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Changes in trophic position affect rates of contaminant decline at two seabird colonies in the Canadian Arctic

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ABSTRACT

Some Arctic food web structures are being affected by climate change with potential consequences for long-term trends of environmental contaminants. We examined the effects of changes in trophic position of an Arctic-breeding seabird, the thick-billed murre (*Uria lomvia*), on declining rates of six major organochlorines (hexachlorobenzene, heptachlor epoxide, oxychlordane, dieldrin, *p,p′*-DDE and Σ_{69}PCB) at two breeding colonies in the Canadian Arctic, one in northern Hudson Bay and one in the high Arctic. As a result of a change in diet, murres breeding in Hudson Bay lowered their trophic position during 1993–2013. After adjusting for the change in trophic position using egg δ^{15}N values, the rates of decline in concentrations of all six organochlorines were reduced in the Hudson Bay murre eggs. In contrast, the murres at the high Arctic colony experienced an increase in trophic position which resulted in an increase in the rates of decline for all adjusted concentrations, except for *p,p′*-DDE and Σ_{69}PCB which remained relatively unchanged. This suggests that the dramatic reduction in emissions of these compounds during the 1970s/1980s had a greater influence on the time trends than changes in diet at the high Arctic colony. Linkages between climate change and food web processes are complex, and may have serious consequences for our understanding of contaminant temporal trends. Valid trends can be deduced only when these factors have been taken into account.

1. Introduction

There is growing evidence that changes in climate can affect the biogeochemical cycles of many environmental contaminants entering the Arctic (Kallenborn et al., 2012; Macdonald et al., 2005; Stern et al., 2012). Species distributions and diets may also be altered as a result of climate change (AMAP, 2011; Noyes et al., 2009; Parmesan and Yohe, 2003; Prowse et al., 2009), which could potentially change the biomagnification pathways of persistent organic pollutants (POPs), thereby influencing levels and trends of POPs measured in upper trophic-level organisms (Macdonald et al., 2005; McKinney et al., 2009; Rigét et al., 2013). There is already strong evidence that the food web structure in Canada's Hudson Bay ecosystem is changing as a result of warmer sea-surface temperatures and diminishing ice cover (Mallory et al., 2010).

Arctic cod (*Boreogadus saida*), a cold-water species associated with sea ice, is a "keystone" species in Arctic ecosystems, linking primary producers and upper trophic-level species such as marine mammals and seabirds (Harter et al., 2013; Stern and Macdonald, 2005). Historically, Arctic cod dominated the diet of thick-billed murres (*Uria lomvia*) breeding in the Canadian high Arctic (Gaston and Bradstreet, 1993) and, until the mid-1990s, was the most common prey item found in the diet of nestling murres throughout the Canadian Arctic (Gaston, 1985; Gaston and Jones, 1998). During the 1990s, ice conditions changed in Hudson Bay causing a shift in the diet of thick-billed murres breeding in northern Hudson Bay from Arctic cod to primarily capelin (*Mallotus villosus*) (Gaston et al., 2003, 2012; Provencher et al., 2012) which occupy a lower trophic position and have lower mercury concentrations than Arctic cod (Braune et al., 2014a).

Given that POPs biomagnify through the food chain (Borgå et al., 2004; Hop et al., 2002), variation in diet over time may change the exposure of these murre populations to POPs. Other studies have shown how changes in diet have affected patterns of contaminant exposure in biota (Hebert and Weseloh, 2006; Hebert et al., 1997, 2000, 2009; Ismail et al., 2009; Leat et al., 2011). In

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particular, dietary changes associated with a longer ice-free season in Hudson Bay have altered the dietary exposure of thick-billed murres as well as beluga (*Delphinapterus leucas*) to mercury (Braune et al., 2014b; Gaden and Stern, 2010), and polar bears (*Ursus maritimus*) to halogenated contaminants (McKinney et al., 2009).

Eggs of thick-billed murres have been monitored for environmental contaminants at Prince Leopold Island in the Canadian high Arctic since 1975 (Braune, 2007) and at Coats Island in northern Hudson Bay since 1993 (Braune et al., 2002). Emissions of many legacy organochlorines were reduced following voluntary or imposed bans or restrictions during the 1970s/1980s (de March et al., 1998) and these reductions are reflected in the declining trends of concentrations for many of these compounds measured in murre eggs at Prince Leopold Island (Braune, 2007; Braune et al., 2001). Given the change in diet documented for thick-billed murres breeding at Coats Island, the objective of this paper was to determine if changes in diet affected the rates of change for six major legacy organochlorines measured in eggs of thick-billed murres. Determination of relative trophic position, as a reflection of diet, is possible through the measurement of naturally occurring stable isotopes of nitrogen ($^{15}N/^{14}N$, expressed as $\delta^{15}N$) (Hebert et al., 1999; Hobson and Welch, 1992; Hobson et al., 1994). In the case of seabird eggs, stable isotope ratios reflect the diet of the female prior to or during egg-laying (Hebert et al., 1999; Hobson, 1995). Trends in organochlorine concentrations in murre eggs were adjusted using an indicator of past diet of the laying female ($\delta^{15}N$ in lipid-free egg homogenates) and the resulting regression slopes (rates of change) compared with slopes of the unadjusted data. Our objective was to determine if the observed trophic changes in high and low Arctic murre colonies resulted in commensurate changes in rates of decline in POPs in murre eggs.

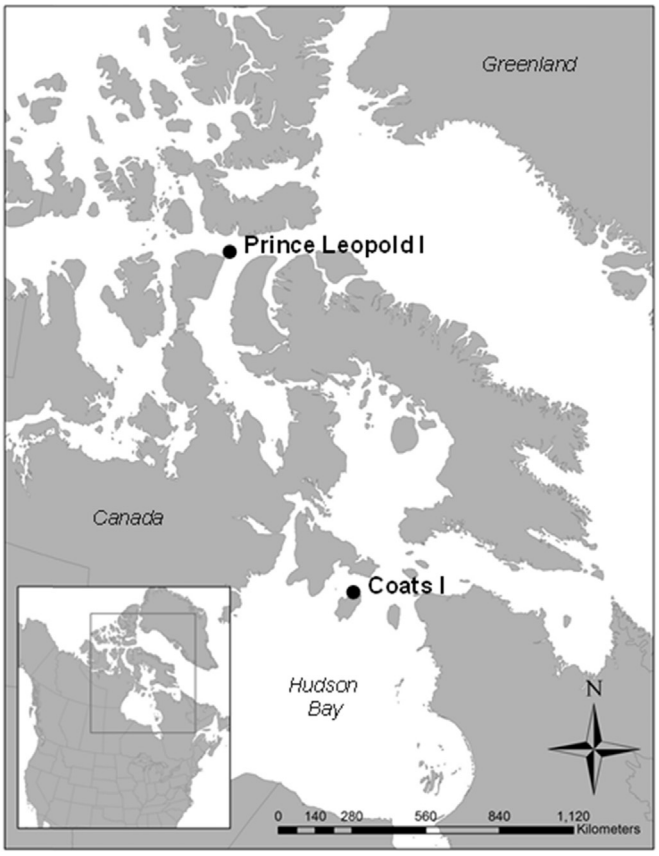

Fig. 1. Thick-billed murre colonies sampled at Coats Island in northern Hudson Bay and Prince Leopold Island in Lancaster Sound.

2. Materials and methods

2.1. Sample collection and preparation

Eggs of thick-billed murres were collected by hand from the Prince Leopold Island Migratory Bird Sanctuary (74°02′N, 90°05′W) in Lancaster Sound, Nunavut, Canada, from 1975 to 2013 (1975, 1976, 1977, 1987, 1988, 1993, 1998, 2003, annually 2005–2013), and from Coats Island (62°98′N, 82°00′W) in northern Hudson Bay from 1993 to 2013 (1993, 1998, 2003, annually 2005–2011, 2013) (Fig. 1). Eggs were kept cool in the field and shipped to the National Wildlife Research Centre (NWRC) in Ottawa, Ontario, Canada, for processing and residue analyses. Egg contents were homogenized and stored frozen (−40 °C) in acetone–hexane rinsed glass vials for subsequent organochlorine analysis. The validity of this storage method has been previously discussed by Braune (2007). Archived samples collected prior to 1993 were retrieved from the National Wildlife Specimen Bank at NWRC and analyzed retrospectively, whereas samples collected from 1993 to 2013 were analyzed within six months of collection. Egg homogenates were analyzed for organochlorines as pooled (composite) samples with each pool consisting of three individual egg samples ($n=9$ eggs per colony per year from 1975 to 1988 analyzed as three pools of three eggs each; $n=15$ eggs per colony per year from 1993 to 2005 analyzed as five pools of three eggs each). Lipid-free egg homogenates from 1975 to 2005 were also analyzed for $\delta^{15}N$ as the same pooled (composite) samples as for the organochlorine analyses, whereas the eggs from 2006 to 2013 ($n=15$ eggs per colony per year) were individually analyzed for $\delta^{15}N$.

2.2. Organochlorine analysis

Organochlorine analyses were carried out at NWRC. Pooled egg homogenates were analyzed for organochlorines (OCs) including hexachlorobenzene (HCB), oxychlordane, heptachlor epoxide (HE), *p,p′*-DDE, dieldrin and PCB congeners (ΣPCB). ΣPCB consisted of 69 PCB congeners identified according to IUPAC numbers (Ballschmiter et al., 1992): 16, 17, 18, 20, 22, 28, 31, 32, 33, 41, 42, 44, 47, 48, 49, 52, 56, 60, 64, 66, 70, 74, 76, 85, 87, 90, 92, 95, 97, 99, 101, 105, 110, 118, 128, 130, 137, 138, 141, 146, 149, 151, 153, 156, 157, 158, 167, 170, 171, 172, 174, 176, 177, 178, 179, 180, 183, 187, 190, 194, 195, 196, 199, 200, 202, 203, 206, 207, 208. Samples were analyzed for organochlorines by gas chromatography using a mass selective detector (GC/MSD) and lipids were determined by gravimetric methods. Chemical extraction and cleanup of PCBs and organochlorine pesticides followed the procedures of Lazar et al. (1992). Briefly, tissue homogenates were ground with anhydrous sodium sulfate, spiked with labeled ^{13}C-OC/PCB quantification standards and extracted with dichloromethane:hexane (50:50% v/v). Sample clean-up was performed by gel permeation chromatography followed by activated Florisil chromatography. Chemical analysis was performed using a capillary gas chromatograph coupled with a mass selective detector operated in selected ion monitoring electron impact mode. Method blanks and in-house reference materials (HGQA) were run for quality control. Internal standard recoveries were ≥75% and, therefore, residues were not corrected for internal standard recoveries. The nominal detection limit was 0.0001 μg g^{-1} wet weight (ww).

2.3. Stable-nitrogen isotope analysis

Stable-nitrogen isotope analyses for the 1975–2011 samples