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Mercury in seabird feathers: Insight on dietary habits and evidence for exposure levels in the western Indian Ocean

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Abstract

Breast feathers were used to estimate mercury levels in six marine birds nesting in the tropical western Indian Ocean, *i.e.* Sooty Tern (*Sterna fuscata*), Brown Noddy (*Anous stolidus*), Lesser Noddy (*Anous tenuirostris*), Audubon Shearwater (*Puffinus lherminieri bailloni*), Barau's Petrel (*Pterodroma baraui*) and the White-tailed Tropicbird (*Phaethon lepturus*). Juveniles consistently showed lower plumage mercury than adults. The lowest mean level was noted in juvenile Sooty Terns from the Glorioso Archipelago (0.05 $\mu g\ g^{-1}$). The highest levels were obtained for adult Barau's Petrels from Reunion Island (0.96 $\mu g\ g^{-1}$). An inter-site analysis of Sooty Tern showed higher mercury levels in birds nesting on Juan de Nova Island. Levels were low in comparison with values reported in the plumage of seabirds worldwide. The potential impacts of the size, the type (fish/cephalopod) and the origin (epi-/meso-pelagic) of prey on mercury intake in birds are discussed. Although the diet composition of individuals within a species appeared to be quite variable, combining results on mercury levels with common knowledge of each species allowed additional information on their dietary and foraging habits to be unraveled.

Keywords: Marine birds; Trophic ecology; Mercury; Bioaccumulation; Contamination; Tropical islands

1. Introduction

Seabirds are a major component of tropical oceanic environments. Yet, knowledge of tropical seabirds in general, and of their trophic ecology in particular, is still lacking. This is particularly obvious in the tropical western Indian Ocean, home to many avian species that breed on very dispersed islands, forming large colonies sometimes numbering hundreds of thousands of pairs (Le Corre and Jaquemet, 2005). This lack of knowledge may be attributed in part to the logistical difficulties involved in studying animals that scatter over huge areas. Consequently, most knowledge of feeding ecology obtained by conventional methods is restricted to the bird's breeding season because sightings usually occur close to islands and stomach contents (generally obtained at the colony) only give information on the seabird's last meal. Global Positioning System (GPS)

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satellite tracking methods, however, have recently been used to investigate the foraging ecology of non-breeding birds (Weimerskirch et al., 2005a).

Because of its bioaccumulation specificities, the analysis of mercury (Hg) in the tissues of seabirds and their prey is a useful technique to complement conventional studies. Mercury levels in an organism depend on a certain number of factors such as its species, its size and the type (fish/cephalopod), the size and/or the origin (demersal *vs.* pelagic or epi- *vs.* meso-pelagic) of its prey (Monteiro et al., 1996; Stewart et al., 1997b; Monteiro et al., 1998; Becker et al., 2002; Ochoa-Acuña et al., 2002; Bustamante et al., 2006). Interpreting mercury levels in birds with respect to these factors may offer clues to the birds' principal dietary mercury sources and hence provide information on their dominant prey. Mercury is also the only metal known to be clearly biomagnified in the food chain (Atwell et al., 1998). Its determination in seabirds also serves as reference for environmental contamination monitoring as seabirds are considered as good bioindicators of mercury levels in the marine environment (Furness et al., 1993).

Many studies of mercury in marine birds rely on the use of feathers (*e.g.* Doi et al., 1984; Burger et al., 1992; Thompson et al., 1993). The non-invasive sampling of feathers allows them to be used for the study of threatened or endangered species, permits the sampling of large numbers of birds, and enables repeated sampling from the same individual over many years. During feather formation, mercury present in the blood and mercury mobilized from various tissues such as liver or kidneys (essentially methyl mercury) are sequestered in the growing feathers, where it binds to sulfhydryl groups of keratin (Goede and De Bruin, 1984; Burger, 1993). Once the feather is formed, the blood irrigation subsides implying that no further metal can be deposited. Therefore, feathers remain as a record of exposure during the months preceding feather growth. Body feathers and wing coverts are the major elimination routes for mercury in the plumage (Lewis and Furness, 1991). Breast feathers, that will be used in this study, are particularly interesting because they do not reflect molt sequence as do flight feathers. Furthermore, they represent the plumage as a whole and usually show low variability in mercury levels providing the best approximation of the bird's exposure (Lewis et al., 1993; Burger and Gochfeld, 2001).

This investigation is based on the use of breast feathers to estimate mercury levels in six marine birds inhabiting the tropical western Indian Ocean, *viz.* the Sooty Tern (*Sterna fuscata*), the Brown Noddy (*Anous stolidus*), the Lesser Noddy (*Anous tenuirostris*), Audubon Shearwater (*Puffinus lherminieri bailloni*), Barau's Petrel (*Pterodroma baraui*) and the White-tailed Tropicbird (*Phaethon lepturus*). Phylogenetic, biological (age), ecological (diet) and geographical (breeding location) factors influencing mercury levels in feathers were investigated. The results were discussed in the light of the bio- and ecological specificities of each species to reveal information on their dietary habits. The tropical zone of the Indian Ocean houses very little anthropogenic activity. It is suspected that this situation may result in lower mercury levels in the avian top predators inhabiting this oceanic area in comparison with those found in temperate oceans, and perhaps in other tropical waters under anthropogenic influences. Mercury levels determined in these six seabirds were thus compared with mercury in feathers of marine birds originating from other areas worldwide.

2. Materials and methods

2.1. Study sites

The seabirds studied during this investigation originated from colonies established across the western Indian Ocean. The following islands were chosen in the intention of giving a representative overview of the region (Fig. 1): Bird Island in Seychelles (4°53′S, 55°12′E), Lys Island which is part of the Glorioso Archipelago in the North of the Mozambique Channel (11°33′S, 47°17′E), Juan de Nova which is located in the center of the Mozambique Channel (17°03′S, 42°45′E), Europa, located in the southern part of the Mozambique Channel (22°20′S, 40°22′E) and Reunion Island (21°07′S, 55°33′E).

2.2. Studied seabirds

The main morphological and biological characteristics of the studied species are presented in Table 1 and in the following sections.

2.2.1. Geographical distribution and breeding patterns

The Sooty Tern, a widely scattered pan-tropical seabird, is the most numerous of the six species with nearly 6 million pairs living in the western Indian Ocean where they breed on various islands: Cosmoledo, Europa, Glorioso, Juan de Nova, Madagascar, Mauritius, Rodrigues, Seychelles and Zanzibar (Schreiber et al., 2002; Le Corre and Jaquemet, 2005; Feare et al., in press). They breed synchronously in very large colonies although breeding seasons vary among islands (in austral winter at Europa and Seychelles, in austral summer at Juan de Nova), and among years (on Lys Island for example) (Le Corre,