Accumulation of persistent organic pollutants in trout from the Canadia Rocky Mountains

Marc J. Demers[1], Erin N. Kelly[2], Jules M. Blais[1], Frances R. Pick[1], Vincent L. St. Louis[2], David W. Schindler[2]

[1]University of Ottawa
[2]University of Alberta

Introduction

Semi volatile persistent organic pollutants (POPs) follow successive evaporation and deposition cycles resulting in their migration from temperate areas to high latitude and high altitude regions[1]. High mountain lakes are typically characterized by low temperatures, high precipitation, low plankton biomass, and extended periods of ice cover[2]. These factors may enhance bioaccumulation of POPs at high altitudes, either by suppressing evaporation[1], enhancing atmospheric deposition[3], or enhancing bioavailability. Projected climate warming may also amplify these effects by increasing releases of POPs from warmer emission areas, as well as promoting releases from glaciated environments, which can be a major source of chlorinated POPs to surface waters[4].

In part, due to decreased temperatures, the aquatic biota in high altitude lakes are generally characterized by higher lipid storage, longer life cycles, and slower growth rates in comparison to their conspecifics at lower altitudes. These characteristics may further enhance the bioaccumulation of POPs in high altitude lakes, independently of greater exposure. Elevated concentrations of POPs have been reported in fish[5-10] from high mountain lakes.

Our primary objective was to examine whether concentrations of POPs in trout increase with lake elevation in the Rocky Mountains. We considered fish age, growth rate, lipid content, $\delta^{13}C$, and $\delta^{15}N$ as potential explanatory variables.

Materials and Methods

Lakes were chosen to maximize a range of elevations in the Rocky Mountains of Alberta and British Columbia, Canada (760 to 2360 m.a.s.l.). All of the lakes were located within National Parks (Banff, Jasper, and Yoho). Basic physical and chemical characteristics of the lakes are shown in Table 1.

Approximately 8-10 g of muscle tissue (including skin) were homogenized with Hydromatrix © using a mortar and pestle. Samples were packed into 33 mL cells and internal standards of were added to determine extraction efficiencies. Fish samples were extracted using an accelerated solvent extractor (ASE® 200 with ASE solvent controller). The first extraction was with dichloromethane (DCM) at a temperature of 125ºC and a pressure of 2000 PSI (Dionex Application Note 342). The second extraction was with hexane at a temperature of 100ºC and a pressure of 2000 PSI (Dionex Application Note 322).

Lipids were removed from the extract using automated gel permeation chromatography (GPC) using a GPC Autoprep 1002A. The extract was cleaned and fractionated on a silica gel column. Mirex was added as an internal standard.

Extracts were analyzed by a Hewlett Packard 6890 Series II GC equipped with a split/splitless injector, a 30 m x 250 mm i.d. DB-5 with a 0.25 mm thickness, and a ^{63}Ni microelectron capture detector. Chromatographic analysis and quantification of sample extracts were performed using HP Chemstation software. Sample extracts were screened for 27 OC compounds and 127 PCB congeners, some of which coeluted to give 94 peaks. All samples were blank corrected and a NIST standard reference material (2978 mussel tissue, organic contaminants, Raritan Bay, NJ; US Department of Commerce National Institute of Standards and Technology, Gathersburg, MD, USA) was routinely analyzed with every sample batch.

Trophic position was estimated by the difference in $\delta^{15}N$ between trout and primary producers from the same lake,

while $\delta^{13}C$ was used as a measure of carbon source (i.e. benthic vs. pelagic).

Table 1. Some physical, chemical, and biological characteristics of lakes sampled in the Canadian Rocky Mountains. Water chemistry is from surface waters (1st meter) from May 2001.

	Shere	Pyramid	Patricia	Moab	Johnson	Emerald	Moraine	Bighorn
Altitude (m.a.s.l.)	760	1180	1180	1249	1320	1416	1917	2360
Latitude (°N)	53,02	52,54	52,54	52,39	51,11	51,26	51,19	51,28
Longitude (°W)	119,36	118,05	118,05	117,57	115,29	116,32	116,10	115,39
Surface area $X10^5$ (m^2)	0.66	12.41	6.45	2.13	10.29	1.56	3.92	0.15
Volume $X10^6$ (m^3)	679	46,264	3,846	4,563	67,643	20,724	65,178	172,312
Catchment area $X10^6$ (m^2)	0.88	32.17	3.17	3.42	42.40	11.56	33.33	80.65
Temperature (°C)	17.25	15.5	16.0	16.0	15.0	13.0	7.0	5.0
DOC ($mg \cdot L^{-1}$)	5.07	2.40	7.67	1.66	1.41	0.82	0.76	0.86[a]
TP ($mg \cdot L^{-1}$)	11.0	4.5	6.6	4.5	4.9	9.9	1.7	5.2[a]
Chl *a* ($mg \cdot L^{-1}$)	1.33	1.02	1.37	1.25	0.92	1.00	0.11	2.87[a]
Abs 350 nm	0.1714	0.0886	0.0391	0.0711	0.0524	0.0393	0.0200	N/A

a- measured in 1997.

Results and Discussion

Fish age, % lipid, and δ^{15} N were not correlated with elevation, while length, weight, and growth rate were negatively correlated with elevation (r^2 = 0.12, 0.16, 0.21 respectively) and δ^{13} C was positively correlated with altitude (r^2 = 0.26). A wide range of organochlorine pesticides and PCBs were detected in samples. The most abundant compound detected was *p,p'*-DDE (173 to 36200 $pg \bullet g^{-1}$ wet weight).

Most POPs showed a significant positive correlation with altitude. This relationship became even stronger when POPs were expressed per gram lipid weight (Fig. 1). The relationships were strongest for the less volatile organochlorine pesticides (i.e. DDT, DDE, DDD, dieldrin). PCBs did not correlate as well with elevation as the OC pesticides. The lighter chlorinated PCBs (i.e. trichloro, and tetrachloro) showed the strongest relationship with altitude.

Multiple regressions revealed that the variance of the more volatile organochlorine compounds (i.e. HCB, a- HCH, g-HCH) was generally best explained by such variables as % lipids and δ^{13} C, while the less volatile organochlorine compounds (i.e. DDT, DDE, DDD, dieldrin) were generally best explained by elevation, % lipid, age, and δ^{15} N. Elevation was the independent variable that explained the most variance in POP concentrations in trout. As in the study by Vives *et* al.[12] the percentage of variance explained decreased with increasing volatility for the organochlorine pesticides. This could also be in part due to the fact that lower volatility compounds like HCB, a-HCH, and g - HCH

have a lower K_{ow} and are not accumulated from food as well as some of the lower volatility compounds with a higher K_{ow}. Higher Kow compounds are more lipophilic and have lower elimination rates (especially at reduced temperatures).

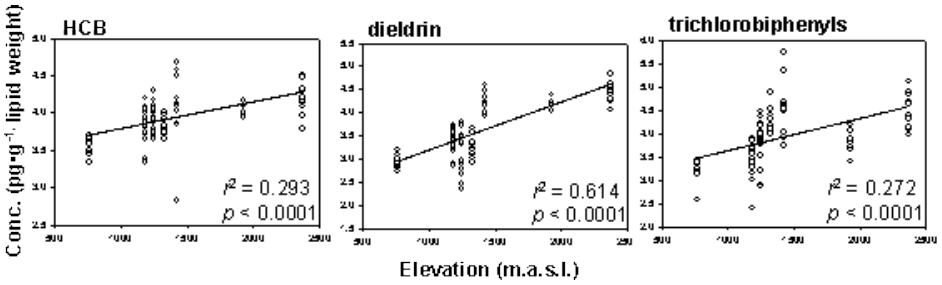

Figure 1. The log concentrations of HCB (hexachlorobenzene), dieldrin, and trichlorinated PCBs in trout shown in relation to lake elevation from Yoho, Jasper, and Banff National Parks.

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