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Blood and feather concentrations of toxic elements in a Baltic and an Arctic seabird population

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ABSTRACT

We report blood and feather concentrations of elements in the Baltic Sea and Arctic population of common eiders (*Somateria mollissima*). The endangered Baltic Sea population of eiders was demonstrably affected by element pollution in the 1990s. While blood concentrations of Hg were higher in Baltic breeding eiders, blood Se, As and Cd concentrations were higher in Arctic eiders. Blood concentrations of Pb, Cr, Zn and Cu did not differ between the two populations. While blood Pb concentrations had declined in Baltic eiders since the 1990s, Hg concentrations had not declined, and were above concentrations associated with adverse oxidative effects in other bird species. Inconsistent with blood concentrations, feather concentrations suggested that Pb, Zn, and Cd exposure was higher in Baltic eiders, and that Hg exposure was higher in Arctic eiders. Our study thus emphasizes the need for comprehensive evaluation of toxic element status, covering the annual cycle of a species.

Toxic elements are considered a major pollution problem because of their negative effects on humans and wildlife, including damage to liver and bones, birth defects, cancer, alteration of genetic and enzyme systems, and damage to nervous and immune systems (Koivula and Eeva, 2010; Nordberg et al., 2014). Although these elements occur naturally in the environment, human activities such as metal smelting, combustion, ore processing, battery manufacturing and recycling cause significant additional anthropogenic releases of elements. All organisms have to cope with element stress, either from exposure to non-essential toxic elements or from depletion, or excess of essential elements. The metals mercury (Hg), cadmium (Cd) and lead (Pb), as well as the metalloid arsenic (As) are toxic and non-essential, while the metals chromium (Cr), copper (Cu), and zinc (Zn), as well as the non-metal selenium (Se) are essential but become toxic at levels above background (Nordberg et al., 2014). Sediments are the ultimate sink for aquatically emitted elements, and coastal environments may have elevated levels of contaminants due to run off, point source pollution, river influxes, atmospheric transport and deposition (Nordberg et al., 2014). Sea ducks are large-bodied marine birds, which primarily feed on benthic invertebrates. These species, notably the common eider (*Somateria mollissima*, hereafter eider), are therefore recognized as important indicators of ecological health and inshore marine pollution (Savinov et al., 2003; Goodale et al., 2008; Meattey et al., 2014). Their exposure to some elements may, therefore, be relatively high compared to other marine birds that are pelagic feeders (Henny et al., 1995). Furthermore, eiders are long-lived birds that may accumulate certain elements, and be chronically exposed to elevated levels of these elements (Wayland et al., 2001). The eider is therefore a good study species for contaminant monitoring in coastal and inshore marine habitats (Franson et al., 2004; Mallory et al., 2004; Mallory et al., 2014; Provencher, 2014).

In the majority of avian studies, toxic element concentrations have been determined in tissues such as liver or kidney (Garcá-Fernández et al., 1996; Eisler, 2010; Shore et al., 2011; Binkowski and Meissner, 2013), a method that requires that the birds are killed. However, many marine bird species are considered threatened (Croxall et al., 2012), and non-destructive techniques using feather, blood and addled eggs are therefore preferable due to animal welfare concerns (Eisler, 2010). Furthermore, non-destructive sampling techniques make it possible to study survival rates in relation to contaminant exposure. Consequently, non-lethal sampling methods are increasingly being used to report toxic element concentrations (Wayland et al., 2007; Burger and Gochfeld, 2009). Blood element concentration is indicative of recent dietary exposure (Evers et al., 2008; Wayland and Scheuhammer, 2011),

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while feather element concentration indicates blood and body concentrations at the time of moulting (Markowski et al., 2013). The aim of the present study was to document blood and feather concentrations of toxic elements in the Baltic Sea and Svalbard eider population. The Baltic Sea has been considered one of the most polluted seas in the world (Fitzmaurice, 1993). It is a semi-enclosed, relatively shallow marine basin that captures and retains pollutants from numerous sources (HELCOM, 2010). During the last part of the 20th century the Baltic Sea has been exposed to large anthropogenic pollutant loads (Vallius, 2015b). The Baltic breeding eider population has declined by over 30% since the 1990s (Skov et al., 2011; Ekroos et al., 2012), and is considered endangered (Bird Life International, 2015). Main threats to this population include increased predation, human impact on marine habitats, oil pollution and changes in the quantity and/or quality of food resources (Ekroos et al., 2012; HELCOM, 2013). Environmental analyses performed in the 1990s revealed elevated element concentrations throughout the Baltic Sea (Borg and Jonsson, 1996; Leivuori, 1998; Vallius, 1999). During the same time period, Hollmèn et al. (1998) reported toxic levels of Se and Pb in blood and liver tissue of Baltic eiders, and dead eiders were diagnosed with Pb poisoning. Furthermore, Franson et al. (2000) reported a negative correlation between blood Pb concentration and delta-aminolevulinic acid dehydratase (ALAD, linked to development of anemia) in Baltic eiders. These studies suggest that toxic element exposure has posed a real threat to Baltic eiders in the past. More recent sediment analyses in the Baltic Sea indicate that toxic element levels have declined significantly during the last two decades (Vallius, 2014). However, there are indications that levels of certain toxic elements, such as Cd, Cu and Hg are still of concern in some areas of the Baltic Sea (Vallius, 2014; Vallius, 2015b). Thus, an updated documentation of toxic element concentrations in the Baltic Sea population of eiders is needed to assess the current toxic element exposure of this seabird population.

Compared to the Baltic Sea, Svalbard is considered a relatively clean area (Fenstad et al., 2016). However, sediment analyses indicate that there may be some Cd, Pb and Hg pollution in regions of the Norwegian Arctic (Lu et al., 2013). The major input of toxic elements into the Arctic, however, results from transport from more industrialized areas (AMAP, 2005), and evidence suggests that Hg deposition in the Arctic may increase due to increased global emissions (Riget et al., 2011). In contrast to the Baltic Sea population, the Svalbard eider population has remained stable over the last three decades (Hanssen et al., 2013). Toxic element levels in Svalbard eiders have, to our knowledge, only been reported in tissues such as liver, kidney or muscle (Norheim and Kjos-Hanssen, 1984; Norheim and Borch-Iohnsen, 1990; Savinov et al., 2003). The reported liver concentrations of Cd, Cu and Se in Svalbard eiders in the 1980s and 1990s were comparable with Baltic eiders, while liver Hg and possibly As concentrations appeared to be higher in Baltic eiders. Liver Pb concentrations have not been reported in Svalbard eiders (Norheim, 1987; Norheim and Borch-Iohnsen, 1990; Hollmèn et al., 1998; Savinov et al., 2003). Sediment analysis from the Baltic Sea (Gulf of Finland) and Svalbard (Kongsfjorden) indicates that the concentrations of Cd and Hg are higher in the Baltic Sea compared to Svalbard, but for other toxic elements, sediment concentrations may be comparable between the two locations (Grotti et al., 2013; Lu et al., 2013; Vallius, 2009, 2015a).

The objectives of the present study were to determine and compare blood and feather concentrations of 8 elements in Baltic and Svalbard eiders. The blood element concentrations in Baltic eiders were also compared and evaluated in relation to previously reported blood concentrations in this population. Furthermore, the toxicological relevance of the blood element concentrations in the two populations was evaluated, based on previously reported adverse effects and threshold levels in birds.

Blood and underlying body feather samples were obtained from incubating female eiders in Tvärminne (N = 28), Finland (~59°84′N, 23°21′E) and at Storholmen, Kongsfjorden (N = 29), Svalbard (78°56′ N, 12°13′E), in 2011. Baltic eiders migrate to Denmark, Germany and The Netherlands during winter (Lehikoinen et al., 2008), whereas Svalbard eiders migrate to Iceland and northern Norway (Fig. 1) (Hanssen et al., 2016). Body feathers are likely moulted in these areas.

The females were caught on the nest using a fishing rod with a nylon snare at the end, or with hand-nets. Female eiders fast during their incubation period and incubation stage may affect blood levels of certain elements (Franson et al., 2000; Wayland and Scheuhammer, 2011). Thus, females were only sampled if the clutch had hatched or was near hatching based on egg floatation (Kilpi and Lindström, 1997). Body mass (to the nearest 10 g) was recorded using a spring balance (Pesola Medio-Line 42500, Ecotone-Poland, 2500 g). Blood (8–10 mL) was sampled from the jugular vein using a heparinised syringe. The blood was transported to the field station within 6 h, and 2 mL whole blood was frozen (−20 °C) for subsequent element analyses. Underlying body feathers were sampled from the back of the females and packed in enclosed transparent plastic bags. Blood samples and feathers were transported to the laboratory at the Norwegian University of Science and Technology (NTNU), Trondheim, at the end of field season. The study complies with the Norwegian and Finnish regulation on animal experimentation, and permission for field work was granted by the Governor of Svalbard and the local authorities in Finland (Animal Experiment Board/State Provincial Office of Southern Finland, permit number ESLH-2009-02969/Ym-23).

Blood and feather samples were analysed for concentrations of the elements Hg, Se, Pb, Cd, As, Cr, Zn and Cu using High Resolution Inductively Coupled Plasma Mass Spectrometry (HR-ICP-MS, Thermo Electronic Corporation, Waltham, MA, USA) at the Department of Chemistry, NTNU.

For the detection of the elements, approximately 500 mg blood was transferred to acid washed Teflon tubes, designed for UltraClave, and added to 0.5 mL 50% Scanpure nitric acid (HNO_3 ultra-pure grade, 14.4 M) for digestion. For the feather samples, approximately 30 mg of feathers was added 2 mL 50% HNO_3 for digestion. The samples were digested using a high pressure microwave system, UltraClave (Milestone, Shelton, CT, USA) over 2 h with temperature up to 240 °C and pressure of 160 bar. Blood samples were diluted to 12 mL and feather samples were diluted to 24 mL with ion exchanged Milli-Q-water before element analysis.

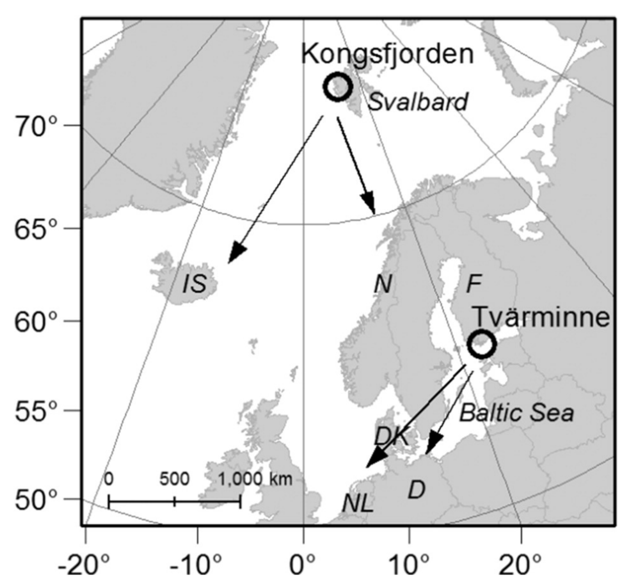

Fig. 1. Breeding locations (circles) of the Svalbard (Kongsfjorden, 78°56′N, 12°13′E) and the Baltic (Tvärminne, Finland (F), 59°84′N, 23°21′E) eider populations. Arrows show the wintering areas in Iceland (IS) and northern Norway (N) for the Svalbard eiders (Hanssen et al., 2016), and Denmark (DK), The Netherlands (NL) and Germany (D) for the Baltic eiders (Lehikoinen et al., 2008). The map is in a North Pole stereographic projection.

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