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Are protected areas covering important biodiversity sites? An assessment of the nature protection network in Sicily (Italy)

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ABSTRACT

GIS spatial analysis of three indicators (vegetation value, faunal richness and landscape heterogeneity) was used to detect and map High-Value Biodiversity Areas (HVBAs), estimate the coverage of biodiversity in the Sicilian protected areas network, and identify new priority areas that could improve long-term biodiversity conservation outcomes. Findings indicated that only 32% of HVBAs are currently covered by the protected areas network. Hotspot analysis revealed that a modest expansion (less than 1%) in the current extent of protected areas would include a disproportionate amount (56%) of biodiversity hotspots, and identified prioritized candidates HVBAs for designation of new protected areas.

1. Introduction

Protected areas are the primary tool for conserving biodiversity, promoting long-term sustainability and raising public awareness of ecological and socio-economic benefits of natural capital and ecosystem services (Bastian, 2013; Geldmann et al., 2013; Kettunen and ten Brink, 2013; Millennium Ecosystem Assessment, 2013; Stolton et al., 2015).

Although protected areas, both in number and coverage, have been globally increasing significantly over the last few decades, the existing global network covers less than 20% of areas important for biodiversity and ecosystem services (UNEP-WCMC, 2014; Joppa et al., 2016; UNEP-WCMC and IUCN, 2016), and does not offer a sufficient contribution to the representativeness of areas important for biodiversity and ecosystem services (Skidmore, 2011; Rodrigues et al., 2004; Tantipisanuh et al., 2016).

To expand the current network, and prioritize systems of protected areas towards the internationally agreed AICHI Biodiversity Targets 11 (Harrison et al., 2010; Joppa et al., 2013; Pringle, 2017), policy makers and land use planners could benefit from science-based spatial biodiversity assessments, which generate metrics and maps tracking biodiversity values that would be understandable to a wide audience (Lorini et al., 2011; SANBI and UNEP-WCMC, 2016; Van Vleet et al., 2016; Scott et al., 2018). However, assessing biodiversity values is a complex, and costly task, especially at large scale. If successful attempts have been made, aggregating these measurements into a single metric tracking full biodiversity value to humans still remains a challenge (Green et al., 2005; UNCED, 2007; Magurran, 2013; Gao et al., 2014; Willcock et al., 2018).

In this study, we develop and implement a simple approach to assess biodiversity values, and analyse spatial relations between existing protected areas and biodiversity distribution in Sicily. Our evaluation approach is consistent with current practice which use “surrogates such as sub-sets of species, species assemblages and habitat types” as measures of biodiversity (Margules and Pressey, 2000; Rodrigues and Brooks, 2007).

We assess and combine in a Geographical Information System (GIS) framework three biodiversity indicators: vegetation value, faunal richness, and landscape heterogeneity. The vegetation value and the faunal richness are composite indicators. For their assessment, we integrate available (surveyed) data on plants, animals, and habitat types with

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expert opinions. In the analysis of flora and fauna, we take into account only endangered, vulnerable and/or near threatened species included in the IUCN Global and Italian Red Lists, European Birds and Habitats Directives, and Bern Convention. Habitat types are examined in terms of: suitability, that represents the capacity of a given habitat to support selected species (U.S. Fish and Wildlife Service, 1981); naturalness, that measure the degree of absence of human modification (Wright, 1977; Rüdisser et al., 2012); and diversity, that denotes the number of different vascular plants per habitat type (Cousins and Ove, 2002; Smith and Theberge, 1986). The landscape heterogeneity indicator measures the land cover/land use fragmentation within the areas of study (Lindenmayer et al., 2000; Suarez-Rubio and Thomlinson, 2009; Morelli et al., 2013; Riccioli et al., 2016). We use GIS spatial analysis to elaborate feature maps for each biodiversity indicator, and integrate them in a biodiversity map. Successively, we identify and compare High-Value Biodiversity Areas (HVBAs) with existing Sicilian protected areas network in order to quantify gaps in the coverage of biodiversity. Finally, we implement hotspots analysis to detect cluster of HVBAs as prioritized candidates for designation of new protected areas.

2. Materials and methods

2.1. Study area

Sicily's land area extends about 26,000 km^2, making it the largest island in the Mediterranean. Its wide range of flora and fauna makes Sicily a relevant global biodiversity hotspot (Médail and Quézel, 1999). The Sicilian ecosystems contain 3252 vascular floral species, 321 of which endemic (Giardina et al., 2007); 43 mammal species (including bats), 155 breeding bird species, 24 reptile and amphibian species make up a diverse and valuable vertebrate fauna (Turrisi and Vaccaro, 1998; AA.VV, 2008).

Sicily's mountain ranges are mainly distributed along the northern sector of the island, namely the Madonie (reaching 1979 m a.s.l.), the Nebrodi (1847 m a.s.l.) and the Peloritani (1374 m a.s.l.) (see Fig. 1a). In the central and southern sector the landscape is mainly characterized by a typical low relief. The highest peak is the Etna volcano (3340 m). This considerable altitudinal heterogeneity encompasses several climate zones, from semi-arid to humid. Annual rainfall varies from 250 to 1400 mm, whereas the average temperature is 18 °C, with values below zero in the inland territory in winter, and over 40 °C along the coast in summer. The smaller islands around Sicily (the Aeolian and the Aegadian archipelagos, the Pelagie, Ustica and Pantelleria) were excluded from the analysis.

2.2. Data

2.2.1. Vascular plants

The information on the distribution of Sicilian vascular species was extracted from the national database, made of 13,948 geo-referenced surveyed records, compiled by Blasi et al. (2010) and Rossi et al. (2013). Each vascular species was classified according to the *A* criterion proposed by Anderson (2002). In particular, vascular plants were categorized into five categories: globally threatened (*Ai*); European threatened (*Aii*); national endemic species with demonstrable threat (*Aiii*); near-endemic/limited range with demonstrable threat (*Aiv*); species of national and regional interest (*AA*). The dataset of Sicilian vascular plants, composed by over 600 existing data belonging to 213 different species, have been used to assess the flora richness (*F_rich*) and habitat diversity (*Hd*). The data set includes: nine species in category *A(i)*, 19 species in category *A(ii)*, 99 in category *A(iii)*, three species in category *A(iv)*, and 83 species in category *AA*.

2.2.2. Vertebrate fauna

The information on the distribution of threatened Sicilian animal species was extracted from the 'Atlas of Sicilian Vertebrates' (AA.VV, 2008) that contains more than 21,000 records regarding the presence of vertebrates on 288 UTM grid cells of 10 × 10 km. Excluding the Chiropterans and all the vertebrates living on the surrounding small islands, the Atlas reveals that 193 species (7 Amphibians, 18 Reptiles, 147 Birds, 21 Mammals) are present in Sicily.

2.2.3. Habitats

Land cover data were based on the Italian Nature Map (*Carta della Natura*), at scale of 1:50.000, that identifies 230 habitat types categorized according to the Corine biotopes classification (European Commission, 1991). This map, based on a Minimum Mapping Unit of 1 ha, offers a greater detail than the over widely used 2012 Corine Land Cover map, that is based on a Minimum Mapping Unit of 25 ha. According to the Italian Nature Map, Sicily includes about 130,000 habitat patches, that are classified in 88 habitat types. As we did not consider urban areas and intensive cultivated areas (greenhouse), our analysis relied on 81 habitat types.

2.2.4. Sicilian protected areas network

The terrestrial nature protection system in Sicily consists of five regional parks (Madonie Mts., Sicani Mts., Nebrodi Mts., Alcantara River and Mt. Etna), 73 nature reserves, 234 Natura 2000 sites (171 Special Areas of Conservation (SAC), 56 Sites of Community Importance (SCI) and 29 Special Protection Areas (SPAs). It is worth noting that several protected areas overlap, making the actually protected terrestrial surface about 580,000 ha, equal to 23% of the Sicilian terrestrial surface.

2.3. Biodiversity indicators

Three indicators, describing the distribution, the extent and the importance of vegetation, fauna, and landscape diversity, were separately estimated and successively aggregate in a GIS environment (ESRI ArcGIS® software). For each biodiversity indicators, we elaborated a raster map, with a resolution of 100 × 100 m and a normalization of values into a 0–100 numeric range. All feature maps were then aggregated into a biodiversity map by using a simple weighted overlay sum. We assigned equal weights to each indicator, since literature does not offer a univocal path regarding the choice of weights. To emphasize high biodiversity areas in biodiversity map, we used the quantile classification method because of its greater accuracy with choropleth maps over other classification methods such as natural breaks, hybrid equal intervals, or standard deviation (Brewer and Pickle, 2002). We then classified as High-Value Biodiversity Areas (HVBAs) the areas that belonged to the upper quantile. Map of HVBAs was utilized to reassess the existing protected area network in Sicily.

2.3.1. Vegetation value

The plant survey of species group, such as vascular plants, is generally considered as an important feature of biodiversity (Duelli and Obrist, 2003; Sauberer et al., 2004; Maes et al., 2005). However, a more informative assessment of this surrogate should consider other aspects, such as the naturalness and diversity of habitat patches (Wright, 1977; Rüdisser et al., 2012; Cousins and Ove, 2002; Smith and Theberge, 1986). In this study, the vegetation value was assessed by combining flora richness, habitat diversity, and habitat naturalness.

Flora richness (*F_rich*) of vascular plants was evaluated by assigning weights, from 1 to 5, to each Anderson's category in order to represent the conservation value of species (Fig. 2a and Fig. 2b). The highest value was assigned to species belonging to category "*A(i) -globally threatened*", and the lowest to species belonging to category "*AA- species of national and regional interest*". Then, in order to take into account the location and the cluster of species as well as the assigned weights, we used the ArcGis Kernel density function to calculate the vascular plant's magnitude per unit of area. This interpolation produced a continuous raster map of 100 m resolution (Fig. 2c)