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Persistent organic contaminants in sediments and biota of Great Slave Lake, Canada: Slave River and long-range atmospheric source influences

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ABSTRACT

Over 1993–1996, we conducted a series of studies to investigate the distributions of legacy persistent organic pollutants (POPs) in the West Basin and East Arm of Great Slave Lake with a focus on sediments and fish species common in traditional diets; lesser attention was paid to polynuclear aromatic hydrocarbons (PAHs) and chemicals associated with pulp and paper mill activity. The Slave River, formed by the confluence of the Peace and Athabasca Rivers, profoundly affects the limnology of the West Basin by transporting large quantities of water and suspended sediments into the lake. Most POPs occurred in substantially higher concentrations in sediments offshore of the Slave River inflow than in the remote East Arm where long-range atmospheric transport was inferred to be the primary source. POP concentrations tended to be higher in East Arm than the West Basin fish possibly because the low productivity of the East Arm provides less opportunity for contaminant dilution through fish growth and the adsorption onto organic particulates in the water column. Overall, POP concentrations were relatively low in plankton, lake trout fillet and burbot liver from both regions of the lake and generally comparable to other lakes located at similar latitudes. Since 1998, we have been monitoring POPs, mercury and other contaminants in lake trout and burbot under the Northern Contaminants Program in which we are contributing to national and international reporting and to the global understanding of contaminants and climate change on northern and other environments.

Introduction

Great Slave Lake (Fig. 1), in the Northwest Territories, is an especially important northern great lake, supporting a number of communities and towns along its shoreline, sustaining commercial fisheries and serving as a transportation hub from the southern provinces to northern communities living along the Mackenzie River and the coastal Arctic as well as various industries including mines to the east (Evans, 2000) of the lake. It is one of several long-term biomonitoring sites established by the North Contaminants Program (NCP, Aboriginal Affairs and Northern Development Canada) which is working to reduce (and eliminate) contaminants from the Arctic environment with a focus on animals that are traditional in the diets of northerners. Information generated from these studies is reported in national and international reports (AMAP/UNEP, 2008; Muir et al., 2013) and is used to influence the development and implementation of international/global agreements to reduce and/or eliminate the production, use and release of contaminants of concern. The focus is on long-range atmospheric transport of these contaminants to these remote regions. The initial program ran from 1991 to 1997 and focused on legacy persistent organic pollutants (POPs) such as PCBs, DDT, and chlordane pathways with findings reported in Jensen et al. (1997). Organic contaminant concentrations were high in some marine mammals as well as toxaphene in lake trout and burbot from Lake Laberge in the Yukon; the latter findings resulted in the closure of the commercial fishery and the issuance of consumption advisories. Since 1998, the focus of the NCP biomonitoring program has been on trend assessment including mercury (and 30 other metals) with PBDEs (polybrominated diphenyl ethers) and other compounds of emerging concern later added to the analytical list. Mercury trends are of particular concern as global warming and increased mercury emissions from Asia with their developing economies are projected to result in increased mercury concentrations in many environments, and warming trends may facilitate the transformation of mercury into bioaccumulative forms (Chételat and Braune, 2012). Trends of mercury increase have been reported for fish from Mackenzie River and Great Slave Lake (Carrie et al., 2010; Evans et al., 2013).

Great Slave Lake, in addition to being influenced by long-range atmospheric transport, is profoundly influenced by inputs from the Slave River which contributes some 74% to the water budget of the lake along with a tremendous suspended sediment load estimated at 2.64–6.72 × 10^{10} kg y^{-1} (Rawson, 1950; Allan, 1979; Gibson et al., 2006). The river is formed by the confluence of the Peace and Athabasca Rivers, north of the Lake Athabasca outflow, and thus has the potential

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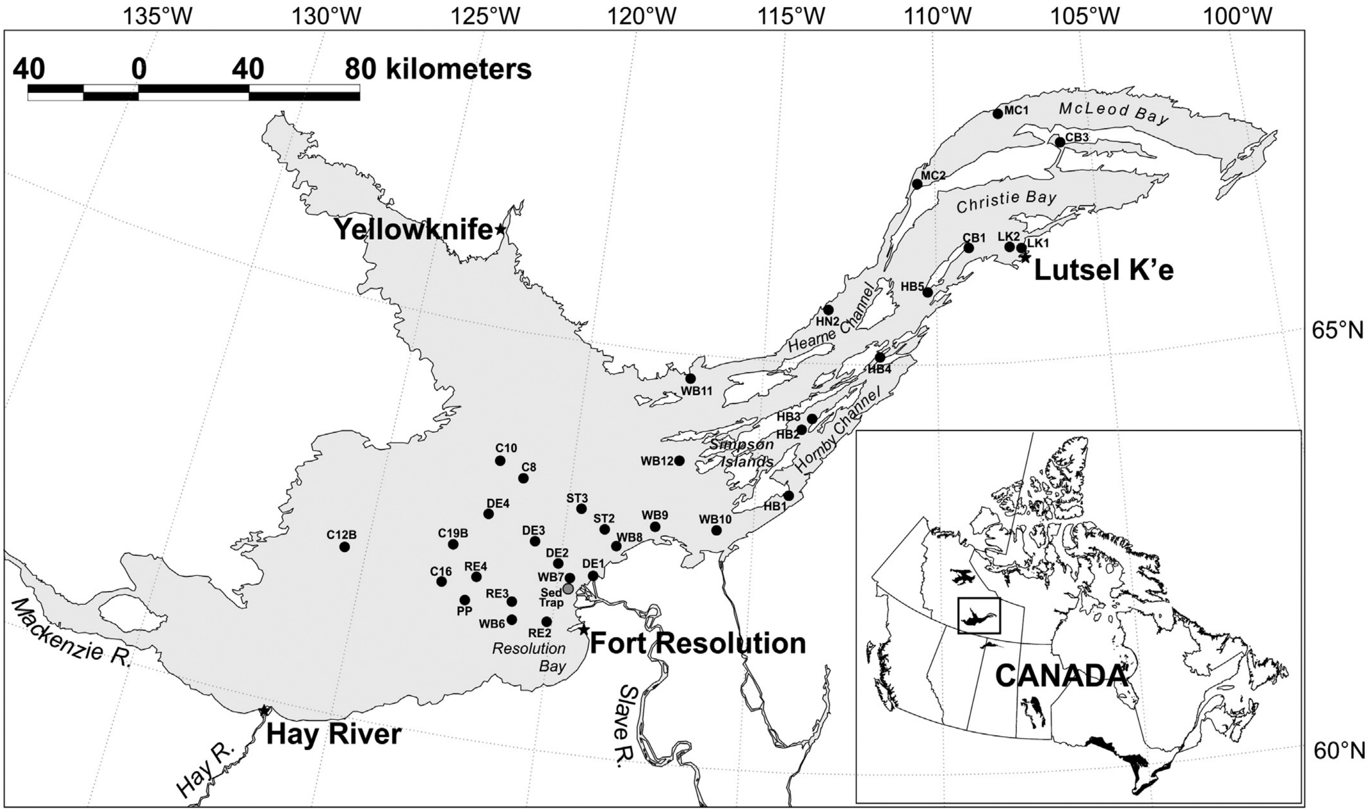

Fig. 1. Map of Great Slave Lake showing major regions, communities, and sediment and/or water sampling locations over 1994–1996.

to bring in significant quantities of contaminants from the more developed regions to the south including releases from the pulp and paper mills, oil sands operations, agricultural areas, and municipalities located along these rivers and in their watersheds. Over 1992–1996, a series of studies were conducted under the Northern River Basins Study (NRBS) to investigate these issues including investigations of contaminant concentrations (POPs, dioxins and furans, polycyclic aromatic hydrocarbons (PAHs)) and their pathways with a focus on not only the Peace and Athabasca Rivers but also considering the Slave River, Lake Athabasca and Great Slave Lake (Northern River Basins Study Board, 1996). Consumption advisories were issued for fish inhabiting the upper reaches of the Peace and Athabasca Rivers based on their dioxin and furan concentrations and a cautionary note was issued regarding the consumption of burbot liver from the Slave River based on their toxaphene concentration. The Slave River Environmental Quality Monitoring Program (SREQMP) was conducted over 1990–1995 and was designed to address the concerns of northerners with upstream contamination from pulp and paper mills, hydrocarbon developments and agriculture (Sanderson et al., 1998). While this program focused on the Slave River, it supported some studies on Great Slave Lake.

The purpose of this paper is to provide a synthesis of studies we conducted in Great Slave Lake over 1993–1996 and with support received under NCP, NRBS, and SREQMP. These programs evolved over 1993–1996 as NRBS and SREQMP broadened their study design to include Great Slave Lake. Overall, our NCP study, which formed the foundation of our research, was designed to obtain baseline information on POP concentrations in lake trout (*Salvelinus namaycush*), burbot (*Lota lota*) and lake whitefish (*Coregonus clupeaformis*) in two regions of the lake — one under a strong Slave River influence and the second more remote region where direct atmospheric sources were more predominant. Lake whitefish and lake trout are important in the commercial and domestic fishery; burbot liver is a delicacy rich in lipids and thus relatively high in lipophilic POPs. Lower trophic levels also were investigated including stable isotope studies. Some limnological studies were conducted to investigate the influence of the Slave River on the lake. There is a remarkable deficit of limnological information for Great Slave Lake with the majority of studies conducted in the 1940s (Rawson, 1947a, 1950, 1951, 1955, 1956) with a focus on the commercial fish yield. Later studies investigated primary productivity and plankton communities (Patalas, 1975; Fee et al., 1985) with other studies focusing on contaminant issues related to the town of Yellowknife and contamination from local gold mine operations (Moore, 1981; Mudroch et al., 1989, 1992). Our initial hypothesis was that POP concentrations would be higher in fish (and sediments) in the vicinity of the Slave River outflow than at more distant areas in the lake where atmospheric sources were more predominant, i.e., the Slave River was assumed to be an additional source with its contaminant inputs from developments along the Peace and Athabasca Rivers to the south.

Great Slave Lake: general features

Great Slave Lake has a drainage area of 949,000 km^2, a surface area 28,568 km^2, a mean depth of 69 m, and a maximum depth of 614 m and is divided into two regions: the West Basin which is relatively shallow (mean depth 41 m; maximum depth 163 m) and the East Arm which is substantially deeper (Rawson, 1947b; Herdendorf, 1982; Gibson et al., 2006). The two main bays of the East Arm are Christie Bay (mean depth 199 m; maximum depth 614 m) and McLeod Bay (mean depth 120 m; maximum ca. 293 m). The West Basin is located on Paleozoic deposits whereas the East Arm is on the Precambrian Shield. The Slave River, together with local geology and water depth, contribute to regional differences in the limnological features of the lake, including productivity and standing stocks (Rawson, 1953, 1955, 1956; Fee et al., 1985).

Great Slave Lake is an important northern Great Lake with a relatively substantial population along its shores including Yellowknife (territorial capital), Hay River (a major transportation hub) and First Nation communities such as Fort Resolution (located on the Slave River Delta

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