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Spatio-temporal variations in biomass and mercury concentrations of epiphytic biofilms and their host in a large river wetland (Lake St. Pierre, Qc, Canada)

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ABSTRACT

Within wetlands, epiphytes and macrophytes play an important role in storage and transfer of metals, through the food web. However, there is a lack of information about spatial and temporal changes in their metal levels, including those of mercury (Hg), a key priority contaminant of aquatic systems. We assessed total mercury (THg) and methylmercury (MeHg) concentrations of epiphyte/macrophyte complexes in Lake St. Pierre, a large fluvial lake of the St. Lawrence River (Québec, Canada). THg and MeHg concentrations were ten fold higher in epiphytes than in macrophytes. THg concentrations in epiphytes linearly decreased as a function of the autotrophic index, suggesting a role of algae in epiphyte Hg accumulation, and % of MeHg in epiphytes reached values as high as 74%. Spatio-temporal variability in THg and MeHg concentrations in epiphytes and macrophytes were influenced by water temperature, available light, host species, water level, dissolved organic carbon and dissolved oxygen.

1. Introduction

Many lakes are affected by mercury (Hg) contamination which can alter human health, mainly through exposure by fish consumption. Wetlands are often seen as sinks for nutrients and metals, such as Hg, but also as sources for methylmercury (St. Louis et al., 1996). Furthermore, methylmercury (MeHg) concentrations in lakes and rivers have been shown to be correlated to the percentage of wetlands within the drainage basin (Mierle and Ingram, 1991). A perturbation of these ecosystems (*e.g.*, dredging or water level fluctuations) can have dramatic consequences on the release of these stored materials in the environment (Westling, 1991).

Although aquatic plants in wetlands can accumulate Hg, the periphytic biofilm that covers them (epiphytes) has a more rapid turnover rate than its host, and is the main food source for macroinvertebrate herbivores (Cleckner et al., 1998; Cremona et al., 2009; Molina et al., 2010). Furthermore, it is known that epiphytes can methylate Hg (Cleckner et al., 1999; Mauro et al., 2001; Hamelin et al., 2011) and that MeHg concentrations within biofilm matrix can reach high levels (*e.g.*, 3–55 ng gDW^{-1} for periphyton growing on rocks, Desrosiers et al., 2006c). Hg and MeHg accumulation in aquatic primary producers could therefore be an important pathway of Hg transfer from the watershed to the aquatic foodweb (Rask et al., 1994; Hill et al., 1996; Cremona et al., 2009).

Few studies have focused on periphytic biofilms as a potential source of Hg to food webs. Most of them were conducted in tropical and subtropical regions (Cleckner et al., 1998; Guimarães et al., 2000; Roulet et al., 2000; Mauro et al., 2002; Huguet et al., 2010), whereas those in temperate regions are sparse (Rask et al., 1994; Desrosiers et al., 2006b in boreal lakes). Considering the extensive presence of wetlands in northern hemisphere (Keddy et al., 2009), it is crucial to investigate the importance of Hg and MeHg concentrations in epiphytes and macrophytes in temperate regions, in order to better predict fish contamination and human exposure.

Epiphyte biomass is not only related to nutrients and light availability, but is also closely related to its macrophyte host as the latter will determine the available surface for colonisation (Cattaneo and Kalff, 1980; Engelhardt and Ritchie, 2001), and specific composition of epiphyte biofilms (Pip and Robinson, 1984). Functional differences in community composition of microorganisms are known to influence Hg methylation and demethylation rates, as well as Hg and MeHg concentrations in biofilms (Macalady

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et al., 2000; Hamelin et al., 2011). Thus, indicators of biofilm composition, such as the proportion of autotrophes *vs* heteotrophes, known as the autotrophic index (see Section 2.3), should be linked to epiphytes Hg contamination.

Physico-chemical characteristics of the water (pH, dissolved oxygen concentrations, nutrients, temperature) have been shown to affect Hg bioavailability and methylation in biota (Callister and Winfrey, 1986; Mauro et al., 1999; Ullrich et al., 2001; Le Faucheur et al., 2011). The relative importance of these physico-chemical variables on Hg processes may vary through the ecological succession of macophyte host and the associated changes of the epiphytic communities. Thus, fluctuations in epiphyte and macrophyte Hg and MeHg concentrations are expected from the beginning to the end of the summer. To our knowledge, there are currently no published seasonal trends of THg and MeHg concentrations in epiphytes or macrophytes of the northern hemisphere.

The aim of the present study was to measure THg and MeHg concentrations in epiphytes/macrophytes complexes, evaluating the effect of: (i) host specificity (macrophytes species and habitat), (ii) temperature and light (related to depth and season), (iii) the proportion of autotroph organisms in biofilms (autotrophic index), and (iv) chemical characteristics of sites (stations).

The study was conducted in, a large fluvial lake (Lake St. Pierre), characterized by high spatial variability in water physico-chemical proprieties, as it is formed by three distinct water masses that flow side by side without mixing (Centre Saint-Laurent, 1996).

2. Materials and methods

2.1. Study site

Lake St. Pierre (46°12′N, 72°49′W) is an enlargement of the St. Lawrence River downstream of Montreal, Québec, Canada (Fig. 1). This long (30 km) lake is relatively shallow (mean depth ~3 m, excluding the navigation channel) and supports large emergent marshes and extensive beds of submerged aquatic vegetation (Hudon, 1997). More information on the study site can be found in the supplementary information.

2.2. Sampling

Four stations were chosen for their contrasting physico-chemical characteristics, but also for their interest as commercial fishing sites (Fig. 1). Two were located on the north shore, one close to the Girodeau Island (GIR, 46° 09′ 82″ N; 72° 59′ 10″ W) and the other in the Maskinongé Bay (MASK, 46° 11′ 56″ N; 72° 56′ 63″ W). The two other stations were situated on the south shore, one in the Anse-du-Fort (ADF, 46° 08′ 24″ N; 72° 54′ 87″ W) and the other in a large eutrophic bay, St. François Bay, (BSF, 46° 06′ 97″ N; 72° 55′ 87″ W), which receives agricultural inputs from the Yamaska and St. François Rivers.

Sampling was carried out once a month for 3 years (in July and August 2002, from June to August 2003 and from May to September 2004), and at 3 different water depths from the surface (0 cm, 30 cm and 60 cm). At each depth and station, three field replicates of macrophyte/epiphyte complexes per dominant macrophyte species were sampled by scuba divers using 0.68 L Pac-man boxes, - a smaller cylindrical version of the 6 L Downing box (Downing, 1986), modified by C. Vis (Parks Canada).

In the laboratory, epiphytes were separated from macrophytes by mechanical shaking (9 min in a Red Devil® paint shaker), a method previously tested in our laboratory for removing periphyton without destroying algal cells (Hamelin et al., unpublished data). 100 ml of epiphyte suspension was subsampled for each measurement: chlorophyll-α (chl, two replicates), dry weight (DW, two replicates), ash free dry weight (AFDW, two replicates), THg (x3) and MeHg (three replicates). Aliquots for chl, DW and AFDW were filtrated on GF/C filters that were pre-combusted (90 min at 500 °C) and pre-weighed for DW and AFDW. Filters were kept frozen (−80 °C) until analysis.

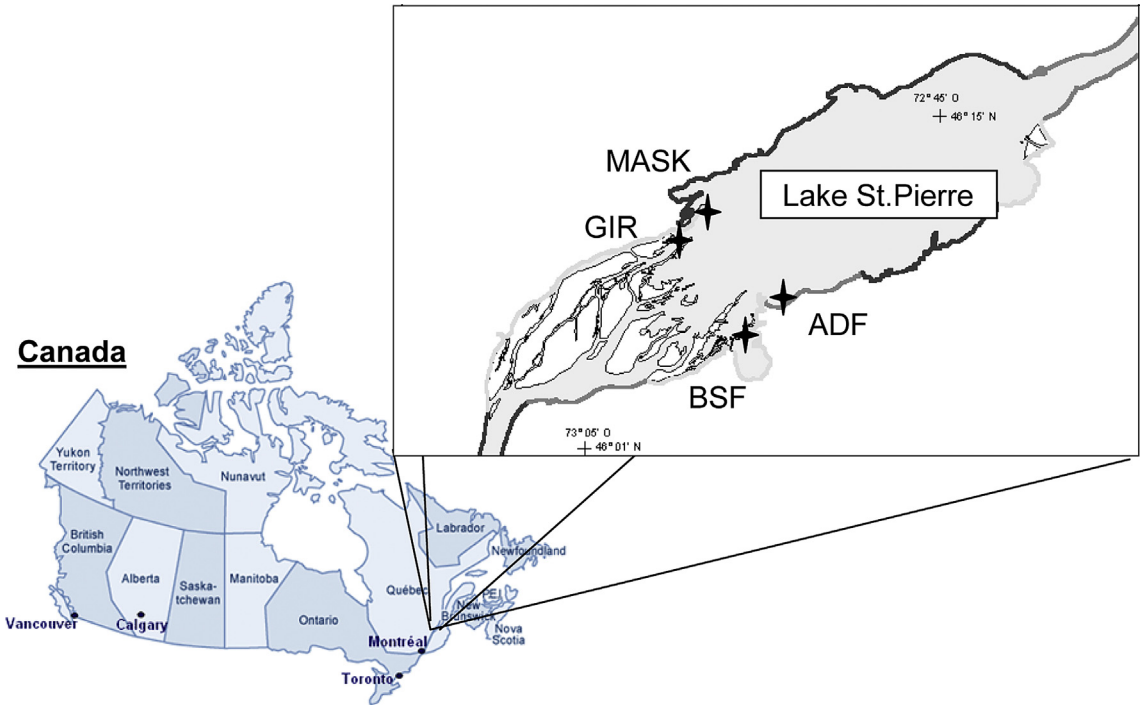

Fig. 1. Maps of Canada and Lake St. Pierre (St. Lawrence River, Québec, Canada) with the four sampling stations Girodeau Island (GIR), Maskinongé Bay (MASK), St. François Bay (BSF) and Anse-du-Fort (ADF).