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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Abstract
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 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 km² (terrestrial) and 6 million km² (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,
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, Aguiler, 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 km²) of Almeria province (8774 km², 700,000 inhabitants, 79.7 inhab/km²; Fig. 2). Almeria is semi-arid 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, Gutiérrez 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 km²) 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 1980 (REPA, 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...
natural heritage. The RENPA network consists of 5 protected areas (mean extent: 642 km$^2$), while the Natura-2000 network is composed of 3 sites (mean extent: 512 km$^2$). The Natura-2000 sites were declared as Sites of Community Importance (SCI) in 2006 because they harbor priority habitats or species of community interest and because they contribute to the coherence of the Natura-2000 network. Hereafter we refer to the Andalusian network of protected areas as the RENPA network, and to the additional Sites of community Importance as Natura-2000 network.

**Modeling and mapping the provision of ecosystem services**

We modeled and mapped the supply of ecosystems services within the two protected area networks and the study area as a whole. We used biophysical indicators to assess four intermediate regulating services and a final provisioning service (see Castro et al., 2014 for method details). We identified areas that maintain habitat for threatened vertebrate species (Fig. 1B-1) with the biodiversity combined index (BCI model from Rey Benayas and de la Montana).
We estimated climate regulation from carbon stock measurements based on soil organic carbon content (Oyonarte, Almendros, Delgado, Pérez-Pujalte, & Delgado, 1994), density (kg/m³), soil depth horizon (m), lithology types and soil maps (Fig. 1B-2). We used the Universal Soil Loss Equation (USLE model) (Kandziora, Burkhard, & Müller, 2013; Palomo, Montes, et al., 2014) to estimate erosion control as an inverse proxy of soil loss (Fig. 1B-3). We estimated water flow maintenance by quantifying the distribution of potential aquifer recharge expressed as the percentage of the average annual rainfall using the APLIS groundwater recharge model (Fig. 1B-4) (Andreo et al., 2008; Quintas-Soriano, Castro, García-Llorente, Cabello, & Castro, 2014). Finally, as a final provisioning service (Fig. 1B-5), we quantified crop production from the average annual yields of the most economically important crops in the region (tomatoes, cucumbers, zucchini, peppers, and eggplant). A summary of the variables used by spatial models and data set in ecosystem services modeling and mapping is provided in Table 1 in the Supplementary Data.

We standardized the data to produce a single map of intermediate regulating services and an additional map of final provisioning service. We used minimum–maximum normalization to standardize data on a 0–1 scale following Willemen, Hein, and Verburg (2010). Because this technique is sensitive to minimum and maximum values, and to avoid erroneous transformations due to outliers, values of ecosystem services maps outside the 5th or 95th percentile were assigned the 5th or 95th value respectively (Willemen, Veldkamp, Leemans, Hein, & Verburg, 2012). Intermediate regulating and final provisioning services were presented and mapped separately using a 1 x 1 km grid.

Assessing the role of protected area networks in safeguarding ecosystem services

We compared the overall delivery of intermediate regulating services between the two networks (RENPA and European Natura-2000 network) and the non-protected lands. We also explored whether there were any significant relationships between the level of protection and the amount of each service supplied by an area. Protection level across both protected areas network increased from sites of community importance (IUCN category VI), Natural Park (IUCN category IV), Paraje Natural (IUCN category III), National Park (IUCN category II), and Natural Reserve (IUCN category Ia). IUCN category V is not used in the area. Using spatial analysis techniques (Zonal statistic tool in ArcGIS Spatial Analyst, version 2010) the biophysical provision of each intermediate service was calculated within each level of protection. We examined differences in the provision of each of the intermediate regulating services by the different protection levels with the Kruskal–Wallis test, as the variables were non-normally distributed. Finally, conservation gaps are defined as non-protected areas that support the provision of intermediate regulating services and were mapped by identifying cells/pixels with an equal or higher value of 0.5 in relation to the final standardized services delivery from 0 to 1 (García-Nieto, García-Llorente, Iniesta-Arandia, & Martín-López, 2013).

Results

Overall intermediate and final ecosystem service delivery

The biophysical provision of ecosystem services varied across the study area, with the greatest delivery of the final provisioning and regulating services in different regions (Fig. 1B). The biodiversity combined index map (BCI in Fig. 1B-1) showed that the whole study area is most important for maintaining habitats for bird species, followed by mammals, reptiles, and amphibians (see Fig. 1 in the Supplementary Data). Soil carbon stocks were largest in the high mountains of Sierra Nevada National Park dominated by coniferous and sclerophyllous forests (80%) (Fig. 1B-2). Erosion control was relatively low throughout the entire study area, with the highest soil losses found in the southern slope of Sierra Nevada and in the Tabernas Desert (Figs. 1B-3 and 2B), and the highest groundwater recharge in the Gádor mountain, a karst system in the sedimentary mountains (Figs. 1B-4 and 2B). Finally, crop production based on greenhouse horticulture was mainly delivered in the southern coastal platform of Campo de Dalías (Figs. 1B-4 and 2B).
Ecosystem services supply by protected area networks

Comparing the resulting maps of aggregated intermediate and final services, the overall supply within the RENPA and Natura-2000 network was particularly important for preserving intermediate services (Fig. 3A). The delivery of the final service mainly occurred outside both the RENPA and Natura-2000 networks (Fig. 1B-5).

The overall supply of regulating services differed with protection status within the RENPA network, but also between the sites of community importance (Natura-2000) and non-protected areas (Fig. 4). The mean value of regulating services was highest within the IUCN category VI (Natura-2000 sites) and category II (National Park) sites. Category IV (Natural Parks) and category III (Paraje Natural) sites showed medium levels of regulating services supply, which did not differ from non-protected areas. The category Ia (Natural Reserve) site, representing the most restrictive protection status, showed the lowest levels for regulating services preservation (although it was relatively important for habitats for threatened vertebrate conservation). Overall, we also observed that all intermediate regulating services were preserved within both protected area networks, with the exception of the erosion control in the Natural Reserve since it is actually a marshland (Fig. 4). The protected areas networks, both RENPA and Natura-2000, were particularly important for the preservation of carbon stocks and groundwater recharge and, surprisingly, less important for the habitat of threatened vertebrates (Fig. 4).

By comparing the spatial mean values for intermediate regulating services across the protection gradient (i.e., RENPA network, Nature-2000 network, and non-protected areas), we observed that overall the greatest values occurred within the SCI of Natura-2000 network, while similar values were observed in RENPA network and non-protected areas (Fig. 5A). Significant differences in the mean supply of all intermediate regulating services were found across all levels of protection (Table 1). While mean values of biodiversity combined index (BCI) show that the habitat for threatened species is better preserved in the Natural Reserve, we observed that National Park and SCI sites of the Natura-2000 were significantly relevant for preserving carbon stocks and groundwater resources.

Conservation gaps in the protected area networks for preserving intermediate regulating services

Our analyses identified several non-protected areas that represent gaps in the preservation of intermediate regulating services (14% of total surface) (Fig. 3B). These gap areas are represented by a value of intermediate regulating services equal or higher than 0.5 (range 0–1). Three priority areas that would be good candidates for incorporating important intermediate services are the northern and eastern portions of the study area (Filabres mountain and Tabernas desert in Fig. 2B) for maintaining habitat for threatened species (Fig. 1B-1), and areas on the northern and southern slopes of Gador mountain for preserving groundwater recharge and carbon stocks (Fig. 1B-2 and 4).

Discussion

Our findings suggest that current protected area networks supply only slightly higher levels of regulating services than non-protected areas: only 59% of the total supply of regulating services occurred within protected areas (Fig. 5B), although they occupy 48% of the total surface. Our gap analysis revealed that targeting the provision of multiple services would require an increase of the protected land area surface by an additional 14%. Through such measures, 83% of the total supply of intermediate regulating services would be within protected area networks. As this increase in protected area surface in the Spanish semi-arid region exceeds the international goal of integrating 17% of land surface in the protected area network, other strategies in conservation planning, such as market schemes or payment for ecosystem services, will likely be required (Chan, Shaw, Cameron, Underwood, & Daily, 2006; Egoh, Reyers, Rouget, Richardson, & van Jaarsveld, 2008; Egoh, Reyers, Rouget, Bode, & Richardson, 2009). Our results demonstrate an important spatial trade-off between the current supply of a final provisioning service (crop production) and the intermediate regulating services needed to support it (e.g., groundwater recharge). Since the local economy of Almeria province is mainly supported by agricultural production that directly depends on groundwater (Downward & Taylor, 2007), our results suggest that a payment for ecosystem services (PES) scheme could help resolve this conflict. Farmers could pay for the preservation of...
those lands necessary for groundwater sources. This approach would reinforce the idea of including new areas supporting the preservation of key intermediate services within protected boundaries.

Although there is consensus that conservation planning and protected areas can benefit from the ecosystem services approach (Chan et al., 2006; Egoh et al., 2008; Palomo, Martín-López, et al., 2014), it is less clear whether all protected areas successfully contribute to the preservation of essential ecosystem services. In fact, previous studies have demonstrated that high levels of protection, such as National Park (IUCN category II) and Natural Reserve (IUCN category Ia), do not ensure the provision of multiple ecosystem services (García-Nieto et al., 2013; Palomo, Montes, et al., 2014). However, at the landscape level of the Spanish semi-arid region, our analysis demonstrated that National Parks provide high levels of intermediate regulating services. In contrast, the SCI of the Natura-2000 network with a lower level of restriction, is the area that provides the highest amount of intermediate regulating services. In fact, in more social-cultural terms, stakeholders frequently assign higher value to the less restrictive categories of protected areas because they perceive a diverse provision of ecosystem services, including provisioning, regulating, and cultural

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### Table 1
Intermediate and final services supply for all status protection across both the RENPA and Natura 2000 network and the non-protected areas. BCI expresses the Biodiversity Combined Index values used for mapping the habitats for maintaining threatened vertebrates, SCI = sites of Community Importance. All values are standardized from 0 to 1.

<table>
<thead>
<tr>
<th>Protection status</th>
<th>Area (km²)</th>
<th>Maintaining habitat</th>
<th>Carbon stocks</th>
<th>Soil loss</th>
<th>Groundwater recharge</th>
<th>Cultivated crops</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IUCN category</td>
<td>Protected area network</td>
<td>Mean BCI (STD) Dunn</td>
<td>Mean (STD) Dunn</td>
<td>Mean Dunn</td>
<td>Dunn Mean Dunn Mean Dunn</td>
</tr>
<tr>
<td>Natural Reserve</td>
<td>Ia</td>
<td>RENPA</td>
<td>529</td>
<td>0.08 (0.09) A</td>
<td>0.05 (0.05) A</td>
<td>0.00 (0.00) A</td>
</tr>
<tr>
<td>National Park</td>
<td>II</td>
<td>RENPA</td>
<td>15,291</td>
<td>0.06 (0.28) B</td>
<td>0.34 (0.34) E</td>
<td>0.11 (0.29) E</td>
</tr>
<tr>
<td>Paraje Natural</td>
<td>III</td>
<td>RENPA</td>
<td>12,816</td>
<td>0.04 (0.23) C</td>
<td>0.14 (0.08) B</td>
<td>0.08 (0.24) CD</td>
</tr>
<tr>
<td>Natural Park</td>
<td>IV</td>
<td>RENPA</td>
<td>37,351</td>
<td>0.02 (0.31) D</td>
<td>0.18 (0.14) C</td>
<td>0.08 (0.26) D</td>
</tr>
<tr>
<td>SCI</td>
<td>VI</td>
<td>Natura-2000</td>
<td>51,233</td>
<td>0.02 (0.25) D</td>
<td>0.42 (0.38) D</td>
<td>0.07 (0.23) C</td>
</tr>
<tr>
<td>Non-protected</td>
<td>none</td>
<td>Natura-2000</td>
<td>128,627</td>
<td>0.01 (0.26) E</td>
<td>0.19 (0.18) C</td>
<td>0.05 (0.27) B</td>
</tr>
</tbody>
</table>

The Kruskal–Wallis test and Dunn groups are used to compare the mean delivery of ecosystem services across the different protection status.

*** Statistical significance – 1.
This study addresses our understanding of the importance of including ecosystem services in land conservation. This study demonstrates the importance of preserving intermediate regulating services at sites of community importance (IUCN category VI). The RENPA network (27% of the surface) preserved only 23% of intermediate regulating services, while the three extra sites of the Natura-2000 network contributed (with only 21% of the surface) as much as 36% of intermediate regulating services. Consequently, although Natura-2000 sites were designed according to ecological and biogeographical criteria, they also are important for preserving multiple ecosystem services (Bastian, 2013; Kettunen, Bassi, Gantioler, & ten Brink, 2009). However, to date Natura-2000 networks have rarely been addressed in the ecosystem services literature (Kettunen et al., 2009). Our results show the importance of these networks in conserving groundwater recharge and climate regulation, which has been recently described because of its importance in greenhouse horticulture as the main driver of the local economy of Almeria province (Quintas-Soriano et al., 2014).

A critical question is whether the food produced by intensive agriculture in the area and that represents an important final service for society (Fisher et al., 2009) should be considered an ecosystem service. The supply of this provisioning service mainly occurred outside both protected area networks, along the coastal platform of Campo de Dallas. Most of the crops are produced by greenhouses horticulture, which is extraordinarily dependent on external inputs such as synthetic fertilizers, pesticides, plastics, electricity, and fossil fuels. In this study, we considered the food coming from greenhouse horticulture as a final provisioning service since it provides important benefits to the regional economy. In fact, 86.2% of the total net income of Almeria province comes from greenhouse horticulture (Sanchez-Picón, Aznar-Sanchez, & Garcia-Latorre, 2011), and 5% of the vegetables consumed in Spain come from this area (Sanchez-Picón et al., 2011). We acknowledge that this agricultural production is to some degree decoupled from local ecosystems. However, it entirely depends on the availability of groundwater resources (Downward & Taylor, 2007), which mostly comes from aquifers that are recharged in the nearby Gador Mountains (Castro et al., 2014; Quintas-Soriano et al., 2014). Hence, this illustrates how the production of final provisioning services in an area directly depends on the maintenance of intermediate regulating services elsewhere. This is consistent with the framework proposed by Haines-Young and Potschin (2010), in which ecosystem services are connected in cascade. The cascade effect from specific regulating services (i.e., here groundwater recharge) to provisioning services (i.e., crop production) also highlights the important role of protected area networks to ensure the delivery of multiple ecosystem services at different spatial scales. However, our study also demonstrates that current protected areas boundaries do efficiently protect the conservation of threatened vertebrate species, which ultimately was the primary criterion for which they were designed.

Finally, our results should be interpreted with some caveats. Although the use of proxies for services quantification is often used at large scales, the biophysical proxies used to quantify an ecosystems’ capacity to supply intermediate services have to be considered with limitations. Examples of this include our use of soil loss as an inverse proxy for erosion control or the use of soil carbon stocks as a proxy for climate regulation (Castro et al., 2014). Another example is the estimation of cultivated crops per hectare as a final service. Our assessment would be more accurate if we had more detailed information on other natural resources (e.g., water or fertilizers) required to produce zucchini versus eggplant, but these data were not available. Our study is an interdisciplinary assessment that compares the potential capacity of protected areas networks to preserve ecosystem services supply at the landscape level; this approach differs from more traditional, smaller-scale ecological studies. Another important issue is the criteria used for the design of current protected areas. Both RENPA and Natura-2000 were specifically designed for preserving landscapes, plant and animal species across unique areas. This is the case of the National park of Sierra Nevada mountain or the Tabernas Desert (Fig. 2B), each considered as global hotspot of biodiversity (Blanca, Cueto, Martinez-Lirola, & Molero-Mesa, 1998; Mendoza-Fernandez et al., 2015). This may explain why some protected areas strongly preserve particular ecosystem services, such as the case of Natural Reserve for habitat of threatened species or forested National Park located for climate regulation.

Conclusions

The Convention on Biological Diversity and other global conservation policies have expressed a clear need to integrate ecosystem services in the design of protected area networks (Haslett et al., 2010). Achieving this goal requires modeling and mapping ecosystem services at the landscape scale. The EU Biodiversity Strategy has an agenda for mapping ecosystem services to support biodiversity conservation policies (Maes, 2012, 2009; Maes, Parachini, et al., 2012). To support the EU Biodiversity Strategy, advanced knowledge about the capacity of Natura-2000 sites to provide essential ecosystem services such as groundwater recharge or carbon storage is needed. However, few studies have used ecosystem services modeling and mapping for protected area planning (see Chan et al., 2006; Egoh et al., 2008, 2009; Palomo et al., 2013; Palomo, Montes, et al., 2014). Our assessed five ecosystem services provided by protected area networks at a regional scale demonstrate that existing networks supply considerable amounts of ecosystem services, in particular carbon stocks and groundwater recharge. It further demonstrates 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 ecosystem services supplied by different IUCN classes of protected areas, 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 intermediate regulating services in the European semi-arid region.

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