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Persistent organic pollutants and organophosphate esters in feathers and blood plasma of adult kittiwakes (*Rissa tridactyla*) from Svalbard – associations with body condition and thyroid hormones

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ABSTRACT

Polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), organochlorine pesticides (OCPs) and organophosphate esters (OPEs) were assessed in blood plasma and feathers of 19 adult black-legged kittiwakes (*Rissa tridactyla*) breeding in two colonies (Blomstrandhalvøya and Krykkjefjellet) at the Arctic archipelago, Svalbard. Potential associations with body condition index (BCI) and thyroid hormones were investigated. All compound classes were detected in both blood plasma and feathers, but due to low sample size and volumes, OPEs could only be quantified in four individuals, warranting larger follow-up studies. Kittiwakes breeding at Blomstrandhalvøya had significantly higher concentrations of organic pollutants in blood plasma than kittiwakes breeding at Krykkjefjellet ($p < 0.001$). Concentrations in blood plasma and feathers did not significantly correlate for any of the investigated compounds, and feather concentrations did not differ significantly between the colonies. This suggests that pollutant levels in adult kittiwake feathers do not reflect local contamination at breeding sites and are as such not useful to monitor local contamination at Svalbard. Significant negative associations between BCI and most pollutants were found in both populations, whereas significant correlations between the BCI, the ratio of total triiodothyronine to free triiodothyronine (TT3:fT3), and several pollutants were only found for kittiwakes from Blomstrandhalvøya (all $r \geq -0.60$ and $p \leq 0.05$). This indicates that higher levels of circulating pollutants during the breeding period covary with the TT3: fT3 ratio, and may act as an additional stressor during this period.

1. Introduction

The first reports of contaminated Arctic wildlife were published in the early 1970's (AMAP, 1998), and now the Arctic is considered as an important indicator region for assessing the persistence and bioaccumulative abilities of emerging contaminants (de Wit et al., 2010). Atmospheric transport is the main and most rapid source of semi-volatile persistent organic pollutants (POPs) to the Arctic (Gordeev, 2002; AMAP, 2015). In the Arctic, POPs enter seabird species, such as the black-legged kittiwake (*Rissa tridactyla*, hereafter just 'kittiwake'), mainly through their diet, and are thereafter distributed to lipid rich tissues (AMAP, 2015). During the reproductive period, when seabirds are believed to function close to their physiological limit (Bech et al., 2002), they rely on energy stored as lipids. Therefore, mass loss during the breeding period is common in birds (Moreno 1989) and kittiwakes are no exception (Henriksen et al., 1996; Bech et al., 2002). This release of lipids to the blood leads to a redistribution of lipophilic contaminants, which increases the concentration of circulating pollutants, and the risk that POPs can reach sites of toxicity (Henriksen et al., 1996). Hence, during the breeding period kittiwakes may be at higher risk of negative effects associated with POPs, than the mean concentration of POPs might suggest (Macdonald and Bewers, 1996).

In Arctic seabird species, several effects have already been related to POP exposure. These include changed reproductive behavior, reduced adult survival rate, wing feather asymmetry, suppressed immune function, reduced offspring performance, and lowered levels of circulating thyroid hormones (THs) (Grasman et al., 1996; Bustnes et al., 2001, 2003; Verreault et al., 2004; Verboven et al., 2009; Nøst et al., 2012). In the present study, all investigated legacy POPs, including organochlorine pesticides (OCPs), polybrominated diphenylethers (PBDEs) and polychlorinated biphenyls (PCBs) have the potential properties to be endocrine disrupting chemicals (EDC; Petersen et al.,

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2007). EDCs may have adverse effects on the TH system, which is vital for seabirds to adapt, reproduce, and survive in the cold Arctic climate (Gabrielsen, 2007).

In birds, the predominant TH is thyroxine (T4), whereas the biologically active TH is triiodothyronine (T3) (McNabb, 1995). T4 is transported in blood mainly by the transport proteins transthyretin and albumin (McNabb, 2007; Hill et al., 2008), and mostly converted to the active form T3 by hepatic type 1 deiodinase (Dawson, 2000). Active THs exert a wide range of effects and are required for growth, differentiation and maturation of several body systems, central nervous system development, and reproductive activity (Dawson, 2000; McNabb, 2007). THs also induce molt and regulate heat production in order to maintain a constant body temperature, which is crucial for Arctic seabirds (McNabb, 2007). Since the Arctic summer is short, proper timing of breeding, molting, and migration is essential for survival. Exposure to EDCs could disrupt the ability of the endocrine system to regulate these events as some EDCs have structural resemblance with THs (Verreault et al., 2004) and may cause decreased T3 levels (Blévin et al., 2017). This could lead to less successful breeding and in the worst case reduced survival (Jenssen, 2006).

Studies, that have investigated the use of feathers for measuring POPs and emerging pollutants, have evaluated feathers as a useful biomonitoring tool for non-destructive detection and quantification of organic pollutants (Dauwe et al., 2005; Jaspers et al., 2006, 2007b; van den Steen et al., 2007; Eulaers et al., 2011; García-Fernández et al., 2013). (Re-)emerging pollutants, such as organophosphate esters (OPEs), have been detected in the Arctic environment (Salamova et al., 2014), but very few studies have investigated their occurrence in Arctic wildlife (Evenset et al., 2009; Hallanger et al., 2015). The present study further addresses this issue by examining POPs and OPEs in feather and blood samples from kittiwakes breeding at the Arctic archipelago, Svalbard.

The main objectives of the present study were to 1) assess plasma and feather concentrations of PCBs, OCPs, PBDEs, and OPEs; 2) examine the relationship between pollutant levels in feathers and blood; 3) evaluate potential correlations between pollutants and thyroid hormones in kittiwakes breeding at Svalbard.

2. Materials and methods

2.1. Study area and sample collection

Sampling was conducted during the kittiwake breeding season in July and August 2014. Two colonies located close to Ny-Ålesund, Kongsfjorden, Svalbard (78°55′N, 11°55′E), Norway, were studied – the 'Krykkjefjellet' colony approximately 7 km southeast of Ny-Ålesund, and the 'Blomstrandhalvøya' colony on the northeast side of Blomstrandhalvøya (Fig. 1). Eight birds (5 males, 3 females) from Krykkjefjellet were sampled mid-July to early-August, and eleven birds (6 males, 5 females) from Blomstrandhalvøya were sampled in early-August. All sampled kittiwakes were adults and caught on their nest or adjacent cliffs with a noose at the end of a 5 m long fishing rod. Biometric measurements of weight, skull-, tarsus- and wing length, as well as blood and feather sampling were carried out immediately after capture. Feathers from the back, the head, and the sixth primary feather (both wings) were sampled and pooled for analysis. Approximately 2 mL of blood was drawn from the alar vein with a 2 mL heparinized syringe (25 G) and stored on ice until samples were centrifuged at 4000 rpm and then frozen (− 20 °C) until analysis. All handling and sampling of the birds occurred by trained personnel and was in accordance with ethical guidelines and approval by the Norwegian Animal Research Authority (FDU permission number 2014/59453-2).

2.2. Sex determination

All birds were sexed at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway, following methods described by Griffiths et al. (1998). In short, DNA was isolated from blood samples by using the Chelex method as described by Walsh et al. (1991), and Chromobox-helicase-DNA-binding genes (CHD-W and CHD-Z) were amplified by PCR. The avian sex chromosome CHD is widely used for sexing purposes, and as CHD-W only occurs in females (ZW) and not in males (ZZ), PCR products separated by electrophoresis result in one band for males and two bands for females.

Fig. 1. An overview of Kongsfjorden situated on the west side of the Arctic archipelago Svalbard, Norway. The two colonies are marked with an asterisk. All map data are from the Norwegian Polar Institute. Map design: Niels Borup Svendsen.

2.3. Thyroid hormone analysis

Total triiodothyronine (TT3) and free triiodothyronine (fT3) were quantified in plasma by a competitive enzyme immunoassay human kit (MP Biomedicals, Ohio, USA) at NTNU, Trondheim. Two blank samples and a human T3 standard reference set were used as quality assurance of the quantification. The mean of two replicates was calculated for both TT3 and fT3 with an average intra-assay coefficient of variation (CV) of 10% for fT3 and 6% for TT3. Levels of T4 and glandular hormones could not be investigated due to limited plasma amounts.

2.4. Contaminant analysis

Contaminant analyses were conducted at the Norwegian Institute for Air Research (NILU) in Tromsø, Norway. In all samples, 8 PBDE congeners (28, 47, 99, 100, 138, 153, 154 and 184), 12 PCB congeners (28, 52, 99, 101, 105, 118, 138, 153, 180, 183, 187 and 194), hexachlorobenzene (HCB), *oxy*-, *cis*- and *trans*-chlordane (OxC, CC, and TC), *cis*- and *trans*-nonachlor (CN and TN), mirex, *α*-, *β*-, and γ-hexachlorocyclohexane (HCH), *o,p′*-DDT and *p,p′*-DDT and transformation products (*p,p′*-DDD, *o,p′*-DDD, *p,p′*-DDE and *o,p′*-DDE) were analyzed. In four individuals, the following 13 organophosphate esters were analyzed in both feathers and blood as well: tris(2-chloroethyl)