ORGANOCHLORINE CONTAMINANTS IN RINGED SEALS (*Phoca hispida*) IN THE WESTERN CANADIAN ARCTIC: TRENDS WITH SEA ICE

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Introduction

Large quantities of organochlorine (OC) compounds accumulate in marine mammals, especially those inhabiting the Arctic. Earth's poles act as sinks for atmospherically relocating contaminants from industrial and agricultural sources in temperate regions[1] and these subsequently biomagnify in the marine food web. Ringed seals (*Phoca hispida*), the main prey of polar bears and an important subsistence resource for northern communities, are exposed to pesticides and PCBs directly via their diet[2]. High levels of OCs have been linked to adverse reproductive and immune effects in marine mammals[3, 4]. Another threat to seal populations is the reduction of sea ice which has shown increased variability but is declining overall in the Beaufort Sea and Amundsen Gulf since the 1970s[5]. Ringed seals depend on ice as substrate in which to excavate lairs within the snow and ice for parturition and lactation[6]. Both contaminant uptake and changing sea ice conditions pose conservation threats for ringed seals and other Arctic marine mammals, but the extent of how climate change affects contaminant loading in marine mammals is not well known. We examined OC concentrations in blubber from ringed seals in the Amundsen Gulf and interpret our results along with sea ice data from the same area for 1993, 1995 and 2002-2005. We also analyzed stable isotope ratios (SIR) in seal muscle tissue to make dietary references to trophic level ($\delta^{15}N$)[7] and location of prey in the water column ($\delta^{13}C$)[8]. Our paper discusses the trends of pesticide and PCB levels in seals in the context of local ice conditions (time of break-up and length of the open water season).

Materials and methods

Ringed seal blubber and muscle samples were collected in the months of June-July from Ulukhaktok (formerly Holman), Northwest Territories, Canada, (70°43'N, 117°43'W) in the Prince Albert Sound, in 1993 (n=10), 1995 (n=6), 2002 (n=13), 2003 (n=11), 2004 (n=15) and 2005 (n=13). Sex, standard length, weight and hip and sternal blubber thickness were measured according to methods described elsewhere[9]. Seals were aged by the same methodology and person since work on ringed seals began in this area in 1971[10]. In this paper we assessed OC levels only with male adults (7+ years old) because females lose OCs via lactation each spring[11]. Males on the other hand tend to accumulate large OC levels with age, so we adjusted all contaminant concentrations to the mean age of our samples (14 yrs). Lipid extraction of blubber, fractionation and chromatography procedures are documented elsewhere[12]. Duplicates, blanks, recovery standards and volume correction were measures taken for QA/QC. Chromatographic peaks representing 36 pesticides and 89 PCB congeners were read for each ringed seal tissue sample. $\delta^{15}N$ and $\delta^{13}C$ analysis of muscle tissue[13] were performed for all study years except 1993. Using ice charts from the Canadian Ice Service, the number of ice-free days and timing of the sea ice break-up in each year of seal harvest in the Eastern Amundsen Gulf were determined[9]. All variables were log-transformed and outliers were omitted before statistical procedures in SYSTAT (version 11 for Windows). We used an analysis of variance (ANOVA) for contaminants and stable isotope ratios with year as a factor. A Pearson correlation was used to assess the strength of linear relations between the different variables. Statistical significance was considered $\alpha<0.05$.

Results and discussion

Trends of contaminants and stable isotope ratios

Concentrations of OC groups (ΣHCB, ΣHCH, ΣCHL, ΣDDT and ΣPCB) in male adult seals varied by year (Figure 1). Tukey post-hoc tests revealed which years significantly differed from others. In general, concentration levels were greater in 1993 in contrast to the early 2000s. We found significantly higher concentrations of ΣHCB in 1993, 1995 and 2003 compared with 2004 and 2005 (Figure 1-A). ΣHCH levels were significantly greater in 1993 than 2003-2005, and 2002 levels were significantly greater than 2004 levels (Figure 1-B). Male adult seals in 1993 and 2005 had significantly higher concentrations of ΣCHL as compared to those in 2003 (Figure 1-C). Levels of ΣDDT were significantly larger in 1993 than 2002 and 2004 (Figure 1-D). 1993 concentrations of ΣPCB were significantly greater than levels obtained from 2003 (Figure 1-E). SIR of nitrogen in muscle were significantly higher in 2005 than in 2002, but $\delta^{13}C$ was not significantly different between the years of study (not shown).

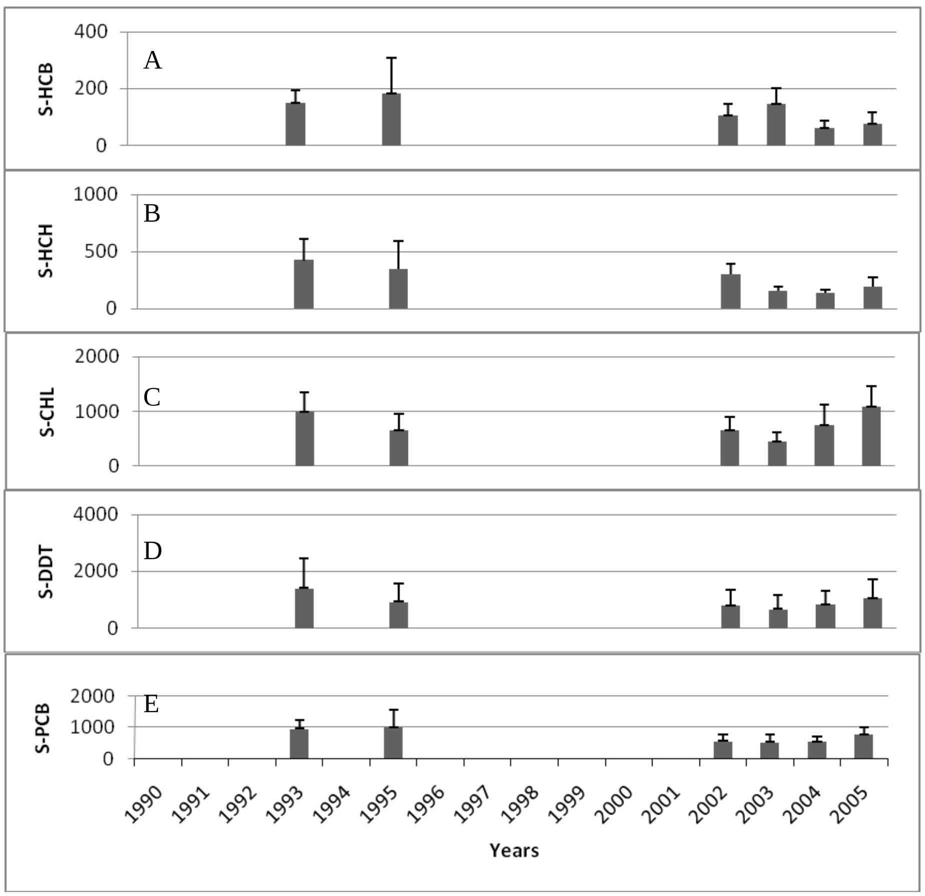

Figure 1: Age-adjusted (14 yrs) means (ng/g lipid weight) and upper 95% confidence interval bars of contaminant groups (A-E) of male adult ringed seals (*Phoca hispida*) at Ulukhaktok, NT, Canada.

Relationships of stable isotope ratios, contaminants and sea ice

Correlations revealed that OC concentrations were strongly related to sea ice parameters while weakly related to SIR. Time of spring break-up was inversely related to the ice-free period in the study years ($r=-0.840$, $p<0.001$).

Less lipophilic compounds such as ΣHCB and ΣHCH ($r=-0.439$, $p=0.02$) declined with $\delta^{15}N$. Others studies also have found significant inverse relationships with HCHs and $\delta^{15}N$ in marine mammals[14], although trends in HCHs are likely more dependent on environmental factors such as air-water exchange[15]. ΣCHL, ΣDDT and ΣPCB were positively, but not significantly, related to $\delta^{15}N$. The elimination of chlordanes, DDTs and PCBs is relatively slow compared to dietary inputs, thus the concentrations of these more lipophilic OCs tend to continually increase with age in male marine mammals[16]. Comparison of ΣCHL, ΣDDT and ΣPCB to SIR should be interpreted with caution because stable isotopes reflect relatively shorter time periods. As for carbon SIR, OC groups were not significantly related to $\delta^{13}C$. SIR in muscle also did not significantly describe OC concentrations in blubber of ringed seals in the Northwater Polyna[16].

SIR were not significantly related to sea ice parameters although the correlation of $\delta^{15}N$ with sea ice break-up was positive. This suggests seals may consume greater quantities of higher trophic level prey in years of later sea ice break-up. The isotopic composition of muscle in ringed seals has been estimated to reflect that of its prey consumed several months previously[17], meaning the SIR of seals in this study caught in June-July likely reference the winter-spring diet. During the ice-covered period, ringed seals prey predominantly upon Arctic cod, and in ice-free periods the diet of ringed seals shifts towards a mixed diet of fish, crustaceans and benthic invertebrates[6]. Cod are at a higher trophic level in the Arctic marine ecosystem than invertebrates[18]. Higher $\delta^{15}N$ values occurred in years of later sea ice break-up associated with longer periods of sea ice cover and thus greater access to Arctic cod. $\delta^{13}C$ was less dependent on sea ice parameters suggesting little change in foraging patterns between pelagic and benthic environments over the years of study[8].

We observed significant relationships between the level of contaminants in seal blubber and the sea ice parameters that we examined. Generally most contaminant groups increased with longer ice-free seasons (Figure 2; ΣHCB: $r=0.464$, $p=0.002$; ΣHCH: $r=0.392$, $p=0.025$; ΣDDT: $r=0.326$, $p=0.01$; ΣPCB: $r=0.427$, $p=0.008$). All groups were also significantly lower in years of later break-up (ΣHCB: $r=-0.419$, $p=0.001$; ΣHCH: $r=-0.498$, $p=0.002$; ΣCHL: $r=-0.288$, $p=0.018$; ΣDDT: $r=-315$, $p=0.013$; ΣDDT: $r=-0.366$, $p=0.002$). We also used a 1-yr lag in our correlations of OC concentrations with sea ice parameters and found ΣHCB and ΣHCH increased with greater ice-free days ($r=0.241$, $p=0.048$ and $r=0.371$, $p=0.002$, respectively). There are several possible explanations for the apparent increase in OC concentrations in years with longer ice-free periods. Seals have a longer, earlier foraging period and thus are able to access more and /or different types of prey. As well, years with earlier break-up may lead to foraging opportunities in areas which were previously not attractive to seals. Although new foraging grounds may provide opportunity for greater resources and less competition amongst ringed seals, prey could also be more contaminated[19]. Our results showed no significant relation between age and morphological measurements with SIR and sea ice parameters. However, in a study with a larger sample size of ringed seals from the same area, including those examined in this paper, blubber thickness of male adults was greater during years with longer ice-free seasons[9]. These results indicate seals are fatter in light ice years, likely as a result of consuming more prey (and contaminants) during such years.

As noted above, $\delta^{15}N$ and $\delta^{13}C$ values did not appear to be strongly linked to changing sea ice parameters. This may be a sampling artefact due to our sample size (n=5 yrs) or SIR in muscle may not reliably estimate diet. Hair may offer a more appropriate tissue because it incorporates the isotopic composition of prey during the period of its growth[20] and would reflect diet since the beginning of the previous year's moult.

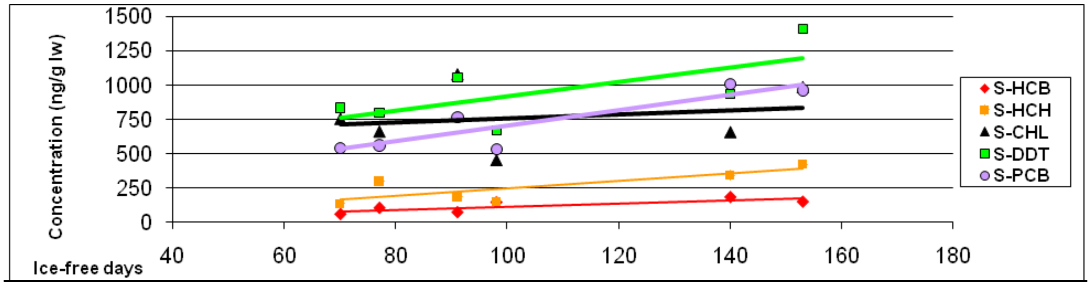

Figure 2: Regression of OC group means (age-adjusted to 14 years) of male adult ringed seals (*Phoca hispida*) at Ulukhaktok, NT, Canada with number of annual ice-free days in the years seals were harvested.

Given our results and the climate predictions for longer ice-free seasons in the future, it is reasonable to predict that contaminant loads will increase in ringed seals of the western Canadian Arctic in the future. More research is needed over a longer period measuring SIR from different tissues to identify possible shifts in diet. However, due to the diligence of many individuals, Ulukhaktok has the longest and most complete time series of Arctic marine mammal collections available for the analysis of the relationship between contaminants and environmental variation.

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