Chemosphere 202 (2018) 438–445

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Organohalogen contaminants in common loons (*Gavia immer*) breeding in Western Alberta, Canada

Tanya M. Brown [a], Sarah I. Lord [b], David W. Schindler [b], John E. Elliott [c,*]

[a] Biological Sciences, Simon Fraser University, Burnaby, BC V5A 1S6, Canada
[b] Biological Sciences, University of Alberta, Edmonton, AB T6G 2E9, Canada
[c] Science & Technology Branch, Environment and Climate Change Canada, Delta, BC V4K 3N2, Canada

HIGHLIGHTS

- PCBs dominate the POP burden in common loons collected from lakes in Alberta, Canada.
- *p,p'*-DDE and ∑PBDEs also contributed significantly to the total POP burden.
- Inter-lake variation for POPs was largely explained by diet and proximity to a dam.
- POPs were 4- to 17-fold lower than levels reported in loons from Atlantic Canada.
- POPs were well below concentrations associated with adverse effects in other birds.

ARTICLE INFO

Article history:
Received 29 November 2017
Received in revised form
15 March 2018
Accepted 16 March 2018
Available online 17 March 2018

Handling Editor: Myrto Petreas

Keywords:
Polychlorinated biphenyls
Polybrominated diphenyl ethers
Organochlorine pesticides
Common loons
Blood
Stable isotopes

ABSTRACT

We examined the influence of biological and geographical factors on the levels and patterns of organohalogen contaminants in blood of adult common loons (*Gavia immer*) collected from 20 lakes in Alberta, Canada. The loons were captured in the 2006 and 2007 breeding seasons over a 900 m elevation gradient across the eastern slope of the Canadian Rocky Mountains. While PCBs dominated the composition of these contaminants in loons at all sites (∑PCBs > *p,p'*-DDE > ∑PBDEs > ∑Chlordanes > HCB), *p,p'*-DDE and ∑PBDEs were also important, averaging approximately 50% and 20% of total PCB concentrations, respectively. ∑PCBs and ∑PBDEs were higher in males than in females. Inter-lake variation was apparent for contaminant concentrations and patterns and were largely explained by dietary signatures ($\delta^{15}N$ and $\delta^{13}C$) and proximity to a large hydroelectric dam. Mean ∑PCB (19.6 ng/g wet weight (ww)) and organochlorine pesticide (OCP) (*p,p'*-DDE: 11.8 ng/g, *cis*-nonachlor: 0.10 ng/g, *trans*-nonachlor: 0.32 ng/g, HCB: 0.34 ng/g ww) concentrations in loons were approximately 4- to 17-fold lower than average concentrations reported in common loons from Atlantic Canada and were well below concentrations which have been associated with impaired reproductive success and eggshell thinning in other piscivorous birds. Dominant PBDE congeners were BDE47, BDE99, and BDE100. The regional mean for ∑PBDEs (4.04 ng/g ww) in loons from the present study was within the range reported for ∑PBDEs in nestling bald eagle plasma from British Columbia. This is the first report of PBDEs in loons and the first report of PCBs and OCPs in common loons from Western North America.

1. Introduction

Long-lived, high trophic level birds such as the common loon (*Gavia immer*) have proven to be useful indicators of ecosystem contamination by organohalogen contaminants (e.g., DDT (dichlorodiphenyldichloroethylene) related compounds; chlordane related compounds, HCB (hexachlorobenzene), PCBs (polychlorinated biphenyls), PBDEs (polybrominated biphenyl ethers)), because of the tendency of such chemicals to biomagnify in aquatic food webs (Elliott and Harris, 2002; Grove et al., 2009).

Studies have investigated the concentrations of organochlorine pesticides (OCPs) and PCBs in loon plasma from Atlantic Canada (Burgess et al., 2005), and in loon body fat and eggs in the Great Lakes region (Frank et al., 1983; Coppock et al., 1990); there are no published reports, however, of organochlorine contaminants in

* Corresponding author.
E-mail address: john.elliott@canada.ca (J.E. Elliott).

https://doi.org/10.1016/j.chemosphere.2018.03.107

loons from Western Canada and none at all on brominated flame retardants in loons.

In other aquatic predatory birds, a variety of reproductive, behavioural and physiological effects have been reported from exposure to PCBs and OCPs (Elliott et al., 1996a, 1996b; Elliott and Norstrom, 1998; Gill and Elliott, 2003; Crump et al., 2008; Blus, 2011; Custer, 2011; Elliott and Bishop, 2011; Harris and Elliott, 2011). In various avian models, reduced productivity, embryotoxicity, and altered endocrine, behavioural and physiological functions (Verreault et al., 2006; Crump et al., 2008; Cesh et al., 2010; Técher et al., 2016) have been caused by or correlated with PBDEs. Most commercial uses of PCBs and OCPs were banned during the 1970s because they are persistent, bioaccumulative, and toxic (Elliott and Harris, 2002) and all are listed among the “Dirty Dozen” under the Stockholm Convention. PBDEs, especially the tetra- and octa-BDEs were phased out in the mid-2000s (Elliott et al., 2005; Law et al., 2014). In 2016, hexabromocyclododecane (HBCD) and deca-BDE were added to the Stockholm Convention (http://chm.pops.int/).

High-altitude regions, such as the upper reaches of mountains, are similar to high-latitude regions in that they tend to have low average temperatures and increased accumulation of organochlorine compounds (Wania and Mackay, 1993; Blais et al., 1998). The increased occurrence of these compounds in high-latitude regions and at higher elevations are largely the result of long-range transport, precipitation and ‘cold condensation’ (Wania and Mackay, 1993; Simonich and Hites, 1995; Wania and Westgate, 2008). Altitudinal effects on organochlorine contaminants have been studied in trout from lakes in the Canadian Rocky Mountains over a 1600 m elevation gradient and in osprey (*Pandion haliaetus*) from British Columbia and the Yukon over a 1210 m elevation gradient (Demers et al., 2007; Elliott et al., 2012). These two studies showed that organochlorine concentrations were partially explained by elevation, in addition to differences in other site characteristics (e.g., relative size and nature of watersheds) and diet. Variables such as lake surface area and lake depth can influence food web structure, which in turn affects contaminant exposure in biota. Furthermore, proximity to anthropogenic activities such as hydroelectric developments have been associated with ecological changes and increased contaminant concentrations in mid- and upper trophic level species frequenting areas that are downstream of reservoirs (Giesy et al., 1994; Elliott et al., 2000; Henny et al., 2004). Migration and the potential for exposure to contaminants on the wintering grounds is also a factor. Radio and satellite telemetry have both been used to study the potential for contaminant exposure while wintering in Latin America in western populations of osprey (*Pandion pandion*) (Elliott et al., 2007) and white-faced ibis (*Plegadis chihi*) (Yates et al., 2010).

Measures of stable isotope rations (carbon (δ^{13}C) and nitrogen (δ^{15}N)) are important measurements that enable inferences about diet of organisms. For example, enrichment of δ^{15}N ratios increases with trophic position due to the preferential removal of light amine groups during deamination and transamination (Hoekstra et al., 2003). Ratios of δ^{13}C can elucidate trophic interactions by establishing the relative contribution of benthic/littoral versus pelagic feeding preferences, whereby, δ^{13}C levels are enriched in organisms feeding in benthic/littoral communities compared with pelagic feeding behaviours (France and Peters, 1997).

Herein, we examine the concentrations, patterns, and distribution of legacy organochlorines (OCs) and PBDEs and determine the ecological variables (e.g., proximity to a large hydroelectric dam and diet), environmental variables (e.g., geographic position, lake characteristics), and biological parameters (e.g., length, body mass and sex) that explain the variance in these organohalogen contaminants in the blood of breeding loons. Our 20 study lakes occur over a 900 m elevation gradient from 701 to 1605 m above sea level (asl), 3.031 degrees of latitude, and 3.919 degrees of longitude. Unlike, for example, osprey or bald eagles, breeding common loons feed primarily on a single lake through the breeding season, so their dietary exposure to contaminants is geographically limited and their blood contaminant concentrations reflect local exposure on their nesting lake (McIntyre and Barr, 1997).

2. Materials and methods

2.1. Sample collection

In May–June 2006 and 2007, over 200 lakes in Western Alberta were surveyed using a small open-deck aluminum-hulled boat for loon breeding activity. Adult loons ($n = 25$) were captured in July on 20 lakes using night-lighting and call-playback (Evers, 1993) (Fig. 1). Blood samples (10 mL) from each bird were collected from the metatarsal vein using non-heparinized red-top plastic Vacutainers®, and frozen on dry ice within 3 h of collection. All samples were later stored at −40 °C until analyzed for stable isotopes and contaminants. Body mass and morphometric measurements were determined in the field. Field identification of the sex of each adult loon by vocalizations and body size was confirmed by genetic analysis, using a size polymorphism in the CHD gene (Chromo Helicase DNA-binding gene) that discriminates between sexes (Griffiths et al., 1998) at Wildlife Genetics International (Nelson, BC). Sample collections were undertaken under the authority of federal and provincial permits and in accordance with protocols recognized by the Canadian Council of Animal Care.

2.2. Chemical analysis

Concentrations of 62 PCB congeners (17, 18, 16/32, 28, 31, 33/20, 22, 52, 49, 47/48, 44, 42, 64/41, 74, 70/76, 95, 66, 56/60, 92, 101/90, 99, 97, 87, 85, 110, 151, 149, 118, 114, 146, 153, 105, 179, 141, 130, 176, 137, 138, 158, 178, 187, 183, 128, 167, 174, 177, 202, 171, 156, 200, 157,

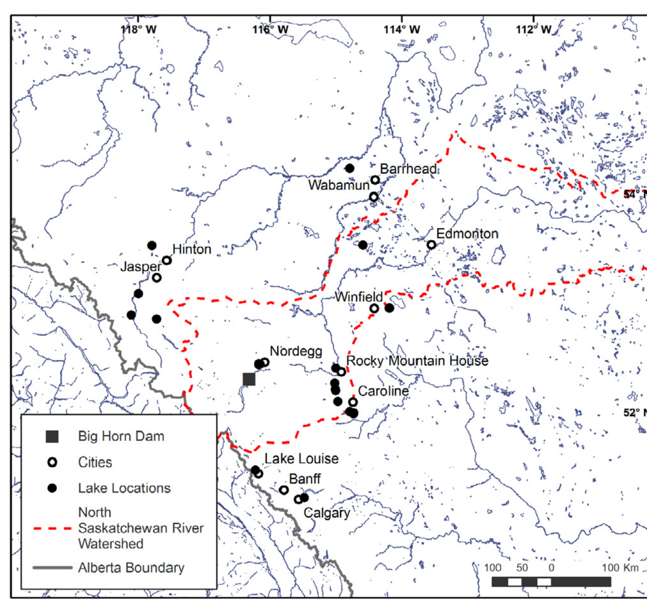

Fig. 1. Study area showing the location of the 20 lakes (closed circles) where adult male and female loon samples (n=25) were collected in Alberta, Canada, 2006–2007. Open circles show nearby cities to the study lakes, the solid square shows the location of Big Horn hydroelectric site, and the hashed line shows the North Saskatchewan River Watershed. The close circle symbol for four of the sample lakes overlaps with other sample lakes located on the map, due to their close proximity to one another.