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Understanding science-society interactions (SSI): diverse viewpoints from mountain biosphere reserves

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ABSTRACT

Addressing global challenges necessitates innovative forms of knowledge production such as various forms of science-society interactions (SSI), increasingly endorsed by international initiatives like the UNESCO Man and the Biosphere (MAB) Programme and its biosphere reserves. Despite strong policy support advocating for SSI characterized by knowledge co-production and local collaboration, scholarly exploration of SSI within biosphere reserves remains sparse. This study employs the semi-quantitative Q-method to identify viewpoints of SSI among representatives of mountain biosphere reserves and examine the extent to which these correspond to the international UNESCO MAB policies. Following the qualitative development of the statements and data collection, principal component analysis was conducted and revealed four distinct viewpoints. Viewpoint 1 emphasizes SSI as inclusive, collaborative endeavours, prioritizing the active involvement of diverse actors in decision-making. Viewpoint 2 frames SSI as science-driven, with a focus on environmental research, monitoring, and expert knowledge, reflecting historical conservation-focused biosphere reserve approaches. Viewpoint 3 emphasizes the relevance of SSI for knowledge integration and diffusion. Viewpoint 4 positions biosphere reserves as catalysts for SSI, dynamic platforms for fostering co-creation, research and innovation. The study illustrates that despite a strong conceptual basis, the nuanced and subjective nature of SSI presents significant challenges for researchers and other actors in understanding them. UNESCO policies guiding SSI implementation and co-creation in biosphere reserves may not align with diverse on-the-ground perspectives, highlighting the difficulty of translating policy into practice and the need for further exploration to develop effective, context-specific SSI initiatives.

HIGHLIGHTS

- UNESCO holds the mandate to advance SSI adoption across biosphere reserves.
- Local views on SSI reveal mismatch between UNESCO ideals and practice on the ground.
- Two contrasting perspectives emerge: local co-creation vs. science-led monitoring.
- Quantifying reserve success via project metrics is seen as least relevant for SSI.
- Policy-practice gap shows need for clearer guidance on implementing SSI.

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transformations;
Q-methodology; viewpoints

Introduction

Our world is grappling with a range of pressing and intricate issues embodied by the triple planetary crisis – climate change, biodiversity loss and land degradation (IPBES 2019; IPCC 2022). Addressing these challenges calls for a broader societal transformation, which requires new forms of knowledge production that integrate a diverse spectrum of perspectives and expertise, such as different forms of interactions between science and society (so-called science-society interactions, SSI; Lawrence et al. 2022; O'Donovan et al. 2022). SSI can

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exhibit varying levels of interaction intensity, reaching from intensive two-sided interactions between science and society (e.g. transdisciplinary research, living labs, open innovation platforms) addressing complex societal challenges (Steger et al. 2021) to less interactive methods such as qualitative interviews (Knott et al. 2022). However, the lack of a clear definition does not hinder the strong support by various national and global initiatives to foster SSI. Global initiatives like the UNESCO Recommendation on Open Science and the OECD Global Science Forum highlight the importance of engaging openly with societal actors and employing SSI marked by higher intensity of interaction (OECD 2020; UNESCO 2021; Cudenec et al. 2022). Furthermore, the emphasis on SSI is particularly evident in the realm of nature conservation and protected area research (Margules et al. 2020). This stems from a growing understanding of the need for an integrative approach, transcending the traditional division between areas designated for nature protection and those for human activities (Durán et al. 2023). Recent official strategic and policy developments within the UNESCO Man and the Biosphere (MAB) Programme and its global network of biosphere reserves serve as a notable example.

The UNESCO MAB Programme along with its biosphere reserve concept have consistently placed SSI at their core (UNESCO 2017); they have been rooted in the principle that communities should actively participate in and benefit from research initiatives (Reed 2019). Founded in 1971, the MAB Programme is a unique global scientific initiative that promotes innovative approaches to sustainable development to improve human-environment relationships (UNESCO 2024). Its biosphere reserve concept was established in 1976 to foster global collaboration in nature conservation, monitoring, and research, largely within the fields of ecology and environmental sciences. Initially hindered by varying understandings and perceptions of being akin to conventional protected areas primarily focused on top-down biodiversity conservation, the concept was redefined through the 1995 Seville Strategy, introducing a stronger focus on sustainable development and the involvement of local communities in management and research initiatives (UNESCO 1996; Reed and Massie 2013; Van Cuong et al. 2017). The latest biosphere reserve guiding documents, the MAB Strategy and the Lima Action Plan (2017), advocate SSI, highlighting the importance of knowledge co-production and local, collaborative research driven by a more prominent focus on social learning (UNESCO 2017; Barraclough et al. 2023) and the important role of the reserves as testbeds for experimenting with policy innovations and/or novel technologies to spur sustainability transitions (UNESCO 2017; Pool-Stanvliet and Coetzer 2020).

Nevertheless, despite these endorsements, there has been limited scholarly investigation and reflection on SSI in biosphere reserves in general (Reed 2019). The few articles that explore this topic show mixed results, which also reflects the broad understanding and definition of what SSI might be. For example, Reed (2019) reports mixed success in involving local people in the reserves, particularly in the initial phases, while Brenner and Job (2022) highlight the widely ignored body of knowledge on actor participation in Mexican biosphere reserves. Koy et al. (2019) emphasize the gap between participatory ideals and their practical implementation in a reserve in the Democratic Republic of Congo, and Ferreira et al. (2020) found that, while local communities in the reserves are often consulted through interviews or surveys, few studies employ methods characterized by a higher level of interaction. Moreover, while biosphere reserves are recognized as areas for knowledge co-production and sustainability science, previous studies also point out that only a small group of researchers operating within them have the skills necessary to successfully facilitate and implement such collaborative research formats (Reed and Abernethy 2018; Barraclough et al. 2023). These examples illustrate that the intricacies associated with SSI remain challenging for both researchers and practitioners, even in the context of sites that share knowledge systems and mandates, like biosphere reserves. They require supportive tools to effectively navigate the diverse dimensions of integration in SSI (Fischer et al. 2024). Previous research and actual practices let one assume that the understanding of SSI 'on the ground' is still vague, which aggravates/hinders the operationalization and implementation of SSI.

To help address this gap, our study utilizes the Q-methodology to explore the occurring viewpoints on SSI among biosphere reserve representatives, specifically focusing on reserves in mountainous regions and addressing the following research questions: 1) *How are SSI understood in mountain biosphere reserves as model regions for sustainable development?* 2) *To what extent do the viewpoints of biosphere reserve representatives align with the UNESCO MAB's strategic prioritization of SSI?* We focus on mountainous areas, because they are home to more than half of the UNESCO designated biosphere reserves (UNESCO 2023) as well as to over a billion people (Aquerreta and Vivien 2022) and are highly vulnerable to global changes (Thuiller et al.

2005), indicating their potential for utilizing SSI to address pressing challenges and foster innovative solutions. Furthermore, mountainous areas, housing many indigenous communities, are particularly rich in diverse traditional knowledge (Mason et al. 2022). The UNESCO MAB strategies also highlight the significance of mountain biosphere reserves as research sites and have spurred the establishment of the World Network of Mountain Biosphere Reserves, dedicated to fostering global scientific collaboration, knowledge exchange, and impactful research initiatives including SSI with higher intensity of interaction (Aquerreta and Vivien 2022).

This paper is structured as follows: The next section (understanding SSI) provides an overview of the foundational concepts surrounding SSI, introducing the heuristic-analytical framework used to analyse SSI in our study. The materials and methods chapter outlines the use of Q-methodology, detailing the Q-set development as well as the data collection and analysis processes. The results chapter presents the results of the Q-sorting process – the four distinct viewpoints on SSI identified through principal component analysis. The final section (discussion and concluding remarks) synthesizes the findings, explores their implications in relation to existing literature and UNESCO MAB policies, and discusses the challenges of implementing SSI in biosphere reserves.

Understanding SSI

The discourses surrounding SSI, especially those marked by high intensity of interaction between academic and non-academic actors have been gaining significant attention in recent years, yet the foundational concepts are not new. For instance, Funtowicz and Ravetz (1993) introduced the concept of “post-normal science”, suggesting that in situations with uncertain facts, conflicting values, high stakes, and urgent decisions, scientists must engage with society, and society needs input from scientists for informed decisions. Similarly, Gibbons et al. (1994) introduced “Mode 2” knowledge production in 1994 as an alternative to traditional disciplinary approaches, emphasizing collaboration among diverse practitioners to address specific, localized problems without disciplinary constraints. However, the intricacies surrounding SSI pose challenges for researchers and other actors (Thompson et al. 2017; Djenontin and Meadow 2018). To examine SSI, this article uses a heuristic-analytical framework (see Figure 1) based on five main categories: a) societal-scientific problem, b) actors, c) knowledge input, d) intensity of interaction and e) knowledge outcome.

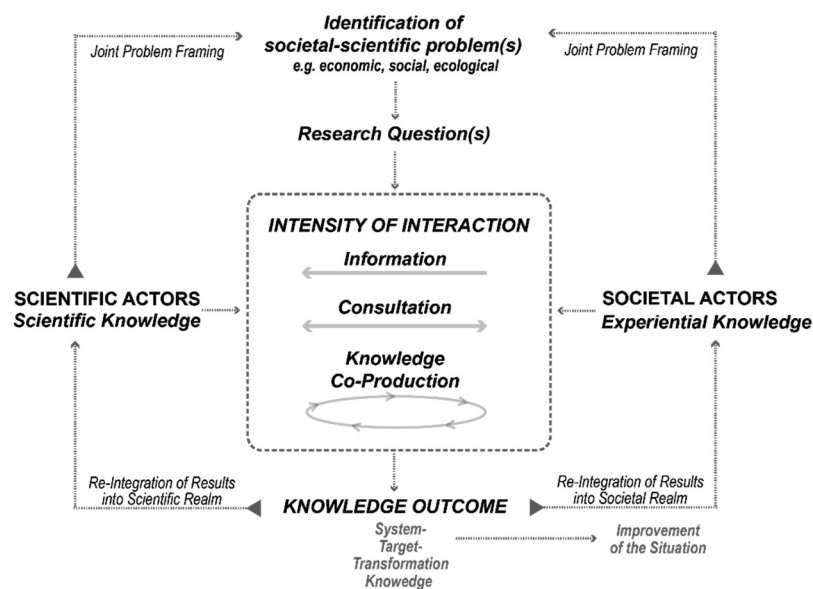


Figure 1. Heuristic-analytical framework illustrating key aspects of SSI (Enengel et al. 2012; Mitchell et al. 2015; Pohl et al. 2017; Galende-Sánchez and Sorman 2021; Bandola-Gill et al. 2023; López Cifuentes et al. 2023).

At the forefront of SSI are the focus on real-world problems and social relevance of research activities; these occur at two points: (i) as a starting point where socially relevant questions are translated into scientific research questions, and (ii) the societal re-integration of the research results, which should put them into value for society (Polk 2015; Schöpke et al. 2018). SSI are required for producing novel knowledge and expertise for adequately addressing real-world issues, which distinguishes them from traditional research projects (Kok et al. 2021; Thapa et al. 2022). In particular, the identification of societal-scientific problems and their translation into research questions is a first crucial step in such SSI (Steger et al. 2021; Horcea-Milcu et al. 2022). The spectrum of such issues and the research themes they encompass are diverse, spanning economic, social, ecological and governance-related domains, among others (Pohl et al. 2017; Scholz 2020).

Secondly, there is a consensus that SSI are interactions involving diverse academic and non-academic actors collaborating in the co-production of knowledge along different research-phases. The range of actors engaged in SSI can extend beyond a simple scientist-non-scientific actor dichotomy. Actors in SSI exhibit diverse backgrounds, interests, and roles, such as core scientists, consultants, professional practice experts, strategic case actors, and local case actors (Enengel et al. 2012). All these actors can have diverging expectations, experiences, skills, disciplines and practices, challenging the collaboration in various forms of SSI (Lang et al. 2012; Scholz and Steiner 2015; Bulten et al. 2021).

At the same time, the involvement of different actors encourages the integration of various knowledge domains to attain a comprehensive understanding of existing challenges as well as potential solutions (Karrasch et al. 2022). Based on the work of Enengel et al. (2012), López Cifuentes et al. (2023) differentiate between experiential and scientific knowledge. Scientific knowledge is characterized by empirical evidence or scientifically acknowledged theories; it is systematic, formalized and explicit (Scholz et al. 2024). Experiential knowledge, on the other hand, is derived from personal life experience or traditional sources; it can include, for example, indigenous knowledge, practice/professional knowledge and other local knowledge (Nimkulrat et al. 2020). This type of knowledge is often implicit or tacit, which poses challenges in its transmission and accessibility (Wuelser et al. 2021). Successful knowledge integration depends on the active engagement of diverse non-academic actors alongside researchers, who play a central role in integrating knowledge from different sources, especially between non-academic and scientific realms (Karrasch et al. 2022).

The types of engagement of non-academic actors can vary, influencing the intensity of SSI. Actor engagement can be classified into three levels: information, consultation, and knowledge co-production (Enengel et al. 2012; Brandt et al. 2013; Galende-Sánchez and Sorman 2021; Bandola-Gill et al. 2023). Information involves one-way communication, which can include communication from scientists to non-academic actors regarding research activities, as well as from non-academic actors to scientists, through data collection methods such as questionnaires or interviews. Consultation involves a mutual exchange; it allows actors to provide feedback on research design, aiming to enhance project relevance. Knowledge co-production represents the highest interaction intensity, integrating actors into project design and result development through, for example, collaborative workshops, thus blurring the boundaries between scientific and experiential knowledge (Zurba et al. 2022).

The types of knowledge outcomes resulting from SSI also vary. Pohl et al. (2017) proposes three types of knowledge outcomes in SSI: systems, target and transformation knowledge. Firstly, systems knowledge delves into the origins, current status, and potential future development of a specific problem; this type of knowledge can span disciplinary, multi-, inter-, or transdisciplinary perspectives, providing insights into various elements of a problem (Pohl et al. 2020). Secondly, target knowledge contributes to the identification of desired goals and necessary changes, fostering an understanding of shared visions among relevant actors. Finally, transformation knowledge addresses the practical aspects of achieving goals, encompassing technical, cultural, social, legal, and other means necessary for transformative actions (Jacobi et al. 2022). Furthermore, Mitchell et al. (2015) introduce the Outcomes Spaces Framework for assessing the outcomes of SSI. They identify three key outcome spaces: the improvement in the situation or field of inquiry, the generation of relevant knowledge, and mutual and transformational learning by the researchers and non-scientific actors involved. Firstly, they argue that SSI should result in tangible advancements, such as shifts in strategy or policy. The second aspect emphasizes the importance of creating and disseminating diverse knowledge resources, ensuring accessibility and relevance for all involved as well as broader audiences. The third outcome, transformational learning, signifies learning that leaves a lasting impact and contributes to

changing the situation (Fam et al. 2020). Thus, learning complements the knowledge aspect of the Outcomes Spaces Framework, extending a project’s influence beyond its immediate scope (Mitchell et al. 2015).

SSI take place across different geographical boundaries and scales, spanning from local to global contexts (Shrivastava et al. 2020). Globally, there has been a shift from predominant North-North collaborations towards more balanced North-South and South-South collaborations, engaging scientists, practitioners and other actors from these regions to collectively address global issues (Maass and Equihua 2015; Barraclough et al. 2023). The duration of SSI varies, encompassing short-term events, like one-time workshops, research projects with varying timeframes, and long-term relations that extend beyond specific projects, taking form of stable and institutionalized interactions (Bergmann et al. 2021; Van Drooge and Spaapen 2022). The said institutionalization involves progressing through distinct stages, marked by evolving rules, standards, routines, and structural changes (Fuenfschilling and Truffer 2014). Furthermore, SSI can encompass various forms of research, including competitive research funded through proposals, contract research commissioned directly by funding bodies or government agencies, or scientific qualification projects such as academic theses (Rogga and Zscheischler 2021; Kastenhofer and Bauer 2023)

Materials and methods

This study used q-methodology to assess how SSI are understood within the mountain biosphere reserves. Q-methodology is a semi-quantitative exploratory method that utilizes inverted factor analysis to investigate the viewpoints of a particular group of people within a specific context (Watts and Stenner 2012; Radinger-Peer et al. 2022). One notable practical advantage of this methodology is the possibility to generate meaningful results from relatively small sample sizes (Ten Klooster et al. 2008). In this method, study participants rank a set of statements, known as the Q-set, related to a research topic/question at hand. Each participant then sorts the Q-set along a predefined scale often resembling a quasi-normal distribution (see Figure 2), indicating their levels of agreement or disagreement (Stenner et al. 2008). This individual ranking is called a Q-sort. Once all Q-sorts are completed, numerical values are assigned to the positions where the respondents placed each statement. The data is then compiled into a Q-sort matrix that serves as a basis for further analysis, uncovering patterns among the sorts as well as underlying viewpoints.

With a total of 474 biosphere reserves situated in mountain areas (World Network of Mountain Biosphere Reserves n.d.), the goal was to create a manageable sample for our Q-study. The first step involved delineating what constitutes a mountainous area. To do so, we adopted the classification by

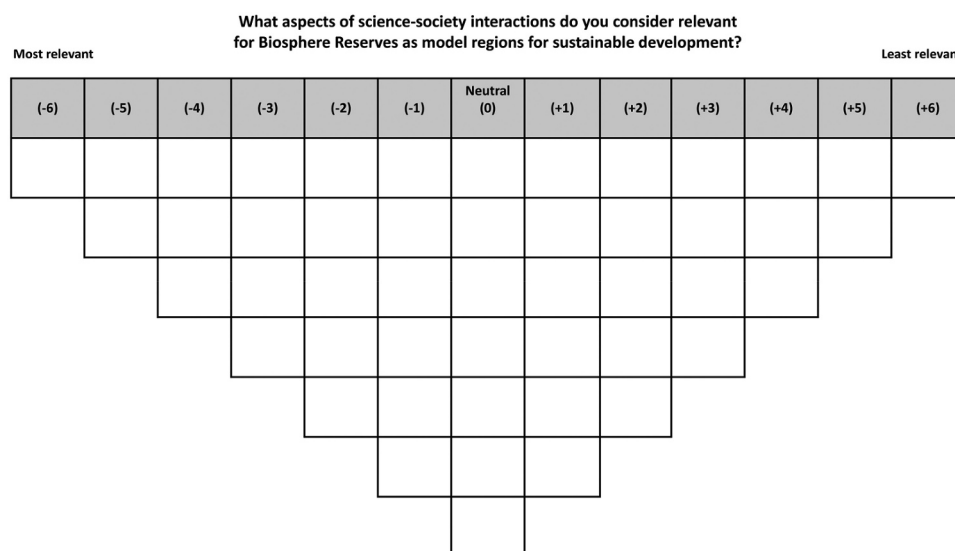


Figure 2. Q-sort scale template; forced-choice distribution from –6 least relevant to +6 most relevant.

Grêt-Regamey and Weibel (2020), which considered key factors such as elevation, climate zones, and major mountain ranges across various continents. They identified 19 primary mountain ranges spanning Africa, Australia, Europe, North America, Oceania, and South America, encompassing approximately 27% of the Earth's surface. Subsequently, the 19 mountain ranges were cross-referenced with the 474 reserves, ensuring that only those located within the said mountain ranges were included. This refinement process reduced our sample to 273 reserves – the basis for our targeted outreach.

Q-set development

Watts and Stenner (2005) emphasize the significance of a well-defined research question in Q-methodological studies, as it does not only shape the content and structure of the Q-set but also acts as a guide for participants during the sorting process. Hence, we initiated the development of the Q-set by formulating a clear research question: *“What aspects of science-society interactions do you consider relevant for Biosphere Reserves as model regions for sustainable development?”*. To inform the statements, we inductively coded the latest policy documents from the UNESCO MAB Programme, the MAB Strategy 2015–2025, and the Lima Declaration. The coding process involved systematically reviewing and segmenting the policy documents into coded units. Seventy-six codes were identified, capturing diverse priorities and directives articulated in the policies, including but not limited to SSI. The codes were subsequently categorized and grouped based on literature and theory-based key aspects of SSI outlined in the *Understanding SSI* section presented above. The eight categories used for grouping included actors, intensity of interaction, scale, knowledge outcomes, knowledge inputs, duration of interaction, societal-scientific problems, and form of research. Some of the codes were multifaceted and related to more than one category. To ensure that all relevant dimensions were captured, these codes were split into several parts, focusing on specific aspects of SSI reflected in the categories. The resulting parts were then carefully rephrased into clear and balanced statements for the Q-sort, reflecting a detailed range of perspectives on the research question. This systematic process resulted in an initial pool of 175 statements.

The statements then underwent four rounds of thorough editing and refining by the six members of the research team. Statements that were very similar in content and could potentially create confusion for respondents were either merged or removed. The team ensured that each statement clearly conveyed a single, focused idea and was framed in a neutral, accessible manner. The representativeness of the Q-set was also assessed, with careful attention to balancing statements across the eight identified categories. The iterative process enhanced clarity and representativeness and allowed for the reduction in the number of statements to a manageable amount of 49, as per Watts and Stenner (2005). The final Q-set (see [Table 1](#)) was reviewed and tested by the Scientific Officer from a Swiss biosphere reserve. Using the UNESCO MAB Programme policy documents for the Q-sort in this study was driven by several factors. Firstly, these documents serve as detailed repositories of most updated general strategies guiding biosphere reserves as model regions for sustainable development. Secondly, they specifically outline the strategic priorities of the UNESCO MAB Programme regarding SSI in the reserves. Additionally, they emphasize the incorporation of sustainability science principles and the recognition of local and traditional knowledge in research and reserve management (UNESCO 2017).

Data collection and analysis

Data for this study was collected using the online q-sort software called *Q-sortware* (Pruneddu 2013). The online Q-sort, instructions and supporting materials were translated into four additional UNESCO languages next to English: French, Spanish, Russian, and Chinese. Five separate survey links were generated in Q-sortware and subsequently sent out via email to representatives of 258 different mountain biosphere reserves; contact information for 15 of them was not found. Outreach efforts included collaboration with the UNESCO MAB Secretariat as well as presenting our research and the survey at the World Network of Mountain Biosphere Reserves meeting in China. However, most of the email addresses of mountain biosphere reserve representatives were obtained through online sources such as the UNESCO biosphere reserve database (2023), the official website of the World Network of Mountain Biosphere Reserves (2022) and individual reserve web pages.

Table 1. Overview of 49 statements, categories, and statement scores across the four viewpoints.

C	No	Statement	Viewpoint			
			1	2	3	4
A	1	It is important that a diverse set of actors - including BRs, research organizations and civil society - are represented in MAB National committees.	-1	5	5	-2
A	2	BRs together with scientists play an important role in producing practical knowledge to address sustainability issues (e.g. biodiversity conservation, livability) on the ground.	3	4	3	1
A	3	BRs are crucial in fostering the development of scientific knowledge.	-2	1	-2	1
A	4	Considering the needs and capacities of young people, women, indigenous and local communities is vital in planning for sustainable development in BRs.	6	3	0	-2
A	5	The inhabitants of BRs, practitioners and researchers use BRs as platforms for knowledge co-production.	-1	-4	-3	1
A	6	Co-production of knowledge between BR inhabitants, practitioners and researchers is crucial for supporting sustainability transitions in mountainous areas.	0	1	4	4
A	7	Local communities play an active role in decision making within BRs.	5	-2	-1	6
A	8	BR staff is crucial for establishing an interface in which science, policy and local communities can interact.	3	-1	-1	3
A	9	Engaging BR-stakeholders (e.g. staff, decision makers and rights-holders) in training activities is vital for fostering sustainable development within BRs.	4	0	1	3
A	10	It is important to have interdisciplinary international networks of scientists and knowledge holders actively engaged in BRs and the MAB Programme.	-2	1	0	-5
I	11	BRs provide research infrastructure to support the generation of research outputs that inform BR management.	0	1	0	-1
I	12	An important role of BRs is to provide opportunities for collaboration among communities that benefit from shared resources.	0	-4	1	5
I	13	BRs' research programs generate robust knowledge essential for informed decision-making and management in BRs.	2	3	3	3
I	14	All stages of research activities in BRs, from planning to implementation, are carried out in a participatory manner.	-1	-2	-6	-1
I	15	For BRs to advance as model regions for sustainable development, it is crucial for collaboration initiatives to be inclusive, dynamic, and results-oriented.	2	-2	2	1
I	16	Co-production of scientific knowledge in BRs is carried out in collaboration with local and indigenous knowledge brokers.	2	-3	1	-1
I	17	Regional and thematic BR-networks (e.g. Global Mountain BR Network) benefit from the enhanced participation of other societal, private and academic actors (e.g. universities, NGOs, businesses).	-4	0	-1	3
S	18	BRs engage with research initiatives on different scales (e.g. local, national, etc.) that contribute to reaching the Sustainable Development Goals.	-2	2	1	0
S	19	BRs as model regions for sustainable development would benefit from having a joint international research and knowledge exchange agenda.	-3	0	4	-4
S	20	The global diffusion of experiences and lessons learned from BRs is crucial to achieving sustainable development.	-1	-2	4	1
S	21	South-South and North-South-South cooperation initiatives between BRs facilitate the co-production of scientific knowledge.	-5	-2	-3	-3
KO	22	The active involvement of BRs ensures the continuous delivery of ecosystem services to support local well-being.	1	-1	-1	2
KO	23	Partnerships in BRs concurrently ensure biodiversity conservation and deliver tangible benefits to local communities.	1	-3	-2	0
KO	24	Research in BRs ensures the long-term conservation and improvement of the local ecosystems/habitats.	0	5	-2	4
KO	25	BRs are model-regions for exploring and establishing innovative approaches that foster community resilience.	-1	-3	3	4
KO	26	Research activities in BRs facilitate the establishment of new BR management strategies.	1	1	3	2
KO	27	It's the BRs duty to encourage stakeholders, local communities and scientists to jointly design and implement collaborative projects that support/inform the sustainable BR management.	1	-1	2	0
KO	28	Research activities in BRs generate crucial knowledge for climate change adaptation and mitigation.	1	4	-5	1
KO	29	Research outputs generated from science-society interactions are relevant to the management of BRs.	0	-1	0	-3
KI	30	Experiences from other BRs (in the World Network of Biosphere Reserves) support BR stakeholders in adopting innovative approaches for the sustainable management of biodiversity and natural resources.	-3	3	2	0
KI	31	To adequately address sustainability challenges in mountainous BRs, it is imperative to integrate different knowledge types, including traditional, indigenous, and scientific ones.	2	4	-1	-4
KI	32	Incorporating local knowledge is crucial for the effective management of BRs.	4	1	6	-3
KI	33	Local practices, traditions and cultures play an important role in research activities in BRs.	3	0	5	0
KI	34	Integrating scientific knowledge in BR research activities is crucial.	0	0	0	-5
D	35	The quality and content of joint BR research agendas, as well as the number of research activities, are key BR performance indicators.	-4	-5	0	-6
D	36	It's important to involve local communities and other stakeholders when designing and implementing research projects in BRs.	3	3	-3	-3
D	37	The number of climate change-related projects and strategies in BRs is a key BR performance indicator.	-4	-5	-5	-3
SSP	38	BRs serve as priority sites for climate change research and monitoring.	-1	6	1	5
SSP	39	Informed decision-making through research is essential for guiding development actions within BRs.	1	2	-1	2
SSP	40	BRs are used as priority sites for climate change mitigation and adaptation.	2	2	-4	0
F	41	Collaborations with unconventional societal organizations (e.g. museums, seed banks, grassroots initiatives) offer new sources of funding for research.	-2	-1	-2	-2
F	42	To foster inclusive BR-networks (thematic, regional) it is important to promote active engagement of all relevant stakeholders.	0	2	-3	0
F	43	Partnerships with universities and research institutions provide training and capacity-building opportunities to BR-stakeholders.	-2	0	-2	2

(Continued)

Table 1. (Continued).

C	No	Statement	Viewpoint			
			1	2	3	4
F	44	Local communities play an active role in science-partnerships to drive action at the local level.	4	0	-4	-2
F	45	Active engagement of BRs in thematic and regional BR-networks (e.g. mountain network) facilitates research collaborations between BRs.	-3	-3	2	-1
F	46	Collaborative projects between all the different stakeholders at the BR level are crucial to address sustainable development challenges.	5	-1	0	0
F	47	The number of strategic partnerships in BRs is a key indicator of their success as model regions for sustainable development.	-5	-4	-4	-4
F	48	The establishment of specialized working groups within BRs, focusing on diverse thematic areas, is crucial for fostering collaborative research projects.	-3	2	1	-1
F	49	Formalized links between BRs and international knowledge networks are vital to foster BR-relevant research activities.	-6	-6	2	-1

Distinguishing statements are in bold. For example, statements 44 and 46 were rated most highly in Viewpoint 1, while in the other viewpoints they were considered as not relevant to varying degrees. Consensus statements are highlighted in grey. For example, statement 47 scored among the lowest across all viewpoints, indicating agreement on its limited relevance to SSI. Abbreviations: C = category, A = actors, I = intensity of interaction, S = scale, KO = knowledge outcomes, KI = knowledge inputs, D = duration of interaction, SSP = societal-scientific problems, F = form of research, BR = biosphere reserves.

Additional data was collected on the respective biosphere reserves, roles in the organization, educational and professional backgrounds (optional). Participants were also given the opportunity to provide comments on any other relevant aspects of SSI overlooked in the statements. The EU General Data Protection Regulation, free-prior and informed consent as well as a project information were part of the mandatory research protocol and included in the beginning of the online survey; the q-sort could only be started if the participants opted in by actively agreeing to participate.

The data collection spanned from September 2023 to November 2023. The process involved four follow-ups with invitation reminders to encourage participation. In total, responses were obtained from 28 participants representing 20 biosphere reserves and 2 reserve networks across Andorra, Austria, Canada, Ecuador, Germany, Morocco, Poland, Russia, Slovenia, Spain, Ukraine, and the Isle of Man, and across seven mountain ranges: the Alps, Andes, Atlas Mountains, Carpathians, Caucasus, Pyrenees, and Rocky Mountains. The roles of respondents included biosphere reserve directors, managers, staff, project managers, research coordinators, employees of managing institutions, youth volunteers, department heads, technicians, scientists/researchers, as well as reserve network representatives (see Table 2).

The resulting 28 q-sorts were analysed using the “qmethod” package available in R software, a specialized toolkit designed specifically for Q methodology data analysis (Zabala 2014). Principal Component Analysis (PCA) followed by Varimax rotation was applied, which allowed for the identification of patterns among the q-sorts and the extraction of four distinct viewpoints (Watts and Stenner 2012; Radinger-Peer et al. 2022). The extraction of the viewpoints was guided by criteria detailed by Watts and Stenner (2005), including an Eigenvalue larger than one and representation by at least two Q-sorts. Furthermore, to ensure a closer alignment between the sorts, the significance threshold was raised to 0.50 (Braitto et al. 2020; Kügerl et al. 2023). The interpretation of results was further supported by crib sheets illustrating the highest and lowest ranked statements for each viewpoint, as well as statement scores (Watts and Stenner 2012; Kügerl et al. 2023).

Results

The Q-sorting of the 49 Q-statements by 28 respondents revealed three clearly defined viewpoints, with an additional, fourth viewpoint represented by only two Q-sorts. The four viewpoints account for 44.6% of the explained variance. These are as follows: Viewpoint 1, emphasizing collaboration with diverse local actors; Viewpoint 2, focusing on science-driven research addressing global environmental challenges; Viewpoint 3, highlighting knowledge integration and diffusion; and Viewpoint 4, seeing biosphere reserves as catalysts for SSI. These will be detailed in the following sections.

All but 12 respondents' Q-sorts showed significant alignment with one of these four viewpoints. Notably, the first viewpoint had the highest number of loaded Q-sorts, totalling eight participants. A summary of the key results is presented in the three tables below. Table 1 provides an overview

Table 2. Overview of respondents by country and role, viewpoint loadings, and correlations between extracted viewpoints.

Loadings			Viewpoint			
P-sample						
No	Country	Role	1	2	3	4
1	Germany	research coordinator	0.482	0.563	-0.029	0.378
2	Canada	project coordinator	0.426	-0.076	0.478	-0.328
3	Slovenia	employee of the managing institution	0.675	-0.097	0.051	-0.060
4	Canada	executive director	0.480	-0.147	0.060	0.085
5	Ukraine	head of department	0.177	-0.092	-0.102	0.778
6	Andorra	co-manager	0.680	0.100	-0.067	-0.061
7	Austria	director	0.316	0.214	0.483	-0.175
8	Isle of Man	project assistant	0.537	0.091	0.105	0.113
9	Poland	staff of national park	0.121	0.177	-0.258	-0.178
10	Austria	project manager	0.733	-0.196	0.335	0.106
11	Austria	project manager	0.562	0.119	-0.035	0.132
12	Austria	youth volunteer	0.116	0.597	0.048	-0.154
13	Germany	staff	0.720	0.151	0.077	-0.169
14	Spain	manager	0.674	0.180	0.126	0.177
15	Andorra	coordinator	0.304	0.061	0.563	0.249
16	Andorra	technician/researcher	0.234	0.093	0.361	-0.264
17	Spain	manager	0.310	0.463	0.219	0.191
18	Andorra	faunal monitoring	0.522	0.369	-0.235	0.189
19	Spain	manager	0.046	0.383	0.412	0.379
20	Spain	coordinator	0.058	0.391	0.409	0.213
21	Spain	manager	0.185	0.035	0.323	0.703
22	Spain	manager	-0.091	-0.013	0.732	0.013
23	Ecuador	dry forest community coordinator	-0.045	-0.672	-0.052	0.103
24	Ecuador	coordinator	0.014	0.538	0.118	0.178
25	Spain	manager	0.496	0.019	0.349	0.295
26	Morocco	development agency	0.158	-0.548	0.116	0.116
27	Morocco	manager and national MAB committee rep.	0.056	0.024	0.394	0.059
28	Russia	scientific staff	-0.145	0.489	0.535	-0.091
No of defining Variables			8	3	3	2
% of explained Variance			16.8	10.2	10.1	7.5
Correlation between viewpoint z-scores						
Viewpoint 1			1	0.34	0.12	0.25
Viewpoint 2			0.34	1	0.16	0.17
Viewpoint 3			0.12	0.16	1	0.13
Viewpoint 4			0.25	0.17	0.13	1

Defining variables (>0.50) are in bold and highlighted in grey. No consistent patterns were observed between respondents' roles or countries and their viewpoint alignment. The z-score correlation matrix in the lower panel confirms the four viewpoints are distinct, with no substantial overlap. While some viewpoints have more defining variables, this does not indicate representativeness; Q methodology is designed to reveal the diversity of perspectives, not their prevalence.

of the 49 statements from the final Q-set, the categories used to group them, and their scores across four viewpoints. Statement scores were calculated based on the weighted average of individual Q-sort rankings within each viewpoint, with weights corresponding to the Q-sorts loadings on the identified principal components. This ensures the scores represent the relative importance of each statement as perceived by respondents aligning with each viewpoint, ranging from -6 (least relevant) to +6 (most relevant). Additionally, distinguishing and consensus statements were identified. Distinguishing statements are those with significant score differences across viewpoints, highlighting unique aspects. Consensus statements show no significant differences across viewpoints, indicating shared agreement. Table 2 details respondents' countries, roles and factor loadings across the four viewpoints. The loadings indicate the strength and direction of each respondent's alignment with the viewpoints. Respondents' sorts with significant loadings (above the 0.50 threshold) on a specific viewpoint are identified as defining variables. The percentage of explained variance shows how much of the variation in perspectives is explained by each viewpoint. Moreover, the correlation between viewpoint z-scores highlights the relationships and distinctions among the viewpoints. Finally, an overview of the most relevant statements (ranked +4 to +6) across the four viewpoints is presented in Table 3. These have been slightly shortened for clarity and comparison.

Table 3. Highest-ranked statements informing viewpoint interpretation.

Viewpoint 1: Diverse local level collaboration	Viewpoint 2: Biosphere reserves – global environmental research sites	Viewpoint 3: Knowledge integration and diffusion	Viewpoint 4: Biosphere reserves – SSI catalysts
No 4 - Sustainable development planning in biosphere reserves must consider youth, women, and local/indigenous communities.	No 38 – Biosphere reserves are key sites for climate change research and monitoring.	No 32 - Incorporating local knowledge is crucial for the effective management of biosphere reserves.	No 7 – Locals actively participate in biosphere reserve decision-making.
No 7 – Locals actively participate in biosphere reserve decision-making.	No 1 - MAB National Committees should include diverse actors like biosphere reserves, researchers, and civil society.	No 1 - MAB National Committees should include diverse actors like biosphere reserves, researchers, and civil society.	No 12 – Biosphere reserves foster collaboration among communities
No 46 - Collaborative projects between all actors at biosphere reserve level are crucial to address challenges.	No 24 - Research in biosphere reserves helps conserve and improve local ecosystems.	No 33 - Local practices, traditions and cultures enrich biosphere reserve research.	No 38 - Biosphere reserves are key sites for climate change research and monitoring.
No 9 - Engaging biosphere reserve actors in training activities is vital for fostering sustainable development within biosphere reserves.	No 2 – Biosphere reserves and scientists play an important role in producing knowledge to address sustainability issues.	No 6 - Knowledge co-production among biosphere reserve residents, practitioners, and researchers supports sustainability.	No 6 - Knowledge co-production among biosphere reserve residents, practitioners, and researchers supports sustainability.
No 32 - Incorporating local knowledge is crucial for the effective management of biosphere reserves.	No 28 - Research in biosphere reserves generates knowledge for climate change adaptation and mitigation.	No 19 - Biosphere reserves would benefit from having a joint international research and knowledge exchange.	No 24 - Research in biosphere reserves helps conserve and improve local ecosystems.
No 44 - Locals play an active role in science-partnerships for action at the local level.	No 31 – Addressing sustainability challenges in biosphere reserves requires integrating different knowledge types	No 20 - Sharing biosphere reserve experiences globally is key to sustainable development.	No 25 - Biosphere reserves are model-regions for exploring and establishing innovative approaches

Statements, slightly shortened, are listed in descending order of relevance within each viewpoint, from +6 (highest rank) to +4. Collectively, they illustrate the emphases of each viewpoint and were particularly important for their interpretation, alongside the statements ranked as least relevant.

Viewpoint 1 – Collaboration with diverse actors at the local level

Viewpoint one emerges as the most prevalent in our sample. This viewpoint distinctly highlights collaboration, inclusivity, and the active involvement of diverse actors in decision-making processes, specifically at the local level, as crucial aspects of SSI (see Table 3). The viewpoint prioritizes the consideration of needs and capacities of diverse groups, emphasizing the vital role of young people, women, indigenous communities, and local inhabitants in shaping plans and strategies within biosphere reserves (4/+6; reads: statement No 4; rank + 6). The importance of collaborative projects involving all actors at the local level (46/+5) and the active participation of local communities in decision-making processes (7/+5) were identified as crucial aspects of SSI addressing sustainable development challenges. The incorporation of local knowledge for effective biosphere reserve management (32/+4), and the active role of local communities in science partnerships at the local level (44/+4) were also highlighted. Statements 46 and 44, both highly ranked, set viewpoint 1 apart from the others. Conversely, statements deemed least relevant within this viewpoint primarily focused on specific indicators of success, such as formalized links with international networks (49/-6) and the number of strategic partnerships (47/-5). Additionally, the low ranking of the statement addressing South-South and North-South-South cooperation initiatives (21/-5) further distinguishes viewpoint one from the others.

Viewpoint 2 – Biosphere reserves as research sites for addressing global environmental issues

The second viewpoint emphasizes that SSI should primarily focus on addressing global environmental pressures and conservation efforts, with biosphere reserves being prioritized as key sites for such initiatives. This becomes evident in the high-ranking of statements emphasizing climate change research, with the top-ranked statement indicating that the reserves are priority sites for climate change research and monitoring (38/+6). Additionally, this viewpoint emphasizes the importance of research activities aimed at long-term conservation of local ecosystems (24/+5), and of generating crucial knowledge for climate change adaptation and mitigation (28/+4). The high ranking of the latter sets this viewpoint apart from the others. Moreover, the statement highlighting the role of biosphere reserves and scientists in producing practical

knowledge to address sustainability issues on the ground is also highlighted as very relevant (2/+4). As in viewpoint 1, the lowest-ranked statements within this viewpoint revolve around quantifiable performance indicators (37/-5) and formalized links with international networks (49/-6). Statements highlighting the inhabitants, practitioners, and researchers using the reserves as platforms for knowledge co-production and collaboration among communities (5/-4, 12/-4) received lower rankings than in other viewpoints, indicating a comparatively lower focus on these aspects.

Viewpoint 3 – Linking knowledge types and knowledge diffusion

This viewpoint highlights the central and multifaceted role of knowledge in SSI. It emphasizes the importance of both local and traditional knowledge, along with the global diffusion of knowledge and international knowledge exchange initiatives. The third viewpoint underscores the importance of incorporating local and indigenous knowledge, practices and traditions in decision-making processes (32/+6) as well as in research activities (33/+5). Furthermore, it accentuates the relevance of global diffusion of experiences and lessons learned to contribute to sustainable development (20/+4) and acknowledges the importance of joint international research and knowledge exchange agendas (19/+4). Viewpoint three is the only one that features statement 19 as relevant for SSI. Hence, it positions knowledge as important for both SSI and biosphere reserve management practices, with implications that extend beyond local boundaries. Interestingly, statements related to the number of climate change-related initiatives (37/-5) as well as on climate change mitigation and adaptation (40/-4) received some of the lowest rankings in viewpoint three. In fact, the latter statement was perceived as least relevant in this viewpoint. The notion that all stages of research activities should be carried out in a participatory manner (14/-6) ranked the lowest compared to other viewpoints, making it one of the most distinguishing features of the third viewpoint.

Viewpoint 4 – Biosphere reserves as catalysts for SSI

Viewpoint four emphasizes the broader role of biosphere reserves as catalysts for SSI, serving as dynamic platforms for collaboration, innovation, and community resilience. The statements ranked most highly within this viewpoint emphasize the important role of the reserves in facilitating collaborations (12/+5) and designate them as priority sites for research initiatives (38/+5), emphasizing the biosphere reserve concept as a platform for fostering SSI. This viewpoint is the only one that considers statement 12 as one of the most relevant. Furthermore, viewpoint four underscores that the reserves play a crucial role in pioneering innovative strategies for community resilience (25/+4). Statements deemed less relevant within this viewpoint focus on specific indicators of reserve success as well as the formalized integration of scientific knowledge (34/-5). The latter ranking sets viewpoint four apart from the others that rather remained neutral on the matter.

Commonalities across viewpoints and additional themes

The analysis revealed six consensus statements across all four viewpoints (see [Table 1](#)). The role of research infrastructure in supporting the generation of knowledge for management (statement 11) was considered as rather neutral in terms of its relevance across all four viewpoints. The contribution of research programs to generating knowledge necessary for informed decision-making (statement 13) was uniformly regarded as a relevant issue in all viewpoints. Similarly, the influence of research activities on the establishment of new management strategies (statement 26) was considered relevant by all viewpoints. In contrast, collaborations with non-traditional societal organizations as potential sources of research funding (statement 41), were seen as having low relevance in the four viewpoints. Finally, the number of partnerships and climate change-related projects as key performance indicators (statements 37 and 47), were deemed as least relevant aspects of SSI across all viewpoints.

Further shared perspectives emerge between some of the viewpoints. For example, the active role of local communities in decision-making (statement 7) stands out as one of the most relevant issues in both viewpoints one and four. The importance of diverse representation in MAB National Committees (statement 1) is of high relevance for both viewpoints two and three. The prioritization of biosphere reserves as

priority sites for climate change research and monitoring (statement 38) is featured as highly relevant in viewpoints two and four. The incorporation of local knowledge for effective management (statement 32) is among the most relevant issues in viewpoints one and three. Additionally, co-production of knowledge for sustainability transitions in mountainous areas (statement 6) holds high relevance in viewpoints three and four.

Several respondents highlighted further aspects deserving attention in comments. One of the respondents emphasized the role of cultivating a sense of place as well as storytelling through SSI. Another noteworthy aspect raised was the importance of science in scaling up management solutions to broader contexts. Moreover, political involvement and the necessity for diversity were also underscored.

Discussion and concluding remarks

Our study unveils divergent understandings of science-society interactions (SSI) in mountain biosphere reserves, as evidenced by the identification of four viewpoints. However, across the viewpoints, two contrasting perspectives emerge as particularly noteworthy. While in some mountain biosphere reserves, SSI are understood as deeply collaborative endeavours involving diverse actors and knowledge systems, in others, they are approached as primarily scientific processes focused on monitoring and research.

Viewpoints 1 (collaboration with diverse actors at the local level) and 3 (linking knowledge types and knowledge diffusion), while clearly differing in emphasis, both reflect an understanding of SSI as highly collaborative, inclusive processes that engage a wide range of actors and thus embrace diverse backgrounds, interests and roles (Enengel et al. 2012). While they share this overarching direction, there are also clear nuances that differentiate the two viewpoints: viewpoint one explicitly focuses on local-level collaboration and the inclusion of diverse actors in SSI, emphasizing participatory decision-making. Viewpoint three also values inclusive engagement, but places greater emphasis on integrating different knowledge systems, particularly local and traditional knowledge, as well as highlights the importance of knowledge exchange beyond the local level. This closely resonates with the Gibbons et al. (1994) concept of “Mode 2” knowledge production, emphasizing collaboration among diverse practitioners to address specific localized problems. Furthermore, both viewpoints recognize the importance of local and traditional knowledge, alongside acknowledging the pivotal role played by strategic and local case actors who contribute *experiential knowledge* deeply rooted in an understanding of local contexts and practices (López Cifuentes et al. 2023). Regarding the intensity of SSI, the viewpoints align with *knowledge co-production* as a level of engagement over *information* and *consultation* (Galende-Sánchez and Sorman 2021; Bandola-Gill et al. 2023). The active engagement of local communities in SSI is highlighted as crucial for tackling challenges related to sustainable development, indicating that it is not only instrumental for improving a given situation (Mitchell et al. 2015) but also leads to *transformation knowledge* as one of the outcomes (Pohl et al. 2017).

In contrast, in viewpoint two (biosphere reserves as research sites for addressing global environmental issues) SSI are seen as primarily research-driven, with a specific focus on climate change research, monitoring, and conservation efforts. This viewpoint is characterized by limited emphasis on collaborative research initiatives and the inclusion of diverse local actors in SSI. When it comes to actors involved in SSI, priority is given to scientific actors, such as *core scientists* and *scientific consultants* (Enengel et al. 2012). In terms of knowledge input, *scientific knowledge* also takes precedence (López Cifuentes et al. 2023), while the outcomes primarily focus on *systems knowledge* (Pohl et al. 2017), reflecting the emphasis on monitoring efforts. However, *target knowledge* (Pohl et al. 2017) is also addressed, particularly concerning climate change adaptation and mitigation. Furthermore, in terms of Mitchell’s OSF (Mitchell et al. 2015), this viewpoint places greater emphasis on situation improvement compared to mutual and transformational learning.

Interestingly, these divergent perspectives on SSI reflect contrasting conceptualizations rooted in the historical evolution of the biosphere reserve concept itself. Viewpoints one and three, emphasizing collaborative SSI and knowledge co-production, align with the post-Seville era of biosphere reserve management. This era is characterized by a stronger emphasis on sustainable development and the involvement of local communities in management and research (UNESCO 1996; Reed and Massie 2013; Van Cuong et al. 2017). Conversely, viewpoint two rather aligns with the Pre-Seville (before 1995) conceptualization of the reserves, where these sites were primarily seen as conservation areas for monitoring and research largely within the fields of ecology and environmental sciences. Hence, despite the modernization of reserve management

strategies, remnants of the pre-Seville era's conceptualization linger, also shaping current understandings of SSI.

In addition to the two contrasting perspectives, there is another rather unique perspective on SSI, represented by viewpoint four (biosphere reserves as catalysts for SSI). Here, SSI are understood as intrinsically linked to the biosphere reserve concept itself, with the reserves seen as pivotal for fostering collaboration as well as serving as priority sites for research and monitoring. Hence, viewpoint four encapsulates elements from the other three viewpoints, positioning the reserves as crucial facilitators of SSI. According to this viewpoint, biosphere reserves themselves embody long-term SSI, bringing together diverse actors and types of knowledge to promote community resilience and sustainable development. They can be seen as models of institutionalized SSI (Van Drooge and Spaapen 2022), being characterized by a framework of evolving rules, standards, and structural changes (Fuenfschilling and Truffer 2014) shaping SSI over time.

Despite the varying understandings of SSI, one common perspective emerges, as evidenced by the consensus statements across the identified viewpoints. Specific indicators of success within SSI initiatives, particularly the quantification of biosphere reserve success based on the number of projects and strategies within them, are seen as least relevant aspects of SSI. This finding suggests a shared understanding that relying solely on metrics may not fully capture the nuances of SSI. It reflects an acknowledgement of the multifaceted nature of SSI, emphasizing the importance of considering a diverse array of factors and complexities. Hence, there is an emphasis on the practical outcomes of SSI over specific performance metrics.

Moreover, just over half of the q-sorts completed by mountain biosphere reserve representatives loaded onto the four viewpoints on SSI. Not all of the viewpoints align with the UNESCO MAB's push for knowledge co-production and local, collaborative research, which characterize SSI with higher degrees of interaction (UNESCO 2017; Barraclough et al. 2023). Viewpoint 2 diverges from this vision, framing SSI as science-driven and focused on monitoring, with limited participatory engagement. Among those that do align, the viewpoint emphasizing collaboration and the active involvement of diverse local actors most closely reflects this push (viewpoint one), while the viewpoint focusing on integrating local and traditional knowledge within a broader context of knowledge exchange (viewpoint three) partly reflects it as well. However, Q-sorts from the remaining respondents did not align with any of the four viewpoints identified. This suggests that there are additional nuanced viewpoints beyond those captured in this study, further illustrating the complexity of understandings of SSI. Additionally, this highlights that the majority of respondents' viewpoints does not reflect the UNESCO MAB's emphasis on SSI characterized by higher intensity of interaction.

By identifying and unpacking distinct viewpoints on SSI among mountain biosphere reserve representatives, this study offers insight into how co-creation processes are understood, valued, and operationalized differently across sites, illuminating the influence of different conditions shaping such processes, like historical policy framings, institutional change, and roles (Kok et al. 2021; Bandola-Gill et al. 2023). The results reflect that, despite a strong conceptual basis, the complexities inherent in SSI present challenges for researchers and other actors (Thompson et al. 2017; Djenontin and Meadow 2018). The absence of a prevailing shared understanding highlights the nuanced and subjective nature of SSI as well as a lack of consensus regarding specific actions or the ideal form that SSI should take.

Furthermore, our analysis suggests that the latest UNESCO MAB policy documents, intended to guide the understanding and implementation of SSI within biosphere reserves may not fully resonate with the diverse perspectives observed on the ground. While these documents advocate for knowledge co-production and collaborative research, our findings indicate that this emphasis might not be uniformly embraced or implemented across all the reserves. This discrepancy underscores the difficulty of translating policy directives into practical applications as well as the need for further exploration and clarification to better guide actors in implementing effective SSI initiatives tailored to the contexts and challenges of their reserves. Shared understandings and conceptualizations are the foundation upon which operationalization depends. Without a shared conceptual ground, efforts to implement SSI risk becoming inconsistent and fragmented, shaped by individual interpretations (Djenontin and Meadow 2018). Before knowledge co-production can serve as a meaningful vehicle for transformative change, including in conservation efforts, there is a need for greater clarity and consensus on what it actually entails (Bulten et al. 2021). This study underscores the importance of addressing this conceptual ambiguity as a prerequisite for translating co-production rhetoric into practice.

Addressing these challenges necessitates a further investigation into the underlying factors leading to the divergent understandings of SSI within biosphere reserves. This includes exploring how governance structures, institutional practices, and management approaches influence current SSI dynamics, as well as identifying barriers actors face when interpreting, engaging with, and implementing UNESCO MAB policies. Understanding these factors is essential for informing targeted interventions aimed at bridging the gap between policy and practice. These interventions may include capacity-building initiatives to enhance the practical skills of reserve representatives in facilitating SSI with high degrees of engagement (e.g. transdisciplinary projects), while fostering a shared understanding of policies and supporting their translation into action (Barraclough et al. 2023). Skilled facilitators play a key role in navigating the complexities of knowledge co-production in biosphere reserves, so providing them with the necessary resources and training should be a priority (Reed and Abernethy 2018). Additionally, strengthening cross-reserve learning platforms, such as the World Network of Mountain Biosphere Reserves, could enhance the exchange of successful SSI practices, further facilitating the integration of local knowledge systems with UNESCO MAB objectives (Aquerreta and Vivien 2022).

Finally, while the Q-method effectively reveals the heterogeneity of viewpoints, it does not capture demographic or geographical patterns within the small sample. To gain a more comprehensive understanding of these patterns, larger follow-up studies focusing on the distinguishing statements of the identified viewpoints are suggested. Such studies could be paired with follow-up qualitative interviews, enabling deeper insight into how specific viewpoints are shaped by institutional, cultural, or regional conditions. Moreover, while our study focused on the perspectives of mountain biosphere reserve representatives, actors directly involved in the implementation of the UNESCO MAB policy directives, it is also very important to consider the understandings of SSI held by local community actors, who were not included in our respondent sample, representing a limitation of this study. Future research could benefit from engaging more directly with these actors to capture a broader range of viewpoints, offering further insights into the community-level dynamics of SSI. The UNESCO MAB Programme has a clear opportunity and mandate to lead this area of investigation, continuing to explore how to effectively translate policy into practice and support the broader adoption of SSI with higher degrees of engagement across the global network of biosphere reserves. We hope that this study will contribute to the ongoing discussion and inspire further detailed investigation into the practical implementation of collaborative research in mountain biosphere reserves and beyond.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical considerations

This study was conducted in accordance with the ethical guidelines of our institution, the relevant national laws in Austria, and the requirements of our funder. In Austria, ethical approval for survey studies of this nature is not required by national law.

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