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Recent progress on our understanding of the biological effects of mercury in fish and wildlife in the Canadian Arctic

Anton Scheuhammer [a], Birgit Braune [a,*], Hing Man Chan [b], Héloïse Frouin [c], Anke Krey [d], Robert Letcher [a], Lisa Loseto [e], Marie Noël [f], Sonja Ostertag [d], Peter Ross [g,1], Mark Wayland [h]

[a] Environment Canada, National Wildlife Research Centre, Carleton University, Ottawa, ON K1A 0H3, Canada
[b] Centre for Advanced Research in Environmental Genomics, University of Ottawa, Ottawa, ON K1N 6 N5, Canada
[c] Jasco Research, 4464 Markam St., Victoria, BC V8Z 7X8, Canada
[d] Natural Resources and Environmental Studies, University of Northern British Columbia, Prince George, BC V2N 4Z9, Canada
[e] Fisheries and Oceans Canada, National Centre for Arctic Aquatic Research Excellence, 501 University Crescent, Winnipeg, MB R3T 2 N6, Canada
[f] School of Earth and Ocean Sciences, University of Victoria, Victoria, BC V8P 5C2, Canada
[g] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC V8L 4B2, Canada
[h] Environment Canada, Canadian Wildlife Service, 115 Perimeter Rd., Saskatoon, Saskatchewan S7N 0X4, Canada

HIGHLIGHTS

- Hg levels in some fish and wildlife exceed thresholds for biological effects.
- Direct evidence of potential Hg effects in Arctic wildlife is inconclusive.
- Strong Hg-Se associations have been found in tissues of Arctic mammals and birds.
- More studies are needed to clarify the effects of Hg on Arctic fish and wildlife.
- Further research is needed on the protective role of selenium against Hg toxicity.

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ABSTRACT

This review summarizes our current state of knowledge regarding the potential biological effects of mercury (Hg) exposure on fish and wildlife in the Canadian Arctic. Although Hg in most freshwater fish from northern Canada was not sufficiently elevated to be of concern, a few lakes in the Northwest Territories and Nunavut contained fish of certain species (e.g. northern pike, Arctic char) whose muscle Hg concentrations exceeded an estimated threshold range (0.5–1.0 μg g^{-1} wet weight) within which adverse biological effects begin to occur. Marine fish species generally had substantially lower Hg concentrations than freshwater fish; but the Greenland shark, a long-lived predatory species, had mean muscle Hg concentrations exceeding the threshold range for possible effects on health or reproduction. An examination of recent egg Hg concentrations for marine birds from the Canadian Arctic indicated that mean Hg concentration in ivory gulls from Seymour Island fell within the threshold range associated with adverse effects on reproduction in birds. Mercury concentrations in brain tissue of beluga whales and polar bears were generally lower than levels associated with neurotoxicity in mammals, but were sometimes high enough to cause subtle neurochemical changes that can precede overt neurotoxicity. Harbour seals from western Hudson Bay had elevated mean liver Hg concentrations along with comparatively high muscle Hg concentrations indicating potential health effects from methylmercury (MeHg) exposure on this subpopulation. Because current information is generally insufficient to determine with confidence whether Hg exposure is impacting the health of specific fish or wildlife populations in the Canadian Arctic, biological effects studies should comprise a major focus of future Hg research in the Canadian Arctic. Additionally, studies on cellular interactions between Hg and selenium (Se) are required to better account for potential protective effects of Se on Hg toxicity, especially in large predatory Arctic fish, birds, and mammals.

* Corresponding author at: Environment Canada, National Wildlife Research Centre, Carleton University, Raven Road, Ottawa, Ontario, Canada K1A 0H3. Tel.: +1 613 998 6694; fax: +1 613 998 0458.
E-mail address: birgit.braune@ec.gc.ca (B. Braune).
[1] Current address: Vancouver Aquarium, PO Box 3232, Vancouver, British Columbia, Canada V6E 3G2.

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1. Introduction

From an environmental toxicology perspective, methylmercury (MeHg) is the most important of the different chemical forms of Hg. Methylmercury biomagnifies through food chains, is very efficiently absorbed from the diet, distributes into many organs of the body including the brain, and is highly toxic. The toxic effects of MeHg in wildlife have been reported and scientifically studied for over 50 years, during which time much has been learned about its food chain transfer, metabolism, and toxicity (Wiener et al., 2003). In recent years, increasingly subtle but important biological effects have been documented, including behavioural, neurochemical, hormonal, and reproductive changes in predatory fish and wildlife exposed to environmentally relevant levels of MeHg (Scheuhammer et al., 2007, 2012). Potential population-level impacts are now being assessed for some species, such as the common loon (*Gavia immer*) (Burgess and Meyer, 2008). However, there is a general paucity of information regarding the effects of MeHg exposure in Arctic wildlife species.

Because MeHg biomagnifies through food webs, it is generally agreed that top predatory animals, particularly those linked to aquatic food chains, are at greatest risk for increased dietary MeHg exposure and potential Hg-related health effects (Wiener et al., 2003). In the Arctic, species at greatest risk include polar bears (*Ursus maritimus*), seals, toothed whales, various predatory seabirds, and large piscivorous fish such as lake trout (*Salvelinus namaycush*), northern pike (*Esox lucius*), and sharks. Conversely, Hg levels are generally far below those required to cause toxic effects in lower trophic level animals; and in most Arctic terrestrial animals not associated with aquatic food webs. Although there is evidence to suggest that non-aquatic birds, such as some forest passerine species, can experience elevated dietary MeHg exposure in sites near Hg-contaminated waterways (Brasso and Cristol, 2008; Cristol et al., 2008), similar scenarios are less likely to occur in the Canadian Arctic where large-scale industrial activity is less prevalent. Data on Hg in insectivorous passerines in the Arctic are currently lacking, but concentrations in other terrestrial avian species are low compared to aquatic predatory species.

For the last decade, the Canadian Government's Northern Contaminants Program (NCP) has funded research to investigate biological effects of mercury in the Canadian Arctic. Using information collected from NCP-funded research as well as other literature sources, we review and assess recent Hg exposure in freshwater and marine species, and summarize findings from recent studies that have begun to investigate potential toxic effects of Hg in Arctic wildlife. An emphasis is placed on geographically-linked information specific to Canada, which complements a recent more generalized review of biological effects for the circumpolar Arctic (Dietz et al., 2013).

2. Mercury effects studies

2.1. Freshwater and marine fish

Studies published within the last decade have documented a range of toxic effects in fish at environmentally relevant levels of MeHg exposure. In a critical review of the recent literature, Sandheinrich and Wiener (2011) concluded that changes in biochemical processes, damage to cells and tissues, and reduced reproduction in fish begin to occur at concentrations of about 0.5–1.0 μg Hg g^{-1} wet weight (ww) in axial muscle (>90% of Hg in muscle is MeHg). Similarly, Dillon et al. (2010) conducted an assessment of numerous fish toxicology studies and estimated with a mathematical model a lowest observable adverse effects level (LOAEL) of about 0.3 μg Hg g^{-1} ww in the whole body of fish—or about 0.5 μg Hg g^{-1} ww in axial muscle. Using 0.5–1.0 μg Hg g^{-1} ww in axial muscle as an estimated LOAEL range for fish, it is apparent that lake-averaged total Hg concentrations in northern Canadian freshwater fish species sampled since 2002 seldom enter or exceed this range (Fig. 1). However, average Hg concentrations in landlocked char from Amituk Lake on Cornwallis Island and lake trout from Cli Lake in the Northwest Territories clearly exceeded the suggested threshold range. Preliminary research has revealed increasing cell damage (necrosis) with increasing Hg concentrations in livers of char from Amituk Lake (Drevnick, 2013).

Concentrations were within the suggested threshold range for landlocked char from Char Lake (Nunavut), as well as for other fish species in several lakes in the Northwest Territories, specifically northern pike and whitefish from Narrow Lake, and lake trout from Kelly Lake and Lac Ste. Therese. A larger, older database of Arctic fish Hg levels from 1971 to 2001 (Lockhart et al., 2005a) showed that length-adjusted mean Hg concentrations in highly predatory species – lake trout, walleye (*Sander vitreus*), northern pike and burbot (*Lota lota*) – exceeded 0.5 μg g^{-1} in < 25% of the survey lakes ($n = 29–94$ lakes per species). Research is warranted to study possible reproductive or other toxic effects of Hg in fish in Arctic lakes where LOAEL thresholds are exceeded.

Consistent with fish data reported in Dietz et al. (2013) for the circumpolar Arctic, muscle Hg concentrations in many common marine fish in Canadian waters tend to be substantially lower than in freshwater fish. As shown in Fig. 2, mean muscle Hg levels in most marine fish

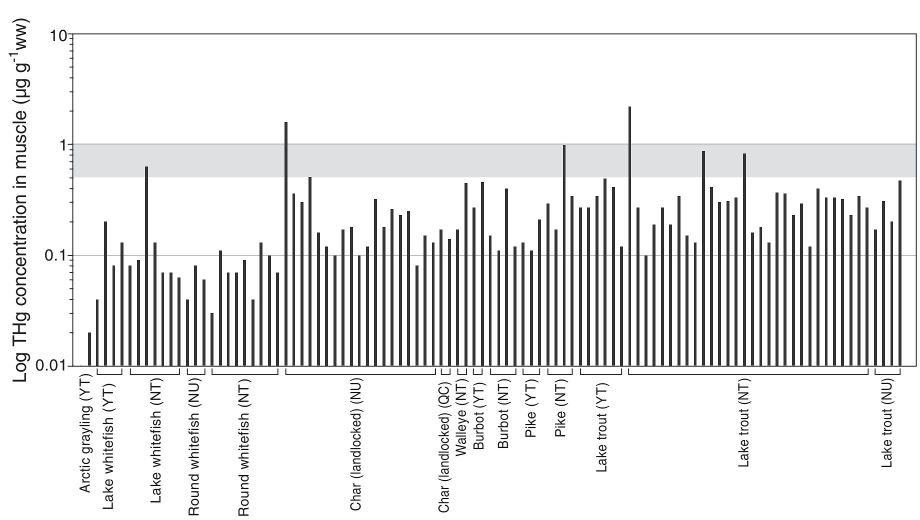

Fig. 1. Mean concentrations of total Hg (THg) in muscle of selected freshwater fish species from various Canadian Arctic lakes (NT = Northwest Territories; NU = Nunavut; YT = Yukon Territory; The shaded area represents an estimated threshold range for fish toxicity based on assessments by Sandheinrich and Wiener (2011) and Dillon et al. (2010). Data plotted are from Depew et al. (2013).