Memoirs of Museum Victoria 71: 289–301 (2014) Published December 2014

ISSN 1447-2546 (Print) 1447-2554 (On-line)
http://museumvictoria.com.au/about/books-and-journals/journals/memoirs-of-museum-victoria/

Shallow-water polychaete assemblages in the northwestern Mediterranean Sea and its possible use in the evaluation of good environmental state

Rafael Sardá[1,*], Letzy Serrano[1,2], Céline Labrune[3], João Gil[1] (http://zoobank.org/urn:lsid:zoobank.org:author:A4107583-591D-4719-AC59-320AD57D6E9E), David March[1,4], Jean Michel Amouroux[3], Sergi Taboada[5], Paulo Bonifácio[6] and Antoine Grémare[6]

[1] Centre d'Estudis Avançats de Blanes, Consejo Superior de Investigaciones Científicas, Carrer d'accés a la Cala Sant Francesc 14, Blanes 17300, Spain.
[2] Autonomous University of Chiriquí. Department of Zoology. Urb. El Cabrero, David, Chiriquí 0427. Panamá.
[3] Université Pierre et Marie Curie-Paris. CNRS UMR7621. Observatoire Océanologique de Banyuls. Banyuls-sur-Mer 66650, France.
[4] Instituto Mediterráneo de Estudios Avanzados, Consejo Superior de Investigaciones Científicas, Miquel Marqués, 21. Esporles 07190. Spain.
[5] University of Barcelona, Department of Animal Biology, Av. Diagonal 643, Barcelona 08028, Spain.
[6] Université Bordeaux 1. UMR 5805 EPOC – OASU. Station Marine d'Arcachon. 2 Rue du Professeur Jolyet. Arcachon 33120. France.
* To whom correspondence and reprint requests should be addressed. Email: sarda@ceab.csic.es

Abstract

Sardá, R., Serrano, L., Labrune, C., Gil, J., March, D., Amouroux, J.M., Taboada, S., Bonifácio, P. and Grémare, A. 2014. Shallow-water polychaete assemblages in the northwestern Mediterranean Sea and its possible use in the evaluation of good environmental state. *Memoirs of Museum Victoria* 71: 289–301.

Forty-four shore-normal transects along the Northwestern Mediterranean coast between the mouth of the Rhône River (France) and Valencia City (Spain) were sampled during the REDIT-I (September 1998, [R1]) and REDIT-II (December 1999, [R2]) campaigns. Polychaete distribution patterns on shallow littoral fine sands (10 to 50 m water depths) were analyzed at a regional scale. A total of 359 species of polychaetes were identified which represents 38% of all polychaete species recorded in the western Mediterranean. Four main soft-bottom communities were identified from the samples in the area: Littoral Fine Sands, Littoral Sandy Mud, Terrigenous Coastal Mud and Detritic Sand. Predominantly sandy environments were characterized by *Ditrupa arietina* and *Owenia fusiformis* while *Lumbrineris latreilli*, *Hilbigneris gracilis* and *Sternaspis scutata* were numerically dominant in muddy environments. Biological diversity assessments at different temporal and spatial scales are required by the European Marine Strategy Framework Directive (2008/56/EC) in accordance with criteria and methodological standards of Good Environmental Status (GEnS). Selected indicators for descriptors are explored based on this mesoscale assessment.

Keywords Polychaeta. Northwestern Mediterranean, Marine Strategy Framework Directive, GEnS. Infauna.

Introduction

The assessment of biological diversity at different temporal and spatial scales is a prerequisite when criteria and methodological standards on Good Environmental Status of marine waters (GEnS, following Mee et al., 2008) need to be evaluated following the Marine Strategy Framework Directive (MSFD) (2008/56/EC) (European Commission, 2008). For these assessments, ecosystem integrity as well as particular pressures requiring management responses, need to be understood across biogeographic regions (Cochrane et al., 2010). Following the recommendations of the MSFD, a suitable set of European ecological assessment areas should be defined to analyse habitat and community distributions and condition. Initial assessments have been recently carried out by member states. This knowledge is basic for cooperation in planning future coastal and marine conservation and uses, as well as for further implementation of the MSFD. Although indicators of GEnS are required by the Directive at national, ecoregional or sub-regional inside subnational economic exclusive zone scales, its application at other geographical spatial scales should be also possible and even advisable in marine management (Sardá et al., in press).

During 1998–99, cooperation between French and Spanish scientific institutions was initiated to assess the biological diversity from shallow soft-bottom environments in the Gulf of Lions and the northern Mediterranean Spanish coast (10 to 50 m water depths). The main aim of the study was to describe the distributions of benthic species present in the region as well as the range of its existing benthic communities. This region comprises around 2000 km of coastal fringe and can be considered as a suitable area for assessment and implementation of the MSFD because of its size, social and ecological importance and existing scientific knowledge.

The Gulf of Lions was the departure point for the pioneer biological description of soft-bottom communities in the Mediterranean (Pérès and Picard, 1964; Picard, 1965; Guille, 1970, 1971; Massé, 1972; Bellan and Bourcier, 1984). Some decades later, the distribution, composition and ecological quality of the benthic macroinfauna in the Gulf of Lions were reassessed by Grémare et al., (1998a; 1998b), and more recently by Labrune et al., (2006a, 2006b, 2007, 2008). The unification of the terminology for the description of the soft-bottom communities observed in the Gulf of Lions by these authors was one of the main results of the REDIT-I Program. Three main communities corresponding with historical community classification data (Pérès and Picard, 1964; Picard, 1965; Guille, 1970) were detected: Littoral Fine Sands (LFS), Littoral Sandy Mud (LSM), and Terrigenous Coastal Mud (TCM).

Polychaetes are one of the dominant and characteristic groups of soft-bottom communities (Knox, 1977; Coll et al., 2010). It has been shown that, in most cases, polychaetes constitute a good surrogate for describing the functioning of the entire benthic community (Giangrande et al., 2005) and aid assessment of environmental condition. The numerical dominance, multiple life history traits and relatively large knowledge base about polychaetes call for inclusion as GEnS benthic indicators and offer a means to understand the mechanisms governing community dynamics.

In Europe, the recently introduced Marine Strategy Framework Directive (MSFD) seeks to implement the ecosystem approach to marine management to deliver protection of marine ecosystems while at the same time recognising the needs of society to benefit from marine resources allowing its sustainable use. The main objective of MSFD is to achieve GEnS for its marine waters by 2020 and the resources upon which marine-related economic and social activities depend through an integrated ecosystem-based approach. The approach promotes a holistic view on management by ensuring sustainable use of the seas; providing safe, clean, healthy and productive marine waters (Browman et al., 2004; Borja et al., 2011). The MSFD establishes European Marine Regions on the basis of geographical and environmental criteria. Each member state, in cooperation with other member states and non-EU countries within a marine region, are required to develop strategies for their marine waters. The marine strategies to be developed by each member state must contain a detailed assessment of the state of the environment, a definition of GEnS at regional level and the establishment of clear environmental targets and monitoring programs to reach and maintain such GEnS.

In this paper we introduce new data from the North-western Mediterranean coast of Spain to the previous analysed Gulf of Lions region (Labrune *et al*., 2006a, 2006b, 2007, 2008). Using all this data, the aim of the present study is to describe the distributional range of soft-bottom communities and their associated polychaete species while addressing the suitability of using particular indicators derived from this analysis for the MSFD, especially for Biodiversity descriptor of GEnS but also to explore the suitability for further descriptors of the Directive.

Material and methods

Sampling and laboratory procedures

Benthic samples were obtained at 44 transects perpendicular to the shore, extending from the mouth of the Rhône River (France) (43º19'55''N, 4º44'56''E at the 10 m station) south to Valencia city (Spain) (39º28'23''N, 0º18'30''E at the 10 m station) (Figure 1). At each transect three macroinfaunal samples were taken from each of five stations at 10, 20, 30, 40 and 50 m water depths. An additional sample was taken for sedimentological analyses. Samples were collected during the REDIT-I and REDIT-II oceanographic campaigns. The REDIT-I campaign (September 1998) was carried out from the mouth of the Rhône River to the French-Spanish border on board the N.O. Georges Petit. The REDIT-II campaign (December 1999) was carried out from the French-Spanish border to the vicinity of the city of Valencia on board the N.O. Tethys. A total of 220 stations were sampled. Sampling failed at 20 stations (10 m samples at R1O, R1P, R2C, R2D, R2F, R2I, and R2S; 20 m samples at R2I and R2S; 30 m samples at R2I; 40 m samples at R1O, R1P, R1Q, R1R and R1S; and 50 m samples at R1O, R1P, R1Q, R1R and R1S).

Samples were collected using a 0.1 m^2 van Veen grab and sieved on board using a 1 mm mesh. The mesh residue was fixed in 5% formaldehyde buffered in seawater. As described in previous works (Labrune et al., 2006a, 2006b, 2007, 2008), this mesh was selected to enable a comparison with previous works carried out in the region. Grabs with penetration lower than 15 cm were rejected and all samples (with none, few or significant algal or detrital material) were treated in the same way. In the laboratory, samples were sorted under a dissecting microscope and all faunal groups separated. Polychaetes were later identified to the lowest practical taxonomic level and counted. Gil (2011) was used as reference work for identification. Unidentified species were only considered when they were sufficiently complete, mature and distinct from identified species. Data analyses were carried out on data pooled over the three replicated sampling units (Ellingsen, 2001). Individual polychaete species biomass was determined as wet weight

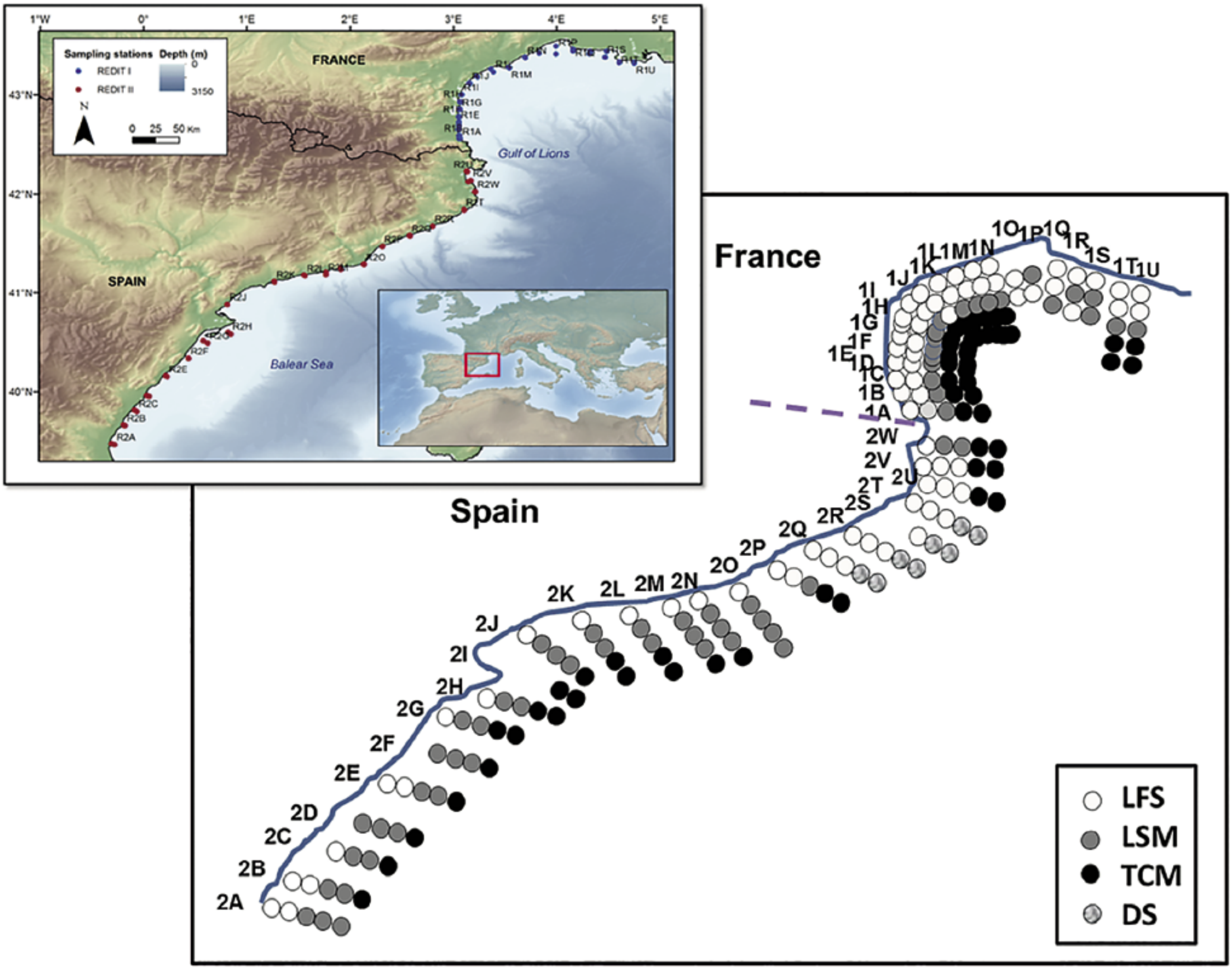

Figure 1. (Upper left graph) Map of the studied zone. Blue circles represent sampled stations from the Gulf of Lions and red circles from the Northern Mediterranean Spanish coast. (Lower graph) Schematic diagram showing the distribution of the four studied communities in the mesoscale studied area

(avoiding presence of water outside the animal when weighting it) to avoid destruction of the collected material except for two nominal species *Ditrupa arietina* (O.F. Müller, 1776) and *Owenia fusiformis* Delle Chiaje, 1844. For these two species we used regressions of width vs. dry weight to convert width measurements to biomass following Sardá et al. (1999).

D. arietina: $DW_{Da} = 0.4522\ (d_{Da})^{3.992}$

O. fusiformis: $DW_{Of} = 0.8434\ (wt_{Of})^{2.177}$

where DW_{Da} and DW_{Of} are dry weights of both species in mg and (d_{Da}) is diameter aperture of the *D. arietina* tube, in mm, and (wt_{Of}) is the maximum width of the tube of *O. fusiformis* in mm. For comparative purposes biomass data given in this paper is expressed in dry weight using the conversion factor of dry weight = 17.6% of wet weight calculated for polychaete species (Rumohr et al., 1987).

Bionomic data are given as means for each measured parameter per station (biological: abundance, biomass, richness, diversity; sedimentological: D50, silt/clay%) for each identified assemblage. Basic sediment texture features that might be correlated with assemblages were derived from granulometric analysis conducted on fresh sediment using a Malvern® Mastersizer 2000 laser microgranulometer.

Data analysis and cartographical work

Analysis of species data for the classification of the polychaete assemblages was performed on reduced sets of species in order to limit noise introduced by less common species and its associated distorting effects in the analytical work. Species present in less than 10% of the obtained samples were excluded; rare species usually have little meaning for the description of benthic communities and their omission does not affect community interpretation.

Table-1. List of the eleven qualitative descriptors of Good Environmental Status (GEnS) according to the Marine Strategy Framework Directive. In parentheses is indicated the task group study for the introduction of indicators

1.	Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions. (Cochrane et al., 2010)
2.	Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems. (Olenin et al., 2010).
3.	Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock. (Piet et al., 2010).
4.	All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity. (Rogers et al., 2010).
5.	Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters. (Ferreira *et al*., 2010).
6.	Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected. (Rice et al., 2010).
7.	Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
8.	Concentrations of contaminants are at levels not giving rise to pollution effects. (Law et al., 2010).
9.	Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards. (Swartenbroux et al., 2010).
10.	Properties and quantities of marine litter do not cause harm to the coastal and marine environment. (Galgani et al., 2010)
11.	Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment. (Tasker et al., 2010).

In this paper we are presenting and using the two obtained sub-regional clusters (France and Spain) following the initial mandate of the MSFD to work on subnational economic exclusive zone regional scales. Multivariate analyses were performed in order to elucidate similarities. Polychaete assemblages were constructed from cluster analysis corresponding to similarities of approximately 25% (Bray Curtis similarity index, average link grouping). Densities were square-root transformed to limit the influence of the most dominant taxa (Clarke and Warwick, 1994). The taxa most responsible for similarities within each cluster of stations or for dissimilarities between clusters of stations were identified using the SIMPER procedure. The Shannon-Wiener information index (H', log *e*) was used as a measure of diversity. All multivariate analyses were carried out using the Primer© 6 software package (version 6.1.13) (Clarke and Gorley, 2006). The Benthic Quality Index (BQI) (Rosenberg et al., 2004) was computed as an estimate of integrity.

Benthic production estimates were based on biomass data. In order to rank the most important polychaete species contributing to the productivity of the region, we estimated secondary production using the allometric equation developed by Brey (1990):

$$P = (B/A)^{0.73} * A$$

where *A* is density, *B* is biomass, *B*/*A* is mean individual biomass and *0.73* is the average exponent of the regression of annual production on body size for macrobenthic invertebrates. This indirect method is based on the use of empirical relationships and yields the secondary production of all species within a community.

The geographical extent of the five identified communities was determined. The study area was defined as the union of a convex hull polygon containing all samples and the relief area of bathymetric data (Catalano-Balearic Sea – Bathymetric chart, 2005, www.icm.csic.es/geo/gma/MCB) from 5 to 55 m contours. The study area was divided into a regular grid of 500 x 500 m. The presence or absence of each community was identified at each station. Inverse distance weighting (IDW, Cressie 1993) was used to interpolate the presence or absence of each community at non-sampled grid cells and estimate community areal coverage. All data were re-projected to the projection system ETRS89 LAEA. Data analysis was conducted using the 'idw' function (ie., setting an inverse distance weighting power = 20) from the 'gstat' package (Pebesma, 2004) and the R software (http://www.r-project.org).

Utility of data as indicators for qualitative descriptors of GEnS

The MSFD (EC, 2008) describes GEnS based on eleven qualitative descriptors and indicators selected from those published by each descriptor task force (Table 1). Recently, both France and Spain presented their initial assessment for the Mediterranean and the Levantine-Balearic regions. Here, we assess the suitability of the use of the REDIT campaigns data in relation with the qualitative descriptor of GEnS to contribute to the improvement of the knowledge of these areas.

Table 2. Mean benthic parameters for the different assemblages identified in the REDIT Campaigns. All values are computed as the mean of each considered parameter (D50, %silt/clay, abundance, biomass, richness, and diversity) per station for all the stations included in the same group except for total richness where the accumulated number of species found in all stations of the group is given. D50 computes the mean grain size for each identified assemblage. (Da)* LFS Spanish assemblage with high numbers of *Ditrupa arietina*.

	Assemblages							
	LFS			LSM		TCM		DS
	France	Spain	Spain (Da)*	France	Spain	France	Spain	Spain
Granulometry								
D50 (um)	145.8	126.1	299.8	86.5	99.6	21.2	25.1	355.0
Silt/Clay content(%)	8.7	5.8	11.7	29.5	56.2	79	77.3	18.9
Biological parameters								
Abundance (ind sq m)	1074	646	1006	473	719	179	468	896
Biomass (mg dw sq m)	1031	385	979	112	1030	184	375	372
Total Richness (#)	105	160	154	85	249	85	138	123
Average Richness (#)	20	26	35	16	32	18	18	36
Diversity (H')	1.58	1.87	2.58	1.95	2.66	2.31	2.27	2.95

Indicator used in the assessment of some of the Good Environmental Status descriptors using data for the REDIT mesoscale assessment (sq m equals to ind m^{-2}).

Results

Assemblage classification and key species

About 35,000 polychaete and sipunculan specimens were identified representing 359 species. More species were found in the Spanish region (325 species) than the French region (175 species), but the area covered by the Spanish campaign was also larger. In the case of polychaetes they constitute 38% of all known Western Mediterranean species (Gil, 2011). In the French region, three main polychaete assemblages were identified based on a 25% similarity level (fig. 2, upper graph). In the Spanish region, based on the same 25% similarity level, two assemblages were identified, both of them with clear sub-clusters (fig. 2, lower graph). The distributions of these assemblages were related to depth and sedimentological parameters. Mean sediment grain size decreased with depth and increasing percentage of silt and clay; only deep stations off rocky shores in the Costa Brava showed a different pattern, forming detritic sand bottoms. Other variables such as abundance, biomass, and diversity are highly correlated to the presence of two, shallow-dwelling species located in sandy environments *Ditrupa arietina* and *Owenia fusiformis*. Sedimentary and biological characteristics of the proposed assemblages are presented in Table 2.

Three main clusters were identified in the French region (fig. 2, upper graph). Cluster I was comprised of 10 and 20 m stations associated with Littoral Fine Sands (LFS sensu Labrune et al., 2007). Cluster II grouped 30 m stations with a higher content of fines (LSM sensu Labrune et al., 2007) and could be separated into two sub-clusters based on geographical considerations (Labrune et al., 2007). Finally, Cluster III gathered 40 and 50 m stations from muddy sediments (TCM sensu Labrune et al., 2007).

In the Spanish region two main clusters were delineated; Cluster I consisted of stations associated with Littoral Fine Sands (LFS), but could be further divided into two sub-clusters (Ia and Ib) due to the presence or absence of the polychaete *D. arietina* respectively. In the sub-cluster Ib, a separate set of stations of the LSM community can be seen with the common presence of *D. arietina* in the samples. Cluster II included the rest of the stations with two sub-clusters: sub-cluster IIa incorporated most of the 50 m deep stations on muddy sediments (TCM), and sub-cluster IIb was composed of a more heterogeneous set of samples, both in depth (with a lower percentage of fines) and in species composition, and were more similar to the LFS assemblage. One particular group of stations within sub-cluster IIb (with asterisk in fig. 2, lower graph) was also differentiated by deeper stations, but with sedimentological composition of medium sands and a smaller (18.9%) percentage of fines. These stations could not be incorporated into any of the previously named assemblages and were assigned to a Detritic Sand (DS) community.

The most abundant species for each of the assemblages are shown in Table 3. The density of the first six species accounted for 66% of the total average density in the Littoral Fine Sands (LFS) assemblages, 53.9% in the Littoral Sandy Mud (LSM) assemblages, 54.7% in the Terrigenous Coastal Mud (TCM) assemblages, and 53.7% in the Detritic Sand environment (DS) off Costa Brava.

LFS assemblages were characterized by high densities (79% in the case of the French region) of two species, *D. arietina* and *O. fusiformis*. The presence of *D. arietina* is the determining factor that separated different assemblages in this community (Table 3). Both species were more abundant in the Gulf of Lions than in the northern Mediterranean Spanish coast resulting in a more homogeneous composition in this area.

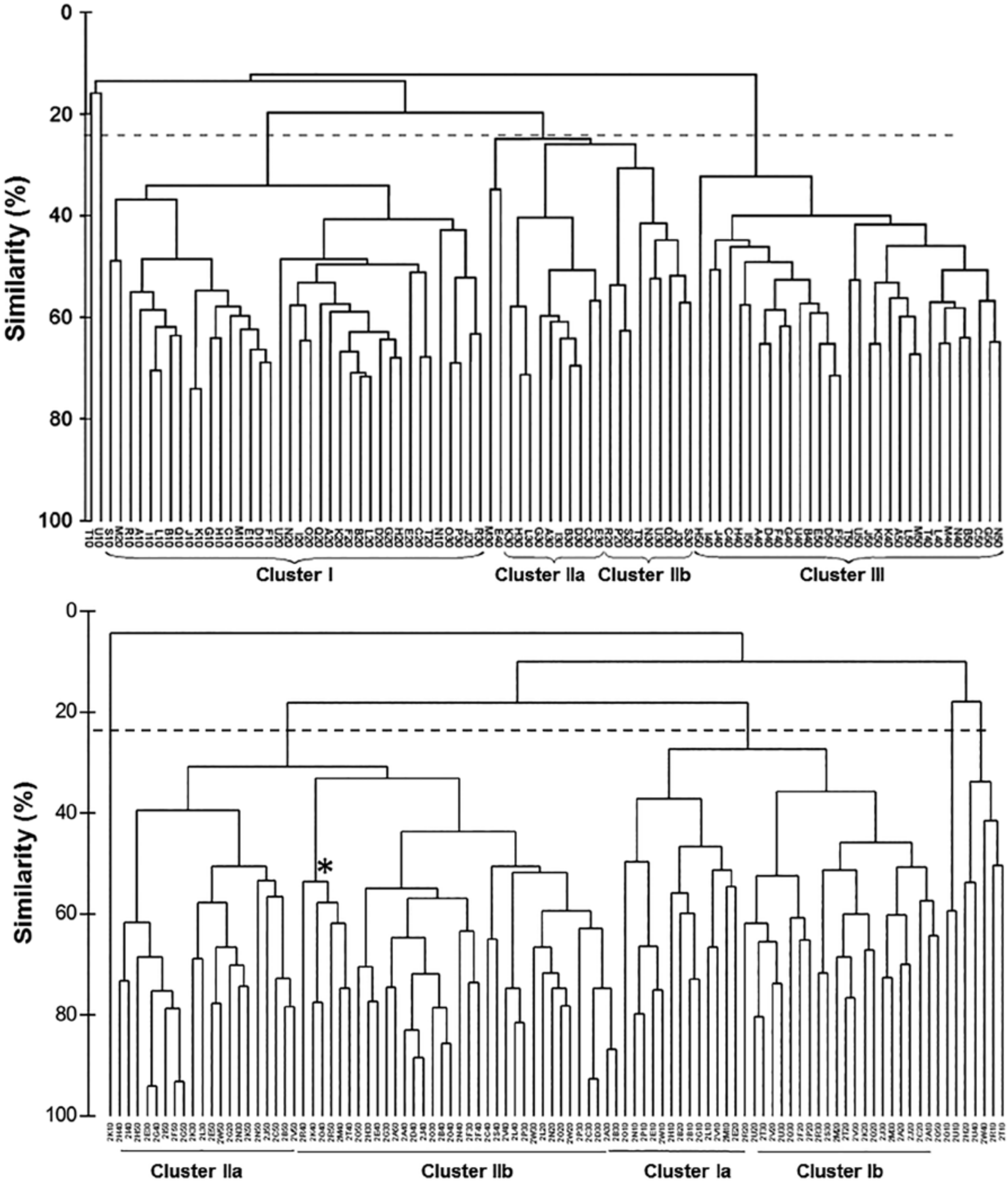

Figure 2. Cluster analysis of polychaete fauna for the Gulf of Lions region (France; upper graph) and the Northern Mediterranean Spanish coast (Spain; lower graph). Asterisk observed in lower graph indicates stations associated with the Detritic Sand Community (DS)

Table 3. Six most dominant species of each assemblage identified during the present study and its average density (ind m^{-2}).

LITTORAL FINE SAND Community (LFS)							
FRANCE				**SPAIN**			
LFS with *Ditrupa*				LFS with *Ditrupa*		LFS without *Ditrupa*	
Ditrupa arietina	616			*Ditrupa arietina*	302	*Owenia fusiformis*	129
Owenia fusiformis	233			*Eunereis longissima*	27	*Spiochaetopterus costarum*	50
Aponuphis bilineata	42			*Aponuphis bilineata*	25	*Chone duneri*	35
Chone duneri	30			*Mediomastus fragilis*	21	*Notomastus latericeus*	30
Scoletoma impatiens	24			*Galathowenia oculata*	21	*Pseudopolydora paucibranchiata*	25
Lumbrineris latreilli	21			*Protodorvillea kefersteini*	21	*Galathowenia oculata*	23
LITTORAL SANDY MUD Community (LSM)							
FRANCE				**SPAIN**			
LSM west Cap ‘Agde		LSM east Cap ‘Agde		LSM			
Lumbrineris latreilli	171	*Lumbrineris latreilli*	91	*Monticellina heterochaeta*	82		
Ditrupa arietina	100	*Nephtys hombergii*	18	*Hilbigneris gracilis*	70		
Goniada emerita	36	*Mediomastus fragilis*	15	*Sternaspis scutata*	30		
Scoletoma impatiens	34	*Glycera unicornis*	14	*Aponuphis bilineata*	27		
Hilbigneris gracilis	30	*Notomastus latericeus*	11	*Notomastus latericeus*	24		
Laonice bahusiensis	21	*Scoletoma impatiens*	7	*Lumbrineris latreilli*	24		
TERRIGENOUS COASTAL MUD Community (TCM) and DETRITIC SAND Community (DS)							
FRANCE				**SPAIN**			
TCM				TCM		DS	
Lumbrineris latreilli	41			*Hilbigneris gracilis*	87	*Aspidosiphon muelleri*	220
Sternaspis scutata	25			*Monticellina heterochaeta*	72	*Sphaerosyllis taylori*	83
Heteromastus filiformis	12			*Prionospio fallax*	34	*Pisione remota*	73
Nephtys incisa	11			*Sternaspis scutata*	29	*Kefersteinia cirrata*	58
Abyssoninoe hibernica	7			*Cirrophorus branchiatus*	18	*Ditrupa arietina*	43
Glycera unicornis	6			*Galathowenia oculata*	16	*Heteromastus filiformis*	34

LSM assemblages were the most diverse group. In the French region, sub group Ia was identified north of Cap ‘Agde (see Labrune et al., 2007 for geographical reference) with Ib south. In both cases *Lumbrineris latreilli* (Audouin & Milne-Edwards, 1833) was the most abundant species, but the absences (north) or presence (south) of *D. arietina* was the main reason for this separation (Table-3). In the Spanish region, *D. arietina* was rare, but *Hilbigneris gracilis* (Ehlers, 1868) and *Monticellina heterochaeta* Laubier, 1961 were numerically dominant.

TCM assemblages in the French region were clearly differentiated from the other two communities both in sedimentological and composition parameters. This community was typically bounded by the 30 and 40 m isobaths. *Lumbrineris* *latreilli* and *Sternaspis scutata* (Ranzani, 1817) were the numerically dominant species. In the Spanish region, these assemblages seem closer to the LSM ones and were characteristic of 50 m and deeper stations. *Hilbigneris gracilis* and *M. heterochaeta* were abundant and common species, but other species such as *Prionospio fallax* Söderström, 1920 and *S. scutata* also reached high densities (Table 3). Off the Costa Brava, the DS assemblage was likely a result of strong currents affecting this area through mechanisms also responsible for the different sedimentary characteristics (Duran et al., 2014). These sediments were characterized by the medium-sized sipunculans (20 mm long average adult size) *Aspidosiphon muelleri* Diesing, 1851 which inhabits empty shells of prosobranchs and *D. arietina*, as well as other small taxa like *Sphaerosyllis taylori* Perkins, 1981 and *Pisione remota* (Southern, 1914) which, due to their average size, surely would have been much more abundant if a smaller mesh size was used.

Potential Good Environmental Status (GEnS)

Five of the eleven descriptors associated with the evaluation of GEnS can directly use data obtained in the REDIT assessment: biodiversity, non-indigenous species, food webs, eutrophication, and seafloor integrity. Our assessment follows these five descriptors. These data also provide regional-scale context within which future studies can evaluate these five descriptors as well as others occurring at different scales (e.g. ecological mechanisms affecting harvests, trophic targets for contamination detection).

Biodiversity - This descriptor has the highest number of potential indicators. The descriptor can be simultaneously assessed at four levels of biophysical organization: ecosystem, landscape, habitat/community, and species states. For the latter two we can directly get indicators for this region from the present study. At the habitat/community level dominant, special, and protected habitats can be identified. One of the dominant habitats in the EUNIS classification (http://eunis.eea.europa.eu/habitats-code-browser.jsp?expand=A#level_A) is Shallow Sublittoral Sediments; the four communities identified in the present work (with their assemblages), LFS, LSM, TCM and DS, represent shallow sublittoral sediments. The areal and geographic extents of these communities are shown in Table 4. At the species level, based on its dominance, five species can be considered characteristic of these communities: *D. arietina* and *O. fusiformis* in shallow sandy environments, and *L. latreilli*, *H. gracilis* and *S. scutata* in muddy environments.

Non-indigenous species - Non-indigenous species, including invasive alien species, have the potential to alter ecosystems (Zenetos et al., 2010) and consequently affect GEnS. The number of such species as well as their range, abundance and impacts on autochthonous communities need to be assessed in the evaluation of this descriptor. Seven polychaete species have been identified as non-indigenous species for the Levantine-Balearic sub-region (Alemany, IEO personal communication). No data are available for the French region. None of the species found in the REDIT campaigns are on this list. The number of new entrants per time unit (i.e. year) is proposed as a numerical indicator for this descriptor. In our case, this number would therefore be 0.

Marine food webs - This descriptor addresses functional aspects of marine food webs, especially the rates of energy transfer within the system, levels of productivity among key components and ecosystem structure in terms of size and abundance of individuals. Although the descriptor is intended to be used for the entire marine food web and addressed from analysis of several trophic levels, estimates of productivity and size at individual levels are needed and may also serve as local proxies. These two indicators are showed in Table 4 for the key characteristic species. The main trophic composition of the three basic communities analyzed can be related to the dominance of the filter feeder *D. arietina* in the LFS community, a much more diverse trophic environment where filter feeders, carnivores and deposit-feeding species are more or less equally distributed in the LSM community, and the biomass dominance of the deposit feeder *S. scutata* in the TCM community.

Eutrophication - Measures of sensitivity to eutrophication can be observed in different ecosystem compartments (e.g. nutrients, chlorophyll, physico-chemical states). Among benthic habitats the relationship between organic enrichment and benthic productivity has been well documented and populations of pioneering species are often used as positive or negative indicators of excessive organic enrichment. The abundance and productivity of *Capitella capitata* (Fabricius, 1780) and closely-related taxa have been used as clear indicators of organic enrichment and eutrophication in the marine environment for many years (see Serrano et al., 2011 for an example of this impact in the studied area). Although *C. capitata* was found in our samples, its average density did not suggest any 'hotspots' of potential enrichment, though sampling density did not provide the spatial resolution required to state that eutrophication on the scale of less than tens of kilometers did not exist in the study area. A second species, normally cited as indicator of organic enrichment and known from the region, *Malacoceros fuliginosus* (Claparède, 1869), did not appear in our samples. It is likely that other species encountered in the present work can be included in the list of indicators, but given the limits of current knowledge, denser sampling along known organic gradients within each biogeographic region is required to identify likely candidates.

Sea floor integrity- The basic indicator of this descriptor gives information on the total area of seabed significantly affected by human activities. Changes in functional diversity and relative abundance of life traits associated with opportunistic and sensitive species can provide estimates of integrity by using different metrics compiled over space and time. The BQI index was used to assess the benthic ecological status of the environment. Table 4 shows the value of this index for the assemblages located in the French part of the study.

Discussion

Among the benthic environments analyzed from the mouth of the Rhône River (France) to Valencia City (Spain), four different polychaete communities with different species and sedimentary characteristics were distinguished, namely the Littoral Fine Sand (LFS), the Littoral Sandy Mud (LSM), the Terrigenous Coastal Mud (TCM), and the Detritic Sand (DS)

Table 4. Indicators used in the assessment of some of the Good Environmental Status descriptors using data for the REDIT mesoscale assessment.

Descriptor 1	**LFS**	**LSM**	**TCM**	**DS**
Habitat extension (ha*103)	200.95	271.30	228.70	14.25

Gulf of Lions (France)

Descriptor 1	**LFS**	**LSM**	**TCM**	**DS**
Species State				
Ditrupa arietina				
Abundance (ind sq m)	616	60	4	
Biomass (mg dw sq m)	962.6	4.6	5.1	
Owenia fusiformis				
Abundance (ind sq m)	233	1	0	
Biomass (mg dw sq m)	106.9	0.1	0	
Lumbrineris latreilli				
Abundance (ind sq m)	21	138	41	
Biomass (mg dw sq m)	18.9	141.0	44.3	
Hilbigineris gracilis				
Abundance (ind sq m)	0	18	4	
Biomass (mg dw sq m)	0	8.5	0	
Sternaspis scutata				
Abundance (ind sq m)	0	2	25	
Biomass (mg dw sq m)	0	23.3	271.9	
Descriptor 2	LFS	LSM	TCM	DS
Non-indigenous species (Nie)				
Number of Nie (#)	0	0	0	
New entrans Nie y-1	0	0	0	
Descriptor 4	LFS	LSM	TCM	DS
Species State				
Ditrupa arietina				
Productivity (mg dw sq m)	853.3	9.2	4.7	
Average biom. (mg dw sq m)	1.56	0.08	1.28	
Owenia fusiformis				
Productivity (mg dw sq m)	131.9	0.2		
Average biom. (mg dw sq m)	0,46	0.10		
Lumbrineris latreilli				
Productivity (mg dw sq m)	19.4	140.2	43.4	
Average biom. (mg dw sq m)	0.90	1.02	1.08	
Hilbigneris gracilis				
Productivity (mg dw sq m)		10.4	0.7	
Average biom. (mg dw sq m)		0.47	0.10	
Sternaspis scutata				
Productivity (mg dw sq m)		12.0	142.7	
Average biom. (mg dw sq m)		11.65	10.88	
Descriptor 5	LFS	LSM	TCM	DS
Species State				
Capitella spp.				
Abundance (ind sq m)	0	0	0	
Descriptor 6	LFS	LSM	TCM	
BQI index	11.70	17.07	19.84	

Northern Mediterranean Spanish coast (Spain)

Descriptor 1	**LFS**	**LSM**	**TCM**	**DS**
Species State				
Ditrupa arietina				
Abundance (ind sq m)	151	15	1	43
Biomass (mg dw sq m)	351.7	44.4	1.4	113.0
Owenia fusiformis				
Abundance (ind sq m)	69	2	1	8
Biomass (mg dw sq m)	125.5	1.2	0.5	2.2
Lumbrineris latreilli				
Abundance (ind sq m)	12	24	10	9
Biomass (mg dw sq m)	5.3	15.0	4.2	9.0
Hilbigineris gracilis				
Abundance (ind sq m)	2	70	87	16
Biomass (mg dw sq m)	0.7	26.1	27.3	0.6
Sternaspis scutata				
Abundance (ind sq m)	0	30	29	0
Biomass (mg dw sq m)	0	59.8	241.5	0
Descriptor 2	LFS	LSM	TCM	DS
Non-indigenous species (Nie)				
Number of Nie (#)	0	0	0	0
New entrans Nie y-1	0	0	0	0
Descriptor 4	LFS	LSM	TCM	DS
Species State				
Ditrupa arietina				
Productivity (mg dw sq m)	279.9	33.1	1.3	87.1
Average biom. (mg dw sq m)	2.33	2.96	1.4	2.63
Owenia fusiformis				
Productivity (mg dw sq m)	106.8	1.4	0.6	3.1
Average biom. (mg dw sq m)	1.82	0.60	0.50	0.28
Lumbrineris latreilli				
Productivity (mg dw sq m)	6.6	17.0	5.3	9.0
Average biom. (mg dw sq m)	0.44	0.63	0.42	1.00
Hilbigneris gracilis				
Productivity (mg dw sq m)	0.9	34.1	37.3	1.5
Average biom. (mg dw sq m)	0.35	0.37	0.31	0.04
Sternaspis scutata				
Productivity (mg dw sq m)		49.6	136.2	
Average biom. (mg dw sq m)		1.99	8.33	
Descriptor 5	LFS	LSM	TCM	DS
Species State				
Capitella spp.				
Abundance (ind sq m)	2	3	0	0
Descriptor 6	LFS	LSM	TCM	
BQI index				

Indicator used in the assessment of some of the Good Environmental Status descriptors using data for the REDIT mesoscale assessment (sq m equals to ind m^{-2}).

communities, following Labrune et al. (2007) classification. Shallow sandy environments of the Northwestern Mediterranean are mostly occupied by the LFS community. Near rocky shores such as the Cap de Creus (Sardá et al., 2012) or highly dynamic deltas such as the Tordera River (Sardá et al., 1999), the LFS community can be replaced by the Littoral Coarse Sand community (LCS). Between shallow sandy and deeper muddy environments, we can find the LSM community, in the past defined as a transition facies (Guille, 1971; Desbruyères et al, 1972–73). This community, normally characterized by sand grains with fine content not higher than 50%, forms a narrow fringe in the Gulf of Lions but is broader and occupies larger areas in the Northern Mediterranean Spanish coast. Where benthic environments are clearly muddy with a high percentage of silt and clay, the species composition is dominated by TCM community. However, as shown in locations off the Costa Brava rocky shores, sometimes oceanographic conditions make sediments change basic profiles and assemblage differences decoupled from bathymetric contours.

Sandy environments at these shallower habitats were easily distinguished by the disproportionate presence of *D. arietina* and *O. fusiformis*. The presence of *D. arietina* was higher in the French region (more than half of the density of the assemblage), and the northern part of the Catalan coast of Spain (one third). Southwards on the Spanish Mediterranean coast the presence of *D. arietina* decreased. Pérès and Picard (1957) pointed out that *D. arietina* was associated with unstable soft sediments and Desbruyères et al., (1972-73) considered this species within the *Nephtys hombergii* Savigny in Lamarck, 1818 community, in which records of *D. arietina* were not so frequent and densities small. Grémare et al., (1998a, 1998b) and Labrune et al. (2007) detected a drastic increase of *D. arietina* populations over recent decades, attributing these high densities to an unidentified response to environmental factors. Sardá et al, (2000) also reported sharp increases of *D. arietina* and *O. fusiformis* after dredging activities on the Catalonian coast. Today, the dominance of the passive filter-feeder *D. arietina* in shallow sandy environments (from 10 to 30 m) in the Gulf of Lions is one of the most obvious components of these benthic habitats. Whether this dominance is related to sediment disturbance, to changes in the sediment release from rivers, to a cascade effect due to other species reductions, or to other unidentified cause or causes, it is worth considering its study and should represent an important aspect of MSFD work. *Ditrupa arietina* was also present in important numbers in the LSM community of the French region.

Owenia fusiformis, *L. latreilli* and *N. hombergii* also deserve comment in these sandy environments. *Owenia fusiformis* populations seem to be more consistent and frequently encountered in this region. Guille (1970) and Desbruyères et al., (1972–73) recorded this species widely in the Northwestern Mediterranean (from well-sorted fine sand in 5 m deep waters to detritic sediments 163 m deep). *Owenia fusiformis* was the second most abundant species on the whole coast in these sediments. Its range covered the entire study area. While *O. fusiformis* was generally restricted to 10 and 20 m stations, *L. latreilli* was the most abundant species at the LSM community in the French region coexisting with populations of another important species *H. gracilis*, in the Spanish region. Desbruyères et al. (1972–73) reported *L. latreilli* as the second most abundant species after *N. hombergii*, however, the presence of the latter species is restricted today and its presence seems to be lower than in past decades. In specific places (e.g. off Barcelona) large alterations to the pattern described in this work have been described and may be a response to organic enrichment (Ros and Cardell, 1992; Cardell et al., 1999; Serrano et al., 2011).

Muddy environments were common at the deepest stations. Nearly all 40 and 50 m stations of the Gulf of Lions and 50 m stations of the Spanish coast were described as mud and grouped in the analysis. In this case, *L. latreilli* in the French region and *H. gracilis* in the Spanish region as well as *S. scutata* can be identified as the most characteristic species following previously identified distributions (Desbruyères et al., 72-73; Galil and Lewinsohn, 1981; Gambi and Giangrande, 1986; Salen-Picard et al., 2003). The exceptions were habitats located off the Costa Brava region where, probably due to stronger currents, mud disappeared and detritic sand environments prevailed.

The MSFD is to be implemented at sub-national economic exclusive zone regional scales. In these regions the essential characteristics and present environmental status of these waters, together with corresponding pressures and impacts, need to be assessed and strategies developed to define GEnS at a regional level. These assessments may also be used at other geographical scales (e.g. administratively defined regions, marine protected zones, tourist destination areas, offshore metropolitan regions). In all these cases, the concept of GEnS in social and ecological assessments can be also applied. Borja et al. (2011) performed an assessment of the environmental status of the Spanish Basque Country following MSFD requirements, and have proposed a method of recombining the eleven descriptors within the MSFD to be applied at a different scale. At whatever assessment scale one works on these issues, the identification, mapping, and consistent evaluation of physical and biological characteristics of benthic habitat types is essential.

The use of the MSFD principles at other scales than the one mentioned in the Directive could be advisable. In any case, the description of GEnS and the interpretation of "good" are key to implementation and relates to human values and worldviews (Mee et al., 2008). Our REDIT work does not pretend to be considered as a kind of standard/reference position for the region in order to set objectives for GEnS, but a "status quo" of its present situation concerning shallow soft-bottom benthic habitats. The definition of "good" for the different descriptors should be determined by those officers managing the region under which the principles of the MSFD would be applied. If GEnS need to be achieved at whatever regional scale an operational definition of GEnS with agreed targets and approaches for integrating assessment results should be approved (Borja et al., 2013).

The mesoscale assessment carried out in the REDIT campaigns contributed to the determination of the distributional range and extension of the three most widespread communities in the Mediterranean exclusive economic zones of the Gulf of Lions and Northern Mediterranean coast of Spain. Abundance and biomass data for dominant benthic macroinfaunal species are relevant indicators for application of the MSFD descriptor 1, biodiversity and by evaluating productivity and average size, biomass, descriptor 4. The absence of non-indigenous polychaete species within an extensive sampling effort has important implications for descriptor 2, invasive species. Although the Mediterranean is, globally speaking, an oligotrophic sea, metropolitan areas and human activities can result in localised eutrophication. This was the case off Barcelona where several studies (Ros and Cardell, 1992; Cardell et al., 1999; Serrano et al., 2011) illustrated an instance of enrichment and eutrophication; however, eutrophication is not a regional problem based on the assessment carried out. Finally, applying metrics such as the BQI in the assessment of seafloor integrity resulted in a "moderate" (LFS, LSM) or "good" (TCM) state for this benthic environment in the French case; however, this trend was mostly due to a single species (*D. arietina*), the community dynamics of which requires investigation to determine its mechanisms of proliferation.

The distributional range and key characteristics of the soft-bottom communities in the Gulf of Lions and the Northern Mediterranean Spanish coast allowed us to consider its potential use in the assessment of GEnS for the region. Besides individual data for key characteristic species in the ecosystem, the use of several benthic metrics could be useful to evaluate GEnS in the region.

Acknowledgements

This study was carried out within the framework of the SYSCOLAG Project (Contrat État-Région 2000-2006). This work was partly carried out within the EU Network of Excellence ''Marine Biodiversity and Ecosystem Functioning'' (MARBEF) and the MEVAPLAYA-II Project. We would like to express our gratitude to Brian Paavo and another reviewer for their dedication and comments on this paper. Thanks are given also to the ''Conseil Regional Languedoc-Roussillon'' and the IFARHU-SENACYT for supporting grants to some of the authors.

References

Bellan, G. and Bourcier, M. 1984. Bilan écologique du détournement permanent d'un petit fleuve côtier dans l'émissaire d'eaux usées d'une grande ville. *Marine Environmental Research* 12: 83-111.

Borja, A., Galparsoro, I., Irigoien, X., Iriondo, S., Menchaca, I., Muxika, I., Pascual, M., Quincoces, I., Revilla, M., Rodriguez, G., Santurtún, M., Solaun, O., Uriarte, A., valencia, V. and Zorita, I. 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., Elliott, M., Andersen, J.H., Cardoso, A.C., Carstensen, J., Ferreira, J.C., Heiskanen, A.-S., Marques, J.C., Neto, J.M., Teixeira, H., Uusitalo, L., Uyarra, M.C. and Zampoukas, N. 2013. Good Environmental Status of marine ecosystems: what is it and how do we know when we have attained it?. *Marine Pollution Builletin* 76: 16-27.

Brey, T. 1990. Estimating productivity of macrobenthic invertebrates from biomass and mean individual weight. *Archive of Fishery and Marine Research* 32: 329-343.

Browman, H.I., Stergiou, K.I., Cury, P.M., Hilborn, R., Jennings, S., Lotze, H.K., Mace, P.M., Murawsñi, S., Pauly, D., Sissenwine, M. and Zeller, D. 2004. Perspectives on ecosystem-based management of marine resources. *Marine Ecology Progress Series* 274: 269-303.

Cardell, M.J., Sardá, R. and Romero, J. 1999. Spatial changes in sublittoral soft-bottom polychaete assemblages due to river inputs and sewage discharges. *Acta Oecologica* 20: 343-351.

Clarke, K.R. and Warwick, R.M. 1994. *Change in marine communities: an approach to statistical analysis and interpretation*. Plymouth: Plymouth Marine Laboratory, 144pp.

Clarke, K.R. and Gorley, R.N., 2006. User Manual/Tutorial. PRIMER-E Ltd. Plymouth. 192 pp.

Cochrane, S.K.J., Connor, D.W., Nilsson, P., Mitchell, I., Reker, J., Franco, J., Valavanis, V., Moncheva, S., J.Ekebom, J., Nygaard, K., Serrão Santos, R., Naberhaus, I., Packeiser, T., van de Bund, W. and Cardoso, A.C. 2010. *Marine Strategy Framework Directive. Guidance on the interpretation and application of Descriptor 1: Biological diversity*. Report by Task Group 1 on Biological diversity for the European Commission's Joint Research Centre, Ispra, Italy. 114pp.

Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Lasram, F.B.R., Aguzzi, J., Ballesteros, E., Bianchi, C.N., Corbera, J., Dailianis, T., Danovaro, R., Estrada, M., Froglia, C., Galil, B.S., Gasol, J.M., Gertwagen, R., Gil, J., Guilhaumon, F., Kesner-Reyes, K., Kitsos, M.-S., Koukouras, A., Lampadariou, N., Laxamana, E., López-Fé de la Cuadra, C.M., Lotze, H.K., Martin, D., Mouillot, D., Oro, D., Raicevich, S., Rius-Barile, J., Saiz-Salinas, J.I., San Vincente, C., Somot, S., Templado, J., Turon, X., Vafidis, D., Villanueva, R. and Voultsiadou, E. 2010. The biodiversity of the Mediterranean Sea: Estimates, patterns, and threats. *PLoS ONE* 5: e11842.

Cressie, N.A.C. 1993, Statistics for Spatial Data, Wiley.

Desbruyères, D., Guille, A. and Ramos, J.M. 1972-73. Bionomie benthique du plateau continental de la côte catalane espagnole. *Vie Milieu* 23: 335-363.

Durán, R., Canals, M., Sanz, J.L., Lastras, G., Amblas, D. and Micallef, A. 2014. Morphology and sediment dynamics of the northern Catalan continental shelf, northwestern Mediterranean Sea. *Geomorpohology* 204: 1-20.

Ellingsen, K.E. 2001. Biodiversity of a continental shelf soft-sediment macrobenthos community. *Marine Ecology Progress Series* 218: 1-15.

European Commission. 2008. Directive 2008/56/EC of the European Parliament and the Council of 17 June 2008, establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). *Official Journal of the European Union* L164, 19-40.(MSFD). 2008.

Ferreira, J.G., Andersen, J.H., Borja, A., Bricker, S.B., Camp, J., Cardoso da Silva, M., Garcés, E., Heiskanen, A.S., Humborg, C., Ignatiades, L., Lancelot, C., Menesguen, A., Tett, P., Hoepffner, N. and Claussen, U. 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.

Galgani, F., Fleet, D., van Franeker, J., Katsanevakis, S., Maes, T., Mouat, J., Oosterbaan, L., Poitou, I., Hanke, G., Thompson, R., Amato, E., Birkun, A. and Janssen, C. 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.

Galil, B., and Lewinsohn, CH. 1981. Macrobenthic Communities of the Eastern Mediterranean Continental Shelf. *Marine Ecology P.S.Z.N.I.* 2: 343-352.

Gambi, M.C. and Giangrande, A. 1986. Distribution of soft-bottom polychaetes in two coastal areas of the Tyrrhenian Sea (Italy): Structural analysis. *Estuarine, Coastal and Shelf Science* 23: 847-862.

Giangrande, A., Liciano, M. and Musco, L. 2005. Polychaetes as environmental indicators revisited. *Marine Pollution Bulletin* 50: 1153-1162.

Gil, J. 2011. *The European Fauna of Annelida Polychaeta*. PhD, Faculdade de Ciências. Universidade de Lisboa. 1554 pp.

Grémare, A., Amouroux, J.M., Charles, F., Medernach, L., Jordana, E., Nozais, C., Vetion, G. and Colomines, J.C. 1998a. Temporal changes in the biochemical composition of particulate organic matter sedimentation in the Bay of Banyuls-sur-Mer. *Oceanologica Acta* 21: 783-792.

Grémare, A., Amouroux J.M. and Vetion, G 1998b. Long-term comparison of macrobenthos within the soft bottoms of the Bay of Banyuls-sur-mer (northwestern Mediterranean Sea). *Journal of Sea Research* 40: 281-302.

Guille, A. 1970. Bionomie benthique du plateau continental de la côte catalane française. II. Les communautés de la macrofaune. *Vie Milieu* 21: 149-280.

Guille, A. 1971. Bionomie benthique du plateau continental de la côte catalane française. VI. Données autécologiques (Macrofaune). *Vie et Milieu* 22: 469-527.

Knox, G. 1977. The role of polychaetes in benthic soft-bottom communities. *Essays on Polychaetous Annelids in Memory of Dr. Olga Hartman*. Allan Hancock Foundation, Los Angeles: 547-604.

Labrune, C., Grémare, A., Amouroux, J.M., Sardá, R., Gil, J. and Taboada, S. 2006a. Diversity of polychaete fauna in the Gulf of Lions (NW Mediterranean). *Vie et Milieu* 56: 315-326.

Labrune, C., Amouroux, J.M., Sardá, R., Dutriex, E., Thorin, S., Rosenberg, R. and Grémare, A. 2006b. Characterization of the ecological quality of the coastal Gulf of Lions (NW Mediterranean). A comparative approach based on three biotic indices. *Marine Pollution Bulletin* 52: 34-47.

Labrune, C., Grémare, A., Amouroux, J.M., Sardá, R., Gil, J. and Taboada, S. 2007. Assessment of soft-bottom polychaete assemblages in the Gulf of Lions (NW Mediterranean) based on a mesoscale survey. *Estuarine, Coastal and Shelf Science* 71: 133-147.

Labrune, C., A. Grémare, J.-M. Amouroux, R. Sardá, J. Gil and S. Taboada (2008). Structure and diversity of shallow soft-bottom benthic macrofauna in the Gulf of Lions (NW Mediterranean). *Helgoland Marine Research* 62(3): 201-214.

Law, R., Hanke, G., Angelidis, M., Batty, J., Bignert, A., Dachs, J., Davies, I., Denga, Y. Duffek, A., Herut, B., Hylland, K., Lepom, P., Leonards, P., Mehtonen, J., Piha, H., Roose, P., Tronczynski, J., Velikova, V. and Vethaak, D. 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, 16 pp.

Massé, H. 1972. Quantitative investigations of sand-bottom macrofauna along the Mediterranean north-west coast. *Marine Biology* 15: 209-220.

Mee, L., Jefferson, R.L., Laffoley, D.d'A. and Elliott, M. 2008. How good is good?. Human values and Europe's proposed Marine Strategy Directive. *Marine Pollution Bulletin*, 56: 187-204.

Olenin, S., Alemany, F., Cardoso, A.C., Gollasch, S., Goulletquer, P., Lehtiniemi, M., McCollin, T., Minchin, D., Miossec, L., Occhipinti-Ambrogi, A., Ojaveer, H., Rose Jensen, K., Stankiewicz, M., Wallentinus, I. and Aleksandrov, B. 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, 4 pp.

Pebesma, E.J. 2004. Multivariable geostatistics in S: the gstat package. *Computers and Geosciences*, 30: 683-691.

Pérès, J.M. and Picard, J. 1957. Note préliminaire sur une communauté benthique récemment mise en évidence: la biocoenose à *Dentalium rubescens* et *Lucina (Miltha) borealis*. *Recueil des Travaux de la Station Marine d'Endoume* 21: 12.

Pérès, J.M. and Picard, J. 1964. Nouveau manuel de bionomie benthique de la mer Méditerranée. *Recueil des Travaux de la Station Marine d'Endoume* 31: 5–137.

Picard, J. 1965. Recherches qualitatives sur les biocénoses marines des substrats meubles dragables de la région marseillaise (France). *Bulletin des Recherches et Travaux de la Station Marine d'Endoume*. 36: 1-160.

Piet, G.J., Albella, A.J., Aro, E., Farrugio, H., Lleonart, J., Lordan, C., Mesnil, B., Petrakis, G., Pusch, C., Radu, G and, Ratz, H.J. 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.

Rice, J., Arvanitidis, C., Borja, A., Frid, C., Hiddink, J., Krause, J., Lorance, P., Ragnarsson, S.A., Skold, M. and Trabucco, B. 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.

Rogers, S., Casini, M., Cury, P., Heath, M., Irigoien, X., Kuosa, H., Scheidat, M., Skov, H., Stergiou, K.I., Trenkel, V.M., Wikner, J. and Yunev, O. 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.

Ros, J.D. and Cardell, M.J. 1992. Seasonal distribution pattern of polychaetes from a heavily polluted coastal area (Barcelona, NE Spain, NW Mediterranean). Pp. 101-110 in: Colombo, G., Ferrari, I., Ceccherelli, V.U. and Rossi, R. (eds), *Marine Eutrophication and Population Dynamics*, Olsen & Olsen PUbl. Fredensborg (Denmark).

Rosenberg, R., Blomqvist, M., Nilsson, H.C., Cerderwall, H. and Dimming, A. 2004. Marine quality assessment by use of benthic-species-abundance distributions: a proposed new protocol within the European Union water framework Directive. *Marine Pollution Bulletin* 49: 728-739.

Rumohr, H., Brey, T. and Ankar, S. 1987. A compilation of biometric conversion factors for benthic invertebrates of the Baltic Sea. *The Baltic Marine Biologists Publications* 9: 1-56.

Salen-Picard, C., Arlhac, D. and Alliot, E. 2003. Responses of a Mediterranean soft bottom community to short-term (1993-1996) hydrological changes in the Rhone river. *Marine Environmental Research* 55: 409-427.

Sardá, R., Pinedo, S. and Martin, D. 1999. Seasonal dynamics of macroinfaunal key species inhabiting shallow bottoms in the Bay of Blanes (NW Mediterranean). *Acta Oecologica* 20: 315-326.

Sardá, R., Pinedo, S., Grémare, A. and Taboada, S. 2000. Changes in the dynamics of shallow soft-bottom due to man-made disturbance processes in the Catalan Western Mediterranean Sea. *ICES Journal of Marine Sciences* 57: 1446-1457.

Sardá, R., Rossi, S., Martí X. and Gili, J.M. 2012. Marine Benthic Cartography of the Cape de Creus (NE Catalan Coast, Mediterranean Sea). *Scientia Marina* 76: 159-171.

Sardá R., O'Higgings, T., Cormier, R., Diedrich, A. and Tintoré, J. in press. Proposal of a Marine Ecosystem-Based Management System: linking the theory of environmental policy and practice of environmental management. *Ecology and Society*.

Serrano, L.G., Cardell, M.J., Lozoya, J.P. and Sardá R. 2011. A polychaete-dominated community in the NW Mediterranean Sea, 20 years after cessation of sewage discharges. *Italian Journal of Zoology 78*: 333-346.

Swartenbroux, F., Albajedo, B., Angelidis, M., Aulne, M., Bartkevics, V., Besada, V., Bignert, A., Bitterhof, A., Hallikainen, A., Hoogenboom, R., Jorhem, L., Jud, M., Law, R., Licht Cederberg, D., McGovern, E., Miniero, R., Schneider, R., Velikova, V., Verstraete, F., Vinas, L. and Vlad, S. 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, 3 pp.

Tasker, M.L., Amundin, M., Andre, M., Hawkins, A., Lang, W., Merck, T., Scholik- Schlomer, A., Teilmann, J., Thomsen, F., Werner, S. and Zakharia, M. 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.

Zenetos, A., Gofas, S., Verlaque, M., Çinar, M.E., Garcia Raso, J.E., Bianchi, C.N., Morri, C., Azurro, E., Bilecenoglu, M., Froglia, C., Soikou, I., Volanti, D., Sfriso, A., San Martín, Giangrande, A., Katagan, T., Ballesteros, E., Ramos Esplà, A., Mastrototaro, F., Ocaña, O., Zingone, A., Gambi, M.C. and Streftaris, N. 2010. Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine Strategy Directive (MSFD). Part I. Spatial Distribution. *Mediterranean Marine Science* 11: 381-493.