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Physico-chemical changes in two northern headwater lakes in the Northwest Territories, Canada, during winter to spring seasonal transitions

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ABSTRACT

This note describes extended monitoring of two small headwater lakes in the Lockhart River in the Northwest Territories (Canada) during consecutive late winter and spring transitions. During these transitions, the lakes changed from isolated ice-bound water bodies to interconnected lakes, throughout which they exhibited similar modifications to their physico-chemical characteristics. Lake temperature changes were linked to ambient conditions, with warming after May 1 initiating snow- and ice melt inflows. Lake temperatures of 3 °C to 4 °C were measured in both lakes at the start of monitoring, which were maintained until a steady increase commenced in early June 1 as ice cover started to recede. This period was also associated with peak water levels and lake discharges. Conductivity decreases (~26 to ~12 μS/cm in the larger, shallower lake, Area 8, to 16 to 11 μS/cm in the smaller, deeper lake, Lake I1) commenced around mid-May, in advance of lake temperatures increases, and stabilized after approximately 3 weeks once lake ice had melted. The extent of lake dilution based on conductivity decreases (54–56% in Area 8, and 31% in Lake I1) was attributed primarily to the ice cover melt volume on each lake at the start of monitoring. DO concentrations were mostly undersaturated at the start of the monitoring period, with values below aquatic life guidelines; Area 8 reached saturation once lake conductivity stabilized, but Lake I1 was saturated once conductivity started to decrease. pH transitioned from slightly acidic (~5.8; below aquatic life guidelines) to circumneutral, with the transition slightly different between lakes depending on the lake conductivity transition.

Introduction

The remoteness of the Shield environment of northern Canada and its extreme weather conditions make water quality data collection very challenging. Data collection typically involves seasonal field programs, which include field data and water sample collection that comprise two or three surveys over the course of a year to capture annual variability during under ice or open-water conditions. Field data are often surface water spot measurements or water column profile measurements collected at a single sampling location. Water quality monitoring during the freshet period of flow accompanying snowmelt in such environments is even more difficult due to access constraints to sites and unsafe ice conditions.

Although many studies have reported extended periods of in situ monitoring of physico-chemical parameters (e.g., dissolved oxygen [DO], pH, specific conductivity, and temperature) in a range of aquatic environments (e.g., Cornell and Klarer 2008, Baehr and Degrandpre, 2002), few have used this approach in northern environments (e.g., Deshpande et al., 2015; Forsström et al., 2007). Such detailed physico-chemical monitoring is not typically conducted in northern lake environments, so the results presented here are unique and advance our knowledge of the physico-chemical changes that northern headwater lakes undergo during seasonal transitions.

This paper describes the in situ monitoring results from two dilute, clear, headwater lakes near a mining development in the Northwest Territories (Canada) during two consecutive late winter and spring transitions. The study area was located at the De Beers Canada Inc. (De Beers) Gahcho Kué Diamond Mine Project (Project). The project is located approximately 280 km northeast of Yellowknife, Northwest Territories, approximately 80 km southeast of the Snap Lake Mine (Fig. 1; centered at 63°25′48″ N, 109°12′00″ W). The site of the project is Kennady Lake, a small headwater watershed within the Lockhart River watershed, which ultimately drains into the north-eastern arm of Great Slave Lake (Fig. 1). These lakes lie within a region dominated by a series of interconnected lakes set in low-lying tundra (Fig. 1). The lakes are naturally developed in granite in the Canadian Shield, which is largely non-erodible and non-soluble, and thus the water quality of the waters draining this geologic formation is characterized as virtually pristine, very dilute (i.e., typical TDS of about 10 mg/L) and supporting low productivity (i.e., low nutrient status, or oligotrophic). At the time of this study, the project was undergoing environmental impact review in 2013 by the Mackenzie Valley Environmental Impact Review Board.

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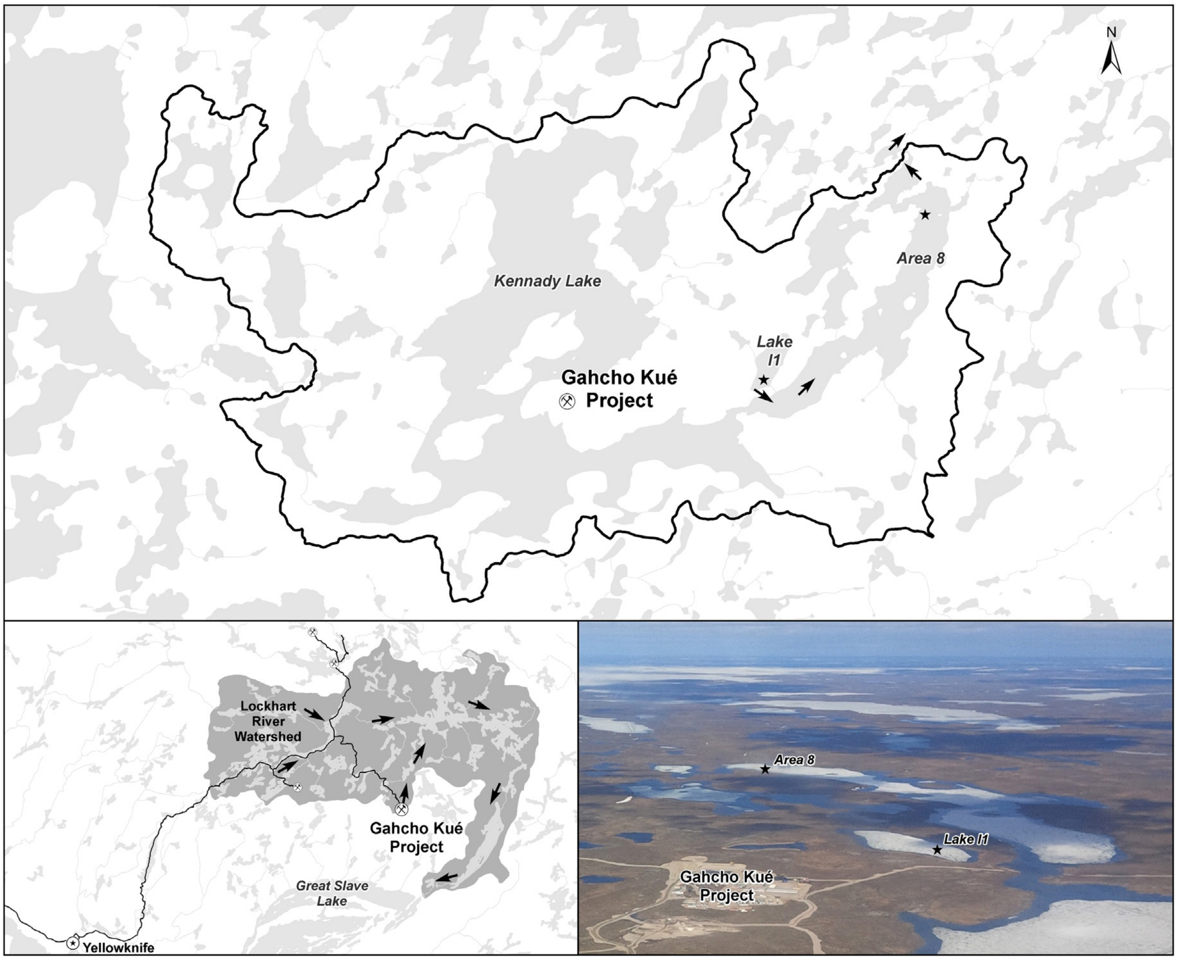

Fig. 1. Location of in situ monitoring locations within Area 8 and Lake I1, and the De Beers Gahcho Kué Project, in the headwater Kennady Lake watershed of the Lockhart River watershed, Northwest Territories. The Kennady Lake watershed boundary is shown and arrows are included to indicate the direction of flow. Photo insert: aerial photo showing the monitoring locations relative to the project on June 6, 2014.

This study was undertaken in 2011 and 2012 with the aim of providing a more comprehensive understanding of the baseline water quality conditions in lakes within the project area, particularly the physico-chemical changes in water quality that occur in northern lakes during the transition between late winter and spring. This period included the annual freshet at these lakes, when the most substantial alteration in water quality conditions occurs each year. This seasonal transition represents a change from initial ice-covered conditions, water level increases as snowmelt starts to enter the lakes before there is any loss of ice cover, the rapid onset of discharge from the lake outlets as the lake ice loosens and lifts from the shore and outlet channels, a period of peak flows and discharge from the ice- and snowmelt inflows, and ultimately open-water conditions as water levels and discharges subside (De Beers Canada Inc., 2010). The water level increase and ice lift before the downstream freshet flows commence is a result of a backwater effect in the lakes due to ice blockage at the lake outlet, or in the small lakes immediately downstream (De Beers Canada Inc., 2010). During the transition, the water quality of these lakes shifts from slightly acidic pH, low temperature, and undersaturated DO conditions during under ice conditions at the end of winter, to circumneutral pH, higher temperature, and saturated DO in late spring (Golder Associates Ltd., 2014).

The small lakes within the Canadian Shield that possess sufficient depth to provide at least 2 m of water below the ice cover in winter also provide overwintering habitat potential for large-bodied fish species, such as lake trout and Arctic grayling (De Beers Canada Inc., 2010) despite the undersaturated conditions for oxygen. Temporary changes to the productivity status in these lakes as a result of mining activities (e.g., mine discharges that possess elevated nutrients) or even longer-term changes as a result of climate change (e.g., a potential increase in watershed import of nutrients and dissolved organic matter to these lakes) will increase primary production and affect the ability of these small lakes to maintain overwintering habitat through increasing winter oxygen demand. Therefore, data from enhanced monitoring provide a basis against which measurements made in the small lakes during mining operations can be compared to identify if changes to water in the receiving environment have the potential to affect overwintering habitat.

Methods

Two headwater lakes within the Kennady Lake watershed in close proximity to the proposed project were selected for this monitoring program. They included Area 8 of Kennady Lake (Area 8), the most downstream basin of Kennady Lake, and Lake I1, a tributary lake that flows into Area 8 (Fig. 1). Area 8 has a surface area of 143 ha, a watershed area of 32.5 km^2, a volume of 3.5 million m^3, a maximum depth of 9 m, and an average depth of 2.5 m (De Beers Canada Inc., 2010). Despite being the most downstream basin of Kennady Lake, Area 8 is isolated from the upstream basins of Kennady Lake and the downstream lakes in winter when ice develops in the shallow region of Kennady