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Assessing current monitoring indicators and reporting for cumulative effects integration: A case study in Muskoka, Ontario, Canada

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ABSTRACT

Climate is changing at an unprecedented rate with impacts being felt in social and ecological systems around the world. Opportunities for building climate resilience of the social-ecological system surrounding freshwater areas are assessed using the aquatic monitoring and reporting programs of Muskoka River Watershed (Ontario, Canada) as a case study. A three-step study design was used: establishment of a knowledge baseline (i.e., what has been done), confirmation of the baseline to ensure perspectives that emerged were inclusive of multiple stakeholders (i.e., broadly applicable) and an exploratory workshop to disseminate recommendations and discuss implementation with key stakeholders. Two themes are discussed: the strengthening of watershed-scale monitoring approaches, and improved communication with stakeholders (e.g., through 'state of the watershed' reporting). This study offers an evaluation of watershed-scale aquatic monitoring and reporting and provides concrete examples from the case study. We test a new process for refining, selecting, or prioritizing indicators for aquatic monitoring. Cumulative effects assessment and monitoring (CEAM) is considered as the suggested monitoring approach at a watershed-scale. Recommendations for developing CEAM in the Muskoka River Watershed include considerations for selection of monitoring indicators, consistent communication of indicators, and implementing a metadatabase. Ways to enhance education of, and engagement with, local stakeholders through improved 'state of the watershed' report cards are highlighted. Resilience is strengthened by addressing two goals in the case study: engaging with the community and improving knowledge of stressor-effect relationships in the watershed via stronger aquatic monitoring.

1. Introduction

Resilience of communities to environmental changes is increasingly a priority as cumulative impacts and changes in climate are becoming increasingly visible (Armitage et al., 2017; Lebel et al., 2006). Climate change threatens resilience in many ways, affecting resource development, causing more frequent devastating storm events (e.g., flooding, fires, drought), interrupting biogeochemical cycles, and increasing the spread of vector-borne diseases (IPCC, 2013). The 100 Resilient Cities global network, pioneered by the Rockefeller Foundation, describes many examples of communities that are focusing on building climate resilience in their economies, communities, and environments, which demonstrates the growing global interest in resilience in general (100 Resilient Cities, 2017). Arguably, the foundation of (climate) resilient communities is the use of monitoring programs (e.g., monitoring the environment as well as policy outcomes) that inform and increase capacity to implement relevant strategies. Without monitoring programs, decision makers, managers, and local communities would not understand what changes are likely to occur, the implications of these changes or the effectiveness of management measures.

The main objectives of environmental monitoring programs, including monitoring of water and watersheds, are to assess current states, identify change (Anderson et al., 2003), predict risks from potential effects (Brack et al., 2009), and to inform a management

Abbreviations: CE, cumulative effects; CEA, cumulative effects assessment; CEAM, cumulative effects assessment and monitoring(/management); COSIA, Canada's Oil Sands Innovation Alliance; CWN, Canadian Water Network; CWRC (or, CWN-CWRC), Canadian Watershed Research Consortium; DMM, District Municipality of Muskoka; HLW, healthy land and water (program – http://hlw.org.au); MWC, Muskoka Watershed Council; THREATS, The Healthy River Ecosystem AssessmenT System, a software by Greenland Group of Companies (consulting firms that focus on civil environmental alternative energy and software engineering, as well as landscape architecture); VEC(s), valued ecosystem component(s); WISKI, water information systems, a software by KISTERS (an international company which specializes in the development of data management software

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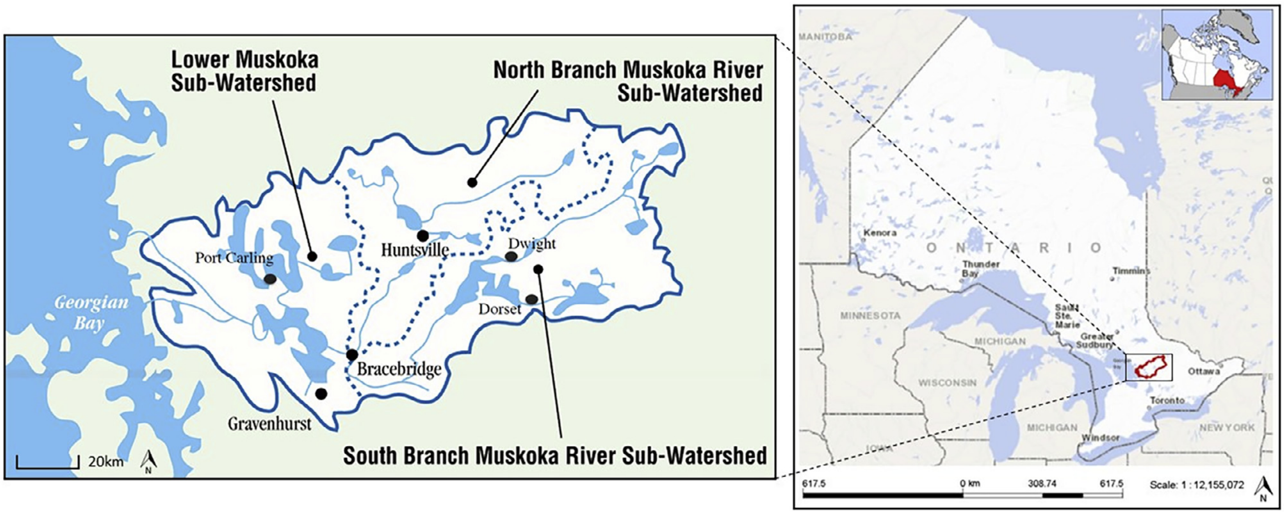

Fig. 1. Map of Muskoka River Watershed in Ontario, Canada. Overlay of Muskoka Watershed provided by Muskoka Watershed Council (MWC, 2016a).

response (Jones, 2016). Water monitoring generally refers to measuring living and/or non-living indicators for water quantity and quality over time. Watershed monitoring incorporates broader indicators that consider implications of land use, climate change, and human activities across a watershed – defined in this paper as the landscape boundary (e.g., high points) surrounding the expanse of land area from and within which water drains to a common outlet. Water management is the practice of balancing social, economic and environmental priorities in decision-making, promoting water use that support these priorities and, in some regions, assisting with or advising in land use planning activities with implications on or from water.

Potential effects in water monitoring include effects from climate change, e.g., changes to amount and frequency of precipitation, different lengths and temporal patterns of seasons, and water-related secondary impacts, e.g., changes in surface water quantity, flows, temperatures and quality. In this way, water monitoring can aid decision makers and water managers in preparing for such potential effects, which in turn increases community resilience. Due to differences in regulatory requirements, water quality standards, land use, and a variety of other biophysical and social dimensions, water management and monitoring must be tailored to the locality (Behmel et al., 2016). As such, each region may choose to incorporate principles of many watershed monitoring approaches, customizing a holistic process for tracking complex environmental change over time.

Cumulative effects assessment and monitoring (CEAM) can integrate components of different watershed monitoring and management approaches, and is applied at a sub-regional, watershed-level. Cumulative effects (CE) are defined as "changes to the biophysical, social, economic, and cultural environments caused by the combination of past, present and 'reasonably foreseeable' future actions" (INAC, 2007; Northwest Territories, 2015). Cumulative effects assessment (CEA) emerged from environmental assessment processes with two main objectives: to clarify trends and variability, and to determine causality between stressors and stresses (Ball et al., 2013; Bidstrup et al., 2016). Cumulative effects assessment and monitoring (CEAM) is defined by Dubé (2015, 1) as "the process of monitoring, tracking and predicting accumulating environmental change relative to established limits".

This study investigates enhancing climate-resilience of communities and ecosystems by improving watershed monitoring in the case study of Muskoka River Watershed in Ontario, Canada. The results and discussion are organized according to the two study objectives: identify opportunities for strengthening watershed monitoring and communicate the state of the watershed with stakeholders (e.g., educate).

1.1. Case study: Muskoka River watershed

As in other areas of Canada (and the world), climate change in the region of Muskoka, Ontario has impacted its air, land, and water, affecting drinking water, angling, biodiversity, and recreational activities (Sale et al., 2016). Changes in weather patterns (MWC, 2010) and movement of species ranges (Waite and Strickland, 2006) are already being observed. Although action has been undertaken in Muskoka to improve regional watershed monitoring, formal climate resilience strategies have not been implemented. Despite monitoring watershed indicators (e.g., water flows and temperature, biodiversity, land use) that may point to impacts from climate change, climatic changes and interactions with them are not explicitly monitored. Also, reporting has thus far excluded framing or discussion around climate change. The consideration of climate interactions is a crucial piece to the region's ability to plan and manage for an increasingly uncertain, potentially volatile, and highly complex future.

The Muskoka River Watershed (Fig. 1) is the largest of four primary watersheds in the Muskoka region. It consists of over 2000 lakes connected by the Muskoka River and its tributaries (Eimers, 2016; Wilson, nd). Its headwaters are in Algonquin Park, flowing southwesterly into Lake Muskoka and then into Georgian Bay (Wilson, nd). At its widest section, it is more than 62 km wide, and it covers an approximate area of 4660 km^2. There is a small resident population of about 60,599 people (2016 data for District Municipality of Muskoka), though the Muskoka region is used throughout the year by similar numbers of cottagers and outdoor enthusiasts (MWC, 2016a). Seasonal residents slightly outnumber permanent/year-round residents. Communities located in the Watershed include Dwight, Dorset, Huntsville, Bracebridge, Gravenhurst and Port Carling (Wilson, nd). The abundance of scenery and wildlife found in the region attracts a plethora of sportsmen and tourists from across Ontario and the world – including some of Canada's wealthiest travelers, earning it the nickname among some, 'Hamptons of the North' (Pigg, 2015).

In Ontario (and other areas across Canada and abroad), local water resources are managed on a sub-regional scale. The widely-accepted unit of management is the watershed, which typically extends beyond individual municipalities, but is more manageable for day-to-day operations than attempting to manage the whole province, territory, or nation. Often, collaboration between watersheds occurs to tackle larger-scale issues, but implementation of management generally occurs within a single watershed (an exception to this is the Great Lakes system, which is sometimes discussed as an entire system including all five lakes and connecting waterways). The Muskoka Watershed Council