Title
Ambiguity: the challenge of knowing and deciding together

Journal
Environmental Science & Policy, 15(1)

ISSN
14629011

Authors
Brugnach, M.
Ingram, H.

Publication Date
2012

DOI
10.1016/j.envsci.2011.10.005

Peer reviewed

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Ambiguity: the challenge of knowing and deciding together

M. Brugnach [a,*], H. Ingram [b,c]

[a] Faculty of Engineering Technology, University of Twente, The Netherlands
[b] Southwest Center, University of Arizona, United States
[c] School of Social Ecology, University of California Irvine, United States

ARTICLE INFO

Published on line 20 November 2011

Keywords:
Ambiguity
Natural resources management
Water management
Water policy
Collective decision making
Knowledge production process
Multiple ways of knowing
Participation
Framing

ABSTRACT

Despite the claims of inclusiveness advanced by integrative approaches to resource management, the substance of decisions hardly reflect the diversity of meanings and interpretations that the inclusion of multiple actors implies. We assess the knowledge production processes currently employed in natural resources management, particularly water resources, and claim that part of this problem resides in how ambiguity is handled. From this perspective, we suggest that coping with ambiguity requires a reformulation of the knowledge production processes employed, in terms of the types of knowledge used, how and by whom it is created, what values are incorporated and how values are weighted. Here, we discuss the flawed assumptions of the operative knowledge production processes and the characteristics and challenges of knowledge production models better able to cope with ambiguity through integrative practices. Finally, we provide practical recommendations to facilitate implementation of knowledge co-production processes that can better actualize integration based on deliberation, open space for dialogue, negotiation and learning.

1. Introduction

During the last decade, integrative approaches considering multi-policy domains and stakeholder participation have become increasingly common in natural resources management e.g., Integrated Water Resource Management (GWP-TEC, 2000) or Adaptive Management (Holling, 1978; Walters, 1986; Gunderson et al., 1995; Lee, 1999; Shindler and Aldred Cheek, 1999). However, despite the claims of integration made by the new management frameworks, real changes in the substance of decisions have remained elusive (Medema et al., 2008). More often than not, planning processes and policy choices hardly reflect the diversity of meaning and interpretations that the inclusion of multiple actors brings (Feldman and Ingram, 2009; Ingram, 2011).

Commonly, the values served by decision choices do not reflect local conditions and preferences. Decisions mirror differentials in power that shape the use of resources to fit the interests of some groups (Ingram and Stern, 2007). Administrative procedures and processes calling for participation are no panacea since decision rules as to who participates and by what kinds of guidelines are also deeply political (Bloomquist and Schlager, 2005). Moreover, open and transparent forums do not make up for unequal power among participants, and the significant resource, skill, and cultural barriers to participation of some disadvantaged populations (Sabatier et al., 2005; Whiteley et al., 2008). For instance, policy decisions have commonly undermined indigenous and peasant communities' interests (Boelens, 2008; Turner et al., 2008). Indigenous populations who rely heavily on experiential and traditional knowledge find that their perspectives have no legitimacy in the expertise-dominated water policy arena. Further, their cultural and religious values associated with water are overlooked (Rodríguez, 2006). Conflicts of interpretations regarding water issues commonly remain unresolved, deepening even further the differences in power, turning participation into an often controversial and futile process (Gray, 2003).

* *Corresponding author*. Tel.: +31 0 53 489 4209.
E-mail address: m.brugnach@utwente.nl (M. Brugnach).
1462-9011/$ – see front matter
doi:10.1016/j.envsci.2011.10.005

Involving multiple stake and right holders in a decision making processes implies accepting that there can be simultaneously many different sensible ways of understanding a problem and finding solutions (Brugnach et al., 2011). Actors frame a decision situation according to their backgrounds, experiences, societal positions, values and beliefs. For example, a situation of water shortage can be framed by one person as a problem of 'insufficient water supply' while by another one as a problem of 'excessive water consumption' (Hoekstra, 1998). This distinction in frames is important since formulating a problem in a different way elicits distinct preferences, different kinds of knowledge, and points towards different solutions. For example, framing water as an economic good, favors market based solutions, which is incompatible with framing water as a human right that favors legal and regulatory solutions. While differences in frames are unavoidable, they often result in ambiguity.

Ambiguity refers to a distinct type of uncertainty that emerges from the simultaneous presence of multiple valid and, sometimes conflicting ways, of framing a problem. In a management situation, it indicates the discrepancies in meaning and interpretation that exists in relation to a particular issue (see Dewulf et al., 2005; Brugnach et al., 2008, 2011 for reviews and details). Under the presence of ambiguity is not clear what the problem or solutions are. Paying attention to how ambiguity issues are resolved is important since it determines the degree to which the views, values and interests of participants are represented in the formulation of a problem and the development of its solution.

We argue that part of the failure of inclusive practices resides in how ambiguity issues are handled. Contemporary water management constitutes still an expert dominated domain, where differences in understandings are dissipated by favoring hard, technical solutions over those that are more innovative and embody the diversity of views, values and interest that water management entail (Conca, 2006). We analyze the problem of ambiguity from the point of view of knowledge production processes. From this perspective, we suggest that coping with ambiguity in a way that is inclusive requires a reformulation of the knowledge production processes employed, in terms of the type of knowledge used, how and by whom this knowledge is created, what values are incorporated and how values are weighted. We discuss these ideas from a conceptual point of view and offer practical recommendations to support a revised process of knowledge production for water policy.

This paper is structured as follow: Section 2 identifies the assumptions made by contemporary knowledge production processes regarding knowledge. Sections 3 and 4, redefine knowledge to better cope with ambiguity and identify some of the challenges that doing so presents. Section 5 considers how conditions that favor different knowledge production can be fostered. Finally, Section 6 summarizes and concludes the paper.

2. The barriers to handling ambiguity in an inclusive way

Ambiguity is an unavoidable characteristic of a participatory process where different people are engaged in some sort of collaboration. In the literature the term ambiguity has been used in two different ways, namely, to refer to the ignorance created by not having sufficient information, and to refer to the degree of confusion that is created in a group from having multiple meanings (Weick, 1995). In this work we adopt this second view, and define ambiguity as the presence of multiple possible interpretations of a situation. As such ambiguity is not related to a deficit in knowledge but to the fact that in a group of people there are different sensible and valid ways of knowing reality. For example, the increasing bitumen commercialisation and mining expansion of the oilsands of Northern Alberta, one the major deposits of bitumen in the world, has resulted in ambiguous interpretations (Westman, 2006). For the national and provincial government of Canada, oilsands deposits are viewed as a promising source of oil for the future, and its production offers unique global market possibilities that may also bring new working opportunities for the local population. Instead, for aboriginal people oilsands developments have a different meaning. For them the land constitutes both a source of subsistence and spirituality, so oilsands expansions are not only viewed as a major threat in terms of nutrition and economy, but also in terms of traditional knowledge development, culture and religion.

Ambiguity is often the result of unrecognized contextual, methodological and substantive differences among knowledge systems. Stake and right holders involved in a participatory process may come from very different knowledge traditions (e.g., indigenous communities and expert advisors), or have different stakes on the situation (e.g., farmers associations and governmental agencies), or have different type of expertise and experience regarding the problem (e.g., lay people and scientists). A knowledge system refers to the information, know-hows, technologies, practices, experiences and beliefs that are developed in a community and used as the basis for decision making. Knowledge systems, in addition to factual explanations, carry information about the way in which knowledge holders interact among themselves as well as with the environment. As such, a knowledge system represents a particular way of making sense of reality, providing understandings and meanings to a situation (Agrawal, 1995). Even when different knowledge system may share facts, there can still be differences in the meaning and implications of the shared information (O'Flaherty et al., 2008).

Handling ambiguity in a way that is inclusive is not limited to solving conflicts of interest among parties but also demands the ability to integrate knowledge systems that may be very different in nature (e.g., indigenous knowledge, cultural rationality (Fischer, 2006), scientific reasoning, etc.). Such integration cannot be reduced to a mere translation from one knowledge systems to another, nor to the additive accumulation of facts. Instead it requires the generation of new shared knowledge through the active participation of different stake and right holders. Thus, the resulting shared knowledge is the product of a process of collaboration and is tied to and reflects the insights of those that participated in it. Doing so implies a reformulation of the role knowledge holders have in processes of knowledge production, accompanied by the delicate task of creating views and solutions that are compatible with the different ways of knowing. However, embedded in contemporary knowledge production processes are several assumptions

that are contradictory to the goals of integration by privileging credentialed participants that use formal scientific procedures. Here, we look in detail at what these assumptions are and how they affect the knowledge production processes employed in management. This analysis is then used in subsequent sections to reformulate knowledge production processes.

2.1. *Assumptions held by contemporary knowledge production processes*

One of the assumptions underlying contemporary knowledge production processes is that humans are regarded as external and static conditions of the natural system to be managed (Pahl-Wostl, 2007a). Thus the natural and human systems are viewed as two separate entities, where the natural system is conceived as subservient to the humans that control it, and the way in which nature can shape humans is ignored (Eldredge, 1995; Vitebsky, 2005). Following this rationale, it is assumed that human intervention can modify the behaviour of the natural system (in its structure and function) to respond to human needs (Holling and Meffe, 1996). Besides affecting practice, this way of framing nature–human relationships also restricts the type of knowledge that is to be considered when making decisions and reaching conclusions. Interactive effects and reciprocal relations of humans and the natural world tend to be slighted. Further, the affective, emotional and symbolic understandings people have of water tend to be ignored as irrelevant knowledge.

Under a frame that considers human and natural systems as independent, the interpretation of problems becomes external of the human experience (Brugnach et al., 2008). Human–nature interactions are reduced to those of humans controlling the natural system (Holling and Meffe, 1996). From this perspective, the natural system is regarded as an abstract structure of physical reality; something that is 'out there' of which humans are not a part, and that can be objectively discovered using the appropriate methods of inquiry (i.e., scientific method). Therefore, factual scientific knowledge can reveal reality by describing conditions, explaining relationships and predicting consequences in an objective, universal and precise way. This understanding of the natural system becomes part of the knowledge base that is used to inform decision making processes. And as the rationale goes, more and better factual explanations can lead to a better understanding of the world, to better-informed decisions, and to an increased ability to find better solutions. In this way, the use of knowledge is conceived as a rational and linear process, in which once a problem is identified and defined, knowledge about it is gathered and used as the basis for decision making (Owens, 2005).

What is assumed to be science in existing knowledge production processes is mainly dominated by the natural sciences and economics, disregarding the insights of other disciplines including politics, anthropology, sociology and other social sciences. Further, indigenous knowledge that frames human–nature relationships as inseparable and integrated and portrays all activities, events and entities as related is marginalized. Operative decision making models treat scientific facts as discoverable rather than conceiving reality as being continuously created and recreated through relationships (Deloria, 1999). Contrary to reigning assumptions, knowledge does not stand alone as an abstract set of propositions, but it is derived from individual and communal experiences in keen interaction with the natural system (Turner et al., 2008; Deloria, 1999). Rather than portraying knowledge as a linear process as assumed in existing decision making, knowledge results from mutual adaptation between the natural and human systems. Contrary to assumptions embedded in contemporary knowledge production processes, science, society, culture, politics and the natural world co-produce each other (Jasanoff, 2004). Facts are not separated from values by traditional knowledge holders, and facts like where fish spawn are combined with value-based judgments that spawning habitat should not be altered (Turner et al., 2008).

The summary statistics upon which natural scientists base their conclusions deviate appreciably from local contexts and conditions (Hulme, 2010). Instead, integrating other knowledge systems, experiential knowledge and traditional knowledge can better represent local realities. In addition of having explanatory power, these knowledge systems can provide normative inputs to decision making processes, indicating the priorities, preferences and beliefs of local populations (Nakashima and Nilsson, 2006; Failing et al., 2007). Being specific to a local environment, these knowledge systems constitute the bases for local-level-decision making, and as such, cannot be ignored (Turner et al., 2008; Berkes, 1999; Rodríguez, 2006).

Also, in problems where multiple parties are involved, despite the assumptions of technical and professional circles that dominate decision making, it is unclear often what facts need to be explained or how facts can be separated from values. Even when there is an agreement about facts, values influence preferred solutions. For example, while flooding of a watershed may be an incontrovertible problem, environmentalists who believe nature should guide human conduct, contend that floods should be managed through floods plains. Developmental groups who believe humans should manage nature may advocate the construction of a dike and to do so favor the relocation of a local population. For yet others who strongly favor weighing benefits and costs, a viable solution must reflect an efficient use of resources. This type of controversy cannot be solved by appealing to facts, but to value based knowledge that can provide judgments about preferences, tolerance to change and to risk (Schön and Rein, 1994; Failing et al., 2007). As stated by Berkes (2007) these are 'people issues', that can only be answered by paying attention to the values and beliefs of those who are considered in the decision making process.

Yet another assumption made by current knowledge production processes is that of maximizing economic profit as the main drivers of decision making, yet this assumption no longer holds in a context in which a diversity of stakeholders is included. Some authors strongly contend that considering water as economic good goes against human rights, since it leads to privatization and market solutions, preventing the access and control of water resources from economically disadvantaged communities (Corpuz, 2006; Solón, 2006). Gregory and Trousdale (2009) argue that there are many components of value that matter to indigenous populations that are ignored in conventional market-based solutions (e.g., knowledge transmission, collective and individual identity, traditional ceremonies, etc.). Even the idea of maximizing profit is at odds when considering the adaptive capacity and

dynamics of the natural and human systems in many contexts (Pahl-Wostl, 2007b).

Following a similar reasoning, Rodríguez (2006) claims that water in the acequia or ditch system in Northern New Mexico has meaning for identity, community, culture and a sense of place that far outweighs the value of water that hydrologists, economists, or even environmentalists might place on it. The collective work of dividing the water and cleaning ditches so that it can flow to users is important to maintaining social relations. She writes:

> All of this adds up to the fact that the New Mexico acequia or irrigation communities involve a moral system, a way of life, a social and cultural identity, and an attachment to place. This is why acequia associations resist the loss or transfer of water rights away from the ditches to nonagricultural use: it threatens the integrity of the whole, by removing not only water from the system, but also labor and participation from the ongoing communal effort to maintain the ditches (Rodríguez, 2006, p.116.)

Above we have discussed the flawed assumptions embedded in the operative knowledge production processes, particularly the inappropriate assumptions about knowledge and science. This is not only a matter of epistemological concern, but it also violates the ideas of inclusiveness and integration that new managing approaches try to embrace. While more diverse perspectives may be formally represented in processes, kinds of knowledge and solutions that serve their views and values are not being considered. Overcoming the shortcomings of contemporary assumptions in coping with ambiguity implies redefinition of knowledge production processes such that better support is provided for the integration of the multiplicity of meanings, framings and perspectives that exists about water issues. However doing so poses several challenges. Next we identify some of the major ones.

3. The challenges of overcoming assumptions

The governing assumptions in knowledge production processes of the professional water community are difficult to change because they serve the interests of powerful individuals and groups. Agency missions advantage some perspectives such as hydrology or agronomy. The privileging of physical sciences and economics slights and obscures issues of fairness, equity, and democratic representation. Widening participation in knowledge creation will threaten the water experts who use specialized language, rules, and methodologies to maintain their advantaged positions in decision making. Only when the governing assumptions are critically assessed and alternatives specified is it likely that support can be mobilized for change.

3.1. *Inclusiveness and diversity*

Broadening the kinds of knowledge holders to create more open and inclusive decision processes can present several challenges (Brugnach and Ingram, 2011). Including a diversity of stakeholders means dealing with disparities in power and resources (Dewulf et al., 2005; Craps et al., 2004; Wenger, 1998). Underlying the generation and use of knowledge are intrinsic assumptions of power and control that are anchored in institutions and values. Ignoring such assumptions leads to discrimination against those knowledge forms that are not commensurate with what the professional water community accepts as valid.

Knowledge has different political valences. Natural scientific knowledge is afforded the status of "hard" science, with strong characteristics of predictability, generalizability, verifiability and reproducibility. Social science knowledge that is often less elegant is afforded less prestige, although, among social scientists, economists and their brand of knowledge are often privileged. Of course, scientific knowledge of all types has greater authority if it is credentialed and based in institutions like universities and government agencies. Lesser regard is often afforded to experiential and traditional knowledge. One of the ways to overcome such power differentials among different kinds of knowledge is the production of blended knowledge that comes from a variety of different sources. Such blended knowledge is likely to come out of studies and decision processes where different kinds of knowledge are engaged in framing questions, designing and engaging in data collection, and drawing conclusions.

3.2. *Decision space or discretionary latitude*

Collaboration and acting in concert are often very difficult among groups whose decision space is dissimilar. Different people and groups have very diverse decision spaces, with some engaged in the collection of broad knowledge while others focus on detailed knowledge of what is in front of them. Others are restricted to their own agency missions that may be quite narrow, and not encompass root causes of problems nor innovative solutions. These bureaucratic groups may be tied to the interests that support their agencies and cannot consider either framing of problems or solutions that would hamper agency constituencies. Some disciplines restrict decision space through their world views such as economists do when restricting time horizons to the relatively near term.

Different kinds of knowledge use different terminology, time scales, methodologies and means of communication. This disparity inhibits collaboration among different kinds of knowledge. Translation problems are bound to arise. Farmers have production data related to growing seasons, while water managers focus on cyclic watershed flows, and the inconsistency is something that must be overcome if these two are to work together. Traditional knowledge privileges long term historical data and is most likely to be communicated through storytelling. Hydrologists seldom have such long periods of record except those collected by tree ring analysis (and that has its own translation problems). Storytelling is an alien form of communication among physical scientists and engineers, and so accepting information in this form is resisted.

3.3. *Trust, credibility and legitimacy*

Different stakeholders are likely to evaluate the credibility and legitimacy of information according to situational factors like past experience with the individuals and groups generating the

information, whether it is conveyed in language they can understand, and who they perceive may win or lose if the information is believed (Cash, 2002; Cash et al., 2003). Water agency officials are likely to have very different perspectives than lay people, especially those with little political power. The water sector has historically been highly technical and dominated by longstanding bureaucratic agencies that embrace physical science more readily than social science, and depend almost exclusively upon information from credentialed sources (Conca, 2006). In contrast, indigenous people and insular minorities have a basic distrust of "official" sources, having long experience with agency use of data to control decisions. For instance, the inability of Native American and rural Hispanics living in the American Southwest for centuries to be able to assert water rights, absent hydrologic data of historic flows and uses, built a legacy of suspicion. Instead of longitudinal monitoring data, traditional people in the American Southwest depended on oral histories and direct experience (Brown and Ingram, 1987). Narratives, metaphors, cultural practices and place names may best express what matters to indigenous communities (Turner et al., 2008). Official data lacked credibility because it was produced by sources whose motives were suspect. Further, it contradicted both more trusted sources and immediate direct experience. This distrust among insular minorities even extends to the courts, since the rules of evidence often privilege economic over other values (Rodríguez, 2006).

Traditional and experiential knowledge draw upon details related to particular places. For example, the longstanding acequia system in Northern New Mexico served Hispanic and Native American populations for years because it was governed by custom and informed by the experiential knowledge of mayordomos or ditch riders who had intimate experience with the consequences or raising or lowering head gates to various parts of irrigation systems (Crawford, 1988). Instead technical and monitoring data depend upon averaging of data from limited numbers of monitoring sites, direct experience and traditional knowledge relate to place based details that are highly relevant to residents. Differences in soil type, slopes, land cover and other particulars related to place can result in wide variations from the mean experience in a particular watershed. Potentially experiential knowledge can provide details that can be very helpful to water management. Despite this potential, many agencies hold a very restricted view of lay science, believing that it must following protocols and data analyses handed down to citizens by experts. As a consequence, credibility and legitimacy gaps exist that exacerbate tensions between those who hold power and those who do not. Of course, not all that purports to be experiential knowledge is actually authentically generated at the local level. Just as some grassroots mobilization becomes "Astroturf" that only pretends to be bottom-up, some local knowledge can be influenced by outside interests. In such cases, the distortion would come from politics not scientific protocols and can only be countered by exposing the actual sources of the information.

3.4. *Building networks through integrative leadership*

Leading an open and inclusive knowledge production process can also present a challenge. Instead of the managerial role based on authority and control, integrative or collaborative leadership requires different characteristics (Schruijer and Vansina, 2008). Rather than envisioning power as the ability of the leader to get the subordinate to do something he or she would not otherwise do, integrative leadership suggests mutual influence. In processes that are inclusive of different ways of knowing there is the need to build networks that cut across the usual divisions. Leaders must have empathy in order to understand where people in very different knowledge camps are coming from, and skill at negotiating differences, facilitating translations, and bridging different forms and styles of communication. Research in water resources has found that collaborative leaders take not only great networking skills, but also considerable perseverance over whole or significant parts of careers (Huitema and Meijerink, 2009). Our own work suggests that leaders must be adept at bringing in diverse voices and neglected nodes of knowledge. Recruiting and retaining such leadership is often a hit or miss affair and deserves more attention.

4. Re-conceptualizing knowledge production processes to better cope with ambiguity

Overcoming the challenges of dealing with ambiguity in an integrative way cannot be met within the constraints of contemporary knowledge production processes. Equal and fair participation suggests democratization in the process of knowledge production so participants are able to develop shared knowledge and define group goals and solutions (Tàbara and Chabay, submitted for publication). From this perspective, knowledge production can be more effective in coping with ambiguity when conceived as a collective, and situation specific process. These ideas imply redefining knowledge and knowledge production process so contextual dependencies are better represented. Doing so brings new insights with respect to the type of knowledge relevant to make decisions, to the ways in which holders of the different types of knowledge are incorporated into the knowledge system and to how knowledge is co-produced and ambiguity resolved.

4.1. *Different types of knowledge*

Different types of knowledge are relevant in knowledge co-production processes. In these processes what is known or not known about a system is not limited to scientific facts or expert opinions (although the engagement of social scientists can broaden professional understanding). Human beings also gain knowledge through experiences, and when making decisions, this knowledge can far outweigh the contribution of scientific understandings. In contrast to factual scientific knowledge, this knowledge is tacit and it is not explicitly expressed except through practices. Moreover, knowledge is also influenced by the views and preferences of the decision maker in relation to those of other actors with whom the decision maker interacts in the context of a specific situation (Schusler et al., 2003; Brugnach et al., 2008). Thus knowledge is situated and it reflects the ability of people to interact with the natural and social systems.

Under this rationale, knowledge is understood to have both, content and a relational aspect (Bouwen, 2001). The content refers to ''what'' is being understood. This includes formal and systematic knowledge, such as hard and quantifiable data (e.g., scientific knowledge). The relational aspect refers to ''who'' is being included and excluded from the problem understanding. This distinction between content and relations is important since it makes explicit that it is not only content that informs decision making processes, but also the relations established among those who decide, those who participate and those who are excluded. Such relations are affected by who has formal authority, who has other resources such as economic power or votes, and who is powerless.

Central to the relational view there is a dynamic conception of knowledge and the recognition that knowledge is being formed and enacted into practice. As explained by Wenger ''every practice is in some sense a form of knowledge, and knowing is participating in that practice'' (1998, p. 141). Knowing from practice implies that knowledge is specific to a particular situation and as such is tied to specific communities (Brugnach and Ingram, 2011). Concilio (2010) elaborates on the dynamic properties of knowledge and identifies four major characteristics. One, knowledge is not stable, but is constantly adapting and adjusting. Two, knowledge cannot be packaged, that is it never becomes an end product. Three, even when dynamically generated knowledge is not always actionable, since knowledge becomes actionable only in a context that can make use of it. Finally, knowledge is not additive, but is the outcome of social interactions and communication among different actors. Thus, knowledge is not static but a dynamic entity that is embedded in a social context and is co-produced through time as a result of social interactions (Wenger, 1998; Fuller, 2002; Jakubik, 2007; Feldman and Ingram, 2009).

4.2. *Reformulating ways in which holders of the different types of knowledge are incorporated into the knowledge system*

The co-production of knowledge is not feasible without the integration of knowledge holders into the process of knowledge creation. This means adopting an analytical frame in which humans are not considered external actors but are an integral part of a social ecological environment being managed. Integrating humans and natural systems implies explicitly acknowledging human–nature interactions, recognizing that any human action will be followed by responses from the natural system and vice versa (Liu et al., 2007). An extensive body of research already exists that looks at human and natural systems as a dynamic socio-ecological system (Gunderson et al., 1995; Pahl-Wostl, 2007b). A socio-ecological system is a system where people and nature interact (Holling, 1973). It is characterized by multiple variables and levels, and it has the capacity to change and to adapt through time applying feedbacks and adaptation mechanisms that are particular to each system.

Adopting these ideas has profound implications for how decisions are made, since humans have the capacity of adapting to new conditions and learning new ways of acting (Brugnach and Pahl-Wostl, 2007). Under this framework of analysis managing solutions cannot any longer be sought as independent from what those who participate value and believe to be important (Bouwen and Taillieu, 2004; Schusler et al., 2003). The understanding of problems becomes enmeshed in human's interpretations, and knowledge creation becomes an activity whose aim is finding the appropriate type of solutions that help to adapt to a particular situation (Ostrom et al., 2007). Knowledge, thus, is context specific and dependent upon who as well as what is involved in knowledge production processes. Thus, what is known about the system to be managed is not any longer outside the human experience, but it is reflected in a subjective representation and understanding of a situation. However, the interpretation of reality is influenced by many factors, such as values, beliefs, biases, and heuristics. A large amount of scholarly research has shown that our information processing capacities are limited, and our perception is selective (i.e., heuristics and biases in interpretation, Tversky and Kahneman, 1974). Consequently, when making sense of reality, focusing our attention in some aspects of the real world and ignoring others is unavoidable. In this way, what is interpreted as a real phenomenon depends partly on who is constructing the reality.

In addition, individuals are not isolated but are part of a social network so the interpretation of reality is also influenced by and influencing other humans (Brock and Durlauf, 2001). Different networks among individuals tend to favor distinct ways of knowing water problems. Academic economists and their colleagues in water agencies have tended to see water problems as best solved by allocating resources where there is the highest economic return; while life scientists and their colleagues in fish and wildlife agencies see preservation of species and habitat of primary concern (Lejano and Ingram, 2009; Ingram and Lejano, 2010). From this perspective, any problem definition or action choice is not independent from the decision maker and the influence of those participating in the decision making process.

4.3. *The relationship between knowledge and decision making*

In knowledge co-production processes, it cannot any longer be assumed that knowledge and decision making have a linear and rational relationship. As previously suggested, generating knowledge is subject to certain heuristics, rules of thumb, and standard operating procedures, and individuals and groups engage in certain shorthand strategies that narrow the search for information and possible solutions to those held to be appropriate and feasible (Wildavsky, 1979). Of course, what is feasible depends a good deal on interpretations of past events and current conditions. Long established patterns of decision making are questioned when results are strongly challenged by events and on-the-ground experiences. For instance, a dam or dyke failure may result in a reconsideration of structural solutions to flooding problems and renewed interest in non-structural alternatives including flood plain zoning. In such cases, engineering knowledge and perspectives may be replaced by social science and planning knowledge. Knowledge is no less important when such adaptation takes place. Instead, what is considered relevant knowledge is selective and adaptive.

4.4. A revised knowledge production process to better cope with ambiguity

The process of knowledge production refers to how knowledge is processed and how new knowledge is created. Adopting the ideas presented above implies that the production of knowledge is a situation specific process that results from complex and synergistic social interactions. It is through these interactions that people make sense of a reality, negotiating the meaning given to it. Therefore, knowledge production involves the coordinated action among individual actors, groups or organizations, who engage in some form of collaboration to produce knowledge that is ready for action (Bouwen and Taillieu, 2004). Such endeavors require the active engagement of participants in working together to jointly define the problem to be solved and goals to be reached. In these processes knowledge is co-produced.

The process of knowledge co-production consists in the creation of knowledge that represents a new social constructed reality, by enlarging individual knowledge through dynamic interactions among knowledge holders. It is by exchanging and sharing individual knowledge through social interactions that knowledge boundaries are expanded and existing knowledge can be converted into new knowledge. The dynamic theory of knowledge (Nonaka, 1994) differentiates among four different patterns of interaction underlying knowledge co-production process: socialization, externalization, internalization and combination, where experiences and perspectives can be articulated, shared, transformed and internalized. By cycling through these four interaction patterns, individual knowledge can be scaled up to group and organizational levels. In this way, concepts that are considered to be valuable by group members can obtain widely currency and become crystallized in the new higher-level knowledge forms (Nonaka, 1994).

A process of knowledge co-production is triggered by the necessity of creating new knowledge to solve a problem. When stake or right holders engage in a collaborative partnership of knowledge production, each of them hold individual knowledge, having their own objectives, frames and perspectives on the problem and the potential solutions. So, part of the efforts of co-production have to be devoted to reaching an agreement among participants about what the problem is, the approaches to be used and the desired outcomes of the collaboration (Gray, 2004). Thus boundaries are socially constructed and fluid rather than predetermined as they are in privileging river basins or watersheds over villages, tribes, or minorities. This process of knowledge production is never static, it changes as new participants emerge and the context changes.

The proposed knowledge co-production process differs in many ways from the contemporary processes generally applied in water management (see Table 1 for a comparison). The first of these differences is that contemporary processes of knowledge production are conceptualized as an information processing mechanism, limited to processing content (hard and quantifiable data) to solve a predefined problem. Instead, the suggested knowledge co-production process is relational and dynamic, where knowledge is constructed through relational practices and is constantly being created and recreated through interactions.

These differences in how knowledge is produced also influence how knowledge is defined. In contemporary knowledge production processes, knowledge is conceived as an abstract body of statements (e.g., factual scientific data) that objectively represents reality. Other types or forms of knowledge are undermined or, only considered when conforming to scientific standards. Differently, in the proposed co-production processes knowledge is rooted in action, procedures, routines, commitments, ideals, values and emotions of people, and as such it is inseparable from social practices. So, in addition to explicit content, there is a tacit element to knowledge that is manifested through relationships. This way of conceiving knowledge also requires a different way of coping with ambiguity, one that can include the diversity of meanings and interpretations that actors can bring.

4.5. Resolving ambiguity

While ambiguity can be resolved in many different ways (see Brugnach et al. (2011) for a review), the proposed knowledge co-production process suggest doing so through interactions that lead to the creation of new shared connected knowledge frame based on which joint goals and expected outcomes are defined. Doing so does not necessarily imply reaching consensus about what the problem is or how it should be solved, but working through differences with participants to arrive at a mutually acceptable solution. This is different than handling ambiguity by invoking a scientific frame as the most important, or imposing a scientific frame through power strategies, or by convincing others of the meaningfulness of one particular frame of reference. Below we presents two different strategies that based on dialogue, learning and negotiation can support the development of a shared knowledge frame in a process of knowledge co-production.

Dialogical learning: This approach proposes to cope with the presence of multiple frames and ambiguity through dialogue and learning (see e.g., Argyris and Schön, 1978). The underlying

Table 1 – Comparison between contemporary and proposed knowledge production processes.

Contemporary knowledge production processes	Proposed knowledge production processes
Knowledge is an abstract body of statements	Knowledge constructed through relational practices
Problem solved by processing information	Knowledge actively co-produced to solve a joint defined problem
Problem and solution independent	Solution situational, derived from shared problem definition
Solution imposed	Solution developed collectively
Only one valid frame accepted	Multiple frames accepted as valid
Ambiguity resolved by imposing the valid frame (generally technical)	Ambiguity resolved by creating a connected frame that represents a shared view on the problem

rationale is that open dialogue leads to a process of mutual understanding that is needed for the creation of a shared and connected frame. The main goal is to transform how a problem situation is framed by exploring, enlarging, and connecting existing frames (see e.g., Gray, 2004; Schön and Rein, 1994). This strategy builds on the assumption that participants are able to question and to listen to each other and that they are also open to change. Its application requires high social skills and the willingness to engage in a constructive dialogue. There are many interventions that can support the implementation of this strategy, some of which are: facilitation, group model building, role-playing games, or the use of concrete case context.

Negotiation: This approach proposes to cope with frame differences by reaching an agreement through negotiations (see e.g., Leeuwis, 2000). This is different from dialogical learning since it does not aim at transforming frames but at reaching a fair deal through the calculative involvement of actors. In a negotiation, actors engage in information exchange taking a strategic positioning while maintaining diverging frames. Thus, it requires the willingness of the actors to negotiate. Negotiations can range from having an 'integrating' quality, when actors develop synergetic win–win outcomes, to being 'distributive', when the actors take a win–lose position and distribute profits and gains in an antagonistic way. This strategy is apt to be applied in situations where, for example, actor's relationships are conflictive and a dialogical learning strategy is not applicable.

While these two approaches for coping with frame differences in collective processes of decision making are theoretically sound, conflicts among the parties, polarization of views, oppositional modes of actions can preclude their applicability in real life situations. Also, conflict resolution strategies can be needed in some situations. What strategy, or combination of strategies, fits better for a particular problem becomes a context dependent question (Ostrom et al., 2007).

In the process of collaborative interactions, a leader – acting as a facilitator, and sometimes as a mediator – can ensure that collaboration among different parties can emerge (Schruijer, 2006b; Obholzer and Miller, 2007). Schruijer and Vansina (2008) characterize a collaborative leader as a neutral person that has no stakes on the problem or holds any formal authority, whose function is to identify commonalities and help solve differences so a shared view of the problem is developed. In doing so the leader must be able to avoid judgment regarding the different views and opinions participants hold and to make sure that in the participatory process power and status differences are minimized. This can only happen in an environment of trust and understanding that allows for building and sustaining good relationships while coping with differences constructively (Schruijer, 2006a). Even when the requirements for collaboration are not present, collaborative leaders can work towards creating and sustaining the conditions that enable or facilitate collaboration.

5. Creating the conditions that foster knowledge co-production

However appealing revised knowledge production processes may be, we are not naïve about the problems of implementation. Contemporary knowledge production processes have persisted despite the new discourse about natural resources management, because ways of doing things are thoroughly entrenched. Bringing into practice the revised mentioned knowledge production model can help redress power imbalances by placing powerful in a position of having to explain, justify, and make efforts to include. This can only happen in contexts that foster collaboration and the construction of new meanings. Here, we have identified three different conditions that promote revised knowledge production processes.

5.1. *Recognize interdependencies*

In a collective knowledge production process, parties do not come together because they are similar but because they are different and they are interested in collaborating (Bouwen and Taillieu, 2004). This type of collaboration among multiple parties (or multiparty collaborations sensu Gray, 1989) is based on the principle of interdependency (Schruijer and Vansina, 2008). This means that parties recognize that they are needed and they need others for the development of effective solutions (Gray, 2004). For example, each party may have access to a unique set of resources, or have competences or skills that can complement well those of the others or that are unfeasible for others to acquire (Schruijer and Vansina, 2008). Thus, solutions are expected to capitalize on the many different and unique contributions that each of the parties could make. In this way the solutions become situational, tailored to jointly defined objectives. This is different from what happens in more contemporary knowledge production processes, where there is a separation between solutions and objectives, with solutions being imported and not clearly linked with collectively defined goals.

5.2. *Building good relationships*

Good relationships cannot be established without trust and credibility among participants. These are features that need time to develop as participants get to know each other and build a history of reciprocal and respectful interactions (Schruijer, 2006a; Vansina, 2007). Contrary to what is desirable, issues of distrust and lack of credibility are unavoidable in group dynamics. Vansina (2007) identified three minimum requirements that leaders must ensure to develop or restore trust: (1) to make participants feel safe in their interactions (e.g., by agreeing on ground rules that regulate the way in which people interact); (2) to facilitate face to face interactions among participants; (3) to secure equity, fairness and respect for one another in the participation. It is the role of the leaders to create the conditions for trust and credibility to emerge, having in mind that doing so may require time, a safe space and, in some cases, even the abilities of a mediator.

The quality of the interactions that result from collaboration has a direct effect on the type of knowledge that informs decision making processes and, in consequence, on the type of decision made (Schruijer, 2006b). Collaborative leadership should be recruited on the basis of ability to bridge differences, act equitably, and ensure that everybody has a fair chance of participating. Where some kinds of knowledge are privileged, strategies that incorporate different understandings and

promote blended knowledge are required. Such strategies can include identifying and fostering inclusive networks, more compelling and inclusive framing, and embracing narratives that incorporate diverse perspectives.

5.3. *Creating the decision space that supports collaboration*

When the conditions that support collective knowledge production processes do not exist, they can be created by collaborative leaders (Vansina, 2007). This can be done through system interventions that alter the group composition, the way in which participants interact, the research methods or techniques used to share data or create new definitions (Vansina, 2008; Lynam et al., 2007). This can occur through focus groups, boundary organizations, citizens' conferences or search conferences, or through the use of methods such as narrative, network or framing analyses that help mapping different types of knowledge while retaining their original values and forms of representation (Brugnach and Ingram, 2011).

Face-to-face engagement has the potential for bringing about trust, shared experiences, empathic understanding, positive relationships, and other community oriented consequences that will enable people to work towards new ways of knowing that are more amenable to collective solutions (Ostrom, 1990; Innes and Booher, 2003; Feldman and Ingram, 2009). Boundary objects (Star and Griesemer, 1989) provide an artifact such as a model, scenario, template, prototype, compact and the like that draws upon necessary but different ways of knowing and enhances mutual understanding among different ways of knowing. Boundary organizations, like advisory committees or task forces drawing upon science and lay members, may perform similar services across organizational boundaries (Jasanoff, 1990; Guston, 2001; Berkes, 2009). Shared or boundary experiences, where not only do people experience the same thing but also talk about it, also can facilitate collaborative action (Feldman et al., 2006).

Collaborative processes are not magic bullets, and simply changing processes for knowledge production will not make other problems disappear. However, substantive change is not likely to take place without process changes, and only through such changes can new techno-scientific ideas that are reflective of the social context emerge. Also, only through collaborative processes involving participation, discourse and communication can effective political strategies be developed (Ingram and Endter-Wada, 2009).

6. Conclusions

While natural resources management, particularly related to water, is supposed to have adopted a new paradigm, this article argues that operative models and modes of knowledge production have not kept pace. The way in which ambiguities are handled in contemporary knowledge production processes does not allow coping with the diversity of meanings and interpretations that exist in relation to water management problems. The separation of humans from the physical environment persists; technical and physical science knowledge is privileged over other relevant knowledge; multiple values and approaches are neither recognized nor incorporated into decision processes; and, relational knowledge where the production of relevant facts and values grow out of interactions in specific problem contexts is not recognized. There are embedded assumptions in knowledge co-production processes that perpetuate power differentiation, control, and cultural dominance, which have resulted in solutions that only embraced the interests of few. Instead, approaches that are inclusive and embrace diversity are needed to handle ambiguity in knowledge production processes.

We envision coping with ambiguity by redefining knowledge production processes. We suggest that knowledge differences can be better handled when supported by a collective, and situation specific, process of knowledge generation. From this perspective, knowledge creation constitutes an interactive process of co-production in which different actors coordinate their actions to reach jointly defined objectives. In this way knowledge held individually is put into a social context, so it is amplified and transformed. This is an interactive process among different knowledge holders, who through dynamic interactions interchange experiences and perspectives with the aim of enlarging their individual views, and create high order conceptualizations. These ideas build on the principle of interdependencies and recognize that each individual or group can offer unique and distinctive contributions in creating solutions.

This process starts with the identification of joint objectives and the creation of a shared problem definition used to derive new knowledge (Vansina, 2008). This is not a linear process that ends once new knowledge is developed, instead is a dynamic process in which problems and solutions are constantly being defined and redefined as new knowledge is created and adopted in practice. Thus, knowledge production shifts from an activity of processing already existing knowledge to solve a problem, to become an iterative process that supports the development of a shared understanding of a problem situation and definition of common objectives from which new concrete forms of knowledge can be derived.

The knowledge co-production model presented here differs from the currently employed models in various ways. In the proposed model, making decisions is not limited to processing information, but also entails the active development of new knowledge. Central to this idea is that knowledge is actionable and can be enacted in practice. Knowledge is therefore redefined relationally. Under this view knowledge is constructed through relational practices, developed in interactions through participation and sharing. Thus, social interactions are the venue to expand, legitimize, create and integrate different knowledge forms. As such, knowledge embeds the meaning and interpretations of those who participate in the process of knowledge creation.

From the point of view of knowledge co-production, multiparty interactions are essential to create knowledge that represents a shared understanding of a situation, that is compatible with the views of all those that participate. This is different from a top down process of consultation and cooperation, since decision choices become the direct product of shared rules, agreements and practices developed from working together. In this process of knowledge co-production there is a shared decision power among participants, where

each party is equal and there is a free exchange of knowledge among them (Barreteau et al., 2010).

When adopting this view of knowledge, decision making becomes a process in which a group define a problem and then develops knowledge to solve it. Thus, decision choices are the result of an interactional process of knowledge development in a group rather than the rational choice of a decision maker. This way of making decisions presents the advantage that solutions can be better tailored to jointly defined objectives, since what a problem is, and how it is approached and solved is determined cooperatively among participants. Further, the strategic use of knowledge is prevented, allowing designing of decision processes that can better capitalize on diversity.

Acknowledgements

The authors would like to thank the constructive comments of two anonymous reviewers as well as those made by A. Hoekstra in earlier versions of this manuscript. We also want to express our gratitude to A. Dewulf, T. Taillieu, S. Schruijer and L. Vansina for the discussions and exchanges on framing issues and multi-party collaborations.

REFERENCES

Agrawal, A., 1995. Dismantling the divide between indigenous and scientific knowledge. Development and Change 26, 413–439.

Argyris, C., Schön, D., 1978. Organizational Learning: A Theory of Action Perspective. Addison Wesley, Reading, MA.

Barreteau, O., Bots, P.W.G., Daniell, K.A., 2010. A framework for clarifying participation in participatory research to prevent its rejection for the wrong reasons. Ecology and Society 15 (2), 1. (online)http://www.ecologyandsociety.org/vol15/iss2/art1/.

Berkes, F., 1999. Sacred Ecology: Traditional Ecological Knowledge and Resource Management. Taylor and Francis, Philadelphia.

Berkes, F., 2007. Community-based conservation in a globalized world. PNAS 104 (39), 15188–15193.

Berkes, F., 2009. Evolution of co-management: role of knowledge generation, bridging organizations and social learning. Journal of Environmental Management 90, 1692–1702.

Bloomquist, W., Schlager, E., 2005. Political pitfalls of integrated watershed management. Society and Natural Resources 18 (2), 101–117.

Boelens, R.A., 2008. The Rules of the Game and the Game of the Rules: Normalization and Resistance in Andean Water Control. Wageningen University, The Netherlands.

Bouwen, R., 2001. Developing relational practices for knowledge intensive organizational contexts. Career Development International 6/7, 361–369.

Bouwen, R., Taillieu, T., 2004. Multi-party collaboration as social learning for interdependence: developing relational knowing for sustainable natural resource management. Journal of Community and Applied Social Psychology 14, 137–153.

Brown, F.L., Ingram, H., 1987. Water and Poverty in the Southwest. University of Arizona Press, Tucson, AZ.

Brock, W.A., Durlauf, S.N., 2001. Discrete choice with social interactions. Review of Economics Studies 68, 235–260.

Brugnach, M., Pahl-Wostl, C., 2007. A broadened view on the role of models in natural resource management: implications for model development. In: Pahl-Wostl, C., Kabat, P., Möltgen, J. (Eds.), Adaptive and Integrated Water Management: Coping with Complexity and Uncertainty. Springer-Verlag, Berlin, Germany.

Brugnach, M., Dewulf, A., Pahl-Wostl, C., Taillieu, T., 2008. Toward a relational concept of uncertainty: about knowing too little. Knowing too differently, and accepting not to know. Ecology and Society 13 (2) Article 30.

Brugnach, M., Dewulf, A., Henriksen, H.-J., van der Keur, P., 2011. More is not always better: coping with ambiguity in natural resources management. Journal of Environmental Management 92 (1), 78–84.

Brugnach, M., Ingram, H., 2011. Rethinking the role of humans in water management: towards a new model of decision making. In: Johnston, B.R. (Ed.), Water, Cultural Diversity and Environmental Change: Emerging Trends, Sustainable Futures? Springer-Verlag, Berlin, Germany.

Cash, D.W., 2002. Salience, Credibility, Legitimacy and Boundaries: Linking Research, Assessment and Decision Making. RWP 02-046. JFK School of Government, Harvard.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J., Mitchell, R.B.H., 2003. Knowledge systems for sustainable development. Proceedings of the National Academy of Science of the United States of America 100 (14), 8086–8091.

Conca, K., 2006. Governing Water: Contentious Transnational Politics and Global Institution Building. MIT Press, Cambridge.

Concilio, G., 2010. Bricolaging knowledge and practices in spatial strategy-making. In: Concilio, G., Cerreta, M., Monno, V. (Eds.), Making Strategies in Spatial Planning: Knowledge and Values. Springer, pp. 281–301.

Corpuz, T.V., 2006. Indigenous peoples and international debates on water: reflections and challenges. In: Boelens, R., Chiva, M., Nakashima, D. (Eds.), Water and Indigenous Peoples. Knowledge of Nature, vol. 2. UNESCO, Paris.

Craps, M., Dewulf, A., Mancero, M., Santos, E., Bouwen, R., 2004. Constructing common ground and re-creating differences between professional and indigenous communities in the Andes. Journal of Community and Applied Social Psychology 14 (5), 378–393.

Crawford, S., 1988. Mayordomo: Chronicle of an Acequia in Northern New Mexico. University of New Mexico Press, Albuquerque.

Deloria Jr., V., 1999. In: Deloria, B., Foehner, K., Scinta, S. (Eds.), Spirit and Reason: the Vine Deloria. Fulcrum Publishing.

Dewulf, A., Craps, M., Bouwen, R., Taillieu, T., Pahl-Wostl, C., 2005. Integrated management of natural resources: dealing with ambiguous issues, multiple actors and diverging frames. Water, Science and Technology 52, 115–124.

Eldredge, N., 1995. Dominion. Henry Holt and Co, New York.

Failing, L., Gregory, R., Harstone, M., 2007. Integrating science and local knowledge in environmental risk management: a decision-focused approach. Ecological Economics 64, 47–60.

Feldman, M.S., Khademian, A.M., Ingram, H., Schneider, A.L., 2006. Ways of knowing and inclusive management practices. Public Administration Review 66, 89–99.

Feldman, D., Ingram, H., 2009. Climate forecast, water management, and knowledge networks: making science useful to decision makers. Water, Climate and Society.

Fischer, F., 2006. Citizens, Experts and the Environment. Duke University Press, Durham.

Fuller, S., 2002. Knowledge Management Foundations. Butterworth-Heinemann, USA.

Gray, B., 1989. Collaborating: Finding Common Ground for Multiparty Problems. Jossey-Bass, San Francisco.

Gray, B., 2003. Framing of environmental disputes. In: Lewicki, R.J., Gray, B., Elliott, M. (Eds.), Making Sense of Intractable Environmental Conflicts: Concepts and Cases. Island Press, Washington.

Gray, B., 2004. Strong opposition: frame-based resistance to collaboration. Journal of Community and Applied Social Psychology 14, 166–176.
Gregory, R., Trousdale, W., 2009. Compensating aboriginal cultural losses: an alternative approach to assessing environmental damages. Journal of Environmental Management 90, 2469–2479.
Gunderson, L.H., Holling, C.S., Light, S.S. (Eds.), 1995. Barriers and Bridges to the Renewal of Ecosystems and Institutions. Columbia University Press, New York, NY.
Guston, D.H., 2001. Boundary organizations in environmental policy and science. Science, Technology and Human Values 26 (4), 399–408.
GWP-TEC (Global Water Partnership Technical Advisory Committee), 2000. Integrated Water Resources Management. TAC Background Papers No. 4 (GWP, Stockholm, Sweden).
Hoekstra, A.Y., 1998. Appreciation of water: four perspectives. Water Policy 1 (6), 605–622.
Holling, C.S., 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4, 1–23.
Holling, C.S., 1978. Adaptive Environmental Assessment and Management. Wiley, Chichester, UK.
Holling, C.S., Meffe, G.K., 1996. Command and control and the pathology of natural resource management. Conservation Biology 10, 328–337.
Hulme, M., 2010. Problems with making and governing global kinds of knowledge. Global Environmental Change 20, 558–564.
Huitema, D., Meijerink, S. (Eds.), 2009. Water Policy Entrepreneurs. A Research Companion to Water Transitions Around the Globe. Edward Elgar, Cheltenham.
Ingram, H., 2011. Beyond universal remedies for good water governance: a political and contextual approach. In: Garrido, A., Ingram, H. (Eds.), Water for Food in a Changing World. Routledge/Taylor/Francis Books, Oxford/New York.
Ingram, H., Stern, P., 2007. Research and Networks for Decision Support in the NOAA Sectoral Applications Research Program. National Academies Press, Washington, DC.
Ingram, H., Endter-Wada, J., 2009. Frames and ways of knowing: key considerations for policy responses to climate risk and vulnerability. In: Paper for the 7th International Science Conference on the Human Dimensions of Global Environmental Change, 26–30 April 2009, UN Campus, Bonn, Germany.
Ingram, H., Lejano, R., 2010. Transitions: transcending multiple ways of knowing water resources in the U.S. In: Huitema, D., Meijerink, S. (Eds.), Water Policy Entrepreneurs. Edward Elgar, Chellenham, UK.
Innes, J.E., Booher, D.E., 2003. Collaborative policymaking: governance through dialogue. In: Hajer, M., Wagenaar, H. (Eds.), Deliberative Policy Analysis. Cambridge University Press, Cambridge.
Jasanoff, S., 1990. The Fifth Branch: Science Advisors as Policy Makers. Harvard University Press, Cambridge.
Jasanoff, S. (Ed.), 2004. States of Knowledge: The Co-production of Science and Social Order. Routledge, London.
Jakubik, M., 2007. Exploring the knowledge landscape: four emerging views of knowledge. Journal of Knowledge Management 11 (4), 6–19.
Lee, K.N., 1999. Appraising adaptive management. Conservation Ecology 3 (3), 16.
Lejano, R., Ingram, H., 2009. Collaborative networks and new ways of knowing. Environmental Science and Policy 12 (6), 653–662.
Leeuwis, C., 2000. Reconceptualizing participation for sustainable rural development: towards a negotiation approach. Development and Change 31, 931–959.
Liu, J., Dietz, T., Carpenter, S., Folke, C., Alberti, M., Redman, C., Schneider, S.H., Ostrom, E., Pell, A., Lubchenco, J., Taylot, W., Ouyang, Z., Deadman, P., Kratz, T., Provencher, W., 2007. Coupled human and natural systems. Ambio 36 (8), 639–647.
Lynam, T., de Jong, W., Sheil, D., Kusumanto, T., Evans, K., 2007. A review of tools for incorporating community knowledge, preferences and values in decision making in natural resources management. Ecology and Society 12 (1), 5., http://www.ecologyandscoiety.org/vol12/iss1/art5/.
Medema, W., McIntosh, B.S., Jeffrey, P.J., 2008. From premise to practice: a critical assessment of integrated water resources management and adaptive management approaches in the water sector. Ecology and Society 13 (2), 29. (online)http://www.ecologyandsociety.org/vol13/iss2/art29/.
Nakashima, D., Nilsson, A., 2006. Linking biological and cultural diversity: local and indigenous knowledge systems (LINKS) project. In: Petitjean, P., Zharov, V., Glaser, G., Richardson, J., de Padirac, B., Archibald, G. (Eds.), 60 Years of Science at UNESCO 1945–2005. UNESCO, Paris, pp. 385–388.
Nonaka, I., 1994. A dynamic theory of organizational knowledge creation. Organization Science 5 (1), 14–37.
Obholzer, A., Miller, S., 2007. Leadership. Followership and facilitating the creative workspace. In: Huffington, C., Armstrong, D., Halton, W., Hoyle, L., Pooley J. (Eds.). Working below the surface. The Emotional Life of Contemporary Organizations. Tavistock Clinic Series. Margot Waddell (Series Editor). H. Karnac (Books) Ltd.
Ostrom, E., 1990. Governing the Commons. Cambridge University Press, New York.
Ostrom, E., Janssen, M., Anderies, J.M., 2007. Going beyond panaceas. Proceedings of the National Academy of Science of the United States of America 104 (39), 15176–15178.
Owens, S., 2005. Making a difference? Some perspectives on environmental research and policy. Transactions of the Institute of British Geographers 30 (3), 287–292.
O'Flaherty, R.M., Davidson-Hunt, I.J., Manseau, M., 2008. Indigenous knowledge and values in planning for sustainable forestry: Pikangikum first nation and the whitefeather forest initiative. Ecology and Society 13 (1), 6.
Pahl-Wostl, C., 2007a. Transition towards adaptive management of water facing climate and global change. Water Resources Management 21 (1), 49–62.
Pahl-Wostl, C., 2007b. The implications of complexity for integrated resource management. Environmental Modelling & Software 22, 561–569.
Rodríguez, S., 2006. Acequia: Water Sharing, Sanctity and Place. School for Advanced Research Press, Santa Fe N.M..
Sabatier, P.A., Focht, W., Lubell, M., Trachtenberg, Z., Vedlitz, A., Matlock, M., 2005. Swimming Upstream: Collaborative Approaches to Watershed Management. MIT Press, Cambridge.
Schön, D., Rein, M., 1994. Frame Reflection: Toward the Resolution of Intractable Policy Controversies. MIT Press, Cambridge, MA.
Schruijer, S., 2006a. Leadership and interorganisational collaboration as perceived by directors and managers. In: Gould (Eds.), Engagement. Short Run Press, Exeter.
Schruijer, S., 2006b. Research on collaboration in action. International Journal of Action Research 2 (2), 222–242.
Schruijer, S., Vansina, L., 2008. Working across organizational boundaries: understanding and working with the psychological dynamics. In: Vansina, L.S., Vansina-Cobbaert, M.-J. (Eds.), Psychodynamics for Consultant and Managers. Wiley, London.
Schusler, T.M., Decker, D.J., Pfeffer, M.J., 2003. Social learning for collaborative natural resource management. Society and Natural Resources 15, 309–326.
Shindler, B., Aldred Cheek, K., 1999. Integrating citizens in adaptive management: a propositional analysis. Conservation Ecology 3 (1), 9. (online)http://www.consecol.org/vol3/iss1/art9/.

Solón, P., 2006. Cultural diversity and privatization of water. In: Boelens, R., Chiva, M., Nakashima, D. (Eds.), Water and Indigenous Peoples. Knowledge of Nature 2. UNESCO, Paris.
Star, S.L., Griesemer, J., 1989. Institutional ecology, translations and boundary objects: amateurs and professionals in Berkeley's museum of vertebrate zoology. Social Studies of Science 19 (3), 387–420.
Tàbara, J.D., Chabay, I. Coupling human information and knowledge systems with social-ecological systems change: reframing research, education, and policy for sustainability, submitted for publication.
Turner, N., Gregory, R., Brooks, C., Failing, L., Satterfield, T., 2008. From invisibility to transparency: identifying the implications. Ecology and Society 13:2, http://www.ecologyandsociety.org/vol13/iss2/art7/.
Tversky, A., Kahneman, D., 1974. Judgment under uncertainty: heuristics and biases. Science 185 (4157), 1124–1131.
Vansina, L., 2007. How could one lead without being the leader? Facilitating working through critical episodes in Collaborative Work Systems. In: MOPAN Conference, Leuven, Belgium.
Vansina, L., 2008. Psychodynamics: a field of study and an approach. In: Vansina, L., Vansina-Cobbaert, M.-J. (Eds.), Psychodynamics for Consultants and Managers. Wiley, London.
Vitebsky, P., 2005. Reindeer People: Living with Animals and Spirtis in Siberia. Harper Collins, London.
Walters, C., 1986. Adaptive Management of Renewable Resources. McGraw Hill, New York, USA.
Wenger, E., 1998. Communities of Practice: Learning, Meaning and Identity. University Press, Cambridge.
Weick, K., 1995. Sensemaking in Organizations. Sage Publications, Thousand Oaks, CA, USA.
Westman, C., 2006. Assessing the impacts of oilsands development on indigenous peoples in Alberta Canada. Indigenous Affairs 2–3, 31–39.
Whiteley, J., Ingram, H., Perry, R., 2008. Water, Place and Equity Cambridge. MIT Press.
Wildavsky, A., 1979. Speaking Truth to Power: The Art and Craft of Policy Analysis. Little Brown, Boston.

Marcela Brugnach is an Assistant Professor at the University of Twente (The Netherlands). She has an interdisciplinary background that combines social sciences, ecology, engineering and modeling. Her research focuses on the themes of uncertainty and ambiguity in collective decision making processes in natural resources management.

Helen Ingram is a Research Fellow at The Southwest Center at the University of Arizona. She is the Warmington Chair Emerita at the University of California at Irvine. She has written widely on topics of politics and policy related to water resources and climate change.