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How many habitats are there in the sea (and where)?

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ABSTRACT

Current policies of habitat conservation, recovery, and management are strongly biased in favour of terrestrial systems, being poorly applicable to marine environments. A sound habitat classification, leading to spatially explicit accounts on the distribution of marine habitats and communities, is a prerequisite to identify conservation priorities, based on appropriate methods for assessing habitat sensitivity to human disturbance, aimed at preventing habitat loss. The ten major European marine habitat classifications, recognizing a total of 1121 marine habitats, have been here revised, and their major differences have been formally tested in terms of multivariate dissimilarity. Mediterranean-based classifications resulted rather uniform, their habitats forming a separate cluster from the rest of European ones; these differences might be due to either distinct ecological features, or to divergences in the way habitats are classified. Either too vague or too detailed classifications, leading to cumbersome appreciations of biodiversity at habitat level, fail to provide proper tools for the conservation and management of marine environments. Different species assemblages can inhabit the same habitat type, representing the well-know natural variability that, at large scale, should not affect the appreciation of habitat distribution. Intra-habitat natural variability, in fact, causes a misleading qualitative interpretation of small-scale biodiversity distribution. Mediterranean classifications have been integrated and simplified by identifying habitats according to explicit criteria: level on the shore, type of primary substrate, presence of bioconstructors, presence of habitat formers, presence of ecosystem engineers. The motivating idea is to limit the current emphasis on spatial dominance as the only criteria for the introduction of species, assemblages, and habitats in the lists, towards a clearer recognition of the structural and functional role of biodiversity. The reduction of previous classifications to a list of 94 Mediterranean marine habitat types represents an initial attempt at providing a simple and flexible tool for the evaluation of biodiversity at habitat level, leading to more feasible conservation measures, potentially extendable at European scale.

1. Introduction

Habitat degradation, destruction, fragmentation, and loss are the most dramatic consequences of anthropogenic pressures on natural ecosystems (Sih et al., 2000; FAO, 2003; Gill, 2005; Hansson et al., 2007; Murdoch et al., 2007). To date, at global scale, up to 38 anthropogenic threats on 23 marine ecosystems have been identified (Halpern et al., 2007). In Europe, destructive fishing (Fanelli et al., 1994), overfishing (Hiddink et al., 2006; Kaiser et al., 2006; Gray et al., 2006, 2007), aquaculture (Pusceddu et al., 2007; CIESM, 2007), spread of invasive species (CIESM, 2002a; Bulleri and Airoldi, 2005), organic enrichment (Lampadariou et al., 2005), large scale oil and gas operations (Chapman et al., 2007; Terlizzi et al., 2008), offshore renewable energy developments, coastal engineering, coastal development (Jones and Rowley, 2002; Airoldi et al., 2005; CIESM, 2002b) and climate change (Easterling et al., 2000) are considered the major responsible for relevant habitat changes, which affect about the 85% of coastline (Airoldi and Beck, 2007). In many cases, historical ecology (Boero, 1996; Carlton et al., 1999; Dayton, 2003; Bolster, 2006) provides information about the replacement of natural conditions (at both habitat and species level) by either artificial structures or successful colonization of new, often alien, species.

In terrestrial environments, habitat loss and fragmentation affect the genetic structure of natural populations (Dixon et al., 2007), the behavioural strategies and body conditions of single individuals (Amo et al., 2007), species richness and community structure (Polus et al., 2007), and plant-animal interactions (Garcia and Chacoff, 2007).

In Europe, the scientific community of terrestrial ecologists developed Habitat Corine, a widely recognized scheme of habitat classification. The use of Habitat Corine allows for the identification and mapping of land cover changes between 2000 and 2006 (http://terrestrial.eionet.europa.eu/CLC2006). In the marine environment, the ecological impact of habitat changes is difficult to assess (Dobson et al.,

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2006; Worm et al., 2006; Halpern et al., 2007) because our understanding of the status and trends of marine habitats is surprisingly low and the effects of anthropogenic activities are more often assumed than quantitatively evaluated (but see Fraschetti et al., 2001). Recent attempts at modelling scenarios of habitat change and their implication for both local and regional biodiversity highlighted a significant drop in the proportion of species with different functional attributes (Thrush et al., 2006). Gray et al. (2006) and Hiddink et al. (2007) measured the sensitivity of seabed habitats to trawling and demonstrated that habitat sensitivities varied widely according to the gear used and the habitat in which it was deployed. However, most information refers to single-source impacts and, furthermore, data on patterns of assemblage recovery after disturbances at habitat level is still scant (Kaiser et al., 2001; Bevilacqua et al., 2006; Hammerstrom et. al., 2007). Therefore, in marine environments, methods for assessing habitat sensitivity to human impacts are urgently needed to measure impact sustainability, develop spatial management plans, and support sound environmental impact assessments. These procedures should be quantitative, validated, repeatable, and applicable at the scales of both impacts and management measures (Hiddink et al., 2007).

John Gray gave a significant contribution to the knowledge of biodiversity distribution, of the causes for species richness, and of the effects of anthropogenic disturbance, always considering the fundamental role of science for non-experts and, in particular, for policy-makers. The title *Using science for better protection of the marine environment* (Gray, 1999) is paradigmatic to show his philosophy. Gray was convinced that *science is continuously progressing continuing to find new methods, which can be used to demonstrate effects of man's activities on the marine environment* (Gray, 1999, p.3). John recently declared that habitat degradation and destruction in coastal areas are perhaps major issues, yet they are not part of the agendas of politicians and legislators (Gray, 2005). We feel that these issues have not even adequately addressed by scientists studying biodiversity at habitat level, so that proper answers to baseline questions are still lacking, largely limiting our current abilities to conserve and manage marine environments.

The conservation and management of coastal habitats is further complicated by baseline difficulties in habitat identification, leading to a non-ambiguous and shared classification. Three main reasons can explain the current situation.

The first reason is a lack of a common vocabulary on habitat types. The term habitat for the Habitat Directive refers to an *environment defined by specific abiotic and biotic factors, in which the species lives at any stage of its biological cycle* (Council Directive 92/43/EEC, p. 4; EC, 2003). Similarly, for Airoldi and Beck (2007, p. 349) the term habitat indicates a focus on the *dominant features determining structural complexity in the environment such as the presence of plants (e.g., phanerogams), animals (oyster banks), or other geological features such as hard substrates and muds*. However, in practice, the analysis of the literature shows different resolution in habitat classifications, these being strongly affected by the different scientific backgrounds of their proponents. Habitat can be simply defined in terms of *composition and relative abundance of species* (Bulleri and Benedetti-Cecchi, 2006, p. 483), or it can rely on *shoreline geomorphology* (Zacharias et al., 1999, p. 225) or, at the opposite, on a complex suite of *standard descriptors of topographical, geological, biological, natural, and anthropogenic features and processes* (Valentine et al., 2005, p. 184). McCoy and Bell (1991) identified three structural variables in relation to the ecological significance of a particular habitat, namely heterogeneity, complexity, and the scale at which the habitat is defined. Heterogeneity refers to the relative abundance (per unit volume or area) of the various structural components, and to their variability. Complexity deals with the absolute abundance of the various structural components. The scale relates to the unit volume or area used to measure heterogeneity and complexity. As a consequence, abiotic surrogates very often do not correlate to biodiversity patterns, some habitats being defined on the basis of the presence of characteristic species that often are not even habitat-formers, and some lists are featured by such a great detail to lead to a cumbersome appreciation of biodiversity at habitat level.

The second reason is that marine environments are less conducive than terrestrial ones to the collection of fine resolution data on habitat distribution and extent (Terlizzi et al., 2007). Mapping marine biodiversity is still operationally difficult and costly, with the consequence that habitat distribution is unknown in most marine areas (Halpern et al., 2008). Paradoxically, most Marine Protected Areas (MPAs) have been established without a proper knowledge of the distribution patterns of habitat diversity included under protection regimes (Fraschetti et al., 2005). This is a serious limit for adequate policies of biodiversity conservation, and for the management and monitoring of the activities allowed within the MPAs.

The third reason is the absence of a single, comprehensive system for the identification and classification of marine habitats. The EU Habitat Directive, together with implementation of the Natura 2000 network, is one of the main tools for the protection of biodiversity in Europe. It recognizes a host of terrestrial habitats, whereas marine habitats are treated sparingly. The scientific community reacted to this superficial treatment of marine habitat diversity with several proposals and actions, sometimes stemming from initiatives of single countries, or of scientific societies, or of international organisms, such as the RAC-SPA at Tunis. These reactions, however, led to many disconnected proposals (EEA, 2004; Connor et al., 2004; Diaz et al., 2004) that, so far, strongly limit our potential of monitoring the present state of habitats.

Halpern et al. (2008), recently indicated that no area at global scale is unaffected by human influence and that a large fraction (41%) is strongly affected by multiple drivers. They emphasized, however, (p. 951) *the need for research on the most basic information such as distribution of habitat types and whether and how different anthropogenic drivers interact*. It is evident that the lack of an adequate classification framework delays filling the gaps. Management and conservation of the world's oceans require synthesis of spatial data on the distribution of habitats. Multinational initiatives should get comprehensive habitat classifications leading to maps of habitat distribution, to cope with the paradoxical situation depicted by Halpern et al. (2008), who showed that we can produce a global map of human impacts but that we cannot infer on their effects on biodiversity, since the distribution and state of habitat diversity are largely unknown.

The goal of this study is twofold. First, we reviewed existing habitat classification systems and we formally tested, in terms of multivariate similarity/dissimilarity, the differences among the ten main classifications produced in the last 50 years. Specifically, we highlighted the limited evolution of recent attempts at classifying marine habitats from past initiatives, and that Corine Habitat - Habitat Directive are possibly well suited for terrestrial systems but surely do not account for the diversity of marine habitats. Second, we provide explicit guidelines for classification criteria of Mediterranean Habitats, also extendable to extra Mediterranean areas, calling for more attention to the functional properties of marine habitats. In a practical example, we applied the integrated and reduced habitat classification for the management of Italian Marine Protected Areas.

2. Material and Methods

2.1. Data collection and statistical analyses

Habitat lists were obtained from the ISI Web of Science and Biological Abstracts database using "*Marine* AND *habitat* AND *classification* OR *habitat list*" as searching terms. Personal literature was also used to cover the period from 1959 to 2006. Further literature research was carried also out through website analysis. Only the habitat lists proposed as general classification schemes applicable at biogeographical scale were included. All the studies with local interest, simply referring to more general lists, were not considered.

Ten classification schemes were selected (Riedl, 1959; Pérès and Picard, 1964; ZNIEFF - Anonymous, 1988; Corine - Anonymous, 1991; Habitat Directive - Anonymous, 1992; Palaearctic - Devilliers and Devilliers-Terschuren, 1993; Bellan Santini et al., 1994; EUNIS - Davies and Moss, 1997, 1999; Connor et al., 2004; RAC/SPA, 2006). A presence-absence data matrix (1121 data × 10 lists) included all the information collected from the lists referring to marine habitats (Supplement_1). Entries were a combination of species (e.g. *Spisula subtruncata* and *Nephtys hombergii* in shallow muddy sand), assemblages (e.g. Biocenosis of fine sands in very shallow waters) and habitats in terms of physical properties (e.g. Infralittoral fine sand). A first multivariate analysis was run on this data set. The differences between the lists were quantified in terms of Bray-Curtis (BC) dissimilarities on presence-absence data, and results were graphically represented through non-metric multidimensional scaling ordination (nMDS) (Kruskal and Wish, 1978) and a dendrogram. All the analyses were run through the PRIMER 6 software (Clarke and Gorley, 2001). The most detailed habitat list (RAC/SPA, 2006) was reduced to a simpler list, whose descriptive potential was compared with that of traditional lists in the evalutation of habitat diversity in 22 Italian Marine Protected Areas (MPAs). The information about the presence-absence of habitats within MPAs was obtained from the *National Interuniversity Consortium for Marine Sciences* (CoNISMa), that collected available data on benthic habitat maps (1:10000 scale, in most cases) produced in the Italian MPAs, using the classification of habitats identified by RAC/SPA. The 187 entries of the RAC/SPA classification scheme were collapsed into a new list, considering only the information concerning: 1- the level on the shore, 2- the primary substrate in term of geologic features, 3- the presence of habitat formers-bioconstructors, 4- and the presence of ecosystem engineers. A first multivariate analysis was run on the matrix list of Habitat × MPAs, multivariate analyses were then repeated with the reduced list.

3. Results

3.1. Classification schemes

The study of marine biology and ecology by direct underwater observation started in the Mediterranean Sea and the first classifications of marine habitats considering hard and soft bottoms were compiled for the Mediterranean region. In many other areas of the world, in fact, the exploration of marine habitats was mostly performed on soft bottoms, by indirect methods, or in the intertidal.

Riedl (1959) made one of the first attempts at classifying marine habitats, especially focusing on Mediterranean rocky substrates. Pérès and Picard (1964, hereafter indicated as PP) compiled a detailed account on Mediterranean communities (often named Biocenosis); their approach and terminology (see also Pérès, 1967) were largely used in the Mediterranean area also to interpret patterns of distribution on marine species and assemblages within a deterministic framework. These efforts produced a hierarchical system that combined physical and biological information to classify ecotypes that represent biological assemblages within habitats. A further scheme covering the whole of the land and part of the coastal areas as Natural Zones of Fauna, Flora and Ecological Interest was termed ZNIEFF (Anonymous, 1988).

The classification of assemblages by PP was used not only for the French coasts, but also for the whole Mediterranean basin. Dauvin et al. (1993, 1994) listed the Parameters and Biocenosis of the metropolitan French coasts, whereas Bellan Santini et al. (1994, hereafter BS) revised past Mediterranean classifications. More recently, in the context of an EU project, the Corine biotopes classification (Anonymous, 1991) developed a further list of 246 entries that, at present, is one of the most used classifications at European scale. This classification, however, is of difficult use for marine purposes, particularly for the Mediterranean zone. The Habitat Directive 92/43 EEC (Anonymous, 1992) stemmed from the Corine classification and represents one of the most structured and official attempts at protecting biodiversity in Europe by providing a list of habitats that deserve protection regimes. Together with the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic, it has been perceived as an instrument to assist in the designation of sites to be protected. Marine sublittoral habitats, however, are treated sparingly in this classification. The classification of Palaearctic habitats (Devilliers and Devilliers-Terschuren, 1993) is a development and a geographical extension of the Corine biotopes, without providing significantly more information for the Mediterranean Sea. The European Nature Information System (EUNIS) habitat classification is a pan-European system, which was developed between 1996 and 2001 by the European Environment Agency in collaboration with experts from throughout Europe (Davies and Moss, 1997, 1999). It covers all types of natural and artificial habitats, both aquatic and terrestrial. Britain and Ireland, within the framework of the Joint Nature Conservation Committee, produced one of the most comprehensive marine benthic habitat classification systems currently in use. The system was developed through the collaboration of a wide range of marine scientists and conservation managers, by the analysis of empirical data sets, and the review of other classifications and scientific literature. It is fully compatible with and contributes to the European EUNIS habitat classification system (Connor et al., 2004, hereafter C). Recently, the RAC/SPA of Tunis (2006) established a classification of the various marine habitats types for the Mediterranean region, which could serve as a common reference for the

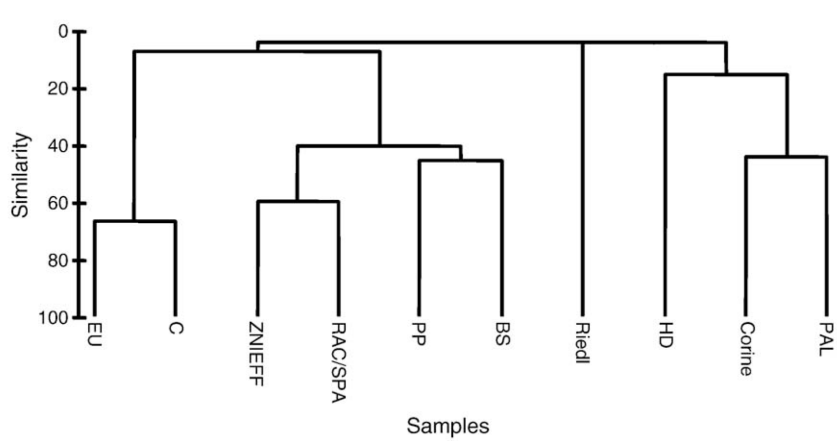

Fig. 1. Dendrogram using group-average clustering from Bray–Curtis similarity measure calculated on presence-absence data of the classification lists.

establishment of national inventories of natural sites of conservation interest. This inventory took into account the previous schemes established by the various national and international bodies for the same purpose.

3.2. Data analyses

The combination of all lists, with the exclusion of terrestrial habitats, yielded 1121 entries, featured by different approaches and specificities in addressing habitat identification. Multivariate analyses showed that the highest similarity values joined the classification schemes by EUNIS and C (67% similarity), and by ZNIEFF and RAC/SPA (60% similarity) (Fig. 1). The classification schemes proposed by PP, ZNIEFF, BS and RAC/SPA, suited for describing Mediterranean habitats, cluster together in the nMDS (Fig. 2) thus indicating that habitat classifications did not change much in the last forty years. Classification lists proposed for the North Atlantic share very few habitats (less than 1%) with those proposed for the Mediterranean Sea. The Habitat Directive shows strong dissimilarity with all classifications, with the exception of the Corine list (Fig. 2).

With the exception of Connor's classification, dealing with northern assemblages, *Posidonia oceanica* meadows is the only habitat reported by all lists. The *Biocenosis of muddy sands and muds* (*lagoons* and *estuaries*), the *Biocenosis of the upper mediolittoral rock* and the *Biocenosis of the lower mediolittoral rock* also show high frequencies. Most of the other habitats are cited only once. The same habitat is often defined with slightly different terms (e.g. *Sublittoral sediments* and *Sublittoral soft seabeds*), maximizing dissimilarity in habitat interpretation. Also, some lists are featured by an overwhelming resolution in habitat classification by lower categories (mainly associations for plants and facies for animals). The case of the brown algae of the genus *Cystoseira* is paradigmatic: the 14 species of this genus in the RAC/SPA classification can be identified only by expert taxonomists. The species *Cystoseira zosteroides* is cited both as an *association* (RAC/SPA, EUNIS) and a *facies* (BS, ZNIEFF), but the rationale behind these choices is not clear.

3.3. Towards the reduction of the list of habitat types in the Mediterranean Sea

Traditionally, Mediterranean habitat types are based on a phytosociological approach, privileging plants and using a formal nomenclature for plant associations (e.g. *Posidonietum oceanicae* for the meadows of *Posidonia oceanica*). This approach has no counterpart for the animal component. This makes sense when vegetation is the backbone of habitats, like in terrestrial domains, but it loses most of its descriptive power in the marine environment, where macrophytes are mostly present on hard substrates and in the euphotic zone only. Sessile marine animals are often habitat-formers just as are plants on land. This difference between terrestrial and marine habitats calls for a radically different approach at habitat definition in the two domains, giving proper relevance to the animal component in the marine environment.

The proposed reduction of the list of Mediterranean habitat types is aimed at allowing habitat identification during visual censuses, based on direct observation by either SCUBA diving or submersibles and ROVs, and is based on several classification levels.

1. the level on the shore. Terms such as High shore or Supralittoral, Intertidal (or Mid-littoral), Infralittoral are present in most of classifications and have been incorporated.
2. the primary substrate in terms of geologic features. The bathymetry is to be coupled with a geomorphological map, providing information on both the nature of substrates, and on the extension of biologically described habitats.
3. habitat formers. Habitats are multilayered entities. Abundant sessile organisms such as algae, higher plants, and sessile animals, usually labelled as habitat formers, cover the primary geological component (see Piraino et al., 2002 for a review). Habitat formers have their own primary habitat but, if they are present, they favour the presence of species assemblages increasing local biodiversity. In the Mediterranean Sea, most important habitat formers are bioconstructors (Bianchi and Morri, 2000). The term applies to organisms with hard skeletons that remain in place after death, becoming a secondary substrate for other organisms of the same species. In this way, the primary geological substrate is covered by a secondary substrate represented by skeletons on which, eventually, also non-bioconstructors can grow. Bioconstructors are also called hermatypic (Schuhmacher and Zibrowius, 1985), ranging from coralligenous formations (formed by coralline algae, sponges, cnidarians, and bryozoans) to *Posidonia* meadows, *Lithophyllum* formations, vermetid reefs, barnacle aggregations (exp. *Balanus spp.*), oyster banks, deep-sea white corals. All bioconstructors are habitat formers, and should have an adequate consideration in conservations policies. Many Mediterranean bioconstructors are not listed as species deserving a special status in conservation priorities. Not all habitat formers are bioconstructors, however. Many algae are relevant components of marine communities, but their presence is often strictly seasonal. Non-seasonal habitat mapping does not have the potential to capture the dynamics of benthic assemblages: algae such as *Cystoseira* can be seasonally replaced by canopies of erect hydroids of the genera *Eudendrium*, *Halecium*, *Aglaophenia,* etc. (Boero, 1984). Thus, the same primary habitat might host completely different secondary habitat-formers in different sampling dates (Coma et al., 2000).
4. functionally important species. Many species do modify habitats not by providing structure but, instead, by performing functions that might change primary or secondary habitats. The species that re-work sediments, for instance, are labelled as ecosystem engineers since they change the features of the sea bottom. Other activities, such as sea urchin grazing, might depress the presence of erect forms, leading to barren grounds inhabited by encrusting animals and algae. Such barrens can be reduced by increased predation on biodiversity depressors (see Guidetti, 2006, for a Mediterranean-based example).

With this approach the 187 entries of the RAC/SPA classification scheme were collapsed into a new list of 94 entries (Supplement_2).

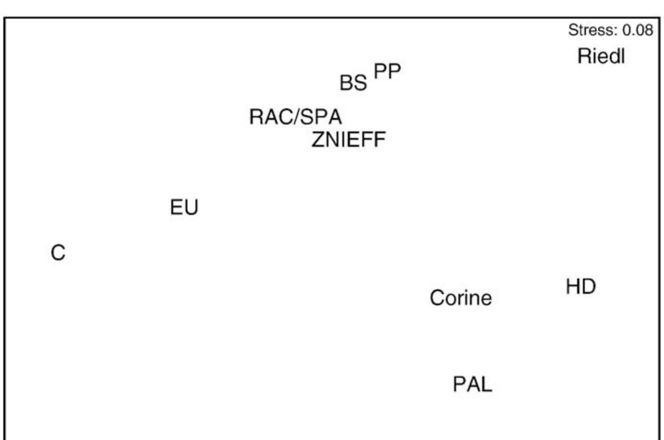

Fig. 2. Non-metric multidimensional scaling ordination (nMDS plot) on the basis of the Bray-Curtis dissimilarity measure calculated on presence-absence data of the classification lists.

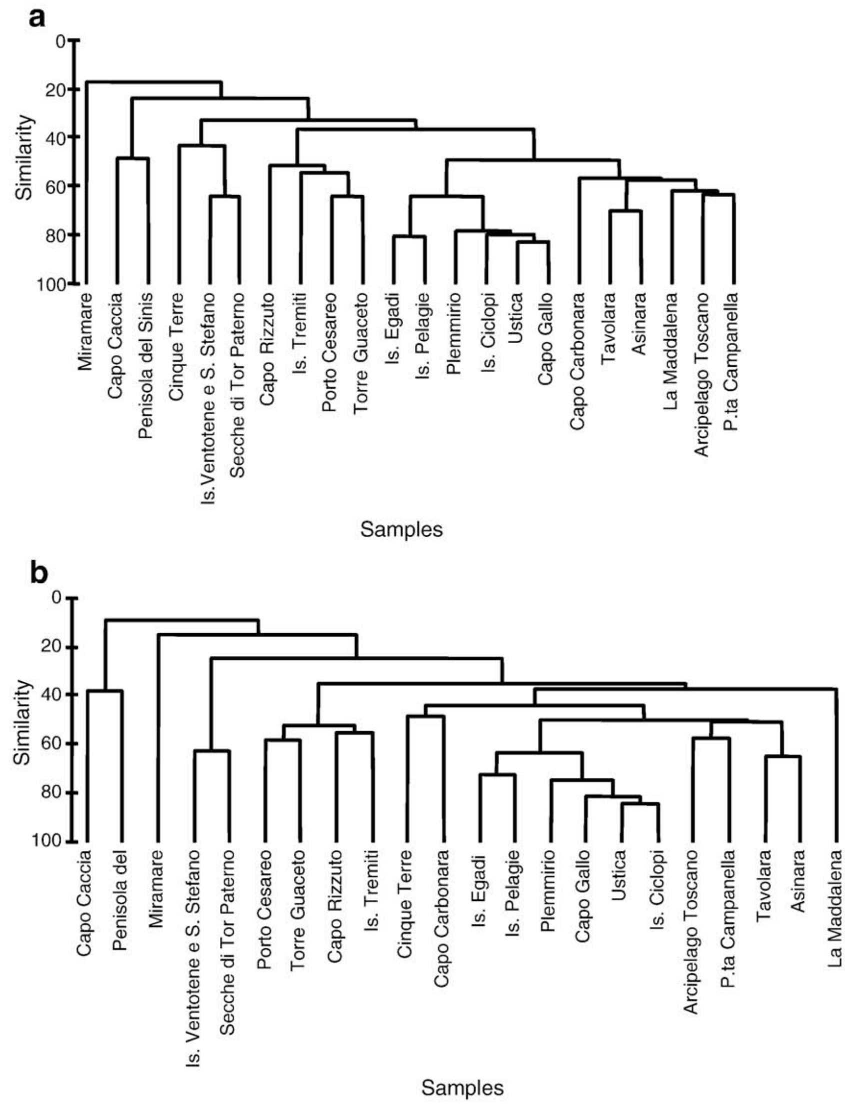

Fig. 3. Dendrograms using group-average clustering from Bray-Curtis similarity measure calculated on presence-absence of the habitats under protection regime following the RAC/SPA classification scheme. a) total list of RAC/SPA habitats b) reduced number of habitats.

3.4. A test of the efficacy of the reduced list

Habitat mapping by using the SPA/RAC (2006) list (187 entries) was used to evaluate habitat diversity in all Italian MPAs (see Material and Methods). The evaluation was then performed by using the reduced list obtained by applying the principles described above. The 94 entries are identifiable also by non-specialists with reasonable accuracy (Supplement_2). Out of the 94 proposed habitats, 66 were present in the Italian MPAs. The MPAs clustered in 5 main groups (Fig. 3a). They correspond to regional differences, thus suggesting that, in Italy, protected habitats change across a geographical gradient. After reducing the list, groups were still well represented and patterns of clustering were almost overlapping (Fig. 3b).

4. Discussion

The quantification of biodiversity using habitats as a proxy for biodiversity is generally acknowledged as more feasible than studying biodiversity at species and/or genus level, especially when the aim is not a detailed inventory of biodiversity at small scale but, instead, a mapping at large spatial scale (Ward et al., 1999, Cushman et al., 2008). Some Authors (Zajac, 2007) have recently claimed the need for studying soft-sediment benthic landscapes, including the development of technology and analytical approaches for sea floor mapping and quantification of benthic landscape, or *benthoscape* structure, to integrate general landscape ecology theory into benthic ecology. This should have the potential to make empirical progress in understanding soft-sediment habitats and other marine systems.

While species taxonomy is being studied since over 200 years, and species distinction is clearly understood by taxonomists, habitats are still difficult to define analytically, and the boundaries among them cannot be determined genetically (as for species), so that any classification is a compromise among different opinions. A unified classification of marine habitats is urgently needed, leading to multi-scale habitat inventorying, protection, and monitoring. An operative habitat classification system should be comprehensive, scientifically sound, unambiguous, and of easy application.

The coverage of habitats in European conservation initiatives is strongly biased towards a terrestrial perspective, causing relevant differences in the potential of management and conservation of terrestrial vs. marine habitats (Dauvin et al., 2008). The present analysis shows that marine classification schemes proposed in the last fifty years are either too vague or too detailed, referring with broad terms to the geological features of the substrate or to a too fine scale definition of biodiversity at species level, often biased towards the plant component (both taxonomically and seasonally). The high taxonomic resolution required in some of the classification lists probably overemphasizes small-scale changes in biodiversity distribution, causing a cumbersome appreciation of biodiversity at habitat level. The same habitat type can be inhabited by different species assemblages representing the natural variability that should be adequately quantified in other experimental contexts but that, at large scale, should not affect the appreciation of habitat distribution. Intra-habitat natural variability causes a misleading qualitative interpretation of biodiversity patterns at small-scale. The drastic reduction of the importance given to species for the identification of habitat types is not an under-appreciation of the importance of a sound taxonomic approach (Terlizzi et al., 2003). Biodiversity analysis at habitat level is just a first step towards a proper evaluation of environmental features at any scale.

Our results demonstrate that Mediterranean marine habitat classifications form a separate cluster from the rest of European ones, with difficulties in the appreciation of the increasing gradient of diversity from northern to southern European marine domains. Different international directives and conventions use different classifications, making their inter-relationship complex (Parks, 2002). It is debatable whether the observed differences are due to distinct ecological features, or to subjective divergences in the way habitats are classified. Differences may be caused by the different taxonomic background of researchers and/or by different sampling approaches. The consequence is that, notwithstanding the effort, habitat classifications still remain context dependent. Also, the use of terms such as *facies*, *associations* and *biocenosis* represents a further limit in classification sharing outside the Mediterranean Sea.

Our list of Mediterranean marine habitats suggests that most approaches are very analytical and that more recent ones often increased previous habitat classifications, with scant consideration of the recent changes in Mediterranean biota. As an example, at least 100 new macroalgal species have been introduced in the Mediterranean Sea, 10 of them becoming invasive (Boudouresque and Verlaque, 2002), with the potential of creating new alien habitats (Klein and Verlaque, 2008). Paradoxically, notwithstanding the effort required to include an extensive number of species within the lists of habitats (in the RAC/SPA, 110 out of 187 entries are defined at species level), with the exception *Halophila stipulacea*, there is no mention of these introductions in the more recent classifications. A more updated account of changes, both natural and human-induced, occurring in the marine environment is crucial for addressing biodiversity management and conservation with appropriate tools. At the same time, marine environments are not limited to coastal areas. Deep-sea sediments make up the 65% of the world surface representing one of the largest reservoirs of biomass and non-renewable resources (Danovaro et al., 2008). All classifications of Mediterranean marine habitats are biased in favour of shallow habitats, revealing objective gaps of knowledge on deep-sea environments. The exploration of the deep sea, with the discovery of new habitats, such as mud volcanoes and hydrothermal vents, is leading to future refinements in marine habitat definition.

The proposal, just as the lists on which it is founded, details much on hard substrata, since these have been better explored in the Mediterranean than anywhere else, due to a strong tradition in the use of SCUBA-diving for marine studies. The simplification of habitat classifications drafted here is an attempt at providing a flexible tool for the evaluation of biodiversity at habitat level, leading to more feasible conservation measures. Level on the shore, primary substrate in terms of geologic features, presence of biocostructors, habitat formers, and ecosystem engineers represent, in fact, a combination of factors that can be easily incorporated at all latitudes, at least for coastal habitats. This approach could lead to limit the current emphasis on spatial dominance as the only criteria for the introduction of species, assemblages, and habitats in the lists. The proposed classification scheme is less rigid and emphasizes functional diversity at habitat level. The motivating idea is to improve the protection of marine habitats (and good and services they can provide), going over the simplistic approach of spatially explicit protection of the marine environment just on the basis of species distribution.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jembe.2008.07.015.

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