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Journal of Maps
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tjom20

Characterization and evaluation of a marine protected area: 'Tavolara - Punta Coda Cavallo' (Sardinia, NW Mediterranean)

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Version of record first published: 11 Mar 2013.

To cite this article: A. Rovere , F. Ferraris , V. Parravicini , A. Navone , C. Morri & C.N. Bianchi (2013): Characterization and evaluation of a marine protected area: 'Tavolara - Punta Coda Cavallo' (Sardinia, NW Mediterranean), Journal of Maps, DOI:10.1080/17445647.2013.778081

To link to this article: http://dx.doi.org/10.1080/17445647.2013.778081

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Journal of Maps, 2013
http://dx.doi.org/10.1080/17445647.2013.778081

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SCIENCE

Characterization and evaluation of a marine protected area: 'Tavolara – Punta Coda Cavallo' (Sardinia, NW Mediterranean)

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(*Received 25 February 2012; Resubmitted 21 January 2013; Accepted 14 February 2013*)

Habitat mapping plays a key role in the management and conservation of natural systems. In protected areas, where sustainable development is always subordinate to conservation efforts, maps are largely used to represent habitats, development pressures, tourist facilities or legal restrictions such as the zoning of a protected area. Some authors have recently developed a methodology that allows the production of a set of maps for the management of marine protected areas. In this paper, we present the application of this methodology to the case study of the marine protected area 'Tavolara Punta Coda Cavallo'.

Keywords: marine protected area; Sardinia; habitats map; diagnostic cartography

1. Introduction

The European Union (EU; Council Directive 92/43/EEC) defines Marine Protected Areas (MPAs) as territories where conservation and management measures for coastal marine environments must be implemented and new approaches tested (Agardy et al., 2003; Francour, Harmelin, Pollard, & Sartoretto, 2001; Guidetti et al., 2008; Jameson, Tupper, & Ridley, 2002).

Cartography is an essential tool to represent the spatial aspects of natural environments (Tricart & Kilian, 1985). Modern cartographic tools are used inside MPAs to map the distribution of natural features and to link them with other environmental landmarks (Salm, Clark, & Siirila, 2000), to identify zones with different protection regimes (Villa, Tunesi, & Agardy, 2002), to analyze spatial relationships between habitats and zones (Bianchi, 2007; Fraschetti et al., 2005; Friedlander, Brown, & Monaco, 2007; Montefalcone et al., 2011; Rovere et al., 2010a, 2010b; Rovere, Parravicini, Firpo, Morri, & Bianchi, 2011) and to identify networks of marine reserves (Leslie, Ruckelshaus, Ball, Andelman, & Possingham, 2003).

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Bianchi, Parravicini, Montefalcone, Rovere, and Morri (2012) proposed a methodology to produce a series of maps for the management of MPAs starting from field data on habitats and species. In this paper, we apply that methodology to the MPA 'Tavolara Punta Coda Cavallo', NW Mediterranean.

2. Study area

The Tavolara-Punta Coda Cavallo MPA (40°35.20′N; 09°48.50′E) is located in North-East Sardinia, Italy. From a geomorphological perspective, high cliffs, interrupted by narrow coastal plains and coastal lagoons, compose the mainland. Two major islands characterize the continental shelf: Tavolara and Molara Islands. From a lithological perspective, the entire study area is composed of granitic bedrock of Ercinic origin (304–251 Myr). The only exception is Tavolara Island, composed almost entirely of Jurassic (201–145 Myr) limestone.

The MPA was established in 1997 due to its peculiar natural, geological and historical values. The MPA is divided into three different zones, subjected to different protection levels:

(i) **Zone A**: access is granted to the MPA staff and researchers for scientific/monitoring activities approved by the management of the MPA. In this zone, visits are possible, but guided by the MPA staff.
(ii) **Zone B**: navigation is allowed, but at low speed. MPA management regulates SCUBA activities. Fishing activities are allowed, but with techniques that do not damage the seabottom, and only if performed by professional fishermen of municipalities within the MPA. The MPA management regulates the amount of daily fished material.
(iii) **Zone C**: navigation is allowed, and MPA management regulates anchoring. Diving activities are permitted. Fishing activities are allowed as in Zone B, plus angling, regulated by MPA management.

3. Material and methods

The procedure reported in Bianchi et al. (2012) is composed of two steps (1) characterization (to identify types), and (2) evaluation (to define status and values) of the marine territory. Bianchi et al. (2012) suggest three thematic maps for characterization: (i) morphobathymetry and sedimentology, (ii) habitats; and, (iii) natural emergencies. The maps for environmental evaluation are: (i) environmental degradation and risk; (ii) vulnerability; (iii) potential environmental quality; and, (iv) susceptibility to human use.

Data available in the study area did not allow the compilation the maps of morphobathymetry and sedimentology (characterization) and environmental degradation and risk (evaluation). This does not hinder the production of the other maps listed above.

While the habitat map is drawn following the distribution of habitats and related features, the other maps report the information according to territorial units (hereafter TUs) corresponding to submultiples of the UTM grid. Territorial units (grid cells) are assigned to one of five classes of evaluation, ranging from 'high necessity of conservation or protection' to 'non-problematic, unimportant or already compromised' (according to the specific map) situations.

For a detailed description on the methods used to calculate the indices as the basis for each map, and for the choice of elements and cartographic symbols, we refer the reader to Bianchi et al. (2012).

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Table 1. Codes of habitat classification adopted by the EU and assigned to the benthic assemblages in the habitats map.

Name in the habitats map	CORINE	Natura 2000	RAC SPA	EUNIS
Lagoon and paralic assemblages	21	1150	III.1.1.	X03
Supralittoral and midlittoral sands	14	1140	I.2.1. II.2.1.	A2
Supra- and midlittoral rocks	18.01	1170	I.4.1. II.4.1. II.4.2.	A1
Lithophyllum lichenoides ledge	11.252	1170	II.4.2.1.	A1.141
Patella ferruginea belt	18.12	1170	II.4.2.	A1.14
Well sorted terrigenous sands	11.22	1110 1160	III.2.2.	A4.23
Posidonia oceanica meadow on matte	11.34	1120	III.5.1.	A4.56
Posidonia oceanica meadow on sand	11.34	1120	III.5.1.	A4.56
Discontinuous *P. oceanica* meadow on sand	11.34	1120	III.5.1.	A4.56
Discontinuous *P. oceanica* meadow on rock	11.34	1120	III.5.1.	A4.56
Photophilic algae	11.24 11.25	1170	III.6.1.	A3.15
Emisciaphilous algae	11.24 11.25	1170	III.6.1.	A3.15
Sciaphilous algae/precoralligenous	11.24 11.25	1170	III.6.1. IV.3.1.	A3.25J
Coralligenous	11.251	1170	IV.3.1.	A3.73
Caves	11.26	8330	IV.3.2. V.3.2.	A3.B21
Coastal detritic bottom with bryozoans	11.22	1160	IV.2.2.	A4.45
Maërl	11.22	1160	IV.2.2.2.	A4.613
Muddy detritic bottoms with scaphopods	11.22	1160	IV.2.1.	A4.28
Sticky muds with sessile epibiota	11.22	1160	IV.1.1.3.	A4.343

3.1 *Characterization of the marine territory*

3.1.1 *Habitats map*

The habitats map (Main Map) presented in this study has been re-drawn and updated from that compiled by Navone, Bianchi, Orru, and Ulzega (1992). The map was originally obtained through direct and indirect surveys. Indirect techniques adopted were analysis of aerial photographs and side scan sonar surveys. Direct surveys were carried out using SCUBA scientific diving techniques (Bianchi et al., 2004; Vacchi, Rovere, & Schiaffino, 2012), bottom dredging and remotely operated vehicle inspections. In 2006, a validation and update of the habitats map was carried out, both with the analysis (and in some case re-analysis) of SCUBA survey campaigns spanning 1989–2005 and with the collection and re-interpretation of data from the literature (Addis et al., 2004; Bianchi & Morri, 1994; Bianchi, Morri, & Navone, 2010; Cattaneo-Vietti, Chemello, & Trainito, 1992; Calvisi, Trainito, Pais, Franci, & Schiaparelli, 2003; Ceccherelli et al., 2004; Ceccherelli, Casu, Pala, Pinna, & Sechi, 2006; Ceccherelli, Casu, & Sechi, 2003; Ceccherelli, Casu, & Sechi, 2005; Cossu & Gazale, 1996a, 1996b, 1999; Cossu, Gazale, & Baroli, 1992; Cudoni & Chessa, 1991; Guidetti and Cattaneo-Vietti, 2002; Guidetti et al., 2004; Murenu et al., 2005; Pais, Trainito, Romor, & Contis, 1992; Pais, Chessa, Serra, Mura, & Ligios 1999; Schiaparelli, Guidetti, & Cattaneo-Vietti, 2003).

Benthic assemblages have been derived from the map by Navone et al. (1992), and have been assimilated to marine habitat classifications proposed by European Community directives and national laws: CORINE, Natura 2000 EUR, RAC SPA, EUNIS (Table 1).

Other than the distribution of habitats, the habitats map reports information on the following ecological dynamics:

(1) *Shaded lower limit* and *Eroded lower limit*. These refer to the type of lower limit of the Mediterranean seagrass *P. oceanica* meadow as defined by Montefalcone (2009). *Shaded lower limit* refers to meadows that exhibit regularly decreasing cover as they approach

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their maximum depth. *Eroded lower limit* refers to meadows exhibiting high cover to their maximum depth, where cover abruptly drops to zero and a pronounced matte step is evident. The type of lower limit provides information on the factors governing the seaward progradation of the seagrass meadow; shaded limits are due to light extinction with depth, eroded limits to bottom currents.

(2) *Offshore influence (prelittoral ensemble)*. The prelittoral ensemble refers to marine habitats typically belonging to offshore sectors (i.e. the outer continental shelf and edge). Species typical of these habitats may occasionally be found within the continental shelf indicating an offshore influence on continental habitat (e.g. due to bottom currents).

(3) *Biotic supply (frontolittoral ensemble)*. The frontolittoral ensemble refers to coastal habitats usually belonging to the inner continental shelf. As a result of currents, frontolittoral habitats (e.g. *Posidonia oceanica*) represent an organic supply toward the prelittoral ensemble.

(4) *Transition communities*. This refers to those assemblages where species composition appears as a mixture of two neighboring assemblages. For instance, sand communities and mud communities are usually separated by a mixed community.

(5) *Mineral and organic settling.* These refer to areas where indicator species point to an excess settling of fine material, either mineral or organic (or both).

(6) *Climax.* Traditionally refers to the end stage of an ecological succession (*P. oceanica* is thought to be a climax community). The term refers to mature communities which are relatively stable across time and thus mainly controlled by climatic conditions.

(7) *Edaphic control*. Contrary to the climax, communities under edaphic control are governed by local factors. Those communities are thus not in equilibrium with regional climatic conditions.

(8) *Anthropogenic degradation*. When evident signs of degradation caused by human activities are present (e.g. signs of trawling or angling; Parravicini et al., 2010)

(9) *Biotic disturbance* (overgrazing). Typically refers to rocky reef communities, the term refers to habitats where the typical 'linear' food chain (i.e. algae-urchins-fishes) is unbalanced (e.g. because of overfishing) leading to the proliferation of sea-urchins overgrazing upon algal communities.

3.1.2 *Natural emergencies map*

A natural emergency is a natural feature that requires intervention to prevent a worsening of the environmental status. In conservation biology, the term 'emergencies' usually refers to species or habitats that, because of their natural value, have to be considered as part of the biological and ecological heritage of a site (Bianchi et al., 2012).

In this map (Main Map), species and habitats protected by international conventions and EU directives concur with the definition of areas where protected species/habitats occur, and the level of protection they require (e.g. strict protection, management, detention, commerce or transport prohibited). Most of these species and habitats are today included in international conventions and EU directives that are being enacted as national laws. The EU Habitats Directive allows the listing of habitats, whilst other conventions only consider species. The Habitats Directive focuses primarily on terrestrial habitats; the only marine 'priority habitats' are *Posidonia oceanica* meadows and coastal lagoons. Thus, protected habitats were of limited utility in the development of a territorial index aimed at representing the level of protection required. In addition, *P. oceanica* is also listed as a protected species, causing redundancy.

To build the natural emergencies map, we used an index based only on protected species which were divided into three groups. The first group includes species in need of strict protection, as explicitly stated in Annex IV of the Habitats Directive. By analogy, the species listed in Appendices 1 and 2 of the Bern Convention (special protection), Annex II of the Habitats Directive (species requiring designation of special areas of conservation) and Annex II of the Barcelona Convention (threatened species) are added to this group. The second group includes species that require management. Such species are listed in Annex V of the Habitats Directive (where removal from the wild can be restricted) or in Annex III of the Barcelona Convention (whose exploitation is regulated). Similarly, the species listed in Appendix 3 of the Bern Convention need appropriate and necessary legislative and administrative measures. The third group includes those endangered species whose trading is limited but for which no particular conservation measure in the wild is required. These are the species listed in the Annexes of the Washington Convention on the International Trade in Endangered Species of wild fauna and flora (CITES).

To represent visually on the map the level of protection required by law, each cell was ranked according to the occurrence of species belonging to the three groups and then assigned a specific color according to the following scale:

(1) Red: occurrence of at least one species of the first group (strict protection required);
(2) Orange: occurrence of two or more species of the second group (management required);
(3) Yellow: occurrence of one species of the second group (management required);
(4) Light green: occurrence of at least one species of the third group (trade regulated);
(5) Dark green: no protected species are present.

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3.2 *Evaluation of the marine environment*

Environmental evaluation procedures address issues related to both environmental impact and management and protection plans (Roberts et al., 2003; Leslie, 2005). They are used to assess the value of the quantity and quality of a manageable area in a territory, though they can also be used to compare the natural values of different areas, or of the same area, through time, providing important information for projects of use (in the first case) or for the estimation of the effects of the use (in the second case).

In every environmental evaluation procedure, the information derived from the typology of environmental units (habitats, biocoenoses, associations, facies) is compared with the characteristics of the species and their economic or environmental value or with their sensitivity to environmental changes (Merson, Merson, Odorico, Falace, & Altobelli, 2006).

3.2.1 *Vulnerability map*

Vulnerability is defined as the capability of a habitat to maintain its structure and its functions when facing real or potential negative influence (Bianchi et al., 2012). The higher the vulnerability, the higher the probability of habitat alteration due to an impact. The map (Main Map) gives information on the level of vulnerability of each territorial unit and on the location of more vulnerable ecosystems.

Habitats identified in the habitat map were matched as far as possible to those of the RAC SPA list, which assigns individual habitats with three distinct levels of vulnerability: elevated, intermediate, and scarce. Habitats with elevated vulnerability were scored ‘3’, habitats with intermediate vulnerability were scored ‘2’, habitats with scarce vulnerability were scored ‘1’. The vulnerability score of each habitat was then divided by the number of cells where the habitat is present, in order to weight its vulnerability with respect to frequency across the whole area.

In order to switch from the (weighted) vulnerability of a single habitat to that of a TU, the scores of vulnerability of the habitats in each cell were summed as:

$$Vt_j = S_i^m (Vh_i \times S_i^{-1})$$

where Vt_j is the weighted vulnerability of the territorial unit j, m is the number of habitats in the cell j, Vh_i is the vulnerability of the habitat i, S_i is the number of cells where the habitat j is present and $Vh_i \times S_i^{-1}$ is the weighted vulnerability of the habitat i.

Cells are then divided into five classes ordered by decreasing weighted vulnerability, and the corresponding cells are represented on the map with different colors.

3.2.2 *Potential environmental quality map*

Potential quality is expressed, directly or indirectly, in terms of natural capital 'contained' or expressed by the environment. The higher the natural capital, the higher the environmental quality. The concept of natural capital has been recently developed in the framework of bio-economy or ecological economy (Costanza et al., 1997).

The map of potential quality of the marine territory (Main Map) gives information on the value of the marine environment, and finds application in cases where a comparison between natural and human or financial capital is required.

While in the case of an MPA conservation will always be the priority, the following activities may occur: (1) education and training in TUs with naturalist value prevailing; (2) sustainable use of natural resources (traditional artisanal fishery) in TUs with economic value prevailing; (3) sustainable ecotourism (including diving) in TUs with esthetic value prevailing and (4) scientific research in TUs with rarity value prevailing.

Computation of potential quality incorporates information from the habitat map. Habitats identified for inclusion were matched as far as possible to those of the RAC SPA list in order to assign them with the proposed natural, economic, esthetic and rarity scores. Each score ranges from 1 (lowest value) to 3 (highest values), and the four scores for each habitat are then integrated into a synthetic index using the following formula:

$$Qh_i = (N_i \times E_i \times A_i \times R_i) \times k^{(1-n)}$$

where Qh_i is the synthetic index of quality for the habitat i; N_i, E_i, A_i, and R_i are the scores of naturalistic, economic, esthetic and rarity values of the habitat i, respectively; k is the maximum value possible (3 in this case) and n is the number of values adopted (4 in this case).

To shift from habitat quality to environmental quality, the quality of the single habitats inside a territorial unit have been summed. The map user is then informed about the prevailing value of the natural capital contained in each cell, superimposing symbols on the background color: ♥ = naturalistic value; ♦ = economic value; ♣ = esthetic value; ♠ = rarity value.

3.2.3 *Map of susceptibility to use*

The map of the susceptibility to use (Main Map) provides indications on the possibility to use a given site for different purposes. It is of primary importance as tool for the choices of territorial planning and in the examination of the conflicts between conservation and development, and can be therefore considered the most important for urgent MPA needs among the evaluation maps presented here.

Whilst the map of vulnerability considers only habitats, the map of susceptibility to use merges the information on the occurrence of protected species together with that of important

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habitats. With regard to protected species, the map of susceptibility to use considers their total number within each cell, in contrast with the map of natural emergencies that highlights the imposed level of protection rather than the total number. Following the logic of emergencies, a strictly protected species is more important than several species that require management measures; in terms of susceptibility to use, however, the occurrence of a number of protected species decreases the availability of a site.

As regards habitat importance, the map of susceptibility to use adopts a three level classification: (i) determinant habitats, whose conservation is mandatory; (ii) remarkable habitats, which deserve specific management attention limiting their use; (iii) unimportant habitats, lacking specific value and therefore available for sustainable use. Habitats identified for inclusion in the map were matched as far as possible to those of the RAC SPA list; then, a score of 3 was assigned to determinant habitats, 2 to remarkable habitats, 1 to unimportant habitats.

The total importance of each TU is computed by summing the importance scores for each individual habitat. Following a linear regression between the total habitat importance and the number of protected species in each cell, an index of susceptibility to use was computed according to the following formula:

$$St_j = \{[S_i^m(Ih_i)]^2 + Eb_j^2\}^{-1/2}$$

where St_j is the index of susceptibility to use for the cell j; m is the number of habitats in the cell j, Ih_i is the importance (scored 1 to 3) of the habitat I; Eb_j is the number of protected species in the cell j. The map of susceptibility to use also contains information about the number of determinant habitats inside each cell, to help evaluate conservation needs: cells with 3, 4, or 5 determinant habitats are marked with black circles of increasing size. The map of susceptibility to use provides a more effective and ductile tool than the mere concept of ‘strict protection’ highlighted by the map of marine natural emergencies.

Cells were then divided into five classes ordered by decreasing susceptibility to use, and colored differently

4. Conclusions

In this study a set of maps of the marine territory in the Marine Protected Area ‘Tavolara Punta Coda Cavallo’ were produced (Main Map). European Union regulations and conventions for the protection of marine environment were translated into indices, which were then associated with habitats and species. This approach is aimed at developing a ‘ready-to-use’ toolbox for MPA managers, which have the possibility, through the maps, to identify areas subject to different susceptibility to use, potential quality, or vulnerability in order to direct conservation efforts or plans for sustainable development of their territory.

These tools can be used in any marine territory where habitat and species distributions are known. The methodology can be easily modified to implement different protection schemes (e.g. regional or local laws, non-EU laws for territories outside the EU). Similar approaches have been successfully applied in other Italian MPAs (Bianchi, 2007; Parravicini et al., 2011), and could provide a first response to the demand of implementation of spatially explicit approaches to marine environmental conservation as asked by the ‘Marine Strategy Directive’ (Directive EC 2008/56).

Software

Esri ArcGIS 9.2 was used to create the maps presented in this study.

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References

Addis, P., Ceccherelli, G., Murenu, M., Farci, S., Ferrari, A., Olita, A., . . . Sechi, N. (2004). Caratterizzazione delle biocenosi associate a Cystoseira spp. in tre Aree Marine Protette della Sardegna. *Biologia Marina Mediterranea*, *11*(2), 397–399.

Agardy, T., Bridgewater, P., Crosby, M., Day, J., Dayton, P., Kenchington, R., . . . Peau, L. (2003). Dangerous targets? Unresolved issues and ideological clashes around marine protected areas. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *13*(4), 353–367.

Bianchi, C. N. (2007). From bionomic mapping to territorial cartography, or from knowledge to management of marine protected areas. *Biologia Marina Mediterranea*, *14*(2), 22–51.

Bianchi, C. N., & Morri, C. (1994). Studio bionomico comparativo di alcune grotte marine sommerse: definizione di una scala di confinamento. *Memorie dell'Istituto Italiano di Speleologia*, *6*(2), 107–123.

Bianchi, C. N., Morri, C., & Navone, A. (2010). The biological assemblages of submerged rocky reefs in the Marine Protected Area of Tavolara Punta Coda Cavallo (north-east Sardinia, Italy). *Scientific Reports of the Port-Cros National Park*, *24*, 39–85.

Bianchi, C. N., Parravicini, V., Montefalcone, M., Rovere, A., & Morri, C. (2012). The challenge of managing marine biodiversity: A practical toolkit for a cartographic, territorial approach. *Diversity*, *4*, 419–452.

Bianchi, C. N., Pronzato, R., Cattaneo-Vietti, R., Benedetti-Cecchi, L., Morri, C., Pansini, M., . . . Terlizzi, A. (2004). Mediterranean marine benthos: a manual of methods for its sampling and study. 6: Hard bottoms. *Biologia Marina Mediterranea*, *11*(suppl. 1), 185–215.

Calvisi, G., Trainito, E., Pais, M., Franci, G., & Schiaparelli, S. (2003). Prima segnalazione di un episodio di mortalità di gorgonacei lungo la costa dell'Isola di Tavolara (Sardegna Settentrionale). *Biologia Marina Mediterranea*, *10*(2), 506–508.

Cattaneo-Vietti, R., Chemello, R., & Trainito, E. (1992). An account of the Opisthobranchs of North Eastern Sardinia with a record of *Cerberilla bernadettae* Tardy, 1965 (Nudibranchia: Aeolidiina). *Lavori della Società italiana di Malacologia*, *24*, 61–68.

Ceccherelli, G., Casu, D., Pala, D., Floris, A., Castelli, A., Curini-Galletti, M., & Sechi, N. (2004). Prime valutazioni sull'effetto di tutela nell'Area Marina Protetta di Tavolara – Capo Coda Cavallo (Sardegna Nord-Orientale). *Biologia Marina Mediterranea*, *11*(2), 406–407.

Ceccherelli, G., Casu, D., Pala, D., Pinna, S., & Sechi, N. (2006). Evaluating the effects of protection on two benthic habitats at Tavolara-Punta Coda Cavallo MPA (North-East Sardinia, Italy). *Marine environmental research*, *61*(2), 171–185.

Ceccherelli, G., Casu, D., & Sechi, N. (2003). The spatial variation of intertidal algal turfs at Tavolara – Capo Coda Cavallo MPA (NE Sardinia): The geographical vs protection effect. 38th European Marine Biology Symposium, Aveiro, Portugal.

Ceccherelli, G., Casu, D., & Sechi, N. (2005). Spatial variation of intertidal algal turf at Tavolara – Capo Coda Cavallo MPA (Sardinia North-East): The geographical vs. protection effect. *Marine Environmental Research*, *59*(5), 533–546.

Cossu, A., & Gazale, V. (1996a). Contributo alla conoscenza del fitobenthos dell'area compresa tra Capo Ceraso, Tavolara e Capo Coda Cavallo (NE Sardegna). *Bollettino dell'Accademia Gioenia di Scienze naturali di Catania*, *29*, 185–198.

Cossu, A., & Gazale, V. (1996b). Incidenza dei principali fattori ambientali sullo sviluppo delle concrezioni di *Lithophyllum lichenoides* Philippi nelle isole del Nord Sardegna. *Biologia Marina Mediterranea*, *3*(1), 447–450.

Cossu, A., & Gazale, V. (1999). Nuove segnalazioni per la flora marina bentonica della Sardegna. *Biologia Marina Mediterranea*, *6*(1), 268–371.

Cossu, A., Gazale, V., & Baroli, M. (1992). La flora marina della Sardegna: inventario delle alghe bentoniche. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology*, *126*(5), 651–707.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., . . . van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*, 253–260.

Cudoni, S., & Chessa, L. (1991). Present and past distribution of *Corallium rubrum* (L.) along the northern and central Sardinian coast. *Les especes marines à protéger en Méditerranée. GIS Posidonie*, 71–81.

Francour, P., Harmelin, J., Pollard, D., & Sartoretto, S. (2001). A review of marine protected areas in the northwestern Mediterranean region: siting, usage, zonation and management. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *11*(3), 155–188.

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Fraschetti, S., Terlizzi, A., Bussotti, S., Guarnieri, G., D'Ambrosio, P., & Boero, F. (2005). Conservation of Mediterranean seascapes: analyses of existing protection schemes. *Marine Environmental Research*, *59*(4), 309–332.

Friedlander, A., Brown, E., & Monaco, M. (2007). Coupling ecology and GIS to evaluate efficay of marine protected areas in Hawaii. *Ecological Applications*, *17*(3), 715–730.

Guidetti, P., Bianchi, C. N., Chiantore, M., Schiaparelli, S., Morri, C., & Cattaneo-Vietti, R. (2004). Living on the rocks: substrate mineralogy and the structure of subtidal rocky substrate communities in the Mediterranean Sea. *Marine Ecology Progress Series*, *274*, 57–68.

Guidetti, P., & Cattaneo-Vietti, R. (2002). Can mineralogical features influence distribution patterns of fish? A case study in shallow Mediterranean rocky reefs. *Journal of the Marine Biological Association of the UK*, *82*(06), 1043–1044.

Guidetti, P., Milazzo, M., Bussotti, S., Molinari, A., Murenu, M., Pais, A., . . . Tunesi, L. (2008). Italian marine reserve effectiveness: Does enforcement matter? *Biological Conservation*, *141*(3), 699–709.

Jameson, S., Tupper, M., & Ridley, J. (2002). The three screen doors: can marine "protected" areas be effective?. *Marine Pollution Bulletin*, *44*(11), 1177–1183.

Leslie, H. (2005). A synthesis of marine conservation planning approaches. *Conservation Biology*, *19*(6), 1701–1713.

Leslie, H., Ruckelshaus, M., Ball, I., Andelman, S., & Possingham, H. (2003). Using siting algorithms in the design of marine reserve networks. *Ecological Applications*, *13*, 185–198.

Merson, E., Merson, B., Odorico, R., Falace, A., & Altobelli, A. (2006). Approccio alla valutazione del territorio costiero mediante l'utilizzo di indicatori del valore naturalistico. *Biologia Marina Mediterranea*, *13*(1), 396–405.

Montefalcone, M. (2009). Ecosystem health assessment using the Mediterranean seagrass *Posidonia oceanica*: A review. *Ecological Indicators*, *9*, 595–604.

Montefalcone, M., Rovere, A., Parravicini, V., Albertelli, G., Morri, C., & Bianchi, C. N. (2011). Evaluating change in seagrass meadows: a time-framed comparison of Side Scan Sonar maps. *Aquatic Botany*, *104*(January 2013), 204–212, In press.

Murenu, M., Pais, A., Mura, F., Addis, P., Olita, A., Ferrari, A., & Ortu, A. (2005). La biodiversità dell'ittiofauna costiera di substrato roccioso in due aree marine protette della Sardegna orientale. *Biologia Marina Mediterranea*, *12*(1), 140–145.

Navone, A., Bianchi, C., Orru, P., & Ulzega, A. (1992). Saggio di cartografia geomorfologica e bionomica nel parco marino di Tavolara-Capo coda cavallo (Sardegna Nord-Orientale). *Oebalia, Suppl*, *17*(2), 469–478.

Pais, A., Chessa, L., Serra, S., Mura, F., & Ligios, L. (1999). Ittiofauna di una prateria di *Posidonia oceanica* nella riserva marina di Tavolara – Capo Coda Cavallo (Sardegna nord-orientale). *Biologia Marina Mediterranea*, *6*(1), 591–594.

Pais, A., Trainito, E., Romor, M., & Contis, M. (1992). Sulla presenza di *Gerardia savaglia* (Bertoloni, 1819) nelle acque dell'isola di Tavolara. *Oebalia*, *17*, 377–378.

Parravicini, V., Rovere, A., Vassallo, P., Micheli, F., Montefalcone, M., Morri, C., & Bianchi, C. (2011). Understanding relationships between conflicting human uses and coastal ecosystems status: a geospatial modeling approach. *Ecological Indicators*, *19*, 253–263.

Parravicini, V., Thrush, S. F., Chiantore, M., Morri, C., Croci, C., & Bianchi, C. N. (2010). The legacy of past disturbance: Chronic angling impairs long-term recovery of marine epibenthic communities from acute date-mussel harvesting. *Biological Conservation*, *143*(11), 2435–2440.

Roberts, C., Branch, G., Bustamante, R., Castilla, J., Dugan, J., Halpern, B. S., & McArdle, D. (2003). Application of ecological criteria in selecting marine reserves and developing reserve networks. *Ecological Applications*, *13*, 215–228.

Rovere, A., Parravicini, V., Firpo, M., Morri, C., & Bianchi, C. N. (2011). Combining geomorphologic, biological and accessibility values for marine natural heritage evaluation and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *21*, 541–552.

Rovere, A., Parravicini, V., Vacchi, M., Montefalcone, M., Morri, C., Bianchi, C. N., & Firpo, M. (2010a). Geo-environmental cartography of the Marine Protected Area Isola di Bergeggi, (Liguria, NW Mediterranean Sea). *Journal of Maps*, *6*(1), 505–519.

Rovere, A., Vacchi, M., Parravicini, V., Bianchi, C. N., Zouros, N., & Firpo, M. (2010b). Bringing geoheritage underwater: definitions, methods, and application in two Mediterranean marine areas. *Environmental Earth Sciences*, *64*(1), 133–142.

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Salm, R., Clark, J., & Siirila, E. (2000). *Marine and coastal protected areas: A guide for planners and managers*. Gland, Switzerland and Cambridge, UK, http://www.iucn.org/about/work/programmes/marine/marine_resources/?1600/Marine-and-Coastal-Protected-Areas-A-guide-for-planners-and-managers.

Schiaparelli, S., Guidetti, P., & Cattaneo-Vietti, R. (2003). Can mineralogical features affect the distribution patterns of sessile gastropods? The Vermetidae case in the Mediterranean Sea. *Journal of the Marine Biological Association of the UK*, *83*(6), 1267–1268.

Tricart, J., & Kilian, J. (1985). *L'eco-geografia e la pianificazione dell'ambiente naturale*. Milano: Franco Angeli Editore.

Vacchi, M., Rovere, A., & Schiaffino, C. F. (2012). Monitoring the effectiveness of re-establishing beaches artificially: methodological and practical insights into the use of video transects and SCUBA-operated coring devices. *International Journal of the society for Underwater technology*, *30*(4), 201–206.

Villa, F., Tunesi, L., & Agardy, T. (2002). Zoning marine protected areas through spatial multiple-criteria analysis: The case of the Asinara Island national marine reserve of Italy. *Conservation Biology*, *16*(2), 515–526.

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