Chapter 8
Mapping the Current Understanding of Biodiversity Science–Policy Interfaces

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Abstract This chapter contributes to improve an understanding of the effectiveness of different biodiversity science–policy interfaces (SPIs), which play a vital role in navigating policies and actions with sound evidence base. The single comprehensive study that was found to exist, assessed SPIs in terms of their 'features'—goals, structure, process, outputs and outcomes. We conducted a renewed systematic review of 96 SPI studies in terms of these features, but separating outcomes, as a proxy for effectiveness, from other features. Outcomes were considered in terms of their perceived credibility, relevance and legitimacy. SPI studies were found to focus mostly on global scale SPIs, followed by national and regional scale SPIs and few at subnational or local scale. The global emphasis is largely explained by the numerous studies that focused on the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Regionally, the vast majority of studies were European, with a severe shortage of studies, and possibly SPIs themselves, in especially the developing world. Communication at the science–policy interface was found to occur mostly between academia and governments, who were also found to initiate most communication. Certain themes emerged across the different features of effective SPIs, including capacity building, trust building, adaptability and continuity. For inclusive, meaningful and continuous participation in biodiversity SPIs, continuous, scientifically sound and adaptable processes are required. Effective, interdisciplinary SPIs and timely and relevant inputs for policymakers are required

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to ensure more dynamic, iterative and collaborative interactions between policy-makers and other actors.

Keywords Natural capital · Ecosystem services · SPI · Science–policy dialogue · Transdisciplinary · Environmental policy · Biodiversity policy · Stakeholder participation · CRELE · IPBES · Knowledge holder · Policy impact · Trust building

8.1 Introduction

A strong interface between science and policy is essential for the effective conservation and management of biodiversity. Science–policy interfaces (SPIs) can generally be defined as social processes encompassing the relations between scientists and actors in the policy process (van den Hove 2007) and can take the form of organizations, initiatives, or projects operating at the boundary between science and policy. SPIs aim to enrich decision-making, improve understanding of problems, and eventually produce well-informed policy and/or behavioural changes as outcomes (Sarkki et al. 2015). The perceived importance of SPIs for biodiversity-related decision-making has been demonstrated by the formulation of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). The purpose of IPBES is to establish a continuous dialogue between decision-makers, scientists and a wide range of knowledge holders for a more robust SPI on biodiversity and ecosystem services, based in large part on a series of comprehensive assessments on pressing conservation issues (Larigauderie and Mooney 2010a).

There is general consensus on the need for good biodiversity science to inform policy decisions (Millennium Ecosystem Assessment [MA] 2005; Sutherland et al. 2004), and a number of approaches to synthesize scientific knowledge have been established (Pullin and Stewart 2006; Pullin et al. 2009; Sutherland et al. 2014). A number of institutions and processes aim to bring this knowledge to policy processes but, in practice, often fail to produce meaningful policy outcomes (Koetz et al. 2008; Can et al. 2009). Furthermore, they often fail to include the full range of existing knowledge and knowledge holders. Consequently, networking and communication components among different stakeholders are not adequately reflected in many existing SPIs related to biodiversity and other scientific fields (Nesshöver et al. 2016).

A number of studies have demonstrated that effective SPIs do not consist of simple knowledge transfer. The linear model of academics providing scientific advice to governments for policymaking has been rejected from both the perspectives of science studies and policy analysis (van Eeten 1999). Instead, reciprocal

(rather than unidirectional) relationships are preferable (Weingart 1999). Scientific knowledge is commonly viewed as information that is useful for problem-solving, but this is only one of a series of different possible uses of science (Roqueplo 1995). Science is a source of legitimacy in the policy process, not only for developing new policies, but also for delaying or avoiding action and for justifying unpopular decisions (Boehmer-Christiansen 1995). In many cases, scientific knowledge is unused or under-used in the policy process (Hisschemöller et al. 2001). Even if particular scientific evidence is used for policymaking, it may remain unclear why it was used while other knowledge is ignored. Scientific rationalization has become an important factor in policymaking, but the decision to connect a policy decision to scientific evidence (and the way in which this is done) depends on political, not academic, factors. Organizing successful SPIs requires some understanding of how the policy process works and how scientific expertise is typically treated in the policy process (Engels 2005).

SPIs have been studied at various geographical scales. Borie and Hulme (2015) looked at the global level with the debate among IPBES experts terminology to include in the IPBES conceptual framework. The key solution was the presence of mediating experts, who finally facilitated the inclusion of both competing terms. At the regional level, Santos and Pierce (2015) reviewed the early implementation of the EU Marine Strategy Framework Directive, focusing on its cetacean biodiversity component. They identified the potential solutions including securing funding for monitoring, reconciling conservation objectives with the needs of other marine/maritime sectors, and clarifying governance structure. At the national level, López-Rodríguez et al. (2015) examined the establishment of an SPI between scientists and policymakers to understand the major environmental problems and priorities in southeastern Spanish drylands. Possible solutions identified for facilitating/operationalizing SPIs included matching different professional groups with concrete problems in their own work fields, using graphical tools to facilitate mutual understanding, clarifying the roles involved in the problem-solving, and promoting a culture of shared responsibility for implementing collaborative actions to solve environmental problem(s). At the subnational level, Chaves et al. (2015) relayed some lessons from a new environmental restoration policy in São Paulo State, Brazil. The study noted that the main solution for effective restoration policymaking is to gain cooperation among scientists, policymakers, and experienced practitioners in identifying appropriate and user-friendly ecological indicators and associated protocols for monitoring and evaluation. These studies suggest a need to share clear visions of SPIs (Santos and Pierce 2015); resource allocation and good governance for SPIs (Santos and Pierce 2015); engagement of different stakeholders and clarification of each of the roles (López-Rodríguez et al. 2015); and collaboration, trust building, capacity building, and conflict management among different stakeholders (Borie and Hulme 2015), in order to improve biodiversity SPIs.

This chapter presents a systematic review of literature on existing SPIs, identifying challenges and possible solutions to effective SPI implementation. This was done in the context of key SPI features—goals, structure, process and outputs, and their policy outcomes (Young et al. 2013a). These SPI features are borrowed from

the SPIRAL project (Science-Policy Interfaces for Biodiversity: Research, Action and Learning), an interdisciplinary research project that studied biodiversity SPIs in an attempt to improve the conservation and sustainable use of biodiversity funded under the EU 7th Framework Programme. SPI **goals** are central to understanding how and why an SPI operates, why people participate, and play a strong role in setting the foundations of credibility, relevance, and legitimacy. SPI **structure** describes how SPIs are set up and the constraints within which the processes are defined. SPI **processes** define the way in which the key functions are actually carried out. SPI **outputs** can be characterized by a set of features describing how they are prepared and presented. SPI **outcomes** are the learning, behavioural, and policy changes that SPIs foster. Table 8.1 provides more a further breakdown of these categories. SPIRAL evaluated SPIs based on their perceived credibility, relevance, and legitimacy (CRELE) (Young et al. 2013a; Nesshöver et al. 2016). In this context, **credibility** is defined as 'the perceived quality, validity and scientific adequacy of people, processes and knowledge exchange at the interface'; **relevance** is 'the perception of the usefulness of the knowledge brokered in the SPI, how closely it related to the needs of policy and society, and how responsive the SPI processes are to these changing needs'; and **legitimacy** is 'the perceived fairness and balance of the SPI process' (Young et al. 2013a).

8.2 Methodology

We searched the peer-reviewed literature on biodiversity-relevant SPIs using a search string of '(science-policy OR policy-science) AND biodiversity' on Scopus (https://www.scopus.com/home.uri), one of the largest databases of peer-reviewed literature. The resulting papers' titles, keywords, and abstracts were screened to identify those on *creating or analysing* SPIs. From these, we extracted information on the relevant SPI study including its location, its spatial scale (subnational, national, regional, or global), the associated key challenges and possible solutions identified in the SPI process, and its outcomes.

We assessed each article's analysis of the relevant SPI according to the SPI features identified by the SPIRAL framework on goals, structure, processes, outputs, and outcomes, as listed in Table 8.1. Our assumption is that the outcomes of an SPI are affected by the other four SPI features, but also by external factors (e.g., political climate and pure chance). For this reason, SPI outcomes may not directly reflect the SPI design/operation choices in the same way as other features (Young et al. 2013b). Most studies evaluated the other four features in terms of their perceived credibility, relevance, and legitimacy (CRELE) as a proxy for evaluating the SPI outcomes.

The literature review under this study focused therefore on identifying the major challenges faced by each of the SPI features (goal, structure, process, and output), as well as the possible solutions to these challenges for each of the features. We also assessed how goal, structure, process, and output contribute to better SPI outcomes, through a systematic review of the studies that analysed their causal link. This was

Table 8.1 Key features of SPIs (adapted from Young et al. 2013a, b)

Feature	Sub-feature	Characteristics
Goals	Vision	Clarity, scope, and transparency of the vision and objective of SPI
	Drivers	Demand-pull from policy, mandates, supply-driven promotion of research, emerging issues
Structure	Independence	Freedom from external control, neutrality or bias in position, range of membership
	Participation	Range of relevant expertise and interests included, competence of participants, openness to new participants
	Resources	Financial resources, human resources (e.g., leadership, champions, ambassadors, translators), networks, time
Processes	Horizon scanning	Procedures to anticipate science, technology, policy, and societal developments
	Continuity	Continuity of SPI work on the same issues; continuity of personnel; iterative processes
	Conflict management	Strategies such as third party facilitation, allowing sufficient time for compromise
	Trust building	Possibilities to participate in discussion, clear procedures, opportunities for informal discussions, transparency about processes and products
	Capacity building	Helping policymakers to understand science and scientists to understand policymakers, building capacities for further SPI work
	Adaptability	Responsiveness to changing contexts, flexibility to change
Outputs	Relevant outputs	Timely in respect to policy needs, accessible, comprehensive, efficient dissemination
	Quality assessment	Processes to ensure quality, comprehensiveness, transparency, robustness, and management of uncertainty
	Translation	Efforts to convey messages across different domains and individuals, and making the message relevant for various audiences
Outcomes	Social learning	SPI participants, audiences, wider public learn and change their thinking about biodiversity
	Behavioural impact	SPI participants, audiences, wider public change behaviour as a result of learning
	Policy impact	SPI information, learning, and associated changes in policymaker behaviour lead to changes in policy
	Biodiversity impact	The above changes lead to changes in drivers and pressures threatening biodiversity, societal responses, and the state of biodiversity

considered an indication of their effectiveness. SPI outcomes were captured by their reported impacts, broadly categorized as social learning impacts, policy impacts, behavioural changes, and biodiversity impacts. The subcategories of SPI features, as listed in Table 8.1, were used as units to analyse impacts.

8.3 Results and Discussion

We identified 178 peer-reviewed articles, published from 1990 to April 6, 2017, with titles, keywords, or abstracts containing our search terms. Ninety-six of these were found to be directly relevant to our review of biodiversity SPIs, which discussed about science policy interface on biodiversity in the articles. As illustrated in Fig. 8.1, the number of these studies has been increasing overall since 2008. This may be due to discussion towards the establishment of IPBES in 2012 and an increasing scholarly interest in SPIs in general for improving environmental policy making.

The subsequent section are based on a systematic literature review of existing studies on biodiversity SPIs, analysing (1) the geographic scales/locations of the SPIs that have been studied, (2) the types of SPI features that have been studied, and (3) the challenges, solutions, and outcomes identified in relation to each SPI feature.

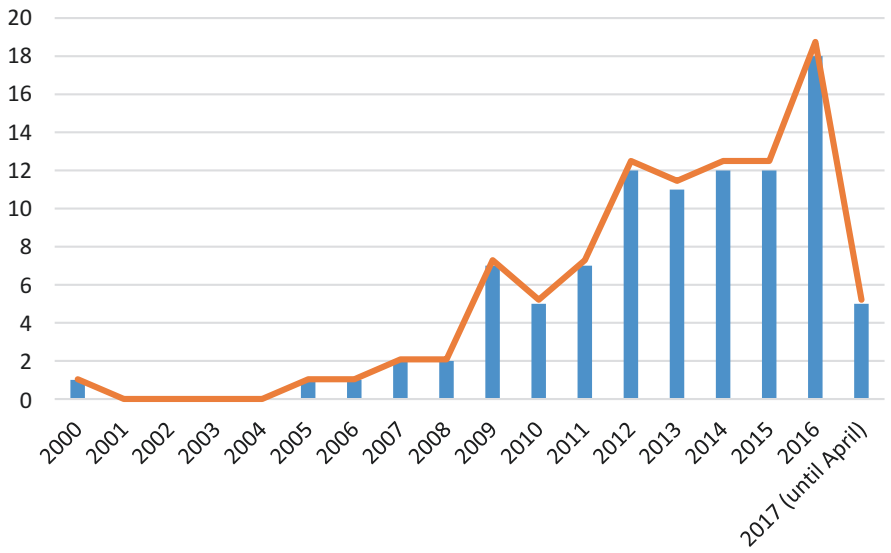

Fig. 8.1 Number of SPI study in each year (2000–2017)

8.3.1 Distribution of SPI Studies

The largest number (36 out of 96) of articles studied global-level SPIs, mostly related to IPBES, while subnational/local and cross-scale SPIs received the least research attention (Fig. 8.2). Rather than reflecting the existence of only a limited number of subnational/local SPIs, this indicates a shortage of studies focusing on the numerous SPIs related to local biodiversity conservation plans and policies. In terms of where the regional-, national-, and subnational/local level SPIs were studied (37 in total), the majority focused on SPIs in Europe (22) and North America (5), while comparatively few studies focused on Asia (3), Oceania (2), Latin America (2), and Africa (1) (Fig. 8.3). Forty-four out of the 96 SPIs were facilitated by government or by government and academia (10), while only 13 were facilitated by academia alone (Fig. 8.4). Most papers (64) involved SPIs with two-way communication between scientists and policymakers, typically with multiple rounds of presentation and feedback. The second most common means of communication was a linear style of one-way communication from scientists to policymakers or vice-versa (12) (Fig. 8.5). Some SPIs used both collaborative and linear means of communication.

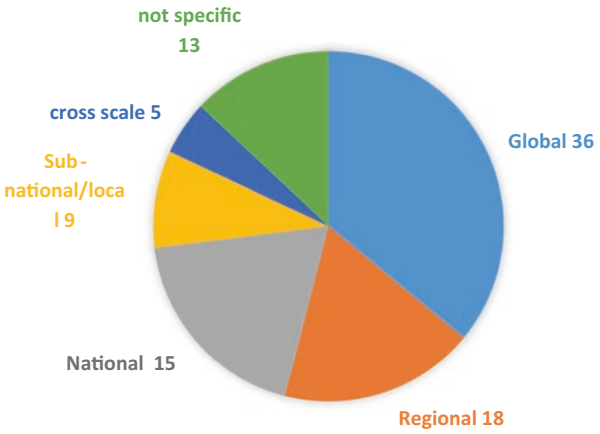

Fig. 8.2 Geographical scale of SPI studies

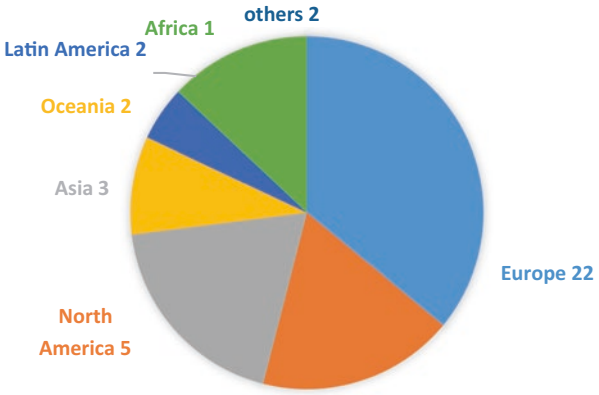

Fig. 8.3 Regional balance of SPI studies

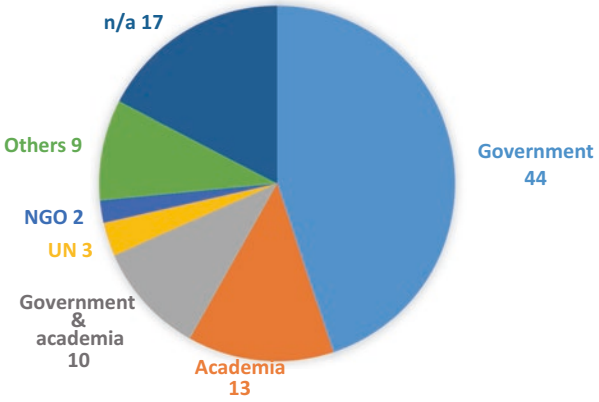

Fig. 8.4 Facilitators of SPI

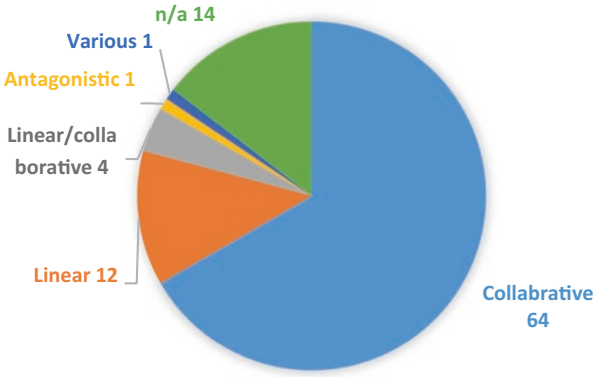

Fig. 8.5 Way of communication in SPI

8.3.2 SPI Features

8.3.2.1 Overview

Challenges and Possible Solutions

Of the 96 articles relevant to our review, 77 discussed the challenges faced, and the possible solutions provided, by SPIs. Some of these identified more than one key feature of the SPI studied; therefore, the total number of features mentioned does not match the total number of articles reviewed. Other 19 articles did not discuss any particular features, challenges, and possible solutions of SPIs. Of the 77 articles analysed, 45 articles discussed challenges and possible solutions in the SPI *process*, specifically in terms of capacity building (18 studies), trust building (16), adaptability (12), continuity (10), horizon scanning (9), and conflict management (5) (Fig. 8.6). Challenges and possible solutions regarding SPI *structure* were discussed in 34 articles, mostly in terms of participation (29). Nineteen articles discussed SPI *output* challenges and possible solutions, with relevance of outputs (12) being the most frequently assessed output component. Challenges and possible solutions related to SPI *goals* were least frequently covered in the literature (only 11 studies), especially in terms of the drivers of the SPI development (e.g., whether it was set up due to policy demand, research interest, or new emerging issues) being evaluated most often (7 studies).

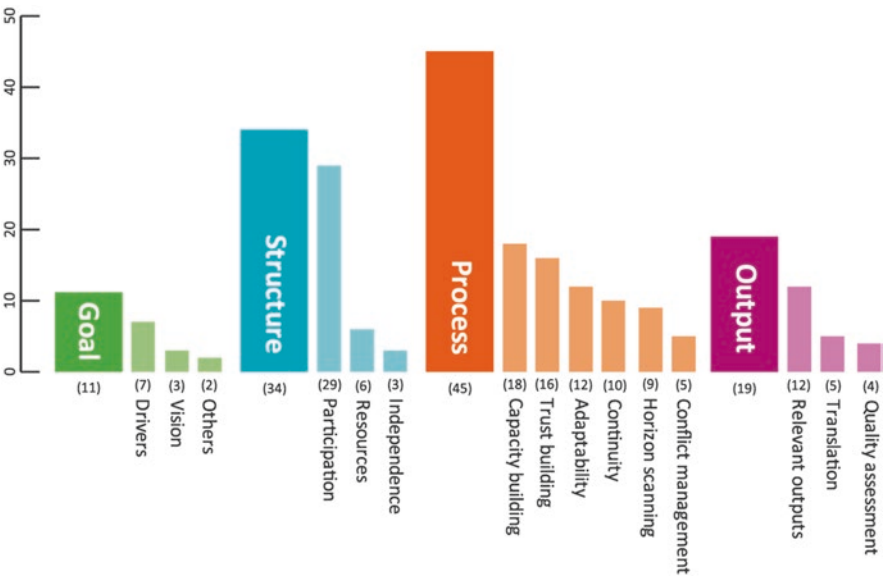

Fig. 8.6 Key SPI features recognized in the articles

Table 8.2 Key challenges and possible solutions identified in the reviewed articles

	Challenges	Possible solutions
Goal	• Identification of key research topic	• Joint formulation of research and policy between researchers and policymakers
	• Goals and objectives of SPI is not clear	• Developing and adjusting clear goal and priority of SPI for participants
Structural	• Assembling a range of knowledge holders and experts relevant to topics	• Formation of SPIs with transparent and open structures
	• High level of complexity of decision-making	• More engagement with social sciences
	• Need to ensure a sound scientific basis of SPI	• Collaborative interdisciplinary teams and involve scientists, policymakers, legal experts, and practitioners from various fields/sectors on board
	• Fragmentation of group of interests of the members involved in SPI	• Establishment of a discussion platform among different stakeholders
		• Putting in place structures and incentive schemes that support long-term interactive dialogue
Process	• Overcoming silos between decision-makers and scientists	• Adequate capacity building for both scientists and policymakers to understand the different processes in which each of them work
	• Appropriate handling of socio-ecological complexity and political dimensions	• More engagement with social sciences
	• Timely provision of consolidated view for decision-making	• Enhancing national level of capacity including data collection and technical skill
	• Better communication between policymakers and scientists and addressing or communicating the uncertainty of science	• Engagement of policymakers in research projects
	• Striking an appropriate balance between scientific complexity and over-simplification	
	Improvement of data collection and use	
	• Lack of common language or philosophies between scientists and policymakers	
Outputs	• Making scientific output policy relevant	• Integrating knowledge more with social science including socioeconomic impacts
	• Transforming knowledge between different communities	• Production of highly relevant outputs of SPIs
	• Need to strengthen scientific basis	

Many SPI studies (29) mentioned participation as a key challenge of SPI structure. Capacity building (18 studies) and trust building (16 studies) were also described as key challenges. Table 8.2 summarizes the common challenges and possible solutions identified in the reviewed papers.

Outcomes

Of the 96 relevant articles, we identified 42 that examined how the goals, structure, process, and output of existing SPIs affected the wider outcomes of the SPI process. In the 42 articles, we identified 92 cases in which outcomes were reported. Among the four SPI features, the SPI process was by far the most studied (52 cases), followed by structure and output. These results were quite similar to those related to SPI challenges and solutions, with process and structure being among the most discussed in relation to outcomes. The relationship between SPI goals and outcomes was the least studied (only 6 cases). As for the types of outcomes investigated, social learning and policy impacts were most studied (Table 8.3). Table 8.4 summarizes different efforts and tools falling under the four SPI feature categories and their outcomes, drawn from our systematic review. These are described more in detail in the following four sections.

8.3.2.2 SPI Goal

Some of the common challenges to achieving the goals of SPIs included the identification of relevant research topics (Pullin et al. 2009; Vohland et al. 2011; Sarkki et al. 2013) as well as a lack of clarity about what these goals and objectives should be (Chapple et al. 2011; Kim et al. 2016). The most common possible solutions identified for overcoming these common challenges included joint formulation of research that would produce science to inform policy, by scientists and policymakers (Noss et al. 2009; Pullin et al. 2009; Ferreira et al. 2012; Sarkki et al. 2013; Young et al. 2014; Chaves et al. 2015; Nesshöver et al. 2016), and developing and adjusting clear goals and priorities of SPIs among different stakeholders at the initial stage of the SPI formulation (Kim et al. 2016). In a survey of the scientific community on the need and possible options for a science–policy platform, many

Table 8.3 Number of the cases of causal link between the four SPI features and outcomes

	SPI outcome subcategory				
SPI feature category	Social learning	Policy impact	Biodiversity impact	Others	Subtotal
Goal	1	4		1	6
Structure	8	5		4	17
Process	23	22	1	6	52
Outputs	3	7	1	6	17
Total	35	38	2	17	92

Table 8.4 Summary of causal link between the four SPI features and their outcomes

SPI features	SPI approaches and tools	Outcomes
Goal	• SPI with clear political mandate	• Higher likelihood of policy uptake
	• Pluralistic and relatively open political structure	• Enable science to frame problems for policies
	• Balance between policy-led and science-led approaches	• Science helps form new priorities, and science responds to imminent policy needs
	• Scientists' and policymakers' joint effort	• Identify priority issues, deliver consolidated knowledge to support policies, and identify research gaps to address emerging issues
Structure	• Balanced participation across space and disciplines	• Sound spatial and disciplinary representation in SPI deliverables
	• Boundary object/participatory assessment	• Trigger diverse stakeholders to work collectively and to share understanding
	• Transdisciplinary institution	• Use of credible scientific results in policies
Process	• Clear protocols and higher transparency	• Create long-lasting mutual trust and learning environment
	• Regular face-to face interactions between science and policy; inclusion of policymakers in research projects	• Enhance mutual understanding between policymakers and researchers
	• Acknowledge and spur the enthusiasm of diverse participants	• Integrate different forms of knowledge and use them in decision-making
	• Adaptive learning by doing framework	• Use of research results in management
Output	• Strengthen social science engagement	• Respond to policymakers' need for identifying effective policies
	• Knowledge synthesis, e.g., policy briefs, white paper, database, red-listing	• Policy changes

respondents considered decision-making (i.e., policymaking) to be complex, iterative, and often selective in the information used. The authors concluded that joint formulation of policy would be preferable (Young et al. 2014).

In terms of the contributions of SPI goals to outcomes, most studies (four of five) investigated how the goal features were related to policy impacts. Sarkki et al. (2013) found a higher likelihood of policy uptake of the findings and recommendations from SPIs with a predetermined political mandate, referring to experience from the Intergovernmental Panel on Climate Change (IPCC). Conversely, pluralistic and relatively open political structures and processes were found to enable scientists to better identify and prioritize problems for policies (Tzankova 2017). Thus, both policy-led and science-led approaches have merits, where science can help identify new priorities while responding to existing policy needs (Sarkki et al.

2013). This is well supported by López-Rodríguez et al. (2015) and Nesshöver et al. (2016), who noted the contribution of scientists' and policymakers' joint efforts to identify priority environmental issues, delivering a consolidated body of scientific knowledge to support relevant policies, as well as to identify research gaps to address emerging issues. This also applies to ecosystem management. Drawing on their experience with scientists' engagement in the management of Greater Blue Mountains World Heritage Area in Australia, Chapple et al. (2011) emphasized the importance of the collaboration and information flow between scientists and managers to collectively define problems and management objectives that guide research directions and uptake.

8.3.2.3 SPI Structure

The most common challenges to structuring SPIs included assembling a range of knowledge holders and experts relevant to topics (Ferreira et al. 2012; Plant and Ryan 2013; Spranger et al. 2014; Schewenius et al. 2014; Hauck et al. 2014; Walther et al. 2016); the high level of complexity of decision-making processes (Young et al. 2014; Tzankova 2017); and the need to ensure a sound scientific basis of the SPIs. A lack of incentives for scientists and policymakers to participate in SPIs (Granjou and Mauz 2012; Sarkki et al. 2013) and fragmentation of interests of the members involved in the SPIs (Gustafsson and Lidskog 2013; Hauck et al. 2014; Arpin et al. 2016) constitute further challenges.

In terms of solutions to these problems, the formulation of SPIs with transparent and open structures was frequently identified as a solution. For example, Arpin et al. (2016) found that the major challenges in the process of establishing IPBES were handling the fragmentation and plasticity of the group of interest involved in the institutionalization process, and the 'exercise of an art of having everybody on board through techniques of inclusiveness' was a key to success. Many studies observed that, in order to tackle complex and multidimensional issues of biodiversity, it is vital to have collaborative interdisciplinary teams and to involve scientists, policymakers, legal experts, and practitioners from various fields/sectors (Srebotnjak 2007; Koetz et al. 2008; Arts and Buizer 2009; Mishra et al. 2009; Blythe and Dadi 2012; Ferreira et al. 2012; Kueffer et al. 2012; Paloniemi et al. 2012; Giakoumi et al. 2012; Ardoin and Heimlich 2013; Gustafsson and Lidskog 2013; Keune et al. 2013; Young et al. 2014; Hauck et al. 2014; Chaves et al. 2015; Sarkki et al. 2015; Andaloro et al. 2016; Arpin et al. 2016; Kovács and Pataki 2016; Walther et al. 2016). Kueffer et al. (2012), noting the complexity of problems, and impartiality of expertise and salience of knowledge which impede effective research for sustainable development, found that one solution is to conduct research in interdisciplinary teams, forming research partnerships with actors and experts from outside academia, and framing research questions with the aim of solving specific problems. In order to do so, Seddon et al. (2016) suggested that ecologists and conservation biologists need to engage much more strongly with, and draw on, the social sciences as well as the humanities. It was also considered critical to establish a discussion plat-

form among different stakeholders (Sommerwerk et al. 2010b; Cil and Jones-Walters 2011; Thomas et al. 2012; Mace et al. 2013; Spranger et al. 2014; Schewenius et al. 2014; Garibaldi et al. 2017). Putting in place structures and incentive schemes that support long-term interactive dialogue, such as new network opportunities, recognition in an academic society, access to funding and others (Granjou and Mauz 2012; Young et al. 2014; Hauck et al. 2014; Carmen et al. 2015; Santos and Pierce 2015; Sarkki et al. 2015; Nesshöver et al. 2016) was another possible solution to address these challenges.

In order to address these challenges and secure sound participation among different stakeholders in long term, trust building in the SPI process is important to facilitate engagement with social scientists, multiple sectors of governments, practitioners, private sectors, and others. To ensure participation from local and indigenous communities, capacity building and different communicative forms are vital at the same time. Kim et al. (2016) stated that increased participation, per se, does not guarantee the achievement of ethical-moral imperatives (people should have a say in decisions affecting them) or instrumental outcomes such as improving people's ownership and acceptance. To address structural challenges of SPIs, they also pointed to the question of *how* the process was conducted as also being important. And it is affected by institutional culture, transparency, flexibility, and capability for implementation. Mielke et al. (2017) evaluated stakeholder involvement practices in science and concluded that 'more conceptual exchange between practitioners, as well as more qualitative research on the concepts behind practices, is needed to better understand the stakeholder–scientist nexus'. Active engagement of stakeholders with a range of relevant expertise and interest will help an SPI to better handle the socio-ecological complexity and political dimensions of biodiversity-related policy-making. Further, improvement of SPI processes including trust building, continuity, capacity building, and adaptability will also lead to more robust SPI structure (e.g., resulting in more active participation within the SPI). This demonstrates the dynamic relationship between 'structure' and 'process' of SPIs. So, to promote more meaningful and continuous participation in biodiversity SPIs and better SPI structure, it is not enough to invite experts and stakeholders from different sectors to participate in SPIs, but also to secure continuous, trusted, and adaptable SPI processes.

In terms of how the structure of SPIs can contribute to specific outcomes, most studies focused on their social learning impacts (8 out of 17) and policy impacts (5 out of 17). As for social learning, participatory assessment, e.g., biodiversity assessment that involves various stakeholders including scientists and policymakers, can be used to generate comprehensive evidence and underpin shared understanding among stakeholders (Garibaldi et al. 2017). Sarkki et al. (2013) reported that the participation of governments in the IPCC decision-making process increased their likelihood of referencing the IPCC assessments in their policies. Regarding policy impacts, Kovács and Pataki (2016), drawing on their observation of the early-stage development of IPBES, highlighted the need for diverse and balanced participation of experts across regions and countries to ensure the representation of place-specific knowledge in global- and regional-level assessments. Balanced participation was also found to enhance legitimacy in priority setting (Kim et al. 2016). Diverse par-

ticipation allows for bridging of knowledge and skills between experts and public beyond traditional boundaries (Carmen et al. 2015; Andaloro et al. 2016). Transdisciplinary SPIs at regional, national, and local levels saw several cases of success in policy uptake. These included the use of scientific results to define the limits of emission values, best available techniques, and economic instruments under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) (Spranger et al. 2014); the development of England's national biodiversity strategy building on the national ecosystem assessment report delivered by a team of multidisciplinary experts and policymakers (Watson 2012); and the integration of science–policy activities under the International Commission for the Protection of the Danube River (ICPDR) (Sommerwerk et al. 2010a). Problem-oriented and interdisciplinary research and partnership were found to drive transitional change of academic culture (Kueffer et al. 2012).

8.3.2.4 SPI Process

Overcoming silos between decision-makers and scientists (Tinch et al. 2016; Carmen et al. 2015; Lidskog 2014; Sanguinetti et al. 2014; Sarkki et al. 2013; Ruckelshaus et al. 2015; Aslaksen et al. 2012; Koetz et al. 2012; Naylor et al. 2012; Noss et al. 2009; Srebotnjak 2007) and timely provisioning of consolidated views for decision-making (Larigauderie and Mooney 2010b; Thomas et al. 2012; Carmen et al. 2015; Nesshöver et al. 2016) were identified as key challenges to the process of developing and maintaining SPIs. Many articles also emphasized the need for interdisciplinary SPIs to develop policies that can take into account the complexity and interconnectedness of social and ecological systems (Arts and Buizer 2009; Mishra et al. 2009; Pullin et al. 2009; Van Haastrecht and Toonen 2011; Blythe and Dadi 2012; Kueffer et al. 2012; Paloniemi et al. 2012; Keune et al. 2013; Young et al. 2014; Hauck et al. 2014; Sarkki et al. 2015; Raina and Dey 2015; Seddon et al. 2016; Chazdon et al. 2017).

One potential solution to these challenges, which was identified in several past studies on individual SPIs, could be to put in place incentives for scientists and policymakers to support their long-term, interactive dialogue as well as the collaboration of diverse stakeholders and knowledge holders. Some authors noted that contribution to better decision-making required better communication between policymakers and scientists and addressing or communicating the uncertainty of science (Opdam et al. 2009; Rodela et al. 2015; Balian et al. 2016). At the same time, the need was recognized to strike an appropriate balance between scientific complexity on the one hand and over-simplification on the other (Sarkki et al. 2013; Balian et al. 2016). Improvement of data collection and use (Ruckelshaus et al. 2015; Stephenson et al. 2015) and lack of common language or philosophies between scientists and policymakers (Borie and Hulme 2015; Rodriguez et al. 2015; Sarkki et al. 2015; Gigante et al. 2016; Tremblay et al. 2016) were also singled out as means for a better decision-making process between these two groups.

Adequate capacity building for both scientists and policymakers to understand the respective processes in which they work was stated as a key SPI process in 18 reviewed articles. For instance, discussing biodiversity data for decision-making in Africa, Stephenson et al. (2015) stressed the importance of building capacity for data collection, using tools, guidelines, and communities on biodiversity planning and monitoring. In order to promote interaction between scientists and decision-makers to improve mutual understanding in Africa, they also mentioned the need for the improvement of national, international, and cross-sectoral collaboration for biodiversity data management, and the production and use of more data-derived products that encourage data use. Ruckelshaus et al. (2015) pointed out the importance of training local experts in the use of different approaches and tools for building local capacity, ownership, trust, and long-term success. Neßhöver et al. (2013) found that, if policy requires a broad foundation and exhaustive interdisciplinary synthesis, broad assessments such as Millennium Ecosystem Assessment (MA) or The Economics of Ecosystem *and* Biodiversity (*TEEB*) would be more effective in the engagement of policymakers.

Trust building was also frequently identified (in 16 articles) as being a relevant solution to address the challenges in SPI processes, and it is closely related to capacity building. For example, to identify and overcome the numerous social, cultural, and political obstacles to effective transition of policy into action and financial resources that benefit biodiversity, Seddon et al. (2016) stated that ecologists and conservation biologists need to engage much more strongly with, and draw on, the social sciences and the humanities.

In terms of the contributions of SPI processes to outcomes, most studies described the social learning (23 of 52) and policy impacts (22 of 52) in an inseparable continuum. Tinch et al. (2016) found that long-lasting mutual trust and a learning environment were vital to generate positive SPI outcomes including social learning and policy impacts, drawing from a review of ten SPIs at national, regional, and global levels. Clear procedural protocols and higher transparency in SPI process were found to also enhance mutual trust (Kim et al. 2016). Regular face-to-face interactions between scientists and policymakers (Balian et al. 2016), as well as their exchange in the upstream of the research project design process (Neßhöver et al. 2013), can enhance mutual understanding between policymakers and researchers and accelerate the flow of scientific knowledge into policies and practices, and the inclusion of policy perspectives into research projects. Such a reciprocal and iterative process helps policymakers understand and deal with uncertainties, and strengthen learning in and policy relevance of SPI (Sarkki et al. 2013; Balian et al. 2016). In doing so, it was recommended to acknowledge and spur the enthusiasm of various participants to bring different forms of knowledge together and to integrate knowledge in decision-making (Carmen et al. 2015). Ruckelshaus et al. (2015) suggested the need for focused capacity building for local experts on the approaches and tools to enhance local capacity, ownership, and trust, which helps integrate local values in biodiversity planning. Sarkki et al. (2013), on the other hand, were of the opinion that scientists need to be better aware of the cycle of the policy process that they intend to influence. All in all, continuous interaction between scientists and

policymakers from an earlier stage supports more targeted and timely inputs of quality knowledge from scientists in policy cycle (Sarkki et al. 2013; Balian et al. 2016), and an adaptive process would enable appropriate response to changing policy needs and to help shape next generation of policy questions (Sarkki et al. 2013). In policy implementation, an adaptive 'learning by doing' framework was considered to enhance the use of research results (Chapple et al. 2011).

8.3.2.5 SPI Output

Common challenges related to the outputs of SPIs included making scientific outputs policy relevant (Mishra et al. 2009; Vohland et al. 2011; Balian et al. 2016; Donohue et al. 2016; Nesshöver et al. 2016) and an inadequate scientific basis of outputs for policymaking (Koetz et al. 2008; Donohue et al. 2016). The production of highly relevant outputs of SPIs was most frequently cited as a solution, with the relevance of the output being enhanced typically through several rounds of communication between scientists and policymakers. For example, given the impact of conventional intensification of agriculture on biodiversity loss and greenhouse gas emission, Garibaldi et al. (2017) stated an urgent need to provide quantitative evidence of simultaneous ecological and socioeconomic impacts across the globe by alternative agriculture approaches to direct science–policy initiatives, such as SDGs and IPBES. They also proposed a participatory assessment framework as one of the possible solutions to close this knowledge gap. In Brazil, facing the knowledge gaps regarding the ecological impacts of agricultural expansion and the general disconnection between ecological science and environmental policy development processes, Joly et al. (2010) stated that the efforts to synthesize data for policymaking and state-level demand were important for the success of biodiversity conservation.

In terms of how outputs contribute to positive outcomes, most studies focused on policy impacts (7 of 17 studies) and social learning (3 of 17 studies), where social learning was described as a process leading to policy impacts. Extended peer-reviews and well-defined quality assessment process were found to enhance the learning of participants and enhance the quality of outputs (Sarkki et al. 2013; Beck 2014). Diverse ways of presenting synthesized knowledge, including policy briefs, are used as a reliable and handy evidence base for policymaking. For a decision on marine management rules, policy briefs, pictures, maps, and figures were found to be efficient translation tools for simplifying message for policymakers (Sarkki et al. 2013). The BIOTA-FAPESP programme on biodiversity conservation research in the state of São Paulo has provided research underpinning of 4 governmental decrees and 11 resolutions through its efforts to synthesize data in response to the public and state's demand (Ferreira et al. 2012). In the United Kingdom, the National Ecosystem Assessment report was referred to in the National Environment White Paper, which was used to develop a national biodiversity strategy (Watson 2012). IUCN's Red List is a good example of a credible quality SPI output which has become frequently referred to in policies as the representation of the state of biodiversity (Gustafsson and Lidskog 2013). Advancing information technologies for

knowledge integration, such as database and semantic web technologies, enable ecosystem managers to easily access expert knowledge (Blythe and Dadi 2012).

8.3.2.6 SPI Outcome

We can draw some important findings from the above analysis of the outcomes from each of the four SPI features in terms of how they can contribute to enhancing the credibility, relevance, or legitimacy in SPI. Sarkki et al. (2013) highlighted the potential trade-offs between credibility, relevance, and legitimacy in SPIs. The trade-offs, however, are highly context dependent. Our analysis identified generic approaches and tools to reconcile the trade-offs and enhance synergies between credibility, relevance, and legitimacy in SPI. Under SPI goals, scientists' and policymakers' joint efforts with their appropriate power balance can merit the synergies. As for SPI structure, transboundary institutions that ensure a good representation of policymakers, scientists, and other stakeholders in relevant and diverse sectors and disciplines can contribute to enhancing the synergies. The synergies can also be improved through an SPI process with clear protocols for higher transparency and with a mechanism to enhance the enthusiasm of various participants which will also contribute to building synergies.

8.4 Conclusion

In terms of the geographic scale and locations of the SPIs studied, we found that most were global (mainly IPBES) or regional or national SPIs in Europe or North America. Relatively few studies investigated regional or national SPIs in Asia, Africa, or South America, despite the importance of these regions in terms of biodiversity conservation. Studies focusing on the numerous SPIs related to local biodiversity conservation plans and policies are particularly scarce.

The main challenges and solutions facing SPIs are related to participation, although different terms are used to refer to it in different studies (such as 'joint', 'collaborative', 'participative', and 'involve'). Although participation is classified as a sub-feature of SPI *structure* in Table 8.1, it is a critical component of the other SPI features as well. For example, the joint formulation of research and/or policies was found to be a possible solution to overcome key challenges related to the SPI goals, such as a lack of clarity regarding the goals and objectives or missing identification of relevant research topics. In the context of the SPI structure, participation was found to be a particularly relevant sub-feature. To overcome the existing challenges such as a lack of sound scientific basis, high complexity of decision-making processes, and fragmentation of interests, a key solution proposed in many studies focuses on improving participation by establishing collaborative interdisciplinary and multi-stakeholder structures, such as committees, teams, or partnerships involving scientists, policymakers, legal experts, and practitioners. To be sustainable,

however, these participatory structures need to be based on incentive schemes that are able to support the required long-term interactive dialogue to secure continuous, trusted, and adaptable SPI processes. Finally, participatory approaches also constitute possible solutions to challenges faced in the production of SPI *outputs*, by ensuring continuous interaction between scientists, policymakers, and other possible stakeholders to overcome silos and creating participatory assessment frameworks as a possible solution to existing knowledge gaps.

Trust building and capacity building are also important, closely related, possible solutions to existing SPI challenges. Trust building facilitates the engagement of different stakeholders in participatory processes by enhancing the mutual understanding and interaction of scientists and policymakers throughout the stages of setting SPI goals, developing their structures and producing relevant outputs. Flexibility to change and continuity were also identified as relevant sub-features of SPI processes. In this regard, it is vital to ensure more dynamic, iterative, and collaborative interactions between scientists, practitioners, knowledge holders, and policymakers to identify research gaps, consolidate interdisciplinary scientific views, build capacity and long-term trust of organizations, and ultimately develop effective interdisciplinary SPIs that provide timely and relevant outputs to policymakers. Effective instruments for SPIs to deliver credible, relevant, and legitimate outcomes include ensuring a well-defined quality assessment process possibly through extended peer-reviews and the production of a knowledge synthesis that is relevant and handy for knowledge users.

It is important to note that our findings draw on a limited number of studies of a limited number of SPIs. These studies are, furthermore, skewed towards SPIs at global level and/or in Europe and North America. Further studies that empirically assess the features of SPIs and their contributions to outcomes are needed, particularly at underrepresented scales and in underrepresented regions. Further research into how SPI goals and outputs can provide solutions to challenges and lead to positive outcomes is also needed, to develop a more comprehensive choice of approaches that can generate positive outcomes at the science–policy interface.

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