Piet *et al.*, (2010)
4. Elements of marine food webs	Rogers *et al.*, (2010)
5. Human induced eutrophication	Ferreira *et al.*, (2010)
6. Seafloor integrity	Rice *et al.*, (2010)
7. Hydrological alteration	e.g., OSPAR Commission (2012)
8. Contaminants	Law *et al.*, (2010)
9. Contaminants in food	Swartenbroux *et al.*, (2010)
10. Marine litter	Galgani *et al.*, (2010)
11. Energy/noise	Tasker *et al.*, (2010)

The research carried out on the Basque coast has been a big step towards obtaining the knowledge for developing a methodological approach for the implementation of the MSFD (Borja *et al.*, 2011), and more specifically for obtaining the information required for Descriptors 1 and 6 (and indirectly for other biological descriptors, such as 2, 3 and

4). For Descriptor 1 (biological diversity), it is necessary to map different benthic habitat components in criterion 4 (C4) “Habitat distribution” and (C5) “Habitat extent”. Moreover, it is also relevant for C7 “Ecosystem structure” because this criterion includes “composition and relative proportions of ecosystem components, habitats and species”. In relation to this, within this research the area covered by benthic habitats has been detailed and new habitats and species have been described. The high variability of rocky habitats at a small scale is remarkable. As an example, based on previous grab sample data, the area corresponding to the Atlantic and Mediterranean low energy circalittoral rock habitat class (A4.3) located in the western part (670 km^2) was expected to be partly covered by a soft bottom habitat; however, the results of the present research showed that although some small patches of sediment are found within this area, they are very scarce. On the other hand, the diversity of macrobenthic and demersal communities in the studied area is highly linked to the characteristics of the substratum (Borja *et al.*, 2011; Galparsoro *et al.*, 2013). As an example, the variability in demersal communities is highly related to the sediment grain size in the circalittoral sandy mud (A5.35) area located in the western part (890 km^2).

For Descriptor 2 (non-indigenous species) the criteria are related to “abundance and state of non-indigenous species” (C1) and their “impact on native species, habitats and ecosystems […]” (C2). Therefore, habitat mapping is also useful, although it needs to be done at higher EUNIS levels. The data obtained in the study area could be used as baseline data for the indicator of “trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species” (C1). Habitat maps, and background information produced (i.e., bathymetry, seafloor types distribution), together with species distribution modelling techniques have being demonstrated to be useful approaches for this task.

For Descriptor 3 (commercial fish/shell fish), the criteria are "level of pressure of the fishing activity" (C1); "reproductive capacity of the stock" (C2); and "population age and size distribution" (C3). The research carried out in the present study does not contribute directly to these criteria; however, the distribution of commercial fish is determined to a large extent by the substratum characteristics, and habitat mapping data have been used recently for designing the sampling surveys for evaluating this descriptor (Quincoces *et al.*, 2011). Cartographic information produced, facilitated the sampling design in a more efficient way because (i) sampling different habitats and mixing results could be avoided (e.g., trawling only at areas with similar sediment characteristics); (ii) the data collected within each area was supposed to be more representative; and (iii) sampling was safer as trawling in areas with rock outcrops were avoided.

For Descriptor 4 (elements of marine food webs) the criteria are "productivity of key species or trophic groups" (C1); "proportion of selected species at the top of food webs" (C2); and "abundance/distribution of key trophic groups/species" (C3). The research carried out here does not contribute directly to these criteria, but it can be useful indirectly, for sampling design and modelling (Reiss *et al.*, 2014; Rombouts *et al.*, 2013).

For Descriptor 5 (human induced eutrophication) the criteria are "nutrient levels" (C1); "direct effects of nutrient enrichment" (C2); and "indirect effects of nutrient enrichment" (C3). The research carried out here does not contribute directly to these criteria, but the information can be used within the criteria "abundance of opportunistic macroalgae" (related to C2) and "abundance of perennial seaweeds and seagrasses adversely impacted by decrease in water transparency" (related to C3).

For Descriptor 6 (i.e., seafloor integrity) mapping of different benthic habitat components is mainly necessary in C1 “Physical damage, having regard to substrate characteristics” for the two indicators (*i.e.*, “type, abundance, biomass and areal extent of relevant biogenic substrate” and “extent of the seabed significantly affected by human activities for the different substrate types”). As an example, within the studied area it was possible to identify and map the bottom trawling marks, which is considered to be the main pressure on the soft bottoms located at depths greater than 100 m. This information has been used (or is proposed to be used) for the development of different methodological approaches for assessing the seafloor integrity (Galparsoro *et al.*, 2013; Korpinen *et al.*, 2013; Van Hoey *et al.*, 2013), which could contribute to C2 “Condition of benthic community”.

The research carried out here does not contribute directly to the evaluation of the criteria and indicators of the rest of the descriptors; however, it is useful for designing the sampling surveys. For example, for Descriptor 11 (i.e., introduction of energy, including underwater noise), information on bathymetry and seafloor class, as well as biological composition, is valuable for the analysis of noise propagation patterns (i.e., backscatter). Information on seafloor morphological characteristics and changes in them due to human action can be useful for Descriptor 7 (Alteration of hydrographical conditions) because changes in substrate (e.g., due to dredging activities) could imply significant changes in hydrodynamic regimes, wave exposure and erosion regime.

Hence, the research carried out here contributed to the MSFD in 4 out of the 11 descriptors. However, some information gaps should be taken into account: while the soft bottom habitats have been classified to higher EUNIS levels, for the rocky habitats, it was not possible to obtain the same detail when producing the maps (except in those areas covered by direct sampling or video surveys). This is related not only to sampling methodologies (i.e., video surveys for depths greater than 25 m, instead of direct sampling) but also to the differences in the predictability/modelling of the biotic component. Hence, in the studied area, variability in the biotic component of soft bottom habitats can be predicted with acceptable reliability from abiotic characteristics (Galparsoro *et al.*, 2013), but not the biotic component of rocky habitats due to the high variability found on a small scale in this kind of habitat in the studied area. Therefore, the degree of knowledge is noticeable higher for soft bottom areas. Another weakness in relation to the MSFD is related to the evaluation of the environmental status of the hard bottom biota. While for several biological components there are methodologies available for evaluating the environmental status (see e.g., Borja *et al.* (2011) and Diesing *et al.* (2013), this is not the case for rocky habitats within the studied area at sites without direct sampling. Therefore, since rocky habitats make up *c.a.* 50% of the studied area, further research is required.

Moreover, information derived from habitat mapping and monitoring programmes could significantly contribute to the DPSIR (Drivers-Pressures-Status-Impact-Response) framework, among others, providing information regarding to the status of the benthic habitats, but also giving insights to potential impacts produced by human pressures (i.e. abrasion, habitat loss, etc.).

Apart from the value of different aspects of the information on benthic habitats for the implementation of the MSFD, this information has different applications for management purposes. The spatially explicit information on benthic habitats could be baseline data for assessing and mapping marine ecosystem goods and services (Galparsoro *et al.*, 2014; Maes *et al.*, 2013; Salomidi *et al.*, 2012). Moreover, the integration of information on habitat distribution, structure, resilience and connectivity, together with the spatial and temporal distribution of human activities would be interesting information for estimating the cumulative pressures and the impact they exert on the benthic environment (Korpinen *et al.*, 2012), which in turn is very useful for marine management purposes and especially for marine spatial planning (Ehler & Douvere, 2009; Katsanevakis *et al.*, 2011).

4.- CONCLUSIONS

Scientific knowledge regarding to benthic habitat maps on the SE Bay of Biscay has been improved integrating multibeam echosounder information, grab sampling, underwater video surveys and environmental information. Nevertheless, more survey effort is still needed for a good characterisation of deep rocky seabed habitat characterisation. According to the obtained results, EUNIS habitat classification has been demonstrated to be useful for classifying habitats up to Level 3 for sedimentary habitats and Level 4 for rocky because the main environmental characteristics used at these two levels (i.e., the seafloor characteristics, depth, light penetration and wave energy) fit well with the environmental variables that define the habitats and species distributions of the area. Nevertheless, a more detailed analysis highlighted that the biotic compositions of several areas were significantly different from the ones described in EUNIS. A total of 13 potential new classes (or modifications to existing ones) were identified from the results obtained in this research: four of them for sedimentary habitats and nine of them for rocky habitats. These classes are ecologically representative habitats for southern Europe and it is suggested that they are included in EUNIS after a scientific consensus is reached.

Mapping of the different benthic habitat components is considered to be key information for the implementation of the MSFD. According to our analysis, benthic habitat information can be used directly or indirectly for assessing the environmental status for 4 out of the 11 qualitative descriptors and for designing and optimizing survey procedures and monitoring the status. However, further research into hard-bottom habitat components is required in order to develop methodologies for evaluating this habitat's ecological status.

AKNOWLEDGEMENTS

This project was funded by the Basque Water Agency (URA), the Department of Environment, Land Use, Agriculture and Fisheries of the Basque Government, the MeshAtlantic project (Atlantic Area Transnational Cooperation Programme 2007-2013 of the European Regional Development Fund) www.meshatlantic.eu, and, partially, by DEVOTES (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status) funded by the European Union under the 7th Framework Program 'The Ocean of Tomorrow' Theme (grant agreement no. 308392) (www.devotes-project.eu). We would also like to thank the Secretaría General del Mar and Tragsa for providing MBES data from 100 to 200 m water depth, and the Sociedad Cultural Insub for identifying the benthic samples. The Itsasteka survey was funded by the Basque Country Government and European Commission through the European Fisheries Fund. We wish to thank Catherine Stonehouse for revising the English of the manuscript. This paper is contribution number XXX from AZTI-Tecnalia (Marine Research Division).

7.- REFERENCES

Baker, E. K., P. T. Harris, 2012. Habitat Mapping and Marine Management. Pages 23-38 *in* P. T. Harris,E. K. Baker, editors. Seafloor Geomorphology as Benthic Habitat. Elsevier, London.

Borja, A., 1987. Cartografía, evaluación de la biomasa y arribazones del alga *Gelidium sesquipedale* (Clem.) Born. *et* Thur. en la costa guipuzcoana (N España). *Investigación Pesquera*, **51**: 199-224.

Borja, A., 2006. The new European Marine Strategy Directive: Difficulties, opportunities, and challenges. *Marine Pollution Bulletin*, **52**: 239-242.

Borja, A., 2012. Linking EUNIS habitat classification, the Marine Spatial Planning and the Marine Strategy Framework Directive. *Revista de Investigación Marina*, **19**: 26-27.

Borja, A., M. Elliott, J. H. Andersen, A. C. Cardoso, J. Carstensen, J. G. Ferreira, A.-S. Heiskanen, J. C. Marques, J. M. Neto, H. Teixeira, L. Uusitalo, M. C. Uyarra, N. Zampoukas, 2013. Good Environmental Status of marine ecosystems: What is it and how do we know when we have attained it? *Marine Pollution Bulletin*, **76**: 16-27. http://dx.doi.org/10.1016/j.marpolbul.2013.08.042

Borja, Á., I. Galparsoro, X. Irigoien, A. Iriondo, I. Menchaca, I. Muxika, M. Pascual, I. Quincoces, M. Revilla, J. Germán Rodríguez, M. Santurtún, O. Solaun, A. Uriarte, V. Valencia, I. Zorita, 2011. Implementation of the European Marine Strategy Framework Directive: A methodological approach for the assessment of environmental status, from the Basque Country (Bay of Biscay). *Marine Pollution Bulletin*, **62**: 889-904.

Borja, A., I. Tueros, M. J. Belzunce, I. Galparsoro, J. M. Garmendia, M. Revilla, O. Solaun, V. Valencia, 2008. Investigative monitoring within the European Water Framework Directive: a coastal blast furnace slag disposal, as an example. *Journal of Environmental Monitoring*, **10**: 453-462.

Brown, C. J., S. J. Smith, P. Lawton, J. T. Anderson, 2011. Benthic habitat mapping: A review of progress towards improved understanding of the spatial ecology of the seafloor using acoustic techniques. *Estuarine, Coastal and Shelf Science*, **92**: 502-520.

Clarke, K. R., 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, **18**: 117-143.

Clarke, K. R., P. J. Somerfield, R. N. Gorley, 2008. Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. *Journal of Experimental Marine Biology and Ecology*, **366**: 56-69.

Claudet, J., S. Fraschetti, 2010. Human-driven impacts on marine habitats: A regional meta-analysis in the Mediterranean Sea. *Biological Conservation*, **143**: 2195-2206. http://dx.doi.org/10.1016/j.biocon.2010.06.004

Cochrane, S. K. J., D. W. Connor, P. Nilsson, I. Mitchell, J. Reker, J. Franco, V. Valavanis, S. Moncheva, J. Ekebom, K. Nygaard, R. Serrao Santos, I. Naberhaus, T. Packeiser, W. van de Bund, A. C. Cardoso, 2010. Marine Strategy Framework Directive – Task Group 1 Report Biological Diversity. *EUR 24337 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 110 pp.

Cogan, C. B., B. J. Todd, P. Lawton, T. T. Noji, 2009. The role of marine habitat mapping in ecosystem-based management. *ICES Journal of Marine Science*, **66**: 2033-2042. 10.1093/icesjms/fsp214

Davies, C. E., D. Moss, 2002. EUNIS Habitat Classification. Final Report to the European Topic Centre on Nature Protection and Biodiversity. European Environmental Agency. February 2002. 125pp.

Davies, C. E., D. Moss, M. O. Hill, 2004. EUNIS habitat classification Revised 2004. European Topic Centre on Nature Protection and Biodiversity, Paris. 310pp.

De Jonge, V. N., M. Elliott, V. S. Brauer, 2006. Marine monitoring: its shortcomings and mismatch with the EU Water Framework Directive's objectives. *Marine Pollution Bulletin*, **53**: 5-19.

Diesing, M., D. Stephens, J. Aldridge, 2013. A proposed method for assessing the extent of the seabed significantly affected by demersal fishing in the Greater North Sea. *ICES Journal of Marine Science*, **70**: 1085-1096. 10.1093/icesjms/fst066

Ehler, C., F. Douvere, 2009. Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. *Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6. Paris: UNESCO.*: 99pp.

Ferreira, J. G., J. H. Andersen, A. Borja, S. B. Bricker, J. Camp, M. Cardoso da Silva, E. Garcés, A. S. Heiskanen, C. Humborg, L. Ignatiades, C. Lancelot, A. Menesguen, P. Tett, N. Hoepffner, U. Claussen, 2010. Marine Strategy Framework Directive – Task Group 5 Report Eutrophication. *EUR 24338 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 49 pp.

Fontán, A., M. González, N. Wells, M. Collins, J. Mader, L. Ferrer, G. Esnaola, A. Uriarte, 2009. Tidal and wind-induced circulation within the Southeastern limit of the Bay of Biscay: Pasaia Bay, Basque Coast. *Continental Shelf Research*, **29**: 998-1007.

Galgani, F., D. Fleet, J. van Franeker, S. Katsanevakis, T. Maes, J. Mouat, L. Oosterbaan, I. Poitou, G. Hanke, R. Thompson, E. Amato, A. Birkun, C. Janssen, 2010. Marine Strategy Framework Directive – Task Group 10 Report Marine litter. *EUR 24340 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 48 pp.

Galparsoro, I., Á. Borja, J. Germán Rodríguez, I. Muxika, M. Pascual, I. Legorburu, 2012a. 35 - Rocky Reef and Sedimentary Habitats Within the Continental Shelf of the Southeastern Bay of Biscay. Pages 493-507 *in* P. T. H. K. Baker, editor. Seafloor Geomorphology as Benthic Habitat. Elsevier, London.

Galparsoro, I., Á. Borja, V. E. Kostylev, J. G. Rodríguez, M. Pascual, I. Muxika, 2013. A process-driven sedimentary habitat modelling approach, explaining seafloor integrity and biodiversity assessment within the European Marine Strategy Framework Directive. *Estuarine, Coastal and Shelf Science*, **131**: 194-205. 10.1016/j.ecss.2013.07.007

Galparsoro, I., Á. Borja, I. Legorburu, C. Hernández, G. Chust, P. Liria, A. Uriarte, 2010. Morphological characteristics of the Basque continental shelf (Bay of Biscay, northern Spain); their implications for Integrated Coastal Zone Management. *Geomorphology*, **118**: 314-329.

Galparsoro, I., A. Borja, M. C. Uyarra, 2014. Mapping ecosystem services provided by benthic habitats in the European North Atlantic Ocean. *Frontiers in Marine Science*, **1**. 10.3389/fmars.2014.00023

Galparsoro, I., D. W. Connor, A. Borja, A. Aish, P. Amorim, T. Bajjouk, C. Chambers, R. Coggan, G. Dirberg, H. Ellwood, D. Evans, K. L. Goodin, A. Grehan, J. Haldin, K. Howell, C. Jenkins, N. Michez, G. Mo, P. Buhl-Mortensen, B. Pearce, J. Populus, M. Salomidi, F. Sánchez, A. Serrano, E. Shumchenia, F. Tempera, M.

Vasquez, 2012b. Using EUNIS habitat classification for benthic mapping in European seas: Present concerns and future needs. *Marine Pollution Bulletin*, **64**: 2630-2638.

González, M., R. Medina, J. Gonzalez-Ondina, A. Osorio, F. J. Méndez, E. García, 2007. An integrated coastal modeling system for analyzing beach processes and beach restoration projects, SMC. *Computers & Geosciences*, **33**: 916-931. http://dx.doi.org/10.1016/j.cageo.2006.12.005

Harris, P. T., R. Coleman, 1998. Estimating global shelf sediment mobility due to swell waves. *Marine Geology*, **150**: 171-177.

Katsanevakis, S., V. Stelzenmüller, A. South, T. K. Sorensen, P. J. S. Jones, S. Kerr, F. Badalamenti, C. Anagnostou, P. Breen, G. Chust, G. D'Anna, M. Duijn, T. Filatova, F. Fiorentino, H. Hulsman, K. Johnson, A. P. Karageorgis, I. Kröncke, S. Mirto, C. Pipitone, S. Portelli, W. Qiu, H. Reiss, D. Sakellariou, M. Salomidi, L. van Hoof, V. Vassilopoulou, T. Vega Fernández, S. Vöge, A. Weber, A. Zenetos, R. t. Hofstede, 2011. Ecosystem-based marine spatial management: Review of concepts, policies, tools, and critical issues. *Ocean & Coastal Management*, **54**: 807-820.

Korpinen, S., M. Meidinger, M. Laamanen, 2013. Cumulative impacts on seabed habitats: An indicator for assessments of good environmental status. *Marine Pollution Bulletin*, **74**: 311-319. http://dx.doi.org/10.1016/j.marpolbul.2013.06.036

Korpinen, S., L. Meski, J. H. Andersen, M. Laamanen, 2012. Human pressures and their potential impact on the Baltic Sea ecosystem. *Ecological Indicators*, **15**: 105-114. http://dx.doi.org/10.1016/j.ecolind.2011.09.023

Law, R., G. Hanke, M. Angelidis, J. Batty, A. Bignert, J. Dachs, I. Davies, Y. Denga, A. Duffek, B. Herut, K. Hylland, P. Lepom, P. Leonards, J. Mehtonen, H. Piha, P. Roose, J. Tronczynski, V. Velikova, D. Vethaak, 2010. Marine Strategy Framework Directive – Task Group 8 Report Contaminants and pollution effects. *EUR 24335 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 161 pp.

Liria, P., E. Garel, A. Uriarte, 2009. The effects of dredging operations on the hydrodynamics of an ebb tidal delta: Oka Estuary, northern Spain. *Continental Shelf Research*, **29**: 1983-1994.

Maes, J., A. Teller, M. Erhard, C. Liquete, L. Braat, P. Berry, B. Egoh, P. Puydarrieux, C. Fiorina, F. Santos, M. Paracchini, H. Keune, H. Wittmer, J. Hauck, I. Fiala, P. H. Verburg, S. Condé, J. P. Schägner, J. San Miguel, C. Estreguil, O. Ostermann, J. I. Barredo, H. M. Pereira, A. Stott, V. Laporte, A. Meiner, B. Olah, E. Royo Gelabert, R. Spyropoulou, J. E. Petersen, C. Maguire, N. Zal, E. Achilleos, A. Rubin, L. Ledoux, C. Brown, C. Raes, S. Jacobs, M. Vandewalle, D. Connor, G. Bidoglio, 2013. Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg. 60 pp. doi: 10.2779/12398

Olenin, S., F. Alemany, A. C. Cardoso, S. Gollasch, P. Goulletquer, M. Lehtiniemi, T. McCollin, D. Minchin, L. Miossec, A. Occhipinti-Ambrogi, H. Ojaveer, K. Rose Jensen, M. Stankiewicz, I. Wallentinus, B. Aleksandrov, 2010. Marine Strategy Framework Directive – Task Group 2 Report Non-indigenous species. *EUR 24342 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 44 pp.

OSPAR Commission, 2000. Quality Status Report 2000: Region IV - Bay of Biscay and Iberian Coast. OSPAR Commission, London. 134 + xiii pp.

OSPAR Commission, 2012. MSFD Advice document on Good environmental status - Descriptor 7: Hydrographical conditions A living document - Version 17 January 2012., p. 12.

Piet, G. J., A. J. Albella, E. Aro, H. Farrugio, J. Lleonart, C. Lordan, B. Mesnil, G. Petrakis, C. Pusch, G. Radu, H. J. Ratz, 2010. Marine Strategy Framework Directive – Task Group 3 Report Commercially exploited fish and shellfish. *EUR 24316 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 82 pp.

Puertos del Estado, 2007. Clima medio de oleaje. Boya de Vizcaya. Banco de datos oceanográficos de Puertos del Estado (http://calipso.puertos.es/BD/informes/MED_BO_2136.pdf). 34 pp.

Quincoces, I., L. Arregi, M. Basterretxea, I. Galparsoro, J. M. Garmendia, J. Martínez, J. G. Rodríguez, A. Uriarte, 2011. Ecosistema bento-demersal de la plataforma costera vasca, información para su aplicación en la Directiva Marco de la Estrategia Marina Europea. *Revista de Investigación Marina*, **18**: 45-75.

Reiss, H., S. Birchenough, A. Borja, L. Buhl-Mortensen, J. Craeymeersch, J. Dannheim, A. Darr, I. Galparsoro, M. Gogina, H. Neumann, J. Populus, A. M. Rengstorf, M. Valle, G. van Hoey, M. L. Zettler, S. Degraer, 2014. Benthos distribution modelling and its relevance for marine ecosystem management. *ICES Journal of Marine Science*. 10.1093/icesjms/fsu107

Rice, J., C. Arvanitidis, A. Borja, C. Frid, J. Hiddink, J. Krause, P. Lorance, S. A. Ragnarsson, M. Skold, B. Trabucco, 2010. Marine Strategy Framework Directive – Task Group 6 Report Seafloor integrity. *EUR 24334 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 73 pp.

Rice, J., C. Arvanitidis, A. Borja, C. Frid, J. G. Hiddink, J. Krause, P. Lorance, S. Á. Ragnarsson, M. Sköld, B. Trabucco, L. Enserink, A. Norkko, 2012. Indicators for Sea-floor Integrity under the European Marine Strategy Framework Directive. *Ecological Indicators*, **12**: 174-184.

Rodríguez, J. G., A. Uriarte, 2009. Laser Diffraction and Dry-Sieving Grain Size Analyses Undertaken on Fine- and Medium-Grained Sandy Marine Sediments: A Note. *Journal of Coastal Research*, **25**: 257-264.

Roff, J. C., M. E. Taylor, 2000. National frameworks for marine conservation — a hierarchical geophysical approach. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **10**: 209-223. 10.1002/1099-0755(200005/06)10:3<209::aid-aqc408>3.0.co;2-j

Roff, J. C., M. E. Taylor, J. Laughren, 2003. Geophysical approaches to the classification, delineation and monitoring of marine habitats and their communities. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **13**: 77-90. 10.1002/aqc.525

Rogers, S., M. Casini, P. Cury, M. Heath, X. Irigoien, H. Kuosa, M. Scheidat, H. Skov, K. I. Stergiou, V. M. Trenkel, J. Wikner, O. Yunev, 2010. Marine Strategy Framework Directive – Task Group 4 Report Food Webs. *EUR 24343 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 55 pp.

Rombouts, I., G. Beaugrand, X. Fizzala, F. Gaill, S. P. R. Greenstreet, S. Lamare, F. Le Loc'h, A. McQuatters-Gollop, B. Mialet, N. Niquil, J. Percelay, F. Renaud, A. G. Rossberg, J. P. Féral, 2013. Food web indicators under the Marine Strategy

Framework Directive: From complexity to simplicity? *Ecological Indicators,* **29**: 246-254. http://dx.doi.org/10.1016/j.ecolind.2012.12.021

Salomidi, M., S. Katsanevakis, A. Borja, U. Braeckman, D. Damalas, I. Galparsoro, R. Mifsud, S. Mirto, M. Pascual, C. Pipitone, M. Rabaut, V. Todorova, V. Vassilopoulou, T. Vega Fernández, 2012. Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes: a stepping stone towards ecosystem-based marine spatial management. *Mediterranean Marine Science*, **13**: 49-88.

Shumchenia, E. J., J. W. King, 2010. Comparison of methods for integrating biological and physical data for marine habitat mapping and classification. *Continental Shelf Research,* **30**: 1717-1729.

SMC, 2002. Coastal Modelling Aid System (SMC) developed by the Ocean and Coastal Research Group from the University of Cantabria with the support of the Directorate General to the Coast in the Environmental Ministry of Spain.

Swartenbroux, F., B. Albajedo, M. Angelidis, M. Aulne, V. Bartkevics, V. Besada, A. Bignert, A. Bitterhof, A. Hallikainen, R. Hoogenboom, L. Jorhem, M. Jud, R. Law, D. Licht Cederberg, E. McGovern, R. Miniero, R. Schneider, V. Velikova, F. Verstraete, L. Vinas, S. Vlad, 2010. Marine Strategy Framework Directive – Task Group 9 Report Contaminants in fish and other seafood. *EUR 24339 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 36 pp.

Tasker, M. L., M. Amundin, M. Andre, A. Hawkins, W. Lang, T. Merck, A. Scholik-Schlomer, J. Teilmann, F. Thomsen, S. Werner, M. Zakharia, 2010. Marine Strategy Framework Directive – Task Group 11 Report Underwater noise and other forms of energy. *EUR 24341 EN – Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities*: 55 pp.

Templado, J., E. Ballesteros, I. Galparsoro, Á. Borja, A. Serrano, L. Martín, A. Brito, 2012. Inventatrio Español de Hábitats y Especies Marinos. Guía interpretativa: Inventario Español de Hábitats Marinos. Ministerio de Agricultura, Alimentación y Medio Ambiente, Gobierno de España, 229 pp.

Valencia, V., J. Franco, A. Borja, A. Fontán, 2004. Hydrography of the southeastern Bay of Biscay. *Borja, A. and Collins, M. (Eds.) Oceanography and Marine Environment of the Basque Country, Elsevier Oceanography Series,* **70**: 159-194.

Van Hoey, G., D. C. Permuy, S. Vandendriessche, M. Vincx, K. Hostens, 2013. An ecological quality status assessment procedure for soft-sediment benthic habitats: Weighing alternative approaches. *Ecological Indicators,* **25**: 266-278.

Vasquez, M., D. M. Chacón, F. Tempera, E. O'Keeffe, I. Galparsoro, J. L. S. Alonso, J. M. S. Gonçalves, L. Bentes, P. Amorim, V. Henriques, F. McGrath, P. Monteiro, B. Mendes, R. Freitas, R. Martins, J. Populus., Accepted. Mapping at broad scale seabed habitats of the North-East Atlantic using environmental data. *Journal of Sea Research.*

Zampoukas, N., H. Piha, E. Bigagli, N. Hoepffner, G. Hanke, A. C. Cardoso, 2013. Marine monitoring in the European Union: How to fulfill the requirements for the marine strategy framework directive in an efficient and integrated way. *Marine Policy,* **39**: 349-351. http://dx.doi.org/10.1016/j.marpol.2012.12.004

FIGURE CAPTIONS

Figure 1: Study area location and spatial distribution of samples.
Figure 2: Habitat map based on EUNIS classification.

Figure1

Click here to download high resolution image

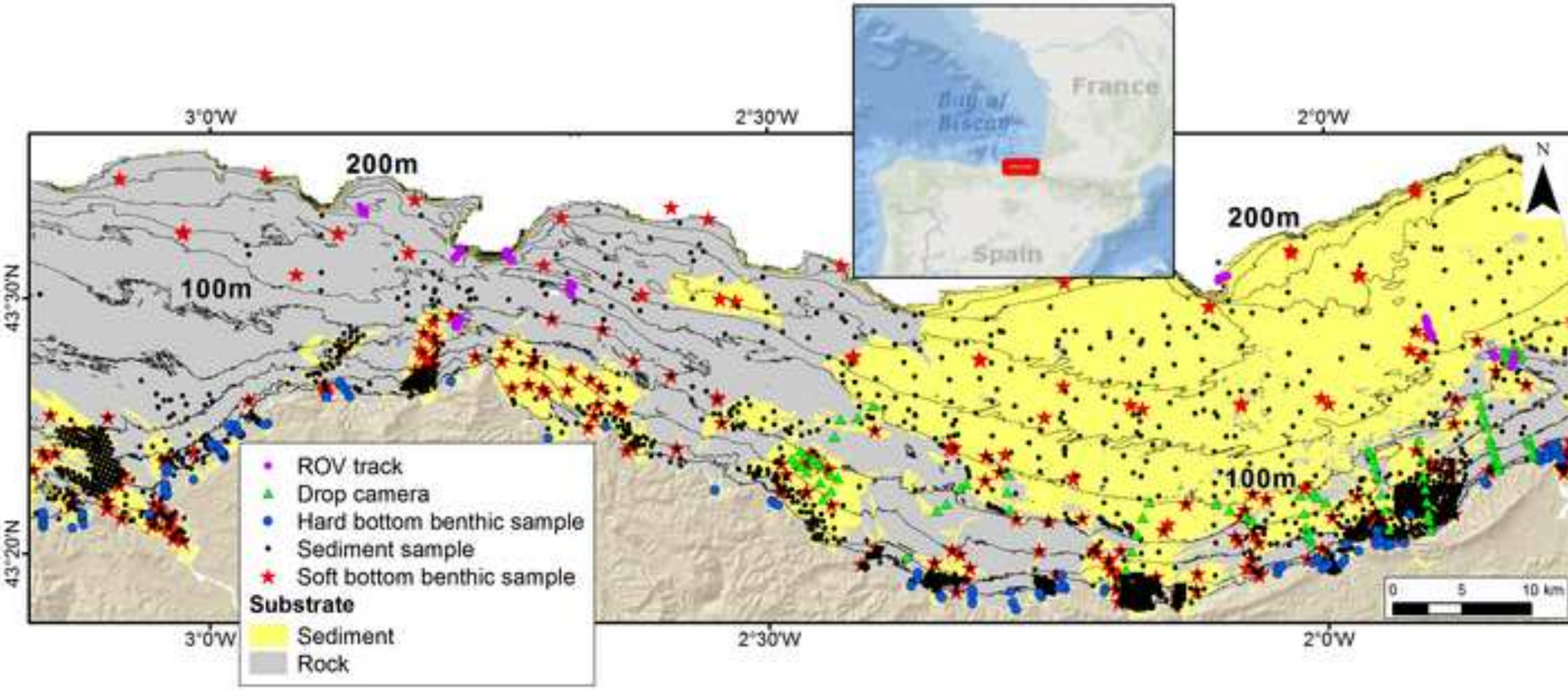

Figure2

Click here to download high resolution image