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Do protected areas networks ensure the supply of ecosystem services? Spatial patterns of two nature reserve systems in semi-arid Spain

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Protected areas are essential for conserving biodiversity, and these lands have traditionally been set aside for this purpose alone. However, the increasing global demand for agricultural and forestry commodities creates conflict and tradeoffs between dedicating land for conservation versus food production. Efforts to set aside new lands for biodiversity conservation are compromised by the globally rising demand, creating trade-offs between lands dedicated to conservation versus food production. Ecosystem services are the benefits that humans obtain from ecosystems. Recent studies suggest that protected areas provide social and economic benefits that can be used to build political support and raise funds for conservation. We analyzed the capability of current protected area networks in the semi-arid region of Spain to provide intermediate regulating services (habitat preservation for threatened species, climate regulation, erosion control and water flow maintenance) to support the final provisioning service of cultivated crops to support local communities. We found that existing networks of protected lands supply considerable quantities of ecosystem services, in particular carbon stocks and groundwater recharge. Our results demonstrate that the integration of systematic analyses of ecosystem services gaps in protected area planning could contribute substantially to safeguarding ecosystem services and biodiversity jointly. However, our study also reveals substantial differences in intermediate ecosystem services supplied by different of protected areas networks, with category VI areas (Natura-2000 sites) generally showing the highest potential for ecosystem services supply. This demonstrates the important role of Natura-2000 sites for preserving regulating services in the European semi-arid region.

Introduction

Protected areas constitute a major global effort to preserve biodiversity (Palomo, Martín-López, Alcorlo, & Montes, 2014; Rands et al., 2010). Traditionally, their principal purpose has been to preserve iconic landscapes and seascapes, charismatic species and their habitats, and biodiversity hotspots (Haslett et al., 2010; Watson, Dudley, Segan, & Hockings, 2014). Over the past few decades, advances in conservation biology and conservation planning have allowed a precise assessment of the number, extent, and quality of protected areas needed to conserve many viable plant and animal populations (Adams, 2004; Southworth, Nagendra, & Munroe, 2006). Consequently, there is a political goal to integrate 17% of the land surface and 10% of the marine surface of the earth into a global protected area network by 2020 (Secretariat of the Convention on Biological Diversity, 2010). In 2010, the amount of area protected globally was 17 million km^2 (terrestrial) and 6 million km^2 (marine), corresponding to 12.7% of the land surface and 1.6% of the marine surface (Bertzky et al., 2012). In the European Union, around 18% of the landscape is now included in the NATURA 2000 network of protected areas (Bastian, 2013). However,

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efforts to set aside new lands for biodiversity conservation are compromised by the globally rising demand for agricultural and forestry commodities, creating trade-offs between lands dedicated to conservation versus food production (Smith et al., 2010).

The increasing human transformation of the biosphere (Ellis et al., 2013) has led to paradigm shifts in how we approach conservation, moving from wilderness prioritization towards a ‘people and nature’ thinking, in which the dynamics between society and nature are recognized. In this new conservation paradigm, management strategies must consider the tight coupling between humans and nature and include safeguarding human well-being in biodiversity conservation plans (Kareiva & Marvier, 2012). In this approach, protected areas serve to preserve iconic landscapes and species as well as safeguard ecosystem services that contribute to human well-being (Palomo, Montes, et al., 2014; Watson et al., 2014). Palomo, Montes, et al. (2014) suggest that the management of protected areas should follow four principles embedded in ‘people and nature’ thinking: (i) integration of protected areas into social-ecological systems; (ii) establishment of participatory processes and co-management to reduce social conflicts; (iii) incorporation of beneficiaries who value, use, or enjoy the ecosystem services supplied by protected areas in the decision-making process; and (iv) avoiding location bias of protected areas in mountain systems through the recognition of their contribution in the creation of multifunctional landscapes able to provide multiple services to society.

An ecosystem services approach is essential for implementing these principles in protected area design and management (Armsworth et al., 2007; Portman, 2013). Ecosystem services, defined as the benefits that humans obtain from ecosystems (Millennium Ecosystem Assessment, 2005), are now widely viewed as a critical component of conservation strategies (Ng, Xie, & Yu, 2013; Redford & Adams, 2009). There is considerable evidence that protected areas provide social and economic benefits to society that can be used to build political support and raise funds for conservation (Haslett et al., 2010; TEEB, 2012). Consequently, the ecosystem services approach is now being incorporated in global protected area and biodiversity conservation policies. For example, the International Union for Conservation of Nature (IUCN) World Commission on Protected Areas (WCPA) (Dudley, 2008) and the Aichi Targets of the Convention on Biological Diversity for 2011–2020 have both specified that future protected area networks should include ecosystem services (Target 11). Similarly, the Madrid Action Plan for the UNESCO network of biosphere reserves established conservation and enhancement of site-specific ecosystem services as central goals for biosphere reserves: “The essence of biosphere reserves as sustainable development sites could be seen as the effort to design and develop place-specific mixes of supporting, provisioning, regulating and cultural ecosystem services that enable the environmental, economic and social well-being of resident and stakeholder communities” (UNESCO-MAB, 2008).

Integrating ecosystem services in protected areas management is challenging because traditionally such areas have not been designed with the preservation of regulating services (Kremen & Ostfeld, 2005), therefore having consequences in the provision of other provisioning and cultural services (Laurence et al., 2012; Martín-López, García-Llorente, Palomo, & Montes, 2011; Zorrilla-Miras et al., 2014). Further progress toward management of protected areas for ecosystem services preservation requires advances in the biophysical quantification and mapping of ecosystem services supply at landscape scales, including an assessment of synergies and trade-offs between different ecosystem services (Castro, García-Llorente, Martín-López, Palomo, & Iniesta-Arandía, 2013; Castro et al., 2014; Palomo, Martín-López, et al., 2014).

Clearly defining ecosystem services is an important first step in their valuation. Fisher, Turner, and Morling (2009) suggested that ecosystem services could be classified into intermediate services, final services, and benefits. With this classification, ecosystem processes and structure are ecosystem services, but they can be considered as intermediate or as final services, depending on their degree of connection to human welfare. In this sense, intermediate ecosystem services can stem from complex interactions between ecosystem structure and processes (e.g., water recharged by aquifers) and lead to final ecosystem services (e.g., crop production), which in combination with other forms of capital provide human welfare benefits (e.g., food production).

Here, we analyze the capability of current protected area networks in the semi-arid region of Spain to provide intermediate regulating services (Fisher et al., 2009). We modeled and mapped the biophysical provision of intermediate regulating services in two protected area networks operating at different organizational scales in southern Spain to identify spatial gaps. We examined four intermediate regulating ecosystem services, habitat preservation, climate regulation, erosion control, and water flow maintenance. These services were selected based on their importance for maintaining cultivated crops as a final provisioning service and for maintaining the well-being of local communities (Castro et al., 2014; García-Llorente, Martín-López, Iniesta-Arandia, et al., 2012; García-Llorente, Martín-López, Nunes, Castro, & Montes, 2012; Iniesta-Arandia, García-Llorente, Aguilera, Montes, & Martín-López, 2014). We did not include cultural services due to the difficulty in accurately quantifying their biophysical value (Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013).

Material and methods

Study area

Our study was conducted in eastern Andalusia in the southeastern Iberian Peninsula and covers approximately 28% (2459 km^2) of Almeria province (8774 km^2, 700.000 inhabitants, 79.7 inhab/km^2; Fig. 2). Almeria is semiarid and considered one of the driest regions in Europe (Armas, Miranda, Padilla, & Pugnaire, 2011), with average rainfall of 250 mm per year (Castro et al., 2011). Winter temperatures vary between 12 and 15 °C, and average summer temperatures are as high as 40 °C (Lázaro, Rodrigo, Gutierrez Carretero, Domingo, & Puigdefábregas, 2001). The area includes all or part of 33 municipalities and local employment is based on the primary and tertiary sector. The study area contains diverse ecosystems including high mountains up to 2.611 masl, valleys, coastal zones, saline marshlands, and agricultural lands (Fig. 2B) (Castro et al., 2014). We selected this area for several reasons. It is a biodiversity hotspot, containing for example the Sierra Nevada National Park and Tabernas Desert. It is representative of the strong need for regulating ecosystem services (e.g., groundwater recharge) for intensive greenhouse horticulture, which has quadrupled the GDP per capita in the last 30 years (National Institute for Statistics, 2005; Wolosin, 2008, 106 pp.). Lastly, it includes protected areas with different levels of International Union for Conservation of Nature (IUCN) protection status.

Approximately 48% (1154 km^2) of the study area is covered by protected areas in two different protected area networks (Fig. 1): (1) the Andalusian network of protected areas created by the Andalusian Law in February 1989 (RENPA, Spanish acronym for Red de Espacios Naturales Protegidos de Andalucía), which includes 27% of the area; and (2) the European Natura-2000 network, which covers an additional 21% of the study area. Both protected areas networks have as main priorities the conservation of the regional