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Chemical and botanical indicators of groundwater inflow to *Sphagnum*-dominated peatlands

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ABSTRACT

Knowledge of whether a peatland is fed by a surface aquifer or is providing water to the aquifer can lead to different aquifer and wetland management strategies. Few studies have been conducted to investigate aquifer-peatland connections, because flow connections are difficult to measure and can be spatially and temporally variable. The objective of this study was to combine chemical and botanical indicators of groundwater inflow to *Sphagnum*-dominated peatlands for a better classification of their water sources. Available knowledge of peatland geomorphic setting, water chemistry, and vegetation data for 12 aquifer-peatland systems of the Abitibi-Temiscamingue region and of the St. Lawrence Lowlands, two contrasting regions of southern Quebec (Canada), were used to derive indicators of groundwater inflow. Total dissolved solids (TDS) is identified as a comprehensive indicator of water mineralization. Threshold values of 16 mg/l (Abitibi-Temiscamingue) and 22 mg/l (St. Lawrence Lowlands) were found to indicate the presence of groundwater within the peatland. Results show that combining chemical (TDS) and botanical indicators can detect the presence of groundwater inflow into most of the studied peatlands. The indicators are more efficient on slope peatlands, where groundwater inflow is more substantial and less spatially variable, than in basin peatlands. A two-step approach is proposed: (1) identify the geomorphic setting of the peatland, and (2) estimate the chemical and botanical indicators. This approach is low-cost and easy to implement, and thus can be used on a large number of sites to assess the presence of groundwater inflow to peatlands.

1. Introduction

Peatlands are wetlands formed through the accumulation of partially decayed organic matter (peat), and represent 50–70% of global wetland resources (Chapman et al., 2003). They are of high conservation value due to the key ecological functions they provide and to their high level of biodiversity (Joosten and Clarke, 2002; Moore, 2002; Limpens et al., 2008). For example, as a result of their organic matter accumulation, peatlands play an important role in the global carbon cycle, having accumulated approximately 600 Gt C during the Holocene (Yu et al., 2010). They also constitute important freshwater reserves and help regulate regional hydrologic fluxes (Acreman and Holden, 2013).

Knowledge of whether a peatland is fed by a surface aquifer or is providing water to the aquifer can lead to different aquifer and wetland management strategies. For example, in a groundwater-fed peatland, a reduction in groundwater level can lead to a reduction of groundwater inflow to the peatland, in turn disrupting the peatland ecology. However, few studies have been conducted to investigate aquifer-peatland connections (some examples include Bourgeault et al., 2014; Levison et al., 2014), probably because such flow connections are difficult

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to measure and can be both spatially and temporally variable.

Approaches using the contrast between surface water and groundwater temperatures to identify groundwater inflows (e.g., House et al., 2015) are an interesting and relatively inexpensive method to identify flow connections.

Classifying peatland types according to their dominant water source (e.g., ombrotrophic peatlands are precipitation-dominated while minerotrophic peatlands are groundwater-dominated) provides a simplified classification scheme of wetland connections to the hydrosystem, which can be useful at the regional scale or as a first approximation. However, these simplifications may not be useful at the local scale, where connections can be discrete and variable in both space and time. In many cases, the peripheral wet zone, or lagg area, that tends to form at the edge of ombrotrophic peatlands is an expression of these connections (Langlois et al., 2015). Groundwater can feed *Sphagnum*-dominated peatlands (poor fen to bog) both laterally and vertically (Drexler et al., 1999; Fraser et al., 2001), without obvious visible indices. Although it represents limited water volumes (e.g., Levison et al., 2014), groundwater inflow can play a crucial role in maintaining moisture conditions that are favorable for many plant species (Grootjans et al., 1988). Such inflow is rarely taken into consideration when assessing the hydrological functions of ombrotrophic peatlands, and yet the peatlands could be negatively impacted if groundwater levels were to be lowered (i.e., through pumping or groundwater extraction).

It is also well known that different water sources provide distinct ions to a peatland. These ions give rise to the presence of different plant species and assemblages, plant communities or individual species, such as *Sarracenia purpurea* in bogs, which have been used to identify the origin of water flowing into peatlands (Wassen et al., 1988; Glaser et al., 1990; Goslee et al., 1998; Mouser et al., 2005; Munger et al., 2014). Much remains to be investigated to fully understand the limits of chemical and botanical indicators in a variety of situations (Lewis, 2012). Combining water chemistry and plant communities provides robust information to identify water source (Johnston and Brown, 2013). However, because they are more time and resource intensive, these methods are rarely used to determine which wetlands have the highest hydrological and ecological value. Based on the current state of knowledge, and considering the limited number of reference wetlands from which thorough understanding of peatland water sources can be identified throughout the world (Cole, 2006), there is a clear need for efficient wetland water source indicators.

The objective of this study was to combine chemical and botanical indicators of groundwater inflow to *Sphagnum*-dominated peatlands for a better classification of their water sources. Available knowledge of peatland geomorphic setting and vegetation data for 12 aquifer-peatland systems of the Abitibi-Temiscamingue region, located 600 km northwest of Montreal, and of the St. Lawrence Lowlands in southern Quebec (Canada) is first described. This knowledge is used in tandem with new data on water geochemistry which is analyzed using principal component analysis. The combination of geomorphic setting, vegetation data, and water chemistry is used to derive a two-step approach to identify the presence of groundwater.

2. Methods

2.1. Study sites

Surficial geology in the Abitibi-Temiscamingue region (hereafter referred to as Abitibi) is characterized by an esker-moraine morphology, surrounded by an extensive glaciolacustrine clay plain. Deposited when the region was submerged in the deep proglacial waters of Lake Barlow-Ojibway, this clay contributes to the highly productive aquifers found in eskers by retaining groundwater in the granular deposits (Nadeau et al., 2015). Approximately 19% of the region is covered by wetlands, most of which are peatlands (Ducks Unlimited Canada, 2009). The five *Sphagnum*-dominated peatlands selected in this study area are slope peatlands (as defined by NWWG, 1997) that have developed on esker slopes (Fig. 1a). They are mostly formed of bogs, with marginally poor to moderate fens at their upgradient limit and fingering organic deposits that drain naturally into small streams at their outer edges. The uphill portion of the complexes are thus geogenous, i.e., they are open to outside hydrologic flows other than precipitation and are flow-through systems, as defined by Mitsch and Gosselink (2007). The following complexes were selected for study: La Belle (two transects: LB1 and LB2), La Coupe (LC), Saint-Mathieu-Berry (SMB), Sources Nord (SN), and Sources Sud (SS).

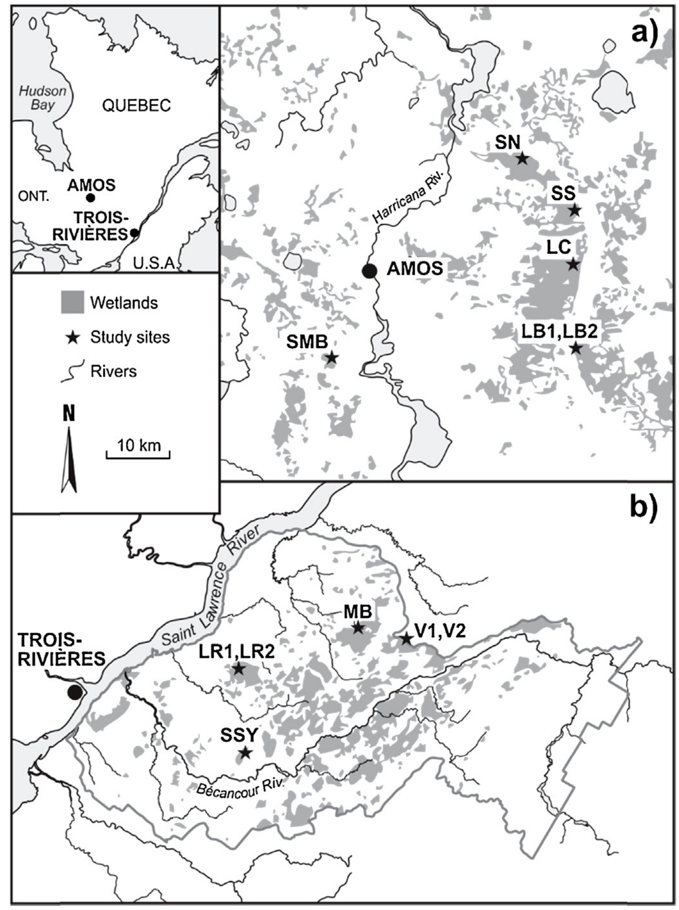

Fig. 1. Locations of individual peatlands for the two study sites (a) Abitibi, and (b) Becancour.

The geology of the Becancour watershed, which contains the studied St. Lawrence Lowlands peatlands, consists of a series of sedimentary and metamorphic rocks, overlain by tills and permeable Quaternary marine deposits that form surface and semi-confined aquifers. The low-permeability tills and Champlain Sea clay deposits that accumulated during and after the last glaciation have favored peat accumulation in topographic depressions (Godbout et al., 2011). Peatlands comprise approximately 6% of the studied watershed (Avard et al., 2013). The four peatlands selected for this study are basin bogs (as defined by NWWG, 1997) surrounded by a minerotrophic lagg, and are located at the head of small or intermediate watersheds (Fig. 1b). All of the peatlands have more than one small stream outflow, and most are drained by