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Bridging science and traditional knowledge to assess cumulative impacts of stressors on ecosystem health

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ABSTRACT

Cumulative environmental impacts driven by anthropogenic stressors lead to disproportionate effects on indigenous communities that are reliant on land and water resources. Understanding and counteracting these effects requires knowledge from multiple sources. Yet the combined use of Traditional Knowledge (TK) and Scientific Knowledge (SK) has both technical and philosophical hurdles to overcome, and suffers from inherently imbalanced power dynamics that can disfavour the very communities it intends to benefit. In this article, we present a 'two-eyed seeing' approach for co-producing and blending knowledge about ecosystem health by using an adapted Bayesian Belief Network for the Slave River and Delta region in Canada's Northwest Territories. We highlight how bridging TK and SK with a combination of field data, interview transcripts, existing models, and expert judgement can address key questions about ecosystem health when considerable uncertainty exists. SK indicators (e.g., bird counts, mercury in fish, water depth) were graded as moderate, whereas TK indicators (e.g., bird usage, fish aesthetics, changes to water flow) were graded as being poor in comparison to the past. SK indicators were predominantly spatial (i.e., comparing to other locations) while the TK indicators were predominantly temporal (i.e., comparing across time). After being populated by 16 experts (local harvesters, Elders, governmental representatives, and scientists) using both TK and SK, the model output reported low probabilities that the social-ecological system is healthy as it used to be. We argue that it is novel and important to bridge TK and SK to address the challenges of environmental change such as the cumulative impacts of multiple stressors on ecosystems and the services they provide. This study presents a critical social-ecological tool for widening the evidence-base to a more holistic understanding of the system dynamics of multiple environmental stressors in ecosystems and for developing more effective knowledge-inclusive partnerships between indigenous communities, researchers and policy decision-makers. This represents new transformational empirical insights into how wider knowledge discourses can contribute to more effective adaptive co-management governance practices and solutions for the resilience and sustainability of ecosystems in Northern Canada and other parts of the world with strong indigenous land tenure.

1. Introduction

1.1. Complementary use of traditional knowledge and science

There have been persistent calls for greater inclusion of local and indigenous or traditional knowledge (TK) alongside conventional scientific knowledge (SK) in making decisions about natural resources (e.g., Huntington, 2000; Mistry and Berardi, 2016; Sutherland et al., 2014). Such a call is ensconced within three wider transdisciplinary movements that intersect knowledge use and decision-making for

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[1] A partnership representing the community members living along the Slave River and delta and local and territorial authorities and Federal agencies with responsibilities for the management of the system.

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environmental management. First, there is an increasing shift towards adaptive co-management in social-ecological systems, defined as the use of different types of local stakeholder and rights-holder knowledge to collaboratively foster diverse forms of knowledge generation (Berkes, 2009; Olsson et al., 2004). Second, hierarchical management is being rejected for more democratic management and governance of non-linear and complex environmental issues (Chaffin et al., 2014; Stringer et al., 2006). Last, there is a recognized need to move away from narrow and linear conventions of technical expertise that marginalises TK through its use of particular reductionist forms of SK in formulating ecosystem, biodiversity and environmental change decision-making and policies (Beck, 2011; Pielke, 2007; Turnhout et al., 2016). This paper empirically contributes to the debates by operationalizing the integration and complementarity of TK and SK for environmental and natural resources decision-making.

The idea of 'interplay', how new knowledge interacts with other forms of knowledge, has been highlighted as one important factor in driving more effective knowledge use for adaptive co-management governance (Lemos, 2015). TK, which refers to the knowledge, innovations and practices of indigenous and local communities that are developed, sustained and passed on from generation to generation, can provide complementary perspectives, borne from long periods of shared observation and experimentation that are often lacking in SK (Sutherland et al., 2014). Both SK and TK can be empirically driven, but TK generally has a highly qualitative element as well. TK is more oral, holistic and requires much face-to-face interaction whereas SK is more reductionist, lab or field-based and requires specialized skills or technology for monitoring. Both forms of knowledge can independently provide powerful insights into understanding ecosystem health, but both can also suffer from the inability to recognize or detect environmental changes (e.g., Bender et al., 2013; Moller et al., 2004). There is abundant literature examining the use of TK with SK for guiding adaptive processes in conservation and resource management (e.g., Berkes et al., 2000; Moller et al., 2004). For example, certain jurisdictions within Canada, Australia and Brazil are taking steps forward in the bridging of scientific monitoring data and traditional local observations for the conservation of threatened species and protected areas (Berkes et al., 2000; Gerhardinger et al., 2009), in managing forestry practices (Pinkerton, 1998), water management strategies (GNWT, 2010; GA and GNWT, 2016), and to inform climate change mitigation, adaptation and policy (Leonard et al., 2013). Co-production of TK and SK can also enhance capacity in rural or vulnerable communities observing resource declines, allow new ideas and tools to improve both local and scientific practices, and provide checks and balances to ensure new ideas are acceptable in terms of customary institutions and values (Johnson et al., 2016; Reid et al., 2006).

Despite these advantages, the combined use of TK and SK for environmental management is often challenging and problematic. There are fundamental differences in the way people perceive the nature of knowledge and tensions can arise in part because of disparate power relations and lack of collaboration between indigenous people and researchers (e.g., Bohensky et al., 2013; Nadasdy, 1999) that leads to only a fractional representation of the complete body of knowledge held in TK (Houde, 2007). This issue can be strengthened by the co-production of research by communities and scientists that leads to the emergence of more inclusive and resilient forms of environmental governance when abrupt changes caused by multiple environmental stressors loom (Folke et al., 2005). Co-production, however, is also affected by other diverse factors such as the politics of indigenous rights and indigenous socioeconomic and cultural differences (Hill et al., 2012). Academic and governmental practices generally require TK to fit within a scientific management system even though the knowledges held by indigenous peoples can be fundamentally different from those held by scientists (i.e., oral vs. written, compartmentalized vs. holistic) (Armitage et al., 2011). Some scientists have even rejected TK as being 'anecdotal', 'biased' and 'inaccurate' (Brook and McLachlan, 2008). Many works therefore continue to advocate the use of TK and its problematic 'integration' with science without describing or even proposing practical means for achieving this goal (Reid et al., 2006).

1.2. Bayesian belief networks as a two-eyed seeing approach

The concept of 'two-eyed seeing' offers a framework on how different types of knowing such as TK and SK can be brought together more often as a developmental practice (Briggs, 2013), while respecting the differences and perspectives that each can offer (Bartlett et al., 2012). As a result, we learn to see from one eye with the strengths of TK, and from the other eye with the strengths of SK. Using both eyes together brings us closer to a more improved understanding of the dynamics of the whole system under multiple stressors both abrupt and long-term (Folke et al., 2005); a new, balanced way of seeing the world that has been created for the benefit of all (Whyte et al., 2015).

Bayesian Belief Networks (BBNs) are one type of participatory modelling (i.e., Barber and Jackson, 2015) in which a two-eyed seeing approach can be embraced and operationalized. BBNs are probabilistic models that provide a graphical representation of key factors and interactions for an outcome of interest (Kjaerulff and Madsen, 2008). Key factors are represented as nodes (parent and child) in the diagram and their dependencies on other key factors, and the outcome of interest, are depicted as directed links to form a directed acyclic graph (Jensen, 1996). A conditional probability table (CPT) is used to describe the probability of each value of the child node, conditioned on every possible combination of values of its parent nodes (Marcot et al., 2006). The information used to populate the CPTs in the network may originate from diverse sources such as empirical data, expert opinion (e.g., TK) and simulation outputs, and can be a combination of quantitative and qualitative data (e.g., Mantyka-Pringle et al., 2014; Martin et al., 2015). Thus, BBNs have been increasingly applied to complex social-ecological problems such as the evaluation of alternative management options for natural systems under multiple stressors (Ban et al., 2014; Mantyka-Pringle et al., 2016), in adaptive management (Nyberg et al., 2006), and for representing TK in SK-based ecosystem management (McGregor et al., 2010).

In this paper, we show how a two-eyed seeing BBN can create a shared understanding of change in an ecosystem that is under cumulative environmental impacts: the Slave River Delta (SRD) in the Northwest Territories (NWT) of Canada. A BBN approach was selected for this study because the method is arguably ideally suited for bridging TK with SK. It provides an intuitive means of exploring system dynamics, and does not have to be explicitly represented at a common scale (Marcot et al., 2006). The SRD offers a useful case study to examine BBNs as a tool for blending TK and SK to address concerns arising from rapid and long-term environmental change (e.g., Schindler and Smol, 2006). Like many other regions of the world (e.g., Ferreira et al., 2014; Mantyka-Pringle et al., 2015; Obidzinski et al., 2012), these effects are felt most strongly in communities that remain dependent on natural resources for subsistence, livelihoods or cultural practices. Cumulative effects are often individually minor but can become collectively significant in ecosystems over space and time (Schindler, 2001; Segner et al., 2014), and these effects can be difficult to detect using conventional SK approaches because of the short-term nature of the instrumental record (e.g., Schwalb et al., 2014). Indigenous people in northern Canada are responding to environmental change through the development of new institutional arrangements with stakeholders, government agencies, and researchers for the co-production of knowledge (Davidson-Hunt et al., 2013b). Our broad aim was therefore to present a theoretical and preliminary BBN for understanding the cumulative environmental impacts of multiple stressors on the SRD ecosystem, including both social and ecological consequences.

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