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Synthesis, part of a Special Feature on Integrating Indigenous Ecological Knowledge and Science in Natural Resource Management: Perspectives from Australia

Indigenous Knowledge, Science, and Resilience: What Have We Learned from a Decade of International Literature on "Integration"?

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ABSTRACT. Despite the increasing trend worldwide of integrating indigenous and scientific knowledge in natural resource management, there has been little stock-taking of literature on lessons learned from bringing indigenous knowledge and science together and the implications for maintaining and building social-ecological system resilience. In this paper we investigate: (1) themes, questions, or problems encountered for integration of indigenous knowledge and science; (2) the relationship between knowledge integration and social-ecological system resilience; and (3) critical features of knowledge integration practice needed to foster productive and mutually beneficial relationships between indigenous knowledge and science. We examine these questions through content analyses of three special journal issues and an edited book published in the past decade on indigenous, local, and traditional knowledge and its interface with science. We identified broad themes in the literature related to: (1) similarities and differences between knowledge systems; (2) methods and processes of integration; (3) social contexts of integration; and (4) evaluation of knowledge. A minority of papers discuss a relationship between knowledge integration and social-ecological system resilience, but there remains a lack of clarity and empirical evidence for such a relationship that can help distinguish how indigenous knowledge and knowledge integration contribute most to resilience. Four critical features of knowledge integration are likely to enable a more productive and mutually beneficial relationship between indigenous and scientific knowledge: new frames for integration, greater cognizance of the social contexts of integration, expanded modes of knowledge evaluation, and involvement of inter-cultural "knowledge bridgers."

Key Words: *ecological; indigenous; integration; knowledge; resilience; science; social*

INTRODUCTION

More than a decade ago, Nadasdy (1999) lambasted the "project of integration" of traditional knowledge and science for what he saw as its flawed central assumption: the cultural beliefs and practices referred to as traditional knowledge conform to western conceptions about knowledge. Integration, Nadasdy elaborated, is too often viewed mainly as a technical problem, ignoring the role of power relations between indigenous people and the state and ultimately creating products that serve scientists and the state rather than indigenous knowledge holders. More recently, other scholars have resisted integration on the grounds that the conceptual models and ontologies of traditional knowledge and science are sufficiently distinct to make these knowledge systems incommensurable (Atran 2001, Verran 2001, Cruikshank 2005), and that some forms of integration can have unintended and undesired consequences (Fox et al. 2005).

"Knowledge integration" is defined on Wikipedia as "the process of synthesizing multiple knowledge models (or representations) into a common model (representation)" and "the process of incorporating new information into a body of existing knowledge." This requires "determining how the new information and the existing knowledge interact, how existing knowledge should be modified to accommodate the new information, and how the new information should be modified in light of the existing knowledge" (en.wikipedia.org/wiki/Knowledge_integration). This definition, simple though it may appear, encapsulates the very dilemma knowledge integration faces in the arena of indigenous knowledge and science: whose knowledge is "new," whose is "existing," and who decides?

Nevertheless, interest in integrating indigenous, local, or traditional knowledge and science is steadily growing along several lines of argument (Rist and Dahdouh-Guebas 2006, Houde 2007). One is that these forms of knowledge are essential for maintaining global cultural diversity and the biological diversity with which it is intricately connected (Maffi 2001, Maffi and Woodley 2010), and will only be appropriately valued and protected through integration that brings benefits to both scientists and local people interested in maintaining that diversity (Edwards and Heinrich 2006). A second argument is that these types of knowledge contribute invaluable information for science and natural resource management; indeed, they often fill gaps in understanding that science cannot (Baker and Mutitjulu Community 1992, Johannes 1998). A third argument is that recognition of traditional knowledge in natural resource management has importance beyond scientific or broader societal merit: it is tantamount to social justice, sovereignty, autonomy, and identity of indigenous peoples (e.g., Agrawal 1995, Nelson 2005, Aikenhead and Ogawa 2007). These different motivations for integrating knowledge are neither mutually exclusive nor entirely harmonious.

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Arguments for knowledge integration also revolve around resilience, the ability of a social-ecological system to withstand disturbance without changing structure, function, feedbacks, and identity (Walker et al. 2006), and to remain flexible in response to changing environmental and social contexts (Redman and Kinzig 2003). The resilience view holds that management of complexity and uncertainty in social-ecological systems can benefit when diverse types of knowledge are combined (Folke et al. 2005). Furthermore, comanagement arrangements that allow knowledge to be integrated through collaboration can build social as well as ecological resilience (Plummer and Armitage 2007).

Despite criticisms that the resilience basis for knowledge integration, like other western epistemologies, may entrench already unequal power relations (e.g., Nadasdy 2007), it merits further consideration at least for the reason that resilience theory emphasizes new ways to address longstanding as well as emerging complex social-ecological challenges. Modern problems cannot be consistently solved with singular, mechanistic, science-centered solutions. Although this plea has been articulated for some time (Agrawal 1995, Holling and Meffe 1996), it remains ignored in much natural resource management, and is virtually unheard where most indigenous policy is concerned (Moran 2009). Moreover, a resilience view of knowledge integration recognizes opportunity in complexity: the constant shifting and flux of worldviews that breed complexity can in fact offer a chance to revisit old problems and paradigms, and collectively construct new models of how the world works (Houde 2007).

The practice of knowledge integration continues to present a number of challenges. Some of these are undoubtedly due to the tensions posed by competing, or even unclear objectives of integration processes. Scientific research, natural resource management, conservation, development, self-determination, and advocacy for indigenous rights have all been legitimate drivers of efforts to integrate knowledge. In some cases, however, knowledge integration has merely become a fashionable trend in natural resource management (Wohling 2009) that amounts to little more than a box-ticking exercise. At present, the broad picture is one of a knowledge integration-in-practice that has not benefitted from extensive academic debate on the subject (Castillo 2009).

This paper aims to contribute to developing more meaningful and appropriate knowledge integration processes for research with indigenous communities. We examine three questions that we believe can contribute to a better understanding of indigenous knowledge, its integration with scientific knowledge, and its relationship to social-ecological system resilience:

1. What themes, questions, or problems are encountered for integration of indigenous knowledge and science?
2. What is the relationship between knowledge integration and social-ecological system resilience?
3. What critical features of knowledge integration practice need greater emphasis to foster productive and mutually beneficial relationships between indigenous knowledge and science?

We examine these questions through inductive and deductive content analyses of a sample of international literature.

METHODS

Selection of literature and terminology

It was important to keep the scope of our investigation manageable for in-depth analysis, i.e., approximately 50 papers. We chose to analyze collected works, i.e., special journal issues or edited books, because these would benefit from specific editorial oversight on the topic, and would be likely to reflect on the state of knowledge integration and lessons learned. Our criteria for selecting these were: (1) a focus either on indigenous knowledge (IK), local knowledge (LK), or traditional knowledge (TK); (2) relevance to the concept of social-ecological system resilience in relation to knowledge integration; and (3) publication in the decade following Nadasdy's 1999 assessment, i.e., 2000-2009. We thus selected three special journal issues and one edited book, comprising 47 papers or chapters, as the basis for our analysis (Table 1). We found that although each of the four bodies of work meets these criteria, they differ considerably from one another and collectively present a wide range of views, allowing for a rich analysis.

Our selection of literature differs from studies such as Davis and Ruddle (2010) that investigated conceptualizations of indigenous and other knowledge in the most frequently cited literature indexed in the ISI Web of Knowledge and Google Scholar. We found these search engines inadequate for identifying literature for an analysis of knowledge integration and resilience, because they returned very few papers on these topics in the context of indigenous knowledge.

We recognize that we have excluded a wealth of literature from our analysis, for example, the special issue edited by Stephenson and Moller (2009) that was published after our analysis was underway. In discussing our analysis, we do relate our findings to other literature with which we are familiar. However, it would be impossible to canvass the entire literature on IK, much less the entire sum of field experience with IK, to obtain a perspective on its integration with scientific knowledge.

Distinct meanings of IK, LK, and TK have been discussed at length elsewhere (Usher 2000, Howden 2001, Nelson 2005, Aikenhead and Ogawa 2007, Houde 2007). Although in many instances the term Indigenous Ecological Knowledge (IEK) or Traditional Ecological Knowledge (TEK) is used, IK is

broader than ecological knowledge and better reflects the holistic worldviews that often underpin indigenous knowledge systems (Rotarangi and Russell 2009). We will therefore use the term IK in discussing our analysis, except where citing literature that specifically uses other terms.

Table 1. Contents of literature review.

Journal/ Publisher	Year	Editor(s)	Title	Number of articles/ chapters
Ecological Applications	2000	Ford and Martinez	Traditional Ecological Knowledge, Ecosystem Science, and Environmental Management	11
Ecology and Society	2004	Folke	Traditional Knowledge in Social-ecological systems	12
Millennium Ecosystem Assessment and Island Press	2006	Reid, Berkes, Wilbanks, and Capistrano	Bridging Scales and Knowledge Systems: Concepts and Applications in Ecosystem Assessment	17
Futures	2009	Turnbull	Futures of Indigenous Knowledges	7

Content analysis

We used content analysis to guide our literature review, focusing on our three questions. In content analysis, written material is coded by the use of terms or phrases (Ekstrom and Young 2009), enabling a systematic analysis of text to interpret data about human thought and behavior (Bernard and Ryan 1998). Content or text analysis is increasingly used to identify patterns in written material, and has several advantages: it tends to be more systematic and objective, and therefore quicker, than qualitative case study analysis, and can rapidly identify co-occurrences of different concepts (Ekstrom and Young 2009). A total of 47 papers or chapters were analyzed inductively and deductively using NVivo software (QSR 2009). An inductive analysis was conducted to explore themes in the literature, whereas a deductive analysis was used to examine the question above about integration and resilience.

Inductive analysis

Themes were identified for each paper that described as succinctly as possible the major focus or foci of the paper. Introductory papers or chapters and the synthesis chapter in Reid et al. 2006 were excluded to avoid double-counting of themes. We identified themes largely from our interpretation of the stated objective and motivation for each paper. To verify our theme identification we also performed text searches on key words where possible (e.g., "culture"). Text searches were less useful for concepts like "similarities and differences" and "institutions," so manual verification was needed in these cases. Where more than one theme appeared to be important, up to three additional themes were selected, but were not ranked. Similar themes were then grouped, resulting in a total of nine themes. Each of the papers was assigned to one or more of these nine grouped themes (see Appendix 1).

Deductive analysis

We performed a text search on all forms of the word "integration" in each paper, excluding paper or chapter headers. We also performed text searches for related words such as "blend," "bridge," "combine," and "interact," but found that these were generally not good proxies for integration. Although "bridge" usually implied integration in the Reid et al. (2006) chapters, it was used in this way in only about half of the other papers. We inspected the NVivo results and excluded those in which integration was not used in reference to IK and science. A second search was performed on all forms of the word "resilience." We then conducted a combined word search to identify instances in which the terms "integration" and "resilience" appeared in the same paper.

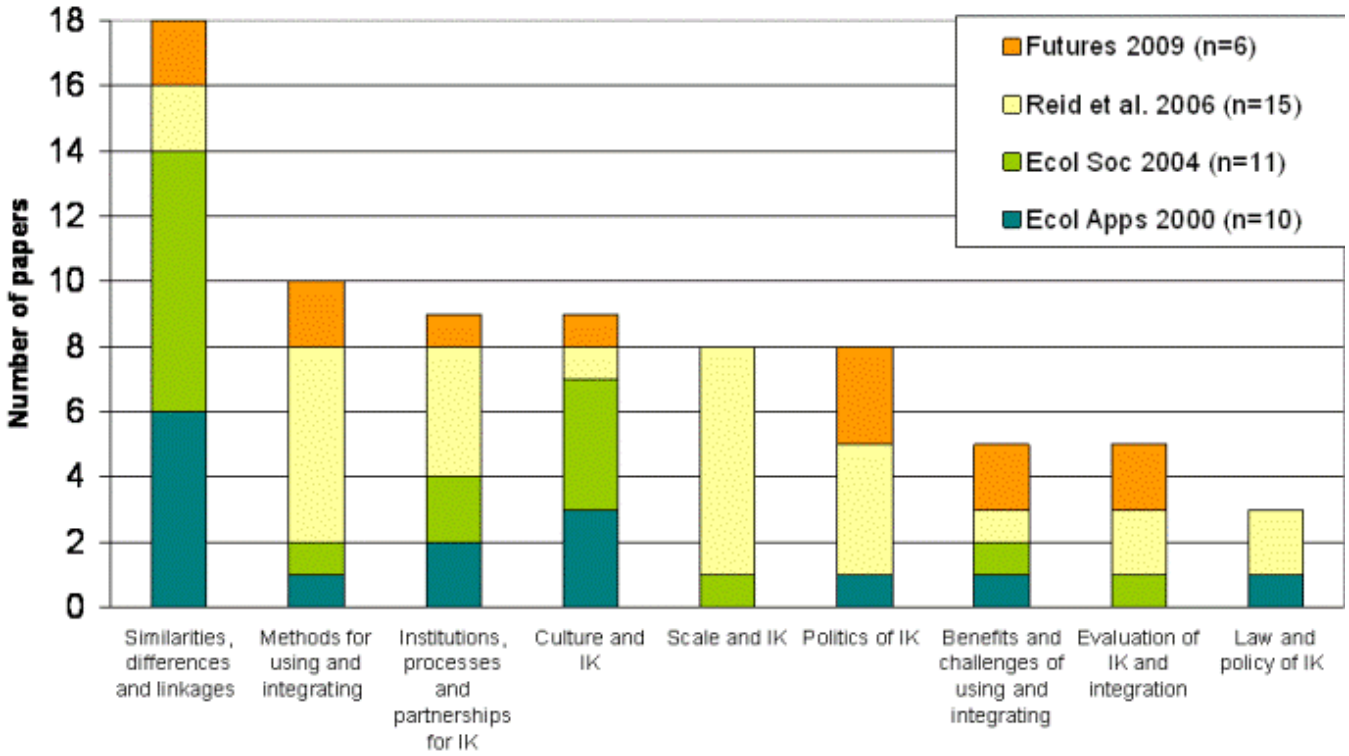
We found the method of content analysis to be useful as a filter of material and to identify cases warranting further inspection. However, our results for the combined usage of the terms "integration" and "resilience" show that this method was insufficient in identifying links between the two concepts, despite being a reliable method for assessing relationships between concepts in other studies (Ekstrom and Young 2009). We therefore manually cross-checked results to ensure that all papers that discussed integration and resilience were identified. We recorded the number of papers in each of the four publications with at least one occurrence of each term, the word count, i.e., the number of times that the word appeared within the publication, and coverage, i.e., the frequency of the word relative to the total words in the publication.

THEMES IN KNOWLEDGE INTEGRATION

Our thematic analysis addresses the first question we pose in this paper: What themes, questions, or problems are encountered for integration of indigenous knowledge and science?

The number of papers featuring each of the themes is shown in Figure 1. The most frequently-identified themes are "similarities, differences, and linkages between IK and science" (43%), "methods for using and integrating knowledge" (26%), "institutions, processes, and partnerships for maintaining and integrating IK" (21%), and "culture and IK" (21%).

Fig. 1. Themes identified in the reviewed literature. Introductions and synthesis chapter of Reid et al. (2006) were excluded from analysis. IK = indigenous knowledge.



The dominant theme in *Ecological Applications* (2000) and *Ecology and Society* (2004) papers is "similarities, differences, and linkages" (60% and 73%, respectively), followed by "culture" (30% and 36%, respectively). The most frequently appearing themes in the Reid et al. (2006) chapters are "scale and IK" (47%), "methods for using and integrating knowledge" (40%), and "institutions, processes, and partnerships" and "politics of IK" (each 27%). The most frequently appearing themes in *Futures* (2009) papers are "politics of IK" (50%) followed by "similarities, differences, and linkages," "methods," "benefits and challenges of using and integrating IK," and "evaluation of IK and integration" (each 33%).

We organize our discussion of these themes into four categories, and draw out key lessons learned for each (Table 2): (1) understanding similarities and differences between IK and science, and benefits and challenges of using and integrating IK; (2) methods for using and integrating IK, and institutions, processes, and partnerships for maintenance and integration of IK; (3) the social contexts of IK; and (4) evaluation of IK and integration.

Understanding similarities and differences between IK and science, and benefits and challenges of using and integrating IK

An understanding of similarities and differences between IK and scientific knowledge, and the benefits and challenges of integrating these different knowledge systems, is considered by some to be a prerequisite to knowledge integration (Moller et al. 2004, Davis 2006). Berkes et al. (2000) maintain that TEK is used to manage complex systems through practices that bear many similarities to Western adaptive management systems, and many of these traditional practices are founded on important social mechanisms. Pierotti and Wildcat (2000) suggest that TEK converges on Western science disciplines like community ecology, emphasizing connectedness and relatedness between human and nonhuman components of ecological systems, and as the basis for indigenous concepts of nature, politics, and ethics, TEK is inherently interdisciplinary. However, compared with science, Pierotti and Wildcat (2000) argue that TEK is place-based and fundamentally "space-based," focusing on spatial relationships in nature. Berkes and Berkes (2009) liken practices of the Inuit and other northern indigenous people to fuzzy logic, whereby environmental change is monitored using rules of thumb and qualitative indicators.

Table 2. Summarized themes, their significance for knowledge integration, and key lessons identified in reviewed literature. Introductions and synthesis chapter of Reid et al. (2006) were excluded from analysis. IK = indigenous knowledge.

Theme(s)	Significance	Key Lessons
Similarities and differences between IK and science, and benefits and challenges of using and integrating IK.	An understanding of similarities and differences between IK and scientific knowledge, and the benefits and challenges of integrating these different knowledge systems, is a prerequisite to knowledge integration.	- IK and Western knowledge systems are complementary or parallel rather than fundamentally incommensurable. - Differences between IK and science can be resolved through collaborative approaches and by finding common ground. - Some IK-based practices resemble Western science but former tend to be based on important social mechanisms. - Science is better equipped to detect causal links, and to evolve quickly enough to accommodate new information. - Tensions between IK and science persist: some IK holders reject Western philosophy's focus on truth, belief, and worldview. - Difficulties of including IK in ecological research may outweigh the benefits.
Methods for using and integrating IK, and institutions, processes, and partnerships for maintenance and integration of IK.	Advances in methods and processes are essential to join knowledge integration theory and practice.	- The methodological toolkit is expanding beyond collection of IK to methods for bringing different sources and forms of knowledge together, i.e., scenarios, mapping, community theater. - A sophisticated array of institutions, processes, and partnerships to integrate knowledge exist as well as reflection on their success.
IK and culture, scale, politics, law, and policy.	Culture, scale, politics, law, and policy all form the social context of knowledge integration.	- Knowledge integration needs to be cognizant of the culture-knowledge link, and its evolution in response to global and regional change. - Choice of scale can influence the agendas or contexts in which knowledge is organized and decisions made, and whose knowledge is relevant. - How knowledge holders position their knowledge in political arenas is important. - Scientists who engage with IK need to understand the international law and policy contexts in which IK is situated, and implications for access to knowledge. - National laws and policies need to make space for indigenous forms of cultural practice.
Evaluation of IK and integration.	Need to assess different types of knowledge, the combined products of integration, and the process by which they are combined.	- Much evaluation of integrated knowledge has largely concerned the credibility of IK in the eyes of science. - Recent initiatives recognize a need for a broader set of evaluative criteria to assess knowledge. - IK has its own rules about processes of knowing, which diverge from the rules of science. - Evaluation processes need to distribute power more equally across knowledge producers. - IK has a crucial role for evaluation of science: through integration, IK holders can scrutinize scientific predictions themselves, increasing the potential for science to be trusted.

Some authors acknowledge differences between IK and science. In her case study of Mongolian pastoralists, Fernandez-Gimenez (2000) distinguishes pastoralists' perceptions from science, noting that science is better equipped to detect a causal link between land use change and threats to pastoralists' livelihoods. Fabricius et al. (2006) recognize the value of local knowledge to science assessments, as a source of fine-grained, detailed information about local ecosystem services in areas where little formal knowledge exists. They also articulate several shortcomings of local knowledge, such as its inability to evolve quickly enough to accommodate change in social-ecological systems, and its tendency to lack relevance outside local context.

Tensions between IK and science are evident: Klubnikin et al. (2000) suggest that indigenous knowledge is essentially scientific because it is gathered through methods that are empirical, experimental, and systematic, whereas Western science, by contrast, may be seen as narrow and naïve in the way it considers and defines questions. Turner et al. (2000) and Long et al. (2003) stress the importance of wisdom and

"showing respect" as distinctive features of traditional ecological knowledge. Maffie (2009) notes the tendency of IK holders to reject what they view as Western philosophy's obsession with truth, belief, and worldview. What matters most to indigenous North Americans, he asserts, is how one lives, not what one believes. However, he acknowledges that much of the perceived incompatibility between science and other knowledge systems also arises from treating Western science or IK as a singular entity when in fact both have multiple forms and dimensions.

Such differences do not necessarily impede integration. Moller et al. (2004) suggest that population monitoring that embraces differences between traditional methods and scientific methods is potentially more effective for managing customary harvests than monitoring that ignores these differences. These methods are in fact complementary, in five respects (Table 2 in Moller et al. 2004): (1) science is diachronic, i.e., tends to collect short-term data over large areas, whereas TK is synchronic, i.e., tends to collect information over long time periods; (2) foci on averages (science) and extremes (TK); (3) quantitative (science) and qualitative (TK) information; (4) improved tests of mechanisms (science) and improved hypotheses (TK); and (5) objectivity (science) and subjectivity (TK). Davis (2006) agrees that IK and Western science are complementary or parallel rather than fundamentally incommensurable. Differences between them, he suggests, can be resolved through collective approaches such as Australia's "caring for country" to nurture and maintain ecosystems, by blending conventional fire management regimes and Aboriginal systems of burning.

Becker and Ghimire (2003) propose that TEK and Western conservation science can collectively support forest preservation in Ecuador, as they have common ground: both rely on direct observation, experience, experimentation, and interpretation. Western science offers broader appreciation of context beyond the local level that may actually favor local sustainability and, thus, cultural survival, whereas TEK offers depth of experience in a local, culture-specific context. Ishizawa (2006) stresses the importance of institutional diversity in collaborations with campesino communities in the central Andes of Peru for in situ conservation. Bridging epistemologies, he suggests, may be viable if the underlying worldviews are considered and made explicit, and if problem identification happens at the contact zone and is reformulated as a global concern.

Huntington (2000) explores reasons for inertia to acceptance and use of TEK. These include unfamiliarity and lack of comfort among ecologists in using social science methodologies and engaging in cross-cultural interactions, and fear of diluting scientific rigor in favor of political correctness. He notes that in some cases, the difficulties of including TEK in ecological research outweigh the benefits, and there is a danger of inappropriate knowledge integration in which treatment of TEK is superficial.

Methods for using and integrating IK, and institutions, processes, and partnerships for maintenance and integration of IK

Advances in methods and processes are essential to join theory and practice of knowledge integration. The literature suggests that the methodological toolkit is expanding beyond ethnographic and ethnobotanical approaches of collecting IK to methods for actually bringing different sources and forms of knowledge together. Huntington (2000) reviews tools for incorporating IK in ecological studies, while others explore a broad realm of methods to share and deliberate over multiple sets of knowledge of multifaceted change processes. These include future scenarios (Bennett and Zurek 2006), mapping and GIS (Bryan 2009, Palmer 2009), and theater performance to communicate scientific knowledge to communities (Fabricius et al. 2006).

There is also evidence of a sophisticated array of institutions, processes, and partnerships in action, as well as reflection on how well these have worked in real-world integration examples. Fabricius et al. (2006) discuss challenges related to the technical and social processes of amalgamating different types of knowledge across spatial scales and epistemologies. They describe how in the Southern African Millennium Ecosystem Assessment, creative tension emerged between scientists operating at different scales and thus using different theories and methods, a situation not often acknowledged openly as a challenge to integration. Dialogue and debate were valuable in building mutual trust among team members, while also highlighting areas of scientific uncertainty. Eamer (2006) describes how joint problem-solving in the Arctic Borderlands Ecological Knowledge Co-op helped indigenous knowledge holders operate as equals with scientists by engaging in long-term collaborative management of the environment.

Gadgil et al. (2000) and Gokhale et al. (2006) describe India's People's Biodiversity Registers Program (PBR) to maintain the practice of folk ecological knowledge and wisdom into the future. In their review of 52 PBR cases, Gadgil et al. (2000) found two self-organized management systems in which biodiversity has been protected, but more frequently observed trends of ecological degradation as well as erosion of ecological knowledge and sustainable use traditions. They therefore assert a need for community-based systems, supported by and collaborating with government and other institutions. Gokhale et al. (2006) discuss how PBR and other frameworks and approaches are used to reward people's knowledge and protect intellectual property rights in India, thereby linking local oral knowledge with global science.

There are also calls for the formation of institutions underpinned by new epistemological paradigms. Maffie (2009) proposes a "polycentric global epistemology" (PGE),

which both requires and strives for the survival and self-determination of indigenous peoples and their knowledge. PGE does not presume there is a single best way for all humans to live or know nature or to realize their own conception of human well-being. He suggests that real-world examples of PGE already exist in a collaborative salmon protection program in British Columbia and numerous medical systems.

Social context of knowledge integration

Culture, scale, politics, law, and policy all form the social context of knowledge integration. Some authors argue that knowledge integration processes and practices need to be cognizant of culture. Garibaldi and Turner (2004) present the idea of "cultural keystone species" that feature prominently in a culture because of their value for food, material, or medicine. They describe how cultural keystones such as the Western red-cedar (*Thuja plicata*) are important to coastal First Peoples of British Columbia as a vehicle for conservation and restoration as well as treaty and land rights negotiations. Long et al.'s (2003) interviews with cultural advisors in the White Mountain Apache community about their views on wetland restoration suggest that cultural traditions can guide ecological restoration efforts. Watson et al. (2003) investigate how global and regional change affect the culture-knowledge link regarding wilderness protection and restoration in the Circumpolar North, arguing that evolution of culture and TEK values related to pristine ecosystems must be considered in Western systems of wilderness management.

The scale of scientific inquiry shapes the social and political dimensions of knowledge integration. Wilbanks (2006) contends that scale is important to our understanding of how the world works, to agency and structure of our responses, and to learning. The choice of scale in science assessments can influence the agendas by which knowledge is organized and stakeholders identified, and hence, whose knowledge is relevant (Lebel 2006). Roth's (2004) analysis of the spatial organization of knowledge at state and local levels in northern Thailand illuminates the challenge of knowledge integration across multiple spatial scales. She suggests that the location of knowledge production is the main driver of differences between communities' TEK and state environmental knowledge and consequently, understanding relationships between knowledge and space is key to conflict resolution.

Implicit in the scale of IK are its politics, including how IK is translated and communicated. Brosius (2006) asserts that there is the need for clearer definition of "local," arguing that much local knowledge is mediated by those who are delegated to speak on the behalf of local people in national and international fora. He shows how scientists have focused overwhelmingly on environmental knowledge and ignored other relevant domains of knowledge, such as knowledge and perceptions of the political world that are so critical to natural resource management. Rather than serving merely as reservoirs of local or indigenous knowledge, knowledge holders are in fact political agents with their own ideas about the salience and legitimacy of various forms of knowledge. What matters, Brosius contends, is not so much what Penan hunter-gatherers in Sarawak, for example, know about their landscape but how they position that knowledge in political arenas.

There are opportunities and risks for IK when integrated into politically charged international science arenas. Global environmental assessments, for example, aim to synthesize knowledge but may also seek to change the constitutional foundations of global order (Miller and Erickson 2006). On the other hand, the potential of IK may be constrained when set within current development ideologies that are heavily influenced by politically dominant Western nations' agendas (Sillitoe and Marzano 2009). This hints that a fundamental problem for IK is that the structures in which IK is used and applied are determined by science, and these structures inevitably will change IK in the process of its use and application.

Bryan (2009) and Palmer (2009) both note the colonizing tendencies inherent in standardization of cartographic and digital technologies that are used to map indigenous territories and knowledge. Indigenous peoples have a choice to "map or be mapped," Bryan (2009:24) argues, and indigenous mapping should strive to change the profoundly colonial geographical understanding of the world. Changing power relations cannot be done by maps alone, but by frameworks for negotiating different kinds of knowledge which can "put the map in its place" (Bryan 2009:31).

Mauro and Hardison (2000) stress that scientists who engage with IK need to understand the international law and policy contexts in which IK and associated rights are situated, and how they affect access to knowledge. Davis (2006), however, notes that the ways IK is defined in law and policy are derived from Western intellectual worldviews and presuppositions, not from indigenous ways of understanding and articulating the world. Space needs to be created within national laws and policies for inscribing indigenous forms of cultural practice and through pluralistic approaches to legislative and policy development.

Boyd (2006) discusses both the reasons for and implications of excluding local knowledge from policy processes. Global discourses on land management in relation to the Clean Development Mechanism (CDM), for example, have tended to ignore local knowledge because local perspectives conflict with the narratives perpetuated by global institutions that oversimplify the complexity of nature. This makes genuine knowledge integration difficult if not impossible.

Evaluation of IK and integration

Some authors note the need to evaluate different types of knowledge as well as combined products and processes of

Table 3. Occurrences of "integration" and "resilience" in the reviewed literature.

	All papers (*n* = 47)	*Ecological Applications* 2000 (*n* = 11)	*Ecology and Society* 2004 (*n* = 12)	Reid et al. 2006 (*n* = 17)	*Futures* 2009 (*n*=7)
"Integration"					
Number of articles with at least one occurrence (% of total)	38 (81)	6 (55)	12 (100)	14 (82)	6 (86)
Word count	245	16	67	140	22
Coverage	5.55	0.35	1.19	3.63	0.38
"Resilience"					
Number of articles with at least one occurrence (% of total)	22 (47)	1 (9)	10 (83)	9 (53)	2 (29)
Word count	186	43	118	20	5
Coverage	3.18	0.63	1.98	0.41	0.16
"Integration" AND "Resilience"					
Number of articles with at least one occurrence (% of total)	21 (44)	1 (09)	10 (83)	9 (53)	1 (14)

Search terms were "integrat*" and "resilien*". Text searched include the entire paper or chapter, including titles, abstracts, reference lists, and acknowledgements, but not paper or chapter headers. Word count is the number of times that the word appeared within the item searched. Coverage is the frequency of the word relative to the total words counted in the item searched.

integration. Evaluation of scientific knowledge has been largely through the process of peer review, but this has shifted with initiatives such as the Millennium Ecosystem Assessment that recognize a need for inclusion of other forms of knowledge and hence, a broader set of evaluative criteria to assess this knowledge (Reid et al. 2006). Even so, much of the evaluation of integrated knowledge has largely concerned the credibility of IK in the eyes of science.

Watson et al. (2003) contend that IK has its own rules about processes of knowing, which diverge from the rules of science regarding evidence, repeatability, and quantification. Green (2009) suggests there is a need for social and cultural critique of scientific knowledge that is neither deferential to nor cynical about natural sciences, and is cooperative rather than competitive. Drawing on an example of astronomical understanding by Palikur communities in Brazil, she argues for a need to widen understanding of "what it means to know," and employ a wider range of tools to evaluate and recognize the contributions of diverse assemblages of knowledge.

The Millennium Ecosystem Assessment used the criteria of salience, credibility, and legitimacy to reflect the interests of the different stakeholder groups it served (Reid et al. 2006). Yet evaluation processes also need to distribute evaluative power more equally across all knowledge producers. Moller et al. (2004) note that TEK has a crucial role for evaluation of science. They suggest that by combining scientific and traditional monitoring methods, indigenous wildlife users can scrutinize scientific predictions on their own terms, increasing the likelihood that they will trust and respond to science.

KNOWLEDGE INTEGRATION AND RESILIENCE

Our second question probes the relationship between knowledge integration and social-ecological resilience. Table 3 presents a summary of occurrences of the words "integration" and "resilience" in the reviewed literature. "Integration" appears in 81% of the papers reviewed. *Ecology and Society* contains the highest percentage (100% of all papers in the issue) and *Ecological Applications* the lowest (55% of all papers in the issue). Reid et al. (2006) has the highest coverage (3.63%), *Ecological Applications* the lowest (0.35%). "Resilience" appears in almost half (47%) of the papers reviewed. It is most prominent in *Ecology and Society* (83% of all papers in the issue; 1.98% coverage), and least prominent in *Ecological Applications* in terms of percentage of papers (9% of all papers in the issue) and in *Futures* in terms of coverage (0.16%). Both terms appear in the same paper or chapter in 44% of the reviewed literature. *Ecology and Society* has the highest percentage of papers with at least one occurrence of each term, and Reid et al. (2006) has the highest

coverage. Our manual search identified 14 (30%) papers that discuss the relationship between integration and resilience (Table 4). In the 14 papers that include a substantive discussion of knowledge integration and resilience, we note several questions for further research:

Table 4. Number of papers in reviewed literature that discuss relationship between knowledge integration and resilience, identified by manual search. (% of total)

All papers (*n*= 47)	*Ecological Applications* 2000 (*n* = 11)	*Ecology and Society* 2004 (*n* = 12)	Reid et al. 2006 (*n* = 17)	*Futures* 2009 (*n* = 7)
14 (30)	2 (18)	9 (75)	2 (12)	1 (14)

Papers are: Berkes et al. (2000), Salmón (2000), Becker and Ghimire (2003), Davidson-Hunt and Berkes (2003), Long et al. (2003), Milestad and Hadatsch (2003), Donovan and Puri (2004), Folke (2004), Garibaldi and Turner (2004), Roth (2004), Tengö and Belfrage (2004), Boyd (2006), Lebel (2006), and Turnbull (2009).

When is IK itself, and when is IK's integration with other knowledge systems, a source of social-ecological resilience?

We found two relevant premises of resilience theory in the literature we reviewed, but neither adequately answers this question. One premise is that IK can enhance resilience of social-ecological systems because this knowledge, accumulated through experience, learning, and intergenerational transmission, has demonstrated the ability to deal with complexity and uncertainty (Berkes et al. 2000). We interpret this to mean that IK is a source of resilience. The second premise is that a diversity of knowledge systems can enhance resilience because the management of social-ecological systems improves when it can draw from a combination of different knowledge systems (Folke 2004). We interpret this to mean that the integration of knowledge, which may include IK, contributes to resilience. However, Folke (2004) also notes that there is a lack of consensus among scientists on whether IK can be brought into the realm of science.

Our thematic analysis highlights similarities, differences, and linkages between different knowledge systems, but there is not a clear message about how these affect resilience. Berkes et al. (2000), Milestad and Hadatsch (2003), and Tengö and Belfrage (2004) describe how traditional management practices in different societies confer resilience, and other papers discuss how resilience benefits from the complementarity of different knowledge systems (e.g., Berkes et al. 2000, Long et al. 2003). A question follows as to whether distinct sets of diverse, but complementary, knowledge may be preferable to a single set of integrated knowledge for addressing some natural resource management issues. Literature outside our sample shows that social diversity, which presumably involves knowledge diversity, has both costs and benefits in enhancing resilience at different times in a society's trajectory (Nelson et al. 2011).

What empirical evidence is there for a relationship between IK or knowledge integration and resilience?

In our analysis, references to resilience are mostly theoretical or hypothetical rather than empirical, and the link between knowledge integration and resilience concepts is often tenuous. In addition, the few papers that discuss how knowledge integration builds resilience in theory offer little explanation of how different knowledge is actually or could potentially be brought together. For example Milestad and Hadatsch (2003) acknowledge the theory that integration of knowledge can build resilience, but the focus of their research is on comparing knowledge systems, rather than on integration. Claims in these papers that either IK or integration practices lead to enhanced resilience do not tend to distinguish aspects of the practices that seem most influential, and the extent to which the practices themselves or other factors, such as institutions or culture, are the major contributors to enhanced resilience. Exceptions are Berkes et al. (2000) who acknowledge the roles of various social mechanisms in maintaining traditional resource management practices, and Fernandez-Gimenez (2000) who notes the importance of local natural resource management institutions that regulate pasture use for sustaining shared norms.

Some authors discuss concepts that are similar to resilience but do not explicitly discuss a relationship between resilience and IK or integration. For example, Salmón's (2000) kincentric ecology shares ideas with resilience theory about social-ecological coupling and adaptive management. Although Roth (2004) does not mention "resilience" in her paper, but cites several resilience-related works, her argument resonates with the social-ecological resilience basis for knowledge integration that we have noted. Some authors focus on the role of knowledge integration in enhancing ecological resilience (Donovan and Puri 2004) but not social resilience, whereas others discuss resilience in a social but not ecological context (Turnbull 2009).

Is there evidence that IK, or integration, builds resilience, and not just that a loss of IK, or lack of integration, erodes resilience?

Papers in our analysis found evidence of declining resilience due to development policies (Becker and Ghimire 2003) and externally-driven ecological restoration (Long et al. 2003) that have negatively influenced knowledge integration. Boyd (2006) and Lebel (2006) describe a positive feedback loop in

which resilience is lost because of the entrenchment of powerful global institutions that hinders meaningful cross-scale knowledge integration. Milestad and Hadatsch (2003) observe that resilience of farms has been lost because of erosion of TEK alongside other factors, such as structural changes in agriculture and societal transformation. However, we did not encounter empirical evidence that resilience has been built through the maintenance or revitalization of IK, or its integration with other knowledge. This is symptomatic of a problem that afflicts resilience studies more widely, in that much of the current understanding of resilience comes from systems that have lost resilience and have crossed a threshold (Walker and Myers 2004).

CRITICAL FEATURES OF KNOWLEDGE INTEGRATION

Our third question seeks to identify critical features of knowledge integration practice that need greater emphasis to foster productive and mutually beneficial relationships between IK and science. We identified these features in reflecting on our findings from the analyses of themes and resilience. The thematic analysis allowed us to inductively gauge patterns in the reviewed literature, whereas the resilience analysis enabled us to explore trends in IK and knowledge integration from a particular angle, of interest for the reasons stated in our introduction. Four critical features appear important:

New frames

The word "integration" remains problematic, invoking past power imbalances and assimilation of IK by science such that the distinct identities of IKs are no longer recognizable. Other terms, such as bridging or blending, have different meanings from integration and thus may not be universally appropriate substitutes. We suggest reframing integration as a process in which the originality and core identity of each individual knowledge system remains valuable in itself, and is not diluted through its combination with other types of knowledge. Collective approaches, such as "caring for country" (Davis 2006) and the Arctic Borderlands co-op (Eamer 2006), and other examples, such as collaborative ethnobiological databasing (Edwards and Heinrich 2006) point to what this reframed integration might look like. Alternatively, integration might begin from the perspective of IK and seek relevant scientific knowledge. Roth (2004) calls on global science to view itself as complementary to local knowledge, and not a replacement for it. Ishizawa (2006) suggests identifying problems locally, in the geographic location in which they occur, and subsequently identifying their global relevance. In bridging knowledge systems to solve real-world problems, there is a need to ensure that the issues addressed and contexts in which knowledge is applied are those important to indigenous peoples, not just to science. This may mean engaging communities as much about their social and political knowledge as their ecological knowledge, and enabling them to position that knowledge, as Brosius (2006) stresses.

Cognizance of social context, including politics and power

Our thematic analysis reveals that the social context of IK is receiving more attention with time; the politics of IK is clearly a prominent theme in Reid et al. (2006) and *Futures*. Indigenous peoples and their rights are increasingly acknowledged as the ultimate drivers of IK and of integration processes. Turnbull (2009) in particular emphasizes that a future for indigenous knowledge can only be ensured by ensuring the survival, resilience, and flourishing of indigenous peoples. In efforts to integrate scientific knowledge with IK, there is an imperative to acknowledge and even address the destructive forces that impinge upon IK holders. As well, there is a need to appreciate how, given a particular social context, IK and science each can contribute to natural resource management and where there may be limitations (Gagnon and Berteaux 2009, Wohling 2009). In some cases, it may not be appropriate to support any such process, but to rather enable IK to be applied instead of science, and vice versa, if that is the most relevant form of knowledge for the situation.

Expanded modes of evaluation

The evaluation of IK needs to go beyond scientific processes of validation to ensure evaluation does not involve only scientists and scientific paradigms (Gratani et al. 2011). Science and IK do sometimes disagree, as noted by Huntington (2000) and elsewhere (Foale 2006, Chalmers and Fabricius 2007), and cannot always be easily reconciled. Evaluation processes must recognize that this apparent incommensurability may have deep roots in different worldviews, and in theoretical and methodological approaches to understanding the world.

Intercultural knowledge bridgers

Though cultural differences need to be openly acknowledged, it is also suggested that they need not be fully resolved for productive collaboration to occur (O'Flaherty et al. 2008). Science, as many of the papers in this analysis argue, can address forces of change that are beyond local control and which impinge on values and aspirations of local communities. The key to ensuring that these values and aspirations are recognized seems to be in the deep involvement of IK holders in relevant science processes (Eamer 2006). Hence, indigenous scientists who span both knowledge systems and appreciate the significance of culture to IK (Rotarangi and Russell 2009) can play a key role as "bridgers" in knowledge integration.

CONCLUSION

Has the "project of integration" evolved since Nadasdy (1999)? Our stock-taking of the literature reveals a picture of knowledge integration that, like knowledge itself, is

multifaceted and complex, and encompasses far more than the dualism between technical and political agendas that Nadasdy presented. Perhaps above all, the literature we analyzed indicates that it is important to comprehend the nuanced meanings of the language used to discuss processes of bringing knowledge together. Greater attention needs to be paid to what various terms imply for how this can be done, and consideration given to changing the ways that knowledge integration has been framed, communicated, and understood.

Little of the knowledge integration literature engages substantively with resilience, and where it does the relationship between IK, integration, and resilience is not particularly clear: can IK itself and its integration with other knowledge both confer resilience in social-ecological systems? Untangling this relationship is a key research frontier for the theory and practice of knowledge integration. There has been a strong theoretical basis, supported by limited empirical studies, for the arguments that IK and knowledge integration contribute to social-ecological system resilience, but our analysis points to a need to further confront these with real-world evidence.

Viewing knowledge integration through a resilience lens does not come without caveats. The idea that multiple knowledge systems are needed to achieve or enhance social-ecological system resilience reflects a perspective that is focused on satisfying the many facets of a system, e.g., societies and ecosystems, as a whole, in line with indigenous views of holism (Rotarangi and Russell 2009). However, this focus on social-ecological systems as the unit of management implies that there will invariably be stakeholders other than IK holders, who may very well wield power to privilege other types of knowledge over IK, precisely what concerned Nadasdy (1999, 2003, 2007). On the other hand, Maffie's (2009) suggestion to deliberately privilege IK over science may compromise the role science can play in system-level understanding. The notion that IK and its integration with science can build resilience invites a fundamental question that must be continually revisited: which social-ecological systems are these integration processes building the resilience of, for whom, and on which scales in time and space?

Resilience theory may not necessarily offer the most useful perspective on knowledge integration, but it does stress the need for novelty and innovation in human interactions with the world, based on different knowledge systems (Moller et al. 2004, Roth 2004, Berkes and Berkes 2009). It is this emphasis on novelty and innovation that we suggest has something significant to offer to the practice of knowledge integration as it further evolves in decades to come, and in this spirit that we reiterate the need to reframe the concept as one in which knowledge identities are maintained, but enriched through interaction with one another.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol16/iss4/art6/responses/

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APPENDIX 1

Table A1.1. Summary of papers in *Ecological Applications* (2000)

Author	Title	Theme(s)	Grouped Theme(s)
Ford and Martinez	Traditional ecological knowledge, ecosystem science, and environmental management	n/a	n/a
Berkes et al.	Rediscovery of traditional ecological knowledge as adaptive management	Similarities between TEK and adaptive management; social mechanisms for traditional practices	1, 5, 6
Mauro and Hardison	Traditional knowledge of indigenous and local communities: international debate and policy initiatives	International law and policy regarding role of TEK in management and conservation of biodiversity; implications for scientists	2
Huntington	Using traditional ecological knowledge in science: methods and applications	Benefits and examples of using TEK; review of methods and challenges	3,4
Turner et al.	Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia	Knowledge systems	1
Nabhan	Interspecific relationships affecting endangered species recognized by O'Odham and Comcaac cultures	TEK and scientific views of species	1
Klubnikin et al.	The sacred and the scientific: traditional ecological knowledge in Siberian river conservation	Application of TEK in conservation; uniting of indigenous people and scientists in protest against Katun dam project	6,8
Gadgil et al.	New meanings for old knowledge: The People's Biodiversity Registers Program	Maintenance and creation of new contexts for folk ecological knowledge	5
Fernandez-Gimenez	The role of Mongolian nomadic pastoralists' ecological knowledge in rangeland management	Application of TEK in resource management; contradictions between TEK and management perceptions	6
Salmón	Kincentric ecology: indigenous perceptions of the human-nature relationship	Indigenous views of human-nature relationship	1
Pierotti and Wildcat	Traditional ecological knowledge: the third alternative (commentary)	Differences between Western natural resource management and indigenous TEK; multidisciplinary of TEK (nature, politics, ethics)	1

Table A1.2. Summary of papers in *Ecology and Society* (2004)

Author	Title	Theme	Grouped Theme
Folke	Traditional knowledge in social–ecological systems	n/a	n/a
Becker and Ghimire	Synergy between traditional ecological knowledge and conservation science supports forest preservation in Ecuador	Indigenous institutions and ecological knowledge used in interactions with conservation NGOs	5
Milestad and Hadatsch	Organic farming and social-ecological resilience: the alpine valleys of Sölktäler, Austria	Similarities/differences between organic farming and farmers' perspectives on sustainable agriculture; implications for resilience	1
Davidson-Hunt and Berkes	Learning as you journey: Anishinaabe perception of social-ecological environments and adaptive learning	Linkages between social-ecological resilience and adaptive learning, focused on TEK	1,6
Ghimire et al.	Heterogeneity in ethnoecological knowledge and management of medicinal plants in the Himalayas of Nepal: implications for conservation	Heterogeneity and complexity of LEK in relation to its practical and institutional context	1
Tengö and Belfrage	Local management practices for dealing with change and uncertainty: a cross-scale comparison of cases in Sweden and Tanzania	Application of local ecological knowledge in management practices	5
Garibaldi and Turner	Cultural keystone species: implications for ecological conservation and restoration	Knowledge systems; species that form contextual underpinnings of a culture	1,6
Watson et al.	The relationship between traditional ecological knowledge, evolving cultures, and wilderness protection in the circumpolar north	Context and application of TEK	1,6
Long et al.	Cultural foundations for ecological restoration on the White Mountain Apache Reservation	Cultural foundations of ecological restoration efforts, adaptive management	1,6
Moller et al.	Combining science and traditional ecological knowledge: monitoring populations for co-management	Evaluation of ways of combining science and TEK to monitor populations; strengths and limitations of TEK	3,4,9
Donovan and Puri	Learning from traditional knowledge of non-timber forest products: Penan Benalui and the autecology of *Aquilaria* in Indonesian Borneo	Role of TEK in identifying critical research needs in tropical ecology	1
Roth	Spatial organization of environmental knowledge: conservation conflicts in the inhabited forest of Northern Thailand	Spatial expression of knowledge at distinct scales	1,7

Table A1.3. Summary of chapters in *Bridging Scales and Knowledge Systems* (2006)

Author	Title	Theme	Grouped Theme
Reid et al.	Introduction	n/a	n/a
Wilbanks	How scale matters: some concepts and findings	Theory of scale in science assessment	7
Lebel	Politics of scale in environmental assessments	Politics of scale	7,8
Pereira et al.	Assessing ecosystem services at different scales in the Portugal Millennium Ecosystem Assessment	Methods for multi-scale assessment	3,7
Davis, C	A synthesis of data and methods across scales to connect local policy decisions to regional environmental conditions: the case of the Cascadia Scorecard	Methods for multi-scale assessment	3,7
Boyd	Scales of governance in carbon sinks: global priorities and local realities	Scales of governance	5,7,8
Brosius	What counts as local knowledge in global environmental assessments and conventions?	Context and politics of local and Indigenous knowledge and its translation	8
Davis, M	Bridging the gap or crossing a bridge? IK and language of law and policy	Divide between IK and "Western" science; understanding IK from non-Indigenous perspectives; cultural translation of knowledge; law and policy	1,2,6
Fabricius et al.	Mobilizing knowledge for integrated ecosystem assessments	Technical and social processes of knowledge integration across scales	3,5,7,9
Eamer	Keep it simple and be relevant: the first ten years of the Arctic Borderlands Ecological Knowledge Co-op	Processes and partnerships for knowledge integration	5
Ishizawa	Cosmovisions and environmental governance: the case of in situ conservation of native cultivated plants and their wild relatives in Peru	Bridging of worldviews that underlie knowledge creation and utilization	1
Raj	Harmonizing traditional and scientific knowledge systems in rainfall prediction and utilization	Methods for knowledge integration	3
Gokhale	Managing people's knowledge: An Indian case study of building bridges from local to global and from oral to scientific knowledge	Knowledge databases; rewarding people's knowledge; intellectual property rights	2,5
Seixas	Barriers to local-level ecosystem assessment and participatory management in Brazil	Process/challenges of knowledge integration	3,4
Bennett and Zurek	Integrating epistemologies through scenarios	Methods for knowledge integration	3
Miller and Erickson	The politics of bridging scales and epistemologies: science and democracy in global environmental governance	Politics of scale and epistemologies	7,8,9
Berkes et al.	Conclusions	n/a	n/a

Table A1.4. Summary of papers in *Futures* (2009)

Author	Title	Theme	Grouped Theme
Turnbull	Futures for indigenous knowledges	n/a	n/a
Berkes and Berkes	Ecological complexity, fuzzy logic, and holism in indigenous knowledge	Parallels between indigenous knowledge and complex systems (fuzzy logic)	1,3
Sillitoe and Marzano	Future of indigenous knowledge research in development	Challenges to IK in mainstream development	4,8
Bryan	Where would we be without them? Knowledge, space and power in indigenous politics	Mapping (as a form of IK) for land claims, and advancement of anti-colonial politics	3,6,8
Palmer	Engaging with indigital geographic information networks	Advantages and disadvantages of indigenous engagement with GIS networks	3,4,8
Green	Challenging epistemologies: Exploring knowledge practices in Palikur astronomy	Ways in which indigenous knowledges might be evaluated in relation to science	9
Maffie	'In the end, we have the Gatling gun, and they have not': Future prospects of indigenous knowledges	Knowledge systems; polycentric global epistemology as a future for IKs	1,5,9

IK = indigenous knowledge

Themes:
1 = Similarities, differences and linkages between IK and science
2 = Law and policy of IK
3 = Methods for using and integrating IK
4 = Benefits and challenges of using and integrating IK
5 = Institutions, processes and partnerships for maintaining and integrating IK
6 = Culture and IK
7 = Scale and IK
8 = Politics of IK
9 = Evaluation of IK and integration