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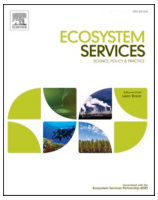

Full Length Article

Differences in the experience of cultural ecosystem services in mountain protected areas by clusters of visitors

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ABSTRACT

Protected Areas contribute to the conservation of nature with associated cultural ecosystem services (CES) and values, such as recreational and educational opportunities, wildlife observation, scenic beauty, inspiration and sense of belonging. Informed management of Protected Areas needs to consider the distinct use and preferences for CES of different types of visitors to increase opportunities for nature experience while avoiding conflicts with biodiversity conservation. Therefore, it is important to understand the linkages between visitor characteristics and their demand for specific sets of CES, particularly in fragile mountain ecosystems. Here we do so by combining information from individual on-site surveys and participatory mapping of visitors in four European mountain Protected Areas. We analysed visitors' frequency of use of eight CES and their socio-demographic information, identifying three clusters of visitors. We also assessed the spatial distribution of CES locations used by each visitor cluster. Our results highlight strong differences between clusters both in the most frequently experienced CES and in the spatial location where those CES were experienced. We suggest that a better understanding of visitors regarding the way they experience nature is relevant for the environmental management of mountain Protected Areas and their surroundings.

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1. Introduction

Protected areas (PA) such as National Parks and Biosphere Reserves aim to conserve biodiversity and ecosystem services, while supporting human-nature interactions and cultural values (IUCN 2008). Indeed, PA, particularly in mountain ecosystems, are highly appreciated by their inhabitants and visitors for the opportunities to experience cultural ecosystem services (CES) (Lavorel et al., 2020; Ndayizeye et al., 2020; Schirpke et al., 2020; Llopis et al., 2021). CES represent the immaterial benefits people obtain from their mental and/or physical interactions with nature (Millennium Ecosystem Assessment 2005), such as opportunities for spiritual, scientific, educational, recreational and aesthetic experiences. The demand for CES can represent a strong motivation to visit mountain PA (Chan et al., 2012). For example, hiking, observing wildlife, and experiencing pristine mountain scenery were indicated as the main motivations for visiting the Swiss National Park in visitor surveys (Backhaus and Rupf 2014). Observing landscape and nature, fauna and flora, and recreation and sports were also the most common CES mentioned in Peneda-Gerês National Park according to Vaz et al. (2022); the main drivers of these top CES were landscape visual-sensory attributes, namely the amount and diversity of landscape colours. Hence, the actual enjoyment of CES depends on management regulations, such as accessibility to PA and allowed interactions and activities (Schirpke et al., 2020; Crouzat et al., 2022). A high demand for CES use, in these important PA for conservation, may put pressure on ecosystems, species and habitats, justifying the implementation of such management regulations. Therefore, identifying the use of CES by different visitors can help managers to support the interests and activities of multiple users within and around mountain PA (Ament et al., 2017).

Despite the importance of CES to PA management, CES are under-appraised and their contributions to wellbeing remain poorly captured (Horcea-Milcu et al., 2016; Nowak-Olejnik et al., 2022), especially the mental wellbeing benefits (Hirons et al., 2016; Bratman et al., 2019; Hussain et al., 2019). One of the reasons for this under-appraisal is that CES experiences can vary greatly across groups of people with distinct motivations, perceptions and interests. Another challenge to assess CES is their "intangible" character (Horcea-Milcu et al., 2016), requiring interdisciplinary approaches and often relying on resource-consuming methods to capture human perceptions, such as questionnaire-based surveys or participatory mapping (Bryce et al., 2016; Schirpke et al., 2016; van Riper et al., 2017). Surveys can be used to assess the frequency of CES experiences, or their relative importance by different people (Torralba et al., 2020), while participatory mapping allows identifying the areas where key CES are experienced (Plieninger et al., 2013). Locating where CES are mostly experienced, and where different visitors may show conflicting uses of CES is particularly relevant for mountain PA, as these areas are already under numerous socio-ecological pressures, and require long times for recovery (Schirpke et al., 2020).

To date, most research aiming to map mountain CES has been conducted using Earth observation data, which locate nature-based attributes underlying CES opportunities (Grêt-Regamey & Weibel 2020; Vaz et al., 2020, Vaz et al., 2022). Fewer studies, however, have taken participatory approaches to map mountain CES and assess their use across a range of visitors (but see Bogdan et al., 2019; Crouzat et al., 2022). Still, only rarely are the former studies applied to mountain PA, despite the importance of this information for the sustainable management of these fragile areas (Schirpke et al., 2021). Hence, a standardized approach is needed to understand the linkages between groups of visitors and sets of CES across distinct mountain PA, in order to upscale learning for PA managers, and better inform the management of PA.

In this paper, we assess and map CES experiences across four European mountain PA and characterize different groups of visitors according to their frequency of CES experiences. We combine information from individual on-site surveys and participatory mapping to assess the match between frequency of different CES experiences by visitors, socio-demographic information and locations of CES experiences in the PA and surrounding environment. In previous studies, CES demand is often assessed by asking participants whether they liked or disliked recreation and aesthetic CES (Hegetschweiler et al., 2017). Often spiritual, educational, scientific, and cultural heritage as identity CES are not examined (Hegetschweiler et al., 2017). Here, we move beyond asking for preferences to assess frequency of use (or demand for) a variety of CES. We aim to answer the following questions: (1) Which CES are mostly experienced by visitors across four European mountain PA? (2) What are the most relevant socio-demographic factors driving the use of such CES? and (3) Where do groups of PA visitors most frequently experience CES? Our results allow us to generalize our findings and provide relevant information for the management of mountain PA to balance conservation interests with the wellbeing opportunities for a range of users. In doing so, our work covers a double knowledge gap. Firstly, it understands the connections between groups of visitors and sets of CES in mountain PA. Secondly, it serves as a standardized method to enhance learning for, and provide guidance to, PA management.

2. Methods

2.1. Study sites

Our study focused on four mountain Protected Areas (PA) located in different continental Europe countries (Fig. 1): Austria (Nationalpark Kalkalpen/Kalkalpen National Park, KNP), Switzerland (Parc Naziunal Svizzer/Swiss National Park and UNESCO Biosphere Reserve Engiadina Val Müstair, SNP), Portugal (Parque Nacional da Peneda-Gerês/Peneda-Geres National Park, PNP) and Germany (Nationalpark Bayerischer Wald/Bavarian Forest National Park, BNP). We chose mountainous PA across Europe within the Ecopotential consortium project (www.ecopotential-project.eu/). The four PA were selected according to the following criteria: along an East-West gradient in Europe, but within more or less similar climate zones; vary in altitude from highly alpine (SNP / KNP) to midrange low mountains in PNP and BNP; and cover a range of PA management regulation from strictly protected sites (SNP with clear access restriction) to less stringent protected sites (PNP).

All case studies are characterized by a complex topography, remoteness, a combination of wild and cultural landscapes and a variety of protection levels (e.g., from strictly protected areas where entrance is not allowed to transition zones where traditional agro-silvopastoral activities take place in some of the locations, see Sup. Box 1 for details). See Sup. Table 1 for the characterization of land cover types and Sup. Fig. 1 for individual maps of the four study areas.

2.2. Data collection

2.2.1. Questionnaire

We designed a 2-page questionnaire to investigate the type of interactions and perceptions that different visitors hold on the landscapes in and around each PA. Specifically, we asked visitors to assess their frequency of experiences for eight CES commonly assessed in mountain areas in general, and some of these PA in particular (Backhaus and Rupf, 2014; Vaz et al., 2022) among those identified by the Millennium Ecosystem Assessment (MEA 2005), IPBES (Díaz et al., 2018) and PA managers (Crouzat et al., 2022): (1) Scenic beauty, (2) Recreation, (3) Identity and belonging, (4) Wildlife observation, (5) Research and education, (6) Inspiration and spiritual experience, (7) Wild plant and mushroom picking, and (8) Hunting and fishing. Each item was assessed on a 5-point Likert scale to assess frequency of CES experience, ranging from 0 (never) to 4 (a great deal); higher scores indicate greater frequency of experience for each assessed CES. This is a common response scale used in questionnaires to assess frequency (Vagias 2006). The questionnaire was accompanied by a guide with definitions and pictures of each CES and was available in seven languages (English, German, Spanish, French, Italian, Portuguese and Czech) to ensure a common

understanding by all respondents (Sup. Mat. Questionnaire Introduction and Guide).

We also collected additional data that might influence CES experiences (i.e., CES drivers), such as socio-demographic information (four explanatory variables, namely: age, gender, duration of the visit and the presence of others in the visit) and their perception of the area (three explanatory variables, namely: familiarity with the place, perceived difficulty in getting self-oriented and degree of perceived naturalness of the area). Age was a numerical continuous variable; gender was a categorical variable (Male, Female, Others/Prefer not to say); duration of visit was a categorical variable (1–2 h, 2–4 h, all day, up to 3 days, up to 1 week, more than 1 week, I live in the Park or the surroundings, Prefer not to say); accompaniment (i.e. presence of others in the visit, White et al., 2013) was a categorical variable (alone, with other adults only, with adults and children, with children only); familiarity with the place (Williams & Vaske 2003) was assessed with a single item, 5-point Likert scale ranging from not at all familiar (1) to extremely familiar (5); easy orientation (i.e. perceived difficulty orientating around the park, Herzog & Leverich, 2003; Herzog & Kropscott 2004) was assessed through a single item, 5-point Likert scale 1 = very difficult, 5 = very easy); artificial place (i.e. perceived naturalness, was assessed with a single item, 6-point semantic differential scale (1 = natural, 6 = artificial), Marselle et al., 2016). The questionnaire was pretested with volunteering respondents outside the study areas prior to their administration in the PA and adapted accordingly to improve its understanding. Questionnaire administration in Austria, Switzerland and Portugal took place in the summer of 2018, while in Germany it was carried out in summer 2019.

2.2.2. Participatory mapping

Following the questionnaire, respondents were asked to map the locations where they most enjoyed the eight different CES assessed. Respondents placed up to 10 sticky dots on a printed A3-size map, assigning each dot to a CES, with the option to assign one CES multiple times and exclude others. The instructions to this exercise were handed out on paper to the participants in seven languages (see Sup. Mat. Questionnaire Introduction and Guide). However, assistance was provided to participants who had difficulty reading and orienting themselves on the maps. The printed map depicted the PA with a buffer zone of 10 km around each PA to better incorporate visitors' experiences, as we do not expect visitors to be familiar with the exact location of the PA perimeter (Crouzat et al., 2022). This approach resulted in maps covering areas from 1367 km^2 (scale 1:70.000) in KNP to 2832 km^2 in PNP (scale 1:115.000) (Sup. Table 1). We used topographic maps as base map (i.e. Carto-AT map in KNP (1:70 000) and OpenStreetMap for PNP (1:115 000), SNP (1:110 000) and BNP (1:100 000)).

2.2.3. Participants and procedure

All respondents were adults (older than 18 years), who were fully informed about the study, and gave their consent to participate voluntarily and without compensation. They were approached in public spaces within or at the entrance of each PA (e.g., parking lots, visitor centres, viewpoints) in several locations, to cover different entry points, activities and types of visitors. We followed a convenience sampling approach, which is a form of non-probability sampling approach commonly used in CES studies (e.g. Hegetschweiler et al., 2017; Subiza-Pérez et al., 2020). Respondents completed the questionnaire and map on their own (or with assistance, if required). Completing the questionnaire and map took approximately 15 min. A total number of 996 respondents answered the questionnaire, from which 810 also took part in the participatory mapping (Sup. Table 2).

2.3. Data analyses

2.3.1. CES experiences

We represented the frequency of experiences of each CES and explanatory variable using the R *likert* package (version 1.3.5) (Bryer & Speerschneider 2016) in R (R Core Team 2020). To identify the main variables explaining the frequency of experiences for each CES across all PA, we conducted linear mixed-effects models (lmm) using the R package *nlme* (version 3.1.153) (Pinheiro et al., 2019). All seven

Fig. 1. Location of the four mountain Protected Areas included in this study: Parque Nacional da Peneda-Gerês/Peneda-Geres National Park (PNP) in Portugal, Parc Naziunal Svizzer/Swiss National Park and UNESCO Biosphere Reserve Engiadina Val Müstair (SNP) in Switzerland, Nationalpark Kalkalpen/Kalkalpen National Park (KNP) in Austria and Nationalpark Bayerischer Wald/Bavarian Forest National Park (BNP) in Germany.

explanatory variables (i.e., four socio-demographic variables and three area perception variables) were used as fixed effects, with the identity of the PA as random effect. In addition, responses with missing data were removed for each CES model. To avoid collinearity among the explanatory variables in the models, we checked that the variance inflation factors (VIF) was below three, as recommended (Zuur 2009). We used the *emmeans* R package (version 1.6.0) (Lenth 2021) to detect significant differences within categorical explanatory variables (i.e., gender, duration of the visit and accompaniment) in the models.

2.3.2. Clusters of visitors

We identified clusters of visitors across all PA together using a hierarchical clustering approach in R (Legendre & Legendre 2012) based on the frequency of experiences of the eight CES assessed. We selected the "complete" method option of the *hclust* function for clustering, together with the *dist* function to compute the distance matrix based on the Euclidean distance, to obtain highly compact clusters based on the furthers neighbour pairs of data (Adams 2018). We found that three clusters allowed us to maximize cluster differences while keeping a more balanced distribution of cluster sizes. We explored differences among clusters of visitors for each of the four numerical explanatory variables (i.e., age, familiarity with the place, perceived difficulty in orientating around the park – "easy orientation", and perceived naturalness –"artificial place"-,) using lmm, with PA identity as random effect. For the three categorical explanatory variables (i.e., gender, duration of the visit, and accompaniment), differences among clusters of participants were explored using the *Fischer's* exact test, which is appropriate when expected counts are below five (McDonald 2014).

2.3.3. Participatory mapping of CES

We digitalized the location of the CES mapped by each participant using ArcGIS 10.3 (ESRI 2015). A total number of 4866 points were mapped (namely, 1073, 826, 526 and 2439 in SNP, KNP, PNP and BNP, respectively) (Sup. Table 2).

CES locations were assigned to the visitor cluster to which the respondent who placed them belonged. We then analysed the similarity between the spatial distribution of the CES location of each visitor cluster over the four PA. To do that, we used the spatial point pattern test (sppt) from the R *sppt* package (Steenbeek et al., 2017), which allowed us to statistically compare the similarity of the point patterns between each pair of clusters taking into account random, uniform or cluster distributions (Andresen 2016). The sppt measures the global S-Index indicating the overall similarity between the spatial point patterns from two clusters, ranging from 0 (no similarity) to 1 (perfect similarity).

In addition, we measured the Kernel density of CES locations, in number of dots per square kilometre. For that, we plot the Kernel density surface of each cluster with a pixel size of 100 m × 100 m. We normalized each Kernel surface from 0 to 1, where 1 indicates the highest density of CES locations for each cluster separately. In order to identify differences in the density of the location between clusters, we

Table 1
Predictors of cultural ecosystem services (CES) experiences across four Protected Areas. Only significant effects are reported, with asterisks (*) indicating significance levels: ***p ≤ 0.001; **p ≤ 0.01; *p ≤ 0.05. (See further model details in Sup. Table 3).

		Predictors							
CES		*(Intercept)*	Familiar place	Artificial place	Easy orientation	Age	Duration of the visit	Gender	Accompaniment
Recreation	F-value	219.493	24.802	5.546	10.283		10.808	3.352	5,421
	p-value	0.000	0.000	0.019	0.001		0.000	0.035	0,001
	Sign	***	***	*	**		***	*	**
Scenic beauty	F-value	4302.139	16.342	16.661	9.486		8.892	14.433	
	p-value	0.000	0.000	0.000	0.002		0.000	0.000	
	Sign	***	***	***	**		***	***	
Wildlife observation	F-value	594.401	46.137		6.557	10.506	3.630	9.070	
	p-value	0.000	0.000		0.011	0.001	0.001	0.000	
	Sign	***	***		*	**	**	***	
Research and education	F-value	1207.435	71.990			10.561	3.856		
	p-value	0.000	0.000			0.001	0.001		
	Sign	***	***			**	***		
Inspiration and spiritual experience	F-value	189.494	26.191					4.092	3,984
	p-value	0.000	0.000					0.017	0,008
	Sign	***	***					*	**
Identity and belonging	F-value	534.942	165.058	5.939	4.319		3.286	3.490	
	p-value	0.000	0.000	0.015	0.038		0.003	0.031	
	Sign	***	***	*	*		**	*	
Wild plant and mushroom picking	F-value	140.292	71.039				20.275		
	p-value	0.000	0.000				0.000		
	Sign	***	***				***		
Hunting and fishing	F-value	7.755			4.886		3.784		
	p-value	0.005			0.027		0.001		
	Sign	**			*		***		

calculated the difference between each pair of clusters using ArcGIS 10.3 (ESRI 2015) raster calculator with 2 standard deviations. Values range from −1 to 1, where the lowest values indicate high density in one of the clusters and low density in the second one; highest values indicate high density in the second cluster and low density in the first one; intermediate values indicate locations shared between the two clusters. Locations not belonging to any of the clusters were not represented to facilitate interpretation.

2.3.4. Travel distance of PA's visitors

To assess the effect of travel distance on the distribution of the visitor clusters, we first calculated the distance from the centre of each PA to the centre of each postal code given in the surveys (i.e. respondents' living place) using MMQGIS from QGIS (QGIS Development Team 2021). Because a few cases had a much larger value of travel distance in relation to other cases, we used the square root transformation following Zuur (2009). Then, we modelled travel distance as a function of clusters using lmm in R, with PA identity as a random effect. We also used the *emmeans* R package (Lenth 2021) to detect significant differences in the travel distance within the clusters in the model.

3. Results

3.1. CES experiences

Across all four PA, we found that scenic beauty was the CES most frequently experienced by visitors, followed by recreation, identity and belonging, wildlife observation and research and education, in this order (Fig. 2). The least experienced CES were hunting and fishing, wild plant and mushroom picking, and inspiration and spiritual experience. Consistent results were observed in each PA separately (Sup. Fig. 2).

3.2. Visitors of mountain PA

The average age of the respondents was 48 years (Fig. 3a). Visitors were generally accompanied by other adults; in most cases the visit lasted a few days or more and we detected equal presence in PA across genders (Fig. 3b). Most people considered the PA familiar places, that were not artificial and where they could easily orient themselves (Fig. 3b).

3.3. Drivers of CES experiences

Across the four PA investigated, *familiarity* was the best predictor for all CES (except for hunting and fishing), meaning that higher frequency of CES experiences was associated to respondents that considered the place as familiar (Table 1). *Easy orientation* was also an important predictor for the frequency of recreation, scenic beauty, wildlife observation and identity and belonging experiences, suggesting that the signage and other things that make it easy for visitors to orientate themselves in the PA increases the opportunity to experience these types of CES. Perceiving the PA as artificial was negatively associated with frequency of recreation, scenic beauty and identity and belonging experiences, indicating that PA that are perceived as more natural increase the opportunity to experience these types of CES. Older age had a positive effect on wildlife observation and research and education.

Female participants experienced all CES more frequently than male participants. Adults visiting the PA alone experienced the CES recreation and scenic beauty more frequently than those accompanied by other adults and children. In terms of duration of the visit, we found that visitors that identified as locals showed a higher frequency of CES experiences and reported a larger number of different CES experiences. Visits shorter than one day had a negative effect on the frequency of recreation, scenic beauty, wildlife observation and research and education experiences. Longer visits had a positive effect on the frequency of wild plant and mushroom picking, identity and belonging, and hunting and fishing (Sup. Table 3).

3.4. Clusters of PA visitors

The cluster analyses revealed three main groups of visitors (Fig. 4). The first group (red outline on the boxplot) exhibited a medium–high frequency of experiences of most CES. The red cluster showed the highest frequency of experiences for scenic beauty, and recreation, and almost no experience for wild plant and mushroom picking and hunting and fishing. The second group (Fig. 4, green outline) showed a comparatively lower frequency of experiences of most CES; again, the most experienced CES in the green cluster was scenic beauty, while wild plant and mushroom picking and hunting and fishing were rarely experienced). The third group (Fig. 4, blue outline) presented the highest frequency of experiences across all CES, especially scenic beauty, but also wildlife observation, education and research, and identity and belonging, wild plant and mushroom picking and hunting and fishing.

Based on the analysis of socio-demographic and area perception variables per cluster (Fig. 5), we describe each of the three clusters of visitors. Cluster 1 (Fig. 5, red outline) is characterized by long-term visits (one week or more), and visitors that recognize the place as familiar and easy to orientate (hereafter, named the "long-stay visitors" cluster). Cluster 2 (Fig. 5, green) is characterized by visitors spending a few hours

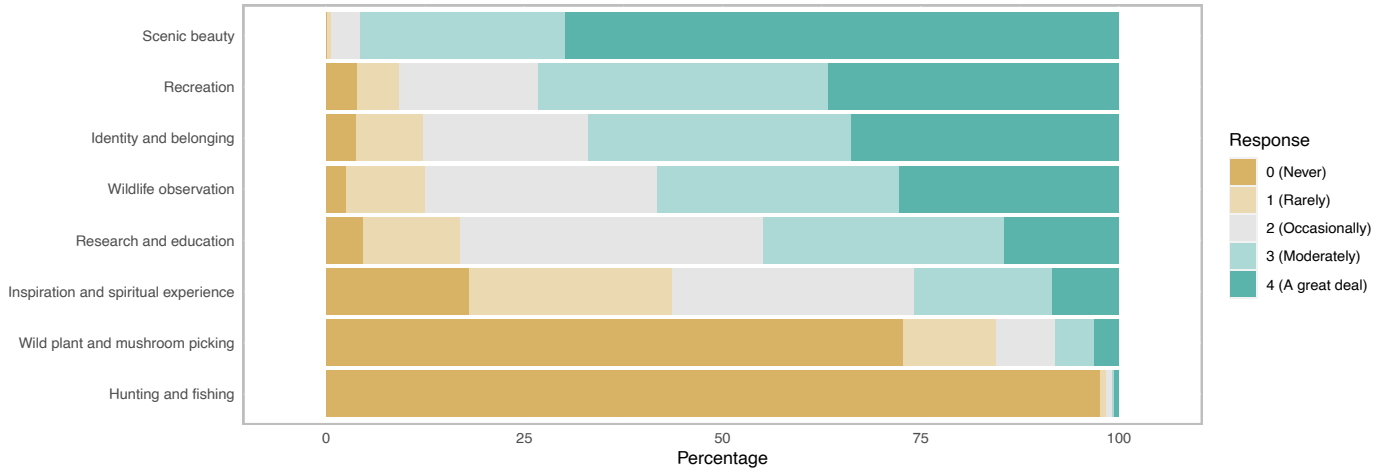

Fig. 2. Frequency of experiences of cultural ecosystem services by visitors across four mountain protected areas. The x-axis represents the percentage of responses to a Likert scale ranging from 0 (*Never*) to 4 (*A great deal*).

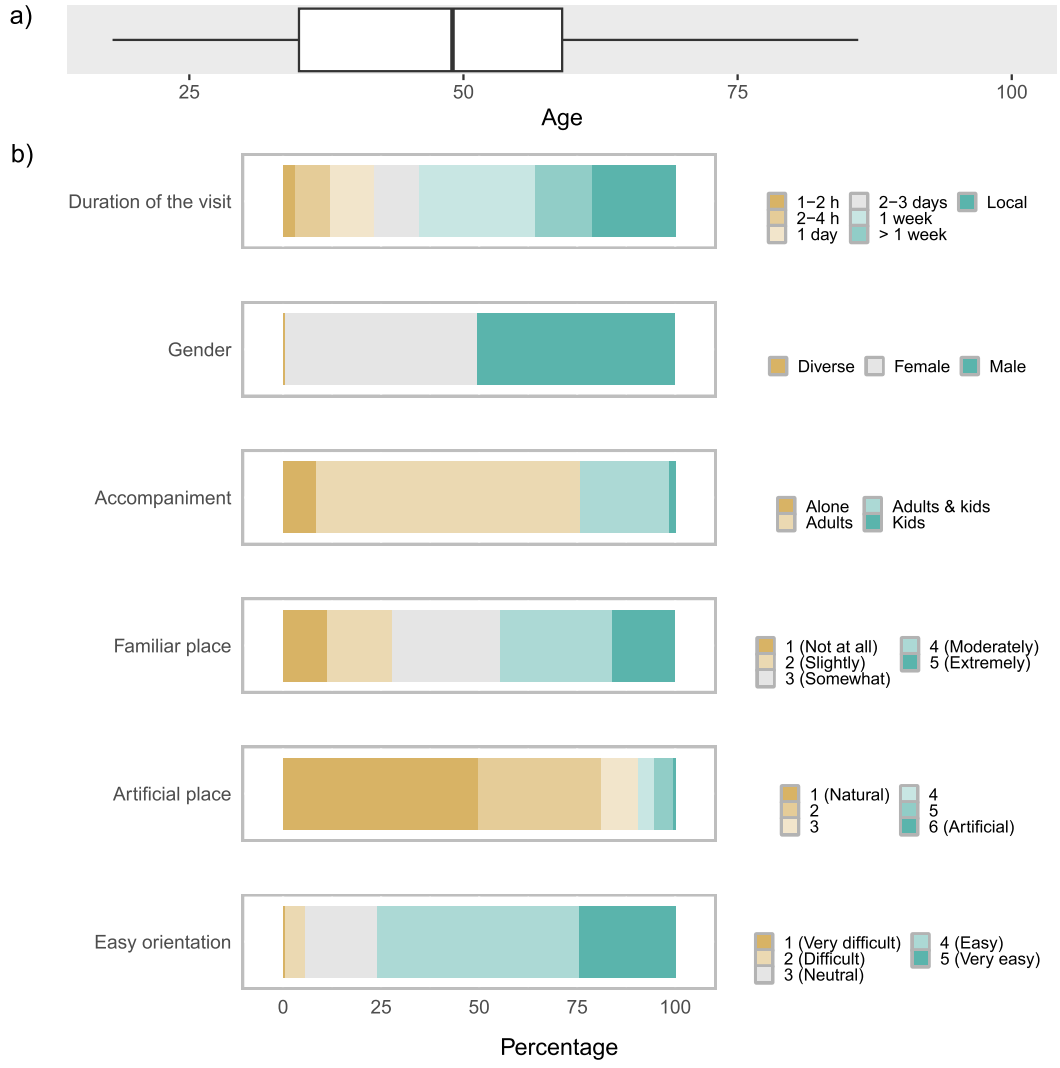

Fig. 3. a) age, b) socio-demographic characteristics and perception of the Protected Areas (PA) by visitors. See Sup. Fig. 3 for PA level results.

on the PA and finding it more difficult to orientate themselves in the PA (hereafter, named the "short time visitors" cluster). Cluster 3 (Fig. 5, blue) is characterized by visitors mostly identifying themselves as locals, often accompanied by other adults and kids (i.e., a familiar group) and that recognize the PA as a familiar place (hereafter, named the "regular visitors" cluster). We also analysed cluster results for each PA individually and found consistent results (Sup. Fig. 4, Sup. Fig. 5).

In addition, we considered the effect of travel distance in the distribution of the clusters and found significant differences among the three clusters based on their postal codes, with the "regular visitors" (cluster 3) having a shorter travel distance to the PA, and the "short time visitors" (cluster 2) having a longer travel distance than the other clusters (Sup. Fig. 6; see further details including model significance levels in Sup. Tables 4–6). At the individual CES level, we could clearly differentiate between CES that decrease their frequency of experiences with increasing visitors travel distance (namely, wild plant and mushroom picking, hunting and fishing, identity and belonging, recreation, education), and CES for which travel distance seems to not affect their frequency of experiences (namely, scenic beauty, wildlife observation, inspiration) (Sup. Fig. 7).

3.5. Distribution of CES location by clusters of visitors

Our results revealed strong differences in the distribution of CES locations across clusters of visitors. The global S-Index values were 0 (clusters 1 vs 2, and clusters 2 vs 3) or 0.5 (clusters 1 vs 3), indicating low similarity in the spatial pattern of CES locations between clusters in these pairwise comparisons (Sup. Fig. 8). The main differences in CES locations were observed between the "short time visitors" (cluster 2, green) and the other two clusters of visitors. The hotspots areas for CES experiences are located close to key natural (e.g. waterfalls, viewpoints) or cultural (e.g. sanctuary) features of the sites, and along most popular hiking trails (Sup. Fig. 1). In general, "long-stay visitors" (cluster 1, red) explored more areas within and in the surroundings of the PA, while "short time visitors" (cluster 2, green) concentrated their visits to a few points, and "regular visitors" (cluster 3, blue), reached more remote places (Fig. 6).

4. Discussion

4.1. Variation in CES experiences according to visitors' profiles

Our study shows that scenic beauty, recreation and identity are the most frequently experienced CES across the targeted European mountain PA. This finding supports the selection of CES commonly made by studies using modelling or Earth observation data, which usually assess scenic beauty and recreation (Schirpke et al., 2016; Grêt-Regamey & Weibel 2020); while recreation is also the main focus of economic

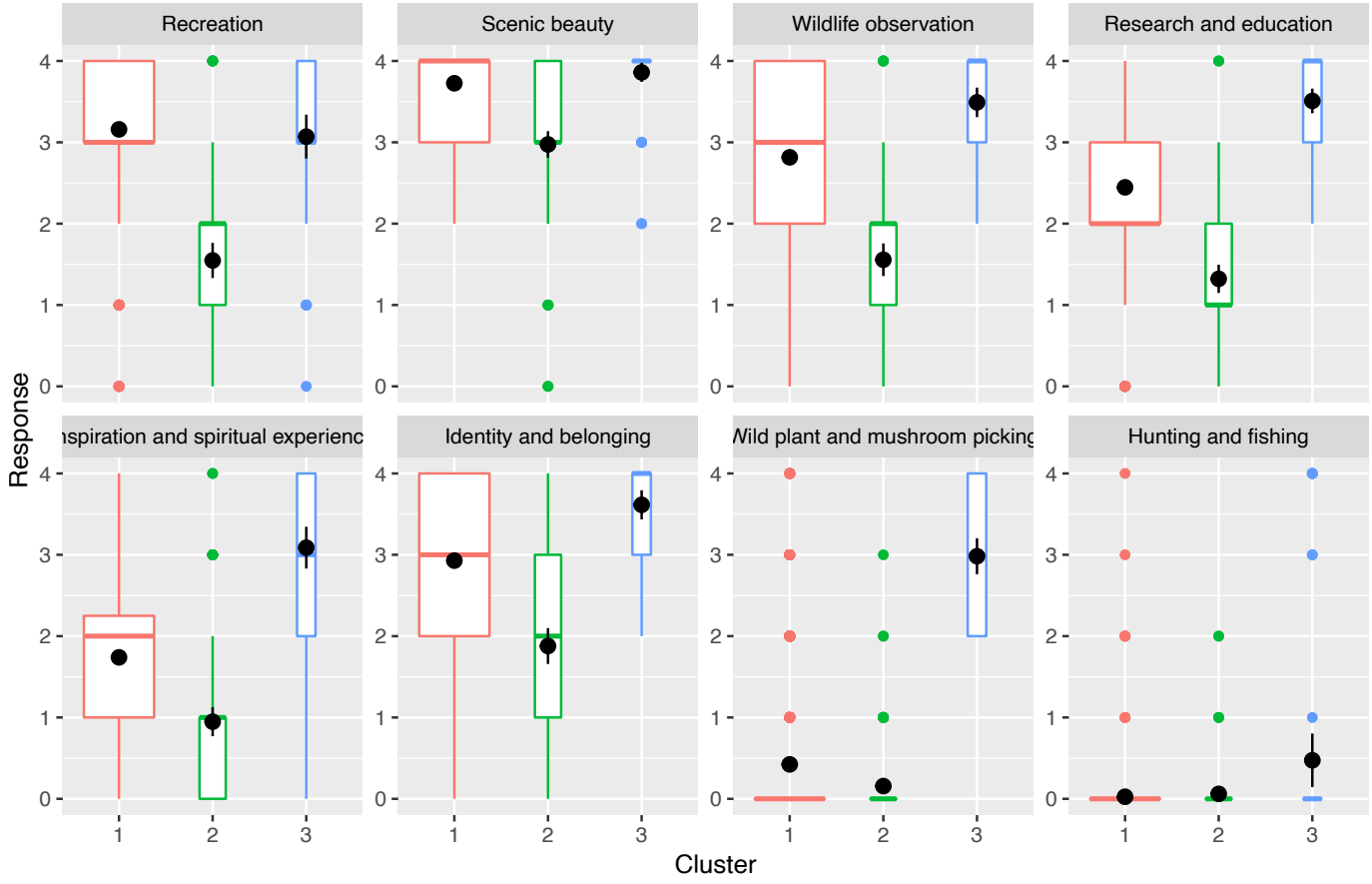

Fig. 4. Frequency of cultural ecosystem service experiences ranging from 0 (never) to 4 (a great deal) for each of the three clusters identified across the four mountain Protected Areas. Boxplot width is proportional to the number of cases. Median (horizontal solid line), mean (black point) and standard error (vertical line) values are indicated. See Sup. Fig. 4 for PA level results.

valuation of CES (van Berkel & Verburg 2014; Schirpke et al., 2018; Vallecillo et al., 2019). Aesthetic values are often the most frequently reported CES in participatory approaches in other contexts as well, including a mountain state park in Brazil (Ribeiro & Ribeiro 2016), a mosaic landscape in Germany (Plieninger et al., 2013), and marine areas (Ocelli Pinheiro et al., 2021). However, our study reveals that identity is another critical CES for PA visitors that is commonly overlooked by those other approaches, highlighting the importance of investing in detailed field-based methods such as participatory approaches for socio-cultural assessments of ecosystem services (Scaini et al., 2022).

Our analyses were able to distinguish among three main clusters of PA visitors, showing consistent results across PA despite the diversity of contexts covered. Our characterization of the visitor clusters as long-stay, short time and regular visitors, based on socio-demographic variables and information on CES experiences, found patterns in the behavior of PA visitors similar to other studies. For example, based on their touristic behavior, Schirpke et al. (2018) distinguished between the regional excursionist, the local recreationist, and the sportive tourist, while Ndayizeye et al. (2020) found differences in CES identified by farmers and hunter-gatherers entering a forested PA. However, still fewer studies have explored the differences between a larger range of CES beneficiaries, i.e. including local people as visitors of mountain PA. Instead, most studies compare CES experiences of local people and tourists, distinguishing between only these two type of visitors (e.g. Plieninger et al., 2013; Ament et al., 2017; Ocelli Pinheiro et al., 2021). These studies suggest that tourists prefer recreational and aesthetic experiences, while the feeling of identity and social relations are most important for local people. These findings partially align with our travel distance's results (Sup. Fig. 6), which suggest that the frequency of experiences for identity and sense of belonging and recreation decrease with visitors' travel distance, but that scenic beauty is experienced by all visitors independently from their living place. In any case, all these studies highlight the importance of considering the variation of CES experiences among individuals and of taking CES experiences by different types of visitors into account in planning and decision-making.

In line with other studies (Plieninger et al., 2013), we found that familiarity with the PA best explained the frequency of CES experiences (Table 1), which could be related to the duration of the stay, another important predictor of CES experiences by mountain PA visitors (Table 1). For example, Fig. 5 shows long-stay visitors (Cluster 1, red) and regular visitors (Cluster 3, blue) being more familiar than short time visitors (Cluster 2, green) and these clusters of visitors also engaged in more CES experiences (Fig. 4). This suggests that familiarity with the place and duration of visit both enable greater opportunities to experience a wider variety of CES. Similarly, some studies indicate that PA relatively close to urban areas are more visited by people who prime such familiarity with the surroundings (Martinez-Harms et al., 2018). On the other hand, other studies show that visitors prefer remote and unknown areas to experience contact with nature, which can be related to people's preferences to visit areas that are less crowded or used by others, or reflect people's desire for exploration, as we observed in SNP for the regular visitors (Fig. 6).

Interestingly, our results reveal the relationship between familiarity and the CES of identity and belonging (Table 1), which indicates the feeling of connectedness to a place. Although previous literature shows that familiarity is positively related to place attachment (i.e., our emotional bonds to a place; Tveit et al., 2018), this has not yet been analysed for CES experiences. We argue that identity, belonging and

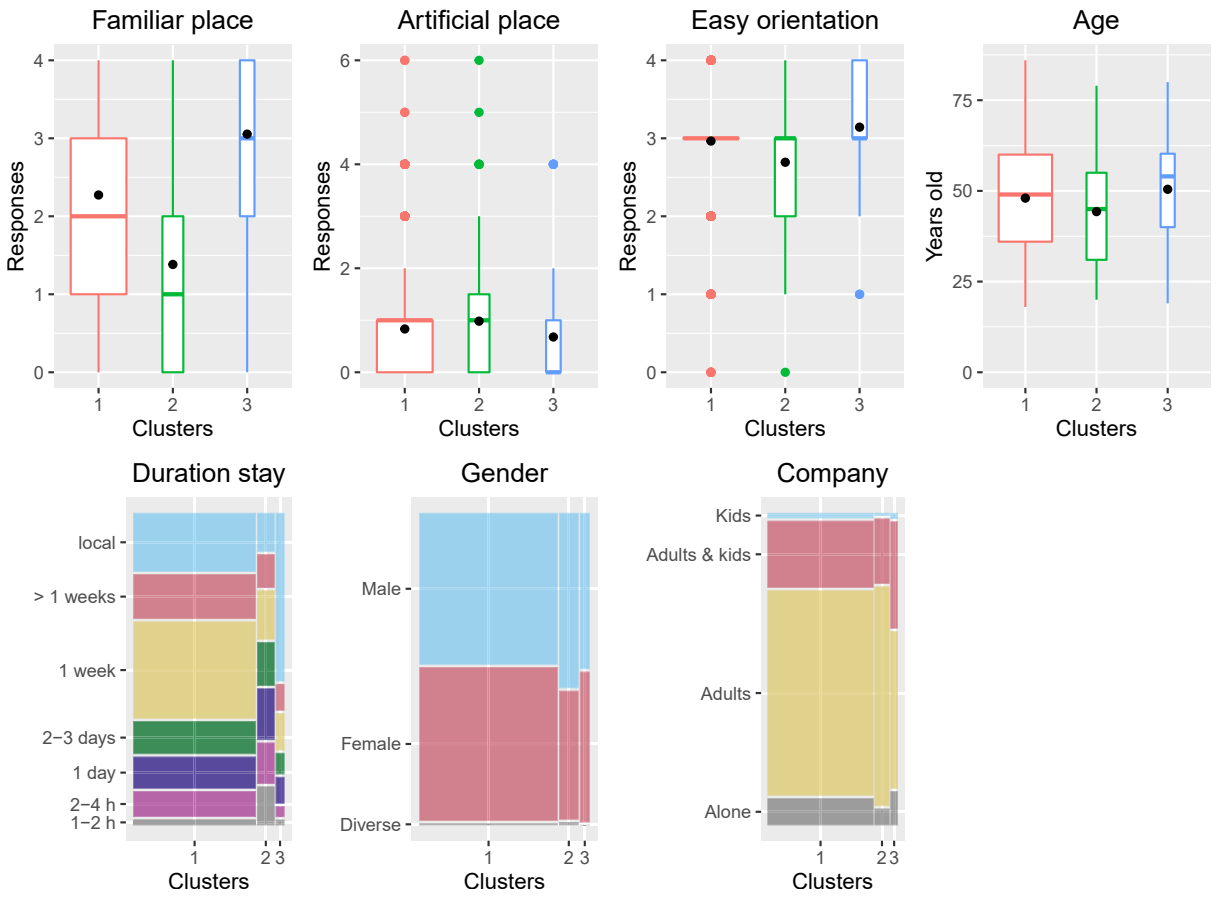

Fig. 5. Socio-demographic characteristics and perceptions for each cluster of visitors across the four mountain Protected Areas. Plot width is proportional to the number of cases. For numerical variables, they Y-axis indicate the frequency of responses; familiar place responses range from 0 (not at all familiar) to 4 (extremely familiar); easy orientation responses range from 0 (very difficult) to 4 (very easy); artificial place response range from 0 (natural) to 6 (artificial). Box-plots indicate median (horizontal solid line) and mean (black point). For categorical variables, mosaic plots indicate the frequency of responses per cluster. See Sup. Fig. 6 for individual PA results.

sense of place should be investigated more as CES experiences in PA. This is especially important with the growing interest in relational values – the meaningfulness of people-nature interactions, and interactions among people (including across generations) through nature (e.g., sense of place, spirituality, care, reciprocity) – at the international policy level (IPBES 2022). Further study of these CES experiences will help assess people's relational values about PA (de Vos & Rouz, 2018).

Our results show that across the visitor clusters, orientation was high, despite relatively lower perceived familiarity with the PA. In environmental psychology literature, orientation is known as legibility, the features in the environment that enable wayfinding (Kaplan et al 1989; Herzog & Kropscott 2004), such as landmarks and visual access (Herzog & Kropscott 2004). Our results found that easy orientation was an important predictor for several key CES experiences (e.g. recreation, scenic beauty, wildlife observation and identity and belonging experiences); this suggests that PA management should usefully improve signage, maintain pathways or enhance landmarks to enable wayfinding and the opportunities to experience these types of CES. Further, environmental preferences have been described by Kaplan et al. (1989) as the combination of coherence and legibility (which are about understanding or "making sense" of an environment) and complexity and mystery (which lead to exploration or involvement with the environment), which could partially explain CES experiences. For example, in PNP we observed most CES experiences closer to trails and other accessibility infrastructures (Fig. 6). These findings support the importance of increasing PA accessibility by promoting the existence of PA closer to urban areas to facilitate access by a largest share of the population, as protecting only remote areas may limit access to PA, potentially excluding the most vulnerable sectors of society from CES experiences.

In addition, our results revealed that the main differences between clusters of visitors were not only the socio-demographic characteristics (i.e. duration of the stay) and perception of the area (i.e. level of familiarity and orientation in the PA), but also the spatial location of the sites where visitors mapped the CES they enjoyed. Other studies have also found that the location of CES is not randomly distributed but rather reflects variations in the landscape and accessibility parameters (Plieninger et al., 2013; Crouzat et al., 2022). For example, in SNP, regular visitors were most likely to visit remote places; in PNP, short term visitors where the only cluster visiting a popular religious place while long-stay and regular visitors also visited mountain viewpoints, waterfalls and forests along walking trails; and across PA, long-stay visitors tended to visit places outside the borders of the PA (Fig. 6). These results highlight the importance of assessing both the frequency and location of multiple CES to understand the variation of preferences among CES beneficiaries and improve PA management (Palomo et al., 2013).

4.2. *Contributions to CES research and outlook*

Our work is the results of a comprehensive, large-scale European-level study where the same survey to assess CES was conducted in four different countries (Sup. Mat. 1). Although large-scale studies are often conducted in other fields, such as ecology, this is still a novelty in the

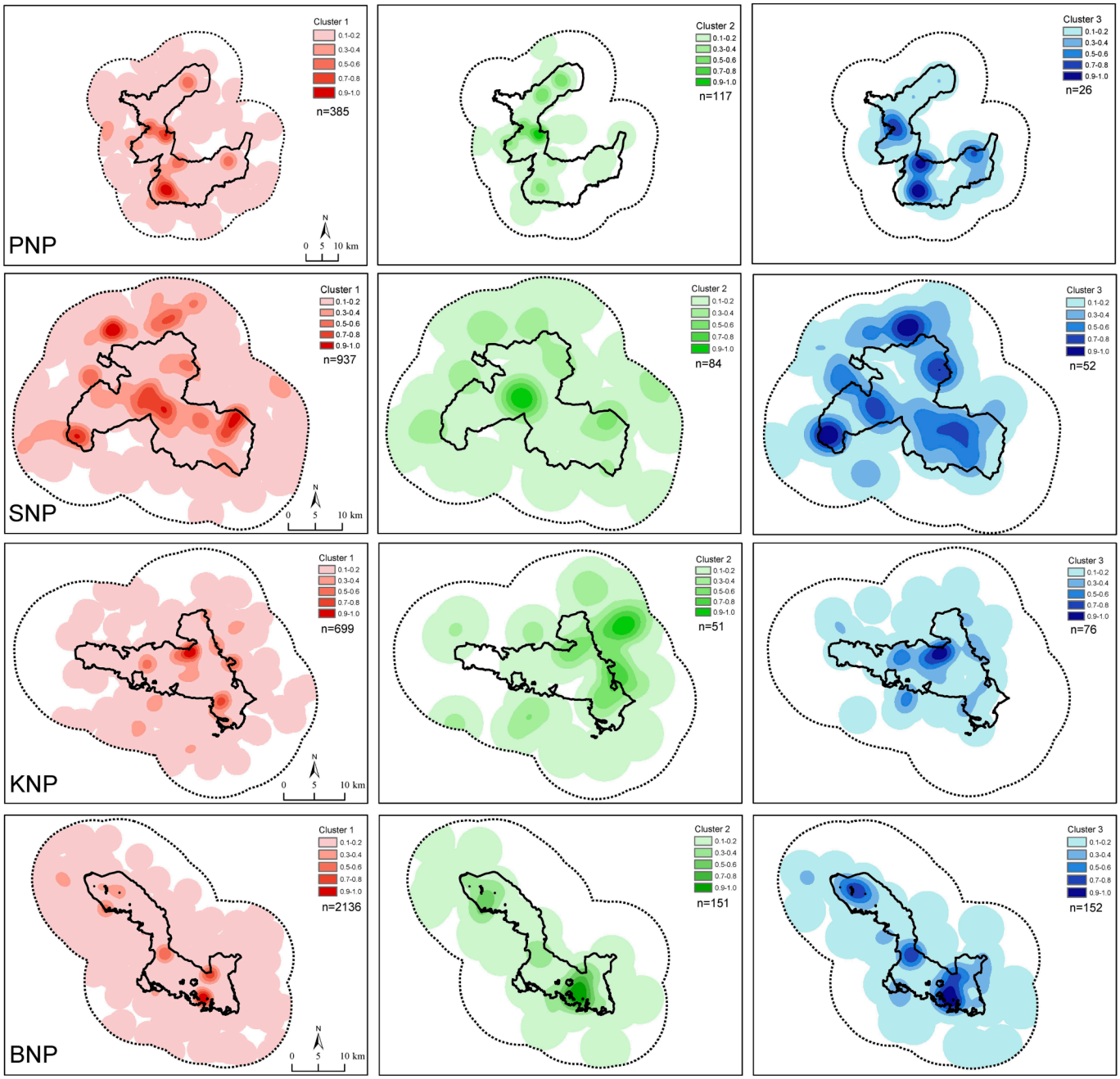

Fig. 6. Kernel density of CES locations for each cluster and PA, including a 10 km buffer around each PA (Swiss National Park and UNESCO Biosphere Reserve Engiadina Val Müstair, SNP; Kalkalpen National Park, KNP; Bavarian Forest National Park, BNP; Peneda-Geres National Park, PNP). Colour intensity is proportional to the Kernel density of CES locations, in number of dots per square kilometre normalized between 0 and 1. Lighter colours represent lower density and darker colours higher density, white represents no CES locations (i.e., 0 density) and n indicates the absolute sample size (number of dots). Pixel size of 100 x 100 m.

study of social-ecological systems, and it contributes replicable methods and methodological standards to ecosystem services research. Indeed, our methods can be used to set the basis for field sampling protocols and promote the comparability of studies across social-ecological systems or landscapes. In this way, our work contributes to developing a strategy for the standardized monitoring of Essential Ecosystem Services Variables (EESV) in the context of GeoBON (Balvanera et al., 2022), while also serving as a complementary and validated way for other emerging CES analysis, such as those arising from social media (Cardoso et al., 2022). In addition, using our methodology to monitor changes in the frequency of CES experiences over time, we can contribute to understanding and forecasting the drivers of change in socio-cultural and relational values through generalisable and scalable procedures (Vaz et al., 2021). The temporal dimension has rarely been addressed in the assessment of CES, although it holds great potential to inform policy and decision-making (Tengberg et al., 2012; Felipe-Lucia et al., 2015). Hence, we suggest future studies to use standardized base maps, as provided by OpenStreetMap® for reproducibility and comparability. Further, comparing the spatial co-occurrence of potential CES supply with the location of CES experiences can provide additional insights to understand the drivers of CES experiences.

An additional way forward in CES research is combining results of CES assessments with those of other disciplines, such as tourism or cultural heritage studies, which could enhance the understanding of the system from different perspectives and contribute to better and more coordinated management approaches (Tengberg et al., 2012) and

reduce potential conflicts (Schirpke et al., 2020). In this sense, the concept and definition of CES would need to widen in order to embrace the multiple cultural values of landscapes, and their biotic or abiotic origins.

4.3. Applications and limitations for the management of PA

Most PA might already have a good level of knowledge on visitors' management for biodiversity conservation. However, less effort has so far been placed in developing methodologies that could help them achieving a better understanding of CES experiences and management. Our study reveals that several CES can be experienced during a given stay in a mountain PA, becoming a strong motivation to visit them. Therefore, a key aspect for the management of these mountain PA is to have a planned and strategic vision for CES offer, articulated with the multiple relevant entities from local and regional governments, administration departments, environmental and social NGOs, which could guide a multidimensional perspective of PA management. In general, facilitating wayfinding for people to easily get familiar with the place and orient themselves in the area could be a general recommendation for managers to increase the benefits people receive from visiting PA, as these were the main predictors of increasing frequency of CES experiences. However, to balance nature conservation and CES experience in the management of mountain PA, investments in environmental education activities could be a promising way forward to meet and enhance PA double role and reduce conflicts between CES users and biodiversity conservation (Schirpke et al., 2018; Lavorel et al., 2020). For example, conflicts could arise if management is not balanced between goals such as enhancing biodiversity conservation, increasing tourist revenues and providing quality experiences (Roux et al., 2020). Particularly mountain PA need to carefully consider their management approaches given their high vulnerability to disturbances and slow recovery (Kokkoris et al., 2018; Grêt-Regamey & Weibel 2020). In addition, conducting regular mapping and questionnaires with visitors would facilitate the monitoring of CES experiences, offering updated information to PA managers about where pressures to nature and biodiversity are predominant. For example, accessibility has been found to be a main driver of the location of CES hotspots (Paracchini et al., 2014; Crouzat et al., 2022). These findings highlight again the importance of protecting accessible places as well as ensuring appropriate access to CES-providing areas (Ridding et al., 2018).

Although scenic beauty was the CES most frequently experienced by all visitors, our work showed evidence of how visitors of mountain PA experience a variety of other CES, which can help identify specific management needs for different types of visitors. In line with other studies (Schirpke et al., 2018), this demonstrates the utility of distinguishing between clusters or types of visitors according to the CES they aim to experience in their visit to a PA. Based on the results of our study, we identified that for the "short time visitors", having a short and accessible way to get to a scenic viewpoint might be sufficient to meet their CES needs. This might also include improving legibility of the sites, i.e. improving trails and signage to help people better understand how to find their way and not get lost. For the "long-stay visitors", a variety of hikes, destinations or sites of recreational activities would be more important, as well as a robust offer of accommodation, possibly ecotourism units. In turn, for the "regular visitors", it could be more critical to maintain access to locations related to the identity of the site and that offer unique educational opportunities to show the "typical" identity of the area (e.g. through the observation of endemic species or wildlife and cultural interpretation centers). These findings can guide management decisions in PA in terms of providing information, resources and services to visitors as well as to manage visitors' flow to increase the use of particular places or reduce pressures in the environment (Schirpke et al., 2018).

Our study did not delve into the details of different modes of enjoying a given CES, such as different recreational activities (e.g. hiking, mountain-biking, horse-riding), which would provide additional relevant information to PA managers, as these different recreation activities can create conflict if practiced on the same trails. Future studies could also offer participants the opportunity to provide their feedback in terms of direct suggestions for improving the management of the PA and the experience of CES (e.g. guided tours, information, trail creation or maintenance, seating, signage), as well as to indicate their average expenditure to capture their contribution to the local economy (Schirpke et al., 2018). Given that extensive fieldwork is required to collect these data, which is often time consuming, based on our experience we suggest using simple questionnaires for PA visitors, while workshops could be organized to identify nuances in CES experiences (Crouzat et al., 2022) and as a tool to promote social learning (García-Nieto et al., 2019).

5. Conclusion

Our study identified multiple commonalities in CES experiences and their drivers across four mountain PA, which facilitates the transfer of knowledge and practices across Europe and other mountain PA. Across all four PA, we found that scenic beauty was the CES most frequently experienced by visitors, which was not affected by travel distance. We identified three main clusters of visitors of mountain PA (namely, "short time visitors", "long-stay visitors", and "regular visitors") according to the CES they experienced more frequently and their socio-demographic variables. The main difference between the clusters were due to visitors perceptions regarding familiarity with the place, legibility of the site and duration of the stay. Familiarity with the place and duration of the stay also explained best the frequency of CES experiences. Understanding the spatial patterns of CES experiences among different user groups could help PA design more effective visitor management approaches. Our results highlight different management needs for each type of visitor that should be taken into account to increase the benefits people receive from visiting mountain PA. For example, short-term visitors less familiar with the area may be more responsive to signage and directions, while such measures are less likely to affect the spatial behaviour of regular visitors who seek out remote areas. In turn, this kind of study, if replicated, can set a basis for social-ecological systems protocols and contribute to monitor Essential Ecosystem Service Variables.

CRediT authorship contribution statement

María R. Felipe-Lucia: Writing – original draft, Formal analysis, Conceptualization. **Ángel de Frutos:** Writing – review & editing, Visualization, Methodology, Formal analysis, Data curation. **Emilie Crouzat:** Writing – review & editing, Methodology, Investigation. **Volker Grescho:** Writing – review & editing, Visualization, Software, Resources, Investigation, Conceptualization. **Jonna M. Heuschele:** Writing – review & editing, Investigation. **Melissa Marselle:** Writing – review & editing, Methodology. **Marco Heurich:** Writing – review & editing, Resources, Funding acquisition. **Franziska Pöpperl:** Writing – review & editing, Investigation. **Florian Porst:** Writing – review & editing, Methodology. **Ana Paula Portela:** Writing – review & editing, Investigation. **Christian Rossi:** Writing – review & editing, Investigation. **Claudia Carvalho-Santos:** Writing – review & editing, Investigation. **Ana Stritih:** Writing – review & editing, Investigation. **Ana Sofia Vaz:** Writing – review & editing, Investigation. **Aletta Bonn:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2024.101663.

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