Understanding Ecosystem Services through Managers' Perspectives: Insights from the Portuguese Biosphere Reserves

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Abstract

Defined as the benefits derived from nature to humans, the Ecosystem Services (ES) concept clarifies how ecosystems contribute to human well-being. Despite its relevance, integrating this concept into decision-making processes remains a challenge. Participatory approaches have proven crucial in developing mechanisms for managing, conserving, sustainably using and valuing ES. This work aimed to analyse the perceptions of Portuguese Biosphere Reserves' (BR) managers regarding the ES provided by these territories through a participatory workshop. During the workshop, each participant specified the most relevant ES provided by the BR. The study identified three key ES: "Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes", "Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge" and "Characteristics of living systems that enable education and training". Additionally, participants discussed perceived threats, opportunities and potential solutions to enhance the value of these key ES in these areas. "Climate change" and "Pollution" were identified as the most significant threats, while "Climate adaptation", "Quality of life" and "Sustainable agriculture" emerged as the main opportunities. Solutions to address threats and maximise opportunities include the establishment of a closer, systematic and articulated relationship within BR to promote sustainability and resilience. Overall, the workshop was positively evaluated and deemed productive. It was also considered a powerful tool to foster collaboration towards a more holistic promotion of BR' sustainable governance, benefitting the environment, communities and the economy.

Keywords

Sustainable management, natural resources governance, participatory methodologies, stakeholders

Introduction

UNESCO Biosphere Reserves (BR) were created specifically to balance the protection of natural ecosystems with human development. The overarching objective of this programme is to foster sustainable development through the effective stewardship of land, water and biodiversity, while also serving as hubs for educational outreach, training, research and biodiversity monitoring for the UNESCO´s Man and the Biosphere Programme (UNESCO-MAB 2017; UNESCO 2021). By the end of 2023, the World Network of Biosphere Reserves (WNBR) comprised 748 BR in 134 countries, 23 of which are transboundary BR (TBR), spanning several biomes and ecosystems globally (Rollo and Martins 2023).

Conceptually, the BR are divided into three zones, core, transition and buffer, as each possesses distinct characteristics that offer diverse ecosystem services (UNESCO-MAB 2017, UNESCO 2021) and they have three main functions: conservation (encompassing local natural and cultural values), sustainable development and logistic support (regarding education, research and monitoring) (UNESCO 1996). Besides, it has recently been argued that BR contribute to at least nine of the targets of the Kunming-Montreal Global Biodiversity Framework (CDB 2022) including area and non-area-based targets of the goals (Barraclough and Måren 2022).

The integration of ES into decision-making processes related to natural resources management, the conservation of biodiversity and ecosystem health maintenance is being strongly advocated for by scientists and conservation experts (Bryan 2010, Ernstson 2013, Maes et al. 2014, Schaefer et al. 2015, Paruelo et al. 2016, Longato et al. 2021). Ecosystem Services (ES) are defined as the direct or indirect benefits provided by ecosystems to humans (Millennium ecosystem assessment, MEA. 2005, Reid et al. 2005), such as air and water purification, pollination of crops, climate regulation, recreation or natural resource provision (Costanza et al. 1997, Cardinale et al. 2012, Riis et al. 2020). Assessing ES facilitates informed decisions about land use, conservation and resource management (Maes et al. 2020, Behboudian et al. 2021), contribute to the monitoring and valuation of natural resources (Buckley et al. 2019, Kay et al. 2019, Vallecillo et al. 2019a, Vallecillo et al. 2019b) and the incorporation in decision-supporting tools (Maes et al. 2014, Cortinovis and Geneletti 2019, Geneletti et al. 2020, Ouyang et al. 2020, Konczal et al. 2023).

Despite this potential, the ES concept still lacks effective implementation in decision-making processes (Guerry et al. 2015, Polasky et al. 2015, Geneletti et al. 2020). Some case studies attempted to provide a framework for conducting decision-relevant ES assessments (Rosenthal et al. 2014), sharing learned lessons (Ruckelshaus et al. 2015) or identifying factors in ES assessment that impact decision-making (Grêt-Regamey et al. 2017).

Several studies have found that participatory approaches lead to more accurate and comprehensive assessments of the ES value, while also fostering engagement and support for the assessment process and its outcomes (Reed 2008, Vári et al. 2024). By granting all stakeholders a voice, more equitable, inclusive and sustainable management strategies can be developed (Förster et al. 2015, Spangenberg et al. 2015, Sterling et al. 2017, Hölting et al. 2020, Cabral et al. 2021). Thus, these codesign processes ensure the consideration of various perspectives, needs and concerns, significantly contributing to the decision-making (Martín-López et al. 2014, Spangenberg et al. 2015, Cusens et al. 2021).

Participatory approaches combine ecological, sociocultural and economic valuation tools to capture the diversity of values related to ES, including intrinsic and relational values that go beyond strictly human benefits, such as religious and cultural significance to communities (Pascual et al. 2017). It is important to consider the sociocultural context of communities when identifying ES. Studies relying solely on data or literature reviews may overlook this critical aspect, potentially identifying ES that are not as significant or relevant to local actors (Mascarenhas et al. 2010, Kenter et al. 2015), thus masking the true diversity of ES benefits and hindering conservation efforts. Human activities are the main drivers of ecosystem degradation, including within Biosphere Reserves (BR), resulting in global biodiversity loss and biotic homogenisation (Kehoe et al. 2017). This not only undermines conservation objectives, but also affects the supply of many ES on which communities, especially farmers, rely. Therefore, it is vital to prioritise and identify relevant ES in each territorial context to undertake necessary actions for their conservation (Bommarco et al. 2013, Scorza et al. 2020).

Participatory approaches in BR of other countries have demonstrated their ability to facilitate communication and interaction amongst stakeholders, fostering social learning and a deeper understanding of diverse perspectives, thereby nurturing lasting relationships (Niedziałkowski et al. 2018, Spyra et al. 2018). In Portugal, participatory approaches are not widely used and are often viewed as a source of conflict amongst stakeholders, which can hinder the achievement of desired conservation targets (Marta-Costa et al. 2016). However, our workshop experience revealed that participatory approaches can foster better communication and understanding between different groups, leading to more favourable outcomes. This work aimed to bring together managers from all Portuguese Biosphere Reserves to analyse their perceptions on key ecosystem services (Key ES) in these territories. Through a participatory workshop, stakeholders discussed potential threats and opportunities affecting their territories and associated key ES, proposing a range of solutions to enhance the value of ecosystem services and reinforce territorial resilience. The diversity of perspectives and ideas proved invaluable in developing a comprehensive set of actionable measures to safeguard the environment and the quality of life of its residents.

Material and methods

In Portugal, there are 12 BR (Figure 1): four in the Azores Archipelago - Corvo Island, Graciosa Island, Flores Island, Fajãs de São Jorge; two in Madeira Achipelago - Santana Madeira and Porto Santo Island; six in mainland Portugal, - Paul do Boquilobo, Castro Verde, Berlengas, - Gerês/Xurés Transboundary, Meseta Ibérica Transboundary and Tejo/Tajo International Transboundary, the later three of which comprise territories in both Portugal and Spain.

On 20 October 2021, we held a workshop attended by 11 participants who were closely associated with nine Portuguese Biosphere Reserves (1. Paul do Boquilobo, 2. Corvo Island, 3. Graciosa Island, 4. Flores Island, 6. Berlengas, 8. Meseta Ibérica Transboundary, 9. Fajãs de São Jorge, 10. Tejo/Tajo International Transboundary and 11. Castro Verde – Fig. 1). Participants included local decision-makers, technicians and researchers who were involved in the BR management boards.

Workshop organisation

The workshop was structured in four stages (Fig. 2) - following Lopes and Videira (2016) and Boeraeve et al. (2018) approach:

1. Plenary Session - an initial informative plenary session aimed to transmit the goals and planned tasks of the workshop;
2. Table discussion - the participants were organised in three discussion tables, mediated by our team members with the aim of identifying potential ES provided by their BR;
3. Selection of priority ecosystem services - Participants were asked to select the key ES present in the BR territories, based on a group activity through a points-based exercise and
4. General discussion on key ES - discussion amongst the attendees sought to determine the main threats and opportunities for the key ES and possible solutions to tackle those threats.

Finally, participants were invited to leave their feedback regarding their initial expectations. For the classification of the ES, we used version 5.1 of the Common International Classification of Ecosystem Services (CICES, Haines-Young and Potschin-Young (2018)), which covers provisioning, regulation and maintenance and cultural ES.

Plenary Session

To our knowledge, this was the first participatory event in Portugal, that brought together managers from the majority of Portuguese BR, aiming to identify and value their territories' key ES, collaboratively. The team members communicated the goals and the outline of activities for the session and laid out the concept of the project, notions on ecosystem services and their valuation. In this phase, we also wanted to gauge the relevance and impact of the initiative to the participants. Thus, prior to the start and after the end of the session, everyone was encouraged to express their expectations, concerns, opinions and hopes through anonymous post-it notes, that were qualitatively analysed.

Table discussion

For the second part of the workshop, participants were deliberately divided into three groups so that representatives of the same BR did not stay together at the same table and exert influence on each other. Each group engaged in a 30-minute discussion, mediated by our team member, to identify potential ES provided by their BR (Fig. 3). Each table was assigned one type of ecosystem services: Provisioning, Regulation and Maintenance or Cultural to discuss the ES provided by the BR. Each moderator had a printed list with the ES grouped under the CICES V.5.1 classification (Haines-Young and Potschin 2018), which was used to record the number of times that each ES was mentioned. Each round of discussions lasted 30 min, so the table discussions had a total duration of 90 min (Fig. 4).

Selection of priority ecosystem services

All mentioned ES were written on scenario paper or post-its and placed on the table for everyone to see. At the end of the round, we tallied up the number of times each ES was mentioned, including those written on the scenario/post-it paper. Only the mentioned ES were subsequently put to the vote in phase 3, where the participants had 30 minutes to vote for the three most important ES, based on a colour-point system. We used a whiteboard to display the ES list and pens of different colours were available to rank the services: Green for the most important service (3 points), orange for the second important (2 points) and red for the least important (1 point). Subsequently, the scores assigned to each ES by the attendees were summed up. This allowed us to identify the key ES that were prioritised as key for all BR together. From this, we identified the eleven ES with the highest scores as the key priorities for all BR in Portugal. This process enabled us to determine the most essential ecosystem services that needed immediate attention, considering that a participatory approach that validates and grounds the classification and valorisation of ecosystem services in the needs, perspectives, knowledge and values of people who rely on the ecosystem services (Barton et al. 2024).

General discussion on key ES

During the last phase of the workshop (phase 4), the participants and team members engaged in a discussion to identify the primary perceived threats and opportunities associated with the key ES. The managers also proposed potential strategies and solutions that could promote the value of these services. The discussion lasted for 50 minutes and was a valuable opportunity for all parties to share their perspectives and insights.

Data Analysis

The ideas and messages described in the expectations, concerns and hopes were grouped into key categories. "Learning and Knowledge" was one of those, comprising concepts like "new learning", "expanding knowledge" and "learning to apply". The analysis of the responses obtained from participants regarding threats, opportunities and solutions regarding the key ES was conducted using Text Mining, which is also known as "Document Mining". This process involves obtaining useful information from unstructured textual databases. We extended this method from Data Mining, which involves the extraction of knowledge from structured databases (Tan 1999). To identify the main topics, we used the Classification and Categorisation method, which involves counting the words in the text (Kushwaha et al. 2021). Usually, categorisation tools rely on a ranking method that tells the order of documents with the most similarity for each topic (Talib et al. 2016). We grouped similar words that referred to the same topic, such as "to adapt", "adaptations", or "adapted", all referring to the related noun "adaptation". To better visualise the results of these analyses, we plotted them on "word cloud" graphs. All analyses were conducted in the virtual environment RStudio using the NPL, tm, RcolorBrewer, wordcloud2 and rcolors packages (R Core Team 2023).

Results

Selection of key ES

From a total of 39 ES services cited in the discussion tables in phase 1 (Table 1), participants have selected 11 key ES (two of them with the same score) for the BR after ranking them in phase 3. The top three ES were ‘1.1.1.1- Cultivated terrestrial plants (including fungi, algae) grown for nutritional purpose’ (15 points), ‘3.1.2.1 - Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge’ and ‘3.1.2.2 - Characteristics of living systems that enable education and training’ (11 points each). Other high-scored ES included “Ground water (and subsurface) used as a material (non-drinking purposes)”, “Surface water for drinking” and “Characteristics of living systems that are resonant in terms of culture or heritage” (9 points each). Additionally, “Filtration / sequestration / storage / accumulation by micro-organisms, algae, plants and animals”, “Hydrological cycle and water flow regulation (including flood control and coastal protection)” and “3.1.1.1 - Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions (8 points each)” were also key ES in the BR. From the 39 ES that were cited, 29 were voted and all the ES mentioned and scored in the 6.3.x.x section were cultural ES (Fig. 5).

Threats, opportunities and solutions

Based on the data gathered from participants' perceptions (Fig. 6), the most cited potential threats were "Climate change" and "Pollution", with a total of 13 mentions each. Additionally, "Overexploitation of natural resources" was mentioned seven times (see the frequency of each term provided by Text Mining analysis in Table 2).

The text mining analysis for the perceived opportunities arising from the key-ES showed that the most frequently mentioned terms in the discussion tables (phase 2) (Fig. 7) were "Authenticity/Identity" with five mentions, followed by "Local people" and "Valorisation of local culture" with four mentions each (see the frequency of each term provided by Text Mining analysis in Table 3). Furthermore, it was mentioned that societies must strive to discover new technological advancements and methods to enhance the efficiency of natural resources utilisation, ensuring least impacts to prevent resources depletion.

In total, 44 terms were considered relevant to be included in the solutions identified in phase 4 (Fig. 8). The two most mentioned terms were "Connections" and " More presence of private initiatives" with 12 and 10 citations, respectively, followed by "Increase production" and “Scientific Research” (nine and seven mentions, respectively) (see the frequency of each term provided by Text Mining analysis in Table 4).

During the discussion (phase 4), it was revealed that the concerns regarding the BR were directly linked to the perceived threats faced by cultural ES. The participants emphasised the urgent need to address the issue of "Loose cultural heritage and lack of cultural appropriation by not knowing". They posited that this could be attributed to rural exodus and the absence of incentives for younger people to maintain agricultural and traditional activities. The participants strongly recommended that environmental education/training and capacity-building activities should be developed to face these threats.

Expectations, concerns and hopes

According to the evaluation of the workshop's relevance and impact, participants described their expectations, concerns and hopes before the workshop began, which were grouped into key categories described in Table 5. The terms/expressions “Sharing” and the desire to improve “networking” and “skills” were the most common expectations transmitted.

Participants’ feedback on the workshop

The participatory workshop was highly appreciated by most participants, who found it to be an engaging and informative opportunity for sharing knowledge and learning. They also noted that it provided a platform for establishing a network around the BR areas and that it helped to create a shared vision for management and planning in these areas. Some participants did express concern about the limited time available for each discussion table. However, they acknowledged that finding a balance between allowing for productive group discussions and ensuring high participations can be a challenge. Overall, the workshop was seen as a positive step forward.

Discussion

This study presents new insights into managers' perceptions of ecosystem services in the Portuguese BR. The results revealed that participants perceive that these areas provide a wide range of key ecosystem services, primarily in the provisioning and cultural categories. Amongst provisioning services, cultivated plants for nutrition had the highest score. This feature may reflect the rural and farming landscape that characterises most of the Portuguese BR. It is worth noting that Portugal relies heavily on agriculture for its economy and food security, with crops such as cereals, fruits and vegetables playing a crucial role (Instituto Nacional de Estatística - INE 2022). In fact, in nine out of the 12 BR in Portugal, more than 40% of the total area is dedicated to agroecosystems, such as agriculture and pasture (Caetano and Marcelino 2019).

In Portugal and Europe, different stakeholders have recognised that agroecosystem resources are amongst the most significant ecosystem services (Marta-Pedroso et al. 2018, do Rosário et al. 2019, Cusens et al. 2021, Vaz et al. 2021). In the BR of Paul do Boquilobo and Castro Verde, this is particularly noticeable since more than 85% of their total area is used for agriculture and pasture (Caetano and Marcelino 2019, Rollo and Martins 2023). Apart from providing food, traditional agricultural practices and crops can also play a crucial role in preserving the cultural landscape and heritage (e.g. Biasi et al. 2012, Špulerová et al. 2018, Cusens et al. 2021). The traditional agroforestry systems of Portugal, such as olive, chestnut, "*montado*" (oak) groves or vineyards, are culturally and historically significant and have helped to shape the country's unique identity (do Rosário et al. 2019). Provisioning and cultural services are often strongly interlinked, particularly when analysing traditional farming practices and crops. Thus, prioritising ES related to agricultural values can also value associated cultural ES (Reyes-García et al. 2015, Maldonado et al. 2019).

From our workshop outcomes, we observed that the participants highly valued cultural ES. The most voted ES classes were "Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge" and "Characteristics of living systems that enable education and training”. These results differed slightly from the European context of the Biosphere Reserves, where ES classes related to recreation activities (CICES 3.1.1.1 and 3.1.1.2) are usually the most valued (Fagerholm et al. 2012, Kosanic and Petzold 2020). By improving the knowledge of local culture and history, communities could be equipped with the necessary tools to maintain cultural heritage and values. This action could prove to be a helpful strategy, as studies have shown that forging local and scientific knowledge synergies may create fundamental opportunities to advance sustainable ecosystem governance across various spatial scales (Tengö et al. 2017, Cheng et al. 2020). From the managers’ perspective, addressing the cultural ES related to “Authenticity Identity, Local people and Valorisation of local culture” with these actions, could generate relevant opportunities to prevent the loss of cultural heritage knowledge in the BR. Furthermore, participants perceived climate change as one of the main threats affecting ES in the Portuguese BR. These results are in accordance with other studies that recognise climate change as one of the most severe environmental problems affecting society today (do Rosário et al. 2019, European Commission 2021, Marques et al. 2023).

All European regions are vulnerable to the effects of climate change, but some areas will be impacted more severely than others. According to the European Environment Agency (European Commission 2021, European Environment Agency 2024), southern and south-eastern Europe, including Portugal, is expected to be a climate change hotspot and will likely experience the highest number of negative impacts. "Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes" was considered a key ES by the participants. However, given the predicted scenarios for climate change, significant changes in crop conditions are expected to occur (Fraga and Santos 2021). For instance, with the heightened sensitivity of temperate fruit trees to thermal conditions, it becomes evident that ongoing global warming may substantially affect the quality and productivity of cultivated terrestrial plants (e.g. Fernandez et al. 2020). In this context, the BR landscapes may be vital for regulating the hydrological cycle and water flows, as well as preserving nursery populations and habitats, as discussed in the workshop (de Lucio and Seijo 2021). Since the workshop attendees had a close relationship with the BR management, they could share their vision regarding the potential climate change impacts on the BR territories.

Regarding the impact of climate change on ES, despite its widespread recognition as a threat, participants also recognised it as an opportunity. Specifically, they explored the potential of ecological intensification in agriculture to tackle the challenge of food production, while simultaneously conserving ecosystems and their resources. This is of utmost importance given the escalating concerns over food security and the need for agricultural production to keep pace with the demands of our expanding population (Food and Agriculture Organization 2023). Ecological intensification can be characterised as a knowledge-driven procedure demanding the optimal oversight of natural environmental functions and biodiversity. It aims to enhance the performance and efficiency of agricultural systems, ultimately benefitting farmers' livelihoods (Food and Agriculture Organization 2023). As the BR look forward, they need to contemplate shifting their food production systems towards greater sustainability. Some studies (Baulcombe et al. 2009, Clay 2011, Foley et al. 2011, Raj et al. 2021, Food and Agriculture Organization 2023) indicate that the shift towards ecological intensification is feasible and exceptionally beneficial. This entails harnessing ecosystem resources like soil, water, biodiversity and energy in efficient and regenerative manners, thereby mitigating adverse environmental effects. During the discussion, some participants emphasised the need to recognise the value of agroecosystem services beyond the production of food and other tangible products. They pointed out that services like pollination, soil conservation and water management are also crucial components of a healthy and sustainable agricultural system. When ecological intensification was first introduced, the main focus was on improving soil fertility and nutrient efficiency in combination with technological advances to increase crop yields in high-producing areas (Cassman 1999). However, this concept has since been broadened to include other important ecosystem services like biological pest control, soil services and crop pollination (Bommarco et al. 2013, Muneret et al. 2019).

Participants cited that it is important to find ways to address the excessive use of water in agriculture through sustainable practices. This is a problem that needs to be solved and the participants pointed that technology and sustainability may help. Additionally, they prioritised the effective implementation of existing legislation and regulations to tackle climate change. Considering the solutions to address the threats affecting the BR' territories in mainland Portugal and the islands, there were strong perceptions that having more private initiatives to valorise ecosystem services would be a positive factor. In the BR, the land is mostly privately owned and managed for profit, but when management becomes unprofitable, plots are often abandoned or replaced with other land uses. To ensure the adequate protection of these areas, it is crucial, from the participants' perspective, to incentivise sustainable management practices within these communities. This involves implementing policy changes at the regional level and providing technical support and incentives at the local level, which will encourage a shift from management focused solely on maximising provisioning services to a more balanced approach that considers multiple environmental service categories. Developing instruments for ES valuation that landowners and producers can understand will be essential to support this point of view. In Portugal, there are already some tools available to value ES economically, such as the schemes for the payment for Ecosystem Services (PES) and public funding (Santos et al. 2019). It is important to note that there are funding opportunities for conservation and sustainable land-use projects in Portugal through the European Union's Life programme, despite the limited use of these funds (Bugalho et al. 2011, Santos et al. 2015). Implementing effective strategies can provide economic incentives to landowners and farmers (Peltonen-Sainio et al. 2016), which is crucial in facilitating the adoption of sustainable land-use practices that deliver essential ecosystem services, such as mitigating greenhouse gas emissions and enhancing water quality (Henriksen et al. 2011, Santos et al. 2015, Salmon et al. 2018). In this workshop, participants recognised the significance of these strategies in conserving ES in the BR.

One thing that most of the participants emphasised as being crucial for sustainable development was the fact that many residents do not realise they live in a BR and what that means for their way of life. This limited understanding was considered as an obstacle to the territory's sustainable progress. To address this challenge, they felt that it was imperative to find ways to increase communication and collaboration between stakeholders and academia. By working together and sharing information, it was advocated that raising awareness and promoting more sustainable practices would be possible (Requier et al. 2020). A greater sense of cooperation and communication would encourage a shared commitment to protect the natural and cultural values of BR, where stakeholders would be given the power to implement sustainable practices and make informed decisions, while academia would see their findings used (Bouamrane et al. 2016, Hedden-Dunkhorst and Schmitt 2020, Barraclough et al. 2023). In the end, this collaboration between stakeholders would spark a deeper awareness of the value of Biosphere Reserves and the crucial part they play for sustainable practices by working together, showing to a wider public the benefits of responsible environmental management and spurring group action for a more sustainable future.

This scenario reinforces the concept that improving knowledge transfer from researchers to politicians, managers and other key stakeholders in the BR Portugal is crucial, especially considering that raising awareness is one of the MAB programme's objectives (UNESCO 2021). Better communication strategies can increase knowledge about the importance of conservation and sustainable development, providing opportunities for raising awareness, environmental education and outreach. Furthermore, it will also help to understand the impacts of climate change and all the threats mentioned at the workshop, and to identify the actions needed for the BR to consolidate their goal as model areas of sustainability.

Conclusions

The study presented an innovative approach, engaging managers of nearly all the Portuguese BR. By employing a participatory approach, we explored the threats and opportunities facing these territories, collaboratively seeking solutions to enhance the valuation of BR' Ecosystem Services. Effective engagement and participation are pivotal for the success of conservation policies and our findings indicated that participants' perceptions were in accordance with this perspective.

As BR managers convened to discuss their territories, they were able to identify the unique characteristics of each one. However, most importantly, they recognised that all these areas were part of one territory, common to all and needed to unite efforts. It is imperative to engage and collaborate with different stakeholders to capture various viewpoints and ensure that all interests are represented. By doing so, we can work towards a more comprehensive and effective valorisation and valuation of the ecosystem services of the BR that can benefit both the environment and the economy. The participants were pleased with the outcomes of the discussion and the activities carried out during the workshop, considering it to be dynamic and valuable for establishing a network amongst all the BR managers. Overall, the meeting was positively evaluated and deemed productive. For the first time, it was successfully pinpointed which ecosystem services are regarded as priorities in the Portuguese BR and the main threats affecting them. They also identified the main opportunities that BR should maximise and designed a set of solutions, all of which share the common goal of fostering sustainable management principles within the BR territories.

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Conflicts of interest

The authors have declared that no competing interests exist.

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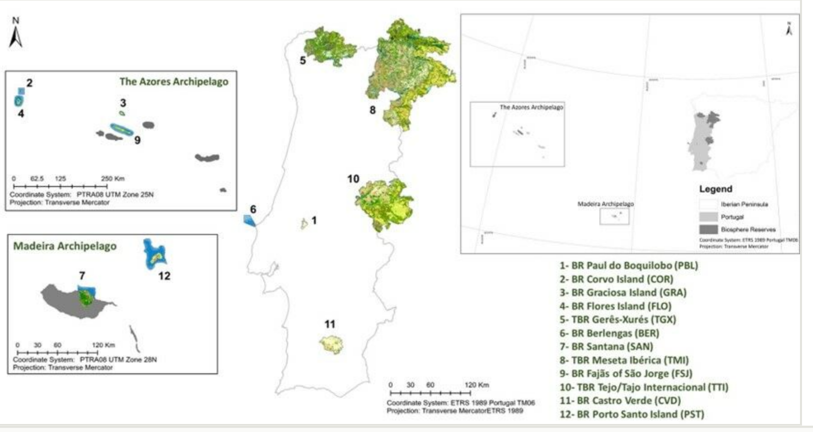

Figure 1.

Geographical location of the 12 Portuguese Biosphere Reserves (right top corner) and the identification of each Biosphere Reserve (ordered chronologically by the year of UNESCO designation).

Figure 2.

Scheme of the phases in the Biosphere Reserves workshop.

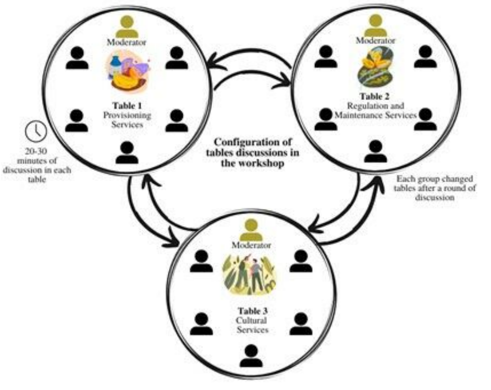

Figure 3.

Configuration of the discussion tables in the Biosphere Reserves workshop.

Figure 4.

Discussion groups in the Biosphere Reserves workshop.

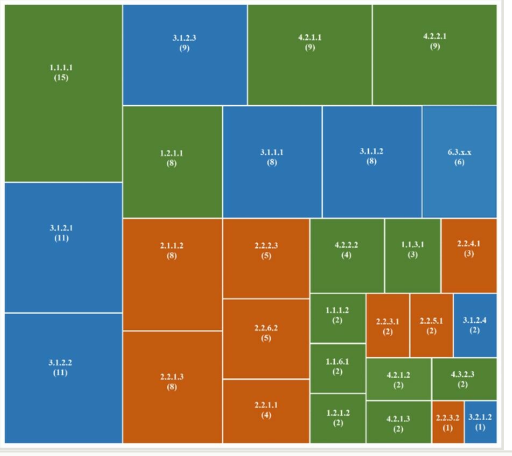

Figure 5.

Individual Ecosystem Services (n = 29) scores attributed by the managers in the Portuguese Biosphere Reserves. The colours represent the different groups of Ecosystem Services: Green – Provisioning services; Orange - Regulation and Maintenance services; Blue - Cultural services. The number in parenthesis refers to each ES score. Please see the Table I in the supplementary material for the name of each CICES code.

Figure 6.

Main threats identified to the Biosphere Reserves.

Figure 7.

Main opportunities identified for the Biosphere Reserves.

Figure 8.

Main solutions identified for the Biosphere Reserves.

Table 1.

Table 1. Ecosystem services list according to CICES classification and number of times mentioned by the participants in each discussion table. (Biosphere Reserves: PBL - Paul do Boquilobo, COR - Corvo Island, GRA - Graciosa Island, FLO - Flores Island, TGX - Gerês/Xurés Transboundary, BER - Berlengas, SAN - Santana Madeira, TMI - Meseta Ibérica Transboundary, FSJ - Fajãs de São Jorge, TTI - Tejo/Tajo International Transboundary, CVD - Castro Verde and PST - Porto Santo).

CICES Code	Class (CICES)	PBL	COR	GRA	FLO	TGX	BER	SAN	TMI	FSJ	TTI	CVD	PST	All	Number of mentions
1.1.1.1	Cultivated terrestrial plants (including fungi,algae) grown for nutritional purposes		1	1	1					1				7	11
1.1.1.2	Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)													7	7
1.1.1.3	Cultivated plants (including fungi, algae) grown as a source of energy													3	3
1.1.4.2	Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials)													3	3

1.1.2.2	Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials)													3	3
1.1.3.2	Fibres and other materials from reared animals for direct use or processing (excluding genetic materials)													4	4
1.1.6.2	Fibres and other materials from wild animals for direct use or processing (excluding genetic materials)													3	3
1.1.3.1	Animals reared for nutritional purposes	1												3	4
1.1.4.1	Animals reared by in-situ aquaculture for nutritional purposes													3	3
1.1.6.1	Wild animals (terrestrial and aquatic) used for nutritional purposes													3	3
1.2.1.2	Higher and lower plants (whole organisms) used to breed new strains or varieties													4	4
1.1.2.3	Plants cultivated by in-situ aquaculture grown as an energy source								1						1

1.2.1.1	Seeds, spores and other plant materials collected for maintaining or establishing a population													3	3
1.1.5.1	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition						1							1	2
2.1.1.2	Filtration/ sequestration/ storage/ accumulation by micro-organisms, algae, plants, and animals	1				1			1			1		2	6
2.2.1.1	Control of erosion rates	1												4	5
2.2.1.3	Hydrological cycle and water flow regulation (Including flood control and coastal protection)	3	1	1	1	1	1		1	1		3		10	23
2.2.2.3	Maintaining nursery populations and habitats (Including gene pool protection)	1							1			2		2	6
2.2.3.1	Pest control (including invasive species)		1	1	1				1	1		1		4	10
2.2.3.2	Disease control	1	1	1	1					1		1		3	9
2.2.4.1	Weathering processes and their effect on soil quality													4	4

2.2.5.1	Regulation of the chemical condition of freshwaters by living processes	1													1
2.2.6.2	Regulation of temperature and humidity, including ventilation and transpiration	3	1	1	1	1	1		1			4		10	23
3.1.1.1	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions													10	10
3.1.1.2	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions													10	10
3.1.2.1	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge													7	7
3.1.2.2	Characteristics of living systems that enable education and training													7	7

3.1.2.3	Characteristics of living systems that are resonant in terms of culture or heritage													6	6
3.1.2.4	Characteristics of living systems that enable aesthetic experiences													7	7
3.2.1.2	Elements of living systems that have sacred or religious meaning													7	7
4.2.1.3	Freshwater surface water used as an energy source					1			1					2	4
4.2.2.1	Ground (and subsurface) water for drinking	1	1	1	1			1		1			1	5	12
4.2.2.2	Ground water (and subsurface) used as a material (non-drinking purposes)													5	5
4.2.1.1	Surface water for drinking													1	1
4.2.1.2	Surface water used as a material (non-drinking purposes)													1	1
4.3.2.5	Geothermal		1	1	1					1					4
4.3.1.3	Mineral substances used as an energy source											2		5	7
4.3.1.2	Mineral substances used for material purposes	1	1	1	1					1		1		6	12

4.3.2.3	Wind energy		1	1	1			1		1			1		6

Table 2.

Table 2. Text Mining analysis of the perceived threats to BR ecosystem services

Term	Frequency	Term	Frequency
Climate change	13	Common Agricultural Policy (CAP)	1
Pollution	13	Competition	1
Overexploitation of natural resources	7	Economic activities	1
Anthropogenic pressure	6	Education	1
Agriculture	5	Environmental policies	1
Lack of financial resources	5	Extraction	1
Land-use change	5	Harvesting techniques	1
Exotic species	4	Inadequacy	1
Increased consumption	4	Industry	1
Microplastics	4	Irrigation	1
Rural exodus	4	Lack of communication	1
Fires	3	Lack of cultural appropriation	1
Lack of logistics	3	Lack of field experience	1
Pandemic	3	Lack of initiatives	1
Reduction of cultural manifestations	3	Lack of partnerships	1
World market prices	3	Lack of traditional knowledge	1
Dimensioning the area	2	Lack of training	1
Forestry	2	Loss of immaterial heritage	1
Lack of intergenerational contact	2	Maintenance	1
Loss of biodiversity	2	Market	1
Loss of cultural memory	2	Modernisation	1
Natural habitats	2	Monocultures	1
Other land uses	2	Social devaluation of agriculture	1
Rural areas	2	Soil degradation	1
Water quality	2	Uniformisation	1
Academy	1	Unsustainable land use	1
Ageing population	1	Wildlife	1
Bad management	1	Youth	1

Colonisation	1		

Table 3.

Table 3. Text Mining analysis of the perceived opportunities to BR ecosystem services.

Term	Frequency	Term	Frequency
Authenticity/Identity	5	Cereal self-sufficiency	1
Local people	4	Changes in harmful behaviour	1
Valorisation of local culture	4	Circular economy	1
Capacity building	3	Contribution to human settlement	1
Climate adaptation	3	Creation of new jobs	1
Cost reduction	3	Economy	1
Local tourism	3	Greater promotion of ES	1
Opportunities	3	Knowing the territories	1
Partnerships	3	Local development	1
Promotion of biodiversity	3	Maintenance of native biodiversity	1
Quality of life	3	Making the most of resources	1
Sustainable agriculture	3	More accessible tools	1
Crop diversification	2	New communication channels	1
Extended learning	2	New knowledge	1
Increased demand	2	New populations	1
New food trends	2	New uses of varieties	1
New markets	2	Pandemic	1
Plantations	2	Protecting ES	1
Political involvement	2	Public Policies	1
Reclaimed areas	2	Reducing the ecological footprint	1
Schools	2	Safe food	1
Senior public	2	Settlement of people	1
Universities	2	Sharing	1
Vegetarianism/Veganism	2	Territory dynamics	1
Appreciation of private property	1	Water treatment	1

Table 4.

Table 4. Text Mining analysis of the perceived solutions to BRs ecosystem services.

Term	Frequency	Term	Frequency
Connections	12	Ensuring compliance	2
More presence of private initiatives	10	Industry	2
Increase production	9	Practical examples	2
Scientific research	7	Producers	2
Innovation	5	Regulation	2
Territory	5	Supervision	2
Valorisation	5	Sustainable use	2
Market differentiation	4	Compensation	1
Article publications	3	Control of legislation	1
Companies	3	Forest management	1
Cultural identities	3	Land registration	1
Fieldwork	3	Major economic activities	1
Focus	3	Organisation of farmers	1
Focus on the present	3	Pilot projects	1
Investments	3	Professionalisation	1
More experiments	3	Proper use of water	1
More participation	3	Public policies	1
Realisation	3	Services	1
Solutions	3	Society	1
Determination	2	Soil regeneration	1
Ecosystem services	2	Specificity	1
Enforcement	2	Water retention	1

Table 5.

Table 5. Key categories and total terms and expressions were listed by the participants regarding their expectations, concerns and hopes related to the workshop.

Expectations		**Concerns**		**Hopes**	
Key categories	**Terms/ expressions**	**Key categories**	**Terms/ expressions**	**Key categories**	**Terms/ expressions**
Learning and knowledge	- New learning and knowledge - Learning - Expand knowledge	Lack of knowledge	- Lack of knowledge	Increase networking	- Interconnection - Closer relationships between BRs - Mutual help - Teamwork - Possibility to visit other Reserves - Strengthen BRs network
Deepen skills applied to territory development	- Learn to apply - Deepen skills - Ideas that can be applied to the development of territories - Get to know the potential of each of the BRs	Environmental concerns	- Difficulties with climate change - Disappearance of natural values	Increase knowledge and skills	- To learn - Training - Knowledge - Learning in different areas - Greater management skills - Communication and training
Networking	- Networking - Exchange of ideas - Create relationships - Meet representatives of other BRs - Interconnection with partners	Difficulty understanding other realities	- Incompatibilities - Difficulty understanding other realities - Inability to convey the message	Community involvement	- Greater community involvement - Consolidate community appropriation of sustainability - Greater capacity and retention of young people
Sharing	- Openness of mind - Debate - New points of view - Find common ground - Sharing Information exchange	Political/ regulatory concerns and applicability in the territory	- That all the results cannot be applied in practice - Impractical plans/ documents - Lack of consequences in BRs - Overlap with other conservation/ classification statutes	Create solutions	- Solutions - Leverage resources - Daily and future work strategies

To contribute	- To contribute	Lack of focus and disinterest	- Lack of focus - Disinterest - Non-mobilisation of actors	Greater recognition of the BRS	- Affirm the Reserves - Value BRs' particularities - Valorisation of the BRs
Promotion of the BRs	- Promotion of the BRs	Generalisation	- Standardisation of values - Condense information		
		Over-disclosure	- Over-disclosure		