Article

Where do ecosystem services come from? Assessing and mapping stakeholder perceptions on water ecosystem services.

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Abstract: Reductions in water availability and increasing rainfall variability are generating a narrative of growing competition for water in the Mediterranean basin. In this article, we explore the distribution and importance of water resources in the Muga River Basin (Catalonia, Spain) based on key stakeholders' perceptions. We performed a sociocultural evaluation of the main water ecosystem services in the region through stakeholder interviews and participatory mapping. The basin was generally perceived as a hotspot of ecosystem services, but we detected varying opinions and considerable differences in the perceptions of importance and spatial distribution of water ecosystem services. These discrepancies were linked to the varying levels of stakeholders' dependence on water. Our findings are important for contributing to correct water planning and management in the river basin, which is a complex water social system marked by conflicts between different stakeholder groups vying for the same resource. This complex situation requires bottom-up strategies to create transparent, participatory decision-making models.

Keywords: socioecological systems; water ecosystem services; participatory mapping; stakeholder values; spatial analysis; river basin.

1. Introduction

Water ecosystems in the Mediterranean basin are increasingly under threat from anthropogenic pressures in a scenario marked by profound environmental changes that are placing even greater stress on these systems and diminishing their ability to provide an adequate flow of ecosystem services (ES). The Mediterranean basin is one the most vulnerable areas of the planet [1,2] and water resources one of the main causes of socio-environmental conflicts [3]. According to recent forecasts, the Mediterranean is facing a future marked by increasing water demands, declining rainfall, rising temperatures and longer drought periods [2,4]. Water scarcity is therefore a matter of great concern and like many environmental issues, it is closely linked to problems of a social, economic, and political nature [4].

Most economic activities, including tourism, are heavily dependent on water and have a significant impact on its use and consumption [5]. Demand peaks in the summer months, which is precisely when the Mediterranean's water ecosystem services (WES) are at their most vulnerable. Although coastal wetlands are one of the world's most degraded ecosystems [6], they are a major tourist attraction due to the wealth of opportunities they offer for recreational activities such as walking, bird watching and fishing [7].

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Although human activities have a direct and indirect influence on water resources, few studies have considered their combined effects [8]. Surface and groundwater flows are needed to produce food and energy [9] and to shape landscapes and ecosystems that provide both passive services (e.g., enjoying a beautiful scenery) and active services (e.g., recreational activities) [10]. Ecosystems and society, however, are closely linked and constantly interacting with each other [11]. But how aware is society of these links? Sociocultural evaluations of ecosystem services serve to explore differing perceptions and value systems among stakeholders, identify priorities, needs, and objectives, and integrate these into joint decision-making processes [12]. Such evaluations also help determine different levels of stakeholder dependence on their surroundings and identify divergent interests in terms of landscape planning and management [13].

The main purpose of this research was to examine stakeholder preferences and the spatial distribution of WES in the Muga River basin and to determine how changes in the supply of these services might influence stakeholders either directly or indirectly. The article is structured into four sections, each with a different aim: i) to identify the most important WES in the basin, ii) to explore stakeholder preferences, perceptions (from a qualitative and spatial perspective), and social values in relation to these services, iii) to identify and map WES hotspots in terms of supply, demand, and threats, and iv) to analyze key stakeholder concerns in relation to water resources in the Muga river basin.

2. Study Area

This case study was performed in the Muga river basin, which is located in northeast Catalonia, Spain, just south of the French border (Figure 1).

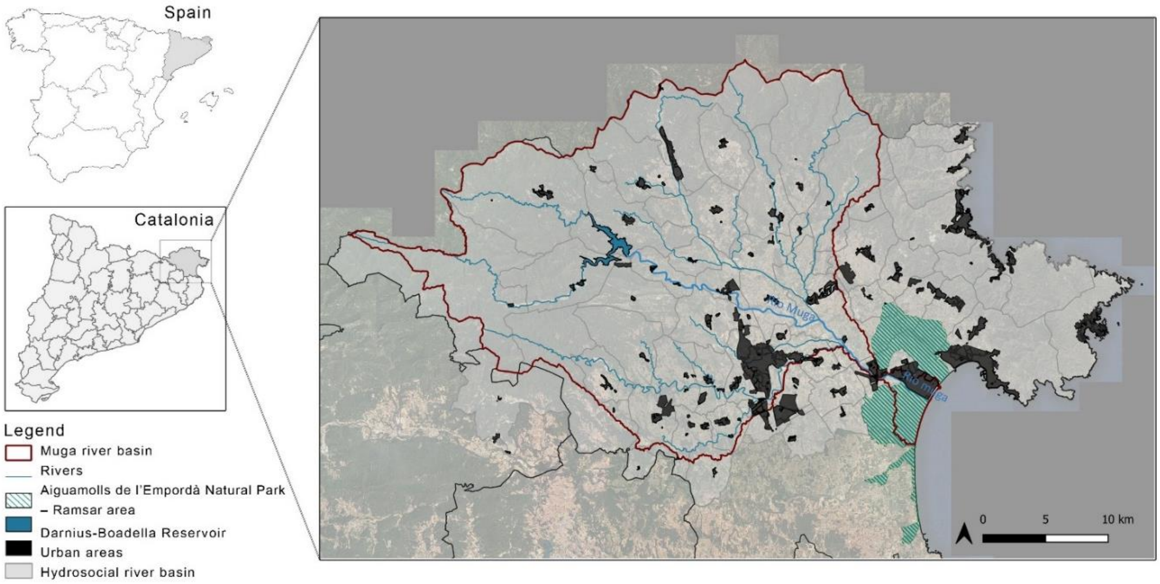

Figure 1. Territorial framework of the Muga river basin.

The basin covers a surface area of 854 km² and the river runs for 64 km. It is born in the Pre-Pyrenees (in the Puig de la Llibertat mountain) at an altitude of 1200 m and flows into the Gulf of Roses through the marina in Empúriabrava. With a mean annual flow of 2.5 m³/s [14], the river has a typically Mediterranean regime, although its flow is regulated by the Darnius-Boadella reservoir, which is the main source of water supply for the entire basin. Since the mid-20th century, the Muga river basin has experienced a progressive increase in intensive crop and livestock farming and urban and tourism development, particularly along the coast. The particularities of the basin, coupled with the changes in recent decades, have fueled tensions and conflicts over increasingly scarce water resources [15,16]. The basin is a socioecological system, where the landscape has been shaped by dynamic

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interactions between society and ecosystems and where heritage elements related to water have historically been and continue to be of enormous social and cultural importance.

Geographically speaking, the basin can be divided into three main areas: the headwaters (the high basin), which is an eminently mountainous area with extensive forestland; a central area (the middle basin), home to one of the most Catalonia's productive agricultural plains and the city of Figueres; and a coastal area (the low basin), a renowned international tourist destination [17]. The coastal area contains the Aiguamolls de l'Empordà Natural Park (referred to hereinafter as the AENP), a natural reserve that has been a member of the Ramsar International Network of Protected Wetlands since 1993 [18]. These three unique areas converge to form a dynamic river basin with extraordinary environmental, social and economic diversity. Additional information on the study area is given in Table 1.

Table 1. Characteristics of the Muga river basin.

River length	65 km (from La Garrotxa d'Empordà mountains to Castelló d'Empúries beach)
Extension	758 km²
Landscape typology	Mountain (holm oak, cork oak, and pine trees and bushes) Agricultural plain (irrigated crops: corn, sorghum, sunflowers, rice; fruit trees: apple, nectarine, peach; vineyards, olive trees and rain-fed cereals) Coastline (coastal dunes and wetlands, tourist and residential buildings, tourist facilities and campsites)
Protected areas	Albera Natural Park, Alta Garrotxa Natural Park, Salines-Bassegoda Natural Park, and Aiguamolls de l'Empordà Natural Park (Ramsar wetlands site)
Population	140,000 inhabitants
Land uses	71% forest, 24% crops (estimated 75% of all water consumption in basin), 10% urban (estimated 20% of all water consumption in basin) (Pascual et al., 2016)
Sources of socio-environmental conflicts and tensions	Water contamination due to high nitrate levels in agricultural soil (pig farming); excessive groundwater extraction; morphological changes to river; invasive species; morphological changes to coastline.

The growth of tourism from the mid-20th century onwards changed the traditional composition of the river basin, particularly along the coast, where the proliferation of hotels, campsites, holiday homes, and tourist facilities transformed the seafront into a powerful tourist attraction [19,20]. Tourism peaks in the summer months, placing considerable demands on local water resources and generating a veritable tourism-dependent water cycle *(hydro-tourist cycle),* that has a decisive influence on the hydrological and social water cycles. The tourism industry is heavily dependent on water and is also a major beneficiary of the ecosystem services it provides. The basin has also experienced a growth in intensive crop and livestock farming in recent decades, which has resulted in an increase in agricultural land and changes in crop types (from dryland to irrigated crops). Intensification of livestock farming, and pig farming in particular, has also placed greater demands on water supplies and contributed to the nitrate contamination of many of the main aquifers in the basin [21].

3. Materials and Methods

The methodology used to collect and analyze data in this study is summarized in Figure 2.

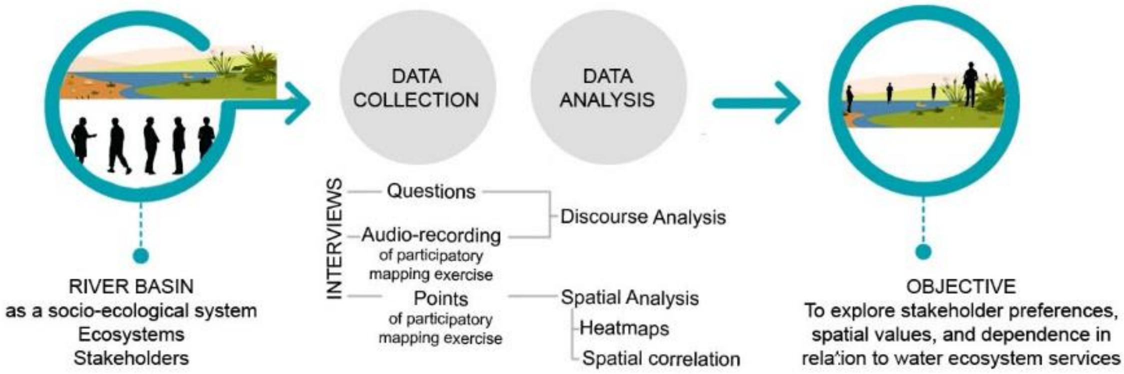

Figure 2. Methodological workflow.

3.1. Identification of WES by an expert panel

We assembled a panel of experts from different scientific disciplines familiar with the study area to identify the main WES in the Muga river basin for use in a subsequent participatory mapping exercise with a selection of key stakeholders. The panel was held in July 2019. It lasted for approximately 4 hours and brought together six experts from different backgrounds (ecosystem services, water ecosystems, climate change, and other fields of expertise). Drawing on the work of Palomo et al. [22], the experts were first tasked with selecting the eight most important WES in the basin using previously prepared panels featuring all the ecosystem services in the area, based on the *Common International Classification Ecosystem Services*, v5.1 [23].

Each expert was asked to fill out a form in which they had to rate the importance of each WES on a scale of 1 to 5 and identify the trends of each ecosystem service and the scale of its beneficiaries (local, regional, national or international). They then compared notes in an open debate. In the event of discrepancies, they were encouraged to continue their discussions until they reached a consensus. The WES identified and selected according to their importance were then mapped in a participatory exercise. The same mapping process was used with the selected stakeholders (section 3.2.).

3.2 Data collection: interview design, sampling, and participatory mapping

The data generated by the expert panel was used to build the stakeholder interview model under the premise that "ecosystem services research should be 'user-inspired' and 'user-useful'" [22,24]. A mixed model with open and closed questions was chosen to allow interviewees to express their opinions and explore in depth themes not initially covered. The interview was structured into five parts designed to explore: i) familiarity with the study area, (ii) familiarity with the concept of ES, (iii) perceptions of WES importance, demand, vulnerability, and spatial position, (iv) perceived problems (existing and future) and concerns about water resources, and (v) socioeconomic profile (gender, age, place of residence, etc.). The interview model was built on the work of Iniesta-Arandia et al. [25] and was reviewed by researchers outside the project.

The stakeholders were selected by non-proportional quota sampling [26,27] to ensure that all major stakeholder groups were represented. The initial list of potential participants was expanded with the help of stakeholders already identified in previous studies in the same area [28,29]. The stakeholders were categorized into two groups: i) those that were directly dependent on the water cycle (DD stakeholders), such as crop and livestock farmers, natural park service officers, and members of the on-site recreational tourism sector; and ii) those that were indirectly dependent on the water cycle (ID stakeholders), such as members of the business tourism sector, environmental groups, and technical and political officers (Appendix A). One of the main reasons for this grouping was to analyze whether different levels of dependence influence perceptions and concerns about possible changes in WES provision [25]. Thirty-two stakeholders were contacted and 27 agreed to participate in the interview. The five people who declined were from the hydroelectric and tourist sectors. The interviews were held between June and November 2019. Each interview was audiorecorded and transcribed in full. The facilitators responsible for leading the discussions were key to the success of the mapping exercise, where the communication between the interviewee and the interviewer has been fundamental to ensure that everyone's opinions are taken into account and to avoid mechanisms that could affect the mapping results, as explained by Brown and Kyttä [30]. Following the methodological lead of Brown et al. [31] and Raymond et al. [26], we opted for a hard copy mapping system as we consider this to be an ideal tool for stimulating debate, encouraging participation, and facilitating the location of WES [32–35]. We used a 1:50000 topographic map on which the experts and the stakeholders interviewed were asked to position the following for each WES: (i) service provision units (SPU), (ii) service benefiting areas (SBA), and (iii) degraded SP units (dSPU) [12,22]. They marked these points on separate maps using colored dots (green, blue, and orange, respectively), with a radius of 1 cm (equivalent to 500 m in reality) [12,22,32]. They were allowed to place as many dots (points) as needed. Once all the WES had been mapped (3 maps for each WES, with a maximum of 18 maps per stakeholder), a vertical photograph was taken of each map to facilitate subsequent digitization of points in GIS layers.

3.3 Data and content analysis

To analyze stakeholder preferences and perceptions, their answers to the interview questions were coded by category and the overall responses analyzed by descriptive statistics. The transcripts of the conversations that took place during the mapping exercise were analyzed by discourse analysis. Such conversations can provide invaluable insights into reasons underlying decisions and spatial values. We therefore coded each of the units – SPU, SBA, and dSPU - and the reasons given for deciding on their location. The use of coding to understand the spatial distribution of WES hotspots and areas is based on the premise that elements that are mentioned most often are presumably those considered to be most important to society and should therefore be given priority in decision-making processes [36,37].The transcripts were coded in Maxqda software v. 10 [38] and the data processed and analyzed in Jamovi (v. 1.0.7.0) [39].

3.4 Spatial data analysis

The results of the participatory mapping exercise were digitized and analyzed using QGIS v.3.10 [40]. Vector data in the form of shapefiles were created using the points on the maps and the associated information on WES category, name, and unit (SPU, SBA, dSPU), and stakeholder profile. A total of 11,023 points, including those marked by the expert panel, were digitized and divided into 428 layers. In line with the definition of *hotspot* by Palomo et al. [22], point density was analyzed by calculating kernel density rasters (*qgis:heatmapkerneldensityestimation)* in PyQGIS. To this end, we used a mobile window (radius) of 5000 m (after some trials, we decided that as the optimal size that best suited our data) and a cell resolution (pixel size) of 500 m (the same size as the colored mapping dots) [41]. The different heatmaps were then combined and overlaid to obtain SPHs, SBAHs, and dSPHs maps [22]. Correlations between areas were analyzed according to stakeholder groups categorization (DD and ID) using the raster library in R [42]. We also analyzed correlations between WES involving trade-offs and their SPH to assess trade-offs and synergies (bundles) between ecosystem services [43]. Differences between stakeholder groups were determined using the Wilcoxon test (non-parametric equivalent of *t* test) [44].

4. Results and Discussion

4.1 Identification of the most important WES

The WES identified by the experts were water for irrigation, water for livestock, drinking water (provisioning services); biodiversity, water regulation, and water purification (regulating services); and aesthetic values and opportunities for recreational activities (cultural services). To select which WES to map, these were ordered according to the importance with which they were rated by the experts [45]. The final WES identified as most important were six: water for irrigation and drinking water (provisioning), biodiversity and water regulation (regulating), and aesthetic values and opportunities for recreational activities (cultural). In this way, water for livestock and water purification were placed in the last position in the experts' importance ranking and it was therefore decided not to map them. The experts considered that the WES were of medium to high importance and showed a downward trend. They stressed that changing trends in the context of ecosystem services are closely linked to management activities implemented in a given area over time. The scale of beneficiaries was identified as local-regional for provisioning and regulating WES and regional-international for cultural WES.

Most of the stakeholders worked in the study area (59%), were men (85%), and had a university education (70%); they were aged between 32 and 76 years (Table 2).

Table 2. Sociodemographic characteristics of stakeholders (n=27).

Variable	Category	n	%	Mean	SD
Gender	Female	4	14.8		
	Male	23	85.2		
Age (years)				47	23.5
Educational level	Primary school	3	11.1		
	Secondary school	1	3.7		
	Vocational training	2	7.4		
	University	19	70.4		
	No studies	1	3.7		
	No answer	1	3.7		
Place of residence	Inside study area	16	59.3		
	Outside study area	11	40.7		
Stakeholder group	Directly dependent on water ecosystem services (DD)	14	51.9		
	Indirectly dependent on water ecosystem services (ID)	13	48.1		

Before being asked to identify and map the different WES, the stakeholders were asked if they were familiar with the concept of *ecosystem services*. Eleven knew how to define it, twelve had never heard of it, and four had heard of it but did not know how to define it accurately. Following the approach of Iniesta-Arandia et al. [25] and Raymond et al. [26], we used the term *benefits-contributions* instead of *ecosystem services* for the rest of the interview to ensure clarity and minimize educational and cultural biases [25,26].

The content and discourse analysis of the interview transcripts produced 61 codes (Appendix B). All the interviewees considered that the Muga river basin benefited people a lot or quite a lot. When asked to give an example, the most common benefits mentioned were quality of life, availability of food and the ability to produce fresh vegetables and other products, rich biodiversity of flora and fauna, beautiful scenery, wide range of opportunities for recreational activities, and lack of air pollution. These results are of particular interest, as most studies of ecosystem services that have used open-ended questions to date have not detected answers related to regulating services [31,46–48]. In general, all the stakeholders, regardless of whether or not they lived in the Muga river basin expressed a very strong sense of belonging and considered that basin had an almost bucolic air about it. Comments included "*We like this landscape that has been embellished by the hand of man. It is our cultural landscape, it's what makes the Alt Empordà beautiful*"; "*This area is like the Garden of Eden, it has everything, it offers all the resources we need, it's wonderful. I'm in love with it.*"

DD and ID stakeholders ranked the WES in a similar order of importance (Wilcoxon test, $p>0.05$). Water for irrigation and drinking purposes were ranked first, followed by biodiversity and water regulation. Cultural WES were perceived as important as they were a tourist attraction but they were not considered essential for well-being. Accordingly they were largely ranked in position 5 or 6, in agreement with findings by Raymond et al. [26] (Figure 3).

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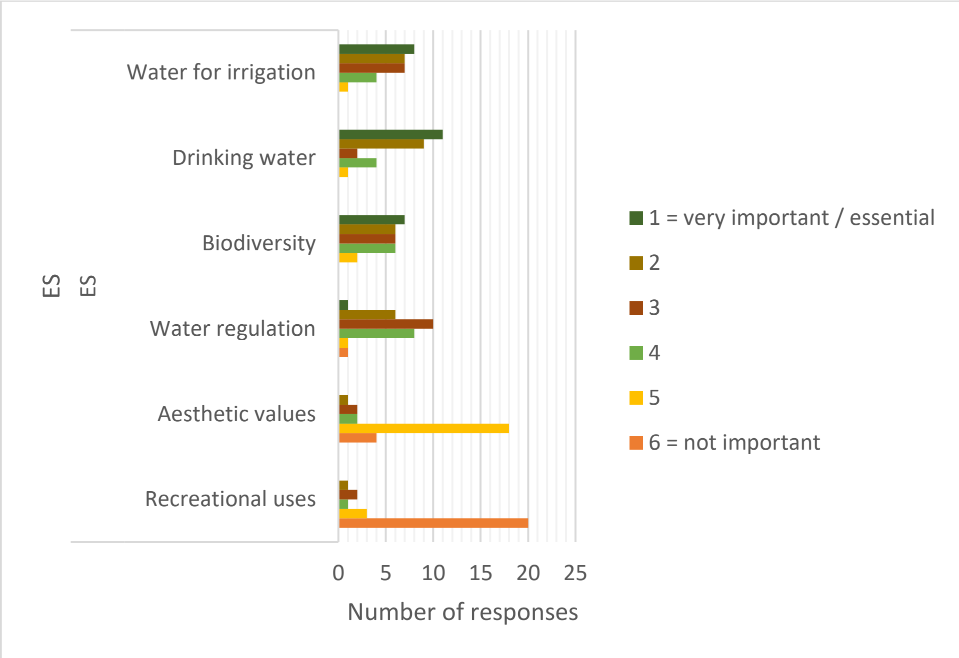

Figure 3. Perceived importance of water ecosystem services among stakeholders.

The number of dots used (points on the map) did not vary significantly between DD (n=5688) and ID stakeholders (n=5575) (Wilcoxon test, p=0.544). Regulating services had the most points (38.1% of total), followed by cultural (36.1%) and provisioning services (25.8%). WES that are perceived as important but that have few points on the map (e.g., provisioning services) can be considered to be particularly vulnerable, as they are dependent on just few supply areas. The number of points used to map a WES is not always linked to its perceived importance. Drinking water, for example, is very important, but it was mostly concentrated at the Darnius-Boadella reservoir (a single point). The interviewees also perceived landscapes with aesthetic values as being very valuable in terms of biodiversity and habitats; they therefore typically used similar points to identify regulating and cultural services. The WES with the highest number of points was biodiversity, with 2349 points (20.9%), followed by aesthetic values, with 2056 points (18.3%) (Table 3). Stakeholders in the DD group used more points to map biodiversity, water regulation, and cultural WES, while those in the ID group used more points to map provisioning WES. DD stakeholders (e.g., crop and livestock farmers) used fewer points to map WES they interacted with daily in relation to their sociodemographic profile and familiarity with WES. Better knowledge of the basin, for example, resulted in more accurate mapping, with a greater focus on the position of provisioning units and better positional accuracy and completeness of each WES. The reliability of data obtained via ES mapping, however, remains to be determined in many cases [48].

Table 3. Number of points mapped for each water ecosystem service category and unit by stakeholders who are directly and indirectly dependent on these services (DD and ID stakeholders).

Number of points mapped			
Category	Water ecosystem services (WES)	Group	
		DD	ID
Provisioning		1372	1535
	Water for irrigation	603	637
	Drinking water	769	838
Regulating		2264	2027

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	Biodiversity	1245	1104
	Water regulation	1019	983
Cultural		2052	2013
	Aesthetic values	1023	1033
	Recreational uses	1029	980

4.2 Social perceptions and spatial distribution of WES

The WES hotspots mapped out were distributed differently through the basin according to category (provisioning, regulating, cultural) and unit (SPU, SBA, dSPU) (Figure 4). The provisioning WES hotspots mainly coincided with the Darnius-Boadella reservoir (around 190 points), which is the main source of irrigation and drinking water in the basin [16]. The Muga river also had two small dams that distribute water to irrigation channels in two key agricultural areas and to a number of towns and villages [49]. The agricultural plain was also considered a provisioning ES supply hotspot area (with around 230 points) as it contains numerous wells that extract water directly from the underground aquifers. Just eight of the 27 stakeholders considered that the forests and woods in the upper basin had a decisive role in guaranteeing the provision of water to the rest of the basin (around 43 points), contrasting with the views of the experts, who saw forests as having a crucial role in water storage and regulation. The stakeholders, however, did consider that forests in the upper basin (with around 70 points) and the main stem of the river, its tributaries, and the coastal wetlands (with around 530 points) were crucial for water regulation and for the presence and conservation of natural aquatic habitats. These results highlight the importance that stakeholders attach to the AENP in the lower basin and show that they recognized the important role that coastal wetlands play in biodiversity and in minimizing coastal erosion and the effects of heavy rainfall, river overflow, and sea storms [6]. The cultural hotspots identified were the AENP, the coastline, the high stretch of the river, the river mouth (about 325 points) and the Darnius-Boadella reservoir (around 163 points). These elements were mainly perceived as cultural hotspots because of their natural beauty and the opportunities for recreational activities.

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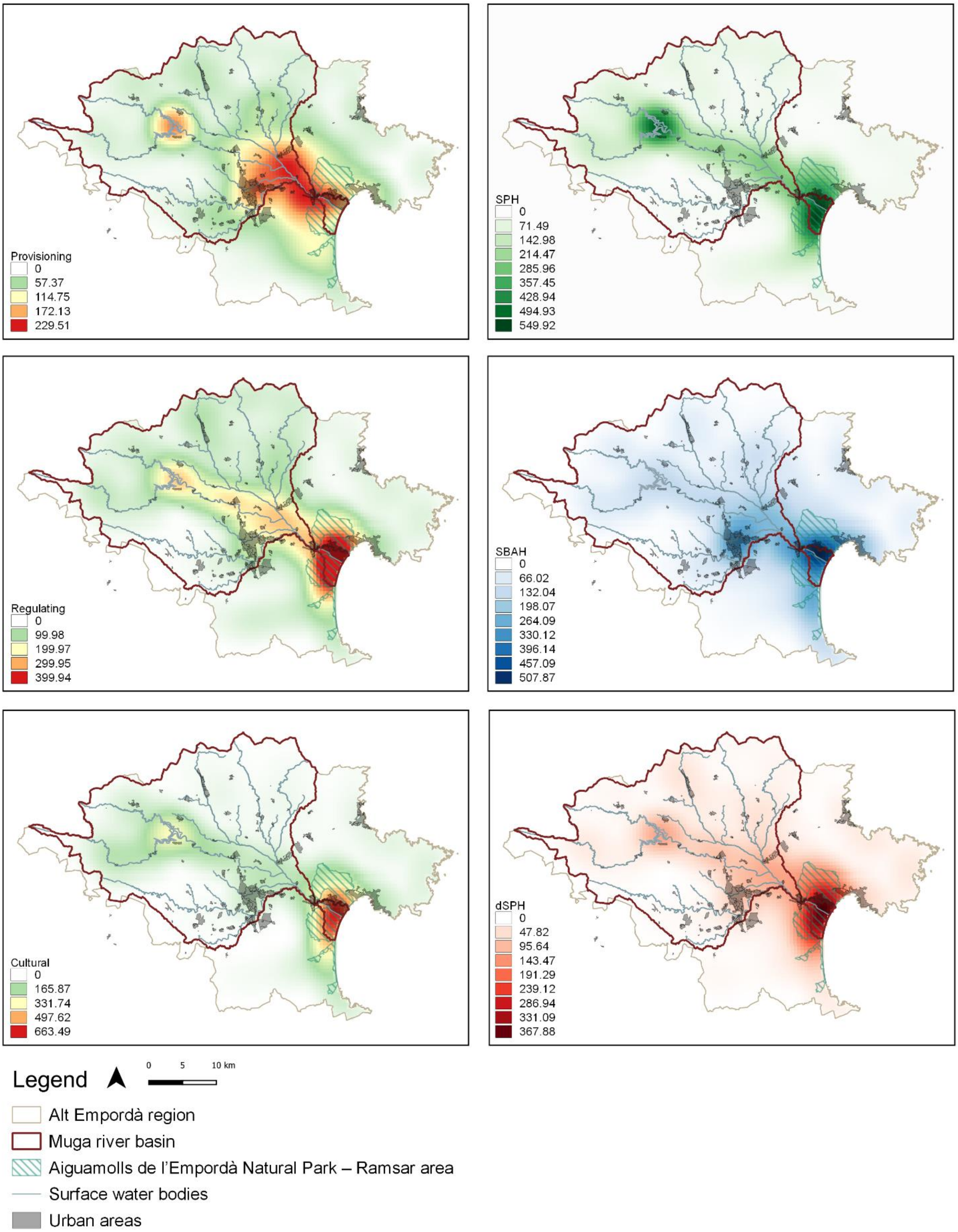

Figure 4. Intensity raster maps of water ecosystem service categories (left) and units hotspot (SPH, SBAH, and dSPH (right) as perceived by stakeholders. SPH indicates service provision hotspots, SBAH, service benefiting areas hotspots, and dSPH, degraded service provision hotspots.

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There were no significant differences between DD and ID stakeholders in terms of the number of points used to map SPH, SBAH, or dSPH or in their spatial distribution. As shown in Figure 5, ID stakeholders used more points to identify degraded SPHs (with the exception of water regulation). By contrast, DD stakeholders used more points to map SBAH, which were mainly located on the coast, in urban areas, and in the agricultural plain.

As for WES categories (Figure 5), the stakeholders used more points to map regulating SPH (in particular biodiversity) and cultural SPH. In the case of SBAH, water for irrigation and human consumption, aesthetic values, and opportunities for recreational activities had the most mapped points. dSPH were the least frequently mapped units. However, the hotspots related to the water regulation ecosystem services (rivers, forests in the high basin, and coastal wetlands) were considered to be the most degraded areas. All the stakeholders recognized the different anthropogenic pressures on the lower part of the Muga river and the AENP, which was considered both an SPH and a dSPH.

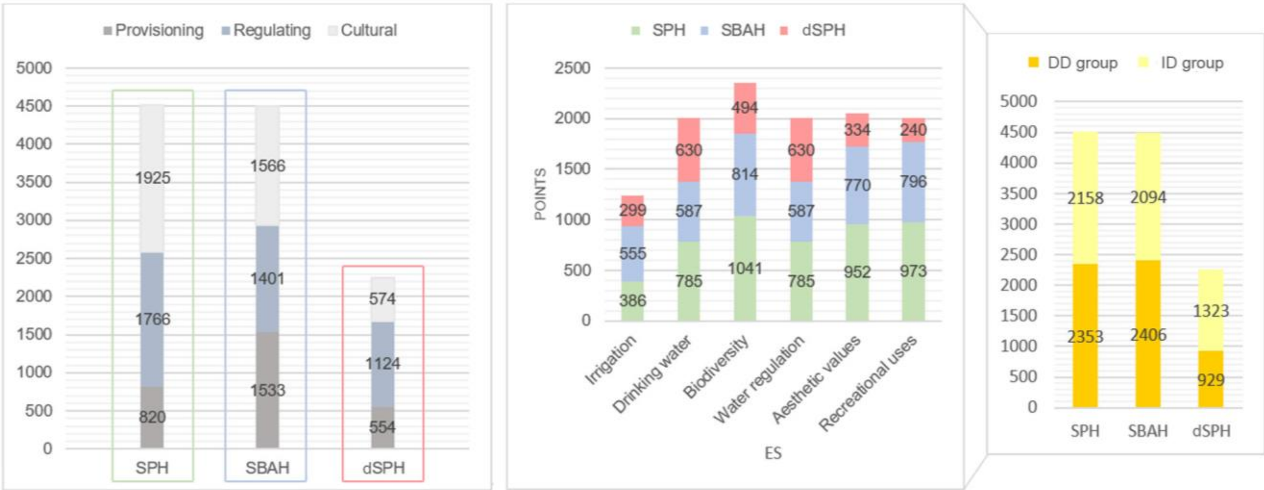

Figure 5. Distribution (number of points) of SPH, SBAH, and dSPH by water ecosystem category (left side), unit (center), and stakeholder profile (right). SPH indicates service provision hotspots, SBAH, service benefiting areas hotspots, dSPH, degraded service provision hotspots, DD, directly dependent; ID, indirectly dependent.

Our findings are consistent with those reported by Palomo et al. [22], who showed that provisioning ES tend to be located outside protected areas, while regulating and cultural ES tend to be located within these areas.

Urban dwellers and national and international tourists were all perceived as WES beneficiaries. Both DD and ID stakeholders, however, mapped regulating services SPU and dSPU in the same area. Moreover, our density maps show that DD and ID stakeholders differed in their perceptions of the location of hotspots. For the DD stakeholders, these tended to be located more in natural spaces (rivers, wetlands, and forests), while for the ID stakeholders, they were spatially more spread out and particularly present along the coast.

The analysis of participatory mapping audio-recordings revealed differences in perceptions according to type of WES category (provisioning, regulating, cultural) and unit (SPU, SBA, and dSPU). For example, in answer to the question "Where, in your opinion, does irrigation water come from?" or "What are the supplying areas of this benefit?", the stakeholders typically answered *"the water clearly comes from the sky, is there another possible answer to this question?"*. When asked to map the WES units, the stakeholders identified humanmade elements, such as the reservoir, wells, irrigation canals, and dams along the river as provisioning SPU and natural elements such as forests, mountains, and rivers as cultural SPU. In a study of the links between cultural ecosystem services and urban forest features, Baumeister et al. [41] showed that people considered humanmade elements to be an important part of cultural services. Our study shows that this was also the case for provisioning and regulating WES in the Muga river basin, which are in theory more closely linked to the ecological functioning of ecosystems than to cultural aspects. Most of the SBA elements were positioned in urban areas, in the agricultural plain, and along the coast (mainly campsites and tourist resorts). Most of the dSPU elements identified were natural features, such as the AENP, the coastline, the agricultural plain, the river and its tributaries, and the river mouth. Nonetheless, humanmade elements, such as irrigation channels, historical-cultural features (mills, factories, and fountains), the reservoir, and urban areas were also identified as dSPU (Figure 6). It is important to note that while the stakeholders coincided in their choice of dSPH, their reasons varied according to stakeholder profiles. This confirms that stakeholders not only perceive different ES, but also may differ when they have to evaluate the same ES, expressing different value systems which can generate conflicting views [25,46], as dependence on a given ecosystem service would affect perceptions of possible impacts on their activities.

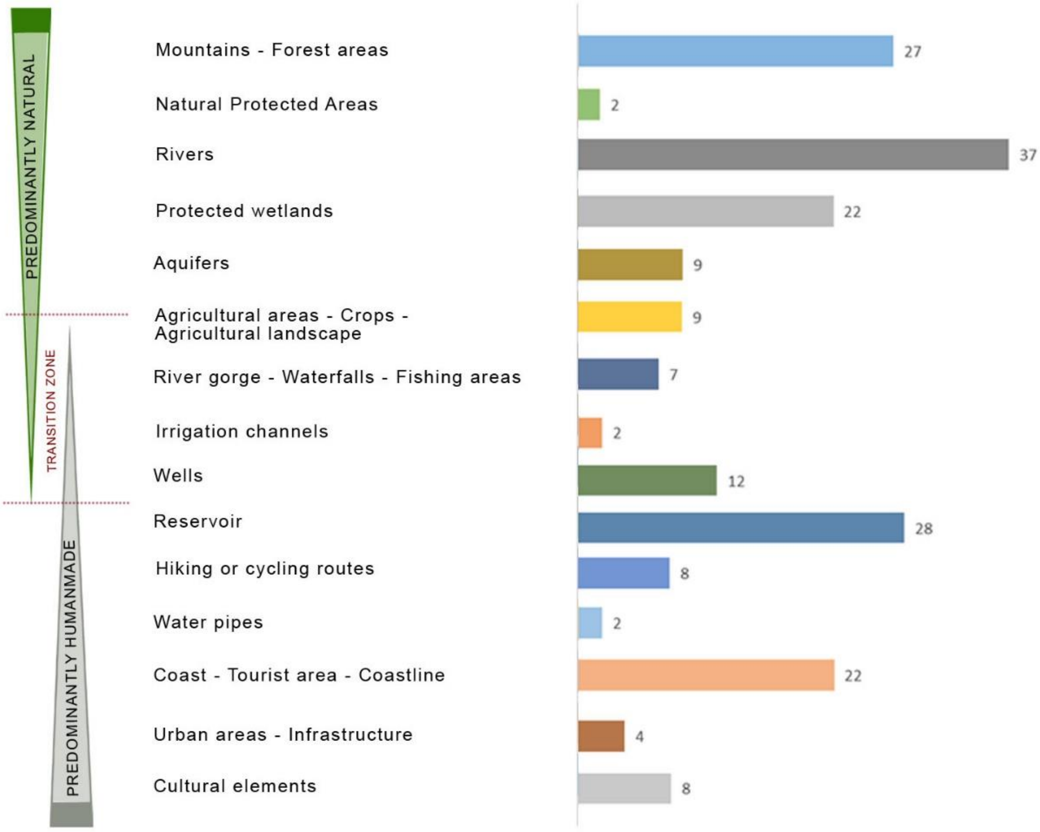

Figure 6. Gradient of elements mentioned as predominantly natural or humanmade and frequency of mentions as service provision hotspots, service benefiting areas hotspots, or degraded service provision hotspots (adapted from Palomo et al. [50]).

The spatial correlation analysis allowed us to explore differences in value systems, visualize potential sources of conflict over the use of water resources and better understand the power relations that shape decision-making processes [26,46,51] (Table 4).

Table 4. Spatial correlations between water ecosystem service SPH, SBAH, and dSPH according to perceptions of directly dependent (DD) and indirectly dependent (ID) stakeholders.

	SPH-DD	SPH-ND	SBAH-DD	SBAH-ND	dSPH-DD	dSPH-ND
SPH-DD		0.944	0.808	0.647	0.892	0.801
SPH-ND			0.742	0.631	0.832	0.794
SBAH-DD				0.919	0.924	0.835
SBAH-ND					0.816	0.857
dSPH-DD						0.883

dSPH-ND						

Abbreviations: DD, directly dependent; ID, indirectly dependent; dSPH, degraded service provision hotspot; SBAH, service benefiting areas hotspot; SPH, service provision hotspot.

The supply areas of WES were strongly spatially correlated and consequently as such are sources of potential conflict between WES involving trade-offs between them. SBAH and SPH, however, were not positioned in the same area, indicating that stakeholders perceive that most WES are not "consumed" in the same place in which they are generated. We also observed a greater overlap between SPH and SBAH among DD stakeholders suggesting that they perceive a lower mobilization of WES than ID stakeholders. Accordingly, DD stakeholders would appear to perceive themselves as having a close relationship with provisioning WES supply points, probably because changes in supply would affect their activities more than those of ID stakeholders.

Analysis of divergences and factors influencing preferences is crucial for identifying potential areas of conflict or tension and for understanding the reasons behind different choices [12,25,37,46]. Analysis of trade-offs between WES thus can help identify at-risk areas and potential conflicts between groups of stakeholders. The concept of "trade-off" indicates that the provision of one ES would reduce the provision of another. Therefore, when two ESs involving trade-offs are strongly correlated, it means that they are being generated in the same place and may therefore generate conflicts. Trade-offs were identified by the question "Do you think there is competition for water? And if so, what are the main problems?” [52]. Based on the answers to these questions, the relationships between WES were classified as trade-offs or bundles (Table 5).

Table 5. Direct interactions between water ecosystem services in the Muga river basin as perceived by stakeholders.

WES (X) WES (Y)	Irrigation	Drinking water	Biodiversity	Water regulation	Aesthetic values	Recreational uses
Water for Irrigation		↓	↓	↓	↔	↔
Drinking water	↓		↓	↔	↓	↔
Biodiversity	↔	↔		↔	↑	↑
Water regulation	↑	↑	↑		↓	↓
Aesthetic values	↔	↔	↔	↔		↓
Recreational uses	↔	↓	↓	↓	↓	

↓	An increase in (Y) has a reducing effect on (X) Strong probability for exclusion and competition perceived by stakeholders (trade-offs) → Negative relationships
↑	An increase in (Y) has a supporting effect on (X). Strong probability for mutual support perceived by stakeholders (bundles) → Positive relationships
↔	An increase in (Y) has no relevant direct effect on (X) → No significant direct interactions perceived by stakeholders

We also tested the correlation between different SPH (Table 6).

Table 6. Spatial correlation between provisioning water ecosystem service hotspots (SPH) generating trade-offs.

	SPH_ Irrigation	SPH_ Drinking water	SPH_ Biodiversity	SPH_ Water regulation	SPH_ Aesthetic values	SPH_ Recreational uses
SPH_Irrigation		0.8449133	0.6556189	0.8113572	0.6382932	0.6106935
SPH_Drinking water			0.5101186	0.7811566	0.6545207	0.6117226
SPH_Biodiversity				0.8889195	0.9065911	0.9027135
SPH_Water regulation					0.8927745	0.8598754
SPH_Aesthetic values						0.9833962
SPH_Recreational uses						

	Spatial match and trade-offs → Negative relationships
	Spatial match and synergies (bundles) → Positive relationships
	Partial spatial match

Water for irrigation and drinking water (two provisioning services) and water for irrigation and water regulation involved the most trade-offs between each other (r > 0.80). The correlation coefficients between provisioning services and biodiversity, followed by cultural WES, confirmed that these two categories do not coincide spatially. We also observed that relationships between WES could be negative (trade-offs) or positive (bundles) depending on the direction of the relationship [43]. For example, an increase in water for irrigation would reduce water regulation, but an increase in water regulation would not increase the availability of water for irrigation. A similar trend was observed for cultural WES, which coincided in terms of position and had clearly opposing trade-off directions. All the stakeholders were of the opinion that an increase in opportunities for recreational activities would result in a reduction in aesthetic values, while an increase in aesthetic values would result in increased opportunities for recreational activities (synergy). An increase in biodiversity was also perceived as positive as it would increase both aesthetic values and opportunities for recreational activities (e.g., bird watching in wetlands). By contrast, an increase in aesthetic values and opportunities for recreational activities would have a negative impact on biodiversity.

Our findings for trade-offs and bundles based on the correlation analysis and interview data shed light on possible sources of conflict or tension among stakeholders in the Muga river basin. Twenty of the 27 interviewees were of the opinion that there was competition for water. The main concerns expressed in response to the question "Are you worried about a decline in water resources and if so, why?" (Appendix B, q4.2) were related to climate change, in particular greater rainfall variability and more intense drought episodes. These concerns echo those raised in a recent study of tourist accommodation owners and managers in the Muga river basin who expressed concerns about the effects of climate change in the basin [53]. Nonetheless, most of them did not perceive serious risks to the future of tourism or their businesses, and some were even of the opinion that global warming could benefit them by lengthening the tourist season.

The stakeholders interviewed in our study were very concerned about loss of biodiversity and habitat destruction and about the increased demands on water due to human pressures, particularly from the urban and tourism sectors. The agricultural sector was perceived as the most problematic sector (mentioned by 20 of the 27 stakeholders); this perception is in line with the findings of the European MEDACC life Project [21], which estimated that 75% of all water in the Muga river basin was used for agricultural purposes. The tourism and urban sectors were mentioned as problematic by a similar number of stakeholders (17 and 16, respectively) (Appendix C). The above perceptions are supported by the results of the mapping exercise. Many stakeholders, however, claimed that conflicts due to competing demands for water arise in times of scarcity. In other words, they are closely linked to climate conditions and the availability of water at a given time. The discourse analysis of the opinions expressed by the stakeholders support the data presented thus far. The agricultural industry was identified as the main consumer of water in the basin: *"All the water from the reservoir goes to agriculture; the levels drop to dramatic levels two months a year and all the water is used for agriculture; there's no water in the river the rest of the year, we're outraged, they're throwing it away"*. The farmers, by contrast, said, "*When there's a drought, priority is given to urban and tourism uses, and we're the ones who are most affected. We're the only ones who change what we do to use water more efficiently, for example, by planting crops that are more suited to the effects of climate change (temperature, rain, wind, humidity)"*. These were some of the burning issues that sparked debate among the various stakeholders, confirming the tensions that have historically marked the use of water in the Muga river basin [16]. Ten of the 27 stakeholders stated that competition was greatest between the agricultural sector and the tourism industry, particularly in the summer months, when water for irrigation is needed most and when the number of visitors to the area (local and international holidaymakers) is at its highest [16,19,20]. Some of the stakeholders from the agricultural sector went into quite some detail on this issue:

"More and more water is needed for general consumption and tourism; the entire coastline consumes a lot of water here in summer. The thing is, this area has always been agricultural; tourism came later and water that used to be for agriculture has been extracted from the aquifers and now there is less. The need for water has increased, but there is no control, nobody is looking at how many showers tourists are taking a day, for example. But everything we do is controlled. But in our case, a high proportion of the water we use goes back to the aquifer."

The stakeholders also mentioned problems related to the salinization and nitrate contamination of groundwater and water from wells, which reduce the supply of water fit for human consumption and have a negative impact on natural habitats and biodiversity. These issues also spark conflicts between the agricultural sector and conservationists. On the contrary, the stakeholders were of the opinion that the agricultural sector has less influence in decisions regarding water use than the urban and tourism sectors. Thirteen of the 27 stakeholders considered that the agricultural sector had considerable power versus 17 who thought that was the case for the other two sectors. Just 10 of the 27 stakeholders considered that conservationist sector had a medium level of influence, while most think it has no power in decision making processes. All the stakeholders agreed that the public administration sector had the greatest decision-making power and they mentioned a lack of communication and a prevailing top-down approach (Appendix C).

5. Conclusions

Water ecosystems provide a diverse range of ecosystem services that are crucial to our well-being. While some of these services are clearly recognized by stakeholders, such as provisioning and cultural services, the results of this study show that also ecosystem services that are generally less evident, such as regulating ones [54], are perceived by stakeholders with greater or lesser intensity, according to their degree of dependence on water. The findings of this study demonstrate the importance of understanding how perceptions and decision-making processes related to water resource management in a scenario of conflict marked by increasing demand for water and increasingly scarce water resources are influenced by sociocultural values. In a context of ever-greater complexity, one of the strengths of sociocultural evaluation and participatory techniques is that it can identify ES hotspots that are potential sources of conflict for sectors with incompatible or divergent interests.

Our findings also highlight the importance of recording and analyzing opinions expressed during participatory mapping as this provides essential information for subsequent data evaluation and interpretation. This approach enabled us to explore in detail the involvement of stakeholders in water resource management, their level of decision-making power, their knowledge and vision of the basin, and their views of bottom-up strategies [12,34].

At the end of the interview, the stakeholders were asked about their opinions on the methodology used. Most of them thought that mapping was a very useful tool for visualizing the location and distribution of problems, for obtaining information, for improving the management of natural resources, and, in particular, for creating a shared awareness of the region. Highlighting, however, the power game that exists between certain groups, six of the 27 stakeholders stated that the methodology should be accompanied by scientific validation and representativeness, stating that *"if only the most influential actors put points where they want, lying about reality and their behaviors, and influencing the weakest, they'll end up making their own interests prevail, like always."* This statement reflects the difficult interaction between multiple stakeholders and the lack of transparency in how environmental problems are managed at the public administration level. We believe that more studies of how WES are understood and perceived by stakeholders are needed to gain a better understanding of the multifunctional nature of river basins and to generate new knowledge that will contribute to greater social acceptance of conservation measures and restoration of aquatic ecosystems [54].

Our findings also highlight an interesting paradox: WES are not humanmade, but many of the service providing units (SPU) of these WES were, indeed, humanmade elements (reservoir, wells, irrigation channels, water purification plants) that in many cases eclipse the role of ecosystems and

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our dependence on them. They also highlight a lack of awareness of the close link between water availability and ecosystems, and the difficulty of answering questions like, "Where does the water in the reservoir come from? And in the well? And the tap?"

In conclusion, it is essential to integrate frequently divergent outlooks, experiences, and priorities to create tools that will ensure a holistic, cross-disciplinary vision of a river basin. The ultimate goal is to avoid egocentric attitudes and water and territorial management models not grounded in the needs and perceptions of different sectors, as this will ultimately help achieve a shared consensus and build social resilience for addressing the changes that lie ahead. In line with the findings of other authors [48,55], this study shows the need to apply wisdom of the crowd approaches to water and WES management, using collective intelligence and social learning to identify problems and conflicts and to find inclusive solutions that account for the complexity of interests, opinions, and values in order to foster a better relationship between humans and nature.

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Appendix A

Table A1. Stakeholders' categorization.

Stakeholder Groups	
DD (Directly dependent on WES)	Crop – Livestock farmers (Agricultural)
	Natural Protected Areas
	On site recreational tourism sector
	Recreational leisure tourism sector
ID (Indirectly dependent on WES)	
	Tourism business sector
	Environmental groups and associations
	Administrative - political level
	Administrative - technical level

Appendix B

Table B1. Coding of the interview responses and categories derived from the content analysis (Code structure - categories - code frequency).

Q1.5 If you have to describe this territory to a person who live outside the Muga river basin, how would you describe it in a minute?	
q1.5\Rurality	3
q1.5\ Place of passage and communication	6

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q1.5\ Landscape diversity - Landscape multifunctionality	16
q1.5\Tourism	7
q1.5\It gives you many options	0
q1.5\ Physical description	
q1.5\ Physical description\Land uses (crops, urban areas, different landscapes)	8
q1.5\ Physical description\Coast - plain - mountain	11
q1.5\ Physical description\Weather	3

Q2.2 Do you think that this territory, defined by the Muga river basin, and the different manifestations that the water element has in it, provides some kind of benefit or positive effect for your well-being and the well-being of society? For example, which ones?

q2.2\Benefits limitation	3
q2.2\Quality of life	7
q2.2\Economic benefits-services	10
q2.2\Cultural ES	
q2.2\ Cultural ES\Hunting	1
q2.2\Cultural ES\Natural Protected Areas	4
q2.2\Cultural ES \Recreational activities-tourism	8
q2.2\Cultural ES\Calm and quiet	2
q2.2\Cultural ES\Beautiful landscapes-sense of place attachment	6
q2.2\Regulating ES	
q2.2\ Regulating ES \Biodiversity-Habitats	8
q2.2\ Regulating ES \Good weather - Climate regulation	5
q2.2\ Regulating ES \Clean air	5
q2.2\Provisioning ES	
q2.2\Provisioning ES\Wood	2
q2.2\Provisioning ES\Cattle raising	2
q2.2\Provisioning ES\Water	5
q2.2\Provisioning ES\Food and fresh vegetables	11

Q4.2 What are the most serious water-related problems in the Muga river basin for you? Could you indicate the most important ones?

q4.2\Ignorance of the subject	1
q4.2\Territory and landscapes management	1
q4.2\Human pressures	6
q4.2\Human pressures \Lifestyle changes	2
q4.2\Human pressures \Urban-tourist growth	5
q4.2\Human pressures \Agriculture	6
q4.2\Climate change	
q4.2\Climate change\Biodiversity-habitat loss	6
q4.2\Climate change\Fires	2
q4.2\Climate change\Temperature	4
q4.2\Climate change\Drought	6

q4.2\Climate change\Rain regime changes-decrease water	17
Q4.6 Do you think there is competition for the use of water resources? If so, do you think that this competition is or could be an incentive or a barrier when implementing water saving measures? Can you justify your answers, please?	
q4.6\Water management proposal	3
q4.6\No competition	5
q4.6\Barrier	3
q4.6\Incentive	3
q4.6\Yes-No competition (it depends on the time of the year or available water)	4
q4.6\Competition	
q4.6\Competition\Urban sector	2
q4.6\Competition\Tourism sector	1
q4.6\Competition\Agricultural sector	7
q4.6\Competition\Agricultural sector\Agricultural sector- Environmental groups	4
q4.6\Competition\Agricultural sector\Agricultural sector-Administrative sector	1
q4.6\Competition\Agricultural sector\Agricultural sector-Urban sector	3
q4.6\Competition\Agricultural sector\Agricultural sector-Tourism sector	6
q4.6\Competition\Administrative sector- Environmental groups	1
q4.6\Competition\Tourism sector-Urban sector-Environmental groups	3
q4.6\Competition\Participatory processes	2
q4.6\Competition\Administrative sector	8
Q4.8 Do you think that working with ecosystem services for the well-being of people and society can help efficient water management in the river basin? Can you justify your answer, please?	
q4.8\ I don't believe in this method	3
q4.8\I don’t know how	0
q4.8\To construct a better territory vision-better natural resource management	9
q4.8\Communication and dissemination of the study	2
q4.8\To visualize problems on a map	4
q4.8\Study representativeness and validity	6
q4.8\To get information	3
q4.8\Hydraulic works	2
q4.8\To create a shared awareness-vision among people	11

Appendix C

Table C1. Comparison between the level of water use and consumption by stakeholder sectors (A) and the level of influence in decision-making (B) according to stakeholder perceptions.

(A) LEVEL OF WATER USE AND CONSUMPTION				(B) LEVEL OF INFLUENCE IN DECISION MAKING	
SECTOR	LEVELS	COUNTS	% OF TOTAL	COUNTS	% OF TOTAL
Urban	High	16	59.3	17	63.0

	Medium	8	29.6	4	14.8
	Low	3	11.1	6	22.2
	Does not have				
Agriculture	High	20	74.1	13	48.1
	Medium	7	25.9	8	29.6
	Low			5	18.5
	Does not have			1	3.7
Tourism	High	17	63.0	17	63.0
	Medium	7	25.9	3	11.1
	Low	3	11.1	6	22.2
	Does not have			1	3.7
Conservationist	High			3	11.1
	Medium	8	63.0	10	37.0
	Low	17	29.6	13	48.1
	Does not have	2	7.4	1	3.7
Hydroelectric	High	3	11.1	3	11.1
	Medium	7	25.9	5	18.5
	Low	13	48.1	16	59.3
	Does not have	4	14.8	3	11.1
Forest sector	High	1	3.7	1	3.7
	Medium	6	22.2	4	14.8
	Low	17	63.0	20	74.1
	Does not have	3	11.1	2	7.4
Administrative	High			25	92.6
	Medium			2	7.4
	Low				

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