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Knowledge brokering at the environmental science-policy interface — examining structure and activity

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ABSTRACT

The environmental science-policy interface, consisting of dynamic interactions between various actors, is increasingly an object of study. In this interface, new types and kinds of boundary organisations are emerging and new types of knowledge brokering are taking place. Given the increasing calls for more evidence-based policy, it is pertinent to examine what type of SPI can be identified at the national level, how knowledge is brokered in it and how boundary organisations function and are positioned within the network. To do this, we utilise a mixed method approach, combining a survey questionnaire and interviews as data collection methods with social network analysis and qualitative content analysis to examine the national science-policy interface in the environmental domain in Finland. Our results show a centralised network with weak reciprocal links. The network is centred more around knowledge brokers and users than knowledge producers. In this network, knowledge is mainly brokered through media and personal communication, with no single actor group assuming responsibility. The boundary organisation studied here engages in brokering activities and actively creates venues for knowledge brokering. Our findings are in line with previous research, demonstrating the need for further strengthening of not only the structural foundations of the science-policy interface, but also of the actors engaging in knowledge brokering.

1. Introduction

While scientific endeavours play a crucial role in discovering, understanding and comparing solutions to meet existing challenges, governing is rarely an act where scientific knowledge alone determines the outcome. There have been calls to re-examine the knowledge system supporting the use of research in decision-making for some time now (Karcher et al., 2021; Maag et al., 2018). Science and policy processes are much more nuanced, context specific and dynamic, and they often involve two-way interaction across the boundary between science and policy-making (Hoppe and Wesselink, 2014, p.74).

Hence, the science-policy interface (SPI) has become a principal concept for assessing the relationship between science and policy-making. SPI is defined as 'social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making' (van den Hove, 2007, p. 807). Furthermore, these processes can take place across a wide variety of platforms that range from informal exchanges at the level of individuals to institutionalised, formal arrangements with specific objectives for knowledge transfer (Hoppe and Wesselink, 2014).

Different types of boundary arrangements have emerged in recent years, wherein a specific knowledge broker or boundary organisation creates the conditions for interaction and knowledge exchange (Hoppe and Wesselink, 2014; Clark et al., 2016; Kirsop-Taylor and Russel, 2022). These boundary organisations have been studied as a means of demonstrating just what qualities and features appear to support or hinder interactions between actors (Hoppe et al., 2013). Knowledge brokering, the actions taking place within these boundary organisations, can be characterised as a process between the producers and users of knowledge, in which research findings are translated into meaningful policy options (Van Kammen et al., 2006), or more broadly speaking, its function is to create connections between researchers and their various audiences (Meyer, 2010). An increasing number of empirical studies have examined the SPI (Cvitanovic et al., 2015; Rose et al., 2017), particularly boundary organisations dealing with, for example, climate

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change or biodiversity policies from a sectoral perspective (Cook et al., 2013; Young et al., 2014; Rose, Assmuth and Lyytimäki, 2014, 2015; Saarela et al., 2015; Saarela, 2019).

While such points of focus yield important insights on how science is used in decision-making, there are not many studies that capture and examine how the SPI is structured at the national level. Thus, drawing on the van de Hove (2007) definition, we consider the national level SPI in the environmental domain to be the social processes between different actors, which can be facilitated by boundary organisations in those processes. These processes are dynamic, engage number of different actors, including boundary organisations that bring other actors together to disseminate scientific knowledge. Thus, knowledge brokering takes places within these processes in the form different types of knowledge sharing actions.

To examine the national SPI, we pose three research questions. First, what kind of SPI can be identified at the national level? This means mapping out which actors are connected to others when it comes to national level environmental policy-making. Second, what types of knowledge brokering actions take place? This means examining what type of actions are used to distribute and disseminate scientific information. Third, how does a forum-type broker operate within the SPI? This means identifying the position of a boundary organisation in the SPI and considering its role in knowledge brokering. To answer these questions, we adopt a mixed method approach and use two different sets of data of quantitative social network and qualitative interview data from environmental domain at the national level in Finland.

2. Framing the science-policy interface and knowledge brokering

2.1. SPI as a network

Turnhout et al. (2007) have described the SPI as a 'fuzzy boundary area where science and policy overlap'. This interface between science and policy has been interpreted both as a formally institutionalised setting as well as a more a more informal relationship, one taking place at the micro, meso or macro level (Hoppe and Wesselink, 2014). Examples of formal arrangements include the different types of environmental assessments required by law (Sundqvist et al., 2015). Additionally, more informal exchanges can take place through personal connections or through different types of information-sharing platforms. Thus, the idea of an interface highlights the flexibility and the range of characteristics in the area between these two seemingly separate domains. The rules and institutions emerging from the science domain have influenced policy, and vice versa. The two domains are not divided by clear, insurmountable borders (Rip, 1997; Guston, 2001).

When seeking to understand this interface, it is important to consider the context within which the interactions between different actors take place because the context also affects the activities within that particular interface (Reed et al., 2014). For this reason, science and policy and the interface between the two domains can be understood as a social network (Kelemen et al., 2021, Brockhaus, 2014, Martinuzzi and Sedlacko, 2017). Social networks are dynamic and change over time, and the change is driven by both social structures and social forces (Batagelj et al., 2014). Social structures consist of regularities in the patterns of relations among concrete entities (Hollstein et al., 2017; Knoke and Yang, 2008). An entity may be, for example, a person, an organisation, an institution or even a nation-state (Knoke and Yang, 2008; Prell, 2012).

When the SPI is understood in this way, it is possible to examine its structure, as well as the social forces influencing a science-policy network, the initial state of the social network, the model guiding the social forces and the processes by which they are created (Batagelj et al., 2014). The SPI is thus an emergent and dynamic social network of action that incorporates both the formal decision-making structures and the informal relationships and exchanges between different types of actors.

As part of these networks, boundary organisations have become a feature of environmental governance that support the use of scientific knowledge. Guston (2001) has described boundary organisations as boundary objects that sit between two different societal worlds and that manage the reciprocal networks between actors. Michaels (2009) further argues that the formation of boundary organisations arises from the motives and meaning of the organisation and that the primary tasks and purposes of a knowledge broker may differ. Their main goal may either be to *converge* or *diverge* in relation to different domains (Suni et al., 2016). A knowledge broker may fulfil different roles and tasks at a different point in time and depending on the situation (Michaels, 2009; Hoppe, 2005; Turnhout et al., 2013).

Guston has outlined (2001) the tasks of a boundary organisation as maintaining and taking care of the roles and tasks of a knowledge broker, having the capacity to bring knowledge producers and users into dynamic interaction with one another. For the interaction to be successful, a boundary organisation must create social order through providing necessary resources to both knowledge producers and users (Guston, 2001). Furthermore, effective boundary work by an organisation is comparable to the role of a 'dual agency', whereupon an agent simultaneously produces knowledge and social order (Latour, 1987).

To operationalise this research and analyse the SPI empirically, we consider it necessary to map out which actors are connected to others when it comes to national level environmental policy-making (RQ1). In terms of methodological approach, we use Social Network Analysis (SNA), which is commonly used in different fields of science to measure and map social relations and the flows that occur between people, groups, institutions, organisations and systems (Borgatti and Lopez-Kidwell, 2014; Prell, 2012). These actors form a social network that can be studied from different perspectives. A social relation may, for example, be formed by transferring money, knowledge or foodstuffs (Knoke and Yang, 2008; Prell, 2012). More specifically, and in line with previous research, we focus on identifying the density of the network and its structure to assess how it is constructed and whether any links exist indicating that knowledge brokering is taking place. We also focus on activities within the network by identifying the kinds of activities that the network is based on. Furthermore, we study the role of Forum for Environmental Information (FEI) by using the SNA to examine the density of the network and the position of the FEI within it as well as its connections to the network. We also use questionnaire data to understand how different stakeholders see the role of the FEI in the network.

2.2. Knowledge brokering

Scientific knowledge is translated into usable knowledge within the SPI, meaning that knowledge is brokered in this interface (Turnhout et al., 2007). Knowledge brokering can have multiple goals, and it is most often seen as a means to enhance evidence-informed policies (Michaels, 2009; Van Kammen et al., 2006). According to Fazey et al. (2013), the term highlights the deliberations taking place between different parties and mediation by a third party to resolve difficulties in communicating between two cultures.

Knowledge brokering can be done by the knowledge producer, the knowledge user or a third outside party, a designated knowledge broker (Bielak et al., 2008; Meyer, 2010), who is responsible to both the scientific community and policymakers (Van Kammen et al., 2006). To put it simply, in knowledge brokering knowledge is moved and connections are created between researchers and their stakeholders (Meyer, 2010). Knowledge brokering can enhance and alter different dimensions of the knowledge system: it can create substantive knowledge, it can cause knowledge-based networks to 'multiply, disseminate and expand knowledge', and it can also enhance the abilities of the system to adapt and build knowledge. Rather than simply 'pushing science to undefined audiences', knowledge brokering also aims to enhance the generation, dissemination, and eventual use of knowledge (Meyer, 2010). Knowledge brokering enhances the production of information relevant to

decision-makers, the utilisation of research by the policy domain (Van Kammen et al., 2006) and appreciation of new knowledge by decision-makers (Michaels, 2009).

Turnhout et al. (2013) have divided the actions involved knowledge brokering into three categories: supplying, bridging, and facilitating. With supplying, the relationship between science and the rest of society is mostly linear: knowledge production and utilisation are considered different domains, and the actions undertaken do not aim to blur the borders separating the two domains. Actions are passive in nature; the knowledge broker can put the different actors together but does not aim to impact the process (Turnhout et al., 2013). With respect to bridging, the broker has a more active role, and the interactions that shape knowledge brokering are more intense. When compared to supplying, stronger emphasis is put on the process with bridging. The most 'intense' form of action takes place within the facilitating category (Turnhout et al., 2013), where knowledge production and utilisation are integrated. Designing a good knowledge creation process to find solutions to a problem is given a more substantial role in facilitating than in the other two categories. Turnhout et al.'s (2013) division is done based on the perspective of a relation between the science and policy domains. Knowledge brokers with a certain conception of the relationship between science and policy domains are most likely to engage in a certain set of activities. It is important to note that the framework addresses different roles that knowledge brokers employ based on different structures in the process, such activities, and roles performed by other actors in the same process (Ward, House, and Hamer, 2009). A knowledge broker can employ one or more of these repertoires during the same process, switch between roles in different processes or strongly relate to only one repertoire.

Furthermore, Mitton et al. (2007) have divided knowledge brokering into promoting and hindering factors at four different levels: the individual level, the organisational level, the communication level and the time or timing level. Mitton et al.'s (2007) review study focused the main barriers and facilitators found in the literature on knowledge transfer and exchange. The terminology in this research is altered from the original study from barriers to hindering factors and from facilitators to promoting factors (borrowing the terminology from e.g., Cameron and Lart (2003) and Schildkamp et al. (2017) in a knowledge brokering process. On the individual level, they find ongoing collaboration, respect for research, networks, the building of trust and clear roles and responsibilities being the most important facilitators (Mitton et al., 2007). Most important barriers have to do with a lack of experience and capacity to assess evidence, mutual mistrust, and negative attitudes toward change. On the organisational level, most important barriers have to do with an unsupportive culture, competing interests, the researcher incentive system, and frequent staff turnover. Significant facilitators include the provision of support and training (capacity building), sufficient resources, authority to implement changes and collaborative research partnerships (Mitton et al., 2007).

We empirically examine what type of actions are used to distribute and disseminate scientific information at the SPI in Finland (RQ2). We further identify the position of a boundary organisation in the SPI and consider its role in knowledge brokering (RQ3). We use the three categories suggested by Turnhout et al. (2013) to analyse the actions that different actors take and what kind of role they consider other actors to have. Additionally, we employed the hindering and promoting factors identified by Mitton et al. (2007) to analyse which factors are evident in the SPI that we studied.

3. Material and methods

3.1. Case study justification

We chose to focus on the national level SPI in Finland as a case study (Yin, 2017) for three reasons. *First*, environmental governance in Finland has recently started to address the science-policy gap by evolving towards a more interactive form of engagement (Saarela, 2020, p. 54). Researchers and policymakers have started to acknowledge that bridging the science-policy gap requires different kinds of interactions at and across the border of science and policy in Finland, and these collaborative SPI processes are being welcomed both by researchers and policymakers (Saarela, 2020). It is also recognised that neither policymakers nor researchers necessarily have the required competencies to take on these roles (Saarela, 2020).

Second, we wanted to examine a case with a boundary organisation that acts as a knowledge broker for environmental issues at the national level. A forum is one type of model for a boundary organisation that often includes actors on both sides of the border. The model provides a framework for the efficient co-creation of sustainable knowledge (Kaaronen, 2016). The FEI was established in Finland in 2010 to promote the utilisation of environmental knowledge in decision-making and to increase interactions between knowledge producers and knowledge users, and it is funded by private foundations.

Third, Finnish society is not very hierarchical, and it is possible to approach decision-makers in ministries and in parliament via a phone call or direct messages. The lack of a strong hierarchy may enable and support a functional SPI, where open dialogue and co-learning between researchers and policymakers is possible.

3.2. Data collection and analysis

Given our that our interest is in both understanding the network of social processes, i.e., the SPI, its actors and the knowledge brokering that takes place in it, we operationalised this research with a mixed method approach and use the methods to examine the structure and process simultaneously. We chose a mixed methods approach because of data expansion and complementarity (Johnson and Onwuegbuzie, 2004). We consider expansion to mean in this case that by using two methods we expand the range of research with different methods to capture both the structure of the social processes (social network) and the actions in it (knowledge brokering). With complementarity, we consider that the results of both methods observed together enhance and elaborate the results since one data set could not comprehensively answer this question.

Our mixed methods approach two data collection methods and qualitative and quantitative content analysis and social network analysis (see Table 1). We adopted this approach to depict the subject being studied as accurately as possible (Hollstein et al., 2017).

3.2.1. Data collection

Both sets of data were collected between January and April 2018 with frequent dialogue and communication in terms of methodological choices made by everyone on the research team during data collection and analysis. Two data collection methods were used:

Survey questionnaire: Data for the SNA was gathered using a questionnaire sent to approximately 300 people who use, broker, or produce

Table 1
Research approach.

	Data collection method	Data analysis method
Research question		
RQ1 What kind of SPI can be identified at the national level?	Survey questionnaire	Social network analysis (SNA)
RQ2 What types of knowledge brokering actions take place?	Semi-structured key informant interviews	Descriptive statistics, qualitative content analysis
RQ3 How does a forum-type broker operate within the SPI?	Survey questionnaire, semi-structured key informant interviews	Social network analysis, descriptive statistics and qualitative content analysis

scientific environmental knowledge in their daily work. Altogether, 88 people from 37 organisations completed the questionnaire, a 29.33 % response rate. They represented multiple sectors in the environmental field in Finland: foundations, research institutions, media persons, expert panels, science journalists, government officers and municipal decision-makers. The questionnaire was addressed to individuals and the results were analysed at the organisational level and the respondents were aware of the fact they were answering on behalf of their organisations. The participants described whether they were responding as 1) a producer or 2) a broker of scientific environmental knowledge, 3) a public officials, 4) a decision-maker or politician, or 5) other. We distinguish between public officials as civil servants who work in government ministries under the political steering of the political parties in power. The representatives of these political parties are considered to be decision makers or politicians in this study.

Semi-structured key informant interviews: Altogether 18 interviews were conducted, one of which was a group interview with three interviewees. The interviews were conducted as semi-structured, key-informant interviews (Silverman and Marvasti 2008), and the interviewees were identified as key decision-makers in the field of environmental policy at the national level in Finland by the science policy experts of the FEI's steering committee. The interviewees represented different sectors of environmental governance in Finland: members of the government, members of the parliament, and government officials and civil servants involved in preparing policies and research, all of whom engaged with environmental affairs on a daily basis. The interviewees also included decision-makers in different sectors, such as foreign policy decision makers and civil servants from government ministries.

3.2.2. Data analysis

Social Network Analysis: As a first step when conducting SNA, relevant actors need to be identified to approximate network boundaries (Prell, 2012), which was done via the questionnaire and interviews. As the next step, we identified the links connecting the actors (Prell, 2012). Links may form two-way relations, which, in this study, signify environmental knowledge flowing in two directions. At this point, we formed a matrix, the basic body of the network based on the actors and their relations with one another. In the third step, we evaluated the data and characteristics of the network using UCINET, a software package for analysing social network data. Social networks can also be described through graphs, which are created using nodes and lines (Prell, 2012). We used graph theory and presented the actors as nodes and the links as lines based on valued and directed data. The density of the entire network communicating scientific environmental knowledge was further calculated using UCINET. The resulting graph presents all relations (lines) between actors (nodes), however weak or strong. The lines present in the network were categorised as weak or strong. Weak and strong lines were identified based on the questionnaire, where respondents indicated who they received environmental information from or else how they produced it. In the questionnaire, the respondents were asked to name five actors and rate their connection as weak (1) indicating occasional contact or strong (2) indicating close and constant contact. The answers were then graded, and averages were counted for each organisation. To study the position and role of the FEI in such processes, we collected attendance records from all FEI events between 2014 and 2017, a total of 45 events. We created a matrix based on this finding and analysed it with two variables.

Qualitative and quantitative content analysis: Content analysis is used to locate 'humane meanings' from data in written form (Tuomi and Sarajärvi, 2003). The meanings are located in the text by classifying large amounts of text into categories, each of which represents different meanings associated with the research topic (Weber, 1990). Content analysis allows the researcher to infer formerly unseen meanings, while assuring objective analysis of all the units. The possibility for inference allows the researcher to ask questions from the data that are not clearly visible: 'texts may become meaningful in ways that a culture may not be aware of' (Krippendorff, 2018). The analysis process here began by using the three categories suggested by Turnhout et al. (2013) as the coding scheme to analyse the actions that different actors take. We also used the hindering and promoting factors identified by Mitton et al. (2007) The different expressions of these in the data were marked using specific codes in relation to the categories. This last phase was done with the help of a computer-assisted qualitative data analysis programme (CAQDAS), Atlas.ti 8.0 (Scientific Software Development GmbH).

4. Results

4.1. Science-policy network for environmental information

Based on the survey and the questionnaire, a network illustrating the environmental SPI in Finland is presented in Fig. 1. Overall, it shows 58 nodes with 587 links, with knowledge producers denoted by pink circles, brokers by black triangles and users by blue squares. The yellow lines represent reciprocal links between the nodes, or actors. Central actors are named in the graph. It shows that the complete network is not intensely centralised, which means that the various nodes are connected to other nodes and that they share many lines of relation, indicating that information may flow along multiple pathways through the network. However, the network has inner and outer layers, in which strongly connected nodes (receiving and sharing multiple lines) are located in the inner part of the network and weakly connected nodes are located in the outer layer of the network. If the weak lines are ignored, marginal nodes lose their connections to the network, and some weakly connected nodes become marginal. As a result, the central nodes become even more central, meaning that the network becomes a more centralised one.

Degree of centrality implies popularity and prestige in a network, and it can be measured by indegree and betweenness (Borgatti and Lopez-Kidwell, 2014). The most central and powerful organisations located in the inner layer of the network that share and receive multiple lines of relation are the Finnish Environment Institute (SYKE), the Ministry of the Environment (MoE), the Natural Resources Institute Finland (Luke), the Ministry of Agriculture and Forestry of Finland, (MoAF), the University of Helsinki (UH) and the media (see Table 2). The organisations forming the core of the network (SYKE, Luke, MoE and MoAF) have the power to influence the whole network. This implies that decision-makers especially seek environmental knowledge from the government research institutes, SYKE and Luke. Even though politicians are active, politicians and decision-makers do not share noteworthy links with the actors producing environmental knowledge at the organisational level, i.e., universities and research institutions.

The whole network lacks reciprocal effects, even though many lines exist between the nodes. Occasional interactions occur, but mostly the lines run exclusively one way. This implies that the network has a dense central layer formalised by multiple actors that can reach others easily, and though information travels within the network by short paths, the central actors have the power to govern its flow. Thus, information may flow quickly across the whole network and reach all the actors in a short amount of time. Weak interaction between the actors, due to a lack of reciprocal ties, can be a concern because finding an agreement may require reciprocal effects.

Fig. 2 shows strong lines of relation in the science-policy network based on our analysis of the role of organisations (producing $n = 19$, brokering $n = 17$, using $n = 22$). When weak lines are not considered, only one strong reciprocal relation connects a knowledge producer and a user. If strong and weak links are considered, 12 links can be identified, and if weak ones are considered as well, then 118 links exist in the network. These weak links are evenly distributed between the three groups. Thus, though the network lacks strong interaction, simple communication, and a weak interaction between the three subgroups exist.

Fig. 2 also shows that knowledge brokers share more lines of relation

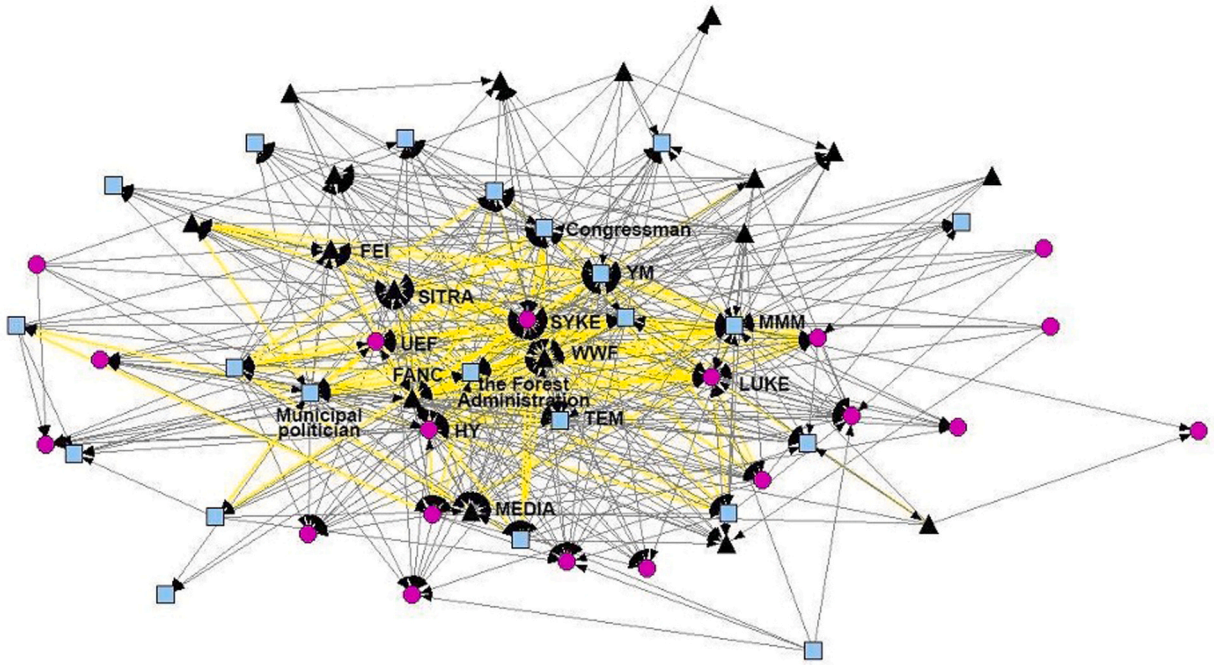

Fig. 1. The network of an environmental SPI in Finland].

Table 2
Ranking of most important actors based on centrality.

Organisation_Indeg	Indeg	Organisation_Betweennes	Betweenness	Organisation_Eigenvec	Eigenvec
Finnish Environment Institute	30	Finnish Environment Institute	287.6	Finnish Environment Institute	0.257
Ministry of the Environment	27	Ministry of the Environment	153.2	Metsähallitus	0.254
Natural Resources Institute Finland	24	Natural Resources Institute Finland	152.5	Ministry of the Environment	0.231
University of Helsinki	22	University of Helsinki	114.3	WWF	0.224
Media	22	Ministry of Agriculture and Forestry	102.2	University of Helsinki	0.221
Ministry of Agriculture and Forestry	21	Councillors of the municipalities	67.2	Ministry of Agriculture and Forestry	0.213
Sitra	19	Members of Parliament	62	Natural Resources Institute Finland	0.212
VTT	18	WWF	54.3	The Finnish Association for Nature Conservation	0.207
Prime Minister's Office	17	Metsähallitus	52.5	Councillors of the municipalities	0.205
The University of Eastern Finland	16	The Finnish Association for Nature Conservation	33.4	Members of Parliament	0.2
WWF	16	Sitra	32.5	Sitra	0.194
Forum for Environmental Information	16	University of Turku	21.5	The University of Eastern Finland	0.191
Members of Parliament	15	The University of Eastern Finland	19.9	The Central Union of Agricultural Producers and Forest Owners (MTK)	0.187
Finnish Meteorological Institute	14	The Central Union of Agricultural Producers and Forest Owners (MTK)	15.2	The Ministry of Economic Affairs and Employment	0.175
Aalto University	14	Parliamentary officials	13.5	Media	0.152

(NOTE: Indegree is calculated based on how many connections the actor receives, while betweenness is calculated based on how many connections an actor receives at the centre and the eigenvector is calculated based on the connections with an actor: the higher the value, the more often the shortest possible connection is forged through that actor. The table does not use normalised values).

with knowledge users than with knowledge producers. Additionally, knowledge producers share more lines of relation with knowledge users than with brokers. However, the knowledge brokers of the network have fewer links with knowledge users than with knowledge producers. When dividing the knowledge users into two groups, 1) a group consisting of public officials and 2) a group consisting of politicians and decision makers, we clearly see the interface within the network being studied (Table 3).

The table shows that scientific environmental knowledge does not reach politicians and decision-makers equally compared to public officials. Politicians and decision-makers share their strongest links with actors that are weakly linked to the network of scientific environmental information, and they lack reciprocal relationships in their ego networks. This means that they reach out frequently but do not maintain strong links to others. Our analysis shows that politicians and decision-makers in Finland lack links to universities, while their links to research institutes are weak, but they share stronger links to the media (knowledge broker) and to the Ministry of Economic Affair (knowledge user). In addition, knowledge produces do not reach out to other actor groups actively.

4.2. *Types knowledge brokering*

Decision-makers mostly see knowledge brokering as part of the

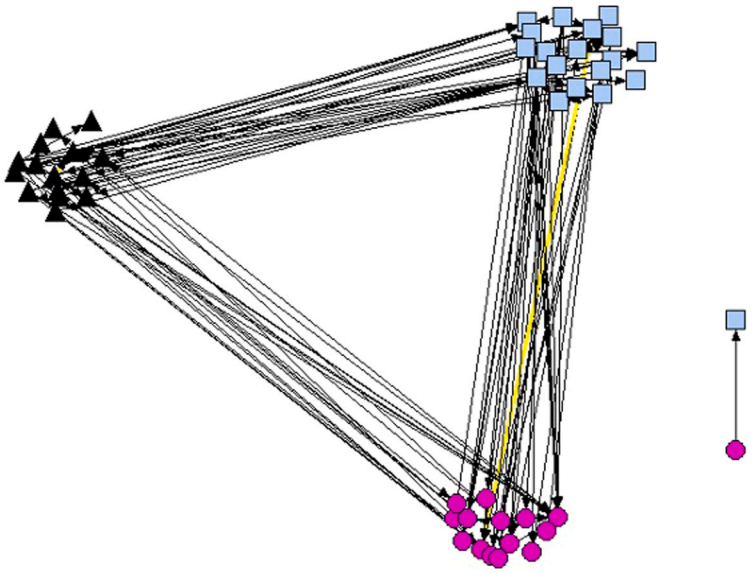

Fig. 2. Connections between three subgroups.] *Actors producing (pink squares), brokering (black triangles) or using (blue squares) scientific environmental information. Only strong lines of relation are present in the figure. Only one strong reciprocal relation exists in the network (yellow line).*

Table 3
Centrality and activity of actor groups.

Number of connections			**Number of connections**		
Role	*Indegree total*	*Average*	*Role*	*Outdegree total*	*Average*
Knowledge producer	221	11.5	Knowledge producer	171	8.55
Public official	162	10.8	Public official	177	11.8
Knowledge broker	137	8.56	Knowledge broker	146	9.13
Politician, decision-maker	36	12	Politician, decision-maker	62	20.7
Other	32	8	Other	32	8

(NOTE: Indegree is the number of connections received and outdegree number of connections forged; the average is calculated based on the number of incoming and outgoing connections)

Table 4
Types of knowledge brokering.

Categories (Number of mentions per category)	**Actions of the broker**	**Number of mentions per category** (the densest is marked with (1), followed by (2), etc.
Supplying (194)	Providing knowledge users with appropriate experts	110 (3)
	Interacting with knowledge users to know what questions need to be answered	47 (6)
	Providing knowledge users with relevant knowledge in its original form	37 (7)
Bridging (416)	Mediating and translating answers and solutions	170 (1)
	Broker persuades knowledge producers to interact with knowledge users	120 (2)
	Summarising and synthesising research and policy	107 (4)
	Broker persuades knowledge users to articulate their questions	18 (10)
	'Stepping over' any uncertainties regarding scientific knowledge	1 (12)
Facilitating (150)	Designing a good process of interaction	83 (5)
	Includes or accepts other forms of knowledge that are found to be important to find the solution	36 (8)
	Integrating knowledge production and use to create solutions for the problem at hand	24 (9)
	Motivating participant	7 (11)

bridging category (Table 4). The most common actions of the broker mentioned fell under the subjects 'mediating and translating answers and solutions' and 'persuade interactions', both of which belong to the bridging category. With respect to the supplying category, the subject 'providing experts' was brought up multiple times.

The decision-makers mostly see knowledge brokering actions as the responsibility of the knowledge producers and brokers, not as the responsibility of the knowledge user, i.e., the decision-makers themselves. Actions such as 'broker persuades knowledge users to articulate their questions' or 'interacting with knowledge users to know what questions need to be answered' received far fewer mentions than actions highlighting the role of the broker or the knowledge producer, such as the broker's role in 'mediating and translating answers and solutions' or when the 'broker persuades knowledge producers to interact with knowledge users' (see Table 2). However, it is evident that all the subgroups see the other's responsibility as being greater than their own.

The most relevant promoting factors (see Table 5) had to do with communication, such as journalistic style and the suitable formulation of the message, more specifically formulating the message concisely. For example,

> The compactness and plainness of the expressions. I'm telling you: two pages is almost already too long. And preferably two pages that are easy – [with] the main message from each section bolded. (Civil servant)

One thing that researchers ought to forget is the idea that you would somehow look down on the recipient if you tried to crystallise a few

Table 5
Hindering and promoting factors of knowledge brokering.

Hindering factors		Promoting factors	
Individual level	**124**	**Communication**	**174**
Attitudes and trust	50	Formulation	48
Lack of capacities	32	Compact communication	29
A missing expert	26	Genuine interaction	27
Fixed on one viewpoint	16	Presence in daily media	26
Organisational level	**85**	**Process-related factors**	**147**
Resources	49	Diversity	82
Strong political steering	13	Direct contact with the relevant decision-maker	21
Partiality	13	Solution-focused factors	17
No one's responsibility	10	Involvement of all participants in the process	14
Knowledge product	**65**	**Individual level**	**123**
Not robust	28	Networks	34
Depth of knowledge	9	Capacities	31
Complexity	8	Attitudes	24
Lack of synthesis	7	Close contact with policy domain	15
Communication	**64**	**Knowledge product**	**47**
Formulation	36	Synthesis	18
Quantity	16	Depth of knowledge	8
Monolog	7	Research setting is visible	7
Length	5	Quality of the research	5
Timing	**38**	**Organisational level**	**69**
Wrong timing	38	Impartial organisation	23
		Institutionalised knowledge brokerage	21
		Trust	14
		Reputation	7
Process	**8**	**Timing**	**68**
Delay between the demand and the supply	7	Current questions	39
Physical space	1	Right timing	19
		The matter is making its way onto the agenda	10

> main points. As [if] it would be polite to offer a bunch of abracadabra. (Politician)

Genuine interaction and face-to-face communication are also required. Decision-makers highlighted the importance of having a presence in the daily media as a promoting factor for knowledge brokering.

The analysis shows that the most relevant hindering factors are related to individuals, organisational factors or to the knowledge product itself. The most relevant promoting factors are related to communication, process and the individual (see Table 5). Of the promoting factors, the diversity of different types of knowledge and the diversity of various branches of science and experts, customising the information to fit the needs of specific knowledge users, a solution-focused process and involving everyone in the planning process are most important. Almost as relevant are the factors related to the individual level, such as networks, the capabilities of the knowledge broker, the knowledge user, the knowledge producer and the attitudes of the participants. Many respondents mentioned hindering factors related to the depth of knowledge: how deeply should experts dig into a specific theme during the knowledge brokering process. The analysis shows that the answer depends quite strongly on the context: some decision-makers complained of too shallow a level of information, whereas others noted that the information provided by researchers was too theoretical and detailed to be immediately relevant.

The importance of personal contact between the knowledge user and producer should not be neglected, as it contributes to networks, timing and capacities, all found to be important in this analysis. Personal contacts facilitate another crucial factor, the importance of correct timing:

> from the impact point of view, it is necessary to be on the move very early on. Probably you should take the information to some circles in the government early on, so, that the government's proposal has not been written, but it's in their heads. In the parliament, the matters are often kind of locked, [meaning] that they are not changed anymore. (Civil servant).

Personal contacts can be long-lasting and generate more contacts in the future: a great number of decision-makers highlighted that the easiest way to obtain information is through friends and former colleagues. The results highlight the significance of personal attitudes, trust and understanding the other parties' domain. In terms of hindering factors, trust emerged as an important factor again, with a lack of trust causing some to question the role of science altogether:

> And also, there has been trust in research and, overall, that trust in research, that legitimacy, has gotten weaker in this society and that is also a fact. (Civil servant).

In terms of the channels and tools they see as the most efficient, the participants noted that the presentation scientific results and interviews with researchers in the daily media are the most efficient channel for transferring environmental information into decision-making practices (Fig. 3). This point was also raised in the interviews, the significance of the media when disseminating scientific information was stressed. Second, participants mentioned different forms of face-to-face interaction as important: compact seminars around certain topics, roundtable discussions, face-to-face meetings and collaboration on projects. Third, with respect to written forms of knowledge brokering methods, policy briefs were the only format that scored well in the survey.

4.3. Role of FEI in knowledge brokering

FEI's objective is to support societal decision-making to counteract harmful environmental problems by cooperating in a broad network of those providing environmental information — with researchers from a wide range of universities and disciplines and with information users from ministries, municipalities, parliament, and companies. FEI organises seminars, workshops and small-group discussions to strengthen the interaction and cooperation between knowledge producers and knowledge users.

As discussed in Section 4.1, the network consists of two layers, a dense inner layer, and a loose outer layer. Actors in the inner layer receive and send multiple links to each other, thus being considerably tightly bound into the network. FEI is positioned in the inner layer, being a central and well-connected actor within the network. However, it is not one of the central actors in the network identified earlier in Section 4.1. It is possible to measure the level of activity of different actors in the network. An actor has a high activity score when it has a considerably high number of contacts with other actors in a network. FEI has a high activity level, and it has reached a position, where it can control the information flow, i.e., the scientific environmental information that flows through the network between the producers, users, and brokers of environmental knowledge. FEI 'sits' between multiple actors, and information flows through it. It is noteworthy that FEI does not 'sit alone' between central actors, which means that it has not yet reached a key role of knowledge broker in the network.

Moreover, the role analysis conducted with UCINET shows that FEI has a relatively minor role as an intermediary when compared to other knowledge brokers, such as the World Wildlife Fund (WWF) and Finnish Environment Institute. However, we should bear in mind that these measures concern only the flow of information. The analysis shows that SITRA as a more central boundary organisation in the network than FEI. Both SITRA and FEI are strongly connected to the network, but SITRA works closely with policymakers and may control information flow in the network better than FEI. While SITRA appears to be a more central actor in the network, FEI has tighter links with knowledge producers.

Knowledge producers were the most active group participating in the FEI events. This in interesting within the context of the entire science-

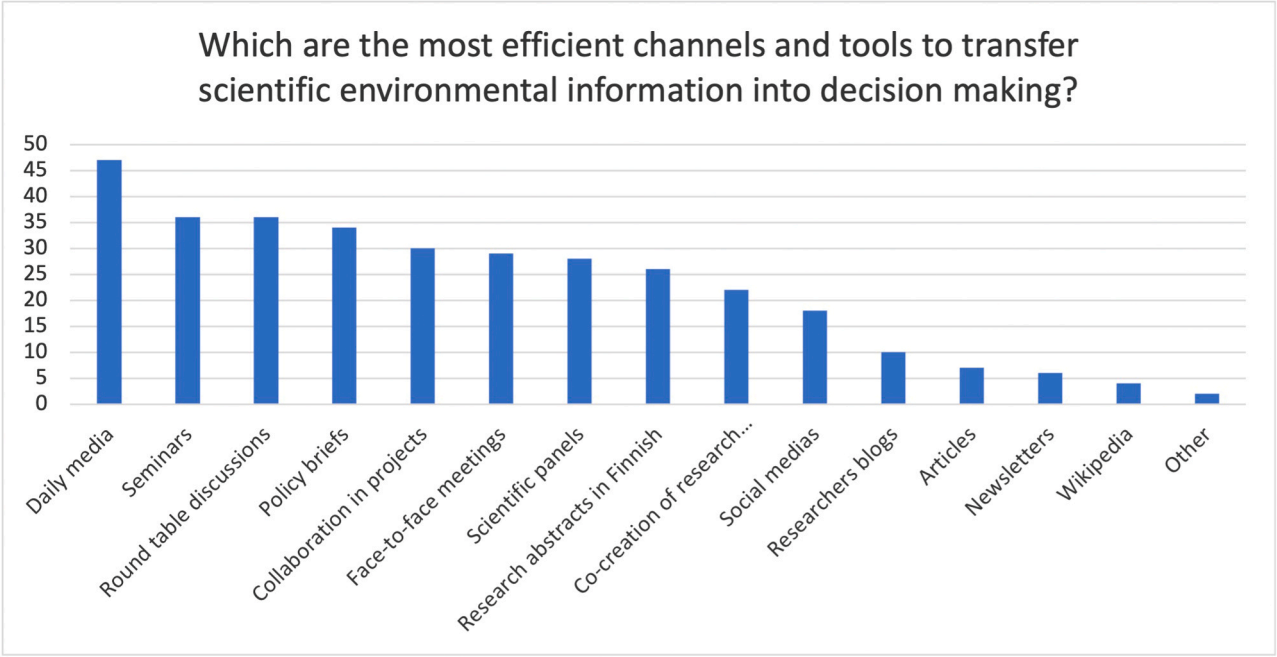

Fig. 3. Most efficient channels and tools for transferring scientific information.].

policy network, where knowledge producers are the most inactive group. This may indicate that knowledge producers need more forums where they can interact and share information and find partners to collaborate with. The effectiveness and usefulness of FEI was studied via the questionnaire (Fig. 4). According to the responses, FEI has succeeded in forwarding information between actors and organising places for different actors to meet and find new co-operation partners. However, the figure supports the above findings that decision-makers and politicians do not find FEI that useful.

5. Discussion and conclusion

We conceptualise the national SPI to consists of social processes, where actors, such as boundary organisations, are engaged in knowledge brokering. Thus, to understand the role of science in national environmental policy-making, we study the structure of network, knowledge brokering in it and the role of boundary organisations in this social network. Our results show that the network itself is composed of two layers, an inner layer and an outer layer with a very strong core of actors. The lack of strong reciprocal links illustrates that information

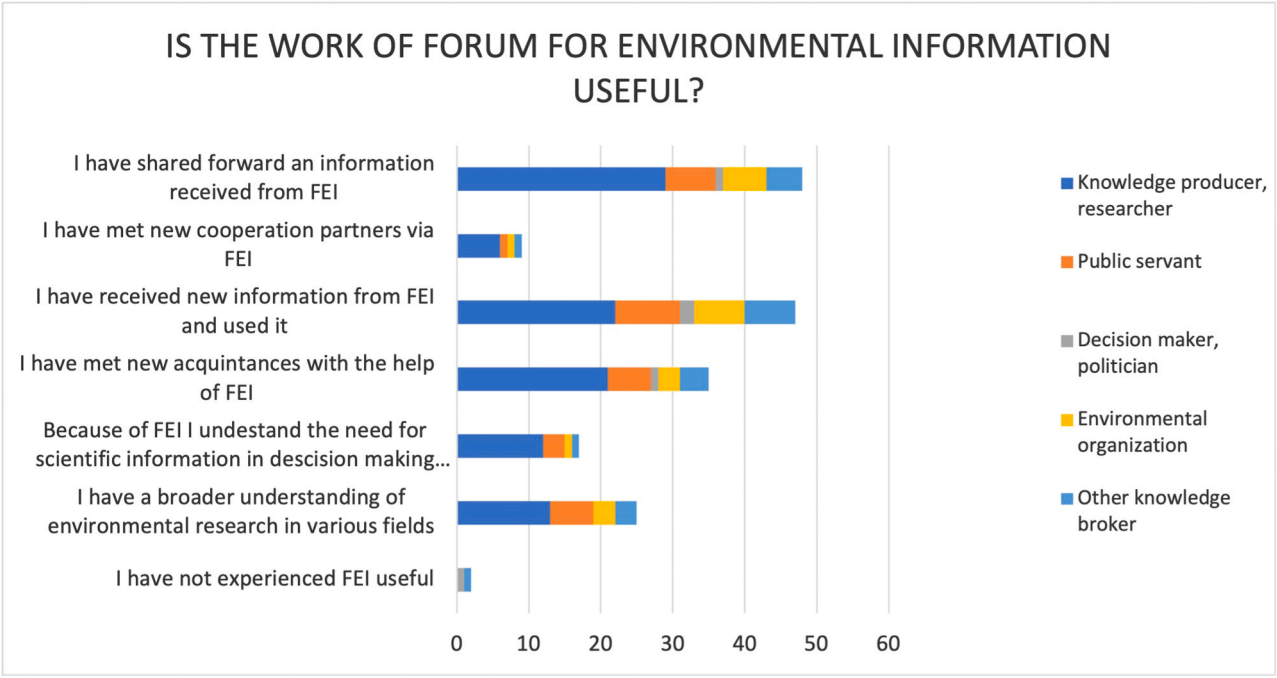

Fig. 4. Usefulness of the FEI] . *The colours illustrate each actor group: eight decision-makers and politicians, six public officials, 43 knowledge producers and two 'others' responded to the claims. Altogether, 67 people answered the questions out of a total 87 people.*

mainly flows one way, with knowledge brokers and users in closer collaboration than knowledge producers. Examining the type of knowledge brokering further demonstrates that bridging actions take precedence, while the responsibility for such actions is allocated to other groups. This means that no one actively takes responsibility for brokering knowledge. Hindering and promoting factors influence each other, stressing the importance of trust and personal relationships, and to some extent, explain why connections in the SPI network are rather weak. In terms of the channels of knowledge brokering, the media predominates, followed by face-to-face types of interactions. Policy briefs are most popular written forms of communication. In terms of boundary organisations, the FEI is an active member of the inner layer, though not the central actor. It does, however, facilitate and have closer links with knowledge producers than other boundary organisations.

The results show that Finnish policymakers seem to lack commitment to the network, and decision-makers' understanding of both how to utilise the research and of knowledge brokerage actions are quite limited compared to what is presented in the scientific literature. Our study is in line with findings presented by Cornell et al. (2013) in that decision-makers do not see themselves as actively engaged in knowledge production and rather see a clear and strong border between the science and policy domains. Thus, it is evident that one of the major roles for boundary organisations in Finland is to support policymakers in finding new contacts and to engage more with the network.

Simultaneously, our results show that knowledge producers are not active actors in the SPI either, even though they are quite committed to the network. The most important roles for knowledge brokers in the case of Finland are to facilitate and forge links between politicians and policymakers and the rest of the network and to support and assist knowledge producers in transferring scientific knowledge to other parties, especially politicians. These findings are similar to those presented in previous studies (e.g., Nutley, 2003). The activities may require that boundary organisations pursue such strategies as supplying scientific information (Turnhout et al., 2013) and engaging with other actors (Michaels, 2009).

In our study, the roles for knowledge brokers are not among the most 'intense' roles identified in the existing literature (Turnhout et al., 2007). Moreover, the need for intense boundary work is not recognised among the subcategories, even though the lack of reciprocal processes refers to its necessity. For example, even though decision-makers see knowledge brokers as necessary actors in the interface, they mostly see knowledge brokering as actions taking place as part of the bridging category (Turnhout et al., 2013). This includes syntheses of the scientific knowledge gathered and presented by an outside party. This was also confirmed by the interviews as the most beneficial form of knowledge for decision-makers and public officials However, the creation of such a synthesis requires intensive boundary work as well (Michaels, 2009; Hegger et al., 2020),

For the of intense boundary work to emerge, it may be that a cultural shift is needed within the SPI (Bielak et al., 2008), including the researchers (Ojanen et al., 2021). This study shows that there are new and unaddressed roles and positions for boundary organisations in the network, as well as for actors brokering knowledge. The lack of interaction between science and policy is evident in the network studied; thus, more knowledge brokering is needed, as is widely noted in the science policy literature (Karcher et la, 2021, Bielak et al., 2008; Maag et al., 2018; Meyer, 2010).

The SPI is strongly impacted by the actions of politicians and decision-makers since they gather information from multiple sources, with scientific environmental knowledge in the process becoming diluted with non-scientific information from other sources in their ego networks. Moreover, it seems that decision-makers do not have a clear view of their own role in the SPI and as part of a successful knowledge brokering process in Finland. The low activity rate of knowledge producers blocks the interaction between knowledge users and producers. Thus, it can be argued that the interface occurs due to a lack of reciprocal interaction in the network, as explained above, and the interface is located surprisingly close to the decision-makers and politicians. This finding, in turn, is supported by the result that communication is arguably the most popular way to promote science-policy relations but other actions that support reciprocity ought be explored also. According to our analysis, hindering and promoting factors are assessed differently, with the most important hindering factors occurring at the individual or organisational level and the promoting factors being related to communication and processes.

Our study also supports the notion of examining the SPI more as a dynamic landscape where continuous processes of knowledge brokering take place between various actors. In this case, the network centres more around knowledge brokers and users than knowledge producers, and knowledge is mainly brokered through the media and personal communication, with no actor group taking ultimate responsibility. This supports previous studies in that the relationship between science and policy is opaque and the area separating the two domains is pierced by multiple links. This further supports the notion of a boundary being replaced with an interface, described as a fuzzy area where science and policy overlap, resulting in the use of scientific knowledge in decision-making processes in various different ways. While boundary organisations engage in brokering activities, their effectiveness is not a given. Overall, our findings demonstrate the need for further strengthening not only the structural foundations of the SPI, but also the actors engaged in knowledge brokering.

CRediT authorship contribution statement

Sirkku Juhola: Conceptualisation, Methodology, Writing original draft, Writing- Reviewing and Editing, Supervision. Essi Huotari: Methodology, Investigation, Data curation, Formal analysis, Visualisation. Liisa Kolehmainen: Methodology, Investigation, Data curation, Formal analysis, Visualisation. Outi Silfverberg: Methodology, Investigation, Data curation, Formal analysis, Visualisation. Kaisa Korhonen: Conceptualisation, Writing- Reviewing and Editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

We declare no conflict of interest.

Data availability

Data will be made available on request.

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