

## Albatross as Sentinels of Heavy Metal Pollution:

### Local and Global Factors

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**Abstract.** Heavy metal pollution in the Pacific Ocean has garnered significant attention in recent years, especially with regard to rising mercury emissions from Asia. Uncertainty exists over the extent to which mercury in biota may have resulted from increases in anthropogenic emissions over time. Albatrosses, including those inhabiting the North Pacific, are wide-ranging, long-lived, keystone, avian predators. Consequently, they serve as ideal sentinel species for investigating the effects of historical and contemporary pollution as well as local and global factors related to heavy metal exposure, bioaccumulation, and ecotoxicological risk. To date, high levels of mercury and lead have been documented in albatross species throughout the Pacific. To address biotic exposure to these multiple stressors, here we synthesize and conduct meta-analyses of total mercury, methylmercury, and lead exposure data in Black-footed albatross (*Phoebastria nigripes*) and Laysan albatross (*Phoebastria immutabilis*). Our approach includes data from the field and literature, and for total mercury and methyl mercury, we use measurements from museum feathers spanning the past 130 years for Black-Footed albatross. We discuss the use and application of stable isotopes ( $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$ ) as a way to control for temporal changes in trophic structure and diet and we demonstrate the importance of conducting speciation analyses for mercury to account for historical, curator-mediated, inorganic mercury contamination of specimens. Our data showed higher levels of inorganic mercury in older specimens of Black-Footed albatross as well as two non-pelagic species (control samples) lacking historical sources of bioavailable mercury exposure, which suggests that studies on bioaccumulation should measure methylmercury rather than total mercury when utilizing museum collections. Changes in methylmercury levels in Black-Footed albatross were consistent with historical global and recent regional increases observed among published estimates and proxies of anthropogenic mercury emissions. At the local scale, previous research has also reported that lead paint exposure from buildings was also an important environmental stressor for Laysan albatross. Thus, albatross species face heavy metal exposure threats at both local (lead) and global scales (mercury, and potentially heavy metals in plastics). Specific types of plastic pollution entering marine environments have been documented to contain heavy metals at levels, which if bio-available, may present a non-localized source of lead exposure in albatross species known to ingest (and regurgitate to their young) large amounts of marine plastic. Heavy metal toxicity along with other stressors may undermine current and future reproductive outcomes in these seabird species, although unraveling effects from specific metals in the context of a complex metal mixture presents some challenges. Collectively, our findings and review of the literature suggest that albatrosses in this region may be an effective marine flagship species and raising the profile of these organisms likely would successfully support broader biodiversity conservation efforts in the North Pacific.

**Keywords:** Heavy metals, Albatross, Sentinel species, Lead, Mercury, Global change, Plastic pollution