VIEWPOINT

Conservation of Mediterranean habitats and biodiversity countdowns: what information do we really need?[†]

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ABSTRACT

1. The relentless increase in both human activities and exploitation of marine resources is a threat to marine habitats and species.

2. For marine systems, several protection initiatives have been outlined over the past decade to significantly reduce the current rate of biodiversity loss at global, regional, and national levels, and to establish representative networks of marine protected areas with the aim of protecting 10–30% of marine habitats.

3. Reliable estimates of the total area occupied by each habitat are crucial to set adequate protection initiatives. Habitat mapping requires a sound habitat classification. Many classification schemes have been developed in different areas of the world, sometimes based on questionable criteria.

4. A critical analysis of the most recent marine habitat classification list produced for the Mediterranean Sea from the Regional Activity Centre for Specially Protected Areas (RAC/SPA) showed that (i) 39% of habitats and associated species considered in the list are scarcely covered by scientific knowledge from Web-based resources; (ii) 62% of the species/genera included in the list are primary producers; (iii) quantitative information about the geographical distribution of selected habitats and associated species is scant; and (iv) when available, information is largely unbalanced and biased towards the shallow western Mediterranean Sea.

5. Improved inventories of marine habitats are needed to support accurate and consistent mapping activities. The combination of large-scale mapping and sound habitat classifications will allow better estimates of biodiversity distribution, to reverse regional/global habitat loss rates through the achievement of conservation targets and deadlines that, for the moment, are systematically not met.
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INTRODUCTION

Worldwide, ocean degradation is leading to an increasing depletion of biological diversity and associated goods and services to human welfare (Jackson *et al.*, 2001; Worm *et al.*, 2006; Halpern *et al.*, 2007). The Mediterranean hosts 6–8% of described marine species despite covering less than 1% of the global oceans (Bianchi and Morri, 2000; Boero, 2003; Boero *et al.*, 2008; Lejeusne *et al.*, 2010). This alone makes this

marine region a top conservation priority. Human pressure on these rich and unique marine ecosystems is high, with intense fishing pressure, densely populated coastlines (~450 million people, supplemented by an additional 220 million tourists that are projected to double by 2025; UNEP/MAP, 2005), and an increasing number of introduced species (over 600; Boudouresque *et al.*, 2005). Such intense pressure has resulted in major alterations of Mediterranean ecosystems (Lotze *et al.*, 2006; Airoldi and Beck, 2007; Ferretti *et al.*,

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2008). Climate-induced stressors further contribute to changes in the Mediterranean biodiversity, driving the basin to potentially uncharted territories (Boero, 2003; Coll *et al.*, 2010; Lejeusne *et al.*, 2010).

In this fast-degenerating scenario, local management tools, such as isolated marine protected areas (MPAs), are insufficient. Suitable strategies for conservation and sustainable management of marine biodiversity require large-scale integrated regulation of the exploitation of marine resources (Allison *et al.*, 1998; Lubchenco *et al.*, 2003).

Unfortunately, the fragmented geopolitical scenario characterizing the Mediterranean basin still leads to weak, uncoordinated, conflicting, or non-existent regulatory frameworks, policy mechanisms and enforcement. Ecosystem-based management (EBM) frameworks are invoked as sensible strategies (Lester *et al.*, 2010), but single-sector management strategies are still the rule. Examples of effective EBM are rare: Pergent-Martini *et al.* (2006) describe a case study of *Posidonia oceanica* meadows (seagrass beds) along the Corsican coastline (NW Mediterranean) to exemplify the usefulness of ecological data to EBM programmes.

The European Council (2001) followed by the International Union for Conservation of Nature (IUCN) (2004) and by the Eighth Ordinary Conference of the Parties to the Convention on Biological Diversity (CBD) (2006) promoted the commitment to achieve by 2010 a significant reduction of the current rate of biodiversity loss at global, regional, and national levels, with the aim of protecting 10–30% of marine habitats. Also, the World Summit on Sustainable Development (WSSD) in 2002 and the Fifth World Parks Congress (WPC) in 2003 stressed the need to establish representative networks of MPAs by 2012 (Wood *et al.*, 2008; Wabnitz *et al.*, 2010; Countdown 2010, http://www.countdown2010.net). The lack of quantitative information on the extent of major habitats, together with a lack of knowledge about the potential connectivity between sites to be networked, make also 2012 an unrealistic deadline to be achieved (Abdulla *et al.*, 2008).

Coll *et al.* (2010) considered marine habitat loss or destruction as the second most important human impact presently occurring throughout the Mediterranean Sea, preceded only by overexploitation and followed by eutrophication, introduced predators, disease, and general disturbance. So far, strategies to halt habitat loss have been largely ineffective (Perkol-Finkel and Airoldi, 2010). In the last EU report on the Progress Towards the European 2010 Biodiversity Target (EEA, 2009), terrestrial systems received most attention. The report includes generic comments on the alarming status of commercial fisheries and the spreading of invasive marine species, lacking updated information on the threats to Mediterranean marine ecosystems. The estimates of marine habitat loss between 1990 and 2000 seem unrealistic (<1%), especially when compared with data coming from other scientific literature (Benedetti-Cecchi *et al.*, 2001; Airoldi and Beck, 2007; Mangialajo *et al.*, 2007; Claudet and Fraschetti, 2010; Fraschetti *et al.*, 2011). The report concluded that 'the target of halting biodiversity loss in Europe by 2010 will not be achieved'. Having failed with their 2010 target, EU ministers have recently set a new biodiversity deadline for 2020, and the 27 governments agreed to try to do more to halt biodiversity loss.

To meet the challenge of halting habitat loss, several countries such as the UK, Australia, and New Zealand developed, or are developing, national classification systems and mapping protocols for marine habitats (Guarinello *et al.*, 2010). Habitat mapping is crucial to get reliable estimates of the total area occupied by each habitat, so as to reach the required conservation targets and to satisfy concepts such as habitat representativeness (i.e. a sample of every habitat occurring in the area under consideration should be included in a MPA) (Costello, 2009).

Key concepts and considerations in designing marine habitat classifications have been developed by many authors (Dauvin *et al.*, 2008; Costello, 2009; Guarinello *et al.*, 2010; Howell, 2010; Last *et al.*, 2010) focusing on the definition of habitat, the measurable features used to describe it, the scale and the hierarchical framework to be used. However, current classifications generally lack explicit recognition of overarching scientific criteria for the choice of habitat/species inclusion in the lists.

In Europe, the EU Habitats and Species Directive (HSD: 92/43/EEC) is the main tool for the conservation and management of biodiversity at the habitat level. It plans for the establishment of Special Areas of Conservation (SACs) to protect selected habitats and species listed in its Annexes A and B. The majority of the 200 habitat types and 700 species listed in the annexes are terrestrial; marine habitats and species are treated sparingly, with only nine marine habitats included (Fraschetti *et al.*, 2008). In the Mediterranean Sea, environmental agencies such as the Regional Activity Centre for Specially Protected Areas (RAC/SPA) tried to counterbalance this lack of consideration toward the marine environment by elaborating a reference list of habitat types and species for selecting the sites to be included in the national inventories of sites of conservation interest (UNEP-MAP-RAC/SPA, 2006). This reference list takes into account the previous classifications established by several authors and national and international bodies (Pérès and Picard, 1964; Anonymous, 1988; Bellan-Santini *et al.*, 1994; Dauvin *et al.*, 1994; Devilliers and Devilliers-Terschuren, 1996,) and represents a baseline for the conservation, management, and long-term monitoring of the marine habitats and associated species of this basin (Bellan-Santini *et al.*, 2002), which has few equivalents elsewhere in the world (see as an example the effort by Connor *et al.*, 2004, for Britain and Ireland). Fraschetti *et al.* (2008) listed all the Mediterranean habitat types present in the classifications developed so far, discussing the similarities/dissimilarities among the lists produced over time at the EU-Mediterranean scale (Riedl, 1959; Pérès and Picard, 1964; ZNIEFF–Anonymous, 1988; Corine–Anonymous, 1991; Habitat Directive–Anonymous, 1992; Palaearctic–Devilliers and Bellan-Santini *et al.*, 1994; Devilliers-Terschuren, 1996; EUNIS–Davies and Moss, 1997, 1999; Connor *et al.*, 2004; UNEP-MAP-RAC/SPA, 2006) and highlighting the lack of a common vocabulary on habitat types.

In this study, the RAC/SPA marine habitat classification is analysed to (1) review the scientific information available on habitats and associated species included in the list; (2) analyse the rationale used for the inclusion of habitats and associated species; and (3) focus on the scientific information needed to improve the ability to achieve international conservation objectives, providing guidance on priority issues.

MATERIALS AND METHODS

The *ISI Web of Knowledge* database was searched from 1990 to 2009, to obtain information on the species/genera included in the list of the 'Classification of Benthic Marine Habitat Types for the Mediterranean Region' (UNEP-MAP-RAC/SPA, 2006), including more than 160 entries, a widely used source for the establishment of inventories of natural sites for conservation priorities. In this classification list, the definition of habitat refers to that provided by the Habitats Directive. The classification follows a hierarchical structure referring to: position along a depth gradient (e.g. infralittoral, circalittoral); primary substrate in terms of geological features (e.g. sand, rock); and species assemblages and foundation taxa (e.g. *Posidonia oceanica*) associated with each habitat. Considering all levels of the hierarchy, the classification includes 130 species/genera (Figure 1). All species/genera of the RAC/SPA classification were searched for in the 'Topic' field of the search engine. The field of investigation has been further restricted to publications that explicitly referred to the species/genera in the title, abstract and/ or keywords. A factorial combination of the keywords 'Mediterranean' and 'name of the species/genus' was used (see Table 1 in Supplementary Material). For each entry, the total number of publications was listed, together with the topic and the geographical area where the particular study took place. All studies were analysed to ascertain whether information on patterns of distribution and conservation status of listed taxonomic groups were available. To report on the geographical distribution of the assembled studies, publications were ascribed to the seven ecoregions of the Mediterranean Sea (Spalding *et al.*, 2007), namely the Adriatic Sea, Aegean Sea, Levantine Sea, Tunisian Plateau/Gulf of Sidra, Ionian Sea, Western Mediterranean, and Alboran Sea. General reviews on the Mediterranean Sea without specific information on species/ genera from the list were not considered in the analysis. *Posidonia oceanica*, *Cymodocea nodosa*, *Zostera* spp. and *Mytilus galloprovincialis* account for well-documented ecological information at the basin scale and share a widely recognized conservation value (e.g. for the group of Angiospermophyta:

European Environmental Agency, 2006; Boudouresque *et al.*, 2009; for *M. galloprovincialis*: Thébault *et al.,* 2008). In the results, a report on the number of studies dealing with these four species and a comment is presented, but the list of references is not included in the Supplementary Material.

RESULTS

In total, 438 articles were analysed (see Table 1 in Supplementary Material). Scientific information on taxa included on the list is extremely variable. Algae comprise 62% of the listed species/genera, hence the classification scheme is mostly algae-oriented (Figure 1). Most algae are Rhodophyta and Ochrophyta (44 and 24 species/genera respectively). No records were found for 39% of the species/genera on the classification list, 20% were cited in only one or two papers, and 75% of the species/genera were cited in less than six studies (Figure 2). The relevance of many of the studies to the question of conservation planning is also limited. For example, the published studies for species such as *Lithophyllum byssoides*, *Ceramium ciliatum* and *Lamprothamnium papulosum* cover only geological (Kershaw, 2000) and physiological (Diannelidis and Delivopoulos, 1997) issues, or distribution at a small scale (Christia and Papastergiadou, 2006). The brown algae Genus *Cystoseira* (with 13 species) are some of the most represented in the classification list. Data on the conservation status and distribution pattern of this genus are available for some regions of the western Mediterranean (Thibaut *et al.*, 2005; Fraschetti *et al.*, 2006; Boudouresque *et al.*, 2009; Sales and Ballesteros, 2009), but four species of the 13 were not covered by any study (i.e. *Cystoseira crinitophylla*, *C. sauvageauana*, *C. dubia* and *C. usneoides*), and the number of studies is negligible for all the other species (see Table 1 in Supplementary Material). There are also exceptions, such as for the serpulid polychaete *Ficopomatus enigmaticus*, where there are data on the species biology (Schwindt and Iribarne, 2000; Schwindt *et al.*, 2004), ecological effects on other species (Heiman *et al.*, 2008), and
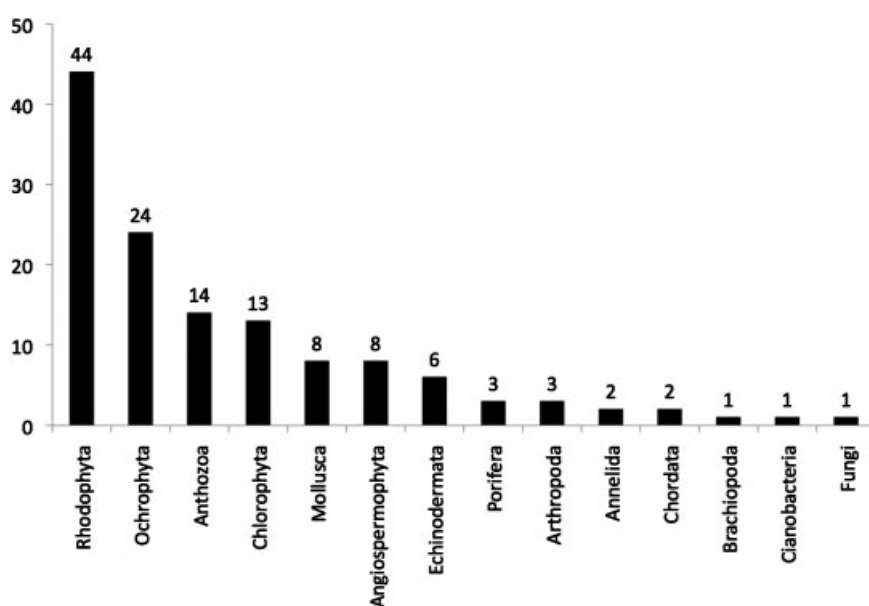

Figure 1. Number of species/genera included in the RAC/SPA classification scheme according to the different taxonomic groups to which they belong.

management initiatives (Bruschetti *et al.*, 2008; Diawara *et al.*, 2008) although there is nothing on the large-scale assessment of its distribution patterns. Other examples of well-documented species include the seagrasses *Posidonia oceanica* (cited in 555 papers), *Cymodocea nodosa* (156) and *Zostera marina* (151), and the bivalve *Mytilus galloprovincialis* (323). Although information on the distribution and conservation status of seagrasses is largely available, it is mostly restricted to limited areas, with very few large-scale assessments (European Environmental Agency, 2006; Boudouresque *et al.*, 2009).

Ficopomatus and *Mytilus* apart, invertebrates are largely unrepresented and taxa such as vermetids, hydroids, and bryozoans are included in the list only as general groups, with no mention to species or genera. A considerable number of publications cover the Anthozoa (138 papers, Table 1 in Supplementary Material), even if the information focuses just on four species: *Eunicella singularis* (cited in 13 papers), *Cladocora caespitosa* (23), *Corallium rubrum* (41), *Paramuricea clavata* (46). In this case, information on the effect of direct human disturbance (Di Franco *et al.*, 2009), conservation status (Santangelo *et al.*, 2007), and climate change (Coma *et al.*, 2006) is available, especially for the shallow western Mediterranean Sea (Table 1 in Supplementary Material).

Also for the other taxa, most information refers to the western basin, whereas the eastern sectors are relatively poorly investigated (Figure 3). The large-scale mapping of coralligenous
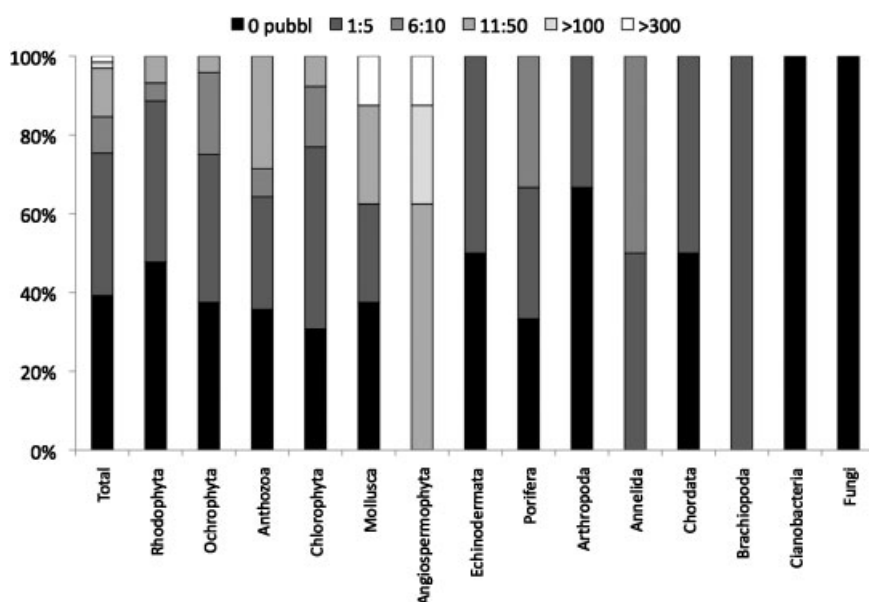

Figure 2. Cumulative and relative percentage of scientific publications of species/genera listed in the RAC/SPA classification list for each taxonomic group.
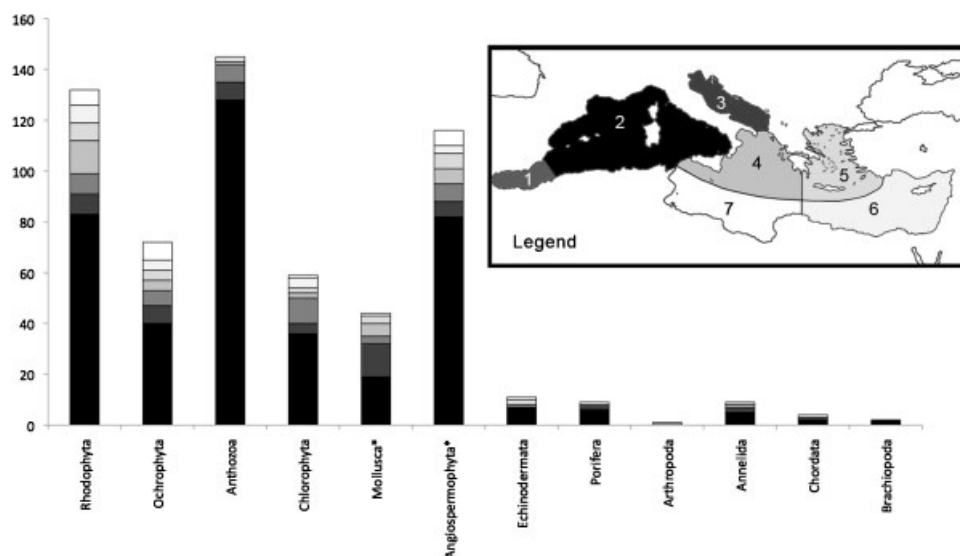

Figure 3. Total number of scientific publications for each taxonomic group with indication of the corresponding Mediterranean ecoregion, according to the classification by Spalding *et al.* (2007): 1–Alborán Sea; 2–Western Mediterranean; 3–Adriatic Sea; 4–Ionian Sea; 5–Aegean Sea; 6–Levantine Sea; 7–Tunisia Plateau / Gulf of Sidra. *Publications dealing with the seagrasses *Posidonia oceanica*, *Zostera marina*, *Cymodocea nodosa* and the bivalve *Mytilus galloprovincialis* were not considered in the analysis (see the text).

formations in the eastern basin is a noticeable exception (Georgiadis *et al.*, 2009). Assessments at a Mediterranean scale are not available for any of the entries present in the classification list, not even for geological features such as sand and rock as primary substrate or in terms of species assemblages and foundation taxa.

DISCUSSION

Overall, the results show that: (1) the classification scheme used in the Mediterranean Sea is still incomplete and needs optimization to be of use in conservation planning; (2) most entries on the list are not covered by the consulted Web-based resource, so lacking the basic ecological information justifying their selection to serve as a common reference for conservation priorities; and (3) large-scale information both on habitat types and associated species are largely lacking.

Phycologists provided a crucial contribution in building this inventory of Mediterranean habitats. However, the adoption of the traditional phytosociological approach characterizing previous classification schemes from which the RAC/SPA list derives, led to an over-representation of primary producers. Plant-based landscape classification schemes are appropriate in terrestrial domains, where vegetation is the main structural component of habitats. But they are not adequate in marine environments, where, together with algal species, sessile animals are often habitat-formers (Bianchi and Morri, 2000; Piraino *et al.*, 2002; Ballesteros, 2006). In this respect, a detailed list of algae of the genus *Cystoseira* can be considered crucial considering recent alarming information on their status (Perkol-Finkel and Airoldi, 2010). However, organisms such as *Dendropoma* spp. and *Ostrea edulis* are just two examples of species that should be also considered as top conservation priorities and included in the inventory together with the hydroid genus *Eudendrium* that, in the winter, takes the place of algae as an important habitat former (Boero *et al.*, 1986).

A close collaboration between specialists with different backgrounds, together with long-term financial commitment and improved communication between managers and researchers, should be a starting point to fill present gaps.

Furthermore, deep-sea habitats and the water column, both dominated by animals, deserve the same consideration given to shallow habitats. Instead, they are largely absent from the list, in spite of having a crucial role in the functioning of the whole basin (Mastrototaro *et al.*, 2010). This adds weight to calls for a critical revision of this classification list, as attempted by Fraschetti *et al.* (2008), especially considering the emergent focus on areas beyond national jurisdictions where only these habitats are represented (Howell, 2010).

Criteria for the inclusion of habitat and associated species should be clarified to demonstrate their ecological relevance, as all the recent efforts carried out in different geographical areas and ecological contexts suggest (Zacharias *et al.*, 1998; Connor *et al.*, 2004; Davies *et al.*, 2004; Snelder *et al.*, 2007; Costello, 2009; Howell, 2010). To implement sound classification systems, taxa should be selected across all taxonomic groups, capitalizing on the analysis of the accessible scientific information about their functional role, current conservation status, and distribution across the whole Mediterranean Sea

(not only the western portion). In parallel, a quantitative understanding of the vulnerability and/or sensitivity of habitats and species to the multiple stressors presently impinging on the basin must integrate the expert opinion approach (Halpern *et al.*, 2007, 2008). Although expert opinions can be used as a proxy for true impacts on habitats, they are not as meaningful as quantitative assessments, which are presently lacking. Better science is also needed to understand the functional role of habitats and species. Guarinello *et al.* (2010) proposed a multi-scale hierarchical framework with a particular focus on finer scale habitat classification levels, also providing conceptual schemes to guide habitat studies and management decisions in which the functional roles of species are characterized.

Most of the ambitious conservation goals to conserve biodiversity are habitat-directed since mapping the distributions of all species is unrealistic (Howell, 2010). Also, species-focused conservation and management attempts are liable to be ineffective, owing to current knowledge gaps, whereas a habitat approach is more feasible. Marine habitats such as reefs, seagrass meadows and deep-sea corals are socially and economically important, and they allow for ecosystem services that are estimated to be worth trillions of dollars to the global economy each year, irrespective of the species inhabiting them (Costanza *et al.*, 1997). The targets of achieving effective conservation of 10–30% of each of the world's ecological regions, and of greatly increasing the marine and coastal areas managed through marine protected areas by 2012, should correspond to systematic efforts towards large-scale mapping based on consistent habitat classifications, since the targets implicitly assume quantitative and standardized estimates of the surface area and level of representation of each habitat at both country and regional scales. At present, knowledge about the distribution of crucial habitats such as *Posidonia* beds, coralligenous formations, caves, and deep-sea corals is limited to a few initiatives carried out at local scale. Systematic analyses over the whole region are needed to increase our understanding of how multiple pressures can act in concert to influence these ecosystems, and to provide guidance regarding priority issues and focal areas for conservation action. The EU Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC, http://ec.europa.eu/environment/water/marine/index_en.htm) provides an unprecedented opportunity to integrate management of the many human uses and activities of the Mediterranean Sea. To support ecosystem-based management and marine spatial planning within the Mediterranean, the distribution of biodiversity at basin scale must become known, along with what activities occur where, and what are their cumulative impacts on marine ecosystems.

In conclusion, in spite of a general effort in harmonizing and standardizing information at the basin scale with initiatives carried out at the EU scale, Mediterranean-based attempts to provide habitat classification schemes represent a relevant starting point that needs to be refined for selecting sites of conservation interest within the framework of marine spatial planning. Improved inventories of marine habitats are urgently needed to support accurate and consistent mapping activities at the basin scale. Large-scale information and sound habitat classifications will allow the biodiversity heritage to be estimated more accurately and to reverse habitat loss rates through proper application of conservation measures that

respect targets and deadlines which, for the moment, are systematically not met.

REFERENCES

Abdulla A, Gomei M, Maison E, Piante C. 2008. *Status of Marine Protected Areas in the Mediterranean Sea.* International Union for Conservation of Nature (IUCN): Malaga, Spain; and World Wildlife Fund (WWF): France.

Airoldi L, Beck MW. 2007. Loss, status and trends for coastal marine habitats of Europe. *Oceanography and Marine Biology: An Annual Review* **45**: 345–405.

Allison GW, Lubchenco J, Carr MH. 1998. Marine reserves are necessary but not sufficient for marine conservation. *Ecological Applications* **8**: S79–S92.

Anonymous. 1988. Inventaire du Patrimoine Naturel. Programme National d'Inventaire des Zones Naturelles d'Intérêt Ecologique Faunistique et Floristique. Zones Marines. Région Provence-Alpes-Côte d'Azur, Ministère de l'Environnement. Tomes 1 et 2.

Anonymous. 1991. Commission of the European Communities. - CORINE biotopes, Office for Official Publications of the European Communities for Commission of the European Communities, Luxembourg, 1st ed. 300 pp.

Anonymous. 1992. Directive 92/43/CEE du Conseil du 21 mai 1992. *Journal des Communautés européennes* **22**. (7. 92N L 206/7-N L 206/50).

Ballesteros E. 2006. Mediterranean coralligenous assemblages: a synthesis of present knowledge. *Oceanography and Marine Biology: An Annual Review* **44**: 123–195.

Bellan-Santini D, Lacaze JC, Poizat C. 1994. Les biocénoses marines et littorales de Méditerranée, Synthèse, menaces et perspectives. *Collection Patrimoines Naturels, Museum National d'Histoire Naturelle publ.* **19**.

Bellan-Santini D, Bellan G, Bitar G, Harmelin J, Pergent G. 2002. Handbook for Interpreting Types of Marine Habitat for the Selection of Sites to be Included in the National Inventories of Natural Sites of Conservation Interest. Ed. UNEP RAC/SPA, Tunis.

Benedetti-Cecchi L, Pannacciulli F, Bulleri F, Moschella PS, Airoldi L, Relini G, Cinelli F. 2001. Predicting the consequences of anthropogenic disturbance: large-scale effects of loss of canopy algae on rocky shores. *Marine Ecology-Progress Series* **214**: 137–150.

Bianchi CN, Morri C. 2000. Marine biodiversity of the Mediterranean Sea: situation, problems and prospects for future research. *Marine Pollution Bulletin* **40**: 367–376.

Boero F. 2003. State of knowledge of marine and coastal biodiversity in the Mediterranean Sea. Project for the preparation of a Strategic Action Plan for the conservation of biological diversity in the Mediterranean region. (Sap BIO). United Nations Environmental Programme, Regional Activity Centre for Specially Protected Areas, Tunis.

Boero F, Balduzzi A, Bavestrello G, Caffa B, Cattaneo-Vietti R. 1986. Population dynamics of *Eudendrium glomeratum* (Cnidaria: Anthomedusae) on the Portofino Promontory (Ligurian Sea). *Marine Biology* **92**: 81–85.

Boero F, Bouillon J, Gravili C, Miglietta MP, Parsons T, Piraino S. 2008. Gelatinous plankton: irregularities rule the world (sometimes). *Marine Ecology-Progress Series* **356**: 299–310.

Boudouresque CF, Ruitton S, Verlaque M. 2005. Large-scale disturbances, regime shift and recovery in littoral systems subject to biological invasions. In *Large-scale Disturbances (Regime Shifts) and Recovery in Aquatic Ecosystems: Challenges for Management Towards Sustainability.* Velikova V, Chipev N (eds). UNESCO Publisher: 85–101.

Boudouresque CF, Bernard G, Pergent G, Shili A, Verlaque M. 2009. Regression of Mediterranean seagrasses caused by natural processes and anthropogenic disturbances and stress: a critical review. *Botanica Marina* **52**: 395–418.

Bruschetti M, Luppi T, Fanjul E, Rosenthal A, Iribarne O. 2008. Grazing effect of the invasive reef-forming polychaete *Ficopomatus enigmaticus* (Fauvel) on phytoplankton biomass in a SW Atlantic coastal lagoon. *Journal of Experimental Marine Biology and Ecology* **354**: 212–219.

Christia C, Papastergiadou ES. 2006. Ecological study of three lagoons of Amvrakikos Raivisar site, Greece. *Fresenius Environmental Bulletin* **15**: 1208–1215.

Claudet J, Fraschetti S. 2010. Human impacts on marine habitats: a regional meta-analysis in the Mediterranean Sea. *Biological Conservation* **143**: 2195–2206.

Coll M, Piroddi C, Kaschner K, Ben Rais Lasram F, Steenbeek J, Kaschner K, Lasram FBR, Aguzzi J, Ballesteros E, Bianchi CN et al. 2010. The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. *PLoS ONE* **5**: e11842.

Coma R, Linares C, Ribes M, Diaz D, Garrabou J, Ballesteros E. 2006. Consequences of a mass mortality in populations of *Eunicella singularis* (Cnidaria : Octocorallia) in Menorca (NW Mediterranean). *Marine Ecology-Progress Series* **327**: 51–60.

Connor D, Allen J, Golding N, Howell K, Lieberknecht L, Northen K, JBR. 2004. *The marine habitat classification for Britain and Ireland, version 04.05.* Joint Nature Conservation Committee (JNCC), UK.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill R, Paruelo J, Raskin RG, Sutton P, van den Belt M. 1997. The value of the world's ecosystem services and natural capital. *Nature* **387**: 253–260.

Costello MJ. 2009. Distinguishing marine habitat classification concepts for ecological data management. *Marine Ecology-Progress Series* **397**: 253–268.

Dauvin JC, Bellan G, Bellan-Santini D, Castric A, Comolet-Tirman J, Francour F, Gentil F, Girard A, Gofas S, Mahé C, Noël P, de Reviers B. 1994. Typologie des Znieff-Mer. Liste des paramètres et des biocénoses des côtes françaises metropolitaines. 2ème édition. *Museum National d'Histoire Naturelle*, Paris.

Dauvin JC, Bellan G, Bellan-Santini D. 2008. The need for clear and comparable terminology in benthic ecology. Part I. Ecological concepts. *Aquatic Conservation-Marine and Freshwater Ecosystems* **18**: 432–445.

Davies CE, Moss D. 1997. *EUNIS Habitat Classification.* European Environment Agency.

Davies CE, Moss D. 1999. *EUNIS Habitat Classification.* Version May 1999. European Topic Centre on Nature Protection and Diversity, Paris.

Davies CE, Moss D, Hill MO. 2004. EUNIS Habitat Classification Revised 2004.

Devilliers P, Devilliers-Terschuren J. 1996. A classification of Palaearctic habitats. *Conseil de l'Europe, Nature et environnement*, **78**.

Di Franco A, Milazzo M, Baiata P, Tomasello A, Chemello R. 2009. Scuba diver behaviour and its effects on the biota of a Mediterranean marine protected area. *Environmental Conservation* **36**: 32–40.

Diannelidis BE, Delivopoulos SG. 1997. The effects of zinc, copper and cadmium on the fine structure of *Ceramium ciliatum* (Rhodophyceae, Ceramiales). *Marine Environmental Research* **44**: 127–134.

Diawara M, Zouari-Tlig S, Rabaoui L, Hassine OKB. 2008. Impact of management on the diversity of macrobenthic communities in Tunis north lagoon: systematics. *Cahiers De Biologie Marine* **49**: 1–16.

European Environmental Agency. 2006. Priority issue in the Mediterranean environment. *EEA Report*, No 4, 92 pp. http://www.eea.europa.eu/publications/eea_report_2006_4.

EEA. 2009. Progress towards the European 2010 biodiversity target.

Ferretti F, Myers RA, Serena F, Lotze HK. 2008. Loss of large predatory sharks from the Mediterranean Sea. *Conservation Biology* **22**: 952–964.

Fraschetti S, Terlizzi A, Bevilacqua S, Boero F. 2006. The distribution of hydroids (Cnidaria, Hydrozoa) from micro- to macro-scale: Spatial patterns on habitat-forming algae. *Journal of Experimental Marine Biology and Ecology* **339**: 148–158.

Fraschetti S, Terlizzi A, Boero F. 2008. How many habitats are there in the sea (and where)? *Journal of Experimental Marine Biology and Ecology* **366**: 109–115.

Fraschetti S, Terlizzi A, Guarnieri G, Pizzolante F, D'Ambrosio P, Maiorano P, Beqiraj S, Boero F. 2011. Effects of unplanned development on marine biodiversity: a lesson from Albania (central Mediterranean Sea). *Journal of Coastal Research* **58**: 106–115.

Georgiadis M, Papatheodorou G, Tzanatos E, Geraga M, Ramfos A, Koutsikopoulos C, Ferentinos G. 2009. Coralligene formations in the eastern Mediterranean Sea: Morphology, distribution, mapping and relation to fisheries in the southern Aegean Sea (Greece) based on high-resolution acoustics. *Journal of Experimental Marine Biology and Ecology* **368**: 44–58.

Guarinello ML, Shumchenia EJ, King JW. 2010. Marine habitat classification for ecosystem-based management: a proposed hierarchical framework. *Environmental Management* **45**: 793–806.

Halpern BS, Selkoe KA, Micheli F, Kappel CV. 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. *Conservation Biology* **21**: 1301–1315.

Halpern BS, Walbridge S, Selkoe KA, Kappel CV, Micheli F, D'Agrosa C, Bruno JF, Casey KS, Ebert C, Fox HE, *et al.* 2008. A global map of human impact on marine ecosystems. *Science* **319**: 948–952.

Heiman KW, Vidargas N, Micheli F. 2008. Non-native habitat as home for non-native species: comparison of communities associated with invasive tubeworm and native oyster reefs. *Aquatic Biology* **2**: 47–56.

Howell KL. 2010. A benthic classification system to aid in the implementation of marine protected area networks in the deep/high seas of the NE Atlantic. *Biological Conservation* **143**: 1041–1056.

Jackson JBC, Kirby MX, Berger WH, Bjorndal KA, Botsford LW, Bourque BJ, Bradbury RH, Cooke R, Erlandson J, Estes JA *et al.* 2001. Historical overfishing and the recent collapse of coastal ecosystems. *Science* **293**: 629–637.

Kershaw S. 2000. Quaternary reefs of northeastern Sicily: Structure and growth controls in an unstable tectonic setting. *Journal of Coastal Research* **16**: 1037–1062.

Last PR, Lyne VD, Williams A, Davies CR, Butler AJ, Yearsley GK. 2010. A hierarchical framework for classifying seabed biodiversity with application to planning and managing Australia's marine biological resources. *Biological Conservation* **143**: 1675–1686.

Lejeusne C, Chevaldonne P, Pergent-Martini C, Boudouresque CF, Perez T. 2010. Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. *Trends in Ecology & Evolution* **25**: 250–260.

Lester SE, McLeod KL, Tallis H, Ruckelshaus M, Halpern BS, Levin PS, Chavez FP, Pomeroy C, McCay BJ, Costello C *et al.* 2010. Science in support of ecosystem-based management for the US West Coast and beyond. *Biological Conservation* **143**: 576–587.

Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MK, Kidwell SM, Kirby MX, Peterson CH, Jackson JBC. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science* **312**: 1806–1809.

Lubchenco J, Palumbi SR, Gaines SD, Andelman S. 2003. Plugging a hole in the ocean: the emerging science of marine reserves. *Ecological Applications* **13**: S3–S7.

Mangialajo L, Ruggieri N, Asnaghi V, Chiantore M, Povero P, Cattaneo-Vietti R. 2007. Ecological status in the Ligurian Sea: the effect of coastline urbanisation and the importance of proper reference sites. *Marine Pollution Bulletin* **55**: 30–41.

Mastrototaro F, D'Onghia G, Corriero G, Matarrese A, Maiorano P, Panetta P, Gherardi M, Longo C, Rosso A, Sciuto F *et al.* 2010. Biodiversity of the white coral bank off Cape Santa Maria di Leuca (Mediterranean Sea): An update. *Deep-Sea Research Part Ii-Topical Studies in Oceanography* **57**: 412–430.

Pérès JM, Picard J. 1964. Nouveau manuel de bionomie benthique de la Méditerranée. *Recueil des Travaux de la Station Marine d'Endoume* **31**: 1–37.

Pergent-Martini C, Pasqualini V, Ferrat L, Pergent G. 2006. Ecological data in integrated coastal zone management: case study of *Posidonia oceanica* meadows along the Corsican coastline (Mediterranean Sea). *Environmental Management* **38**: 889–895.

Perkol-Finkel S, Airoldi L. 2010. Loss and recovery potential of marine habitats: an experimental study of factors maintaining resilience in subtidal algal forests at the Adriatic Sea. *Plos One* **5**: e10791.

Piraino S, Fanelli G, Boero F. 2002. Variability of species' roles in marine communities: change of paradigms for conservation priorities. *Marine Biology* **140**: 1067–1074.

Riedl R. 1959. Die Hydroiden des Golfes von Neapel und ihr Anteil an der Fauna unterseeischer Höhlen. Ergebnisse der Österreichischen Tyrrhenia-Expedition 1952, Teil XVI. *Pubblicazione della Stazione Zoologica di Napoli* **30**: 591–755.

Sales M, Ballesteros E. 2009. Shallow *Cystoseira* (Fucales: Ochrophyta) assemblages thriving in sheltered areas from Menorca (NW Mediterranean): relationships with environmental factors and anthropogenic pressures. *Estuarine Coastal and Shelf Science* **84**: 476–482.

Santangelo G, Bramanti L, Iannelli M. 2007. Population dynamics and conservation biology of the over-exploited Mediterranean red coral. *Journal of Theoretical Biology* **244**: 416–423.

Schwindt E, Iribarne OO. 2000. Settlement sites, survival and effects on benthos of an introduced reef-building polychaete in a SW Atlantic coastal lagoon. *Bulletin of Marine Science* **67**: 73–82.

Schwindt E, De Francesco CG, Iribarne OO. 2004. Individual and reef growth of the invasive reef-building polychaete *Ficopomatus enigmaticus* in a south-western Atlantic coastal

lagoon. *Journal of the Marine Biological Association of the United Kingdom* **84**: 987–993.

Snelder TH, Leathwick JR, Dey KL, Rowden AA, Weatherhead MA, Fenwick GD, Francis MP, Gorman RM, Grieve JM, Hadfield MG *et al.* 2007. Development of an ecologic marine classification in the New Zealand region. *Environmental Management* **39**: 12–29.

Spalding MD, Fox HE, Allen GR, Davidson N, Ferdaña ZA, Finlayson M, Halpern BS, Jorge MA, Lombana A, Lourie SA *et al.* 2007. Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. *BioScience* **57**: 573–583.

Thébault H, Rodriguez Y, Baena AM, Andral B, Barisic D, Benedicto Albaladejo J, Bologa AS, Boudjenoun R, Delfanti R, Egorov V *et al.* 2008. ^{137}Cs Baseline levels in the Mediterranean and Black Sea: a cross-basin survey of the CIESM Mediterranean Mussel Watch Programme. *Marine Pollution Bulletin* **57**: 801–806.

Thibaut T, Pinedo S, Torras X, Ballesteros E. 2005. Long-term decline of the populations of Fucales (*Cystoseira* spp. and Sargassum spp.) in the Alberes coast (France, North-western Mediterranean). *Marine Pollution Bulletin* **50**: 1472–1489.

UNEP/MAP. 2005. Review and Assessment of National Strategies for Sustainable Development in the Mediterranean region, United Nations Environment Programme/Mediterranean Action Plan, Athens, Greece.

UNEP-MAP-RAC/SPA. 2006. Classification of Benthic Marine Habitat Types for the Mediterranean Region, UNEP RAC SPA, Tunis.

Wabnitz CCC, Andrefouet S, Muller-Karger FE. 2010. Measuring progress toward global marine conservation targets. *Frontiers in Ecology and the Environment* **8**: 124–129.

Wood LJ, Fish L, Laughren J, Pauly D. 2008. Assessing progress towards global marine protection targets: shortfalls in information and action. *Oryx* **42**: 340–351.

Worm B, Barbier EB, Beaumont N, Duffy JE, Folke C, Halpern BS, Jackson JBC, Lotze HK, Micheli F, Palumbi SR *et al.* 2006. Impacts of biodiversity loss on ocean ecosystem services. *Science* **314**: 787–790.

Zacharias MA, Howes DE, Harper JR, Wainwright P. 1998. The British Columbia Marine Ecosystem Classification: rationale, development, and verification. *Coastal Management* **26**: 105–124.