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Lead exposure in an urban, free-ranging parrot: Investigating prevalence, effect and source attribution using stable isotope analysis

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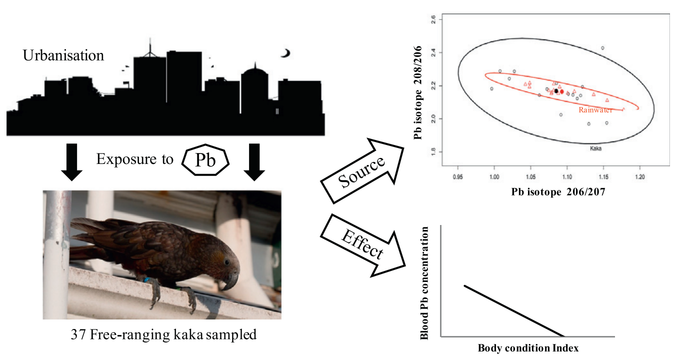
HIGHLIGHTS

- Significant prevalence of lead exposure in an urban population of a free-ranging parrot
- Negative association of blood lead concentration on body condition index in kaka
- Pb isotope analysis suggests roof-collected rainwater is one potential urban source of lead exposure in kaka.
- Variability in kaka blood Pb stable isotopes suggests there are multiple environmental sources of exposure.

GRAPHICAL ABSTRACT



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ABSTRACT

Anthropogenic lead use has resulted in widespread environmental lead contamination known to affect wildlife populations worldwide. Ecotoxicological investigations in wild birds have thus far prioritised waterfowl and raptor species and primarily addressed contamination in natural ecosystems. Urban areas are increasingly associated with high levels of heavy metal contamination, however the risk of lead exposure in urban wildlife is less well known. This study investigates lead exposure in an urban population of North Island Kaka (*Nestor meridionalis septentrionalis*), an endemic New Zealand parrot. The inquisitive nature of these birds, an expanding urban population and increased availability of food in the urban environment are the primary factors implicated in their dispersal into urban areas where there is increased exposure to anthropogenic sources of lead. Blood lead concentrations were assessed in free-ranging birds to quantify the prevalence and magnitude of lead exposure. The impact of lead on physiological and neurological function was assessed using behavioural and clinical examinations. Finally, lead stable isotope analysis was employed to investigate lead in roofing material as a potential source of exposure in the urban environment. Results indicate a significant prevalence of lead exposure in this population (43.2%) with a maximum recorded plasma concentration of 50.7 μg/dL. Although no mortality was observed during this study, lead exposure was associated with reduced body condition in kaka. Behavioural changes were present in one individual with the highest recorded blood lead concentration. Lead isotope values of roof-collected rainwater overlapped with kaka blood lead isotope values, suggesting this to be an important source of exposure in this population. The prevalence of lead exposure observed in this study suggests that lead is a toxin of importance to kaka in this urban area. Wildlife intoxications largely result from anthropogenic lead sources and this study identifies a previously undescribed urban source of lead for wildlife.

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1. Introduction

Lead is a persistent environmental toxin that is regarded as a threat to wildlife populations worldwide (Tranel and Kimmel, 2009; Haig et al., 2014). In birds, it is a primary cause of mortality in several avian species, and is implicated as a major hindrance to reintroduction and conservation programmes around the world (Pain et al., 2007; Lambertucci et al., 2011; Finkelstein et al., 2012). A large proportion of work in lead exposure in avifauna has thus far focused on investigating contamination in natural ecosystems (Mateo et al., 2001; Meharg et al., 2002; Vallverdú-Coll et al., 2015), however there is increasing scrutiny on pollution in urban environments and the resulting implications on wildlife (McMichael, 2000; Swaileh and Sansur, 2006; Scheifler et al., 2006). Expanding urbanisation is a major threat to wildlife and an understanding of risks associated with anthropogenic toxins is vital to manage wildlife at the urban interface.

In birds, the physiological effects of lead exposure are diverse and dependent on dose, duration and route of exposure. Additionally, the clinical manifestation of lead toxicity can be variable across species, therefore calculating the risk on a population scale is rarely straightforward (Haig et al., 2014). In terrestrial birds, ingestion is the primary route of exposure (Fisher et al., 2006). During the immediate period following ingestion, lead concentrations are highest in the blood. Subsequently, lead is redistributed to soft-tissue compartments such as liver, and kidney, and is later incorporated into bone (Franson and Pain, 2011). Blood lead concentration is therefore considered an indicator of recent exposure, and provides a non-destructive and sensitive measure of acute exposure to lead.

Exposure to high concentrations of lead can result in clinical signs of acute toxicity, while long-term or repeated exposure to low concentrations of lead can result in a range of disease from chronic sub-clinical toxicity to clinical disease and mortality. Lack of detectable clinical signs does not translate to a lack of effect, as subtle physiological and behavioural alterations associated with sub-lethal lead toxicity have been shown to influence long-term survival, especially in the presence of contributing stressors present in a natural ecological setting (Fisher et al., 2006).

Kaka are forest parrots, endemic to New Zealand and classified as endangered by the IUCN (BirdLife International, 2014). Once well distributed throughout mainland New Zealand, their population is declining rapidly, due to habitat destruction, predation and competition for food (Berry, 1998). As part of a restoration initiative, in 2002, kaka were reintroduced to Zealandia Ecosanctuary, a 225 hectare predator proof reserve on the doorstep of urban Wellington (Fig. 1). Their population has since expanded due to habitat restoration, predator management, and the provision of supplementary food (Miskelly et al., 2005; Charles and Linklater, 2013). As a result kaka are increasingly venturing into urban Wellington. They are regularly sighted on roofs and known to cause damage to roof joinery, cladding and chimneys (Charles, 2012; Charles and Linklater, 2013; Recio et al., 2016). Increased interaction with the urban environment, including lead-based products such as roofing materials and paint, is a potential risk factor for lead exposure in kaka and this study provides an opportunity to investigate lead exposure in this urban setting.

Investigations of lead toxicity in wildlife should ultimately be directed towards identifying the potential sources of lead in the environment as source attribution can provide valuable information directing policy and management around lead use (Scheuhammer and Templeton, 1998). In recent years, lead stable isotope analysis is increasingly used in wildlife ecotoxicological studies to trace pathways of lead exposure (Scheuhammer and Templeton, 1998; Church et al., 2006; Finkelstein et al., 2012). There are four main naturally occurring isotopes of lead (^{204}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb), and the composition of these isotopes can vary between sources. This variability essentially creates a “fingerprint”, allowing for the differentiation between sources of lead in the environment; both anthropogenic and environmental in origin (Jiang and Sun, 2014). Furthermore, physico-chemical processes do not alter lead isotope ratios, allowing for accurate traceability to the original source (Komárek et al., 2008). Investigating the isotopic composition in environmental samples and comparing these to biological samples from wildlife can be used to trace specific sources of lead.

The aim of this study was to evaluate if lead is a toxin of importance to urban kaka. This involved: (i) identifying the prevalence and concentrations of lead exposure in free-ranging adults; (ii) evaluating the acute physiological effects of lead exposure; and (iii) identifying the source of lead in the urban environment. Managing wildlife in urban areas requires a considered approach, which includes a thorough understanding of the risks and threats of urban exposure in wildlife. Heavy metal pollution is one of many threats confronting wildlife species inhabiting urban areas, and population success is dependent on overcoming or adapting to these challenges.

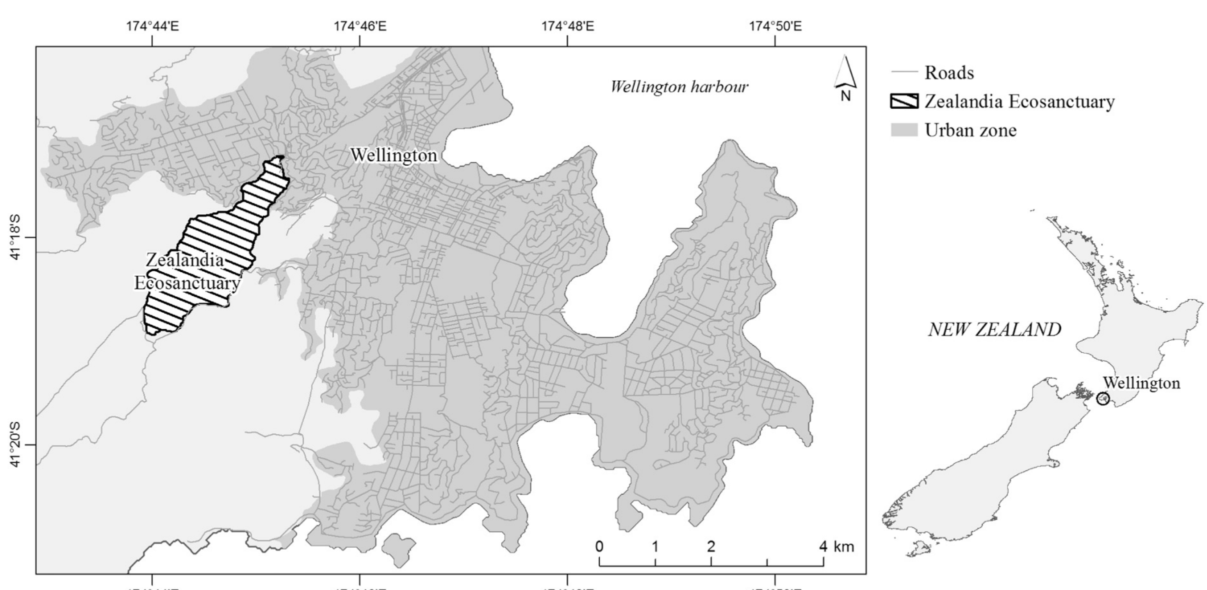

Fig. 1. Map of Wellington city outlining Zealandia Ecosanctuary in proximity to the urban zone.