



Weaving Indigenous and sustainability sciences to diversify our methods

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Introduction

Indigenous and sustainability sciences have much to offer one another regarding the identification of techniques and methods for sustaining resilient landscapes. Based upon the literature, and our findings, it is evident that some Indigenous peoples have maintained distinct systematic, localized, and place-based environmental knowledge over extended time periods.¹ These long-resident knowledge systems contain extensive information regarding not only how to maintain but also to steward biodiverse ecosystems. For example, the Nisqually Tribe of western Washington State, USA blends various aspects of ecological science with their Indigenous knowledge to support the restoration and management of the Nisqually river system watershed along with its associated natural resources of biological and cultural significance. We believe these kinds of Indigenous observations and perspectives are critical for establishing or expanding collaborations with sustainability scientists.

Fikret Berkes observed in his foundational text, *Sacred Ecology*, a “growing interest in traditional ecological knowledge since the 1980s is perhaps indicative of two things: the need for ecological insights from indigenous practices of resource use, and the need to develop a new

ecological ethic in part by learning from the wisdom of traditional knowledge holders” (2012: 19). The primary focus of the papers in this special edition of *Sustainability Science*, including this editorial introduction, is an exploration of the intersection of Indigenous and sustainability sciences. We challenged key thinkers in these research areas to cultivate mutually conducive and appropriate principles, protocols, and practices that address humanity’s collective need to sustain landscapes that demonstrate the ability not only to maintain human life but more crucially the interrelated more-than-human biosphere. The authors were asked to address the strengths and limitations posed by both Indigenous and sustainability sciences in this endeavor. We also encouraged discussion concerning how these two scientific paradigms might collaborate, acknowledging that protocols will need to be identified, or created, to enable successful collaborations. It is our hope that this special edition might add to what Scholz and Steiner (2015) have identified as a scant literature documenting the benefits of transdisciplinary research.

This special edition was inspired by an internationally diverse set of Indigenous academics, community scholars and non-Indigenous academics who participated in a National Science Foundation funded workshop entitled Weaving Indigenous and Sustainability Sciences: Diversifying our Methods (WIS²DOM).² The next three sections

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¹ For examples see: Berkes (2012) *Sacred Ecology*; Cajete (2000) *Native Science: Natural Laws of Interdependence*; and McGregor (2004) *Traditional Ecological Knowledge and Sustainable Development: Towards Coexistence*.

² The 4-day workshop was held at The Evergreen State College’s Longhouse in Olympia, Washington, USA in 2013 and funded under NSF Grant # 1233266. The WIS²DOM Workshop Report may be accessed at <http://ipsr.ku.edu/cfirst/wis2dom/WorkshopReport2013.pdf>.

of this introduction are abbreviated versions of the workshop's three keynote presentations on sustainability science, Indigenous science, and the protocols for bridging these two scientific paradigms.³ We then present our findings and recommendations regarding how Indigenous and sustainability sciences may find common ground upon which to collaborate, ending with an introduction to the papers in this special edition.

Sustainability science

The difficulty of developing a prolonged and nurturing dialogue between sustainability science and Indigenous sciences is surprising and warrants serious reflection. Ostrom (2007) noted there are no easy answers in coupled human–natural systems: no panaceas—and no simple way of representing, understanding or responding to the complexity in settings that are simultaneously biophysical and cultural (Wilcock et al. 2013). Sustainability science explores the wisdom that emerges from scholarly consideration of human–nature interaction. Human–nature interactions' however, always entwine questions of social and environmental justice and deeper metaphysical questions of connection and meaning, inevitably giving rise to questions of human rights, Indigenous rights and environmental rights. Yet to date sustainability science has been largely disengaged from questions of Indigenous science, Indigenous knowledges and Indigenous rights.

This observation allows the possibility of dialogue between sustainability science and Indigenous sciences as both invitation and challenge. This brief note frames sustainability science's interaction with Indigenous experience in three ways, politically, epistemologically and methodologically. It advocates framing and reframing as central to the task of developing a more humble, welcoming and receptive engagement between sustainability science and Indigenous science in the future. Adopting a position of “radical contextualism” as the basis for thinking about our particular place in the “awkward sticky messes that characterize the experiences and practices of coexistence—of being-together-in-place” (Howitt 2011: 132), it considers the wider importance of context in dialogue between sustainability science and Indigenous science.

³ Richard Howitt of Macquarie University addresses the strengths and limitations of sustainability science in sustaining resilient landscapes. Gregory Cajete of the University of New Mexico addressed these same questions regarding Indigenous sciences. Fikret Berkes of the University of Manitoba addresses strategies for developing collaboration between these scientific paradigms.

Framing the politics of science

Opening dialogue between sustainability science and Indigenous sciences requires acknowledgement that power underpins the place of science in contemporary global society. Framing Indigenous knowledges (and peoples) as out of place and out of time (in so many senses!) is common amongst dominant (colonizing) culture commentators. But in the case of sustainability science, it risks reducing Indigenous peoples as anachronistic sources of insights, information and knowledge that can be used by science to produce authoritative, authentic and useful universal knowledge in the present, for the future. For example, Callicott's rejection of post-contact Native American thinking and experience (1990; see also Curtin 1999) as irrelevant to the development of a contemporary environmental ethics is an extreme case, but consistent with much of the science-focused discourse of sustainability science. In the Australian setting, Turnbull (2000a, b: 18) reported that Indigenous collaborators in the late-1990s felt that “information [they] shared with non-Indigenous researchers is often still regarded as if the communities have no real moral or legal claims to dictate how it will be represented or used within the wider world.” Contrary to utilitarian or instrumentalist valuing of Indigenous ‘environmental knowledge’, there is an increasing acknowledgement that locally specific, contingent and conditional sciences persist in many places. Confronted with changing environmental conditions, changing political, economic and social relationships, Indigenous science is not limited to ‘traditional’ knowledge.

Universities and academic disciplines of science and social science have unequivocally been part of the structure and infrastructure of European colonial power and its specific impacts on particular Indigenous peoples and their places and institutions. Entry of Indigenous voices into both the academy and political institutions has been—and typically remains—contingent and conditional. Compliance with scientific notions of rigor and method remain implicit requirements in most circumstances and Indigenous participants in debates are commonly expected to respond in ways as representatives of knowledge that would never be asked of other scientists. Consistently framed in negative terms by the dominant colonizing cultures, Indigenous cultures and the knowledges they produce have too often been seen and treated as out of place in academic discourses and institutions.

Framing epistemological differences

Perhaps the key challenge for sustainability science in uncertain circumstances is to provide information to support and motivate societal transformation. But that begs the

question of how judgement might be made about what is better. In shaping a dialogue with Indigenous sciences, the explicit universalism of science and the need for more than locally or contextually tailored solutions to problems, confronts a need to build frameworks for understanding that are themselves pluralist, open and engaged across (linguistic, cultural, epistemological, spatial and temporal) difference.

In the context of this discussion, Nakata et al. (2012) offer a timely warning in reflecting on the challenges of shifting university students away from colonized thinking. Rushing towards a politically defined end-point (in our case, dialogue)—surely recognized as a dangerous tactic in a sustainability science that grapples with dynamic uncertainty in both earth and human systems—risks skipping “the more complex theoretical dilemmas students need to engage with to understand the conceptual limits of their own thinking” (Nakata et al. 2012: 121). In engaging in dialogue with Indigenous sciences, scientists cannot skip to the end-point imaginary of a dialogue of equals. We have to learn to listen and to hear: remember Louis’ provocative words—“Can you hear us now? ... Have I got your attention yet? I hope so because it’s really not my intention to preach about the ills and woes of Indigenous peoples in relation to research” (Louis 2007: 130–131). Scientists have to learn to see our own privilege, our own context, our own deep colonizing. We have to learn to think anew—to think in ways that take seriously and actually respond to information, understanding and knowledges as if difference confronts us with the possibility of thinking differently.

Framing methodologies

There is an important, extensive literature and emergent practice around questions of Indigenous methodologies (e. g. Coombes et al. 2014)—with implications for a dialogue between sustainability science and Indigenous sciences. For the science community, which values methodologically sound research as the foundation for authoritative knowledge, Smith’s opening statement in *Decolonising Methodologies* (1999) heralds a huge challenge:

The word itself ‘research’ is probably one of the dirtiest words in the indigenous world’s vocabulary. When mentioned in many indigenous contexts, it stirs up silence, it conjures up bad memories, it raises a smile that is knowing and distrustful (Smith 1999: 1).

Many Indigenous commentators challenge their science collaborators to shift focus; to reconsider how they construct and use knowledge. In the discipline of geography, for example, Louis (2007) challenges the traditional practice of science as the acquisition of knowledge by means of power. While there may be a tendency to characterize

differences between ‘Western science’ and Indigenous knowledge systems in terms of oversimplified binaries, there is increasing recognition in the Indigenous methodologies discourse of the strengths of participatory, narrative and ethical engagement with context as foundational to methodologies that are ‘fit for purpose’.

Reframing the invitation and challenge

In opening both an invitation and challenge to sustainability science regarding developing engagement with Indigenous sciences, we need to recognize the existing frames that contextualize the relationships involved, and actively reframe those relationships. In the scientific frame, for example, we need to unsettle assumptions that scientific method alone is able to produce authoritative knowledge. In public policy frames we need to reframe the relationships between the producers, users and beneficiaries of knowledge in the overlapping contexts of local cultural survival and global ecological survival. Learning to listen to each other’s concerns and proposals with respect, and openness to change is an important element of the process of dialogue between sustainability science and Indigenous sciences.

For Indigenous participants, decolonization of one’s understanding of science, escaping the dominant privileging of science to allow valuing of local knowledge, weak theory and contextualized ethics often demands a transcendence of long histories of colonization, colonial education and deep colonizing patterns of thought (Tuck and Yang 2012). For scientists, recognizing that the social, political and historical context of scientific method hides the specificity (non-universalism) of scientific method and the knowledge it produces similarly demands decolonization of how sustainability science is pursued.

The organizers of the *WIS²DOM* workshop choose to frame the discussion at the scale of ‘resilient landscapes’—a concept that has not been widely discussed in the literature and thereby presents its own challenges. In Australian Aboriginal discourse, this is the scale of ‘Country’, the scale at which cosmological relationships and processes intersect with human (and non-human) presences and responsibilities (Howitt 2002; Hsu et al. 2014). This is the scale of human responsibility in an everyday sense. In political terms, however, landscape is a slippery scale to work with.

Framing a call for dialogue at this scale pushes us to contextualize our thinking in novel ways. In reframing sustainability science in radical contextualist terms (Howitt 2011), one is drawn to the wider value of a dialogue across knowledge systems that is humble, respectful and hopeful; which listens to Country and all its peoples; which recognizes not only the need to acquire knowledge, but also the

need to transform and respond to different knowledges, understandings, meanings, and opportunity.

There can be no doubt that the challenge of sustainability is both complex and multifaceted. It is, of course, captive to the contexts in which ideas of sustainability science and contemporary governance have been framed. As Benessia et al. remind us,

the very notion of sustainability is embedded in an essentially modern framework, entailing a number of contradictions and paradoxes, which can be interpreted as epistemic and normative diversions and obstacles, preventing the needed transformation (2012: 75).

Framed at the landscape scale, sustainability science and Indigenous sciences will see things quite differently. It should not surprise us to find each convinced of its own importance. The discursive space created by dialogue, however, invites transformation in both approaches; challenges both approaches to stretch towards understanding the other(s), and in the process to deepen our understanding of the context of the simultaneous pursuit of justice and sustainability. This is a space we should enter with hope and excitement, but with caution as well. There can be no simple solutions; no panaceas; no short cuts—indeed, there can actually be no obvious target end-point against which to measure progress in any simple sense. In entering this space, we journey together on the paths of dialogue to share understandings, learning and possibilities, and looking forward to the challenges involved.

Sustaining Indigenous community in the context of climate change

In a natural community the diversity of plants and animals is directly related to the resilience and ability of the system to sustain itself in the face of a changing environment. In human community, preserving dynamic socio-cultural diversity is just as important. In many ways, the fate of Indigenous peoples in their quest to develop the capacity to re-build the social ecology of their communities through their attempts at self-determination and re-asserting their communal Indigeneity in thought and action is indicative of the broader fate of human communities worldwide. How Indigenous communities fare in their attempts to sustain their unique forms of community may well foretell the fate of larger modern communities to sustain themselves in the face of global climate change. Indeed, the accelerated disappearance of Indigenous cultures, languages and communities, in and of itself, reflects a profound dysfunctional state in the integrated social–physical ecology of our global societies.

Indeed, climate change is already presenting profound challenges to many tribal cultures, economies, resources and well-being. Climate change has had significant effects on cultural ways of life and place based rights. For example, land based traditional hunting and gathering has been affected. This, in turn, results in a loss of traditional knowledge because of loss of key plants, animals, and geo-physical context. Coastal tribes are equally impacted by sea rise and disruption of traditional fishing and gathering practices. Globally, the challenges also include ensuring freshwater supplies, secure food supplies, and mediating impact on key plant and animal species. For Indigenous Peoples these challenges require attention to *practiced* forms of community. It requires reforming of traditional eco-knowledge, and to exercise of sovereignty. It requires that planning locally, cooperating with educational organizations, NGO's, governmental agencies and other tribes.

Healthy communities are cultural and natural systems where life and learning are nourished by the actions of members. This requires a *community* education process, gathering and sharing of information, formal research, strategic planning and appropriate and effective implementation. This includes an application of existing treaties and agreements to protect key habitats. Equally important is the creation of new agreements and policies that move the agenda of Indigenous community based sustainability forward. Added to this is the systematic development of renewable energy and food sources. While also creating authentic strategies for engaging youth and all community members' participation in this reassertion of Indigenous community knowledge (Charles and Samples 2004: 10–11).

What do we have to build from in our communities? We have our *traditional knowledge* handed down, based on stories and experiences of a people through time. There is *empirical knowledge* gained through careful observation and practice over time. We have *revealed knowledge* gained through vision, ritual and ceremony. And, finally *contemporary knowledge* gained through experience, education and problem solving. These four forms of community knowledge are what we have to re-engage and augment in a truly restorative community education process.

What does the re-assertion of Indigenous Community imply for the communities themselves? It implies the re-assertion of a “sense of purpose” for the continuance of Indigenous communities. It asserts the quest for “agreement on core values” through deep dialogue. It requires that communities reform around participation, communication, commitment, collaboration, and trust. On the part of all participants it requires a conscious choice, shared responsibility that is predicated on acceptance, accountability, respect reciprocity, and demonstrated efficacy (Ibid).

To do this, Indigenous communities must educate for the re-creation of cultural economies around an Indigenous paradigm. Indigenous communities must begin by learning the history and principles of (our) Indigenous Way of Sustainability and explore ways to “translate” their lessons into the present. Indigenous communities must research the practical ways to apply these Indigenous Principles/Knowledge Bases. In all, this entails engendering a new kind of Native education predicated on guiding Native people once again toward an authentic community vision of health, renewed and revitalized, sustainable and economically viable Indigenous communities. This is what will ultimately enable peaceful and sustainable futures for Indigenous communities. It is, in the final analysis, a transformative vision for Indigenous community that comes from deep within the community itself for which we must now lay the groundwork through creating a new “indigenized process of community education” (Wolfgramm 2007).

Indigenous science may be defined as a ‘multi-contextual’ system of thought, action and orientation applied by an Indigenous people through which they interpret how Nature works in ‘their place’. Indigenous knowledge may be defined as a ‘high-context’ body of knowledge built up over generations by culturally distinct people living in close contact with a ‘place’, its plants, animals, waters, mountains, deserts, plains, etc. Epistemological characteristics of Indigenous science include oral transmission; observation over generations; cyclical time orientation; quantification is a macro level; specific cultural/literary style and symbolism; knowledge is context specific to a tribal culture and place; conservation of knowledge through time and generations. Development of knowledge through Indigenous science is therefore guided by: spirituality, ethical relationships, mutualism, reciprocity, respect, restraint, a focus on harmony, and acknowledgement of interdependence. This knowledge is integrated with regard to a particular ‘place’ toward the goal of sustainability. Indigenous science knowledge is derived using the same methods as modern Western science including: classifying, inferring, questioning, observing, interpreting, predicting, monitoring, problem solving, and adapting. The difference is that Indigenous science perceives from a ‘high-context’ view including all relational connections in its consideration. In contrast, Western science perceives from a ‘low-context’ view, reducing context to a minimum. (Cajete 2000: 59–83).

Indigenous science and culturally responsive education instigates the inclusion of Indigenous knowledge on an equal par with modern Western science. This is a relatively new and radical idea for Western science, which has been met with much debate. For proponents of the inclusion of Indigenous science, all cultures have developed a form of

science, which is important to the overall diversity of human knowledge related to the biosphere. However, for some, only Western science is ‘true science’ and all other forms of knowledge must be subordinate. In spite of such attitudes, teaching for sustainability provides a context for the inclusion of Indigenous science in all aspects of science education (Cajete 2000: 59–83).

Sustainability, or the ability of current generations to meet their basic needs within the context of a given place, is by its nature an interdisciplinary inquiry that is inclusive of sciences, technology, business, politics, philosophy, and the arts. This inquiry takes place around a focus upon a specific place, populations and time period. The goals of such an inquiry are to engage students in the production of knowledge, to learn various research methods, to develop a critical voice in writing, and most importantly, to understand the importance of sustainability. According to Orr (1992: 28–40), there are four challenges to doing sustainable education. These are: (1) creating better more integrated science and accounting tools to measure biophysical wealth; (2) getting people involved; (3) transforming societal value systems through ‘empathic education’, and (4) improving knowledge transfer around sustainability. Tied to these challenges is the need to address issues associated with human health, social justice, equity, economic development, ethical valuing, and governance.

The context in which this occurs must be understood and bring about the balanced and ethical interaction of three interacting circles of relationship between individuals, community and the environment. And in understanding these relationships, the aim must be to maintain cultural diversity, protect human health, create and maintain sustainable economic relationships, reconcile social issues non-violently and most essentially protect the environmental life support system (ibid).

Sustainability oriented Indigenous science education can be strategically applied for the re-creation of cultural economies around an Indigenous paradigm of sustainability. This begins by learning the history of a particular Indigenous way of sustainability and explores ways to translate its principles into the present. There must be research into the practical ways to apply these Indigenous principles and knowledge basis. Added to all this Indigenous people must revitalize, re-learn or otherwise maintain their traditional environmental knowledge. This can be accomplished through applying the Indigenous communal strengths of resourcefulness, industriousness, collaboration, and cooperation. In addition, we must once again apply our collective and historical ability to integrate differences in our political organisations, forge alliances and confederations, and re-introduce our propensity for trade and exchange. We have ancient systems of extended family,

clan and tribal relationship that we can mobilize in positive ways to implement sustainable changes in our economies. In addition we have developed modern political, social, professional trade organisations, federations, associations, and societies which we can enlist in the addressing the challenges which we now collectively face. These are the new areas of Indigenous education which must be explored and operationalized in the context of Indigenous education toward the development and revitalization of Indigenous communities as they face the challenges of surviving the ecological, social and political challenges of a twenty first century world.

Bridging sustainability and Indigenous sciences

How can these two kinds of knowledge (Indigenous science and Western science) collaborate toward sustaining resilient landscapes, and what methods or models can be used to aid in this collaboration? The two paradigms can best be considered together by combining knowledge in a collaborative way around a particular topic. For example, ethnobiology is a field that has developed specifically to use the two kinds of knowledge together. Ethnobotanists have developed methodologies that combine botany with Indigenous knowledge related to species identifications and classification (Hunn and Selam 1990). Many of the attempts to combine the two kinds of science occur around species biology and ecology (e.g., Goldman 2007; Gagnon and Berteaux 2009), or around ecosystems such as forest ecosystems (Posey 1985; Parrotta and Trosper 2012). More to the point regarding resilient landscapes, it can also occur around biocultural landscapes (Kimmerer and Lake 2001; Johnson and Hunn 2010), biocultural landscape change (Robson and Berkes 2011); and landscape biodiversity conservation (Bhagwat et al. 2005).

Combining the two kinds of knowledge is especially important in situations of insufficient information. Using the two paradigms together can improve problem solving. Such co-production of knowledge has been defined by Armitage et al. (2011: 996) as “the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem.” Knowledge co-production has been used productively in relation to questions about which neither knowledge system by itself has sufficient information to deal with the issue. Climate change is one such problem, and the complementarity of Indigenous knowledge and Western science produces a better understanding of the issue than either would alone (Tyler et al. 2007; Nakashima et al. 2012).

These examples together indicate that respecting the integrity of each knowledge system produces healthy

results. The operative word, therefore, should be “bridging” knowledge systems (Reid et al. 2006). Such an approach is preferable to “synthesizing” or “combining” or “integrating” knowledge systems. If and when integration occurs, such integration often works to the disadvantage of Indigenous people and Indigenous knowledge systems due to differences in power. As many examples show, power imbalances make local and Indigenous communities and their knowledge vulnerable to outside forces (Berkes 2012). Hence, bridging knowledge systems is preferable to integrating them. It certainly is preferable to “mining” Indigenous knowledge and using it, often out of context, as “data” for Western science!

A number of methods exist to bring together the two kinds of knowledge in ways that is respectable and generally acceptable to knowledge holders. Some of these methods, such as participatory rural appraisal, have a relatively long history of use. Others, such as community-based monitoring, are still being developed. The following list is by no means comprehensive. New approaches are being developed all the time. As well, the various approaches in the list are not equally applicable in a given situation for combining Indigenous science with Western science.

Participatory rural appraisal, originally developed for agricultural applications, is a toolkit that has been in use for some decades (Chambers 1983). It has been adapted for using local and Indigenous knowledge along with agricultural and other kinds of Western science (Warren et al. 1995).

Participatory action research also has a relatively long history and is closely related to participatory rural appraisal (Chambers 1983). However, it is not a toolkit but an approach that emphasizes collective inquiry and social change (Fals-Borda 1987). It seeks to understand the world by trying to change it collaboratively and reflectively.

Participatory education (critical pedagogy) comes out of a tradition of empowering learners. Freire’s (1970) *Pedagogy of the Oppressed* proposes a new relationship between teacher, student and society, in which the learner is treated as the co-creator of knowledge. Some of these ideas have been applied to Native American education by Indigenous scholars (Kimmerer 2002).

Similar to the communities of practice concept in education that emphasizes learning-as-participation, place-based **learning communities** refers to groups of people with a shared interest, learning through partnerships through regular interactions based in practice (Davidson-Hunt and O’Flaherty 2007).

A number of processes use techniques to elicit and understand local and Indigenous views and knowledge. **Participatory mapping** (Chapin et al. 2005) is probably the best known of these techniques. Film, video and other visual arts can also be used in a similar way.

Participatory workshops and modeling have been used successfully with both Indigenous and non-Indigenous rural knowledge holders such as ranchers (Knapp et al. 2011). They include a suite of techniques that can be adapted to different kinds of knowledge and different cultural backgrounds. Some sustainability science work, for example with the Saami, has used participatory workshops (Tyler et al. 2007).

Participatory scenario planning is a part of the toolkit of participatory workshops and modeling approaches. Scenarios in this context are plausible and challenging sets of stories about how the future might unfold. The approach was developed and used widely by the Scenarios Working Group of the Millennium Ecosystem Assessment (Bennett and Zurek 2006).

Community-based monitoring involves reading signs and signals of environmental change based on the ways of knowing of a given group (as opposed to monitoring based strictly on Western science). In using the two kinds of knowledge, there often are complementarities of scale, with Indigenous science contributing local expertise. Applications include Arctic Borderlands Ecological Knowledge Co-op (Eamer 2006).

Participatory conservation planning aims for the use of complementary knowledge from Western science and local/Indigenous communities. As in the case of monitoring, participatory conservation planning makes use of scale complementarities between the two kinds of knowledge (Roth 2004).

In a similar vein, **participatory environmental restoration** uses both local/Indigenous knowledge and Western science. In some cases, local knowledge can provide essential information not otherwise available to science (Robertson and McGee 2003).

Some of these ways of bridging knowledge systems are based on research methods and processes (participatory rural appraisal; workshops, modeling and scenario planning), and/or approaches that consider local and Indigenous people as equal partners (participatory action research; participatory education). Some rely on cooperating around a particular task at which local and Indigenous communities have specific expertise: environmental monitoring; conservation planning; and environmental restoration. Yet others may be based on new institutions and governance arrangements such as bridging organizations that assist in co-management (Berkes 2009). Many are interactive: co-management, learning communities, and knowledge co-production. Some of the ways of bridging may take advantage of the similarities between Indigenous knowledge and some areas of Western science such as fuzzy logic and adaptive management (Berkes 2012).

In facilitating the cooperation of the two paradigms, Indigenous science and Western science, can work

together, a number ways exist to bridge the two paradigms. This does not necessarily mean that there are well-established, sure-fire ways to bring together the two paradigms respectfully. In some cases (e.g., spiritual practices) it may not be appropriate to attempt any bridging at all. In other cases (e.g., knowledge co-production for conservation), it may be appropriate to go beyond bridging to synthesize the two kinds of knowledge creatively. General protocols for bridging are difficult to formulate. Each bridging effort will be unique and will no doubt take much hard work from all the partners involved.

Findings

Through our dialogue, we have arrived at a number of key findings regarding how these two scientific paradigms might collaborate in creating a “transition discourse” that could, as Escobar (2011: 138 emphasis in original) observes, assist us in positing a “radical cultural and institutional transformation—indeed, *a transition to an altogether different world.*” In reviewing the strengths and limitations of sustainability science toward sustaining resilient landscapes, we acknowledge that while sustainability science has moved in directions that further articulate social–ecological systems, it has increasingly been coupled with sustainable development and technocentric approaches to environmentalism that aim to sustain ecosystems, and the services they provide, by building a ‘smarter planet’. The technocentric and development-based approach presupposes that the planet and human societies require improvement and depend upon Western science to advance human interaction with their ecological systems.

We observe that both the strengths and limitations of sustainability science can be traced to its dominant Western worldview and the methodologies employed that have emerged from that ‘scientific tradition’. These include a systems theory framework that provides a wide range of tools and technologies to examine the effects of change on an environmental system. We also agree that the scientific method and measurement provide methodologies and the associated metrics necessary for the quantification and monitoring of negative and positive actions over time. A willingness to adopt a transdisciplinary approach that draws from multiple scientific paradigms allows sustainability science to bring together a diverse set of methods, contributing to pluralistic solutions that fit specific environmental conditions. These strengths are countered by considerable limitations though, founded within the same Western scientific traditions. As sustainability science has emerged over the past two decades, concern with securing its place in the discourses of science has led to it being framed as a discourse about science as much as a discourse

about sustainability. The openness of scientific enquiry is threatened by a powerful and self-referential expertocracy that is embedded within academic structures, supported by and perpetuating both state and corporate interests. These interests threaten not only sustainability but also Indigenous peoples' knowledges and resources. As a result, much scientific research, including in sustainability science, pursues only those questions for which funding can be secured from government and corporate sources.

Contrary to the Western approach that seeks to dominate and interrogate nature, Indigenous societies and knowledge systems have developed to sustain reciprocal relationships between culture and nature and therefore utilize scientific approaches that are rigorous in their own methods and rely on long-term observations. These scientific approaches are spatially localized and place-based. They integrate short-term periods to extend upon long-term observations. Significantly, they acknowledge humans as a part of the natural world without the binary reductionism found within Cartesian constructs. In addition to providing a glimpse outside of the ontological constructs of Western scientific thought, we identify that Indigenous science also provides access to deep-spatial knowledge. This knowledge is constituted within long-term and empirical observations with landscapes and non-human others to produce understandings based upon sustainable resilience. Indigenous science is as diverse as the groups around the world who engage local and traditional forms of ecological knowledge, but are also surprisingly similar in many regards. As Berkes's work with his colleagues⁴ has demonstrated, Indigenous peoples' ecosystem management is capable of sustaining some of the most biodiverse ecosystems globally. As Wark (2014) notes, "our ecological interactions are not framed as exploitation, but are instead seen as mutually beneficial relationships. Humans are an integral component of the health of the land; we provide for it even as it provides for us." Momaday (1976) described this as a "reciprocal appropriation" between humans and non-human others and serves as a hallmark of Indigenous science and its local ecological knowledge systems.

We also observe though two limitations to Indigenous sciences' ability to collaborate effectively with sustainability science. First, despite one of its greatest strengths being long-resident observations and associated deep-spatial knowledge, frequently this knowledge is based within place-specific constructs that are culturally integrated, posing difficulties in translating this knowledge for broader audiences. The second related critique is that Indigenous science is integrated into the spiritual belief systems of Indigenous communities adding to difficulties in finding protocols to share this knowledge with Western scientists.

⁴ See Berkes et al. (2000) and Gadgil et al. (1993).

The quest for common ground between Western and Indigenous sciences will require a recognition that all scientific traditions have place-based origins (Turnbull 2000a). Indigenous scientific practitioners could also aid these collaborations by making the metaphors embedded in their scientific records more accessible to Western scientists seeking respectful collaboration (Louis 2014).

Our final set of findings focuses on how Indigenous and sustainability sciences might create 'best practices' for collaboration. Our central question revolves around whether or not these two paradigms can successfully work together, and if they can what protocols would be required. More specifically, what new or newly adapted methods and protocols will be required to aid in addressing the challenges that face the world in the midst of the anthropocene? As Keali'ikanaka'oleohaililani (2014) observes, any collaboration must be based upon "curiosity, compassion, and the willingness to flex and evolve our own practices. We do this by creating and fulfilling our personal relationships to being-human and to the more-than-human." We observe that sustainability is "simultaneously *the ability* and *the processes* necessary for the earth to support life—all life, not just human life" (Johnson et al. 2014: 19 emphasis in original). Unfortunately, there are too many variables to consider in formulating and articulate specific protocols within the constraint of this paper, but through our continuing research dialogue we intend to address this in future publications.

By framing our discussion at the landscape scale, sustainability science and Indigenous science will likely interpret things quite differently. It should not surprise us to find each convinced of its own importance. Indigenous sciences will likely raise issues of connection, responsibility, and meaning while sustainability science will point to issues of management, governance, and adaptation. "In between is the discursive space to be created by WIS²DOM—a space that challenges us and invites transformation in both approaches" (ibid:12). It is our intent that a productive and reciprocal collaboration between Indigenous and sustainability sciences could create a new vision for sustaining resilient landscapes. As Escobar observes, together we could create a notion of sustainability, "capable of inspiring the popular and scientific imaginations alike to take steps that are at once pragmatic and transformative in the path toward more ethical and ecological worlds" (Escobar 2011:139).

Articles in this special edition

The thirteen articles in this special edition all, in one-way or another, advance the deliberations concerning how Indigenous and sustainability sciences might work together

in productive collaborations. Some are aimed at articulating specific Indigenous knowledge systems, frequently at the local scale, that are geared toward understanding how these protocols and practices can inform sustainability at a larger scale. Mark Palmer's article explores how Aboriginal Australian knowledge is mapped and represented in UNESCO World Heritage documents establishing Uluru-Kata Tjuta as a heritage site. This article also explores how utilizing an Indigenous geographies research approach can inform sustainability science. Whyte, Brewer and Johnson utilize examples from Meskawki and Anishnaabe traditions to inform protocols related to stewardship and caretaking by humans and non-humans alike. They introduce this central concept within American Indian tradition so that sustainability scientist can become more accustomed to thinking about stewardship in relation to scientific inquiry. Fang, Hu and Lee describe how the Atayal peoples of Taiwan have developed a sustainable hunting culture, demonstrating the importance of ecological balance within many Indigenous communities globally. They observe that Taiwanese Aboriginals utilize moral values based within their spiritual practices to construct their sustainable environmental practices. Ziker, Rasmussen and Nolin describe how Indigenous Siberian communities establish food-sharing protocols in order to maintain reciprocity within communities. In this example, we again see that ethical concepts such as kinship, reciprocity, and generosity illustrate Indigenous perspectives on resource entitlements. Keali'ikanaka'oleohaililani and Giardina share a method of integrating Western and Indigenous sustainability practices, grounded in Hawaiian perspectives. They orient the reader to the northeastern coast of Hawai'i island providing a transformational vision of sustainability focused on sacred relationships that place the success or demise of our planet's ability to sustain human life in our hands.

Several of the papers in this special edition approach the interaction between Western and Indigenous science from the perspective of sustainability science, exploring how Indigenous knowledge may inform transdisciplinarity. Cohran and her co-authors address the perplexing issue of appropriate temporal and spatial boundaries in sustainability science by studying Indigenous ecological calendars in Amazonia toward defining the scales of climate change and sustainability assessment. Their paper considers how possible climatic changes may impact the sustainability of resources, by bringing together knowledge from the Tukano ecological calendar with a methodology for examining changes in precipitation and river levels and their interactions at multiple timescales. Their collaborative work highlights how high spatial and temporal variability in precipitation patterns and river levels might complicate climate change and sustainability analyses.

Alessa and her co-authors explore how Indigenous observers in the Arctic are incorporated, along with their Indigenous ecological knowledge, into community-based observing networks to improve monitoring of environmental and climatic change. Their efforts are aimed at improving effective response and adaptation strategies in addition to incorporating Indigenous observations into broader data networks. Lin and Liu introduce the concept of cooperative game theory to analyze conflicting views of locally based Community Based Natural Resource Management initiatives in the Truku tribal territory in Taiwan. Cooperative game theory provides scenarios for groups engaged in consensual decision-making processes. In this case both groups of people consist of Indigenous villagers who either support or oppose the government's natural resource management planning process with regard to ecotourism. Robinson and her co-authors focus on participatory mapping research to attain 'useable knowledge' for inter-Indigenous community sharing to address how competing and conflicting Indigenous knowledge systems and collective standards for Indigenous knowledge contributions and partnerships are negotiated among the Giringun in northern Queensland. This process promoted critical dialogue and collective knowledge co-production amongst Giringun participants.

The final set of papers focus on finding appropriate methods and protocols for dialogue between Western and Indigenous paradigms toward establishing successful and adaptive sustainability practices. Dockry and his coauthors explore the creation of a sustainable development model by the College of Menominee Nation based upon the tribe's profound attachment and relationship with their land, which has allowed them to adapt to environmental and social change over time. Their paper provides examples illustrating how the model has been utilized for educational, community planning, and research purposes. Zanotti and Palomino-Schalscha discuss the vexing roles, challenges, and opportunities of non-Indigenous academics working at the interface of Indigenous and non-Indigenous knowledges, highlighting the critical issues governing the roles and responsibilities of non-Indigenous researchers in decolonizing the reproduction, and co-production of knowledges. The paper enhances our understanding of the epistemological consequences of engaging in such work and the critical need for spaces of plural co-existence. Gondor explores how Inuit knowledge is employed in the co-management and regulation of environmental impact assessment in Nunavut Territory, Canada. By reviewing an environmental assessment of a gold mine in the region, the author explores how traditional ecological knowledge is brought into dialogue with scientific principles in the decision making process. In our final paper, Herman proposes embracing indigeneity's holistic approach to

knowledge production while also utilizing scientific advancement to reshape human behavior toward sustainable strategies. The author develops a ‘new cultural discourse’ aimed at reshaping society toward a more sustainable future.

Together the papers in this special edition further articulate the possibilities for improving the transdisciplinary reach of sustainability science through engaging Indigenous sciences. They also explore the central philosophical concepts upon which Indigenous peoples’ sustainability is founded, such that sustainability scientists might explore how these concepts could inform sustainability initiatives more broadly. We hope that the dialogue begun in this special edition will lead to further collaboration based within a shared curiosity and compassion for difference.

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