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Article

Indicators for Ecosystem Conservation and Protected Area Designation in the Mediterranean Context

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Abstract

Protected areas constitute a key foundation for national and international strategies of effective biodiversity and ecosystems conservation. Yet, they are not islands; they are components of their surrounding social and ecological contexts. Reconciling biodiversity conservation, people, protected areas and sustainable livelihoods requires a focused strategic planning for conservation and development. The designation of new reserves must be thus based on sound indicators within ecological, socioeconomic, institutional, and financial contexts. Many of the ecological and socioeconomic indicators have been designed for this purpose by practitioners and conservation planners around the world. Although these indicators are crucial to orient conservation priorities and protected areas' designation patterns, their identification remains a big challenge, largely due to the fact that an indicator is a simplification of a system (whether natural or social) which is characterized by high structural complexity, considerable spatial heterogeneity and temporal fluctuations. This paper presents a review of ecological and socioeconomic indicators globally used to orient conservation planning on the global and national levels. It also suggests a set of suitable, relevant, and practical set of indicators, adapted to Mediterranean-type continental environments.

Keywords: Socio-ecological systems, Indicators, Decision-support tool, Biodiversity, Mediterranean, Protected areas

INTRODUCTION

IUCN's World Database on Protected Areas (WDPA 2014) records over 100,000 protected areas worldwide, covering over 12% of the Earth's land surface. Protected areas are recognized as the most important core units for *in situ* conservation (Gaines et al. 2010; Game et al. 2009; Gray 2010; Lester et al. 2009; Lubchenco et al. 2003, 2007; Pimm et al. 2001). Conservationists and protected area managers around the world spend millions of dollars each year to conserve biodiversity and create new protected zones (Castro and Locker 2000). However, measuring the number and extent of protected areas provides only a unidimensional indicator of political and national commitments to biodiversity conservation (Chape et al. 2005).

Protected areas play a vital role in biodiversity conservation. Yet they are not islands, they are components of their

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surrounding social and ecological contexts (Brandon et al. 1998). The most significant challenge facing both conservation and development is the need to support rural livelihoods by adequately assessing and capturing the value of environmental services (Kremen et al. 2000). Reconciling biodiversity conservation, people, protected areas and sustainable livelihoods thus requires a focused strategic planning for conservation and development, which upholds biodiversity and ecosystem services without imposing serious restrictions on livelihoods (Brandon et al. 2005; Ferraro and Pressey 2015). Still, the creation of new protected areas remains essential to maintain biodiversity and avoid major species losses (Brandon et al. 2005; Geldmann et al. 2013). The designation of new reserves that halt habitat degradation and species extinction must be based on sound information on the ecological, socioeconomic, institutional, and financial contexts (Cowling and Pressey 2003). Building on such information, it is possible to design protected areas that are integrated into the landscape and that support, rather than detract from, local livelihoods. Understanding such complex systems requires simplification, and essential to this understanding is the construction of a simple picture with a limited set of relevant factors: indicators (Turnhout et al. 2007).

What indicators to orient conservation priorities and prioritize protected area designation patterns in complex socio-ecological contexts? Conservation efforts usually emphasize the preservation of individual species, landscapes, indicator species, and endemic or rare species, rather than socio-ecological processes (Margules and Pressey 2000). This is partially due to a lack of informative indicators on ecosystem function and socio-ecological dynamics (Bowker et al. 2008; El-Hajj et al.2016). Unfortunately, many reserve systems throughout the world are highly biased toward particular subsets of natural features, usually small habitats with less economic value and fewer species, while larger and biologically richer areas are inadequately protected (Pressey 1994). Therefore, although individual reserves may be valuable, existing reserve networks often fail to represent adequately the biodiversity within a particular region (Brandon et al. 2005; El-Hajj et al.2016; Gaston et al. 2008; Le Saout et al. 2013; Rodrigues et al. 2004). The ideal design of a protected area has to be based on numerous factors, including habitat assets, species diversity, conservation status, suitability of the area, and the socioeconomic context in and around the proposed reserve (Brandon 2002; Cowling and Pressey 2003; Pressey1998). Several frameworks were tailored in this context to address ecosystem conservation, mainly the Pressure-State-Response (PSR) and the Driver-Pressure-State-Impact-Response (DPSIR) models (OECD 2001; Kristensen 2004). These models suggest "pressure" and "response" indicators, both on the ecological and socioeconomic levels to assess the fittingness of an area for conservation, such as (inter alia) the impact of anthropogenic pressures on the ecological state of a given ecosystem (i.e. number of threatened or extinct species),

Arising from this complex understanding of protected areas and their socio-ecological importance, this paper presents a review of key ecological and socioeconomic indicators used by practitioners and conservation planners around the world to establish new protected areas. Consequently, it suggests a justified set of suitable, practical and adapted indicators to pertinently orient protected areas' designation in Mediterranean-type continental environments. The Mediterranean basin constitutes a particularly interesting case study due to the long history of human impact and the complex socio-ecological embedded dynamics. This systematic review brings forward research contributions investigating indicators and criteria related to protected areas' designation worldwide, and thus highlights the main findings in this field, while underlining the most fitted options for Mediterranean-type ecosystems.

METHODOLOGY

A systematic assessment of peer reviewed and grey literature is applied to investigate ecological and socioeconomic indicators and the criteria used for setting conservation priorities and designing protected areas worldwide. This comprehensive review brings forward the diversity of criteria employed in conservation initiatives and highlights major conservation schemes and processes. It constitutes an important contribution to the literature as it compiles research studies gathered from around the world to address a common multifaceted question. Based on this bibliographic review, a specific set of indicators is identified to orient designation of protected areas in Mediterranean environments. This minimum number of pertinent indicators describes the maximum ecological and socioeconomic features of a specific site. These indicators cover key ecological and socioeconomic variables that reflect the major processes and aspects that orient protection patterns. They do not overlap with each other (no redundancy) but are instead complementary, and are specifically adapted to Mediterranean environments. They are also integrative, easy to measure, practical, customized for continental environments (at least), and above all, address both the ecological and socioeconomic aspects of conservation. Justification of their adaptation to Mediterranean environments is provided for each indicator. Mediterranean continental-type ecosystems are recognized for their particularly interesting socio-ecological complexity, shaped by human impacts and globally recognized for their irreplacability and vulnerability (Cody 1986; Cowling et al. 1996; Dallman 1998; Underwood et al. 2009).

ECOLOGICAL INDICATORS: SIMPLIFYING COMPLEXITY

In connection with the growing focus on conservation, ecologists must develop sound methods for monitoring, assessing and managing ecological integrity through the use of indicators. Ecological indicators represent key information and provide a simple and efficient method to examine the ecological structure, function, and composition of an ecological system while capturing the complexities of the ecosystem (Karr

1981). Yet, these indicators should remain simple enough to be easily and routinely monitored and modeled (Dale and Beyeler 2001). However, this is not an easy task. This has to do with the fact that an ecological indicator is a simplification of nature, which is perceived to be a system characterized by high structural complexity, considerable spatial heterogeneity, and temporal fluctuations. Ecological indicators attempt to measure the ecological quality of ecosystems and can be used as instruments to evaluate the effects of policies on nature (Turnhout et al. 2007). Many different levels exist for ecological indicators, making it a complex and potentially confusing concept.

The concept of biological or ecological indication goes a long way back in history. Kolkwitz and Marsson (1902) were among the first to describe aquatic systems in terms of indicator species. For terrestrial systems, Ellenberg (1974) made an important contribution by systematically linking abiotic soil factors with existing vegetation. Margules and Usher (1981) examined nine published schemes concerned with the assessment of conservation potential and ecological value. In each case, they listed the criteria used to judge the suitability of a habitat for conservation. These include diversity (including species richness and habitat diversity), rarity, naturalness, numbers of biological interactions (e.g. predatory, competition), area, threat of human interference, typicality, representativeness, educational value, amenity value, recorded history, scientific value, uniqueness, wildlife reservoir potential, ecological fragility, position in ecological/geographical unit (spatial position), potential value, availability, replaceability, ease of acquisition, and management considerations.

To date, the use of ecological indicators to assess biodiversity status and prioritize conservation needs has been growing worldwide and new conservation systems and protected areas based on a set of specific indicators are emerging despite the presence of a wide set of criteria used for ranking the relative ecological and conservation values of potential reserves. The design of conservation reserves has been widely debated for decades. At the global scale, several schemes have been employed to identify areas that may be particularly important for the long-term maintenance of biodiversity. As decision criteria, these schemes have variously used data on patterns of species richness, endemism, phylogenetic age of species, vulnerability, irreplaceability, as well as other habitat features. They have led to the recognition of, for example, biodiversity hotspots (Mittermeier et al.1998; Myers et al. 2000); centres of plant diversity (Davis et al. 1994, 1995); endemic bird areas (Bibby et al. 1992; Balmford and Long 1994; Stattersfield et al. 1998); key biodiversity areas (Eken et al. 2004); alliance for zero extinction sites (Ricketts et al. 2005); eco-regions (Olson and Dinerstein 1998) and many other priority areas for conservation. To varying degrees, such schemes have influenced both thoughts and actions.

In prioritizing areas for conservation at the national (administrative) scale, conservationists around the world have used various criteria for evaluating natural areas for the intent of land-use planning and protected area designation. These include, among others, rarity (on the specific and habitat levels), site uniqueness, species richness (diversity), size, site naturalness, fragility, representativeness, spatial connectivity, typicality, vegetation structure, fragility, number of plant alliances, number of plant structural formations, vulnerability, irreplaceability and endemism (Tubbs and Blackwood 1971; Tans 1974; Gehlbach 1975; Goldsmith 1975; Wright 1977; Van der Ploeg and Vlijm 1978; Rabinowitz 1981; Smith and Theberge 1986; Pressey et al. 1994; Gubbay 1995; Pressey and Taffs 2001; Noss et al. 2002; Laguna et al. 2004; Derous et al. 2007; Kier et al. 2009; Gauthier et al. 2010;). The use of these indicators led to the recognition of numerous types of protected areas worldwide - varying from one country to another according to each nation's legislations and conservation needs - such as micro-reserves, nature reserves, protected forests, sanctuaries and protected seascapes (Chape et al. 2003).

While the focus on rare, threatened and endemic species has commonly been retained (Abbitt et al. 2000; Bode et al. 2008; Bonn et al. 2002; Daniels et al. 1991; Dobson et al. 1997; Drinkrow and Cherry 1995; Troumbis and Panayotis 1998), studies revealed that reserve networks focusing solely on threatened and endemic species may not be sufficient to preserve the overall species diversity present in a country (Bonn et al. 2002).

In terms of size, several debates argued whether a Single Large Or Several Small (cf. the SLOSS debate, 1970-1980) reserves were a superior means of conserving biodiversity. While numerous studies confirmed that larger protected areas are more desirable for long-term species conservation and maintenance of ecological and evolutionary processes (Cowling et al. 1999; Bierregaard et al. 2001), other researches argued that small reserves are adequate for some species and are almost always better than no reserve or management over an area at all (Turner and Corlett 1996).

Karr (1991), Angermeier and Karr (1994) and Noss (1995) used ecological integrity as a key criteria for ecosystem assessment. Ecological integrity refers to system wholeness, including the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa. Measuring ecological integrity can rely on a set of indicators including number of populations, species richness, spatial distribution of communities, stand's age, etc. Such an approach is increasingly being used to guide monitoring efforts across protected areas (Wurtzebach and Schultz, 2016).

In Europe, the Natura 2000 network is a network of protected sites scattered along the European Union, made up of Special Areas of Conservation and Special Protection Areas, designated respectively under the Habitats Directive and the Birds Directive, and including both terrestrial and marine sites (Ostermann 1998). It uses species and habitat features such as representativeness, conservation status, functionalities (resting, breeding, feeding, wintering or summering area), habitat size, population density of target species, spatial connectivity and species vulnerability as main indicators to orient the designation of the protected sites (Lepareur 2011; Viry 2013).

The international union for conservation of nature (IUCN) also invested significant efforts in defining protected area categories and ecological selection criteria such as naturality, representativeness, size and conservation status (Dudley 2008).

Ecological indicators tailored to orient conservation priorities and protected area designation also include site heterogeneity (Lindenmayer et al. 2000), site unicity and natural character (Gubbay 1995).

Even though the use of ecological indicators and criteria is gaining further interest in conservation planning, all these indicators remain unstandardised, as they belong to different categories (quantitative/qualitative, species/habitat) and are frequently found duplicated and sometimes not applicable, although the goal still remains: ecological conservation.

SOCIOECONOMIC INDICATORS: A KEY DIMENSION TO CONSERVATION

Throughout the world, established protected areas are under severe natural and human threats such as land use change, urbanisation, excavation, harvesting, hunting, pollution and climate change, which are leading to their progressive fragmentation and isolation (Brandon et al. 1998; Oates 1999; Carey et al. 2000; Sala et al. 2000; Bruner et al. 2001). With continued economic growth, it is likely that the pressure on biodiversity will further increase.

Socioeconomic data enable the evaluation of the human context of protected areas - that is, the number of people present, their geographic distribution, and socioeconomic and sociocultural characteristics - in order to provide key insights into the effectiveness of potential new reserves (Brandon et al. 2005). Biodiversity can be well managed or heavily impacted by the actions of relatively few people (Gorenflo 2002). Reserve categories such as man and biosphere reserves or other sites with human residents, can only be successful if there is participation and management of zoning and use designations. Therefore, successful conservation planning requires socioeconomic data (Polasky 2008).

Socioeconomic indicators mainly communicate aspects related to external threats on protected areas, economic value of the protected site, educational suitability, management appraisal, potential amenity use, accessibility, as well as financial and legislative contexts for conservation (Gehlbach 1975; Haughton and Siar 2006; Roberts et al. 2003; Smith and Theberge 1986; Wright 1977). Bode et al. (2008) use data on the cost of establishing new biological reserves as indicators to address conservation allocation patterns. Furthermore, socioeconomic indicators provide sound information on the socioeconomic dependence of the surrounding communities on the potential protected area (hunting, recreation, tourism, harvesting, etc.), and the cultural value of the latter (educational, historical or archeological importance) (Jacot 2009).

Unfortunately, this category of indicators is not sufficiently taken into consideration during conservation planning. For instance, the designation of Natura 2000 sites in Europe is founded only on ecological indicators. Socioeconomic aspects are considered only in the management phases of these sites (Smith and Theberge 1986).

However, the concepts of ecosystems services and the economic value of biodiversity are gaining more interest among conservation planners who are further mainstreaming the economic values of ecosystems and biodiversity into conservation initiatives (Naidoo et al. 2008). This upsurging interest draws attention to global economic benefits of biodiversity and highlights the growing cost of biodiversity loss and ecosystem degradation (Sukhdev et al. 2010). Ecosystem services constitute the key foundation of this relatively new concept, where humankind benefits in a multitude of ways from supporting, provisioning and regulating the cultural services provided by ecosystems by virtue of their very existence, a value estimated at US$33 trillion per year (Costanza et al. 1998). This economic and market-based valuation of ecosystem services constitutes the foundation of a model of conservation that promotes economic profits for local communities based on the exploitation of ecosystem goods and services. This model has been criticised as "neoliberal conservation" (Igoe and Brockington 2007; Büscher 2012; Holmes and Cavanagh 2016). In this context, assessing the economic value of biodiversity provides pertinent socioeconomic indicators related to the direct use value, indirect use value, option value and existence value of a given ecosystem (MA 2005).

INTEGRATING ECOLOGICAL PRIORITIES WITH SOCIOECONOMIC GOALS

Throughout the last decades, conflicts between the socioeconomic and the ecological spheres in densely populated areas such as the Mediterranean region has brought more burdens to protected areas. Changes in the traditional relationship between humans and their environments created new challenges to protected areas, where emerging technologies, globalization, industrial growth, changes in land use, urbanization, excessive exploitation of natural resources, and population growth, all have had a severe impact on terrestrial ecosystems (Lampic et al. 2012; Huwart and Verdier 2013). This co-evolution (and not just competition) of humans and ecosystems underlines a strong need for understanding and aligning ecological and socioeconomic priorities for an integrated conservation of natural resources (Sodhi and Ehrlich 2010).

Striking a proper balance in conservation planning requires good communication between economists and ecologists (Eppink and van den Bergh 2007). The need to communicate the scientific concepts of ecological indicators to non-scientists is increasingly being tackled by teams of environmental scientists working with social scientists (Schiller et al. 2001; Redman et al. 2004). Yet, integrating ecological indicators with social and economic goals for resource management remains a big challenge (Dale and Beyeler 2001).

Due to the complexity of ecosystems and the normative aspects involved in assessing ecosystem quality, indicators used to orient conservation priorities cannot be solely science-based but are situated in a fuzzy area between science and policy (Turnhout et al. 2007).

Recognising the fact that humans and nature are interdependent elements, integrating both ecological and socioeconomic aspects in prioritizing conservation patterns is a key first step to achieving such optimal conservation. The concept of socio-ecological systems (S.E.S) is currently gaining further interest among conservationists as it acknowledges the complexity of interactions between humans and their natural environment, where both traditional ecological aspects along with the human dimension in nature protection are taken into consideration during conservation planning (Cioffi-Revilla, 2016; Folke 2007; Lagadeuc and Chenorkian, 2009; Liu et al. 2007; Redman et al. 2004).

Integration of the social sciences into long-term ecological research is an urgent priority, and what is often divided into "natural" and "human" systems has to be considered as a single complex socio-ecological system when approaching conservation targets (Redman et al. 2004).

SUGGESTING A SET OF ECOLOGICAL AND SOCIOECONOMIC INDICATORS FOR PROTECTED AREA DESIGNATION IN MEDITERRANEAN CONTINENTAL ENVIRONMENTS

The Mediterranean basin, one of the most biologically diverse regions in the world (Médail and Quézel 1999; Mittermeier et al. 1998; Myers et al. 2000), owes its high diversity and spectacular scenery to its location at the intersection of two major landmasses, Eurasia and Africa. This basin has experienced intensive human development and impact on its ecosystems for thousands of years, significantly longer than in any other biological hotspot. Important human settlements have existed in the area for at least 10,000 years, shaping its landscapes and downing its resources. From habitat fragmentation to the mass development of road networks and tourism hubs on coastal areas, today a mere 5% of the original extent of the hotspot contains relatively intact vegetation, placing the Mediterranean basin among the four most significantly altered biodiversity hotspots on Earth (Cuttelod et al. 2008; Underwood et al. 2009).

Yet, the extent to which existing protected areas are effectively representing, maintaining and conserving key ecological features in the Mediterranean region is still poorly understood: indeed protected area designation seems to follow political priorities and opportunities (such as in Lebanon) rather than being founded on pertinent ecological and socioeconomic criteria that would highlight the relevance and priority for conservation measures (El-Hajj et al.2016). In such a complex socio-ecological context, orienting conservation priorities and protection patterns in the Mediterranean region remains thus a challenge. To achieve optimal ecological conservation, there is a need to:

i) Identify pertinent criteria and indicators that would objectively orient conservation priorities based on relevant ecological and socioeconomic indicators encompassing all aspects related to biodiversity (flora and fauna), physical environments (soil, topography, geology, etc.) and livelihoods (El-Hajj et al. 2016).
ii) Achieve efficient environmental governance, including effective local initiatives (Agrawal and Lemos 2007) and targeting an improved application of policies and indicators related to conservation planning (Smith et al. 2003)

At this stage, we chose to select a minimum number of pertinent indicators able to describe maximum ecological and socioeconomic features of a specific site in view of its potential designation as a protected area. These indicators cover key ecological and socioeconomic variables that reflect major processes and aspects, orienting protection patterns in one direction or another. They do not overlap with each other (no redundancy) but are complementary, and they are adapted to Mediterranean environments by considering some specific socioeconomic aspects particular to the Mediterranean countries (such as Lebanon), aspects that might affect and challenge conservation initiatives on the national level. Suggested indicators are inspired from the corpus of indicators globally used to orient conservation priorities and protected area designation. They are integrative, easy to measure, practical, and above all, tackle both ecological and socioeconomic aspects of conservation (Tables 1, 2 and 3).What's more, these indicators reflect distinct socio-ecological aspects known to be very particular to the Mediterranean (such as property constraints and species rarity). In other types of ecosystems, such as mangrove ecosystems, different types of indicators can be of additional value (such as water characteristics, pH, etc.). They are thus adapted to Mediterranean-type continental environments (at least) but can be potentially used to orient conservation planning (protected area designation) in other types of ecosystems (Mediterranean marine ecosystems, polar ecosystems, tropical ecosystems, etc.). However, applied to other types of ecosystems, they won't be as much representative, specific and adapted as for Mediterranean-type contexts. Furthermore, the categorization of suggested indicators partly overlaps with the quite well-known and widely adopted PSR/DPSIR categorization, as it somehow exhibits causal dependencies between the interacting socio-economic and environmental systems for a pertinent orientation of conservation measures.

Each indicator may contain one or more separate measures, each of which can be assessed separately to identify whether it is changing, and if so, whether this change will affect or not, the conservation priority.

CONCLUSION

Drawing on a comprehensive global gap analysis undertaken by Conservation International in 2003, Rodrigues et al. (2004) concluded that the degree to which biodiversity is represented within the existing network of protected areas is unknown. Although a number of countries have designed and implemented protected area system plans, studies have confirmed that protected area establishment does not frequently

Table 1
List of suggested indicators

Indicators collected from literature	Suggested indicators (inspired and adapted from the corpus of indicators collected from literature)	Justification of adaptation to Mediterranean environments
ECOLOGICAL INDICATORS		
Diversity (species and habitats) Rarity (species and habitats) Replaceability/irreplaceability Endemism	Rarity or irreplaceability (species and/or habitat level)	The criterion related to diversity or specific richness has not been taken into account among the ecological indicators selected above as its use is hampered by both the absence of objective thresholds and the difficulty of its assessment on-field. However, it is indirectly used in this selected indicator. In fact, the only method that suggests the use of this criterion is that of Important Plant Areas criterion "B" (Anderson 2002; Foster et al. 2012), but its application in concrete cases is difficult and rarely possible (*cf.* Vela and Pavon, 2012). Practically, only criterion "A" (presence of globally, regionally and/or nationally threatened species) and to a lesser extent criterion "C" (presence of threatened habitats/vegetation) are usually used (Yahi et al. 2012). Endemism degree *per se* provides information on the biogeography of a site, but neither recommends nor discourages its protection or management unless it is rare. Thereby, if a given species is a common endemic at a regional level (e.g. *Teucrium marum* in Corsica-Sardinia), its protection on the national level wouldn't be of great relevance compared to a rare endemic species on the same territory (e.g. *Seseli praecox*). Therefore, endemism is not considered as such as an indicator, but is rather included as one of the "rarity or irreplaceability" indicator's modalities, particularly considering the cases of more or less severe restriction of the distribution range (Smith and Theberge 1986). Compared with other regions of the world (Europe, Australia, California, etc.), the Mediterranean basin hosts more than twice as any in terms of rare species (Cody 1986; Cowling et al. 1996; Dallman 1998). Therefore, rarity is retained as an indicator. However, in order not to miss species whose presence might go beyond a rarity threshold - which itself is subjective and arbitrary - while only very partial data is available, it is preferred to measure the irreplaceability value (divided by the number of stations in the study area) of each species onsite, regardless of the number of individuals per species. Thus, the cumulative value or sum (for all species present onsite) will serve as a definition of the indicator value (Vanderpert 2007).
Size (area) Typicality Representativeness Uniqueness	Habitat extension (representativeness)	Habitat extension reflects the "significance" of habitat "representation" within a protected area or at the national level, and thereby, the landscape's structure and the importance of the ecosystem's functions. Habitat mapping is crucial to get reliable estimates of the total area occupied by each habitat (i.e. surface of every habitat occurring in the area under consideration), so as to reach the required conservation targets (Costello 2009). Areas selected to be representative necessarily include typical or common species, habitats, geophysical characteristic, and so on. Therefore, the concept of representativeness, subsumes typicality (Margules and Usher 1981). The idea of representation is better thought of as an approach to conservation rather than simply a criterion. Representativeness and uniqueness can be the extremes of a spectrum. A unique area is one that is rare, whereas areas which are representative are typical of a biome or habitat type, typical being defined as "containing all (or most) of the commoner and more widespread species" (Usher 1980).

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Table 1
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Indicators collected from literature	**Suggested indicators (inspired and adapted from the corpus of indicators collected from literature)**	**Justification of adaptation to Mediterranean environments**
		Habitat extension provides a key dimension for the conservation of typical Mediterranean-type continental ecosystems, adapted to distinctive Mediterranean climatic regimes, and characterized by restricted ranges of specific conifers and broad-leaved species (Di Castri and Harold 2012).
Naturalness Position in ecological/geographical unit(spatial position) Spatial connectivity	Spatial connectivity	The knowledge of the extent and spatial scale of connectivity between natural habitats/ecosystems is of vital importance for the effective design and implementation of protected areas. The connectivity depends on the spatial structure of the landscape and on the permeability of the different components that make it up. It also infers the naturalness of the environment (percentage of natural or semi-natural areas in contact with the perimeter of the area to be protected) (Mugica et al. 2002). Spatial connectivity plays a vital role in the design of a coherent conservation network, especially in Mediterranean environments subject to progressive fragmentation challenges (Dudley 2012).
Number of biological interactions Wildlife reservoir potential Vegetation structure Number of plant alliances Number of plant structural formations Ecological integrity Conservation status Ecological functionalities Population density of target species Site heterogeneity	Functional integrity Regional dynamic or evolutionary trend	Ecological integrity or functional integrity is a complex concept which pulls together many underlying notions. It is a key indicator of the ecosystem's health, biodiversity, stability, conservation status, sustainability, structure and wildness, but is however particularly challenging to measure as ecosystems are not static entities (Noss 1995). The concept of functional integrity has been discussed by many authors from many perspectives (Cairns 1977; Karr and Dudley 1981; Edwards and Regier 1990; Gauthier 1992; Munn 1993; Woodley et al. 1993; Pimentel et al. 2000; Wurtzebach and Schultz, 2016) and refers to a system's wholeness, where ecosystem's structure and functions are appropriately operating and where the ecosystem's core (structuring) species are present at viable population levels. In conservation strategies, ecological integrity is a key criterion for maintaining sustainable reserve networks in Mediterranean environments (Noss 1995). On another level, the knowledge of species/ecosystem regional dynamics is a key element for orienting conservation strategies (Flournoy 2003). This type of information set up the foundation for conservation biology (Soulé 2005) and is of utmost importance in Mediterranean ecosystems, characterized by high spatial and temporal heterogeneities, where environmental stress and human disturbances have a major impact on biological system dynamics (Médail and Diadema 2006).
SOCIOECONOMIC INDICATORS		
Threat of human interference Recorded history Ecological fragility Vulnerability	External human threats	From habitat fragmentation to species overexploitation and climate change, global conservation assessments recognized the Mediterranean basin as one of the more fragile and threatened biomes on earth, and a priority for the conservation of the world's biodiversity (Underwood et al. 2009). Designing efficient protected area networks in Mediterranean environments requires a thorough understanding of these threats and is critical in prioritizing conservation strategies (Kiringe and Okello 2007). The nature and degree of a threat is likely to change over time. For this reason, consideration of past, present and foreseeable future influence of human activities on a candidate site for conservation is important (Roberts et al. 2003).

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Table 1
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Indicators collected from literature	**Suggested indicators (inspired and adapted from the corpus of indicators collected from literature)**	**Justification of adaptation to Mediterranean environments**
		To be effectively employed as a criterion for prioritizing conservation initiatives and establishing new protected areas, mitigatable and non-mitigatable human threats should be identified and quantified where possible (Roberts et al. 2003). In many cases, a site may be exposed to more than one threat.
Economic value Educational value Amenity value Scientific value	Site economic value (use or non-use value)	A site's total economic value is classically split only in two sub-criterion: its use and non-use value (Freeman 1993; Pearce and Warford 1993). Use value is not split here into direct and indirect values (respectively obtained through removable and non-removable products in nature), as the main objective is to spot whether the site provides or not an economic or economic-like benefit (ecosystem services: provisioning services, regulating services, cultural services, supporting services). The non-use value also includes the existence value and the option value (that could later become a use value). The economic value of a given site has a major impact on conservation priorities. Greater the economic value of a site, lesser should be the priority for strict conservation. Mediterranean continental ecosystems are recognized for their high economic value. From carbon sequestration to watershed protection, recreation and hunting, grazing, timber and fuelwood extraction, etc., the total economic value of a Mediterranean terrestrial ecosystem is estimated up to 350 USD per hectare (Pagiola et al. 2004).
Availability Ease of acquisition Cost of establishment of a new reserve Accessibility Management considerations	Financial and land-use/property constraints	In prioritizing new areas for conservation, the availability of financial means for establishing the conservation initiative (cost of establishment of a new reserve) as well as the ease of acquisition of the land (land use property status), are crucial elements to account for while assessing the feasibility of the conservation project (Worboys et al. 2015). The absence of financial means and/or the complexity of land control can affect protected area establishment. This is the case of few Mediterranean countries such as Lebanon, where private property is protected by the Lebanese Constitution (Article 15), which consequently imposes restrictions on the establishment of protected areas on private lands and therefore hampers any official conservation initiative without the consent of the landowner. In France in contrast, the governmental control on private land ownership for the establishment of protected zones is easier.
Legislative context for conservation	Legislation/level of national legal engagement	No conservation initiative can be established on any natural site unless the local, national or regional legislative framework is favourable (Worboys et al. 2015). Legal instruments are crucial tools for the creation of effective protected area networks, which makes this criterion of utmost importance in prioritizing conservation actions; as greater conservation laws are enforced, more are protection initiatives efficient. In Lebanon, despite all the efforts invested by ministries, municipalities and local communities to establish new categories of protected areas such as natural parks, the legal framework for protected area designation and management is still missing. Besides, environmental infractions on existing protected zones are rarely and partially penalized by existing laws, which calls for a serious law enforcement. In France on the contrary, the legal framework for protected areas is comprehensive and satisfactory, laws are respected and infringements are somehow totally penalized.

Table 2

Detailed description of suggested ecological indicators/indicators

Indicator	Definition	Suggested variables to be measured
Rarity or irreplaceability (species and/or habitat level)	A rare or irreplaceable area is an area containing: Rare or unique species or populations; and/or Habitats (in the broad sense): complete ecosystem (biotope + biocenosis), biocenosis (communities, phyto-sociological associations, etc.), or biotopes (geomorphological or geological and bioclimatic features) that are unique, rare or unusual. Five different types of species' rarity are discerned in the literature: "widespread rare species" that occur over a wide geographical area but are scarce wherever they do occur and may have a patchy or continuous distribution; "endemic species with restricted geographical ranges"; "disjoint populations that are geographically separated from the main range of the species"; "peripheral populations that are at the edge of their species' geographical range"; and "declining species that were once more abundant and/or widespread but are now depleted" (Smith and Theberge 1986), which makes rarity assessment processes often complex. A rare area is an area where species, populations and geomorphological features are irreplaceable. The irreplaceability of some ecosystems implies the absence of ecological equivalents elsewhere on the structural and functional levels (nature of stands, geomorphological features, and functional integrity). Their loss would mean the probable permanent loss of a certain feature, or the loss of diversity at a given level. The irreplaceability (or uniqueness) of a site is the degree to which spatial options for conservation are lost if the site and its biodiversity are lost (Pressey et al. 1994). Irreplaceability is based on a site's biological composition in relation to the biological composition of other sites. A site has extreme irreplaceability if one or more of its species or habitats are totally confined to it and thus the site is the only option for protecting this species/habitat. The more options that exist for conserving a species, the lower the irreplaceability of the sites at which it occurs. All else being equal, a site with high irreplaceability is a higher priority for conservation action than one with lower irreplaceability (Langhammer 2007).	Ratio of rare species if species inventories are comprehensive (number of rare species divided by the total number of species). Presence/number of rare species if species inventories are not comprehensive (only partial). Habitat rarity or unicity (ecosystem, biotope or biocenosis) if habitat or bioclimatic or geologic inventories or maps are available in the study area (regardless of the availability or not of species inventories). Presence/number of endemic species (restricted range and/or site restricted species) with species inventories comprehensive or not.
Habitat representativeness/ extension	Representativeness refers to the degree to which an area represents a habitat type, an ecological process, a biological community, a geographic or physical characteristic, or any other natural features on a given territory; an area that is an illustrative and exceptional example of specific biodiversity, ecosystems, ecological or physiographic processes, habitat types, communities or other natural characteristics.	Habitat extension on the territory scale (administrative level): Relative surface of the habitat in the administrative area (e.g. national/county level) compared to the total surface of the administrative area (e.g. county). Habitat extension within the site of interest (relative area of the habitat in the potential protected area compared to the total area of the habitat at the administrative level.)
Spatial connectivity	Ecological connectivity refers to the functional connectivity that links all the elements of an eco-landscape (natural or semi-natural habitats, buffer zones, biological corridors) between them (excluding buildings and human infrastructure) from a species or a population (or a combination of these entities) point of view, for all or part of their development stages, at a given time or for a given period. By extension, connectivity decreases when fragmentation increases.	Naturalness of the environment (percentage of natural or semi-natural areas in contact with the perimeter of the area to be protected) Maximal permeability (of the neighboring ecosystem having the highest permeability with the main ecosystem of the area to be protected)

Contd...

Table 2
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Indicator	Definition	Suggested variables to be measured
Functional integrity	Functional integrity (or ecological integrity) is the degree to which an area is a functional unit; a self-sustaining ecological entity (Wurtzebach and Schultz, 2016). More an area is ecologically autonomous, greater it is effective in protection strategies.	Local dynamic/autonomy of the target ecosystem (s) (regressive, progressive or stable dynamic) within the area to be protected Local dynamic/autonomy of the target specie (s) (source, recipient or balanced population) within the area to be protected Structure of the target ecosystem (s) (complete, nearly complete, incomplete vertical structure)
Regional dynamic or evolutionary trend	The regional dynamic refers to the evolutionary trend of an ecosystem or a species on the territory level (e.g. national/country level). It reflects the general tendency of an ecosystem/species to progress, slowly regress, strongly regress, or remain stable on the territory level. An ecosystem/ species (of major ecological interest/value) can have a local progressive dynamic on a given site (*cf. indicator number 4*), versus a global regressive tendency on the studied national/territory scale.	Of target ecosystem (s) (stable dynamic, progression or regression of the ecosystem) Of target specie (s) when species inventories are available along with the levels of their regression/ progression on the territory scale

Table 3
Detailed description of suggested socioeconomic indicators

Indicator/	Definition	Suggested measures
External human threats	External threats are threats directly or indirectly caused by man. The impact of a threat mainly depends on the intensity of the latter as well as the vulnerability/ resilience of the exposed ecosystem. A threat can be partial and reversible, partial and irreversible or total and reversible, or finally total and irreversible. An area prone to natural or human stress factors may need special protection, especially if it hosts a relatively high proportion of habitats, biotopes or sensitive species that are functionally fragile (highly susceptible to degradation or depletion by human activities or natural events) or with slow recovery rates.	Former (past) threat having ended on the site (the main threat in case there are many) Actual threat taking place on the site (the main threat in case there are many) Probable, predicted or planned threat (climate change; land-use planning: urbanization, road, construction, dam, quarry; area prone fire, erosion, floods, volcanoes…)
Site economic value (use or non-use value)	The economic valuation of ecosystem services is a tool for quantifying "benefits" provided by an ecosystem in monetary units most of the time. It is an important tool for the economic evaluation of biodiversity. It responds primarily to the wish and need to use the "economic language" for nature conservation and biodiversity to better integrate the environment into economic dynamics. Direct use values are the values of tangible benefits of effective use (hunting, grazing, timber, etc.). These direct use values reflect the direct consumption of resources and the direct interactions with the ecosystem. Non-use values represent the satisfaction of knowing that there is an ecosystem or species (patrimonial, emblematic, spiritual value, etc.).	Surface area of direct use value: supply and/or cultural interest (food, timber, grazing, water, recreation, etc., regardless of whether the service is commercial or non-commercial) Surface area of emblematic and/or spiritual value (non-use value)
Financial and land-use/ property constraints	No conservation initiative can be established unless financial means are made available for the implementation of this initiative, and land-use/property aspects are favorable to this implementation especially in Mediterranean countries. The property value of the land, the possibility of implementing a conservation project on the land, and the type of land (public, private, military), are key element determining the potential possibility of initiating a conservation action on a given site. Similarly, the availability and easiness of retrieving financial means to ensure the implementation of the protected area are crucial components for the success of the initiative.	Land use status or control pattern (possible, negotiable control on the property; high/low property value; impossible control over the property…) Financial means for the implementation of the protection initiative (possibility degree of getting international, national, local, or individual funds)

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Table 3
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Indicator/	Definition	Suggested measures
Legislation/level of national legal engagement	The presence and application of laws and regulations related to environmental protection and biodiversity conservation are key elements to the success of conservation initiatives. Legal enforcement enhances the establishment of new protected areas and sets a specific framework for their creation and management. The presence of legislations is crucial on the national level to improve conservation planning. However, the challenge remains in the application/respect level of these regulations. The more strict and penalized they are, the more conservation is efficient, and vice versa. The assessment of this aspect is essential to orient the type of conservation towards a strict or more or less flexible pattern.	Presence of national regulation related to the conservation of biodiversity and/or protected areas Presence of other specific regulations (water, rivers, coastline, forests, etc.) that can be applied to protect the site Level of enforcement/compliance with existing regulations (strict and complete, partial, level of penalization…)

correlate with identified conservation priorities (Margules and Pressey 2000; Pressey et al. 2002; Rodrigues et al. 2003; El-Hajj et al. 2016).

Protected area data, in combination with habitat, species and socioeconomic information, can provide a basis for determining gaps in the extent of biodiversity protection, and thereby inform decision-makers and stakeholders about priorities for conservation action.

However, it is important to choose indicators that are useful at the national/regional levels to provide the baseline framework in which protected area designation can be framed. By doing so, we can provide meaningful assessments of whether or not biodiversity targets are met.

Inspired by a systematic literature review reconsidering worldwide efforts for biodiversity and ecosystems conservation, the set of suggested indicators in this paper can be further used to develop a decision support tool that can serve practitioners and decision-makers in Mediterranean environments to objectively orient protected area designation. In this context, El-Hajj et al. (in preparation) developed a decision support tool ("MedConserve") addressed to conservation planners around the Mediterranean basin, aiming to support decision-making processes related to protected area designation based on a pertinent and scientific approach. This tool prioritizes and reflects the impact of each and every socio-ecological aspect, to different degrees, on the design of a protected area.

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