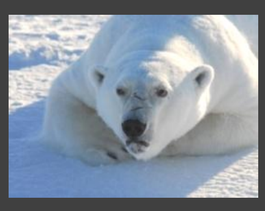
Persistent Pollutant Exposure and Metabolomic Profiles as Indicators of Effects in Polar Bears and Ringed Seals from the High Arctic and Hudson Bay, Canada

Anaïs Remili [1,2]*, Adam D. Morris [3]*, Derek C.G. Muir [4], Magali Houde [5], Tanya M. Brown [2,6], David A.D. Blair [7], Robert J. Letcher [7]

[1] *Dept. of Natural Resource Sciences, McGill U., Sainte-Anne-de-Bellevue, QC, H9X 3V9, Canada*
[2] *Dept. of Biological Sciences, Simon Fraser University, Burnaby, BC, V5A 1S6, Canada*
[3] *Northern Contaminants Program, Crown-Indigenous Relations and Northern Affairs Canada, Gatineau, QC, K1A 0H4, Canada*
[4] *Environment & Climate Change Canada (ECCC), Aquatic Contaminants Research Division, Burlington, ON, L7S 1A1, Canada*
[5] *ECCC, Aquatic Contaminants Research Division, Montreal, QC, H2Y 2E7, Canada*
[6] *Fisheries & Oceans Canada, Pacific Science Enterprise Ctr., W. Vancouver, BC, V7V 1N6, Canada*
[7] *ECCC, Ecotoxicology and Wildlife Health Division, National Wildlife Research Centre, Carleton University, Ottawa, ON, K1A 0H3, Canada*



Crown-Indigenous Relations and Northern Affairs Canada
Relations Couronne-Autochtones et Affaires du Nord Canada

Environment and Climate Change Canada
Environnement et Changement climatique Canada

NCP Project M-22

(Remili, A., Morris, A.D., Muir, D.C.G., Houde, M., Brown, T.M., Ferguson, S.H., Blair, D.A.D., Letcher, R.J. **2025**. *Environ. Res.* 269, 120862)

Contact: robert.letcher@ec.gc.ca

Introduction

- Metabolomic profiling is a powerful technique for identifying and quantifying low molecular weight molecules (metabolites) produced by an organism's metabolic processes
- These metabolites include sugars, amino acids, fatty acids, membrane lipids (phospholipids), neurotransmitters, other important molecules
- Metabolomic analysis produces large amounts of information on endogenous metabolites and the pathways by which they are formed and provides information on insights into an organism's physiological state
- Metabolomic studies on wildlife are presently limited and focused on metabolite differences related to e.g. age, sex, and reproductive condition
- For polar bears and their ringed seal prey, a comparison is necessary of contaminant and metabolite profiles between species and regions, potentially revealing how trophic interactions influence these relationships

Study objectives:

- Compare metabolome and contaminants in high Arctic (HA) and Hudson Bay subpopulations of bears and ringed seal (liver) samples from similar HA and WHB locations
- To improve the understanding of relationships of contaminants and physiological responses at the molecular level revealing potential effects biomarkers

Study Design

	Polar bears		Ringed seals	
	WHB	Baffin Bay	WHB	Lancaster Sound
Year	2015	2015	2015	2016
Month	Sept-Oct	Oct-Dec	Oct	May-June
Age	6.5 ± 3.9	> 3	6.6 ± 7.1	7.8 ± 7.1
n	15	15	15	13
Adult males	6	7	2	5
Adult females	4	1	6	4
Subadults	5	7	7	4

High Arctic (HA) – Baffin Bay
- polar bear samples in Pond Inlet (Mittimatalik), Clyde River (Kanngiqtugaapik), and Qikiqtarjuaq
- seals from Lancaster Sound (Tallurutiup Tariunga) around Resolute Bay (Qausuittuq)

Low Arctic - West Hudson Bay (WHB)
- polar bears in Rankin Inlet (Kangiqtiniq), Whale Cove (Tikiraqjuaq), and Arviat
- ringed seals in Arviat

SGS AXYS

Metabolomics (239 metabolites)

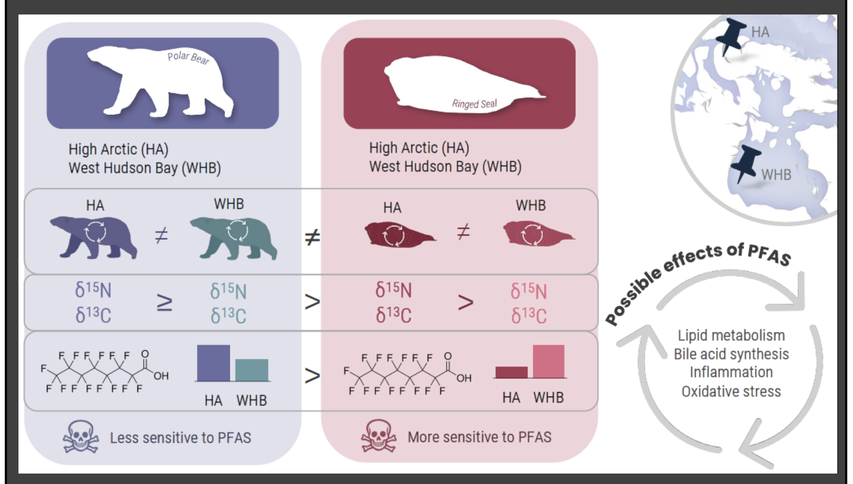
HPLC-MS/MS:
Amino acids (AAs, **21**)
Biogenic amines (BAs, **21**)
neurotransmitters
Bile acids & salts (BCs, **13**)
Fatty acids (FAs, **17**)
ΣHexoses (**1**)

Flow injection-MS/MS:
Acylcarnitines (ACs, **40**)
Membrane lipids (**104**):
phosphatidylcholines (PCs)
lysophosphatidylcholines (lyso-PCs)
sphingomyelins (SMs)

POPs (161) and Mercury Contaminants
- **161 persistent organic pollutants (POPs)** and total mercury (**THg**) by **GC-MS or LC-MS based methods** (Letcher *et al.* 2018, Morris *et al.* 2019)
- POPs included PCBs (**75**), OCPs (**20**), PBDEs (**25**), other retardants (**23**), poly/per-fluorinated alkyl substances (PFAS) (**18**)
- POP analyses for bear and seal liver by ECCC Letcher Lab; THg in bear liver at Laboratory Services/NWRC (Ottawa, Canada)
- PFAS and THg in seal liver analyzed at ECCC-Canada Center for Inland Waters (Burlington, Canada)

Multivariate statistical analyses of metabolites alone or metabolites with dietary tracers and contaminants were performed using the bioinformatics platform MetaboAnalyst 6.0 (www.metaboanalyst.ca):

Highlights / Conclusions



- High Arctic and subarctic bears and seals show distinctly different metabolomic profiles driven by diet variations and contaminants
- Metabolite profiles are better differentiated between the two species than locations
- Metabolite-PFAS relationships suggest effects on lipid metabolism, bile acid synthesis, inflammation and oxidative stress; <u>does not mean cause-effect relationships</u>; actual contaminant-metabolite relationship and the also effect of change as a result of an external physiological stress (e.g. nutritional deficiency, diet)?
- The ringed seal metabolome appears to be more sensitive to PFAS than polar bears

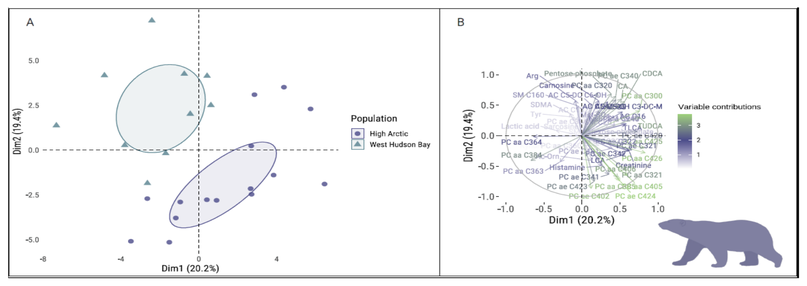
These contaminant-metabolome findings underscore the influence of environmental contaminants on the health of Arctic wildlife and emphasize the need for further monitoring, risk assessment, and conservation efforts

Acknowledgements

Bear and seal sampling was by community hunters in accordance with Nunavut Wildlife Research Permits and harvesting quotas (Government of Nunavut). We thank Amelie Roberto-Charron and others at the Nunavut Department of Environment and participating Nunavut HTOs. We thank laboratory technicians and field staff at NDE and ECCC (NWRC, David Blair) for processing polar bear sub-samples. Xiaowa Wang is thanked for processing seal samples and Mary Williamson for PFAS analysis in seals. Financial support was provided by the NCP (CIRNAC; to R.J.L.).

Results

Figure 1: Principle component (PC) analysis: Metabolomic profiles of High Arctic and WHB polar bears and ringed seals



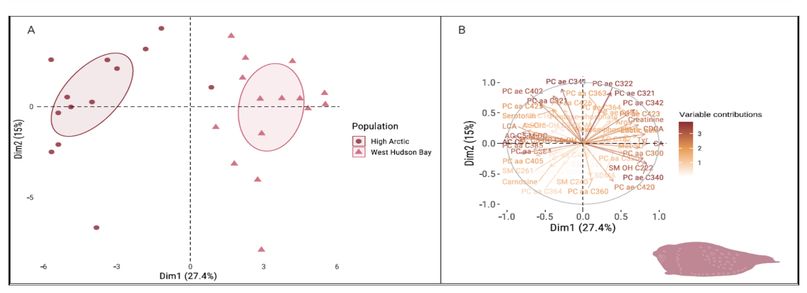


Figure 2: Metabolomic partial least square discriminant mean analysis (PLS-DA) and associated variable importance in projection (VIP): High Arctic and WHB polar bears and ringed seals

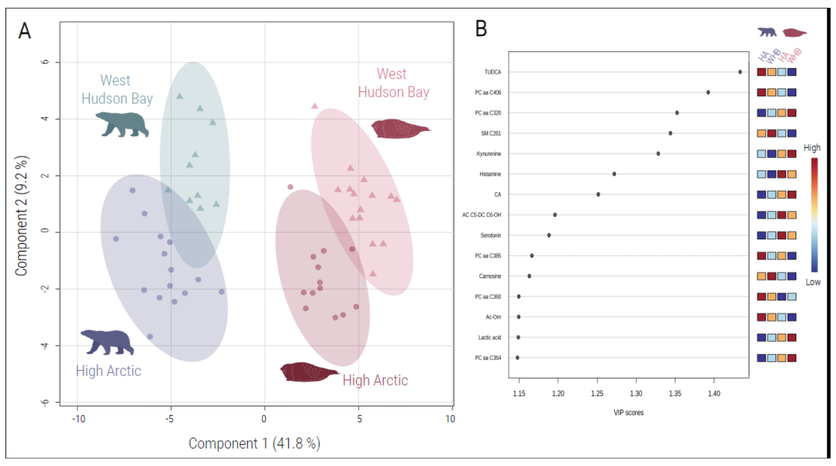
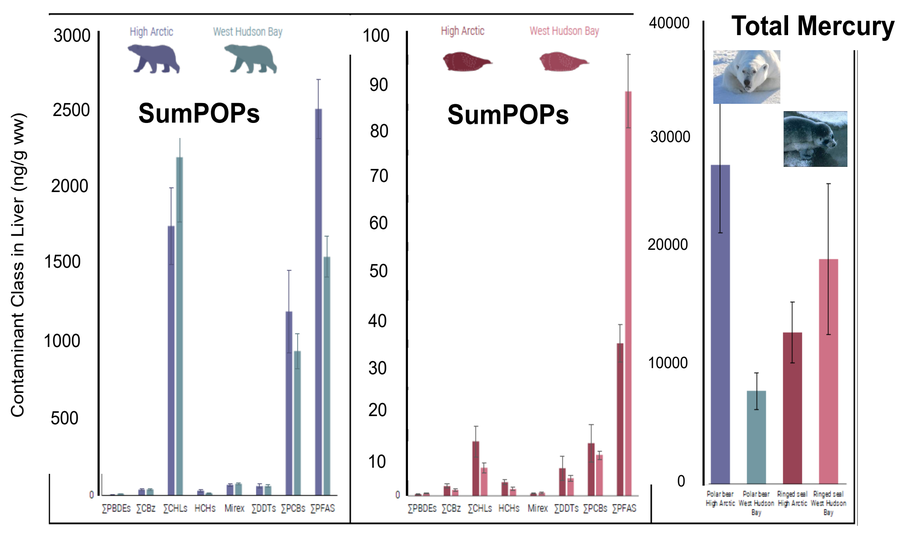


Figure 3: Sum POP concentrations in the liver of A) polar bears and B) ringed seals and THg from HA and Western Hudson Bay



18 Individual PCBs, OCs, PBDEs, non-BDE FRs, and PFAS that **were detected in > 80% of liver samples in both species**