Mercury in the Pelagic Food Web of the Canadian High Arctic

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INTRODUCTION

- Within the Arctic, mercury has become a focus of international research following the discovery of MDEs (Mercury Depletion Events), together with high mercury (Hg) concentrations in upper trophic level species such as seals, whales and polar bears.
- Although it is clear that photo-chemically mediated MDEs remove gaseous Hg from the bottom km of the atmosphere after polar sunrise and deposit it to surfaces in a reactive biologically available form, it remains unknown whether MDEs actually result in increased loadings of Hg to aquatic systems.
- The observation of up to 4-fold increases of Hg over the last two decades in marine mammal tissues poses a question of enormous significance to human and ecological health.
- Even though the Arctic atmosphere shows no recent increasing trend in Hg levels, the increasing trends of Hg in marine mammals suggest that something has been changing in the Arctic biogeochemical cycle of Hg and/or in the food web structure which conveys Hg and carbon to upper trophic level species.
- Certainly, MDEs as a recent or recently enhanced phenomenon might offer one explanation but, there are likely others linked to climate change which has been shown to alter hydrology, organic carbon cycling, and marine ecosystem structure in the Arctic.

OBJECTIVES

- To study contaminant process and cycling, specifically mercury (Hg), in the Canadian High Arctic: North Water Polynya, the Archipelago and the Beaufort Sea.
- To look at the bioaccumulation and biomagnification of THg, MeHg in benthic and pelagic food webs in each of the different regions using stable isotopes ($\delta^{15}N$ and $\delta^{13}C$) and fatty acids.
- To measure THg and MeHg in: (1) near surface air; (2) snow and ice cores; (3) vertical ocean water profiles (dissolved and particulate); (4) suspended and bottom sediments; water column measurements of $\delta^{18}O$, salinity, and nutrients in an effort to try and link together physical and biological processes.

Figure 1. CCGS Ice-Breaker Amundsen

Figure 2 & 3. Picking and sorting zooplankton

Figure 4. Monster Net

Figure 5. RMT

METHODOLOGY

- Water, zooplankton and sediment samples have been collected from CCGS Amundsen (Fig. 1) on Leg 1 cruise from August 5th to September 15th in three different areas of the Canadian High Arctic; North Water Polynya (Fig. 6), the Archipelago (Fig. 12) and the Eastern part of the Beaufort Sea (Fig. 18).
- Water was collected from the rosette at every full and basic station. A total of 91 samples were collected for each of the following; THg and MeHg, Salinity, Trace Metals and $\delta^{18}O$ at several depths from the surface to the bottom with an average of 6 depths per station.
- Zooplankton was collected at each full and basic stations with three types of nets: Monster (1x500um) (Fig. 4), Tucker (1x500um) and RMT (1600 um) (Fig. 5). A total of 53 tows were collected and sorted (Fig. 2 &3).
- Total mercury concentrations for *Themisto libellula* and *Calanus hyperboreus* were obtained with cold vapour atomic absorption spectroscopy. A small amount (~0.15 g dry weight) of each individual was acid digested with a hydrochloridric-nitric acid mixture (HCl; HNO_3) and heated at 90 °C. References materials were used to ensure precise and reproducible results.
- The determination of relative trophic level was made using equations derived from the model reported in Campbell *et al*. (2005). Trophic level was determined relative to *Calanus hyperboreus*, a primary herbivore, which it is assumed to occupied trophic level 2. $TL_{consumer} = 2.0 + (\delta^{15}N_{consumer} - \delta^{15}N_{calanus})/3.8$

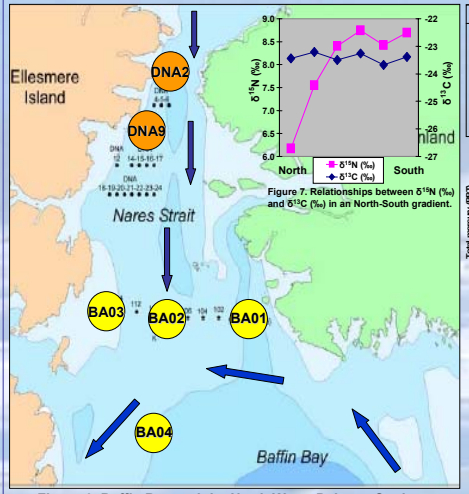

Figure 6. Baffin Bay and the North Water Polynya Stations. Arrows represent ocean currents.

Figure 7. Relationships between $\delta^{15}N$ (‰) and $\delta^{13}C$ (‰) in an North-South gradient.

Groups	Species	n	Trophic Level	$\delta^{13}C$ (‰) Mean ±S.D.	$\delta^{15}N$ (‰) Mean ±S.D.
Copepods	*Calanus hyperboreus*	4	2.00	-24.90±0.63	6.68±1.30
Chaetognaths	*Chaetognatha sp.*	4	2.49	-23.37±0.48	8.56±1.10
Amphipods	*Themisto libellula*	3	2.55	-22.62±1.14	8.76±0.16
Pisces	*Boreogadus saida larvae*	4	2.68	-22.53±1.56	9.28±0.24
Copepods	*Paraeuchaeta norvegica*	4	2.73	-24.40±0.58	9.44±0.51
Mysids	*Mysis sp.*	2	2.78	-21.83±0.65	9.65±1.42

Table 1. Trophic levels, stable isotopes means and standard deviations for zooplankton species in Baffin Bay and Nares Strait (BA01-02-03-04 & DNA 2 & 9).

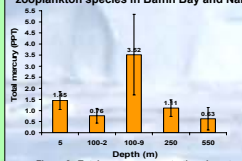

Figure 8. Total mercury concentrations in water in Nares Strait (DNA 2 & 9).

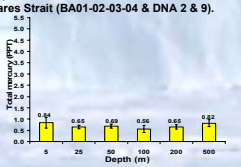

Figure 9. Total mercury concentrations in water in Baffin Bay (BA01-02-03-04).

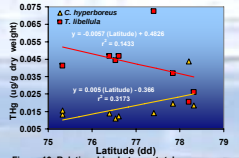

Figure 10. Relationships between total mercury concentrations in zooplankton and latitude.

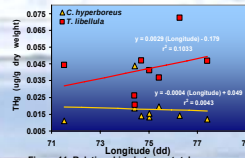

Figure 11. Relationships between total mercury concentrations in zooplankton and longitude.

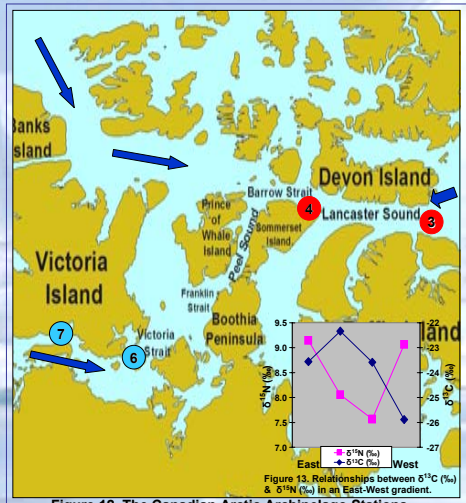

Figure 12. The Canadian Arctic Archipelago Stations. Arrow represents ocean currents.

Figure 13. Relationships between $\delta^{13}C$ (‰) & $\delta^{15}N$ (‰) in an East-West gradient.

Groups	Species	n	Trophic Level	$\delta^{13}C$ (‰) Mean±S.D.	$\delta^{15}N$ (‰) Mean±S.D.
Amphipods	*Gammarus wilkitzkii*	1	1.59	-20.85	6.12
Decapods	*Decapod larvae sp.*	1	1.73	-19.86	6.67
Amphipods	*Onisimus littoralis*	3	1.98	-21.50±2.96	7.60±0.82
Copepods	*Calanus hyperboreus*	4	2.00	-25.95±1.47	7.69±0.57
Amphipods	*Themisto libellula*	4	2.08	-25.16±1.92	7.98±0.45
Mysids	*Mysis sp.*	1	2.25	-24.21	8.63
Pteropods	*Limacina helicina*	1	2.33	-24.23	8.96
Copepods	*Paraeuchaeta norvegica*	1	2.48	-23.07	9.51
Chaetognaths	*Chaetognatha sp.*	4	2.50	-24.04±1.53	9.58±2.00
Euphausiids	*Thysanoessa sp.*	1	2.74	-27.88	10.5
Pisces	*Boreogadus saida larvae*	1	2.77	-22.56	10.6

Table 2. Trophic levels, means and standard deviations for zooplankton species in the Archipelago (Stations 3, 4, 6 & 7).

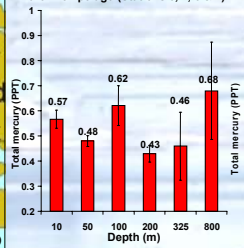

Figure 14. Total mercury concentrations at several depths at stations 3 & 4.

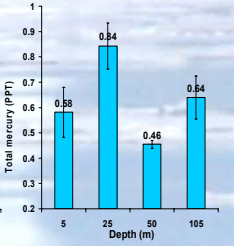

Figure 15. Total mercury concentrations at several depths at stations 6 & 7.

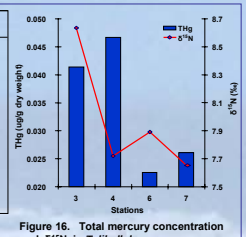

Figure 16. Total mercury concentration and $\delta^{15}N$ in *T. libellula*.

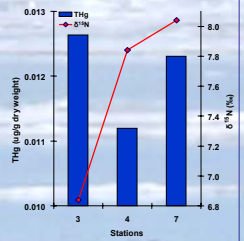

Figure 17. Total mercury concentration and $\delta^{15}N$ in *C. hyperboreus*.

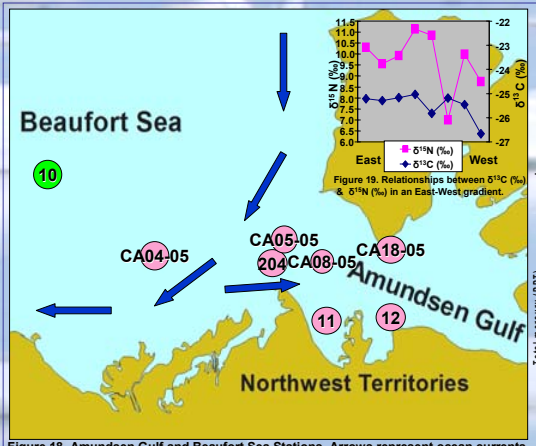

Figure 18. Amundsen Gulf and Beaufort Sea Stations. Arrows represent ocean currents.

Figure 19. Relationships between $\delta^{13}C$ (‰) & $\delta^{15}N$ (‰) in an East-West gradient.

Groups	Species	n	Trophic Level	$\delta^{13}C$ (‰) Mean ±S.D.	$\delta^{15}N$ (‰) Mean ±S.D.
Amphipods	*Onisimus littoralis*	1	1.17	-24.36	5.59
Amphipods	*Gammarus wilkitzkii*	1	1.78	-24.20	7.88
Copepods	*Calanus hyperboreus*	6	2.00	-26.28±0.71	8.73±1.89
Pisces	*Boreogadus saida larvae*	3	2.06	-25.69±0.60	8.95±1.70
Amphipods	*Themisto libellula*	8	2.18	-25.60±0.87	9.41±0.65
Pteropods	*Cliona limacina*	1	2.46	-27.32	10.46
Copepods	*Paraeuchaeta norvegica*	7	2.47	-25.78±0.72	10.50±0.68
Chaetognaths	*Chaetognatha sp.*	7	2.67	-24.85±1.01	11.28±2.52
Mysids	*Mysis sp.*	1	2.79	-23.98	11.75

Table 3. Trophic levels, means and standard deviations for zooplankton species in the western Arctic (Stations 10,11,12,204,CA18-05,CA08-05,CA05-05,CA04-05).

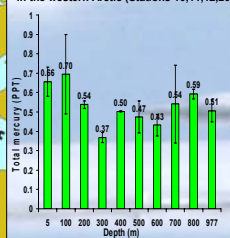

Figure 20. Total mercury concentration in water at station 10.

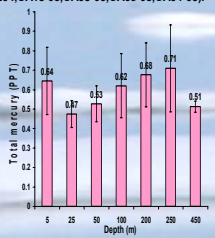

Figure 21. Total mercury concentration in water at stations 11, 12, 204, CA04-08-05-18.

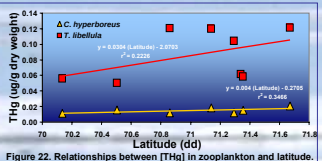

Figure 22. Relationships between [THg] in zooplankton and latitude.

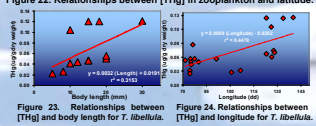

Figure 23. Relationships between [THg] and body length for *T. libellula*.

Figure 24. Relationships between [THg] and longitude for *T. libellula*.

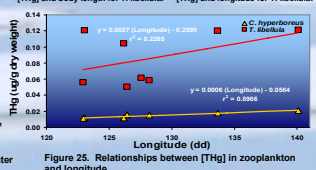

Figure 25. Relationships between [THg] in zooplankton and longitude.

SUMMARY

NOW

-Region with the highest [THg] in water.
-Trophic level values in a NOW food web collected in 1998 (Campbell *et al*. 2005) are very similar to our values from this summer cruise.

Archipelago

-Average [THg] in water is slightly higher in the western part of the Archipelago (0.63 PPT > 0.54 PPT).
-[THg] in *Themisto* is higher in Lancaster Sound than in the Cambridge Bay area (0.044 ug g^{-1} dw > 0.024 ug g^{-1} dw).
-$\delta^{15}N$ and [THg] values in zooplankton from Lancaster Sound collected in 1992 (Atwell *et al*. 1998) are higher then our values.

-[THg] in *Themisto* ↑ in an East-West gradient.
-[THg] in *Calanus* ↓ in an East-West gradient.
-[THg] in *Themisto* ↓ with higher latitude.
-[THg] in *Calanus* ↑ with higher latitude.

Beaufort Sea

-[THg] in *T. libellula* is higher than in the other regions and their body length ↑ in an East-West gradient.
-Average [THg] and $\delta^{15}N$ of *Calanus* and *Themisto* are similar to last year results (Loseto *et al*. 2004).
-$\delta^{15}N$ and $\delta^{13}C$ decrease in an East-West gradient.

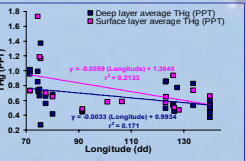

Figure 18. Total mercury concentrations in water in the Canadian High Arctic.

- Average total mercury concentration in both surface and bottom water is higher in the eastern part of the Arctic.
- Average total mercury concentration in surface water gets higher than the bottom layer in an West-to-East gradient.

FUTURE WORKS

Biotic and abiotic samples collected during Leg 1 and Leg 2 (Transit Cambridge Bay-Pond Inlet) of the Amundsen cruises 2005 are presently being analysed for THg, MeHg and trace metals. Besides food web studies, biological and physical processes such as trophic variation, biomass dilution, riverine input, ocean structure, water mass changes and atmospheric deposition will be studied in an effort to understand spatial and temporal trends. Future cruise in 2006 in the Canadian High Arctic (Northwest Passage, Nares Strait and Kane Basin) will allow for more biotic and abiotic data to be collected in an effort to try and couple physical and biological processes.

REFERENCES

Atwell *et al.* 1998. Biomagnification and bioaccumulation of mercury in an arctic marine food web: insights from stable nitrogen isotope analysis. Can. J. Fish. Aquat. Sci. 55: 1114-1121. Campbell *et al.* 2005. Mercury and other trace elements in a pelagic Arctic marine food web (Northwater Polynya, Baffin Bay). Science of the Total Environment, 351:352, 247-263. Loseto *et al.* 2004. Trends in mercury levels in the Beaufort Sea Pelagic Food web: Preliminary Results. CASES International Data Workshop, Montreal, QC Canada.