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Penile density and globally used chemicals in Canadian and Greenland polar bears

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ABSTRACT

Industrially produced chemicals have been a major environmental concern across our entire Globe since the onset of rapid industrial development around the early 1900. Many of the substances being used are known to be endocrine disrupting chemicals (EDCs) and are also known to be long-range dispersed and to biomagnify to very high concentrations in the tissues of Arctic apex predators such as polar bears (*Ursus maritimus*). A major concern relating to EDCs is their effects on vital organ–tissues such as bone and it is possible that EDCs represent a more serious challenge to the species' survival than the more conventionally proposed prey reductions linked to climate change. We therefore analyzed penile bone mineral density (BMD) as a key phenotype for reproductive success in 279 polar bear samples born 1990–2000 representing eight polar bear subpopulations. Since EDC concentrations were not available from the same specimens, we compared BMD with published literature information on EDC concentrations. Latitudinal and longitudinal BMD and EDC gradients were clearly observed, with Western Hudson bears having the highest BMD and lowest EDCs, and North East Greenland polar bears carrying the lowest BMD and highest EDCs. A BMD vs. polychlorinated biphenyls (PCB) regression analysis showed that BMD decreased as a function of the eight subpopulations' PCB concentrations and this relationship was close to being significant ($p=0.10$, $R^2=0.39$). Risk quotient (RQ) estimation demonstrated that PCBs could be in a range that may lead to disruption of normal reproduction and development. It is therefore likely that EDCs directly affect development and bone density in polar bears. Canadian bears had in general the best health and the North East Greenland subpopulation being at the highest risk of having negative health effects. While reductions in BMD is in general unhealthy, reductions in penile BMD could lead to increased risk of species extinction because of mating and subsequent fertilization failure as a result of weak penile bones and risk of fractures. Based on this, future studies should assess how polar bear subpopulations respond upon EDC exposure since information and understanding about their circumpolar reproductive health is vital for future conservation.

1. Introduction

Long-range transported substances that are known to be endocrine disrupting chemicals (EDCs), such as polychlorinated biphenyls (PCBs), rate with climate change (global warming) and infectious diseases as the most substantial environmental stressors of the Arctic ecosystem. The presence of EDCs in the Arctic marine environment is the result of long-range atmospheric transport, which has been known to occur since the 1940s and

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originating from lower latitude sources in the industrialized parts of the world (AMAP 1998, 2004). Due to the lipophilicity of many EDCs, these chemicals persist in the slow growing lipid-rich Arctic food chains. This has resulted in high EDC concentrations in both marine top predators and the Inuit people, who consume large amounts of high trophic level marine mammals, with North East Greenland as a particular hotspot (AMAP, 2009; Dietz et al., 2013; Letcher et al., 2010; McKinney et al., 2013).

Polar bears have recently received considerable focus as a wildlife species impacted by climate change, since projected sea ice loss is argued to restrict their access to principal prey, such as ringed seals, during the autumn (Durner et al., 2009; Molnár et al., 2011; Stirling and Derocher, 2012). However as a long-lived top predator species they may be at greater risk of severe population declines due to EDC exposure. Indeed, in North East Greenland they carry the highest loads of EDCs in the Arctic and are among the most contaminated species on our Globe (Letcher et al., 2010). The consequence of this exposure is EDC biomagnification, which by extension results in high fetal and neonatal exposure that can disrupt growth and normal development of e.g. reproductive organs and skeletal system (Sonne, 2010; Sonne et al., 2012).

The polar bear skeletal system is of special interest due to the multiple factors of chemical and nutritional stress affecting the bone formation and resorption in this species (Herlin et al., 2010; Lind et al., 2003, 2004; Sonne, 2010; Sonne et al., 2004). While the reductions in bone mineral density (BMD) have negative consequences in general, the effect on specific bones may put the species at particular risk of population decline. One example is the penile bone, which requires high strength in order to enable successful reproduction in the cold Arctic environment. In order to elucidate the risk of EDCs on the polar bear BMD, we directly measured penile bone BMD variation among 8 polar bear populations with different EDC contaminant levels and coupled this with risk quotient analysis of published EDC data in order to evaluate disruptive effects on reproductive organs of polar bears.

2. Materials and methods

This study was undertaken using penile bone density in a latitudinal and longitudinal gradient pattern using the North East Greenland and seven Canadian polar bear subpopulations as part of the large-scale international IPY-Fuller-#134 *BearHealth* program focusing on bears, climate change and EDCs.

2.1. Sampling

The study was based on penile bones from 34 North East Greenland and 245 Canadian bears all born in the period 1990–2000. The Canadian bears were collected from seven subpopulations; Baffin Bay (BB, $n=29$), Davis Strait (DS, $n=26$), Lancaster Sound (LS, $n=53$), Gulf of Boothia (GB, $n=27$), Foxe Basin (FB, $n=76$), Southern Hudson Bay (SH, $n=20$) and Western Hudson Bay (WH, $n=14$) while the North East Greenland (NEG, $n=34$) bears were sampled in the vicinity of Scoresby Sound (69–71°N, 22–25°W) (Fig. 1). All penile bones were collected in the period

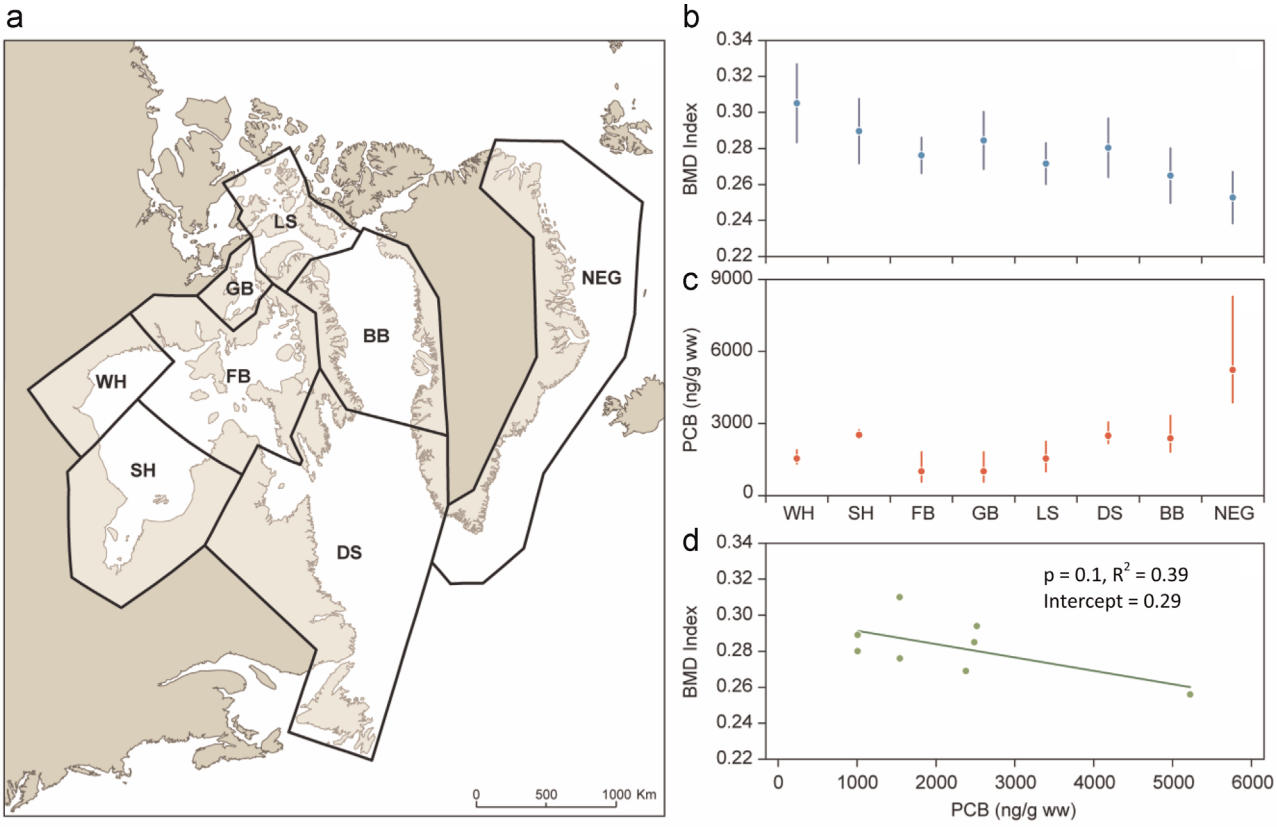

Fig. 1. a: Map of the eight polar bear subpopulations included in the present study. NEG: North East Greenland, BB: Baffin Bay, DS: Davis Strait, LS: Lancaster Sound, GB: Gulf of Boothia, FB: Foxe Basin, SH: Southern Hudson, WH: Western Hudson. b: BMD Index (least square means [LSM] ± SE) from the ANCOVA for penile bone BMD among the eight polar bear subpopulations. c: PCB concentrations in subcutaneous adipose tissue (mean, min–max) in the polar bear subpopulations. Data from Verreault et al. (2005). Southern Hudson Bay data were not reported in by the Verreault et al. study and therefore extrapolated from the WH:SH ratio reported by McKinney et al. (2011). d: Graphical presentation of BMD Index vs. PCB concentrations published in the literature on the polar bear subpopulations (regression line and statistics shown).