Follow the flow: analysis of relationships between water ecosystem service supply units and beneficiaries.

Abstract

A greater understanding of the complex relationships between ecosystem service (ES) supply and demand is needed to ensure a continuous and sustainable flow of ES in socioecological systems. While considerable progress has been made in ES flow mapping, further research is required to integrate beneficiaries' perspectives into these analyses. In this study, we obtained data from stakeholders to analyze the characteristics and distribution of water ES (WES) flows from service production units to beneficiaries and vice versa in order to better understand the mechanisms of management and mobilization along the WES cascade. The study area is the Muga river basin located in northeast Catalonia, Spain. We used a combined methodology of participatory mapping in which stakeholders from the basin were asked to identify service production and benefiting units and semi-structured interviews to assess their perspectives. We found that WES flow patterns and number of beneficiaries varied according to WES category and detected spatial mismatches between supply and demand. A better understanding of ES flow patterns and spatial distribution of beneficiaries can help identify potential sources of conflict. It can also help understand the dynamics and power relationships between groups of stakeholders involved in the coproduction of ES.

Keywords: Socioecological systems, Stakeholders values, Ecosystem service mapping, Supply-demand flow, Spatial relationships, Watershed management

1. Introduction

Ecosystem services (ES) are a useful cross-cutting concept for depicting and understanding the continuous interconnections and flows between the anthroposphere and biosphere. Although unresolved and sometimes controversial questions remain on how ES should be evaluated and applied to decision-making processes, any analysis of these services unveils a complex interaction of socioecological factors (Bennett, Peterson, & Gordon, 2009; Spangenberg, Görg, et al., 2014). Nonetheless, as stated by Fedele et al. (2017:43) the delivery of ES "has often been considered as a linear and direct flow from nature to people without feedbacks or human inputs". ES, however, depend on social processes. According to Fisher et al. (2009), nature's processes only become services when they are of benefit to humans. It is therefore necessary to integrate ES-specific concepts, such as value attribution, mobilization, appropriation, and commodification into concepts that are specific to the ecosystem cascade in which ES are generated (e.g., functions, service potential, and benefits/use value) (Haines-Young & Potschin, 2016; Spangenberg, von Haaren, & Settele, 2014).

Therefore, ES are also coproducts of social construction (Palomo, Felipe-Lucia, Bennett, Martín-López, & Pascual, 2016; Spangenberg, Görg, et al., 2014). They are perceived differently according to the value systems of beneficiaries or groups of beneficiaries (Haines-Young & Potschin, 2018) in a given cultural context, space, and time (Spangenberg, von Haaren, et al., 2014; Von Haaren & Albert, 2011). They can be mobilized to improve accessibility in accordance with cultural, social, and political norms. It is therefore essential to consider the different flows and connections between supply and demand when evaluating the potential influence of human actions on service provision (Castro et al., 2014a; Geijzendorffer, Martín-López, & Roche, 2015; Palomo et al., 2016).

Stakeholders' ability to access, control, and benefit from ES is also influenced by management strategies, needs, power, access, and location in relation to the point of production (Fedele, Locatelli, & Djoudi, 2017; Fisher et al., 2014). Fisher et al. (2009:650) proposed three categories to describe the relationships between the locations at which ES are produced (service production units [SPU]) and used (service benefiting units [SBU]: *i) "in situ, where the services are provided and the benefits are realized in the same location; ii) omni-directional, where the services are provided in one location, but benefit the surrounding landscape without directional bias; and iii) directional, where the service provision benefits a specific location due to the flow direction*". These models, together with more recent work (Bagstad, Johnson, Voigt, & Villa, 2013; Serna-Chavez et al., 2014), have facilitated the study of ES spatial patterns and the classification of services according to these patterns, with identification of provision, use, and sink locations (Bagstad et al., 2013). Analyzing the distances and spatial patterns between SPU and SBU using a sociocultural value dimension can provide complementary insights into the spatial flows of ES and enables reflection on their potential consequences on landscape management and conservation policies (Fagerholm et al., 2016).
The concept of ES flow, however, has not yet been clearly defined, as there are spatial mismatches between different ecosystems producing ES and their beneficiaries. In fact, determining the location of ecosystems producing services and identifying who is using these services and where remains a key challenge in the field (Bagstad et al., 2013). A better understanding of spatial flows and relationships between SPU and SBU will also improve our understanding of spatio-temporal mismatches between ES production and human demand (Li et al., 2016; Serna-Chavez et al., 2014). For the purpose of this study, ES flow is defined as the connection between ES production areas and ES benefiting areas (Bagstad et al., 2013; Serna-Chavez et al., 2014), that is, the transmission of ES (or nature's processes) from ecosystems to humans.

Most studies that have analyzed spatial relationships between SPU and SBU have taken a theoretical rather than an empirical approach (Costanza, 2008; Fisher, Turner, & Morling, 2009; Serna-Chavez et al., 2014; Syrbe & Walz, 2012; Villamagna, Angermeier, & Bennett, 2013). Costanza (2008), for example, proposed classifying ES according to their spatial characteristics and focused mainly on regulating services (e.g. pollination, flood protection, climate regulation, and soil formation). Syrbe and Walz, (2012), in turn, introduced the term "service connecting areas" to refer to the area between SPU and SBU (whose processes can affect flow), but they did not define any specific spatial characteristics. García-Nieto et al., (2015) and Palomo et al., (2013) mapped trade-offs and synergies between SPU and SBU, but they did not empirically analyze their spatial relationships. In short, the need for studies linking ES beneficiaries with biophysical provision has been broadly highlighted, but there are relatively few empirical examples using mixed methods approaches (Silvestri & Kershaw, 2010). Therefore, this study aims to show how integrating stakeholder knowledge and perceptions into studies of spatial flows can improve our understanding of how ES are distributed, how distance between supply and demand points influences the provision of services, and how concentrations of beneficiaries at certain SPU can potentially lead to social tensions (Castro et al., 2014a; García-Nieto et al., 2015; Geijzendorffer et al., 2015; Villamagna et al., 2013). Apart from potentially affecting the flow of ES to different stakeholder groups, spatio-temporal mismatches can also show who is best able to access these services and who is most likely to be marginalized, highlighting inequalities in accessibility (Dronova, 2019) and spatial variations in demand (Wolff, Schulp, & Verburg, 2015). Inadequate management of water ecosystems located in the upper part of a river basin that simultaneously deliver different ES to directly or indirectly dependent stakeholders will have a negative impact on ES flows and the activities of stakeholders downstream (Stosch, Quilliam, Bunnefeld, & Oliver, 2017). A greater understanding of beneficiaries' perceptions of when and where ES are demanded or produced can help identify spatial mismatches between supply and demand and key beneficiaries in the flow of ES, facilitating decision-making and the application of more focused management approaches (Serna-Chavez et al., 2014).

To analyze spatial relationships between SPU and beneficiaries, defined as stakeholders who "*benefit from and demand ecosystem services or someone who is or may be involved or affected positively by a given environmental or management public policy*" García-Nieto et al. (2013:127), we used participatory mapping to analyze ES flows from the perspective of stakeholders in the Mediterranean Muga river basin located in northeast Catalonia, Spain. We focused on water ES (WES) since the study area has been experiencing increasingly complex water-related disputes and because WES are associated with greater "flow" and mobilization than other ES because of the very nature of water. The aim was to examine how a greater understanding of WES spatial patterns could help identify social mechanisms interfering with WES flows and result in improved water resource planning and management. Drawing on the spatial relationship model proposed by Fisher et al. (2009) for SPU and SBU, we also analyzed distances between supply points and beneficiaries to examine proximity and spatial distribution, identify flow routing types for different categories of WES, and determine the accumulation of beneficiaries for each SPU.

2. Study area

We conducted a case study in the Muga river basin, located in northeast Catalonia on the border between France and Spain (Figure 1).

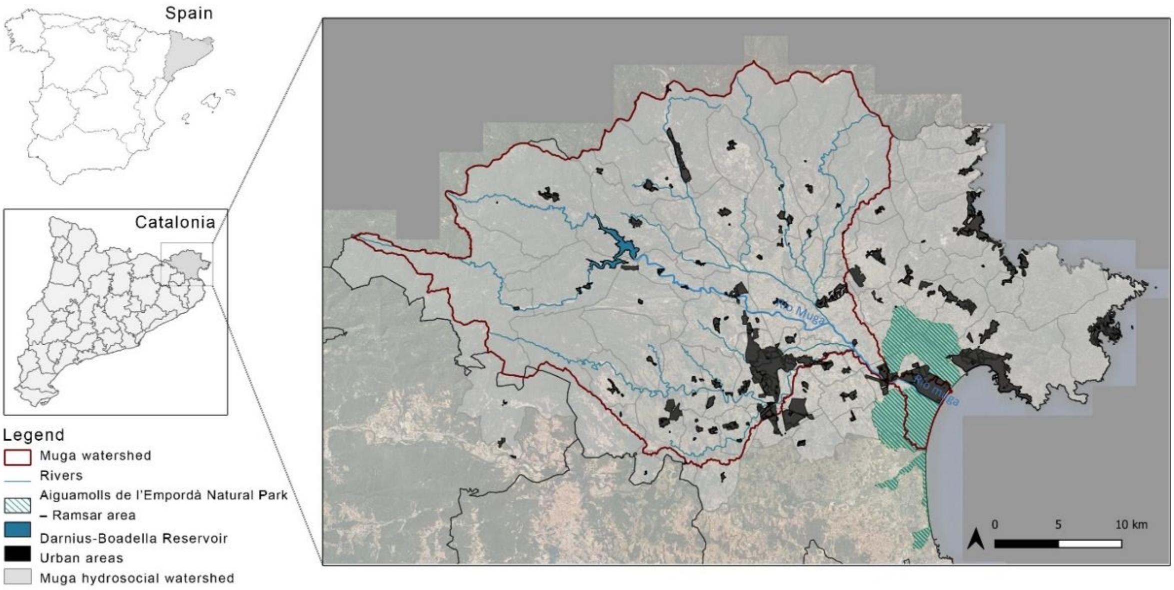

Figure 1. Muga river basin.

The Muga river runs for 64 km through a basin with a surface area of 854 km². It is born in the Pre-Pyrenees at an altitude of 1200 m and flows into the Gulf of Roses through the marina in Empuriabrava. With a mean annual flow of 2.5 m^3/s (IDESCAT, 2020), the river has a typically Mediterranean regime, although its flow is regulated by the Darnius-Boadella reservoir, which is the main source of water for the basin. Since the mid-20th century, the 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 changing trends in recent decades, have increased the demand for increasingly scarce water supplies, fueling both tensions and conflicts (Saurí i Pujol, Ventura Pujolar, & Ribas i Palom, 2000; Tàbara & Saurí, 2004).

The Muga river basin is divided into three main areas: the headwaters (upper basin), consisting mainly of mountains and forestland and featuring the Darnius-Boadella reservoir to the south; a central area (the middle basin), home to one of Catalonia's largest agricultural plains and the capital of the region, Figueres; and a coastal area (the lower basin), a renowned international tourist resort (Gabarda-Mallorquí, Fraguell, Pavón, & Ribas, 2016; Torres-Bagur, Ribas Palom, & Vila-Subirós, 2019) and home to the Aiguamolls de l'Empordà Natural Park, a natural preserve that has been a member of the Ramsar International Network of Protected Wetlands since 1993 (Ramsar, 1999). The Muga river basin is thus an extraordinarily diverse area in terms of ecosystems, landscapes, and socioeconomic activity. A better understanding of SPU and SBU and their flow relationships can offer useful insights for addressing the management challenges of water-related ecosystem services in the study area, especially in the context of climate change that has had a clear impact on water shortages in the Muga river basin (Pascual et al., 2016).

3. Methods

Participatory mapping is a useful technique for identifying SPU and SBU (Castro, García-Llorente, Martín-López, Palomo, & Iniesta-Arandia, 2013; Fagerholm et al., 2016; García-Nieto et al., 2015; Palomo, Martín-López, Potschin, Haines-Young, & Montes, 2013) and it can capture and graphically depict stakeholder values (García-Nieto et al., 2015). Results, however, are prone to bias from different sources, such as evaluation errors or differences in methodological approaches and data types (Brown, Strickland-Munro, Kobryn, & Moore, 2017; Eigenbrod et al., 2010; Holland et al., 2011; Serna-Chavez et al., 2014). To compensate for this limitation, we held semi-structured stakeholder interviews using a mixed model combining closed and open questions to allow interviewees to freely express opinions and to explore in depth themes not initially covered Iniesta-Arandia et al. (2014). The stakeholders were interviewed individually. The interview was structured into thematic sections, including the participatory mapping exercise section, where stakeholders shared their opinions of power dynamics at play in the river basin and levels of influence on decision-making processes. This mixed model was designed to gain insights that might have been missed by participatory mapping alone (Brown, Reed, & Raymond, 2020; De Vreese, Leys, Fontaine, & Dendoncker, 2016; Garcia et al., 2017; King, Cavender-Bares, Balvanera, Mwampamba, & Polasky, 2015; Martín-López et al., 2012; Sova, Thornton, Zougmore, Helfgott, & Chaudhury, 2017; Stosch et al., 2017). In brief, we used the results of the mapping exercise to analyze the spatial flows of different WES and the interviews to confirm and unpack our findings (Figure 2).

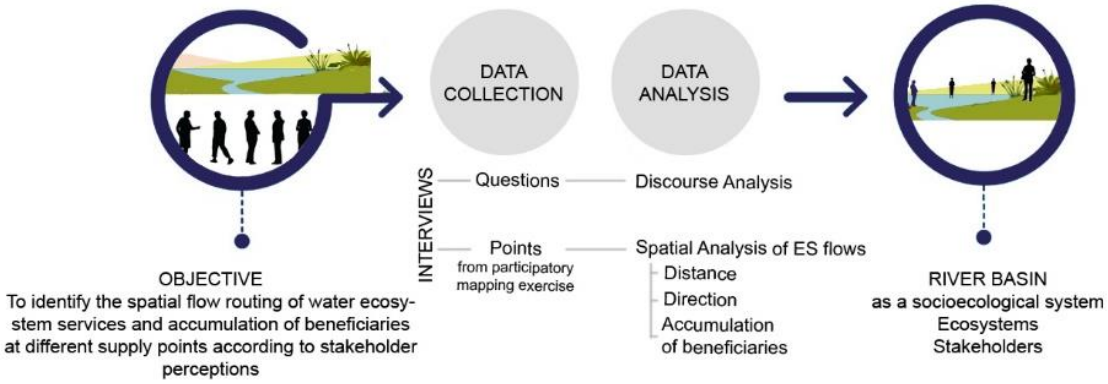

Figure 2. Main methodological steps.

3.1 *Data collection*

The stakeholders were selected by non-proportional quota sampling, since the purpose was not to obtain a proportional sample of each stakeholder group, but to ensure that all groups, both large and small, were adequately represented (Raymond et al., 2009; Tashakkori & Teddlie, 2003). Thirty-two stakeholders were contacted and 27 agreed to participate. The five agents that refused to participate were two hydroelectric power companies and three hotels. The field work was carried out between June and November 2019.

Table 1. Stakeholders interviewed.

Sector	No. of stakeholders interviewed
Research	1+6 (expert panel)
Agriculture	4
Recreational on-site tourism (agents that offer recreational activities directly linked to water ecosystems, such as kayaking, fishing, etc.)	6
Tourism business sector (hotels, campsites, golf courses etc.)	4

Conservation	5
Government – technical level	4
Government – political level	2

Drawing on the work of Palomo et al. (2013), the WES presented to the stakeholders for mapping were chosen by a previous panel of six experts from different fields related to water management in the basin, as a criterion for selecting the ES. The experts were asked to choose which they considered to be the most important WES from those listed in the Common International Classification of Ecosystem Goods and Services (CICES) (v5.1) (Haines-Young & Potschin, 2018). They selected water for irrigation, drinking water, biodiversity, water regulation, aesthetic values (places or cultural elements positively appreciated or experienced aesthetically (Plato & Meskin, 2014)), and opportunities for recreational activities (e.g., swimming, fishing, kayaking, bird watching). In accordance with the methodological framework proposed by Brown, Montag, & Lyon (2012), Brown et al., (2012), and Raymond et al. (2009), we used a paper mapping system as we believe it to be an ideal tool for stimulating debate, encouraging participation, and facilitating identification of the spatial characteristics and distribution of WES (Fagerholm, Käyhkö, Ndumbaro, & Khamis, 2012; Pérez-Ramírez, García-Llorente, Benito, & Castro, 2019; Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013; Pocewicz, Nielsen-Pincus, Brown, & Schnitzer, 2012). For each WES, the stakeholders were asked to map what they perceived to be the corresponding SPU and SBU on a 1:50,000 topographic map of the basin (Palomo et al., 2013). The exercise produced two layers of points (one showing SPU and another showing SBU) for each person interviewed and for each WES, resulting thus in a maximum of 12 layers per interview. The different points on the map were marked using colored dots with a radius of 1 cm (equivalent to 500 m on the map) (García-Nieto et al., 2015; Palomo et al., 2013; Pérez-Ramírez et al., 2019). The stakeholders were allowed to place as many dots (points) as they considered opportune. A vertical photograph was then taken of each of the completed maps to facilitate subsequent digitization of points.

In addition to the mapping exercise, stakeholders were asked about the importance they attached to each WES, their perceptions of demand and vulnerability, and their reasons for placing the points where they did. All interviews (including the mapping exercises) were audio-recorded and transcribed in full.

3.2. Data analysis

The interview transcripts were analyzed and coded into categories in Maxqda (v. 10, 2012) and the descriptive analysis was performed in Jamovi (v. 1.0.7.0). The transcripts of the conversations that took place during the mapping exercise were analyzed by discourse analysis (Macdonald et al., 2013). The first step in the spatial analysis of the participatory mapping data was to calculate the distances and direction of ES flow between each SBU and the nearest SPU selected by the stakeholders under the rational choice theory that beneficiaries would choose the nearest option possible (Blume & Easley, 2007). Although this assumption has its limitations (Chee, 2004), on comparing our results with the opinions expressed by the stakeholders in the interviews and mapping exercise, we found that it provided an accurate representation of most of the flows identified. To analyze each flow, we used SBU as points of origin (one flow per point) and SPU as hubs (where each unit could receive more than one flow). To assess the direction of flows, however, we made the reverse calculation, as flows are delivered from SPU to SBU. Distances and directions were calculated in nngeo, v. 0.3.7 (Dorman, 2020) and the sf package, v. 0.9.4 (Pebesma E, 2018) for R, v. 3.6. (R Core Team, 2020).

Once we had identified the SPU for each SBU, we calculated the total number of flows originating at the SPU (i.e., the total number of beneficiaries supplied by this unit). With this data, we constructed a Lorenz curve and calculated the Gini coefficient for each WES category to determine the degree of equality or inequality in the distribution of beneficiaries among all SPU. The Lorenz curve expresses this distribution graphically by comparing it to a diagonal line depicting perfect equality. The Gini coefficient is the numerical expression of the difference between the Lorenz curve and the diagonal line, which in our case, with *N* equal intervals on the horizontal axis, was calculated using the following formula:

$$Gini = 1 - \frac{1}{N}\sum_{i=1}^{N}(y_i + y_{i-1}) \quad \text{(eq. 1)}$$

where *N* was the number of SPU and *y* the total number of beneficiaries at each SPU (Haughton and Khandker, 2014). The Gini coefficient can range from 0 (maximum equality) to 1 (maximum inequality). It was calculated using the DescTools package, v. 0.99.34 (Signorell, 2020). The Lorenz curve was constructed in gglorenz, v. 0.0.1 (Chen, 2018), combined with the ggplot2 package, v. 3.3.0 (H. Wickham, 2016) in R. All the scripts created can be consulted in the following GitHub repository: https://github.com/jospueyo/follow_flow.

Finally, the WES flows were mapped using the plugin *MMQGIS* v. 2020.1.16 (Minn, 2020) in *QGIS* v. 3.10.3 (QGIS Development Team, 2020).

4. Results and Discussion

The stakeholders mapped a total of 9011 points, distributed among 300 layers. Cultural WES received the most points (3491, 38.7% of total), followed by regulating WES (3227, 35.8%) and provisioning WES (2293, 25.4%). The SPU with the most points were those that delivered cultural WES (in particular opportunities for recreational activities, like fishing, kayaking, bird watching) and regulating WES (in particular biodiversity). The SBU with the most points was for drinking water, followed by biodiversity. At the WES level, biodiversity received the most points (1855, 20.58%), followed by opportunities for recreational activities (1769, 19.63%) and aesthetic values (1722, 19.10%) (Table 2).

Table 2. Number of service production units and service benefiting units mapped by the stakeholders for each water ecosystem service category.

Water ecosystem service	*Service production units (No. 4511)*	*Service benefiting units (No. 4500)*
Irrigation	*386*	*555*
Drinking water	*374*	*978*
Biodiversity	*1041*	*814*
Water regulation	*785*	*587*
Aesthetic values	*952*	*770*
Recreational uses	*973*	*796*

Perceived SPU were the Darnius-Boadella reservoir, wells, irrigation canals, dams along the river (for provisioning WES), forestland in the upper basin, mountains, rivers, wetlands (particularly for regulating and cultural WES), water-related heritage elements (mills, fountains, factories), and cycling and hiking paths (for cultural WES). Most of the SBU were positioned in urban areas, in the agricultural plain, and along the coast (in particular campsites and tourist resorts). The WES flows and concentration of beneficiaries for the different SPU are shown in Figure 3.

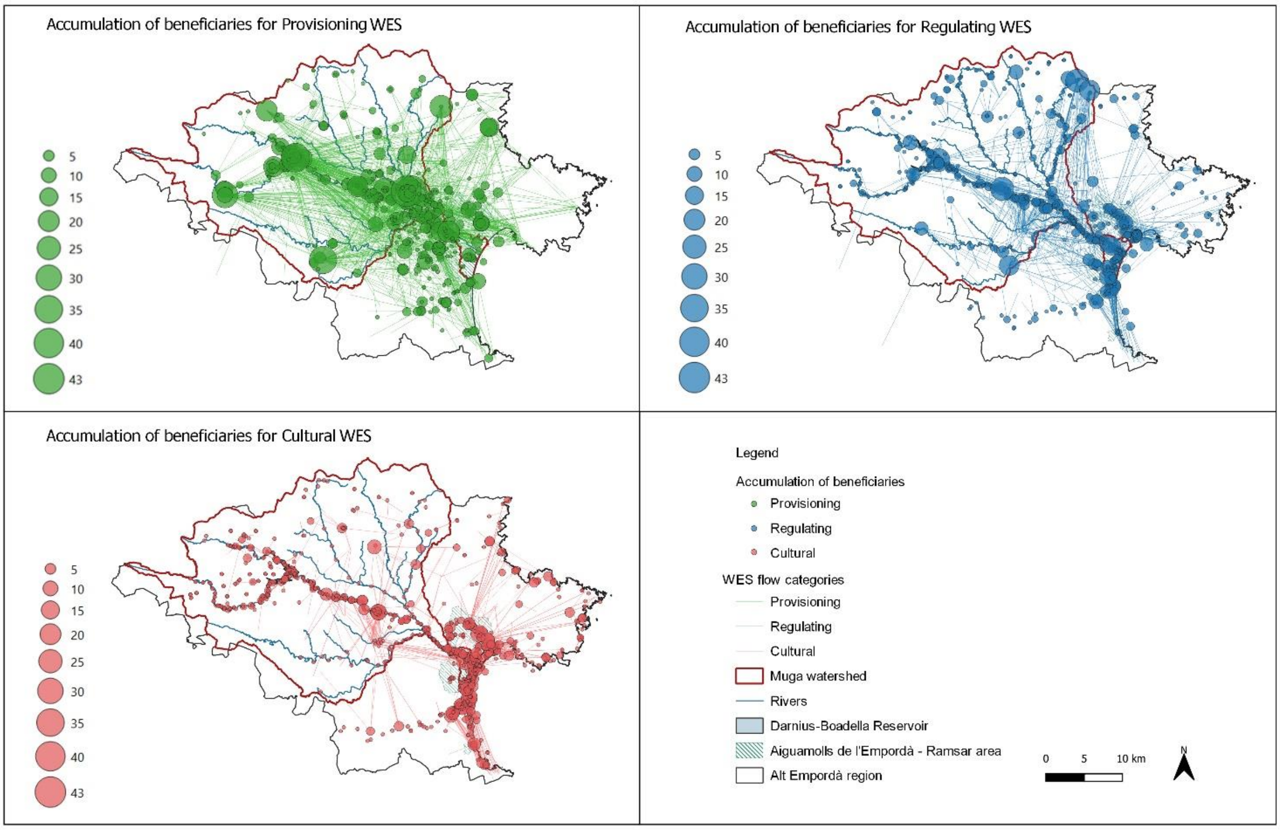

Figure 3. Water ecosystem service (WES) flows and concentration of beneficiaries per service production unit. The dots represent the service production units mapped by the stakeholders, while the size of the dots represents the number of beneficiaries for each unit by WES category.

4.1 Flow lengths

The graph showing the distances between SPU and SBU shows a clearly positive asymmetry, with an abundance of short flows (< 200 m) and a decreasing number of longer flows (typical gamma distribution) (Figure 4).

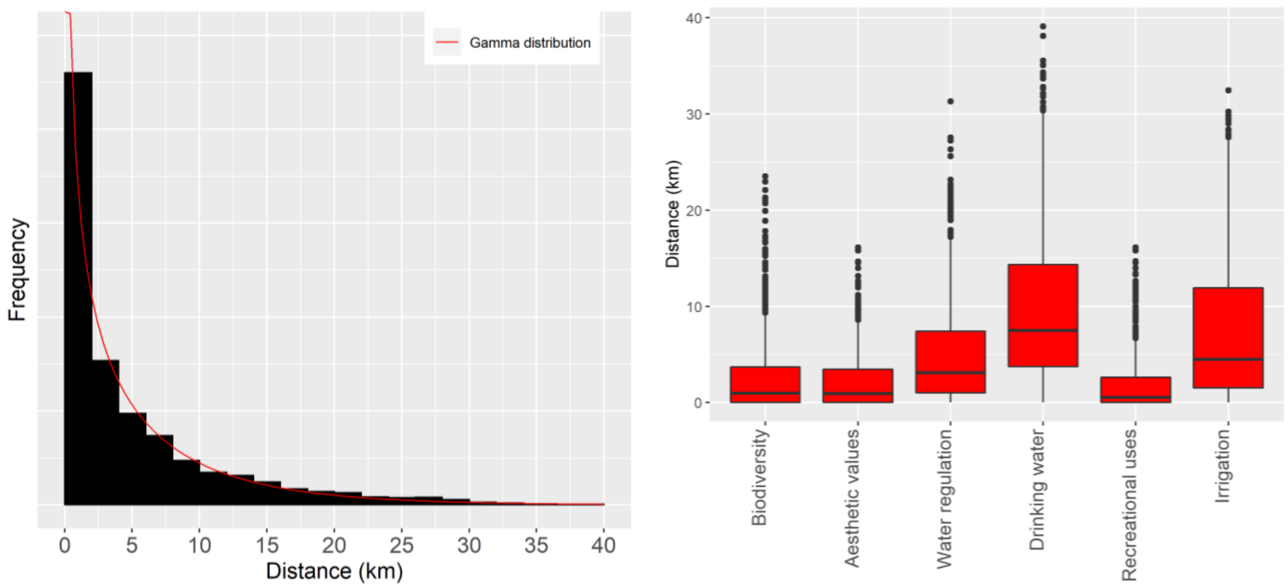

Figure 4. Distribution of distances (left) and boxplot of distances between production units and benefiting units (right).

Provisioning WES had longer flows than cultural or regulating WES, indicating greater mobilization. This means that some ES need to be delivered from ecosystems to beneficiaries through human infrastructure or biophysical processes (Serna-Chavez et al., 2014). We found that stakeholders positioned SBU mainly in the lower river basin, particularly in urban areas, in the agricultural plain, and coastal tourist resorts. The distance from these SBU to the main SPU, the Darnius-Boadella reservoir, is considerable, supporting reports by Fedele et al. (2017) that provisioning WES can be delivered to distant beneficiaries through irrigation canals or pipes. This is an important aspect to take into account, because this infrastructure can modify or change the direction or distribution of the ES flows towards the beneficiary areas, changing the balance in accessibility to the flow. In the Muga river basin, for example, water within the basin is mobilized and controlled by humanmade elements such as irrigation canals, water distribution networks, and small dams along the river, explaining the long distances detected and the high number of beneficiaries that can access the same ES. Our findings also support the results by Pavón et al., (2018) for the same study area showing how (mostly coastal) towns located furthest from the Darnius-Boadella reservoir are all connected to the same water distribution network, which has grown over the years to respond to the increasing pressure on water generated by tourism. The network was further expanded recently to supply drinking water to a number of towns in the agricultural plain that have experienced groundwater nitrate contamination.

Our findings also reveal a teleological dilemma related to the mobilization of provisioning WES that is probably applicable to all provisioning ES. Did the flows become longer thanks to technology (Fedele et al., 2017; Spangenberg, Görg, et al., 2014) or was technology invented to shorten the distances between supply and demand points? Both factors—need and technical capacity—are likely to have had a role. This question, however, is beyond the scope of our study and its investigation would require the collection of data on flows dating from before the construction of the Darnius-Boadella reservoir. The inclusion of humanmade elements such as wells in the category of SPU for provisioning WES is noteworthy, as this should have reduced the length of flows, as SBU are normally located close to the point of supply (e.g., wells for irrigating farmland), but despite this proximity, provisioning WES still had the longest flows. They were located over a wider area, as they were used both locally (e.g., irrigation water from agricultural wells) and at more distant locations (e.g., drinking water for coastal resorts).

Water regulation had longer flows than biodiversity or cultural WES. This is because the stakeholders considered the Muga river, together with its tributaries and the coastal wetlands, to be crucial ecosystems for water regulation and aquifer recharge throughout the basin. In addition, beneficiaries were mostly concentrated in urban areas and coastal tourist resorts in the lower basin. Cultural WES had the shortest flows, as SPU and SBU were largely perceived as having a close spatio-temporal relationship. For example, the recreational opportunities offered by coastal wetlands and rivers were perceived as being enjoyed by people staying in that area, a somewhat surprising finding considering the use values of these ES (e.g., walking, sport, and water activities). If, however, we consider non-use values (e.g., social media photographs, experiences, memories, etc.), the flows would be longer, as the beneficiary scale would be different. The scale of beneficiaries using cultural WES in our study was perceived as being both local and international, which is logical as the area is a renowned international tourist destination. Again, this raises an interesting question. How long is the flow of cultural WES?

Our findings also show that spatial distance could increase the disconnection between ES beneficiaries and production areas (Serna-Chavez et al., 2014), causing some beneficiaries to disengage from the producing ecosystems and resulting in a kind of alienation of nature (Dronova, 2019). This was particularly evident with provisioning services, which showed longer distances, indicating that certain stakeholders found it difficult to answer the question "where does the water you drink come from?" and to map and visualize WES producing a given service. As stated by one stakeholder interviewed: "*urban areas don't know anything, they don't even know where water comes from, they turn on the tap and see water coming out".* This happens, for example, when people do not consider the importance of upper basin woods or aquifers as essential ecosystems for water storage (Castro et al., 2014b). By contrast, the stakeholders interviewed were fully aware that the production areas of cultural ES coincided with areas of demand for these services, affirming that the wetlands must be preserved if they are to continue to provide enjoyment and opportunities for leisure activities.

These differences in mental and spatial disconnection between SPU and SBU show that distance analysis can offer useful information for policy makers when it comes to making decisions on land management and help understand social attitudes towards and awareness of certain ecosystem management measures (Dronova, 2019).

4.2 Flow distribution patterns

The flow distribution patterns observed in our study are very similar to those detected in theoretical models designed by other authors (Costanza, 2008; Fisher et al., 2009; Villamagna et al., 2013).

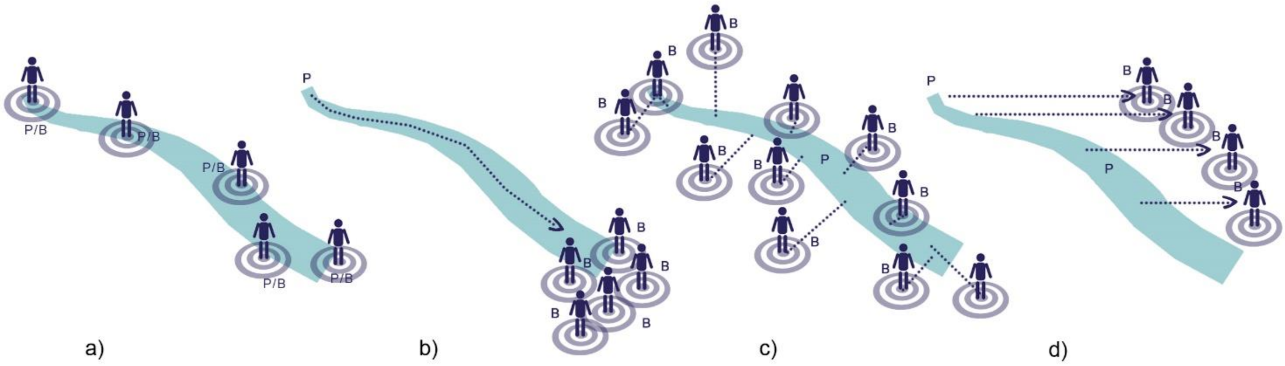

Figure 5. Theoretical model of spatial relationships between possible service production units (P) and service benefiting units (B). a. In situ; b. Unidirectional – Gravitational flows; c/d. Omnidirectional. Adapted from Fisher et al. (2009).

As shown in Figure 5, and in consonance with the theoretical models of Fisher et al. (2009), the directions of flow varied according to WES category. In most cases, the flow of provisioning WES clearly followed the course of the river (north-west/south-east) and had a unidirectional impact (Figure 6A). This was to be expected, as water supplies are typically delivered to beneficiaries from their point of origin. Regulating and cultural WES, by contrast, did not follow such a clear unidirectional pattern (Figures 6B and 6C).

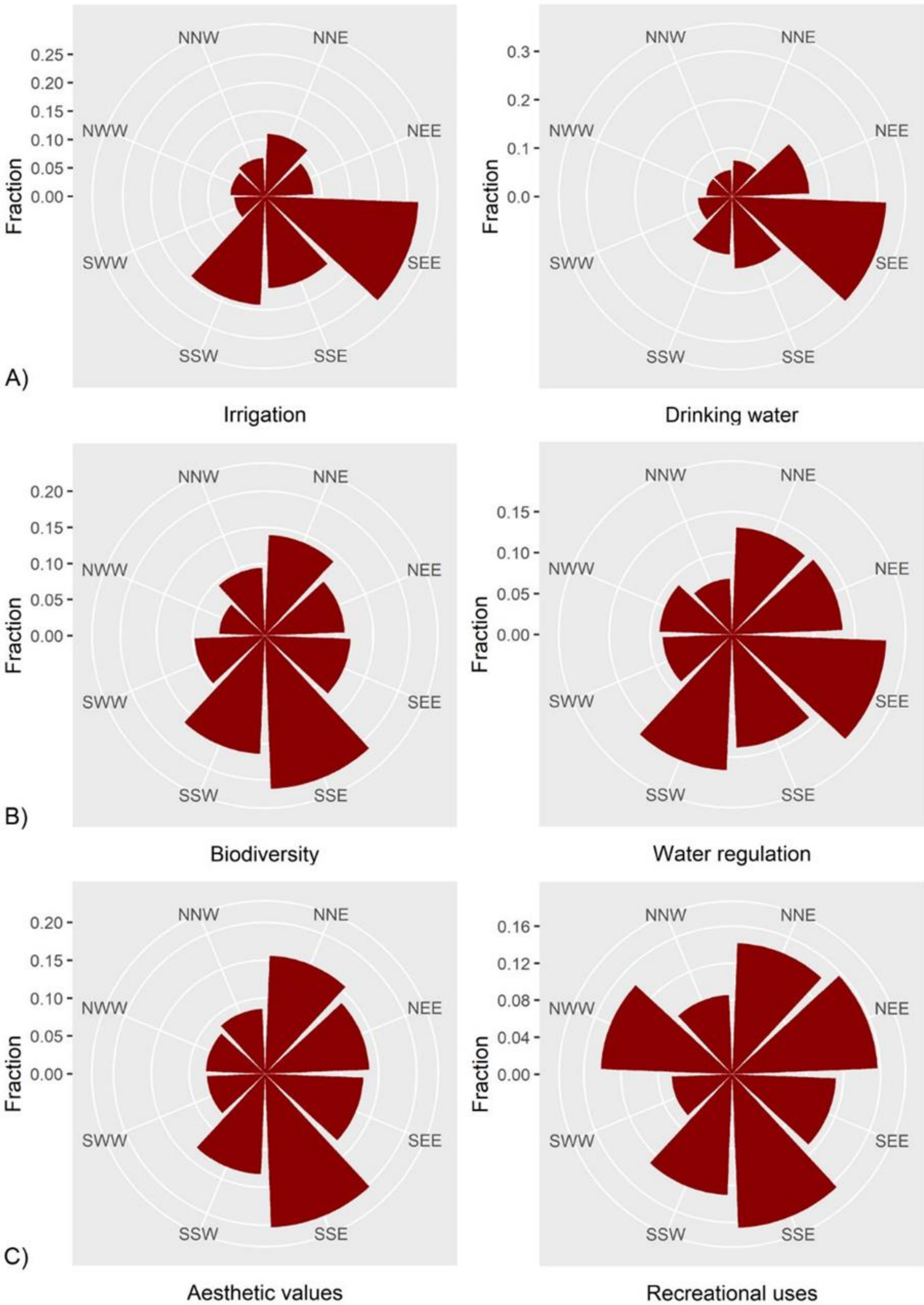

Figure 6. Ecosystem service flow directions. N, north; S, south, E, east, W, west.

Regulating WES (Figure 6B) also followed the course of the Muga river and its tributaries, but the flows also took other directions, positioning thus these services between pattern b) (unidirectional) and pattern d) (omnidirectional) in Figure.5. Regulating WES, for example, also flowed perpendicularly to the main course of the river (north-north-east/north-east-east), following the course of its tributaries. These rivers were perceived by the stakeholders as key elements for flood mitigation and aquifer recharge (*"The rivers, and all their tributaries, are very important for regulating water in the basin, because when it rains, they collect a lot of water and help to smooth flows, but they are also the most critical points, as when it rains a lot, they carry a lot of water") (farmer*).

Cultural WES flows were omnidirectional (Figure 6C) and the corresponding SPU were also spatially more dispersed, probably because ecosystems that produce cultural services—like nearby elements such as cycling or hiking paths, riverside forests, and water-related heritage elements—are not typically associated with water.

The spatial distribution (distances and directions) of SPU and SBU according to WES category is shown in Figure 7. Cultural WES, followed by regulating WES, formed the tightest clusters, confirming their omnidirectional, shorter flows.

Provisioning WES, by contrast, were more widely distributed (indicating longer flows) and followed a more unidirectional pattern, extending from 50° to 180° degrees (where 0 is north and 180° is south). The variety of flow patterns observed shows that empirical models can capture strong contextual influences that may be missed by theoretical models.

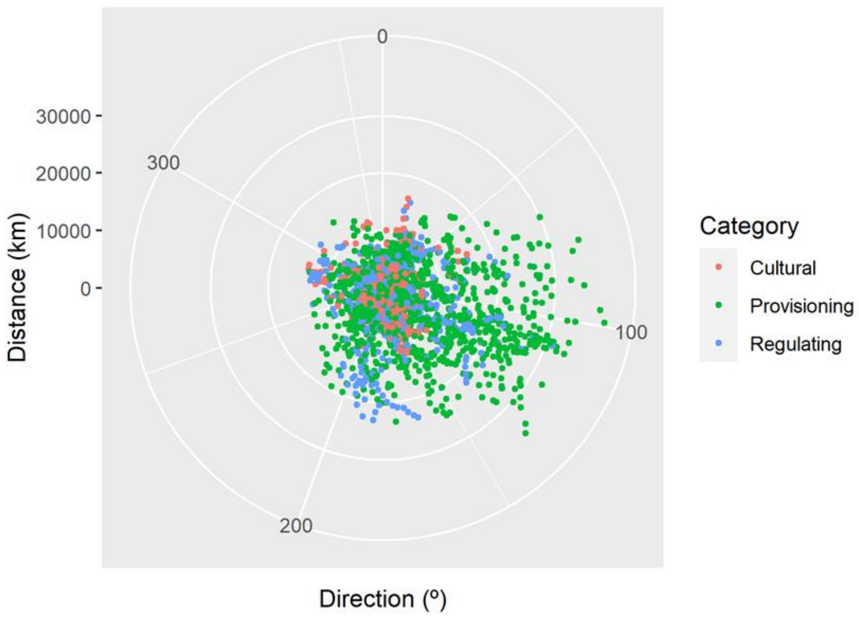

Figure 7. Distances between service production and service benefiting units and direction of flows by water ecosystem service category.

Our findings for flow distribution patterns are supported by the opinions expressed by the stakeholders interviewed. The former director of the Aiguamolls de l'Empordà Natural Park (a Ramsar wetland), for example, said "*Roses and Empuriabrava [two important seaside resorts] are "drinking" water from the Darnius-Boadella reservoir because of us, those in charge of the*

Aiguamolls park. They used to have wells and consumed large amounts of water, the water table was dropping a lot, and there were a lot of problems with salinization; that's why we suggested they connected to the Darnius-Boadella reservoir. By doing this, we limited their supply of water, but prevented the salinization of the most important aquifers associated with the Muga and Fluvià rivers."

The above comment might suggest that ES flows could sometimes be lengthened not in response to economic needs but to prevent a greater evil that would harm the environment. It also reveals the social dynamics underlying supply and demand and also has interesting socioecological connotations. It reflects, for example, the coproduction of WES between humans and nature and highlights the responsibility of stakeholders to find alternative land management options that will allow them to maximize economic benefits, while minimizing environmental impacts (Lerner, Kumar, Holzkämper, Surridge, & Harris, 2011; Palomo et al., 2016). It highlights the importance of taking into account stakeholder values and integrating their knowledge into decision-making processes, as power dynamics and different levels of access and control among stakeholder groups can all affect the provision of ES. Mobilization of given services through humanmade infrastructure, together with certain political decisions, can favor certain ES while harming others, creating trade-offs and spatial mismatches between supply and demand and between stakeholders and services.

Reservoirs, for instance, are a good example of how water and land management policies have fostered processes of maximization, mobilization, and access in relation to drinking and irrigation water, but to the detriment of other WES such as biodiversity, water regulation, and aesthetic values. This "anthropocentric and utilitarian" view of ES and nature is in line with what Stosch et al (2017) referred to as the "commodification" of intrinsic values of nature (Fletcher, 2010), which can indirectly lead to the degradation of parts of the ecosystem that deliver ES with no market value. Nonetheless, this commodification can also have a favorable effect by promoting the coproduction of new ES. In our case, the stakeholders also perceived the reservoir as a social gathering place where people can come together to walk, do water activities, or have a picnic.

The results of the mapping exercise and the views and comments of stakeholders during the interviews show that production units and spatial flows of ES cannot be understood without the consideration of coproduction mechanisms and socioeconomic and cultural value systems.

4.3 Accumulation of beneficiaries

We also analyzed whether beneficiaries were equally distributed among the different supply points or if there were particular points with a high concentration of beneficiaries (and therefore demand). The Gini coefficients obtained highlight the differences between categories (Figure 8). Provisioning WES, with a coefficient of 0.549, had more flows originating from fewer SPU. Specifically, 12.5% of the SPU with the highest concentration of provisioning WES beneficiaries supplied 50% of stakeholders, while 25% of those with the lowest concentration of beneficiaries supplied just 8%. The corresponding percentages for regulating and cultural WES were 20%-50% and 25%-12%, respectively.

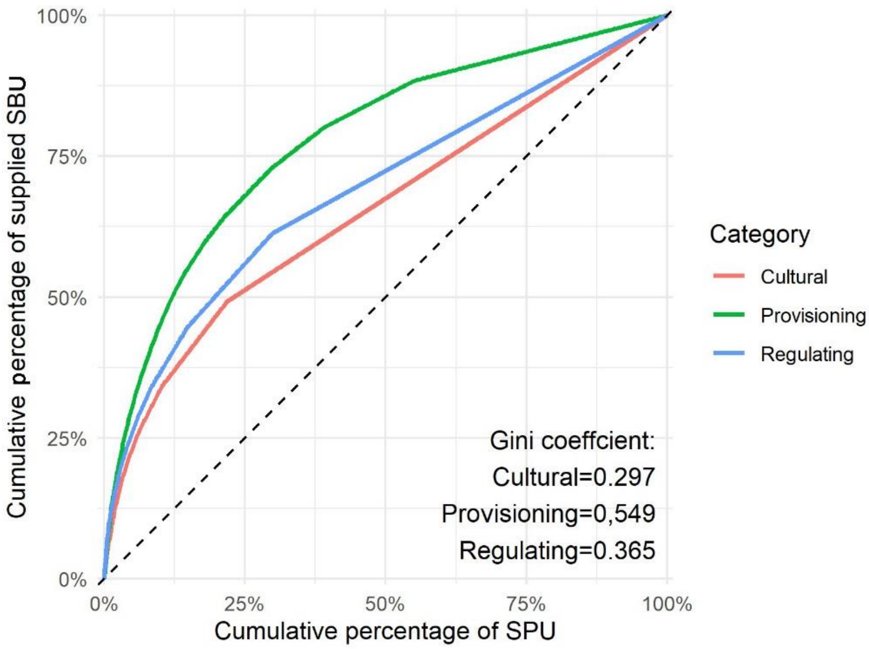

Figure 8. Numbers of beneficiaries per service production unit according to water ecosystem service category.

In short, provisioning WES were perceived as having the most unequal distribution of flows, indicating that certain SPU are under greater pressure and are thus more vulnerable to degradation and a potential source of conflicts between stakeholder groups. The Darnius-Boadella reservoir, located in the upper basin, is a clear example of this, as it was perceived as a hotspot, particularly in relation to provisioning WES. If high-demand hotspots such as the reservoir were to collapse, this would have serious socioeconomic and ecological ramifications for the entire basin. Interdependences between ES are very common in water basins (Green et al., 2015), and poor upstream management can pose a serious threat to the delivery of services further downstream. *"Having water or not depends on the reservoir, and the reservoir, depending on how much it rains, is a critical point. The Muga river basin is small and when it rains, it rains more in other parts of the basin, not at the reservoir. With climate change, we don't know what's going to happen. If the reservoir doesn't fill, there will be water problems throughout the basin, because we all depend on the reservoir" (farmer*). Familiarity with WES flow patterns thus is crucial to inform decision-makers about how changes to the quantity or quality of flows in the upper basin will impact the lower basin. This is evident not only for provisioning WES, but also for regulating WES, for which the SPU with the highest concentration of beneficiaries were located in the lower basin. The basin's ability to provide a stable flow of regulating WES largely depends on the spatial relationships between SPU and SBU in the upper basin, as highlighted by other authors (Domptail, 2013; Vignola, McDaniels, & Scholz, 2012).

According to the Gini coefficients obtained in our study, provisioning WES are more vulnerable than other services and are more likely to be the center of possible tensions and disputes between multiple stakeholders with contrasting interests (water for agricultural, domestic, or tourist uses is a common example in areas with limited water availability like the Mediterranean basin), showing the local equilibrium between supply and demand (Wolff et al., 2015). Provisioning WES also pose management challenges to ensure their conservation and long-term sustainability, as they were characterized by a more unequal distribution of beneficiaries and a greater concentration of demand at fewer supply points.

Water for irrigation, drinking water, and biodiversity conservation WES in the Muga river basin all originate from the same supply point, and are clear examples of divergent priorities among different stakeholders (farmers, urban development/tourism, conservationists). As stated by the owner of a water park in the basin: *"Here, there are conflicts over water among the three economic sectors with power and influence (tourism, government, and towns/cities). The main recent problem is with the agricultural sector in general; urban areas don't know anything, they doesn't even know where the water comes from, they turn on the tap and see water coming out and if it doesn't, it's the government that's the problem, they don't know anything about water problems [...] The agricultural sector has always protested the most, because historically it never had any problems with water, and now with the growth of towns and cities and tourism, people are using more water, reducing the supplies available to agriculture; they used to be able to water as much as they liked, but now they are subject to limitations*".

In short, WES with fewer supply points and multiple beneficiaries with divergent interests could be more vulnerable to reductions or changes in flow and increasing demand. *"I'd be really affected if they used all the water in the reservoir for agriculture, because then I wouldn't have any water in the reservoir and that's what I work with. How could I provide my tourist services without water?"* (sailing school owner at the reservoir). As stated by Bennet et al. (2009), changes in ES flows are dependent not only on land use and land cover (which can obviously have greater or lesser effects on flows), but also on demand and WES management strategies used by different stakeholder groups.

According to Stosch et al. (2017) and Bennet et al. (2009) trade-offs are sometimes the result of specific land management decisions, but they are often due to a lack of knowledge of the different interrelations between ES. Policy-making and land planning decisions that are not based on mechanisms of concentration and mobilization or that do not take into account the power dynamics among stakeholder groups with different visions of the same ES could turn into a ticking time bomb. We agree with Fedele et al. (2017) and King et al. (2015) that predominant views held by certain stakeholder groups can affect ES flows and either facilitate or impede access to services by other potential beneficiaries. Choice of management model will determine the extent of the resulting trade-offs and some stakeholders will benefit while others will lose out. The findings of this study support and build on previous findings (Brown & Raymond, 2014; Castro et al., 2013; García-Nieto et al., 2015; Iniesta-Arandia et al., 2014; King et al., 2015; Lerner et al., 2011) that ES flows depend not only on supply but also on demand and social mechanisms, identifying where the services from a production area are being delivered to particular beneficiaries (Serna-Chavez et al., 2014). The study of spatial flows using a mixed methods approach is crucial to achieving more efficient land management, identifying communities of stakeholders with different interests and levels of influence, and evidencing the complexity of socioecological contexts.

5. Conclusions

The concept of ES can facilitate interconnections between nature and society, promoting interdisciplinarity and a shared vision of a territory as a socioecological system. Stakeholder perceptions and value systems must be taken into account in any evaluation of ES. We showed that understanding the mechanisms involved in the spatial (dis)connections between service production units and service benefiting units provides key insights into how stakeholders perceive and intervene in ES flows, causing spatial and mental mismatches. Incorporation of these views can also help decision-makers identify both shared and divergent priorities regarding ES use and potential sources of social tensions in certain producing ecosystems with a high accumulation of demand, as in our study area. We have also shown that using the Gini coefficient to analyze spatial information can reveal inequalities in accessibility to ES flows and provide key insights for informing alternative land use policies or management strategies based on the needs and motivations of multiple stakeholders.

The analysis of flow characteristics, such as distances between service production units and demand areas, flow directions, and accumulation of beneficiaries, which is based not only on biophysical indicators but also on the mapping of sociocultural values, could provide complementary information for decision-makers to strategically decide which areas or ecosystems need greater attention in the management of ES flows. Application of these concepts may help government bodies assess ES from a different perspective and facilitate decision-making and land management processes that "follow the flow" and take into account both social and ecological aspects of ES in spatial contexts, which is particularly important in climate-vulnerable areas such as the Mediterranean basin.

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