Indicators for Measuring the Contributions of Individual Knowledge Brokers

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Abstract

An increasing number of knowledge brokers work at the interface between research, policy and practice. Their function is to facilitate processes to foster mutual learning among research, policy and practice. For some knowledge brokers, practical methodologies to assess the quality of their work is an important concern. While frameworks exist for assessing research impact at the level of a project or program, few are available for assessing contributions of individual knowledge brokers. In response to this, we have compiled a set of indicators to measure the quantity and quality of the contributions of individual knowledge brokers to projects, programs or platforms at the interface between research, policy and practice. The set is based on a review of the literature and the experience of a group of knowledge brokers active in water research and management in Switzerland, including the co-authors of this article. The set can be used by knowledge brokers to identify ways to improve the effectiveness of their practices and to demonstrate the benefit of their work to their employers and other stakeholders. Our approach is flexible enough that it can be applied where there are limited resources available for assessment.

Keywords: knowledge brokering, evaluation, contribution analysis, process indicators, attributable results indicators

29 *1. Introduction*

30 Environmental research often aims at broader impact on society and the environment.
31 However, the actual impact of such research on policy and practice tends to lag behind
32 aspirations (Campbell et al., 2015; Cornell et al., 2013; Cortner, 2000; Mauser et al., 2013;
33 Roux et al., 2006; Watson, 2017). This is partially due to the fact that knowledge derived
34 from research is just one factor among many that guides decisions of policy makers and
35 practitioners. Pressure from economic markets and civil society, personal and professional
36 values and beliefs, financial and human resource constraints, or cognitive and psychological
37 factors often influence decision-making processes more than research knowledge, thus
38 limiting the influence that research can have on policy and practice (Cairney et al., 2016;
39 Owens, 2005). However, the benefit that research could potentially provide for society and
40 the environment is also constrained by lack of productive exchange across the science-
41 policy/practice interface (SPI). Researchers are sometimes not sufficiently informed about the
42 concerns of decision makers and hence produce knowledge that is barely relevant for decision
43 makers or is poorly timed. On the other hand, decision makers are not always sufficiently
44 aware of available research knowledge or its implications (Porter and Dessai, 2017).

45 Given these limitations, it has been widely argued that more productive processes and
46 institutional arrangements at the SPI are necessary (Cash et al., 2003; Cvitanovic et al.,
47 2015b; Hering, 2016; Holmes and Clark, 2008; Jäger et al., 2013; López-Rodríguez et al.,
48 2015; McNie, 2007; Reed et al., 2014; van Enst et al., 2014). One suggested approach is to
49 invest in knowledge brokers (KBs), that is, individuals (or groups of individuals) in charge of
50 facilitating interactions at the SPI (Cvitanovic et al., 2015a; Cvitanovic et al., 2015b; Hering,
51 2016; Meyer, 2010; Michaels, 2009). In fact, knowledge brokers are active around the world,
52 not only in environmental research, policy and practice (Michaels, 2009), but also in fields
53 such as public health (Bornbaum et al., 2015; Dobbins et al., 2009; Ward et al., 2009a), or
54 education (Kitagawa and Lightowler, 2013; Whitchurch, 2009). However, empirical evidence
55 on the effectiveness of the many and varied processes facilitated by knowledge brokers
56 remains incomplete. This poses a major obstacle to the future development of knowledge
57 brokering, as only with reliable data it is possible to identify the most effective practices and
58 further refine them. KB evaluation therefore has been identified as one of the top priorities on
59 which future SPI research should focus (Cvitanovic et al., 2017; Klein, 2008; Ward et al.,
60 2009a).

In this paper, we respond to this call by presenting a set of indicators to measure the contributions of individual knowledge brokers to projects, programs or platforms at the SPI; in the following, we will refer to projects, programs and platforms simply as 'programs', acknowledging that they differ with regard to team size, time frame, level of complexity and degree of institutionalization. The special feature of our set of indicators is its focus on the assessment of single individuals. Measuring the contributions of individual KBs is a complex task given that their contributions are difficult to disentangle from those of other team members and are subject to various external factors. The challenge is to find indicators that are responsive to the actions of the individual KB and which have low sensitivity to external factors. The focus of this paper is therefore on indicators pertaining to the processes involved in knowledge brokering ('process indicators'), and indicators that reflect process results on which KBs are likely to have a decisive influence ('attributable results indicators'). For both types of indicators, we provide metrics relating to quantity and quality of the contributions. To the best of our knowledge, this paper offers the most focused set of indicators in the sense that it concentrates exclusively on attributable indicators. At the same time, it is broad in terms of breadth of KB processes covered.

Our set of indicators is primarily intended to help knowledge brokers who seek a practicable method for self-assessment. First, it can help them to identify ways to improve the effectiveness of their daily work. Second, the indicators may be useful for knowledge brokers who want to demonstrate the benefit of their work at the SPI to their employers and other stakeholders. Third, it can inspire thinking about alternative processes of knowledge brokering and the desirable characteristics of the results. The inventory of KB processes we provide, together with the indicators, may be particularly helpful in this regard. Finally, our list of processes and indicators can be used by knowledge brokers to sharpen their professional profiles and to clarify their roles vis-à-vis their peers, employers, and other stakeholders.

This article begins by discussing the various roles of knowledge brokers and the contexts in which they operate. It then explains 'contribution analysis' (Mayne, 2008; Morton, 2015) as the broader evaluation approach on which we rely and discusses the challenge of identifying attributable indicators. The subsequent section describes the materials and methods we used to compile the lists of KB processes and indicators. After we have presented the lists, we explain how they can be applied based on a stylized example from our experience. The article closes

with a discussion of the strengths and limitations of the approach and an outlook on further research.

2. What are knowledge brokers?

In the light of pressures on research to produce 'useful' knowledge to solve today's environmental problems (McNie, 2007), knowledge brokers seem to be 'on the rise' (Holgate, 2012; Knight and Lightowler, 2010; Meyer, 2010; Whitchurch, 2009, 2013). However, their profession is not yet fully established (Bielak et al., 2008; Kislov et al., 2017; Knight and Lightowler, 2010; Lomas, 2007; Meyer, 2010; Turnhout et al., 2013). Their functions and roles are often poorly specified (Ward et al., 2009a), and some lack recognition, institutional support and training (Cvitanovic et al., 2015a). Therefore, knowledge brokers are sometimes described as 'invisible' (Meyer, 2010) or 'between worlds' (Bielak et al., 2008; Lomas, 2007).

Given these ambiguities, it comes as no surprise that the literature lacks an agreed definition of what knowledge brokers are. Definitions differ in particular regarding the specific roles and functions that are ascribed to them (Cvitanovic et al., 2015b). For the purpose of this article, we define knowledge brokers as persons who facilitate processes to foster mutual learning among research, policy and practice. The ultimate goal of such processes is to catalyze positive change in society and the environment. This definition is more restrictive than some of the existing definitions in the sense that we consider facilitation a necessary element of KB roles. This implies that, according to our definition, not every person participating in a process at the SPI is a knowledge broker. Only if the person takes an active role as facilitator, he or she is considered a knowledge broker. For instance, a person from a research institute sitting on an advisory board of a government regulatory agency is taking part in a SPI activity and might contribute to a better understanding between researchers and regulators, however, we do not consider the person a knowledge broker unless he or she acts as a facilitator of the advisory board's activities. The same holds if this person gives a presentation during a congress organized by government partners, or teaches at a university or a public school. We are aware that teaching and consulting are sometimes considered part of knowledge broker roles (Meyer, 2010), and we also understand that many individuals we target with this article combine facilitation roles with teaching and consulting. However, for the purpose of this

paper, we opt for the more narrow definition in order to focus on the core KB roles and to distinguish them from other SPI activities.

Knowledge brokers facilitate a broad spectrum of processes (Bornbaum et al., 2015; Michaels, 2009; Ward et al., 2009a). Typical examples of such processes include identifying knowledge needs and gaps, integrating relevant knowledge from various sources and from different knowledge holders, creating common ground and enabling mutual learning among the actors involved, facilitating the development of knowledge products and their dissemination, organizing various types of events, or supporting evidence-based policy and practice. Knowledge brokers combine these and other processes in various ways, thus resulting in unique roles for every KB.

Knowledge brokering roles also vary according to KB's institutional affiliations (Lomas, 2007). KBs may be affiliated to institutions on either side of the science-policy/practice interface, or to a 'boundary organization'. Boundary organizations are organizations specifically designed for the management of the SPI. In the ideal case, they are equally accountable to actors on both sides of the interface and hence can act as legitimate arbitrators (Cash et al., 2003; Guston, 2001; Parker and Crona, 2012; Sarkki et al., 2015). Depending on their organizational affiliation, KBs might face insecure career prospects due to their unconventional placement between established career paths. In the academic context, rules and norms for graduation, promotion and tenure do not always fully recognize knowledge brokering as part of research excellence (Campbell et al., 2015; Falk-Krzesinski et al., 2011; Hering, 2016; Klein and Falk-Krzesinski, 2017; Ward et al., 2009a). For the latter, the current article might be of special interest because it points to ways of demonstrating the value of their work for research, policy and practice.

3. Contribution analysis and attributable indicators

Knowledge brokers are usually appointed with the ultimate goal of facilitating broader impact on society or the environment. However, it is usually very difficult to establish how knowledge brokers actually contribute to this goal, as their contributions conflate with other influences (Bell et al., 2011; Morton, 2015; Reed et al., 2014). To address the complexity of conflated influences, evaluation approaches such as 'realist evaluation' (Salter and Kothari, 2014) and 'contribution analysis' (Bannister and O'Sullivan, 2013; Mayne, 2008; Morton, 2015) have been developed. According to these approaches, evaluations should be based on

156 ‘program theories’ (Chen, 2005; Molas-Gallart et al., 2016; Rogers, 2008). Program theories
157 are sets of assumptions about the ways a particular program is assumed to achieve its final
158 goals (Morton, 2015; Rogers, 2008). They are sometimes also referred to as ‘theories of
159 change’ (Blamey and Mackenzie, 2007; Janzen et al., 2016; Mayne, 2008) or ‘impact
160 pathways’ (Douthwaite et al., 2003).

161 When developing program theories, special attention should be paid to specifying the
162 contextual factors that might influence the effectiveness and efficiency of KB processes. By
163 doing so, program theories can potentially protect knowledge brokers against unjustified
164 accusations of poor performance. Existing KB frameworks can help specifying those parts of
165 program theories that refer to knowledge brokering. For example, Ward (2017) reviewed 47
166 knowledge brokering models and proposed a composite framework based on her findings.
167 Greenhalgh et al. (2016) discuss the strengths and weaknesses of six established frameworks.
168 Further models can be found in Phipps et al. (2016), Cvitanovic et al. (2015b), Michaels
169 (2009), Pennell et al. (2013) or Van Eerd et al. (2016). Finally, Mayne (2008) explains in six
170 steps how program theories can be combined with empirical evidence to yield a ‘contribution
171 story’. The indicators we present in this paper can be used to substantiate such contribution
172 stories (Mayne, 2008).

173 One of the major challenges is to find indicators that are ‘attributable’ in the sense that
174 variation in their score can be attributed to variation in the performance of individual KBs. To
175 the best of our knowledge, this issue has not yet been addressed in the literature on knowledge
176 brokering. However, similar problems are discussed for example in the literature on
177 performance-based contracting (Nullmeier et al., 2016; Selviaridis and Norrman, 2014).
178 Attributable indicators are difficult to find because there are almost always external factors
179 beyond the control of the KB that influence the score of an indicator (Bell et al., 2011;
180 Douthwaite et al., 2003; Mayne, 2008; Morton, 2015). The indicators that are most clearly
181 attributable are those pertaining to characteristics of knowledge brokering processes
182 themselves (‘process indicators’), such as inclusiveness of the process, or clarity in
183 communication (Raitzer and Ryan, 2008; Spaapen and van Drooge, 2011). However, an
184 exclusive focus on KB process indicators is not sufficient as it is also important to know
185 whether these processes yield the assumed results. Therefore, we also consider indicators
186 relating to certain results of the facilitated processes if it can be argued that the KB has a
187 decisive influence on them. We call these indicators ‘attributable results indicators‘. These
188 include indicators relating to intangible results such as team cohesion, group learning or

common ground. But also indicators that measure characteristics of more tangible results such as knowledge products (e.g. fact sheets) or workshops can be considered attributable results indicators if KBs are centrally involved in their production. By contrast, the overall outcome and the impact of a program on society and the environment is usually not reasonably attributable to an individual KB as many other actors and external factors are at play. For this reason, we exclude indicators related to program level outcomes and impacts. Where there is uncertainty about whether a particular indicator reflects program or KB level performance, we decided to include the indicator in order to be as complete as possible.

4. Materials and methods

The lists of KB processes and indicators presented in this article are based on two sources: existing literature and the practical experience of KBs working in the Swiss water sector. The insights gained from these two sources were synthesized and refined using the iterative process described below.

To identify relevant literature, we relied on three strategies: searching electronic publication databases, investigating the reference lists of publications identified through our database searches, and following leads from the professional networks of the co-authors.

Searching the electronic databases involved querying the Core Collection of Web of Science (WoS) and Scopus. We considered not only publications from the field of environmental research and management, but also from public health. Knowledge brokers in these different fields have much in common as explained in a recent study by Phipps et al. (2017). These commonalities are also evident during knowledge brokering conferences which span the different fields, such as the K* conference held in 2012 in Hamilton (Canada) (Shaxson and Bielak, 2012) or the annual Canadian Knowledge Broker Mobilization Forum (http://www.knowledgemobilization.net/forum/). The WoS and Scopus queries targeted publications where titles, abstracts, or keywords included a core KB term ("knowledge broker" or "knowledge mobilization"), as well as terms related either to knowledge brokering processes ("roles") or indicators ("indicator" or "evaluation"). The search was limited to articles, books, or book chapters published between 2000 and 2017 in English language. The exact search strings are reported in the Supplementary Material. The queries returned 142 results (WoS and Scopus results merged). From these publications, we manually selected those where KB processes or indicators were displayed in a structured way, for example in a

table or figure, as a bullet-point list, or under sub-headings. This step reduced the number of publication to 38.

Equally important as the electronic database queries was the analysis of the reference lists of the publications already identified. This strategy allowed us to benefit from seven systematic literature reviews already published on similar topics (Bornbaum et al., 2015; Carr et al., 2012; Fazey et al., 2014; Van Eerd et al., 2016; Ward, 2017; Ward et al., 2009b; Wolf et al., 2013). It also uncovered publications that were not identified by the search terms used in our database searches. As a third strategy to complete our list of publications, we followed leads from our professional networks on relevant literature. The latter two strategies identified 29 additional publications. The full list of publications (n =38 +29 = 67) from which we extracted KB processes and indicators is shown in the Supplementary Material. Most of these publications are peer reviewed, but among them are also project and working group reports (Defila and Di Giulio, 1999; Molas-Gallart et al., 2002).

The second source on which our list of processes and indicators is based, is the practical experience of a group of 14 experienced knowledge brokers organized as a Community of Practice (CoP), hosted by the Swiss Federal Institute of Aquatic Science and Technology (Eawag). The authors of this article are also active in this group. The CoP meets three to four times per year in order to exchange experience in knowledge brokering (Hering et al., 2017; Hoffmann et al., 2017). While all members of the CoP work in the Swiss water sector in a broad sense, their specific knowledge brokering roles differ regarding the kinds of processes they facilitate and their institutional affiliations. In terms of processes, some CoP members focus more on the initiation, coordination and publication of transdisciplinary research, while others concentrate on processes aimed at evidence-based policy and practice. In terms of institutional affiliations, some CoP members work within academic institutions as leaders of applied or transdisciplinary programs, others within boundary organizations, e.g. as executive secretaries of stakeholder platforms, which are organized as associations and co-financed by actors from both sides of the SPI. The current article draws on the diversity of roles and practical experiences of this group of knowledge brokers.

The evidence gained from the literature search and the experience of the CoP members was integrated in an iterative synthesis procedure. In a first step, the co-authors compiled a relatively short and simple list of processes and indicators based on an initial review of the existing literature. This list was then extended and validated in two CoP workshops and five individual interviews with CoP members. Both, workshops and interviews, focused on the

questions: ‘What type of knowledge brokering processes do you facilitate at the interface between research, policy and practice?’ and ‘What indicators would allow you to measure your contributions?’ Between the workshops and interviews, the co-authors updated, rearranged and streamlined the lists of processes and indicators. With this procedure, knowledge from the existing literature was complemented by practical experience.

Our review of the literature and the experience of the CoP members integrates a broad spectrum of KB processes and indicators. However, one domain that is not covered, even though it could be considered part of knowledge brokering according to our definition, is commercialization support. By commercialization support, we mean advice on patents and licenses, or support of start-ups and spin-offs. We exclude this domain because these services are often provided by individuals working within university technology transfer offices who specialize exclusively on the issues involved in this process (Meyer, 2010; Vogel and Kaghan, 2001).

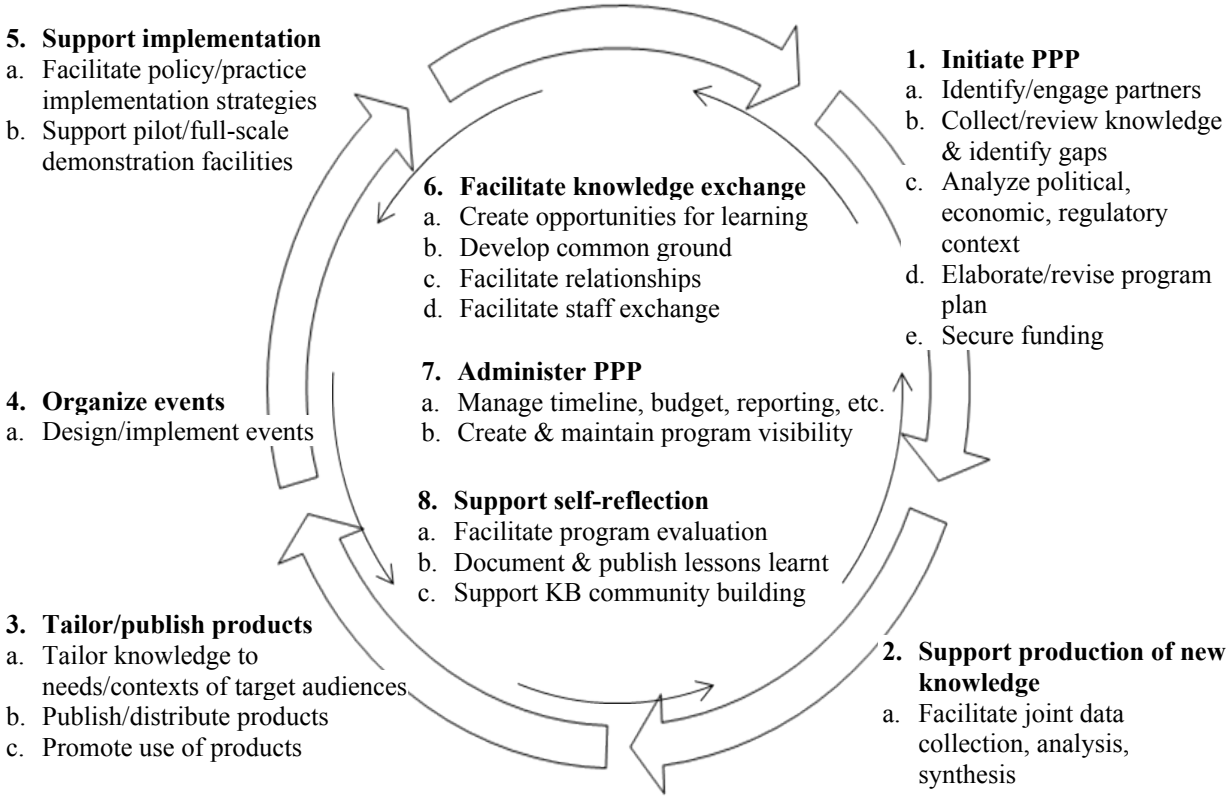
5 Compilation of KB indicators

In this section, we present our set of indicators for measuring the contribution of individual knowledge brokers. We start with process indicators and then continue with attributable results indicators.

5.1 Process indicators

KB processes can be roughly grouped into eight categories as shown in Figure 1. The figure is based on the flow diagram of Kim et al. (2018). In our figure, the outer ring of arrows represents the cyclical nature of the programs where knowledge brokering takes place. Of course, this is a highly stylized representation. In reality, the different stages of the program cycle are performed iteratively with loops and ‘jumps’ (Lang et al., 2012; Phipps et al., 2016). This non-linear aspect is highlighted by the inner circle where the arrows point in the opposite direction. In the middle of the circle are three types of KB processes that take place throughout the entire cycle of a program.

Figure 1: KB processes, arranged along the stages of a stylized program cycle.



The processes represented in Figure 1 can be assessed using process indicators. Essentially, the same indicators can be used for all processes. To quantify the amount of resources spent on the various processes, the following indicators can be applied:

- Amount of time spent on the respective process
- Number and type of internal team meetings/workshops associated with the respective process
- Number and duration of phone calls, face-to-face conversations and visits associated with the respective process
- Number and length of e-mails written in the context of the respective process
- Number of research papers/books, official documents, regulations, webpages, etc. studied in the context of the respective process

Beyond quantifying efforts, the quality of the processes can be assessed using the following indicators:

- Demonstrated use of existing knowledge of KB processes, tools and frameworks, e.g. drawing from experience from similar programs and reviews of the current program, or use of information from scientific and grey literature (on knowledge brokering, transdisciplinarity, team science, system science, science communication, evaluation, etc.)

- Perceived quality of facilitation [survey/interviews, testimonials], e.g. perceived contribution of the KB to efficient work flows (thoughtful planning, adequate timing, flexibility, efficient facilitation of meetings, etc.); perceived contribution of the KB to a transparent, inclusive, respectful process; perceived clarity and efficiency of internal communication (frequency, timing, means of communication, etc.)
- Perceptions of personal skills/qualities of the KB [survey/interviews, testimonials], e.g. motivational skills, negotiation/mediation skills, creativity and flexibility, openness and reactiveness to feedback

We suggest that surveys or interviews can be appropriate methods to evaluate indicators that refer to subjective perceptions. Surveys are structured tools for gathering information on individual perceptions and are useful to target a large number of respondents. By contrast, interviews might be appropriate if there is a relatively small number of interviewees. Respondents can be interviewed individually or in groups. We also consider an informal question to a single key person about his or her perception of some aspect of the program as a form of interview. Questions for surveys or interviews should be formulated in the context of the specific program and the aspects of the work to be assessed. Confidentiality and/or ethics should also be considered when conducting surveys or interviews with external stakeholders for reporting purposes. More information on designing surveys and interviews, as well as on ethics considerations, are available in de Leeuw et al. (2008) and Gideon (2012).

Given the considerable resources required to conduct surveys or interviews, large institutions may consider appointing a staff member or external evaluation office to undertake the task on behalf of all knowledge brokers. In smaller institutions, knowledge brokers will need to consider the trade-off between the resources required to conduct such interviews and the benefits that such assessment may bring. Under strong time constraints, assessments based on self-reflection may be the only option.

5.2 Attributable results indicators

Attributable results indicators are presented in Table 1. The left column of the table lists the processes (graphically represented in Figure 1), while the right column includes the corresponding results indicators. The numbering corresponds across the two columns. In the right column, we use letters (1a, 1b, 1c, […]) for different indicators of quantity and Roman numerals (i, ii, iii, […]) for corresponding indicators of quality.

334 *Table 1: Knowledge brokering processes (left column) and corresponding attributable results indicators (right column).*

Knowledge brokering processes	Attributable results indicators
1. Initiate the program	
1a. Identify and engage research/policy/practice partners 1b. Collect/review existing data/knowledge and identify gaps 1c. Analyze political, economic, regulatory context of the program 1d. Elaborate/revise program plan based on needs, expectations, perspectives of program partners and the wider target audience 1e. Secure funding for the program (including funding for KB processes)	1a. Teams/networks created/maintained i. Size and composition of the team/network as compared to an 'ideal' team/network ii. Level and type of contributions to the program by research/policy/practice partners iii. Persistence/stability of the team/network 1b. Number and type of reviews i. Perceived diversity/representativeness/completeness of data/knowledge considered [survey/interviews] ii. Perceived clarity of conclusions [survey/interviews] 1c. Number and type of context analyses(1) i. See (1b) 1d. Program plan elaborated i. Diversity of perspectives/expectations/needs considered ii. Perceived clarity of common objectives, deliverables, responsibilities, roles, time plan, budget, evaluation approach, etc. [survey/interviews] iii. Breadth and strength of support for the program plan from research/policy/practice partners [official commitments, survey/interviews] iv. Feasibility and flexibility of the program plan [survey/interviews] 1e. Amount and type of co-/in-kind funding granted to the program i. Diversity of funding sources

	ii. Continuing/follow-up program funding iii. Amount and type of funding granted for KB processes
2. Support production of new knowledge	
2a. Facilitate joint data collection, data analysis, synthesis	2a. Number and type of data collections[4], analyses[5], syntheses facilitated i. Number and diversity of research/policy/practice partners contributing to and/or validating data collection, data analysis, synthesis and extent/type of contributions ii. Perceived usefulness of data/analyses/syntheses for science/policy/practice [survey/interviews]
3. Tailor and publish products	
3a. Tailor knowledge to needs/contexts of target audiences & transform it into preferred format (print, online, audio, visual) 3b. Publish/distribute products 3c. Promote/monitor use of products	3a. Number and type of products developed for research[6], policy/practice[7], and public[8] i. Number, diversity of research/policy/practice partners contributing to products, and extent/type of contribution ii. Perceived usefulness of products for science/policy/practice [survey/interviews] 3b. Number and type of products published/distributed i. Circulation of print products, or number of times audio-visual media were broadcast by radio/TV ii. Quality/reputation of the publisher/outlet (rankings, impact factor, etc.), size and composition of its readership/audience (disciplinary/geographical/language reach) 3c. Number and type of uses (intends of use) of products by target groups i. Number of listeners/viewers (radio/TV), downloads/visitors, click rate/depth, dwell time (web-based products) ii. Number of citations in print/broadcast/web publications and social media, quality/reputation of the citing publication/social media platform

	iii. Number of citations in policy documents (laws, regulations, etc.) and implementation documents (guidelines, planning documents, etc.)
4. Organize events for external target groups	
4a. Design and implement events (define goals/agenda, mobilize speakers, facilitate, administrate event, etc.)	4a. Number and type of events designed/implemented for research/policy/practice[9] and for public[10] i. Number and type of co-organizers/partners ii. Quality of speakers (reputation, influence, etc.) iii. Size/composition of audience, representation of key actors from research/policy/practice iv. Level and type of involvement of the audience (e.g. in Q&A, group discussions) v. Perceived event outcomes (learning, networking, etc.) [survey/interviews] vi. Number of reports on event in news, journals, web portals, etc. vii. Expenses born by participants (event fees, travelling, accommodation, etc.)
5. Support implementation	
5a. Facilitate policy/practice implementation plans/strategies 5b. Support pilot/full-scale test/demonstration facilities	5a. Number of implementation plans/strategies facilitated i. Number and type of research/policy/practice partners participating in the development of plans/strategies ii. Breadth and strength of support for plans/strategies from research/policy/practice partners (e.g. letters of agreement, public statements) iii. Degree of compliance with plans/strategies 5b. Number and type of pilot/full-scale test/demonstration facilities i. Amount and type of co-/in-kind funding granted ii. Continuing/follow-up funding

6. Facilitate continuous knowledge exchange among research/policy/practice partners	
6a. Create opportunities for exchange/learning across research disciplines, policy and practice 6b. Develop common ground for discussion (common language, mutual understanding, etc.) 6c. Facilitate relationship building/maintenance among program partners 6d. Facilitate staff exchange between research and policy/practice	6a. Number and type of opportunities created for exchange/learning[2] i. Number and types of research/policy/practice partners participating in individual exchange/learning opportunities ii. Perceptions of the appropriateness of available opportunities [survey/interviews] iii. Increased understanding of each other's needs/expectations/perspectives, organizational constraints and opportunities, work flows and communication channels [survey/interviews] iv. Influence of new perspectives/knowledge on research/policy/practice [survey/interviews] 6b. Common ground developed i. Number and type of boundary objects developed[3] ii. Use of boundary objects within and beyond the program (e.g. in presentations/publications) iii. Perceptions of the extent to which common ground has evolved [survey/interviews] 6c. Relationships built/maintained i. Number and type of opportunities where partners consider each other in projects/commissions/networks outside the program ii. Perceptions of relationships established, refreshed, maintained [survey/interviews] iii. Perceptions of team culture (trust, cohesion, respectfulness, openness, etc.) [survey/interviews] 6d. Number and type of staff exchanges facilitated i. Number of researchers moving to jobs in policy/practice or vice versa ii. Number of temporary staff exchanges iii. Perceived learning effects of staff exchanges [survey/interviews, testimonials]

7. Administer the program	
7a. Manage timeline, budget, reporting, etc. 7b. Create and maintain internal and external visibility of the program	7a. Number and type of program management tasks completed i. Degree of compliance with timeline, budget ii. Degree of accomplishment of deliverables 7b. Level of visibility of the program i. Number of visitors on webpage, click rate/depth, dwell time ii. Reports on the program in news, journals, networks, web-pages, etc. iii. Number of invitations to participate in events organized by target groups
8. Support self-reflection and meta learning	
8a. Facilitate evaluation of the program 8b. Document/publish lessons learnt on knowledge brokering 8c. Support networking, community building, and capacity building among KBs	8a. Number of evaluation reports/workshops facilitated i. Number and type of research/policy/practice partners co-designing and/or participating in evaluation ii. Coverage of key aspects [survey/interviews] iii. Perceived clarity of conclusions/recommendations [survey/interviews] 8b. Number and type of internal documents/publications on lessons learnt (e.g. regarding outcomes/impacts of and drivers/barriers to knowledge brokering) i. If published, see (3b) 8c. Number and type of networks/communities of KBs created and maintained i. Size/composition of the networks/communities of KBs ii. Level and type of activity of network/communities (e.g. meetings, workshops, courses, conferences, newsletters, etc.) iii. Perceived learning outcomes from networks/communities [survey/interviews]

335 (1) e.g. review documents of legislation/regulation/guidance, stakeholder analyses/maps, analysis of public opinion surveys, etc.
336 (2) e.g. informal exchange, presentations, facilitated workshops, etc.
337 (3) e.g. conceptual maps/diagrams/models, objectives hierarchies, progress charts, workshop proceedings, shared language, stories/symbols, etc.
338 (4) e.g. fieldwork, experiments, interviews/surveys, text/web scraping, etc.
339 (5) e.g. modelling, risk assessment, qualitative research, etc.
340 (6) e.g. working papers, (peer-reviewed) papers/books/book sections, etc.
341 (7) e.g. trade journal publications, systematic literature reviews, 'rapid response' summaries, synthesis documents, fact sheets, handbooks,
342 guidelines, knowledge platforms/webpages, newsletters, Massive Open Online Courses (MOOC), indicator/evaluation systems, decision support
343 tools, educational/didactic products, etc.
344 (8) e.g. newspaper articles, interviews, blogs, websites, artistic representations of research, animations, etc.
345 (9) e.g. conferences/congresses, workshops, continuing education courses, etc.
346 (10) e.g. open door days, field days, science fairs, exhibitions, artistic performances, etc.
347

6. An illustrative example of how to use the indicators

In order to clarify the use of the sets of processes and indicators presented in sections 5.1 and 5.2, we now describe possible applications based on our practical experience. For example, many KBs are involved in the identification and mobilization of relevant actors to collaborate in a program (process 1a in Table 1). To evaluate the process, the KB can select from the lists presented in section 5.1 the indicators that seem most appropriate and for which evidence can be efficiently collected. This could be, for example, the number of e-mails exchanged with persons considered for the program in a given period of time. To assess the quality of the process of mobilizing partners, the KB could, for example, explain how he or she has used existing knowledge or experience in the process of engaging potential partners.

However, these indicators are process-related and do not reflect whether the KB's effort was effective. To assess effectiveness, the KB can select from the indicators listed under 1a in the right column of Table 1. Indicator 1a.i for example suggests comparing the actual composition of the team or network to an 'ideal' team. The ideal team could be identified by asking the current team members who else should be part of the team, or by using more advanced methodologies such as stakeholder analysis/mapping (Leventon et al., 2016; Reed et al., 2009). Other possible indicators of the quality of the network created include the level and type of contributions (time, engagement in discussions, etc.) by the team members (indicator 1a.ii) or the persistence and stability of the team or network (indicator 1a.iii). The selection of indicators should be based on the stakeholders' view of which indicators are most relevant to the context and on the availability of resources to collect the necessary information.

This example also illustrates attribution problems attached to results indicators and why process indicators and program theories are important in such situations. For example, the results indicators might show that team composition is far from ideal (indicator 1a.i) or that certain team members do not contribute as expected (indicator 1a.ii). However, this does necessarily have to be due to a poor performance by the knowledge broker. It could also be the result of unpredictable budget cuts in one of the participating institutions that forced certain team members to withdraw from the program. In such situations, it is crucial that the knowledge broker can rely on a solid program theory that outlines the factors that are beyond his or her control. In addition, the knowledge broker can use process indicators (section 5.1 above) to demonstrate that he or has facilitated the process well and hence, the poor result is not his or her fault.

Thus far, the example has focused on a single knowledge brokering process (process 1a in Table 1). This is one possible use of our set of processes and indicators. However, causal links to other knowledge brokering processes and corresponding results are not captured with such an approach. For example, knowledge brokering processes related to synthesis work (process 3a in Table 1) might have feedback effects on the composition of the team or network (indicators 1a in Table 1). These links should be theorized in the program theory and, if feasible, backed with evidence from appropriate indicators.

The results of the exercise just described can be used for learning about knowledge brokering, or for reporting to employers and other stakeholders. The sets of processes and indicators can also serve as a resource from which KBs can gain additional ideas about possible processes or quality objectives. KBs can further use the lists of KB processes to sharpen their professional profiles and to explain their roles to people that are not familiar with the daily work of KBs.

Thinking about possible processes and indicators should ideally take place at the beginning of the program. This creates awareness of quality objectives. Furthermore, if evaluation is planned ahead, data collection could be possible with little additional effort as a byproduct of the daily business (Wolf et al., 2014).

7. Discussion and conclusion

The centerpiece of this article is a set of indicators to measure the quantity and quality of contributions of individual knowledge brokers to project, programs or platforms, in this article referred to as 'programs', at the interface between research, policy and practice. The indicators can help knowledge brokers to learn about their own practices and to demonstrate the value of their work to employers and other stakeholders. At the same time, the lists of processes and indicators can be used by knowledge brokers as a source of new ideas about alternative knowledge brokering processes and desirable characteristics of the results. It can also be used for sharpening KB's professional profiles. The focus in this paper was on indicators of processes and attributable results since these types of indicators are responsive to the actions of the KB, with limited influence of external factors. We emphasized that these indicators have most leverage if used in combination with a program theory outlining the assumed effects of knowledge brokering processes and the intervening factors.

Our article reacts to repeated calls for better methodologies for the evaluation of knowledge brokering (Cvitanovic et al., 2017; Klein, 2008; Ward et al., 2009a). It does so in at least two ways. First, to our knowledge, it is the first paper that focuses explicitly on measuring the contributions of individual knowledge brokers. Most existing evaluation frameworks focus on results at the level of a project or program. These are often not attributable to individual knowledge brokers. Second, while many of the these frameworks focus on a particular subset of knowledge brokering processes or indicators, our article encompasses a broad spectrum of processes and indicators. This is crucial in order to capture the contributions of knowledge brokers as completely as possible.

It was a deliberate decision to focus this paper on indicators. However, it is important to recognize that an excessive focus on indicators can create incentives for behavior that is narrowly aimed at maximizing scores on quickly achievable, uncontroversial indicators (Greenhalgh et al., 2016). Such 'gaming of indicators' can crowd out more complex and diffuse objectives that are hard to measure, thus potentially undermining the overall objectives of a program (Rijcke et al., 2015). As much as possible, indicators must therefore be inseparable from the objectives of a program, i.e. the indicators should represent conditions or behaviors that are likely to progress the program towards its objectives.

Another challenge might stem from potential disagreement about the appropriate indicators among the relevant stakeholders (Bautista et al., 2017). In such situations, making evaluation a participatory process can increase the legitimacy and credibility of its conclusions. The timing of the evaluation is also an important consideration that can have a major influence on the findings (Bell et al., 2011). Measuring indicators soon after the completion of a program could miss impacts and/or contributions of a knowledge broker that take time to emerge. On the other hand, waiting until the full impact on policy and practice have been realized can make it difficult to attribute the impact to a particular program or particular outcome. For example, subsequent programs may build on conceptual foundations, making it difficult for key informants to recall the specific contribution of the original program. Measuring different indicators at different times during and after the completion of the program may help to circumvent this issue.

This article is based on the practical experience of KBs working in the Swiss water sector. Their work is not fully representative of knowledge brokering in general. However, their experience covers a broad spectrum of roles and institutional affiliations. We further considered literature on knowledge brokering in other contexts. Nevertheless, a next step

should be exploring the use of our indicators by KBs in a more systematic way. Subsequent surveys and interviews with KBs would allow further validation and refinement of the KB processes and indicators.

Another topic that requires more attention is prioritization of the indicators. That is, the selection of indicators that are most 'useful' (Bautista et al., 2017) in a given context. This is important for several reasons. First, in a situation where data collection on indicators is time-consuming and resources available for assessment are scarce, prioritization can help with selecting those indicators that provide the best cost-benefit ratio in a given context. Second, prioritization is important because a large number of indicators can distract from the fact that some aspects might be more relevant than others. Finally, comparison of KB evaluations across different programs is easier if there is an agreed set of core indicators. One possible way to prioritize is to encourage experienced KBs apply the indicators to their situation, and let them assess which of the indicators are most valid (actually measuring what they intend to measure), reliable (consistent over repeated measures and over individuals performing the assessment), feasible (achievable with the available resources), and attributable (under reasonable control of the KB). Our list of indicators presents a basis from which such prioritization can start.

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