Food Web Influence on Spatial Variation of Mercury and Other Trace Elements in Polar Bears From Alaska, Canada and East Greenland

R.J. Letcher [1], H. Routti [2], E.W. Born [3], M. Branigan [4], R. Dietz [5], T.J. Evans [6], M.A. McKinney [2], E. Peacock [7], C. Sonne [5]

[1] Ecotoxicology and Wildlife Health Division, Science and Technology Branch, Environment Canada, Carleton University, Ottawa, ON, Canada; [2] Norwegian Polar Institute, Tromsø, Norway; [3] Greenland Institute of Natural Resources, Nuuk, Greenland; [4] Government of Northwest Territories, Inuvik, Canada; [5] Department of Biosciences, Faculty of Science and Technology, Aarhus University, Roskilde, Denmark; [6] United States Fish and Wildlife Service, Anchorage, Alaska, U.S.A.; [7] Government of Nunavut, Igloolik, Nunavut, Canada (*now at USGS, Alaska Science Center, Anchorage, Alaska, U.S.A.*)

Environment Canada Environnement Canada

Greenland Institute of Natural Resources

AARHUS UNIVERSITY

Aboriginal Affairs and Northern Development Canada

Affaires Autochtones et Développment du Nord Canada

Abstract

We investigated the influence of carbon and lipid sources (using carbon stable isotope (SI) ratios ($\delta^{13}C$) and fatty acid (FA) profiles as chemical tracers) on regional differences in total mercury (THg) concentrations in polar bears (*Ursus maritimus*) (*n*=121) from ten Alaskan, Canadian Arctic and East Greenland subpopulations (*1*).

A negative relationship between THg and $\delta^{13}C$ suggested polar bears feeding in areas with higher riverine inputs of terrestrial carbon accumulate more Hg than bears feeding in areas with lower freshwater input. THg concentrations were also positively related to the FA 20:1n-9, which is biosynthesized in large amounts in *Calanus* copepods. This result raises the hypothesis that *Calanus glacialis* are an important link in the uptake of Hg in the marine food web and ultimately in polar bears. Unadjusted THg concentrations showed greater geographical variation among polar bear subpopulations, while THg concentrations adjusted for carbon and lipid sources in Bering-Chukchi Sea polar bear liver tissue remained the lowest among subpopulations. We suggest that food web structure and dietary exposure for polar bears and other high trophic species is taken into account to correct for changes in diet, when assessing spatial and temporal trends of Hg and other long-range transported trace elements.

Introduction

The polar bear is an apex predator and occupies a high trophic position in circumpolar arctic marine ecosystems. Mercury (Hg) has and continues to be reported at high concentrations in polar bears (*2*,*3*). Hg in Arctic biota are influenced by physical factors including riverine output and geology, as well as biological factors such as underlying food web structure that are manifested in the diet of higher trophic level wildlife (*4*). The food web length and diet composition of polar bears are known to vary considerably between Arctic subpopulations (*5*). However, it remains unclear how these factors influence spatial variation in Hg levels in polar bears.

Chemical tracers, such as $\delta^{13}C$ and FA composition, have been used to elucidate trophic relationships and food web structure. $\delta^{13}C$ delineates the major carbon sources of an organism i.e. benthic/pelagic, marine/terrestrial and freshwater/marine. FAs may be used to assess individual diet composition of animals. Carbon and nitrogen SIs have become powerful tools to study dietary exposure and biomagnification of persistent contaminants including Hg in marine ecosystems (*6*), while FA composition has been used in contaminant studies only recently including polar bear subpopulations (*7*,*8*).

Contact: Rob Letcher (robert.letcher@ec.gc.ca)

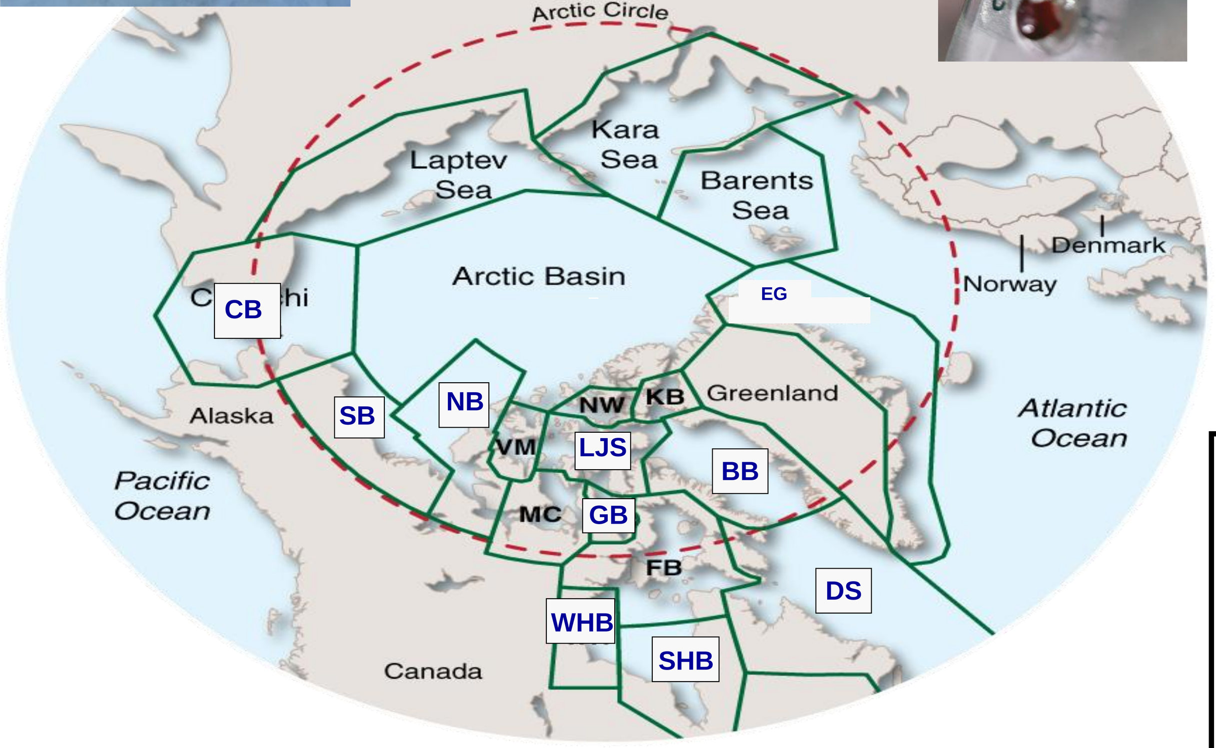
References

1) Routti, H., Letcher, R.J., Born, E.W., Branigan, M., Dietz, R., *et al*. **2012**. *Environ. Toxicol. Chem* . 31, 2739-2747.
2) Routti, H., Letcher, R.J., Born, E.W., Branigan, M., Dietz, R., *et al*. **2011**. *J. Environ. Monit.* 13, 2260-2267.
3) Rigét, F.F., Braune, B.M., Bignert, A., Wilson, S., Aars, J.,*et al*. **2011**. *Sci. Total Environ.* 409, 3520-3526.
4) Munthe, J., Goodsite, M., Berg, T., Chetelat, J., Cole, A., *et al*. **2011**. Chapter 2. In: AMAP Assessment 2011: Mercury. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway: pp. 9-44.
5) St. Louis, V.L., Derocher, A.E., Stirling, I., Graydon, J.A., Lee, C., *et al*. **2011**. *Environ. Sci. Technol.* 45, 5922-5928.
6) Jardine, T.D., Kidd, K.A., Fisk, A.T. **2006**. *Environ. Sci. Technol.* 40, 7501-7511.
7) Loseto, L.L., Stern, G.A., Ferguson, S.H. **2008**. *Environ. Sci. Technol*. 42, 3982-3988.
8) McKinney, M.A., Letcher, R.J., Aars, J., Born, E.W., Branigan, M., *et al*. **2011**. *Environ. Sci. Technol.* 45, 896-902.

Photo: R. Dietz

Study Design and Methods

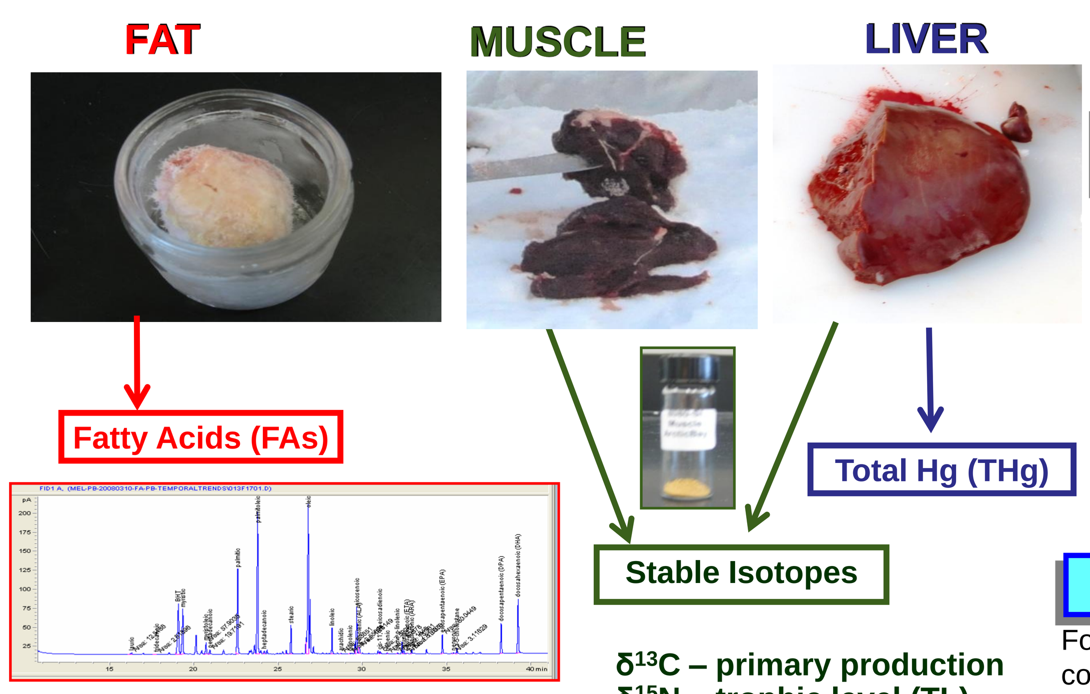
Photo: R. Letcher



Harvests and Sample Collections
- **Season: Fall/Winter (Oct. – mid-May)**
- **Years: 2005-2008 (mainly 2007-2008)**

Table 1. Subpopulation, number of individuals, age and stable isotope ratios of polar bears investigated for the influence of dietary tracers, sex and age on THg conc. (*1*).

Subpopulation	*n* (males: females)	median age, years (range)	$\delta^{15}N$	SD	$\delta^{13}C$	SD
Alaska- Bering-Chukchi Sea (CB)	11 (7:4)	7.0 (2-22)	21.1	0.5	-16.8	0.3
Southern Beaufort Sea (SB)	10 (7:3)	9.0 (4-20)	21.0	0.8	-19.1	0.4
Northern Beaufort Sea (NB)	24 (17:7)	6.0 (3-24)	21.5	0.7	-19.2	0.6
Gulf of Boothia (GB)	6 (4:2)	8.5 (3-24)	21.5	0.8	-17.5	0.5
Lancaster/Jones Sound (LJS)	12 (10:2)	6.0 (3-11)	21.3	0.5	-17.6	0.5
Southern Hudson Bay (SHB)	12 (8:4)	9.0 (3-22)	19.0	0.7	-18.9	0.3
Western Hudson Bay (WHB)	11 (8:3)	7.0 (3-29)	18.8	1.7	-18.8	0.6
Baffin Bay- N.E. Baffin Island (BB)	10 (7:3)	5.0 (2-10)	20.2	0.8	-17.5	0.6
Davis Strait- S.E. Baffin Island (DS)	5 (5:0)	4.0 (3-6)	19.5	1.1	-16.6	0.7
E. Greenland-Scoresby Sound (EG)	20 (14:6)	6.5 (3-19)	18.3	0.4	-18.7	0.3
all females	34	7 (2-24)	20.2	1.5	-18.6	1.0
all males	87	7 (3-29)	20.2	1.5	-18.2	1.0



•Dietary Fatty Acids Only

$\delta^{13}C$ – primary production
$\delta^{15}N$ – trophic level (TL)

Subset of 12 dietary FAs (*7*): linoleic acid γ-linolenic acid *cis*-11-eicosenoic acid, α-linolenic acid (ALA), *cis*-11,14-eicosadienoic acid, *cis*-8,11,14-eicosatrienoic acid , erucic acid, *cis*-11,14,17-eicosatrienoic acid (ETA;), arachidonic acid (ARA;), *cis*-5,8,11,14,17-eicosapentaenoic acid (EPA), *cis*-7,10,13,16,19-docasapentaenoic acid (DPA) and *cis*-4,7,10,13,16,19-docasahexaenoic acid (DHA;)

Results

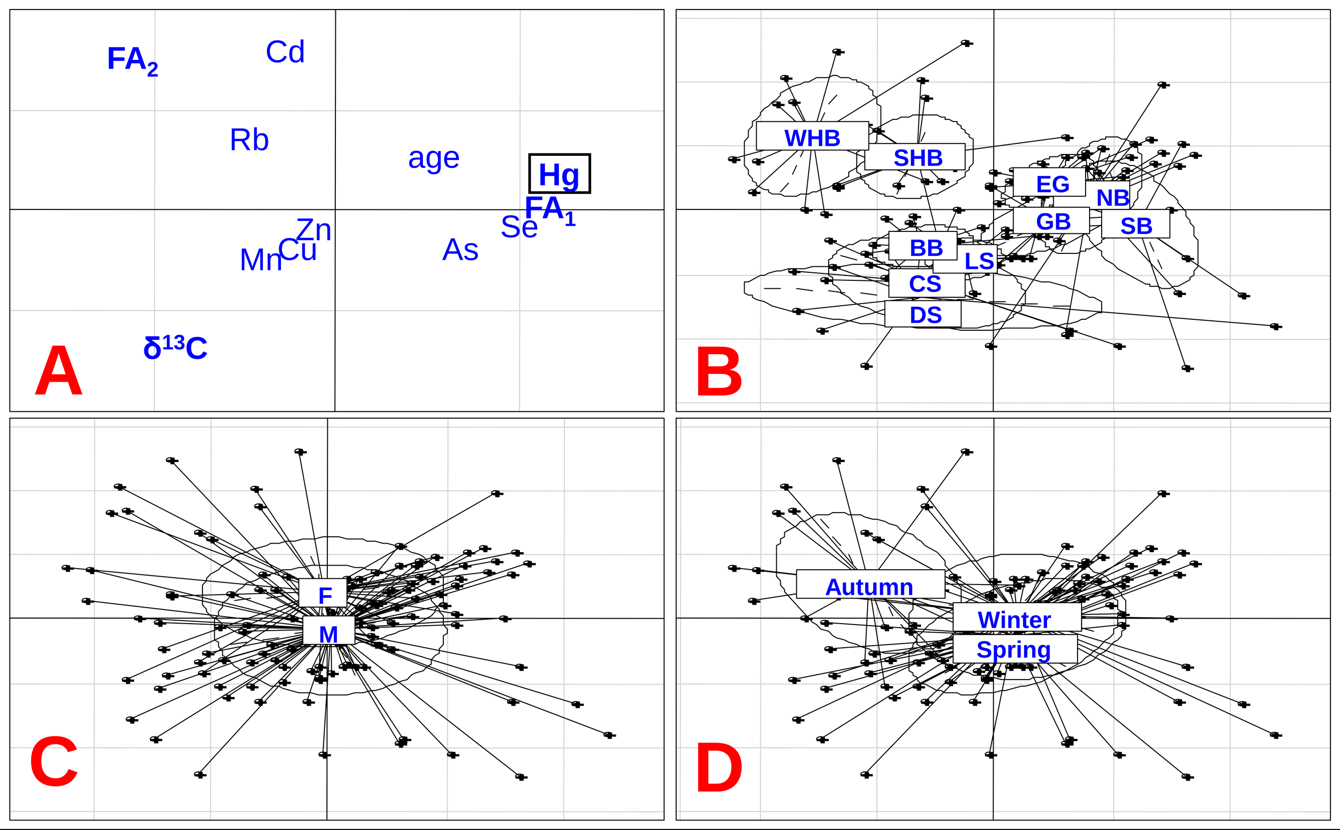


Figure 1. Ordination plots from redundancy analysis (RDA) based on covariance matrix of $\log_e$-transformed THg conc. The relationships are shown between response variables (trace element concentrations) and explanatory variables (chemical tracers and age) (A). The sample scores are grouped by subpopulation (B), sex (C) and season (D). The x-axis explained 89% of the total variation and y-axis, 8.7%.

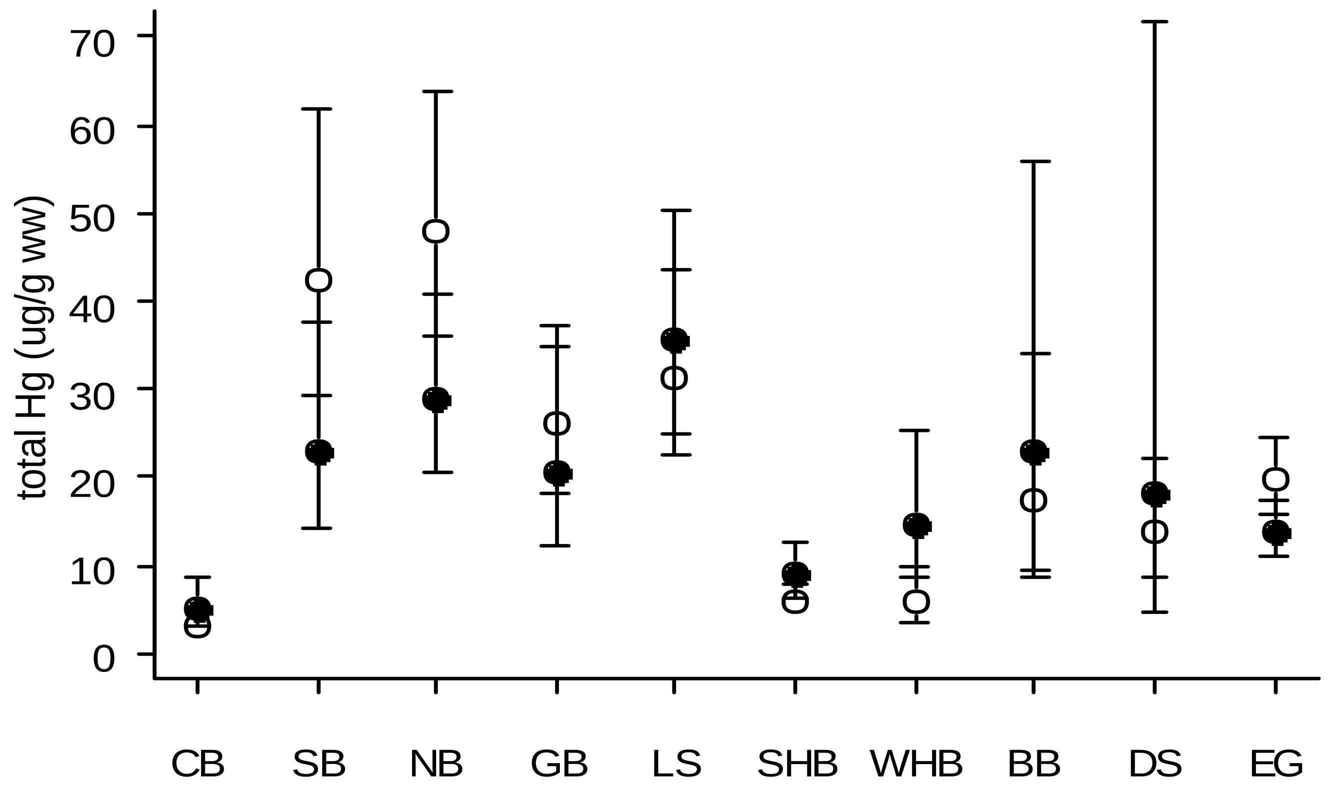
FA composition (not shown, see (*1*)) suggested polar bear diet coupled to the pelagic marine food web; FA composition differed among the polar bear subpopulations, while variation between seasons and sexes was minor; FA results (i.e. 20:1n-9 and 22:1n-9) suggested *Calanus* copepods are proportionally greater in the polar bear food webs in higher vs. lower latitudes.

$\delta^{13}C$ signatures were depleted in the BS, HB and EG bears compared to the remaining subpopulations (ANOVA, $p<0.001$, **Table 1**). Depleted $\delta^{13}C$ in bears may originate from terrestrial organic carbon input by rivers into the BS and HB.

Concentrations of THg were related to FAs and/or $\delta^{13}C$ and the relationships were mainly related to subpopulation differences (**Fig. 1**).

THg conc. significantly ($p<0.05$) higher in WHB and SHB bears and lower in SB and NB bears for $\delta^{13}C$ and FA adjusted versus unadjusted THg conc. (**Fig. 2**). Subpopulation-specific influence of the food web also found for adjusted versus unadjusted Se, Cd and As conc. (*1*).

Figure 2. Geometric mean concentrations (µg/g wet weight 95% confidence intervals) of THg in liver of polar bears from ten subpopulations before (white circles) (*1*) and after (black circles) adjusting for $\delta^{13}C$ and FAs. Concentrations of total Hg were adjusted *a priori* for age. See Table 1 for subpopulation abbreviations on the x-axis.



Conclusions

Regional differences in polar bear food web length appear to play a role explaining subpopulation differences in THg conc. (also and other trace elements).

Changing climate may be affecting the natural cycles and long-range transport of Hg (and other elements), as well as access, abundance, distribution of polar bear prey.

Acknowledgements

For Canadian sampling and assistance, we thank polar bear hunters, Nunavut Hunters and Trappers Organizations, Nunavut Department of Environment conservation officers, polar bear biologists (Markus Dyck, Stephen Atkinson) and lab technicians (Angela Coxon) and Environment Canada's National Wildlife Specimen Bank at NWRC (Ottawa). We thank France Maisonneuve in the Lab Services section at NWRC for THg analysis. Thanks to the Alaska Native hunters who took the extra time to collect and send the polar bear samples for the U.S. FWS for processing the shipment to NIST, and Ms. R. Pugh (Hollings Marine Laboratory, NIST) for assistance with the Chukchi/Bering Sea samples. For East Greenland sampling and assistance, we thank local hunters, J. Brønlund, M. Kirkegaard, S. Joensen and L. Bruun. We thank Stig Falk-Petersen, Mats Granskog, Janne Søreide and Anette Wold for discussions on data interpretation. This study was funded by the Northern Contaminants Program (AANDC), the Molson Foundation and the Canadian IPY Programme (to R.J.L.). Greenland program funding was from the IPY program ''Bear-Health'' by KVUG, DANCEA and the Prince Albert II Foundation and the U.S. FWS, Marine Mammals Management contributed to Alaskan funding.