Science–policy interface for addressing environmental problems in arid Spain

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Community of practice
Culture of share responsibility
Decision-making
Participatory workshop
Water policy

ABSTRACT

Science–policy interfaces are avenues for finding solutions for environmental challenges through strengthening collaborations between research disciplines and public administrations. Here we present a methodology for the conduct of science-policy interfaces between scientists and policymakers for addressing day-to-day environmental problems in the southeastern Spanish drylands. A knowledge brokering approach based on six consecutive workshops was used to facilitate mutual understanding and trust between scientists and policymakers. Water policy and biodiversity loss were identified as major environmental concerns in the region, and 12 final environmental problems were agreed as priorities. A graphical tool was used for diagnosing each environmental problem according to the available scientific knowledge, the current regulatory capacity of administrations, and the level of public engagement necessary for addressing the problem. The use of the graphical tool also allowed for (a) the clarification of roles involved in problem solving, and (b) the promotion of a culture of shared responsibility for the implementation of management actions based on collaborative work. We discuss lessons learned and propose recommendations for future experiences.

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1. Introduction

Science–policy interfaces (SPIs) are communication processes used to open frontiers between research disciplines and other actors by strengthening collaboration, for example for addressing and diagnosing environmental challenges. SPIs are based on collaborative social experiences that enhance exchange and coevolution, and promote the construction of knowledge between different groups involved in decision-making (Van den Hove, 2007). SPIs represent an opportunity for strengthening the link between science and policy in the wide and complex field of environmental problems. These experiences are crucial for different stages of the policy cycle, based on collaborative social experiences that enhance exchange and coevolution, and promote the construction of knowledge between different groups involved in decision-making (Van den Hove, 2007). SPIs represent an opportunity for strengthening the link between science and policy in the wide and complex field of environmental problems. These experiences are crucial for different stages of the policy cycle,
such as the definition of environmental problems, identification of research priorities, implementation of consensual solutions, and assessment and monitoring of implemented policies (Roux et al., 2006).

Traditionally, the interactions between scientists and policymakers have been based on a one-way approach, with knowledge transfer largely originating from the scientists (Roux et al., 2006), and involving the scientists as the producers of knowledge and the policymakers the users. However, scientists have begun to concern themselves with aligning their research to real needs of the policy arena (e.g., Rudd, 2011), in order to improve the impact of scientific knowledge in decision-making. With this aim in mind, there is greater need for a two-way communication approach that allows scientists and policymakers to work together towards identifying environmental priorities and proposing consensual solutions (Roux et al., 2006). Thereby, scientists can gain awareness of the variety of directions in which research can impact policy to develop policy-oriented research plans, and policymakers can note the fields where more applied research is required. In this way, research becomes more effective, as scientific evidence bears a direct and instrumental impact on policy (Rudd, 2011), and policymakers gain access to the latest research to incorporate into their decision-making (Pullin and Knight, 2003).

Currently, there exist SPI experiences consolidated at the regional, national, and international levels wherein science has successfully influenced decision-making domains (Engels, 2005). Previous experiences suggest that these interactions can benefit scientists and policymakers in different ways, such as conferring better access to new sources of information and updated databases. Examples include the inputs to international policy contributed by the Intergovernmental Panel on Climate Change (IPCC), the Convention on Long Range Transboundary Air Pollution (LRTAP), and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). However, some studies have highlighted the need to develop and refine tools and operational methods within SPIs that facilitate understanding and engagement between the actors involved (Cornell et al., 2013). In this regard, one current challenge is how to achieve a culture of shared responsibility in SPI experiences through the creation of communities of practice (PSI-connect project, 2012). Communities of practice are defined as groups of actors who share common interests, knowledge and experiences in particular areas through a collaborative interaction that strengthens trust and mutual understanding (Wenger et al., 2002). In addition, communities of practice serve as workspaces embedded within larger systems of power and knowledge that evolve and change over time (Van Kerkhoff et al., 2006).

Applying SPIs in the current context of global change demands commitment, awareness and willingness by communities of practice to recognize new scenarios in which human activities generate rapid environmental changes (Cornell et al., 2013). SPIs can be incorporated into the assessment of monitoring programmes for the effects of environmental changes, providing a framework wherein scientific advances and societal concerns and needs can be easily coupled. Here, we present a SPI experience achieved in the context of a project for monitoring global change impacts on Spanish arid ecosystems (GLOCHARID project, 2014). Our goal was to conduct a SPI experience that involved scientists and policymakers in strengthening their collaborative work towards addressing day-to-day environmental problems. Specifically, we present a graphical tool used with the aim of promoting a culture of shared responsibility for diagnosing specific environmental problems and proposing collaborative actions based on consensual solutions. We discuss limitations derived from our experience and propose recommendations for future SPIs experiences.

2. Materials and methods

2.1. Study area

The SPI was developed in the southeast Iberian Peninsula drylands (Fig. 1). This area is the most arid region in Europe, with a mean annual rainfall of 200–350 mm and a mean annual temperature of 12–15°C. A warming trend in both the extreme and mean temperatures has been registered in the region in recent decades. This region exhibits a convergence of ecological and socioeconomic factors that produce conflicts of interests between conservation actions and human development. The region supports high levels of biodiversity, with numerous endemic species and habitats of priority interest at European levels. Economic activities in the region are related to greenhouse horticulture and its parallel industries such as packaging and transport, biological control, tourism, and the service sector (Quintas-Soriano et al., 2014).

2.2. Workshops structure, design, and participants

The SPI experience was conducted from October 2010 to May 2012 by organizing a community of practice that included scientists and policymakers from different disciplines with extensive service records. Considering the time limitations and financial constraints of our study, on the science side, we invited 41 researchers from universities and research centres in the region, with a wide range of experiences in biological, geological, socio-ecological, climate, and pollution aspects of the environment. On the policy side, we invited 67 professionals from different public institutions with regulatory competences in environmental decision-making. We first contacted the heads of relevant area organizations by email (to addresses provided at their official websites) and explained the details and goals of the study in an invitation letter (Appendix A). Ultimately, a total of 25 scientists and 45 policymakers responded with their willingness to participate in the SPI (Appendix B). However, the attendance was not constant throughout the experience, and participants varied from 13 to 66 people.

The SPI was organized in two stages comprising six consecutive workshops (Fig. 2). The first stage consisted of two workshops for facilitating information exchange and feedback between scientists and policymakers to identify major environmental concerns in the region. The second stage included two parallel communication processes (each with two workshops) to formulate and diagnose two priority environmental concern areas. The efforts of the community
of practice were oriented towards identifying concrete environmental problems and proposing consensual solutions based on collaborative work.

To ensure dynamism and operability in all workshops, prior to the workshops, all participants were supplied with a timetable and useful materials such as details and goals pursued in the study, a full list of participants, and work schemes. Every workshop was organized according to an outline that included an introduction to the specific goals, individual introductions of each participant, and a final guided discussion to summarize results. To facilitate interaction among participants, worktables were set up in a circle in which professional profiles were alternated. Each workshop had a technical secretary who took minutes of the meeting and sent them afterwards to participants for their approval. These minutes provided transparency and credibility to the process. Furthermore, to ensure a constant flow of communication between scientists and policymakers, communication media (email) were used outside meetings to facilitate constant communication. All workshops were held in the afternoon to facilitate maximum attendance.

The SPI was coordinated and guided by two knowledge brokers, a research broker and an evidence broker (Bielak et al., 2008). Both were prestigious within their fields and were personally capacitated for exploring and understanding the goals and priorities of both scientists and policymakers. Brokers designed the interface strategy and defined members of the community of practice. They also encouraged activities, facilitated interactions between groups, and integrated and summarized results. After each workshop, brokers sent the outcomes obtained to participants to ensure results reflected consensus, and incorporated final suggestions and corrections.

2.2.1. Workshop 1: identifying major environmental concerns

Workshop 1 was designed to identify major environmental concerns in the region based on the experience and expertise of scientists. The workshop started with an introduction by brokers of the SPI’s philosophy and rationale. Then, scientists introduced their specific research lines, clarifying the most relevant findings and methodologies used. After that, brokers guided a debate to prioritize the environmental challenges occurring in the region. To do this, participants were asked to propose scientific topics that matched environmental challenges in the region. All topics were systematically written down on a blackboard and grouped into a final list of key words. Participants were asked to select four of those key words based on their expertise and synergies. A total of 21 scientists from 13 disciplines were involved (Appendix B).

2.2.2. Workshop 2: prioritizing two major environmental concerns for launching the collaborative work between scientists and policymakers

Workshop 2 implemented the collaboration between scientists and policymakers and aimed to select two priority environmental concerns based on a consideration of the available scientific knowledge, the policy context, and the relevance to society. To launch the workshop, brokers
introduced the rationale of the SPI and presented results obtained in workshop 1. Then, policymakers were invited to describe the political-administrative context of each environmental concern to clarify the current environmental regulatory capacity at different administrative levels (Weichselgartner and Kasperson, 2010). A card-writing system was used to identify preferences and constraints of scientists and policymakers regarding the environmental concerns previously identified (Appendix C). All participants were asked to express their professional opinions on the social relevance of each environmental concern. In addition, whereas policymakers were required to indicate their legal competences, scientists indicated their research expertise related to the environmental concerns (Appendix C). Brokers, using the card system results, then promoted a new collaborative debate to prioritize two environmental concerns. Workshop 2 involved a total of 66 participants, 24 scientists (21 from workshop 1, and 3 new researchers) and 42 policymakers (Appendix B). The policymakers were experts from public administrations at different administrative scales with environmental responsibilities such as water management, environmental education, and protected area management.

2.2.3. Workshops 3a and 3b: formulating concrete environmental problems within each priority concern
Workshops 3a and 3b aimed to formulate concrete environmental problems to be implemented in the SPI (environmental concern “a” and “b”, Fig. 2). Both workshops started with a brainstorming activity guided by brokers to create a primary list of environmental problems in the region. All problems were analyzed according to their chains of cause–effect relationships based on the DPSIR model (drivers, pressures, states, impacts and responses, European Environment Agency, 2007). For this analysis we used a similar blackboard system to group the problems accordingly to DPSIR relationships, and scientists and policymakers agreed in means or goals on a final list of environmental problems to work with (in the sense of Hisschemöller and Hoppe, 2001). Workshop 3a included 8 scientists and 5 policymakers, and workshop 3b included 12 scientists and 9 policymakers (Appendix B). All the participants were also involved in workshop 2.

To follow up, after each workshop, brokers explained the domain scheme proposed by Rudd (2011) that establishes the connection between scientific knowledge and the articulation of a policy issue. Scientists and policymakers were asked to identify empirical research evidence and to clarify a regulatory framework for each environmental problem, respectively. This process was open for a period of 2 months. Brokers compiled and incorporated this information in following workshops.

2.2.4. Workshops 4a and 4b: analysing environmental problems and creating collaborative solutions
Workshops 4a and 4b analyzed the selected environmental problems associated with environmental concerns “a” and “b”, respectively. The analysis was based on a conceptual framework which includes three dimensions of information related to science, policy, and society (Edelenbos et al., 2011). Brokers introduced a graphical tool that summarized the state-of-the-art of each dimension (Table 1): the scientific knowledge (science dimension), as the available scientific evidence regarding a specific problem; the regulatory capacity (policy dimension), as the current level of legislative framework relevant to articulating solutions in public administrations; and the public engagement (societal dimension), which reflects the level of social relevance of specific problems to the general public. Each dimension corresponded to a normalized gradient on a categorical scale from 0 to 3. A value of 0 was used to indicate that a particular dimension was not relevant for solving the problem in the short term. Table 1 summarizes the meaning of values from 1 to 3 for each dimension. All participants were asked to rate specific environmental problem according to each dimension. Public engagement was addressed by accounting for the number of formal requests to public administrations indicating concerns or complaints by social actors.

Once environmental problems were analyzed, brokers explored the individual interests of participants to be involved in “interface teams” for taking responsibility to implement actions based on collaborative solutions for each problem. This formalization was open for 6 months. After that, brokers informed the community of practice about the agreements between entities and interface teams and described the actions to be achieved for their approval. Workshop 4a included 8 scientists and 9 policymakers, and workshop 4b included 10 scientists and 9 policymakers (Appendix B). Workshop 4a comprised 59% returning participants and 41% new participants, whereas workshop 4b had 89% and 11%, respectively.
Table 1 – Diagnostic criteria for analysing environmental problems. The three gradients express: the scientific knowledge available to approach each problem, the existing regulatory capacity for making decisions, and the current level of public engagement as evaluated by requests to public administrations to solve a problem. Each gradient shows 4 categorical levels that represent different scenarios.

<table>
<thead>
<tr>
<th>Gradient</th>
<th>Levels</th>
<th>Definition</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific knowledge</td>
<td>Unessential</td>
<td>Scientific knowledge is not currently essential to approach the problem.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Unaligned</td>
<td>There is existing knowledge for approaching the problem, but it is inapplicable.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Aligned</td>
<td>There is existing knowledge applicable to the problem.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Aligned</td>
<td>Existing knowledge has been applied to the problem, but it is unconnected to policy.</td>
<td>3</td>
</tr>
<tr>
<td>Regulatory capacity</td>
<td>Undetermined</td>
<td>The problem has no legislative framework to articulate its solution.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Limited</td>
<td>There is a legislative framework for the problem.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Defined</td>
<td>There are legislative framework and policy instruments for the problem.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Preferential</td>
<td>There are legislative framework and policy instruments for the problem, and the problem is in an area of priority action for environmental policy.</td>
<td>3</td>
</tr>
<tr>
<td>Public engagement</td>
<td>None</td>
<td>The problem just needs scientific, technical or legal solutions, and can be solved without more public engagement.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Public engagement is necessary for approaching the problem, but there is no manifest demand for it.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>There is a manifest need for public engagement to approach the problem, but there is no formal commitment by society to become involved in its solution.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>There is public engagement in the approach to the problem and formal commitment by society to become involved in its solution.</td>
<td>3</td>
</tr>
</tbody>
</table>

3. Results

3.1. Major environmental concerns in Iberian Peninsula drylands (workshop 1)

Workshop 1 identified four major environmental concerns within the region: (1) changes to land-use patterns and land cover by human development; (2) the loss of biodiversity; (3) water related issues in the policy arena; and (4) impacts of climate change on species and ecosystems. These concerns were selected from an initial list of 10 scientific topics that reflected environmental challenges in the region. Appendix D summarizes all topics selected by scientists: land-use change (selected 18 times), biodiversity loss (13), policy water issues (10), impacts of climate change (9), the role of services provided by ecosystems to society (8), desertification (7), increase of invasive species (6), carbon and water balances (5), river health (5), and wetland conservation (3).

3.2. Water policy and biodiversity loss as priority concerns for strengthening collaborative work (workshop 2)

As a result of the workshop 1, water policy and biodiversity loss were identified as the preferred environmental concerns towards which to strengthen collaborative work between scientists and policymakers (Table 2). These priorities emerged as a balance of the professional interests of the participants, the administrative competences of policymakers, the research expertise of the scientists, and the societal relevance perceived by both policymakers and scientists (Table 2). Although there was an initial lack of confluence between the priorities identified by policymakers and scientists (Table 2), the groups debated and ultimately agreed that water policy (96% of total participants) and biodiversity loss (43%) were priority areas with the highest societal relevance.

3.3. Specific environmental problems related to water policy and biodiversity loss (workshops 3a and 3b, respectively)

Workshops 3a and 3b identified 12 environmental problems: five related to water policy and seven related to biodiversity loss (Table 3). Table 3 summarizes the rationale, scientific evidence and regulatory framework for each environmental problem. The 12 environmental problems were formulated during the brainstorming period from a total of 46: 20 related to water policy and 26 related to biodiversity loss (Appendix E). All environmental problems were classified according to the components of the DPSIR analytical model. Thus, 10 were related to different drivers of global change, 2 were categorized as pressures on ecosystems, 3 as reflecting the state of ecosystems, 6 as direct impacts on ecosystems, and 25 as failed response measures. In addition, 12 problems not directly related to the environmental concerns were identified and classified as “others”. These were mostly related to tangential aspects of environmental problems. Appendix E summarizes the primary list of environmental problems identified in workshops 3a and 3b and includes a rebuilt DPSIR model.

3.4. Problem diagnoses and collaborative actions for consensual solutions (workshops 4a and 4b)

Overall, the 12 environmental problems showed different configurations regarding the dimensions of scientific knowledge, regulatory capacity and public engagement (Fig. 3, Table 1). In relation to water policy, the discharge of untreated urban wastewater (Fig. 3.1a) was diagnosed as a problem to be tackled within the boundaries of a pre-established policy dimension. The available scientific knowledge and public engagement were found to be unnecessary for solving this problem in the short term. The problem of lack of criteria for ecological integrity assessment of dryland rivers (Fig. 3.2a)
anticipated both a high availability of scientific evidence and policy instruments for advancing on its solution. However, public engagement was not recognized as essential to the solution of this problem. In contrast, low use of reclaimed urban water (Fig. 3.3a) was diagnosed as a problem for which a potential solution would not require further scientific knowledge because a solution could be implemented by existing policy instruments and by public engagement. Finally, natural radioactivity contamination in aquifers (Fig. 3.4a) and the pollution and overexploitation of aquifers (Fig. 3.5a) were diagnosed as problems whose solutions could be visualized with highly applied research and a consolidated regulatory capacity. Both of them were identified as targets for priority action by policymakers and with a high social relevance based on existing formal requests by the general public to public administrations.

Environmental problems associated with the loss of biodiversity were identified as needing more methodological research, for example, in the case of land planning problems not based on ecosystem services research (Fig. 3.4b) and the problem of a lack of protection of temporal ponds (Fig. 3.2b). Here, spatial and explicit maps of ecosystem services delivery were requested for landscape planning and the identification of potential habitats for amphibian species, respectively. Also requested were new specific policy instruments based on the existence of a general legislative framework. Public engagement was not considered important for progressing towards the solutions for these problems in the short term. The diagnosis of the decline of threatened fish populations (Aphanius iberus) (Fig. 3.3b) as a problem emphasized solutions requiring applied scientific knowledge and the implementation of policy instruments. This problem was also identified for priority action by policymakers. Regarding the problem of the absence of good practices for irrigation reservoirs (Fig. 3.4b), the diagnosis highlighted the difficulty of current policies in addressing the problem due to the majority of reservoirs being located in private properties, and constraints related to technical competences. However, the community of practice resolved that the existing scientific knowledge on the matter was sufficient, and rather called for more environmental programmes for enhancing the public engagement. The problem of the expansion of invasive plant species (Fig. 3.5b) was considered to be best addressed by more applied scientific research and was also identified for priority action, with policy instruments and public engagement considered essential to a potential solution. In contrast, the degradation of Tabernas Desert biodiversity (Fig. 3.6b) was diagnosed as requiring the connection of available scientific knowledge to management actions, as well as policy instruments and new efforts by public administrations to increase public engagement. Finally, the degradation of Mediterranean scrubland (Fig. 3.7b) was categorized as a problem with maximum relevance of all three dimensions. Thus, the problem had applied scientific knowledge towards addressing it, was in an area of policy action priority with existing legal instruments, and had public engagement in its solution.

Five interface teams (two related to water policy and three to biodiversity loss) including scientists, public administrations and other entities were created to implement collaborative problem-solving actions (Appendix G). Appendix G summarizes the collaborative actions proposed to address five environmental problems and the member entities for each interface team. Three action plans, namely Emergency plan for replacing water resources in the Almanzora River Basin, Recovery and regeneration plan for the aquifers in Southern Sierra de Gador-Campo de Dallas and Controlled grazing program to prevent forest

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Major environmental concerns</th>
<th>Water policy</th>
<th>Biodiversity loss</th>
<th>Land-use change</th>
<th>Climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy entities with legal, political and technical competence in environmental decision-making in study area</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes*</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Administrative scale at which policy entities operate</td>
<td>Regional</td>
<td>Regional</td>
<td>Regional</td>
<td>Regional</td>
<td></td>
</tr>
<tr>
<td>Proportion of policymakers interested in participating in the interface process (%)</td>
<td>59</td>
<td>76</td>
<td>10</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Proportion of participants with enough scientific background to provide explanations and predictions (%)</td>
<td>46</td>
<td>67</td>
<td>75</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Proportion of scientists interested in participating in the interface process (%)</td>
<td>38</td>
<td>67</td>
<td>92</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Societal relevance of environmental concernsb</td>
<td>High (96)</td>
<td>High (43)</td>
<td>High (37)</td>
<td>High (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium (4)</td>
<td>Medium (28)</td>
<td>Medium (34)</td>
<td>Medium (4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low (0)</td>
<td>Low (29)</td>
<td>Low (29)</td>
<td>Low (95)</td>
<td></td>
</tr>
</tbody>
</table>

* Legal competences only into protected natural areas.

b Percentage of policymakers and scientists who perceived the social relevance of the environmental concern within each category.
<table>
<thead>
<tr>
<th>Major environmental concern</th>
<th>Environmental problem</th>
<th>Rationale</th>
<th>Scientific evidence</th>
<th>Regulatory framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water policy</td>
<td>1a. Discharge of untreated urban wastewater into public waterways</td>
<td>The lack of control detected for untreated urban wastewater and public waterways fails to ensure compliance with legislation.</td>
<td>Martin et al. (2006); Fahd et al. (2007); Poch et al. (2012)</td>
<td>Mediterranean Basin Management Plan</td>
</tr>
<tr>
<td></td>
<td>2a. Lack of criteria for assessment of ecological integrity of dryland rivers</td>
<td>The criteria required by the Water Framework Directive to measure ecological integrity are not representative of dryland rivers.</td>
<td>Casas et al. (2001); Bonada et al. (2002); Gutiérrez-Cánovas et al. (2008)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3a. Low use of reclaimed urban water</td>
<td>Reclaimed urban water is a relevant resource in drylands. However, there is social rejection for using this type of water in the SE Spanish drylands.</td>
<td>Angelakis et al. (1999); Downward and Taylor (2007); Villar (2010)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5a. Pollution and overexploitation of aquifers used in greenhouse horticulture</td>
<td>Most of the aquifers in the region have been declared as overexploited and are contaminated from agricultural activities. Some stakeholders are willing to address this problem due to their awareness that the groundwater is a crucial resource for greenhouses (the main economic driver of the region).</td>
<td>Domínguez et al. (1988); Pulido (1989); Domínguez and González (1991); Sola et al. (2011)</td>
<td></td>
</tr>
<tr>
<td>Major environmental concern</td>
<td>Environmental problem</td>
<td>Rationale</td>
<td>Scientific evidence (^{a,b})</td>
<td>Regulatory framework(^{b})</td>
</tr>
<tr>
<td>-----------------------------</td>
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<td>---------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td><strong>Biodiversity loss</strong></td>
<td>1b. Land-use planning not based on ecosystem services</td>
<td>The incorporation of the ecosystem service approach into land-use planning is emerging as a conceptual framework and is demanded by several legal frameworks; however, there is a lack of management tools to enable its application in a real-world context.</td>
<td>Millenium Ecosystem Assessment of Spain (2011); Millenium Ecosystem Assessment of Andalusia (2012)</td>
<td>Not found</td>
</tr>
<tr>
<td></td>
<td>4b. Absence of good practices for the protection of irrigation reservoirs and associated biodiversity</td>
<td>Loss of biodiversity associated with inadequate management of agricultural irrigation ponds. Most irrigation ponds are privately owned, and this issue is currently outside the scope of policymakers.</td>
<td>Camacho et al. (2011) Bonachela et al. (2012) Juan et al. (2013)</td>
<td>Not found</td>
</tr>
</tbody>
</table>
| 5b. Expansion of invasive plant species into protected areas (e.g., *Pennisetum setaceum*) | There is evidence of the expansion of invasive plants (*Pennisetum setaceum*) in protected areas. Policy-makers seek control and eradication mechanisms. In addition, lack of environmental awareness in society is detected regarding invasive species. | Sanz et al. (2004); Dana et al. (2005); GLOCHARID Project (2014) | Andalusian Program for Control of Invasive Plants | Habitats Directive (92/43/EEC)  
Law of Natural Heritage and Biodiversity 42/2007  
Law of wild flora and fauna 8/2003  
|---|---|---|---|---|
| 6b. Degradation of a high biodiversity value ecosystem (Tabernas Desert) without environmental protection | Current environmental protection of the Tabernas Desert is inadequate to ensure its biodiversity conservation, and there is scientific information for declaring it as a National Park. | Rueda (1982); Rodriguez et al. (2001); Mota et al. (2004) | Protected Natural Areas Law of Andalusia 2/1989  
Decree 95/2003. Andalusian Network of Protected Natural Areas |
| 7b. Degradation of Mediterranean scrublands due to overgrazing and abandoned farming | Overgrazing causes degradation of Mediterranean vegetation in some areas. However, whereas controlled grazing is viewed as sustainable activity, this traditional activity is disappearing. | Ramos et al. (2010); Olivera et al. (2012); Ruiz-Mirazo and Robles (2012) | Law of Prevention and combating forest fires, 5/1999  
Decree 247/2001. Prevention and combating forest fires regulation  
Emergency Plan for forest fires of Andalusia |

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* We only included scientific evidence related particularly to regional problems.
* Complete references available in Appendix F.
Environmental problems related to water policy

1a. Discharge of untreated urban wastewater into public waterways
Scientific knowledge
Regulatory capacity
Public engagement

2a. Lack of criteria for assessment of ecological integrity of dryland rivers
Scientific knowledge
Regulatory capacity
Public engagement

3a. Low use of reclaimed urban water
Scientific knowledge
Regulatory capacity
Public engagement

4a. Natural radioactivity contamination in aquifers (Almanzora River basin)
Scientific knowledge
Regulatory capacity
Public engagement

5a. Pollution and overexploitation of aquifers used in greenhouse horticulture
Scientific knowledge
Regulatory capacity
Public engagement

Environmental problems related to biodiversity loss

1b. Land use planning not based on ecosystem services
Scientific knowledge
Regulatory capacity
Public engagement

2b. Lack of protection for temporal ponds
Scientific knowledge
Regulatory capacity
Public engagement

3b. Decline in threatened fish populations (Aphanius iberus) due to habitat degradation by invasive plants (Arundo donax)
Scientific knowledge
Regulatory capacity
Public engagement

4b. Absence of good practices for the protection of irrigation reservoirs and associated biodiversity
Scientific knowledge
Regulatory capacity
Public engagement

5b. Expansion of invasive plant species into protected areas (e.g., Pennisetum setaceum)
Scientific knowledge
Regulatory capacity
Public engagement

Legend (for details see Table 1)

<table>
<thead>
<tr>
<th>Scientific knowledge gradient</th>
<th>Regulatory capacity gradient</th>
<th>Public engagement gradient</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unessential</td>
<td>Unaligned</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Unessential</td>
<td>Limited</td>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>Alignable</td>
<td>Defined</td>
<td>Medium</td>
<td>2</td>
</tr>
<tr>
<td>Alignable</td>
<td>Preferential</td>
<td>High</td>
<td>3</td>
</tr>
</tbody>
</table>

Fig. 3 – Graphical tool for the diagnoses of the 12 selected environmental problems according to three gradients: scientific knowledge, regulatory capacity, and public engagement. The triangles describe each environmental problem based on a standardized punctuation for each gradient (on a 0–3 scale).

fires, were collaboratively agreed between scientific, policy and public entities identified for the advancement of solutions to their respective problems (see Fig. 3.4a/5a/7b). The Training program for environmental management of irrigation reservoirs was proposed as an action plan to be implemented between scientific and public entities to address the absence of good practices for irrigation reservoirs (Fig. 3.4b). Finally, the Program to control expansion of Pennisetum setaceum in Cabo de Gata Natural Park was launched by scientific and policy entities to address the expansion of invasive plant species (Fig. 3.5b). For those particular action plans for which public engagement was identified as relevant, the community of practice decided to include a third group to be involved in the interface team in charge of the problem. However, in the case of the Program to control expansion of Pennisetum setaceum, it was not possible to obtain the commitment of any social entity as was planned based on the prior diagnosis.

4. Discussion

Interactions between scientists and policymakers are typically limited due to the lack of a common language, working philosophies, epistemologies, priorities, timeframes, quality criteria and rewards, and incentive systems (Roux et al., 2006; Hegger et al., 2012). Thus, although both groups could share interests and goals, an operational and standardized framework to put into practice collaborative work for addressing environmental challenges is still scarce (Godfrey et al., 2010). The SPI experience presented here provides lessons that can make the communication between science and policy more operative. Specifically, our study (1) collaboratively identified the highest priority environmental problems within the Iberian Peninsula drylands, (2) diagnosed them considering the available scientific knowledge, the existing regulatory capacity from administrations, and the engagement of the general public in problem solving, and (3) promoted management actions over time by creating collaborative interface teams with scientists, policymakers and administrations. However, some limitations were encountered during the process and are discussed below.

4.1. Lessons and recommendations from the SPI experience

DeFries et al. (2012) stated, “within the realm of the science-policy interface, science is relevant if the scale of analysis
matches the scale of decision-making”. With this aim, we
designed an interactive process to promote collaborative work
wherein scientists provided explanations and predictions
about environmental concerns (Van den Hove, 2007), and
policymakers framed them into the legislative context exist-
ing in the public administration (Weichselgartner and Kas-
person, 2010). We started the process by first involving only
scientists in identifying the major environmental concerns,
and then explored their policy-administrative aspects includ-
ing both scientists and policymakers. Although this approach
could be considered aligned with the standard one-way linear
model of communication between scientists and policy-
makers, it has nevertheless been suggested to be a good
starting point for opening collaborative dialogue (Young et al.,
2014). We also believe that involving the scientific opinion first
is an appropriate means to ensure the availability of scientific
knowledge about environmental concerns to be explored that
later will be addressed in the policy context. In this respect, we
also consider that the selection of water policy and biodiver-
sity loss as priority concerns by both groups was an attractive
way to involve the community of practice in the SPI. The
priority placed on water policy was related to its scarcity in
arid regions and its high importance to the local economy
(Quintas-Soriano et al., 2014), whereas biodiversity loss was
prioritized due to the unique ecological value of this region,
which represents a global hotspot of biodiversity (Médail and
Quézel, 1999).

Numerous studies have noted the communications pro-
cess as one of the bottlenecks that can arise in SPIs (Janse,
2008). To alleviate this bottleneck, we used knowledge
brokering to facilitate transfer of knowledge across bound-
aries between science and policy. The use of analytical
frameworks to deliberate on problem definition and solutions
strengthens mutual understanding (Hegger et al., 2012) and
promotes a collective perspective (Moreno et al., 2014). We
therefore adopted the DPSIR model for collectively defining
the final environmental problems to consider in the SPI
(Appendix E). In addition, we introduced a graphical tool
(Fig. 3) for the analysis of environmental problems that
includes dimensions covering the gradient of scientific
knowledge available to meet rapid solutions, the regulatory
capacity of policy makers to address the problems, and the
level of public engagement that could be involved in the
solutions (Fig. 3).

Several authors have argued that SPIs imply that scientists,
policymakers and sometimes other societal actors cooperate
in the exchange, production and application of knowledge
(Hegger et al., 2012). Other authors warn about the potential
difficulties of attempting to implement solutions to certain
problems effectively without the engagement of the general
public (Raymond et al., 2009). In addition to including the local
knowledge, collaboration and involvement of the general
public contributes to ensuring the success of management
actions and adds transparency to decision-making (Clark
et al., 2011; Caudron et al., 2012). We consider the lack of
general public representatives a limitation in our SPI experi-
ence, as they form a key group that should have been involved
at the beginning. However, our research was designed
originally as a pilot experience to improve the interaction
between scientists and policymakers. The SPI experience
including initial three groups (scientists, policymakers and
general public) could be more problematic and lead problems
of legitimacy in knowledge production and decision-making
(Edelenbos et al., 2011). In our SPI experience this limitation is
present in the graphical tool introduced to diagnosing
environmental problems, however, with the aim to get a real
output in the SPI, information related to the “public engage-
ment gradient” (see Fig. 3) was addressed by accounting for
the formal requests made by stakeholder groups to public
administrations. Nevertheless, we suggest that including the
general public in the SPI at the beginning would make the
process more effective, and hence, move the process from a
collaborative practice “for society” towards a practice “with
society” in which the general public plays an important role.
Similarly, we also call for the participation of other actors from
different disciplines, profiles and perspectives such as
sociologists, economists, or anthropologists, to promote the
learning process and to improve the overall understanding of
complex and dynamic systems in the long-term (Tábara and
Chabay, 2013).

4.2. Shaping environmental problems according to
scientific, policy and social criteria helped to promote a culture
of shared responsibility

Van Kerkhoff et al., (2006) stated “the relationships between
research-based knowledge and action can be better under-
stood as arenas of shared responsibility, embedded within
larger systems of power and knowledge that evolve and
change over time”. We believe that the graphical tool used for
diagnosing environmental problems represents an advance in
this direction. For instance, the problem of “lack of criteria in
analysing integrity of rivers” (Fig. 3.2a) obtained a value of 3 in
scientific knowledge, 2 in regulatory capacity gradients, and 0
in public engagement. This means that there was enough
scientific evidence relevant to the problem, and policymakers
had sufficient policy instruments to implement decisions, but
public engagement was not considered important for address-
ingen the problem in the short term. Although scientists and
policymakers first evaluated each gradient separately, the
community of practice as a whole then approved all of them.
We also suggest that the graphical tool was helpful in
clarifying the three roles that reflect each of the gradients,
and helped to promote a culture of shared responsibility for
identifying strategic partnerships to create collaborative
actions for environmental problems. We believe both were
key aspects to the success of the SPI (Van Kerkhoff et al., 2006;
Hegger et al., 2012).

The diagnosis of the environmental problems provided
different scenarios according to three information dimensions
towards reaching potential solutions (Fig. 3). For instance,
the discharge of untreated urban wastewater into public water-
ways (Fig. 3.1a), was considered a problem for which a solution
could just involve the policy dimension. This result suggests
that the community of practice saw the cause of the problem
as being unrelated to the scientific knowledge domain and
that public engagement was not needed to solve the problem.
However, policymakers clearly identified the lack of organiza-
tion from responsible public administrations in implementing
existing regulatory rules as a cause of the problem. In this
sense, as stated by Engels (2005), the diagnostic process allowed for the distinguishing of a problem for which solutions could be considered within the boundaries of one pre-established policy dimension.

Other environmental problems were identified as requiring the combination of two dimensions to advance their solutions. Examples of such combinations are: collaborative work between scientists and policymakers to address the lack of land planning based on ecosystem services research (Fig. 3.1b); more interaction between policymakers and the public to address the low use of reclaimed urban water (Fig. 3.3a), and direct dialogue between scientists and the public to address the absence of good practices for protection of irrigation reservoirs (Fig. 3.4b). Regarding the problem of land-use planning not based on ecosystem services (Fig. 3.1b), despite the recognition of the urgent necessity of integrating the general public as a key stakeholder group for the valuation of ecosystem services and their integration into landscape planning (Castro et al., 2014; Palomo et al., 2014), the community of practice rather perceived as priorities the creation of more scientific knowledge on ecosystem services and the integration of existing tools for mapping services in public administrations.

We also found other cases in which the community of practice identified a requirement for all three dimensions, i.e., a collaboration between scientists, policymakers and the general public for addressing problems. One example was the case of aquifer pollution and overexploitation (Fig. 3.5a). The community of practice observed that there was strong support from policymakers towards addressing this problem because it represents a priority area within the Water Framework Directive (Directive 2000/60/EC, 2000). Policymakers also recognized the concern of the general public through the formal requests presented to public administrations, mostly formulated by irrigation communities (Appendix G). This could be related to the importance of greenhouse horticulture in maintaining the local economy in the Almería province, which depends entirely on the availability of groundwater resources (Castro et al., 2014). In fact, 86.2% of the total net income of Almería province comes from greenhouse horticulture, and 5% of the vegetables consumed in Spain come from this area (Quintas-Soriano et al., 2014).

Finally, we propose that the graphical tool described herein could be adapted to different contexts and implemented in different regions. Towards this end, further research would be required to test the criteria of standardization in other regions where the scientific knowledge is limited, the articulation of policymaking is incipient, and the social structure is still weak.

4.3. Moving from theory to practice: collaborative actions as incentives

Ansell and Gash (2007) highlighted that an incentive system can play a crucial role in SPIs because there is a direct relationship between the time and effort invested by the actors and the usefulness of the outcomes, particularly when the participation is voluntary. Based on this concept, we offered two types of incentives during the SPI. First, all participants were offered the opportunity to participate in specific concern areas (water policy and biodiversity loss) related to their fields of expertise, which could be perceived as potentially beneficial for them as well as their entities (PSI-connect project, 2012). This was the case for the problem of expansion of invasive plant species in protected areas (Appendix G). This problem garnered the interest of two researchers focused on the study of invasive species and three policymakers, and resulted in a management action plan to implement control strategies for invasive species in the Cabo de Gata Nature Park.

The second incentive was to offer to the community of practice the opportunity to launch real actions at the administration level for specific environmental problems. We considered that involving the community of practice with familiar topics promoted a culture of shared responsibility that was useful to move from theory to practice. As a result of our study, we tested the implementation of five collaborative actions (Appendix G). An example was the Controlled grazing program to prevent forest fires, a plan to address the degradation of Mediterranean scrubland due to overgrazing or the abandonment of farming practices (Fig. 3.7b). This agreement was developed with the collaboration of a research group specialized in land-use change and abandonment, the Environmental Management Department of the Andalusia Ministry, and a professional association of shepherds from the Mediterranean scrubland (see Appendix G). The action, currently on-going, promoted new routes for transhumance based on scientific criteria to prevent ecosystem degradation. This action further allowed scientists to align their research interests with the management context (DeFries et al., 2012), and gave policymakers new criteria for decision-making based on scientific evidence (Cook et al., 2012). Furthermore, shepherds found an alternative and sustainable option for developing their profession.

5. Conclusions

Knowledge transfer between scientists and policymakers is often viewed as a bottleneck when addressing environmental challenges. Numerous authors have proposed measures to strengthen the interaction between both groups through SPIs. Based on several assumptions, this study tests a methodological framework to promote the formation of real strategic alliances for dealing with day-to-day environmental problems. We identify essential points for facilitating and operationalizing SPI experiences. These points refer to the matching of different professional groups with concrete problems related to their own work fields, the use of graphical tools to facilitate mutual understanding, and the promotion of a culture of shared responsibility for implementing collaborative actions for solving problems. In addition, we detected the necessity to involve the general public as a key stakeholder group to make the SPI process more effective. In general, we suggest that launching co-learning and co-production processes between scientists, policymakers and general public is key to facilitating mutual understanding and promoting a culture of shared responsibility for addressing environmental challenges. We propose promoting SPI experiences as a mechanism for enriching decision-making processes in the long-term.
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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.envsci.2015.01.013.

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