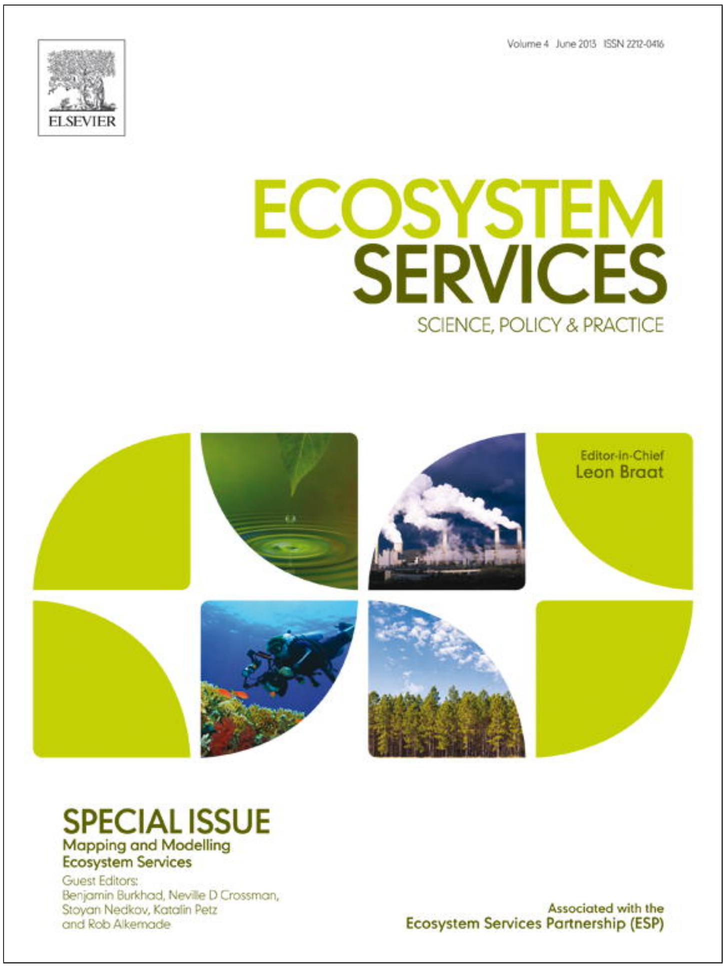
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National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows

Ignacio Palomo [a,*,1], Berta Martín-López [a], Marion Potschin [b], Roy Haines-Young [b], Carlos Montes [a]

[a] Social-Ecological Systems Laboratory, Department of Ecology, Universidad Autónoma de Madrid, Madrid, Spain
[b] The Centre for Environmental Management, School of Geography, Nottingham University, Nottingham, UK

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ABSTRACT

The use of ecosystem service maps for conservation planning is increasing. However, their potential for measuring the benefits derived from protected areas has rarely been studied. To overcome this, information gap, we organized two expert workshops based on participatory mapping techniques for Doñana and Sierra Nevada protected areas. Protected area managers and scientists mapped service provision hotspots, (SPHs), degraded SPHs and service benefiting areas (SBAs). In Doñana, SPHs were located inside the protected area and its surroundings, whereas, degraded SPHs were located primarily within the protected areas. In Sierra Nevada, most SPHs and most degraded SPHs were located inside the protected area. SBAs were located in the surrounding territory for both protected areas, especially in the neighboring cities. We also identified the major issues that faced both protected areas and their drivers of change. We found that most problems originated outside the limits of the protected areas and were produced by drivers associated with economic factors and land use changes. We discuss the implications of using ecosystem services maps for protected area management and the effects of the surrounding territory on areas within the protected zone. The results of our study demonstrate the need for a broader territorial planning strategy.

1. Introduction

The designation of protected areas is one of the most important conservation strategies available to societies (Chape et al., 2005). However, long-term conservation of biodiversity cannot be achieved if the relationships between these zones and the areas that surround them are not considered (McNeely, 1994; IUCN, 2004). A number of studies have shown that intensive land use has recently increased around many protected areas (Joppa et al., 2008; Radeloff et al., 2010; Svancara et al., 2009; Gimmi et al., 2011) and that we cannot, as a consequence, manage them as isolated and static entities (Bengtsson et al., 2003). In this paper, we explore how the concept of ecosystem services, and in particular the patterns of supply and demand for services and their consequent flows, can be used as a way of better understanding trans-boundary issues (López-Hoffman et al., 2010). Although the primary purpose for establishing many protected areas has been the conservation of biodiversity, the increasing emphasis that policy makers are giving to ecosystem services means that we now need to understand whether such areas can also be effective in protecting ecosystem services and how approaches to managing them can be adapted to ensure that threats or risks to the service supply are overcome. In this paper, we focus particularly on the role that mapping techniques can play in resolving these issues.

The ecosystem services concept is being increasingly used in the scientific literature (Potschin and Haines-Young, 2011) and mapping techniques have provided a powerful tool for integrating complex information related to ecosystem services into landscape management and environmental decision-making (Balvanera et al., 2001; Daily and Matson, 2008; Swetnam et al., 2011). Many approaches to mapping ecosystem services have been applied at different spatial scales ranging from the global (e.g., Turner et al., 2007; Naidoo et al., 2008; Maes et al., 2011a, 2011b; Haines-Young et al., 2012) to the national (e.g., Egoh et al., 2009; Schneiders et al., 2012) and local (e.g., Chan et al., 2006; Bryan et al., 2011; Burkhard et al., 2012a; Fagerholm et al., 2012; Kroll et al., 2012). A review of such work suggests that the development of spatially explicit methods that incorporate the locations of ecosystem service supply and ecosystem service demand represents a key challenge for research (Anton et al., 2010). Until recently, studies mapping ecosystem services have focused more on the supply side and have tended to overlook society's demand for these services (Burkhard et al., 2012a; Paetzold et al., 2010). However, some progress has been made. van Jaarsveld et al., (2005) mapped the supply and demand of different ecosystem services for the Southern African Millennium Ecosystem

* Corresponding author.
E-mail address: Ignacio.palomo@uam.es (I. Palomo).

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Assessment. Beier et al. (2008) mapped the ecosystem service supply, demand and disturbance related to fish/wildlife in southeastern Alaska. McDonald (2009) discussed the effect on conservation planning of the distance between ecosystem service supply and demand. Kroll et al. (2012) explored the supply and demand of provisioning services along the rural–urban gradient. Finally, as part of a special issue of *Ecological Indicators* (Burkhard et al., 2012b), different authors focused on analyzing the spatial mismatches between ecosystem service supply and demand. Burkhard et al. (2012a) analyzed ecosystem service supply and demand of energy provisioning services for the rural–urban region of Leipzig (Germany). Nedkov and Burkhard (2012) mapped flood regulating service supply and demand in Bulgaria. Syrbe and Walz (2012) mapped service providing, service connecting and service benefiting areas for the flood regulating service in Saxony (Germany).

However, to our knowledge, no studies have incorporated the spatial analysis of ecosystem service supply–demand flows in protected areas. In this paper, we therefore focus on the service supply–demand flows between protected areas and their surroundings in the two Andalusian National Parks: Doñana and Sierra Nevada. These parks were selected to examine the patterns that arise in two potentially contrasting types of protected areas and to examine how these patterns are seen by the different stakeholder groups associated with the areas. We specifically aimed to: (1) explore the most important ecosystem services that people associate with both protected areas; (2) identify and map perceptions of the capacity of the protected areas and their surroundings to provide key ecosystem services to society and analyze the differences between the protected and unprotected territories as providers; (3) identify and map those degraded areas that have lost their capacity to provide ecosystem services to society; (4) identify and map the areas in which ecosystem service beneficiaries use or consume ecosystem services; and (5) identify the most important threats for both protected areas, their origin, and the drivers behind them. We conclude with a discussion of the critical questions regarding the integration of an ecosystem service framework into the management of protected areas: (1) Do protected areas preserve ecosystem services? (2) Which type of ecosystem services do they preserve? (3) Where are the degraded ecosystem services located? and (4) Which limits shall we consider for managing a diverse flow of ecosystem services in protected areas?

To facilitate this work, we have developed the new concept of service provision hotspots (SPHs) to allow ecosystem services mapping to be conducted with stakeholders in a participatory manner. The concept has been adapted from the notion of service providing unit developed by Luck et al. (2003, 2009), which described 'the capacity of particular area or habitat to provide a specific ecosystem service' without explicit mention of the species, attributes, functional groups, communities, interaction networks or habitat types that provide the service. The 'hotspot' simply defines any locale that is important for generating a service. Following the conceptual framework developed by Syrbe and Walz (2012), we defined service benefiting areas (SBAs) as those spatial areas in which beneficiaries demand ecosystem services.

2. Study areas

Two contrasting protected areas were the focus of this study (Fig. 1). The Doñana National Park was selected because it exemplifies the problems of a protected area at the outfall of a major drainage basin. The National Park is located at the end of the Guadalquivir River Basin, on the southwestern coast of Spain. As such, it has been highly vulnerable to the transformations in land use in the areas upstream (Martín-López et al., 2011). In contrast, the Sierra Nevada National Park is a mountain protected area. Hence, it is a major hydrological source, the origin of important tributaries of the Guadalquivir. It is probable that this area is more typical of the types of protected areas that exist in Spain, where 73% of the territory over 1500 m is protected (Europarc-España, 2010). This mountain protected area may also be typical of the situation internationally. Joppa and Pfaff (2009) noted that the selection of protected areas worldwide has been biased towards high places. The contrasting geomorphological contexts of the two study areas allowed us to consider in detail the different types of spatial relationships that potentially exist between the protected areas and the surrounding landscapes (see Montes et al., 1998 and Jimenez-Olivencia, 1991 for further details; see also Appendix A).

The ecological importance of the two study areas is reflected in the number of international protection categories to which they belong. Both areas are biosphere reserves. Doñana is also a World Heritage Site and a Ramsar Wetland. The two areas are the only National Parks in Andalusia. As National Parks, they belong to the strictest conservation category established by Spain. Both National Parks are surrounded by a Natural Park, the most important regional protection category. As a buffer zone, these natural parks permit more active human use, such as extensive agriculture (e.g., olive and almond trees), hunting, or alpine skiing. In the text that follows, we use the term Doñana and Sierra Nevada Protected Areas to indicate the National and Natural Park areas in conjunction.

3. Methods

We considered it appropriate to map ecosystem services based on expert knowledge provided by protected area board members and managers as well as researchers to deliberatively map ecosystem services, as ecosystem service research should be "user-inspired" and "user-useful" (Cowling et al., 2008). Participatory mapping provides an arena for capacity building and for the incorporation of experiential knowledge in a spatially explicit manner (Sieber, 2006). Data collection was organized through a mapping workshop carried out at both sites in June and December 2011. The number of participants was 21 in Doñana and 20 in Sierra Nevada; the participants included environmental managers of the protected area, environmental experts from the National Park Agency and the regional environmental agency, and scientists working in the study areas belonging to universities and research institutions. Although the number of participants was not high, the participants were selected to include a diverse group of informants with extensive knowledge of the area to ensure the accuracy of the information obtained in the workshops. Appendix B summarizes the composition of the participants in both workshops.

To select which ecosystem services to map, we assessed the importance of each of the protected areas for delivering ecosystem services to society using an individual questionnaire. The questionnaire was organized into three sections. The first section asked for the five most important ecosystem services provided by each protected area and its surroundings. The participants were given a list of the 25 most important services identified by previous studies in the area (e.g., García-Llorente et al., 2011a; Palomo et al., 2011). The list offered an example of each ecosystem service in the area and provided either a definition or a picture. For example, water provision was defined as "good-quality water from surface or below-ground flows". Examples included water for human consumption, agriculture, industry, or desalted water. The participants were then asked to identify the trends shown by these ecosystem services in the past decades, the causes of these changes, and the scale at which beneficiaries used or consumed the services in question. The second section sought to determine the individual participants' perceptions of the importance of ecosystem services for the management of

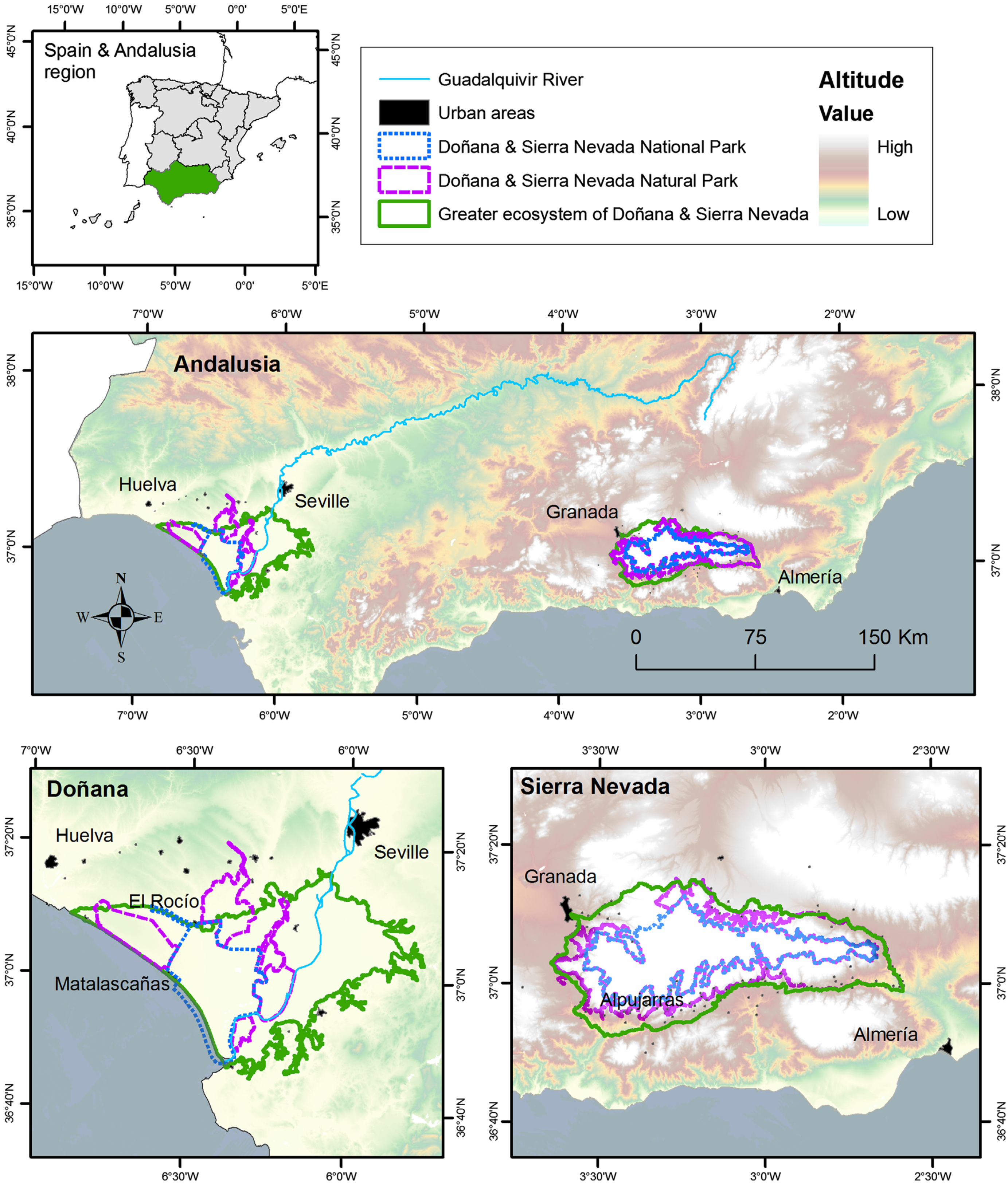

Fig. 1. Study areas. Doñana is located at the end of the Guadalquivir watershed. Sierra Nevada contains the highest peaks in the Baetic mountain system.

protected areas. The items in this section specifically addressed (1) the current use of an ecosystem services framework in protected area management, (2) the general usefulness of the ecosystem service approach to protected areas management and (3) the sections of the protected area policy in which ecosystem services would fit most appropriately. The third section assessed the principal issues facing each protected area and the ways in which the ecosystem services approach could help to resolve these issues. After the workshops, we classified the issues according to their origin (outside/inside of the protected area) and identified the drivers of change creating the issues. Appendix C presents the individual questionnaire used in the workshops, and Appendix D summarizes the list of ecosystem services.

After completing the questionnaire, the participants were split into five groups to reach a consensus on the first section of the questionnaire and to obtain maps of: (1) the SPHs, (2) degraded SPHs and (3) SBAs, of the five most important identified ecosystem services delivered by the protected area and its surroundings. Each group was given three sets of 90 dots (movable plastic discs) in three different colors (green for functioning SPHs, red for degraded SPHs, and blue for SBAs) and a topographic map of the area (1:175.000 for Doñana and 1:100.000 for Sierra Nevada). Dots were available in two sizes, equivalent to radii of 0.75 and 1 km. Participants could allocate dots reflecting the locations of ecosystem service supply, ecosystem service degradation, and ecosystem service use by the society on the map. After each group had mapped a service, a vertical photograph of the map was taken and digitized using a GIS. The maps were converted to shapefiles and to raster files to permit further analysis. We overlaid all the ecosystem service maps to obtain maps of SPHs, risk maps indicating degraded SPHs and following the nomenclature of Bryan et al. (2010), and the hotspots of SBAs. We analyzed the density of dots in each protection category (National Park, Natural Park and surrounding landscape, which is non-protected) to see how different management strategies related to the delivery of ecosystem services and to obtain management recommendations for ecosystem service protection.

4. Results

4.1. Identification of the most important ecosystem services

The results obtained from the questionnaire identified the most important services delivered by both protected areas and their surroundings, their trends and the scale of their beneficiaries (Table 1). In order of importance for Doñana, these services were habitat for species, water provision, food provided by agriculture, scientific knowledge, recreational activities, spiritual values, food provided by cattle, environmental education, eco-tourism, aesthetic values and tourism. Only water provision was identified as declining. In Sierra Nevada, the services identified were water provision, hydrological regulation, habitat for species, rural tourism, eco-tourism, climate regulation, air quality, erosion control, scientific knowledge, ski tourism, aesthetic values, and food provided by non-intensive farming. In Sierra Nevada, climate regulation, erosion control, aesthetic values and non-intensive farming were perceived to diminish.

4.2. Location of SPHs

The spatial distribution of the SPHs in both protected areas is shown in Fig. 2A (Doñana protected area) and 3A (Sierra Nevada protected area). Table 2 shows the distribution of SPHs among management strategies in both protected areas. Doñana's density distribution for SPHs included National Park (40%), Natural Park (42%), and non-protected (18%). In Sierra Nevada, the density distribution of SPHs included National Park (70%), Natural Park (28%), and non-protected (2%). In Doñana, provisioning services were found to be evenly distributed among the National Park, the Natural Park, and their surroundings, but regulating and cultural services were primarily located inside the protected areas of Doñana (Table 2). The relatively high percentage of provisioning services, such as food provided by agriculture and water provision, outside the protected area resulted because these services were primarily provided from the non-protected territory. In Sierra Nevada, the majority of SPHs were located inside the protected areas, primarily in the highest areas included in the National Park. The Natural Park also showed a high density for the delivery of regulating and cultural services (Table 2).

Table 1
Summary of ecosystem services perceived by experts during the workshops on the Doñana and Sierra Nevada protected areas. The relative importance of the service, the ecosystem service trend (based on the majority of experts' views), and the scale of beneficiaries are shown. The data represent the consensus obtained from the first section of the questionnaire.

Doñana protected area				**Sierra Nevada protected area**			
Ecosystem service	**(%)**	**Trend**	**Scale of beneficiaries**	**Ecosystem service**	**(%)**	**Trend**	**Scale of beneficiaries**
Provisioning							
Water provision	20	↓↓	Local	Water provision	27	↑	Regional-local
Food from agriculture	14	↑↑	Global-regional-local	Food from non-intensive farming	1	↓↓	Local
Food from cattle	4	↔	Local				
Regulating							
Habitat for species	28	↔	Global-regional-local	Habitat for species	17	↔	Global-regional-local
				Hydrological regulation	17	↔	Regional-local
				Air quality	5	↔	Global-regional-local
				Climate regulation	6	↓	Global-regional-local
				Erosion control	4	↓↓	Regional-local
Cultural							
Scientific knowledge	13	↑	Global-regional	Eco-tourism	7	↑	Global-regional-local
Recreational activities	8	↑↑	Global-regional-local	Rural tourism	7	↑	Global-regional-local
Spiritual values	5	↑↑	Global-regional-local	Scientific knowledge	4	↑↑	Global-regional-local
Environmental education	3	↑↑	Regional-local	Ski tourism	4	↔	Regional-local
Eco-tourism	3	↑	Global-regional-local	Aesthetic values	2	↓	Global-regional-local
Aesthetic values	3	↔	Global-regional-local				
Tourism	1	↑	Global-regional-local				

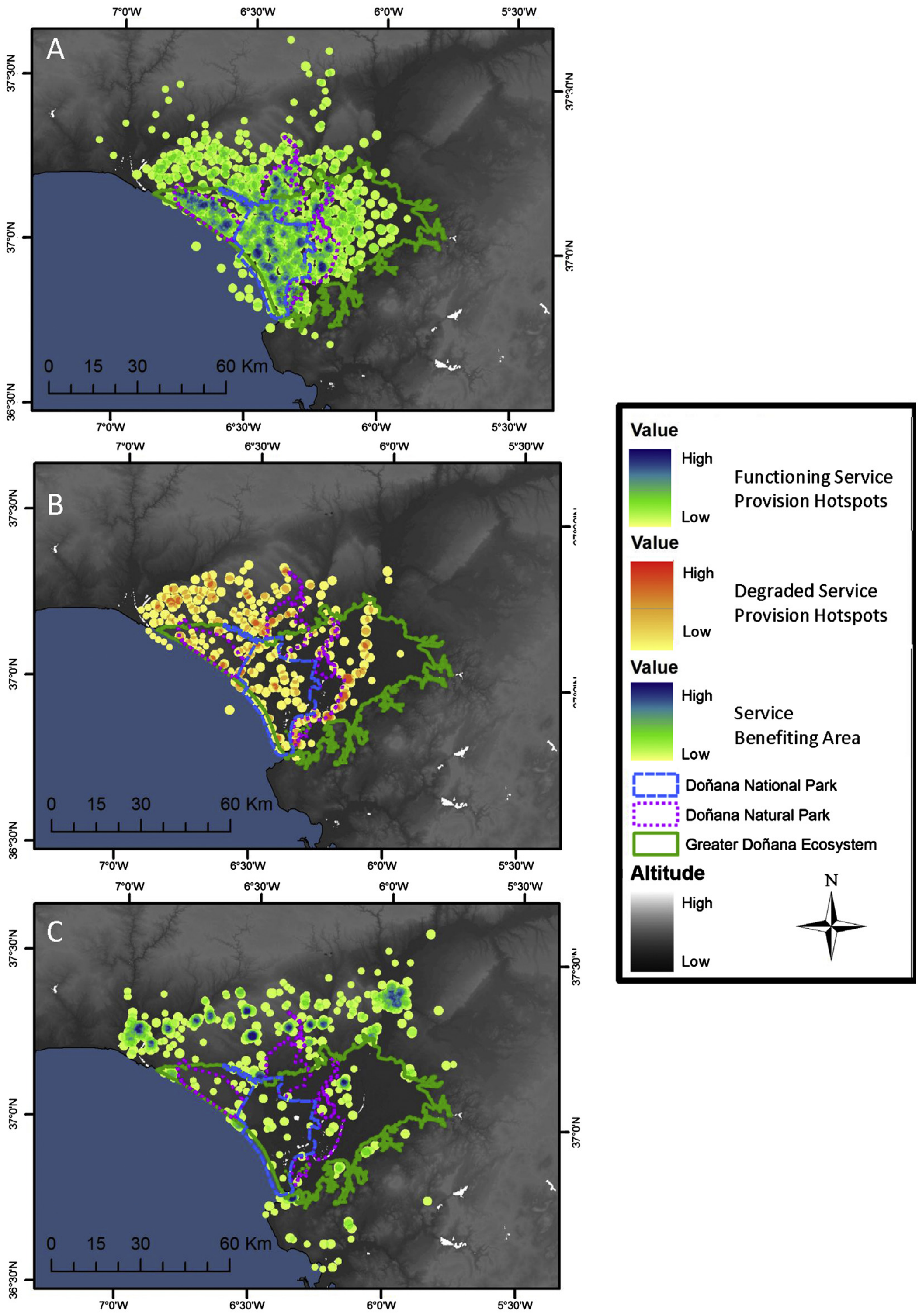

Fig. 2. Distribution of: (A) perceived functioning service provision hotspots (SPHs), (B) risks (degraded SPHs), and (C) service benefiting areas (SBAs) in the Doñana protected area. The surroundings of the protected area also provide many services because of its location at the end of the basin. Most degraded SPHs are located along the Guadalquivir River. Several degraded SPHs are located in the northwestern part of the protected area, where agriculture is more intensive. Beneficiaries are primarily located in the cities of Huelva and Seville.

4.3. *Risk maps: Location of degraded SPHs*

The distribution of the degraded SPHs identified by the workshop participants is shown in Figs. 2B and 3B. In Doñana, the most degraded SPHs were thought to be located in the northwestern part of the protected area, where water provision, habitat for species and aesthetic values were perceived as declining due to land use change associated with intensive agriculture. The Guadalquivir River also appeared as a place where SPHs had been degraded (primarily habitat for species and water provision) due to contamination and intensive water use, a finding confirmed by the literature (Mendiguchía et al., 2004). In Sierra Nevada, the degraded SPHs were primarily located near the ski resort, where services such as climate regulation, erosion control and aesthetic

Table 2
Categories of protection of both protected areas and the perceived distribution of service provision hotspots (SPHs), SPHs of each of the ecosystem services categories (i.e., provisioning, regulating and cultural), risk (degraded SPHs) and service benefiting areas. The data represent the distribution of the density of dots (as percentages, %) for each of the protection categories.

Protection category	SPHs				Risk	SBAs
	SPHs	Provisioning	Regulating	Cultural		
Doñana protected area						
National Park	40	33	42	44	49	10
Natural Park	42	37	46	43	46	8
Non-protected	18	30	12	13	5	82
Sierra Nevada protected area						
National Park	70	79	74	59	26	10
Natural Park	28	16	25	38	64	48
Non-protected	2	5	1	3	10	42

values were perceived as being degraded (Table 1). The results for the protection categories showed that degraded SPHs tended to occur inside the protected area of Doñana, while in Sierra Nevada the higher density of degraded SPHs occurred inside the Natural Park, the location of the ski resort. Table 2 shows the distribution of the density of dots for the three conservation strategies (i.e., National Park, Natural Park, and non-protected) in both study areas.

4.4. Location of SBAs

The beneficiaries were found to be located primarily in the large cities near both protected areas (Seville and Huelva for Doñana and Granada and Almeria for Sierra Nevada) (Figs. 2C and 3C and Table 2). Many urban inhabitants enjoy and use several ecosystem services provided by the ecosystems of protected areas. In fact, the proximity of urban areas and protected areas facilitates their use for recreational activities. Another key ecosystem service used by urban people was scientific knowledge, as university and scientific centers are located in cities. However, for both cultural services (tourism and scientific knowledge), many beneficiaries were located outside the map boundaries in other large cities of Spain (primarily Madrid and Barcelona) and in the rest of the world. In the case of the Sierra Nevada protected area, city dwellers also benefit from clean water coming from the protected area. The clean water is available because of the high altitude of the area's summits and the presence of snow to act as a source of water. In addition, the forests of Sierra Nevada National Park supply the service of hydrological regulation to the cities.

At a local scale, other ecosystem services, such as food provided by cattle, spiritual values, food non-intensive agriculture or erosion control were enjoyed more by the local population in small villages. In fact, higher proportions of beneficiaries occurred inside the Sierra Nevada Natural Park because several small urban settlements are located there.

4.5. Threats identified in both protected areas

In each workshop, the participants indicated the principal issues faced by both protected areas. A summary of the descriptive statistics, the underlying drivers of change, and the location of these problems is shown in Table 3. For Doñana, most of the issues originated outside the protected area. One clear example is the Aznalcóllar mine spill accident, which occurred in the headwaters that fed Doñana's marsh and which seriously threatened the protected area (Grimalt et al., 1999; Montes et al., 2003). Pressure on the protected area from outside economic activities and the isolation of the protected area are the greatest concerns. The isolation of the protected area is strongly related to transformations in the surrounding landscape associated with agriculture and tourism.

In Sierra Nevada, fewer problems were identified as originating outside the protected area than in Doñana. The probable reason for this difference is that the altitude of the Sierra Nevada isolates it from the surrounding territory, although several problems, including those referring to land-use changes, were identified as originating outside the Protected Area. The participants recognized land-use intensification (i.e., urban development and intensive agriculture) as an important driver. The urban development around the city of Granada not only promotes changes in the intensity of land use but also increases the demand for services provided by ecosystems within the protected area. In contrast, the abandonment of traditional uses is recognized as an important problem in many rural areas in Spain. The abandonment of traditional uses also promotes the loss of ecosystem services (EME, 2011; García-Llorente et al., 2012). Both trends in land-use change (i.e., intensity and abandonment) result primarily from the indirect effects of economic and socio-political drivers (Table 3). European and global markets are promoting the development of provisioning services with higher economic values. These changes cause land-use intensification and overexploitation. Meanwhile, economic subsidies to specific crops promoted by national and European policies might foster agricultural intensification outside protected areas and threaten local ecological knowledge and social cohesion (García-Llorente et al., 2011b; Gómez-Baggethun et al., 2010; Martín-López et al., 2011). In Doñana, socio-political drivers are related to problems such as administrative complexity, political interest in such an emblematic territory or the lack of strict application of law. In answer to the question "can the ecosystem service framework help to solve these problems", 84% of the responses were positive for Doñana and 80% in Sierra Nevada.

4.6. The usefulness of an ecosystem service framework for the management of protected areas

The level of current use of the ecosystem services framework in the protected areas management of Doñana and Sierra Nevada is medium, whereas the perceived usefulness of ecosystems service maps is high or very high (Table 4). This difference might indicate the utility of ecosystem service maps for landscape management in protected areas and their surroundings.

Commenting on the specific sections of protected area management ecosystem services in which the framework might best fit (including natural resources management, biodiversity conservation, research, environmental education, communication and participation and public use), the participants indicated that the framework would fit well or very well in any area and indicated no significant differences among the sections.

5. Discussion

5.1. Contributions of ecosystem service maps to protected area management

Previous participatory mapping studies for ecosystem services have shown the effectiveness of the approach for facilitating communication between decision-makers and other stakeholder groups and for performing assessments of several ecosystem services for policy making (Bryan et al., 2010; Sherrouse et al., 2011; Fagerholm et al., 2012). In our case study, we incorporated the degree of land protection as a key variable for ecosystem

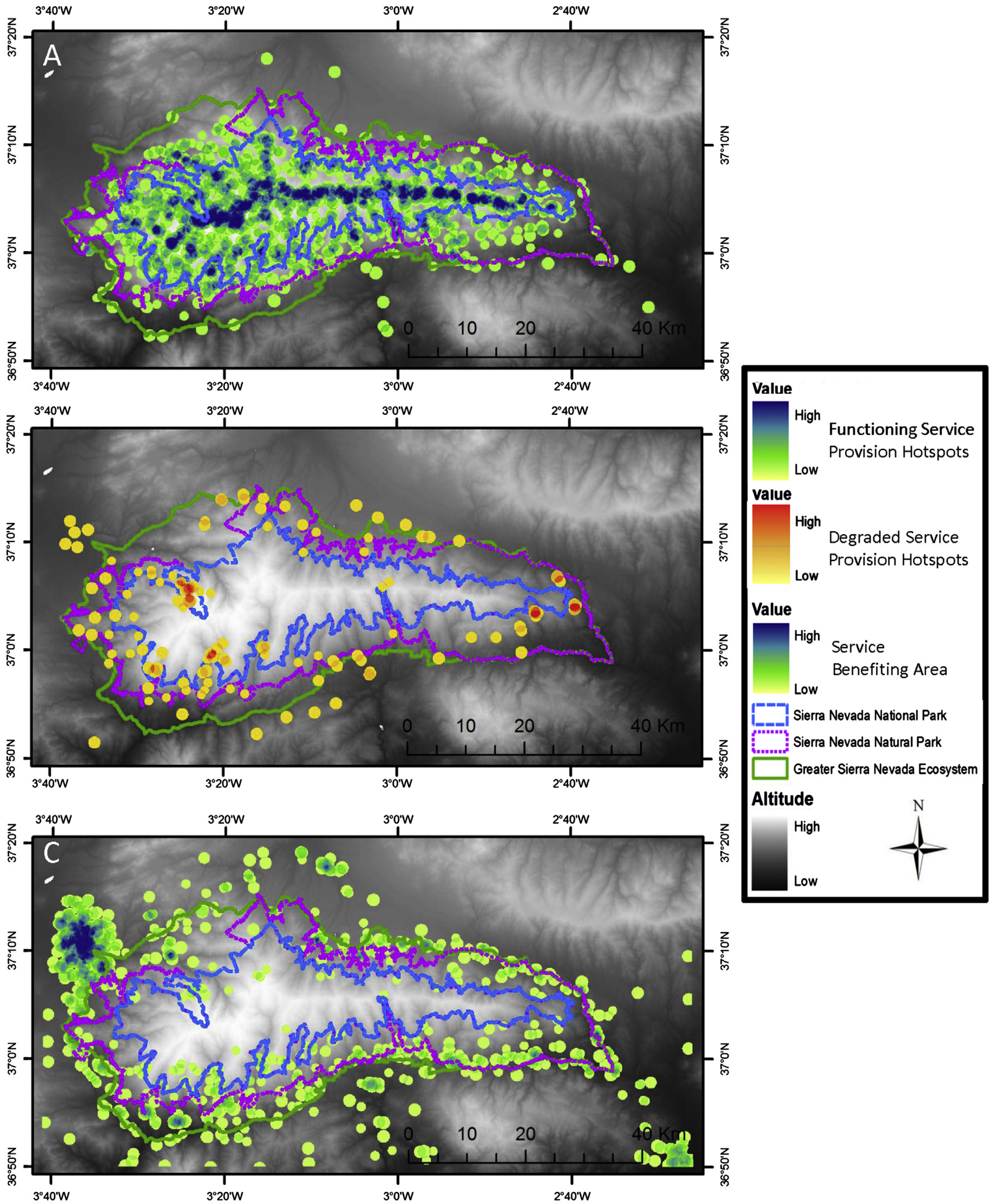

Fig. 3. Distribution of perceived: (A) functioning service provision hotspots (SPHs), (B) risks (degraded SPHs), and (C) service benefiting areas (SBAs) in the Sierra Nevada protected area as perceived by participants. SPHs are concentrated at the summits, with a density gradient from west to east. Most degraded SPHs are located around the ski resort of Prado Llano. Beneficiaries are primarily located in the cities of Granada and Almeria.

Table 3
Summary of descriptive statistics of perceived principal problems in the Doñana and Sierra Nevada protected areas, drivers creating the problems and location of the problems. Percentage of respondents (%) is relative to $N=21$ for Doñana and $N=20$ for Sierra Nevada. Location refers to *inside* protected areas and *outside* them.

Principal problems	(%)	Direct drivers related	Indirect drivers related	Location
Doñana protected area				
Pressure from outside economic activities on the PA and isolation	42	Land-use	Economic	Outside
Effects on quality and quantity of water flows	42	Overexploitation and contamination	Economic	Outside
Contamination	36	Contamination	Economic, socio-political	Outside
Political interests	26		Socio-political	Outside and inside
Aquifer overexploitation	26	Over exploitation and land-use	Economic	Outside
No application of legislation	21		Socio-political	Outside and inside
Overcrowding of tourism	21	Land-use	Economic and cultural	Outside
Administrative complexity and lack of coordination	21		Socio-political	Outside and inside
Ecosystem fragmentation	16	Land-use	Economic	Outside
Invasive species	16	Invasive species		Outside and inside
Sierra Nevada protected area				
Urban development	47	Land-use	Economic	Outside and inside
Abandonment of traditional uses	40	Land-use	Economic, socio-political, demographic and cultural	Outside and inside
Ski tourism	33	Land-use	Economic and cultural	Inside
Emigration of rural population	27		Demographic, socio-political, and economic	Outside and inside
Illegal hunting	20		Cultural	Inside
Invasive species	20	Invasive species		Outside and inside
Overcrowding of tourism	20	Land-use	Economic and cultural	Outside and inside
Monospecific forest areas	20	Land-use		Inside
Intensive agriculture	20	Land-use	Economic and socio-political	Outside

Table 4
Current use of the ecosystem service framework in both protected areas and perceived usefulness of ecosystem services maps for their management. Percentage of respondents (%) is relative to $N=21$ for Doñana and $N=20$ for Sierra Nevada.

	Very high (%)	High (%)	Low (%)	None (%)
Doñana protected area				
Current use of ecosystem services framework	16	47	32	5
Perceived usefulness of using ecosystem services maps for protected area management	56	44	0	0
Sierra Nevada protected area				
Current use of ecosystem services framework	13	33	47	7
Perceived usefulness of using ecosystem services maps for protected area management	62	38	0	0

service supply and identified spatially key issues for protected areas management, including (1) priority conservation areas for ecosystem services preservation that are currently unprotected, (2) areas under protection that are perceived by experts to provide relatively few services, and (3) areas considered suitable for ecosystem service restoration inside the protected area because experts perceived a high level of degraded SPHs.

Our results for new priority conservation areas showed that the northwestern Sierra Nevada National Park, the only part of the National Park not surrounded by the buffer zone of the Natural Park, delivers a diverse flow of ecosystem services (Fig. 3A).

Our findings regarding currently protected areas that experts considered not to supply a relatively large number of services to society showed that the semi-arid eastern region of Sierra Nevada provides substantially fewer services than the western part (Fig. 3A). This finding could be explained because tourism is more developed in the Alpujarras, located in the western part of the area, and because of the negative consequences of rural abandonment for ecosystem services delivery (García-Llorente et al., 2012). An additional reason for the experts' opinion that the eastern region provides relatively few services may be that scientific authorities and experts are not sufficiently aware of these semi-arid ecosystems. For example, an ISI Web of Science search for publications about the Sierra Nevada protected area (2000–2011, Ecology and Environmental Sciences; $N=85$) demonstrates a substantial bias toward the western region. Of these 85 studies, 65.9% were conducted in Granada province, 28.2% in both regions, and only 5.9% in Almería province. In every case, the maps show the need for a value enhancement strategy in the eastern area of Sierra Nevada.

Finally, the maps of degraded SPHs show areas where action should be taken to maintain the provision of ecosystem services (Figs. 2B and 3B). Restoration programs should focus on the Gualdaquivir River restoration in Doñana (Fig. 2B) and the restoration of irrigated terraces (and therefore the service of erosion control) in the semi-arid region of Sierra Nevada and the area of the ski resort (Fig. 3B).

5.2. *Influence of topography and of categories of protection on ecosystem services*

Although the provision of ecosystem services might vary depending on the type of ecosystem (Costanza et al., 1997), it is also influenced by the type of land management practiced (van Oudenhoven et al., 2012). The categories of protection also have an effect on social preferences for ecosystem services (Martín-López et al., 2012). The Doñana protected area has prevented the transformation of natural ecosystems into agricultural land or tourist resorts (e.g., the Matalascañas resort). For that reason, most of the intensively managed provisioning services (e.g., red fruits and rice agriculture) are located outside the protected area, whereas regulating and cultural services have a higher density in the protected categories. These results are consistent with a study by Martín-López et al. (2011) that performed an economic valuation of the ecosystem services of Doñana and showed that an important trade-off occurs between those provisioning services associated with national and global markets delivered by the surroundings of the protected area (i.e., intensive agriculture and fisheries) and those regulating services supplied by the protected area's ecosystems.

In Sierra Nevada, however, all of the selected services are provided primarily by the National and Natural Parks. The reason for this outcome might be that most of the natural assets are located within the protected area. The water supply originates from the tops of the mountains, and there is no intensive agriculture close to Sierra Nevada to affect the supply. Campo Dalias is approximately 20 km from the protected area, on the other side of the Gador mountain system. In Doñana, agriculture in the surrounding lands is having a substantial impact on the protected area because the water table is being lowered by wells located outside the protected area and because part of the water runoff from agricultural lands flows into the protected area. These water supply characteristics clearly differ from those of a mountain system in which the protected area is located in the highest parts of the range and which would not be affected nearly as much by agriculture in its surroundings. All these reflections serve to motivate a conceptual proposal of the distribution of ecosystem services provided by a mountain and a downstream protected area (Fig. 4). The density of degraded services is higher in the borders than in the center of the protected areas due to cross-boundary effects (see Figs. 2 and 3). Border effects are one of the main threats that protected areas currently face (McNeely, 1994; IUCN, 2004). In Doñana, the density of degraded services is higher inside the protected area than outside although more service degraded units are located outside. The reason for this is that participants focused primarily in mapping inside the protected area and it's proximities thus density of degraded services in the whole surrounding territory is reduced.

5.3. *How to cope with the isolation of protected areas? Conceptualizing ecosystem services as landscape connectors*

In the context of protected areas management, there has been a call for a shift to the ecosystem service perspective (Pyke, 2007; Dudley et al., 2011) and an awareness that ecosystem services should be included in conservation planning (Chan et al., 2006). Such moves might be effective in supporting the case for protected areas. However, protected areas would continue to be isolated by a sole focus on protected areas management that ignored the surrounding territorial matrix (De Fries et al., 2010).

Although the managers of a protected area can influence the way in which its surroundings develop (e.g., agriculture in the area surrounding Doñana is adopting more sustainable and efficient methods of water use), this influence might not be sufficiently strong. In Doñana, many SPHs of the intensively managed provisioning services (such as agriculture) have a strong negative influence on the ecological integrity of the protected area due to aquifer overexploitation or water contamination (Custodio et al., 2010). This case furnishes a clear example of the way in which the protected area depends on the management

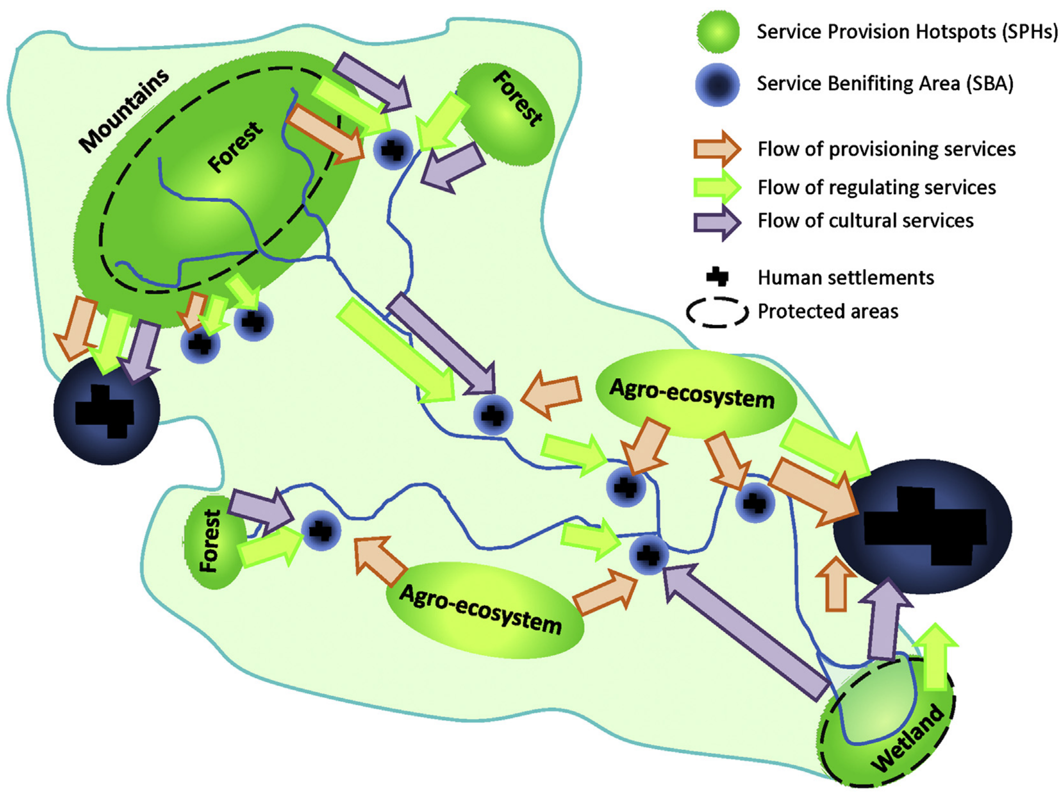

Fig. 4. Simplification of ecosystem service supply and demand for protected areas in a mountainous area and at the end of a drainage system. For the former, most important ecosystem services provided by the protected area and its surroundings will most likely be located inside the protected area (given that it contains the summits and other natural assets, such as forests). In a downstream situation, provisioning services are most likely located outside the area's boundaries (the source of water runoff or the location of agriculture), whereas regulating and cultural services might be provided more intensively by the protected area and also outside the area. Because protected areas normally exclude densely populated centers, ecosystem service demand is most likely located outside the protected area.

of the surrounding lands. Many of the most important problems of the protected area are related to this issue (Table 3).

Moreover, the SPHs for each category of ecosystem services, particularly in Doñana, were located both inside and outside the protected area (Table 2). This finding illustrates the necessity of landscape management mechanisms that ensure a diverse flow of ecosystem services supply to avoid undesired trade-offs between provisioning and regulating services (Elmquist et al., 2011), as well as social conflicts among stakeholders. In Doñana, for example, land-use intensification in the non-protected territory with the aim of increasing agricultural production could cause the degradation of most of the regulating services affecting local actors and could reduce the satisfaction of nature tourists because recreation and aesthetic services are only concentrated inside the protected area (Martín-López et al., 2007, 2011).

Consequently, it is important to understand in which environmental and socio-economic conditions the connection between the supply and demand of ecosystem services takes place. Likewise, it is important to understand the connections among ecosystem services, i.e., ecosystem service bundles (Raudsepp-Hearne et al., 2010). For every service, an identification of key biogeophysical factors underlying the supply of services and the identification of key stakeholders who demand ecosystem services should be an essential step in characterizing the connection between SPHs and SBAs (Syrbe and Walz, 2012) to develop a comprehensive strategy for the management of protected areas.

5.4. *The role of remote places in the management of protected areas*

Urban regions have become focal points of the demand for ecosystem services because urban areas increasingly depend on ecosystem services supplied by protected areas (McDonald et al., 2009) and rural areas (Kroll et al., 2012). Although we found that ecosystem service beneficiaries range from local to global scales (Table 1), it appears that nearby cities are an important focus of ecosystem service demand (Figs. 2C and 3C), primarily for provisioning and for cultural services (recreational and scientific knowledge). The increasing demand for provisioning services in cities near protected areas, as well as the demand for such services in other Spanish and European cities (see Martín-López et al., 2011), promotes land-use intensity changes that have an ultimate negative effect on the integrity of the ecosystems and on the delivery of ecosystem services (García-Llorente et al., 2012; Laliberté et al., 2010; Laliberté and Tylianakis, 2012; Schneiders et al., 2012). Consequently, managing the social demands for ecosystem services in urban areas and cities is an essential step for the management of protected areas. This extension of the scope of management will expand the radius of action associated with protected areas to areas that are located far from the protected areas and that demand ecosystem services from the protected areas or their surroundings.

The design of the management of protected areas based on an ecosystem service framework should be based not only on the scale at which services are delivered but also on the scale at which beneficiaries use the services (Hein et al., 2006). Consequently, based on the spatial scale at which beneficiaries are operating (see Table 1), the management of the Andalusian protected areas should be conducted by institutions from the local level to the level of European organizations with the aim of managing ecosystem service demands. To meet this challenge, there is a need for better communication and coordination among protected area managers at the local and national scales, users of protected areas and local stakeholders. Here, different key aspects should serve to coordinate environmental policies in protected areas. In terms of the supply side of ecosystem services, protected areas and their surroundings should focus on maintaining key ecosystem properties essential to provide a diverse flow of ecosystem services. In this sense, protected areas should be combined with other conservation strategies in the surrounding lands, such as agro-environmental schemes, payments for ecosystem services, land stewardship or multi-tenure protection (Eigenbrod et al., 2010). In terms of the demand side, the analysis of ecosystem service footprints should be developed (Burkhard et al., 2012a) to implement environmental education campaigns and resource-efficient programs as well as incentives for reducing ecosystem service demands where larger footprints are present.

6. Conclusions

The results of this study show that Doñana and Sierra Nevada National Parks and their buffer areas (Natural Parks) provide a diverse range of ecosystem services that benefit the surrounding lands. Furthermore, certain neighboring unprotected areas outside the National and Natural Parks also provide many of these services. Ecosystem service maps were found to serve as a useful first step for a management plan for protected areas based on ecosystem services because we could extract concrete policy proposals from the information provided by the ecosystem services maps. Maps of ecosystem services flows in protected areas and their surroundings serve as a stepping stone for the analysis of the boundaries of protected areas under the ecosystem service framework. Moreover, these maps facilitate the exploration of the consequences for the protected area of demands for ecosystem services originating from remote locations. We have also shown how the majority of the issues for Sierra Nevada, and especially for Doñana, originated in the surroundings of the protected areas, reinforcing the need for a broader landscape management strategy.

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Appendix A

See Table A1.

Appendix B

See Table B1.

Appendix C

See Table C1.

Appendix D

See Table D1.

Table A1
Characterization of Doñana and Sierra Nevada regions. Adapted from García-Llorente et al. (2011b).

Characteristics	Doñana region	Sierra Nevada region
Spatial extent	Greater Doñana ecosystem (2207 km^2). Doñana National Park (54,252 ha). Doñana Natural Park (53,835 ha). Approximate altitude range: 0–280 m	Greater Sierra Nevada ecosystem (2230 km^2). Sierra Nevada National Park (85,883 ha). Sierra Nevada Natural Park (86,432 ha). Approximate altitude range: 180–3482 m
Designation of the principal protection categories	National Park: 1969 Natural Park: 1989	National Park: 1999 Natural Park: 1989
Nearest cities	Seville (700,000 inhabitants) and Huelva (250,000 inhabitants)	Granada (500,000 inhabitants) and Almeria (200,000 inhabitants)
Ecological characterization	Diverse ecodistricts (marshes. dunes. estuary and cost) (Montes et al., 1998) support charismatic endangered species (*Iberian lynx* and *Aquila adalberti*). Major stepping-stone for migrating birds moving between Africa and Europe (García-Novo, Marín, 2005).	Ecodistricts in a great altitude range including high summits to semi-arid environments (Jimenez-Olivencia, 1991) support the most important area for plant diversity and endemism in the western Mediterranean region (Blanca et al., 1998).
Socio-economic characterization	Tourism (beach, nature and religious) and agriculture are the main sectors. The National Park received 350,005 visits in 2008 (Europarc-España, 2010), and a study estimated 4 million visitors to the Doñana region in 2003, 75% of whom visit El Rocío Village. Most visits are on a regional scale (Gómez-Limón et al., 2003). Matalascañas is an urbanized tourism facility surrounded by the National and Natural Parks. Agricultural lands surrounding the protected area produce strawberries and rice for national and international consumption. The unemployment rate is high.	Tourism and agriculture are the main sectors. The National Park received 684,573 visits in 2008 (Europarc-España, 2010). The western part is more densely populated, attracts more tourism (especially in the Alpujarras area) and receives more precipitation. The eastern part suffers from more rural abandonment, an aging population and aridity. The unemployment rate is high.

Table B1
Number of participants and their institutions.

	Doñana	Sierra Nevada
National parks agency	1	1
Regional environmental institutions	2	2
Protected area managers	13	13
University (Seville University in Doñana and Almería, Granada and Pablo de Olavide Universities in Sierra Nevada)	2	4
Other research institutions (Doñana Biological Station—CSIC)	3	

Table C1
Individual questionnaire used in both workshops.

Section 1
1. What are the five most important ecosystem services provided by the protected area for human well-being? Answer in order of importance (*with checklist*).
2. Which trends (increase, constant, decrease) do these ecosystem services follow? Why?
3. At which scale (global, regional, local) are these ecosystem service enjoyed? Where are ESBs located?

Section 2
4. Does the protected area use the ecosystem services framework (very much, quite, little, nothing) in its management?
5. How important (very, quite, little, not necessary) is it to use the ecosystem service approach for protected area management?
6. In which sections of protected area management (public use, natural resources management, biodiversity conservation, environmental education, research and communication) should the ecosystem services maps be applied?

Section 3
7a. What are the main problems faced by the protected area?
7b. Can an ecosystem services management strategy help solve these problems?

Table D1
List of the most important ecosystem services. This list was provided to participants for use with the questionnaire (examples and definitions are summarized here).

	Ecosystem service	Example/Definition
Provisioning	Food provided by: agriculture, cattle, aquaculture, fishing, hunting, collection, beekeeping	Products derived from biodiversity for consumption as food
	Water provision	Good-quality water from surface or below-ground flows for human, agricultural or industrial use, as well as desalted water
	Raw materials of biological origin	Materials such as wood and vegetable fibers to produce goods for consumption
	Raw materials of non-biological origin	Materials such as slate or gneiss used for construction
	Salt	Marine or continental salt used for consumption
	Renewable energy	Energy obtained from geophysical processes or ecosystems such as solar, wind, hydropower or biomass
	Medications and therapeutic compounds	Healing compounds contained in traditional medicines or used by pharmaceutical manufacturers to produce medications
Regulating	Climate regulation	Vegetation capacity to absorb CO_2, mesoclimatic regulation and regulation of temperature by forests and water bodies
	Air purification	Retention of air pollutants by vegetation
	Water depuration	Extraction of contaminants from water by vegetation, invertebrates and soils

Table D1 (*continued*)

	Water regulation	Regulation of water fluxes by aquifers, accumulation of water in snow and its release in spring and summer
	Erosion control	Control of erosion by vegetation to prevent landslides or reservoir siltation
	Soil fertility	Natural fertility of soils, nutrient richness
	Disaster mitigation	Diminution of the effects of perturbations such as fire or floods by ecosystems
	Biological control	Control of pest and diseases affecting agriculture, cattle or humans
	Pollination	Insect cooperation with plants to facilitate reproduction
	Habitat for species	Maintenance of habitat for species to facilitate species conservation
Cultural	Scientific knowledge	Scientific knowledge gathered from the study of ecosystems
	Traditional ecological knowledge	Practices and customs transmitted through generations and used for managing agriculture, cattle, and other relationships with the environment
	Environmental education	Instruction in ecological processes, raising of awareness about biodiversity and ecosystem services in visitor centers or educational activities
	Nature tourism	Responsible travel to natural areas to practice hiking, bird watching, relaxation
	Rural tourism	Travel to rural areas to enjoy customs, traditional architecture or gastronomy
	Ski tourism	Practice of alpine skiing or snowboarding
	Aesthetic values	Appreciation of landscape beauty
	Spiritual values	Practice of traditional processions or conception of nature as something sacred
	Existence value and species conservation	Satisfaction of knowing that certain species and ecosystems exist

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