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Trace element concentrations and gastrointestinal parasites of Arctic terns breeding in the Canadian High Arctic

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HIGHLIGHTS

- Bismuth, selenium, and mercury in Arctic terns were high compared with other published values.
- Selenium, mercury and arsenic concentrations varied across the time periods.
- Selenium concentrations were significantly associated with the presence of gut parasites.
- High bismuth concentrations were associated with the absence of gut parasites.

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ABSTRACT

Baseline data on trace element concentrations are lacking for many species of Arctic marine birds. We measured essential and non-essential element concentrations in Arctic tern (*Sterna paradisaea*) liver tissue and brain tissue (mercury only) from Canada's High Arctic, and recorded the presence/absence of gastrointestinal parasites during four different phases of the breeding season. Arctic terns from northern Canada had similar trace element concentrations to other seabird species feeding at the same trophic level in the same region. Concentrations of bismuth, selenium, lead and mercury in Arctic terns were high compared to published threshold values for birds. Selenium and mercury concentrations were also higher in Arctic terns from northern Canada than bird species sampled in other Arctic areas. Selenium, mercury and arsenic concentrations varied across the time periods examined, suggesting potential regional differences in the exposure of biota to these elements. For unknown reasons, selenium concentrations were significantly higher in birds with gastrointestinal parasites as compared to those without parasites, while bismuth concentrations were higher in Arctic terns not infected with gastrointestinal parasites.

1. Introduction

Anthropogenic activities release numerous environmental contaminants, including trace elements, which can lead to an increase in environmental levels as compared with naturally occurring concentrations. This includes elements such as mercury (Hg) and lead (Pb), which are known to be toxic to biota (Franson and Pain, 2011; Weiner et al., 2003). Once metals and trace elements are in the environment they have the potential to bioaccumulate and biomagnify leading to high levels in top predators (Atwell et al., 1998; Campbell et al., 2005), which might negatively affect wildlife and their populations (Dietz et al., 2013; Sonne-Hansen et al., 2002; Sonne, 2010).

Trace elements in biota are classified as either essential or non-essential elements. Essential elements are those required for metabolic processes, such as calcium (Ca) and copper (Cu), while non-essential elements have no known organismal function, such as Hg (Garcia-Barrera et al., 2012; Hoffman et al., 2003). All elements are naturally occurring in varying amounts in the environment. Although biota is naturally exposed to many elements, all elements may become toxic at high enough levels, even those that are required by the body (Garcia-Barrera et al., 2012; Puls, 1994). Importantly, trace elements can accumulate in tissues that have different turnover rates (Hobson and Clark, 1992), thus examination of trace elements in multiple tissues is important when assessing possible exposure patterns and effects. Additionally, the levels of some elements may vary by sex, so it is important to consider possible gender influences on trace element concentrations in tissues (Robinson et al., 2011).

Tracking of trace elements in wildlife is important to understand how elements may cycle through biota and ecosystems, as well as

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how elements may accumulate within wildlife to potentially toxic levels (Metcheva et al., 2010). Although the tissue concentrations of essential trace elements have been intensively studied for some groups of animals (e.g. livestock; Puls, 1994), less is known about levels in wildlife populations, especially those occurring in remote areas such as polar regions (Metcheva et al., 2010).

In the Arctic, seabirds are top predators that have been useful in the study of trace elements in wildlife (Braune and Scheuhammer, 2008; Burger et al., 2007). Like most top predators, seabirds are exposed to trace elements through their diet, and high concentrations of trace elements may negatively influence wildlife health (Braune et al., 2006; Braune et al., 2012; Mallory et al., 2006). Although few studies exist that define what level of trace elements are safe for wild birds, some field studies have linked high concentrations of trace elements in wildlife with poor body condition (Wayland et al., 2002), decreased immune system function (Wayland et al., 2002), decreased survival (Wayland et al., 2008), and increased parasite burdens (Sagerup et al., 2009b). In addition, studies have documented some trace elements in apparently healthy breeding wild birds (e.g. Franson et al., 2004; Savinov et al., 2003).

Although any single element may affect biota, there are many interactions that may occur within the body between trace elements. Some elements have negative impacts on biota (e.g. Hg), but there are also combinations of elements which may reduce the toxicity of single elements (Shore et al., 2011). Alternatively, some mixtures of trace elements can have a stronger negative effect than those that occur independently (Sarigiannis and Hansen, 2012). Therefore, it is important to also consider trace elements in relation to one another.

Trace elements may also interact with other biological factors such as parasites to influence host health. Possible interactions between trace elements and parasites, and how these interactions may affect wildlife, are unclear as studies examining the interactions have shown that cumulative effects can be additive, synergistic or even antagonistic in both controlled laboratory and field experiments (Bergey et al., 2002; Bustnes et al., 2006; Coors and Du Meester, 2008; McFarland et al., 2012). Interactions between trace elements and parasites are of particular concern in the Arctic as the exposure of wildlife to both is expected to change in the coming decades (Davidson et al., 2011; Munthe et al., 2011).

The Arctic tern (*Sterna paradisaea*) is a small seabird (approximately 112 g) which breeds in the circumpolar Arctic (Hatch, 2002). Arctic terns have the longest known migration of any animal, as they travel between the Arctic and the Antarctic each year (Egevang et al., 2010), spending two to three months in their Arctic breeding range (Hatch, 2002). Although Arctic terns are not of conservation concern globally (Hatch, 2002), declines of breeding Arctic terns in northern Canada (Gilchrist and Robertson, 1999), as well as in Greenland have been reported (Burnham et al., 2005; Egevang and Fredericksen, 2011). Importantly, the long migration route of Arctic terns ensures that this species crosses multiple marine ecosystems during migration, thus possibly exposing them to multiple sources of anthropogenic pollution.

In this study, we examine levels of trace elements and endoparasite burdens in Arctic terns breeding in the Canadian High Arctic. In general, we expected Arctic terns to have comparable trace element concentrations as other seabirds feeding at a similar trophic level in the same region of Arctic Canada. Using Arctic terns as our study species, our specific goals were to: a) determine the liver tissue concentrations of trace elements and compare values to other seabirds breeding in northern Canada and the circum-Arctic region; b) examine how hepatic trace element concentrations relate to breeding stage and sex; c) examine the relationship between Hg concentrations in the liver tissue and brain tissue; d) examine the relationship between hepatic Hg and selenium (Se); and, e) determine whether incidence of gastrointestinal parasites was related to trace element concentrations or whether either were affected by season and sex.

2. Methods

2.1. Field collections

Arctic terns were collected from Nasaruvaalik Island (75°49′N, 96°18′W), just north of Cornwallis Island, Nunavut (Fig. 1; Permits WL000952, NUN-SCI-06-01). Each bird was shot with a 12 gauge shotgun, using #6 steel bird shot. Immediately upon collection birds were examined for ectoparasites (but none were found) and bagged individually (to preserve any missed ectoparasites) and frozen within 2 h of collection. Adult Arctic terns were collected at four different breeding stages in 2007; pre-breeding (27–28 June; $n = 11$), early incubation (7 July; $n = 10$), late incubation (17–19 July; $n = 10$), and chick-rearing (4 August; $n = 10$). Collections were done across the breeding season to determine if breeding stage influenced either trace element concentrations or parasitism as has been found in other birds (Spakulova et al., 1991; Wayland et al., 2005).

2.2. Bird dissections

Arctic tern carcasses were shipped frozen to the Long Point Waterfowl and Wetlands Research Fund Avian Energetics Laboratory, where they were thawed and dissected using standard protocols (e.g. Mallory and Forbes, 2008). Each bird was visually examined for ectoparasites and here again, none were found. They were then weighed, measured for head width, and dissected using acetone/hexane washed instruments and vessels. The brain and liver tissues were removed, and the gastrointestinal tract was examined for the presence of macroscopic endoparasitic helminths. Known tissue turnover rates suggest that the hepatic values

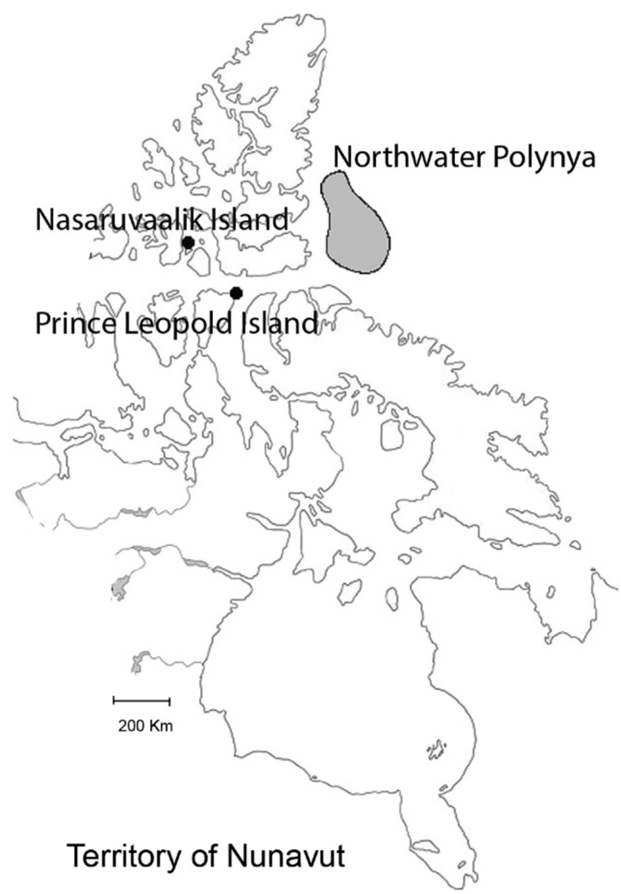

Fig. 1. Map of the Arctic Archipelago indicating the location of Nasaruvaalik Island, and the Northwater Polynya where seabirds have been sampled in 2007 for trace elements in the High Arctic.