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Plastic, nutrition and pollution; relationships between ingested plastic and metal concentrations in the livers of two Pachyptila seabirds.

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Annotation: Naturally occurring metals and metalloids [metal(loid)s] are essential for the physiological functioning of wildlife; however, environmental contamination by metal(loid) and plastic pollutants is a health hazard. Metal(loid)s may interact with plastic in the environment and there is mixed evidence about whether plastic ingested by wildlife affects metal(loid) absorption/assimilation and concentration in the body. We examined ingested plastic and liver concentration of eleven metal(loid)s in two seabird species: fairy (Pachyptila turtur) and slender-billed prions (P. belcheri). We found significant relationships between ingested plastic and the concentrations of aluminium (Al), manganese (Mn), iron (Fe), cobalt (Co), copper (Cu) and zinc (Zn) in the liver of prions. We investigated whether the pattern of significant relationships reflected plastic-metal(loid) associations predicted in the scientific literature, including by transfer of metals from ingested plastics or malnutrition due to dietary dilution by plastics in the gut. We found some support for both associations, suggesting that ingested plastic may be connected with dietary dilution / lack of essential nutrients, especially iron, and potential transfer of zinc. We did not find a relationship between plastic and non-essential metal(loid)s, including lead. The effect of plastic was minor compared to that of dietary exposure to metal(oid)s, and small plastic loads (< 3 items) had no discernible link with metal(loid)s. This new evidence shows a relationship between plastic ingestion and liver metal(loid) concentrations in free-living wildlife.

Keywords: Environmental chemistry, Marine biology, Ecology, Environmental sciences, Ocean sciences.

Pollution of the marine environment by plastics1, metals and metalloids, henceforth “metal(loid)s”, is a major environmental concern2,3. Some metals are dietary minerals, which are essential for the physiological functioning of organisms. These ‘essential’ metals include chromium (Cr), cobalt (Co), nickel (Ni), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn). Other metal(loid)s are considered non-essential for living organisms, having no known biological benefit. These ‘non-essential’ metal(loid)s include arsenic (As), cadmium (Cd) and lead (Pb)4, while the biological role of aluminium (Al) is still unclear. Depending on the type, speciation and concentration, both essential and non-essential metal(loid)s can be toxic to organisms. Metal(loid)s and plastics can adversely affect the health of marine wildlife that

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consumes them8. Plastics may interact with metal(loid)s in the ocean by concentrating them on their surfaces through sorption9, and concentrations of Al, Cr, Co, Ni, Fe, Cu, Zn, Cd and Pb on the surface of beached plastic can be higher than in the background environment9–12. Some metals, including Zn, are plastic additives and serve multiple function as flame retardants and smoke suppressants13. It is not clear whether ingested metal(loid)s adsorbed onto plastics are absorbed into systemic circulation from the gastro-intestinal tract and accumulate in tissues within plastic-ingesting organisms. Similarly, little research has investigated plastic-associated metal(loid) absorption and health impacts within organisms14. Research linking plastic ingestion and metal(loid)s in free-living marine vertebrates is in its infancy, and baselines for metal(loid) concentrations exerting adverse health effects have not yet been established. To improve the understanding of pollutant associations, sentinel species, particularly seabirds, are routinely employed as indicators for environmental health. Ingestion of plastic by seabirds may lead to both lethal43,44 and sub-lethal health effects45, including physical effects, linked to physical damage and nutrition, and chemical effects, concerning the transfer of plastic-additive and plastic-adsorbed chemicals46 (Fig. 1). Though knowledge on the plastics and metal(loid)s in seabirds is increasing, studies exploring how plastic and metal(loid)s interact and the mechanism of significant relationships are lacking. Significant plastic-metal relationships have been found in seabird feathers31; plastic has been suggested as a vector for metals40 and plastic-nutritional effects have been found in sea-turtles26,28. However, metal(loid)-plastic relationships in seabird organs have never been investigated. Understanding the effects of ingested plastic on physiological factors, such as nutrition and pollution, in species of the open ocean is challenging in terms of practical and ethical concerns.

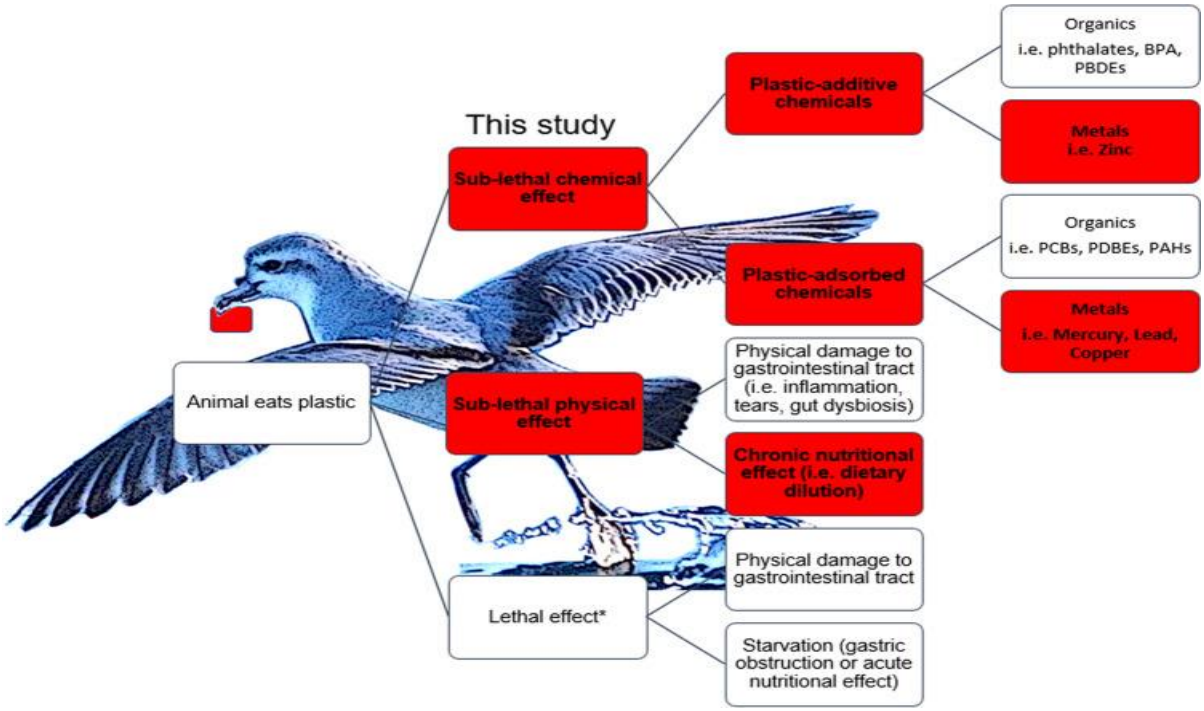

Figure. 1

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Ingestion of plastic by seabirds and other animals may lead to both lethal and sub-lethal health effects, including physical effects, linked to physical damage and nutrition, and chemical effects, concerning the transfer of plastic-additive and plastic- adsorbed chemicals. This study (red coloured boxes) explores the relationship between ingested plastic and liver metal(loid) concentration and potential associations with plastic-adsorbed metal(loid)s, plastic-additive metals and nutrition. Prion photo by L. Roman and image manipulation using GIMP.

Where significant relationships were found between liver concentration of a metal(loid) and the presence of ingested plastic, we investigated potential associative mechanisms based on relationships predicted or suggested in the scientific literature. Two mechanisms that may link ingested plastic with organ metal(loid) concentration are found in the literature. Firstly, metal(loid)s which are plastic additives13 and/or adsorbed to the surface of plastic9–12 may transfer to the body when ingested. Secondly, malnutrition may occur as a result of dietary dilution by plastics in the gut, influencing mineral nutrient concentrations28. The null hypothesis was that no significant relationships existed between ingested plastic presence and liver metal(loid) concentrations, while significant relationships between plastic and liver metal(loid) would lead to two possible explanations (Fig. 2).

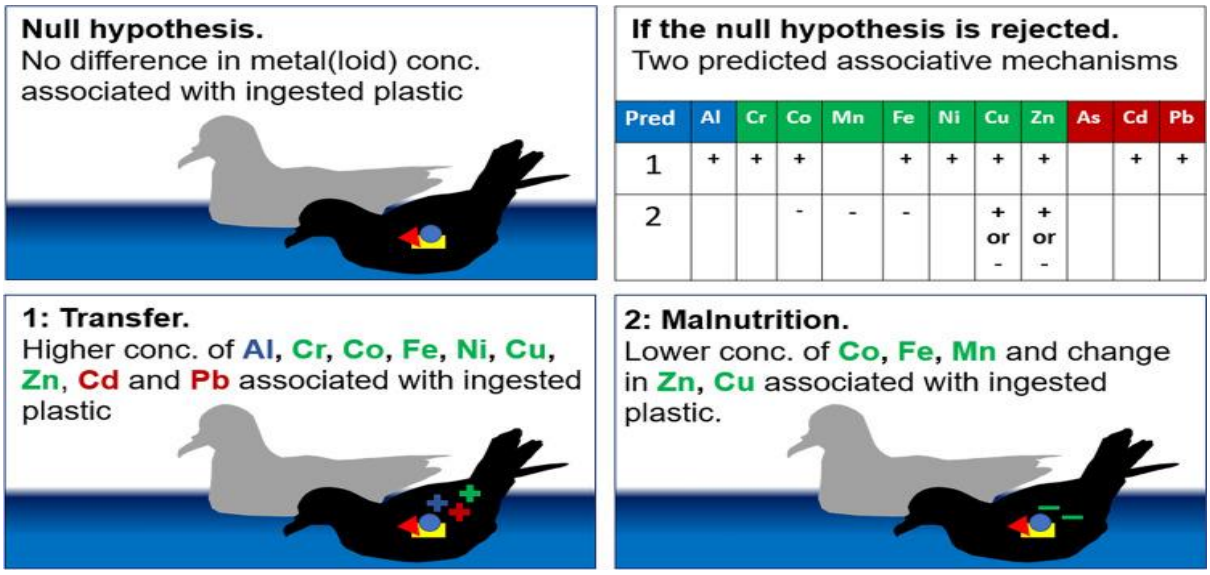

Figure.2

Predictions for the association of plastic with the liver metal concentration of prions, though pre-storm body condition is unknown. The null hypothesis is that there is no difference in liver metal(loid) concentration between prions with and without ingested plastic. Significant differences in the concentration of liver metal(loid)s leads to rejection of the null hypothesis and examination of support for two mechanistic association predictions derived from the literature: transfer of metal(loid)s from plastic or malnutrition due to dietary dilution by plastic in the gut. Essential metals are shown in green, non-essential metals are shown in red, and metals where the biological role is unclear are shown in blue. Prion silhouettes were created using GIMP.

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Plastic ingestion in prions, especially for those individuals with large plastic loads, is associated with reduced Al, Mn, Fe and Co concentrations and increased Cu and Zn concentration in the liver. We posit that this result may be caused by dietary dilution and subsequent malnutrition due to plastic in the gut, and potentially by the transfer of Zn from ingested plastic. This new evidence shows a relationship between plastic and liver metal(loid) concentration in free-living wildlife, with a potential nutrition and pollution link. However, the effect is small and is less important than the effect of external factors such as diet and foraging differences. Plastic load, type of diet and resultant chronic dietary dilution are factors that may affect seabird body condition and consequent resilience and survival in natural events such as storms. We conclude that ingested plastics in loads such as those we examined may affect essential metal(loid) mineral nutrient absorption through dietary dilution but may not be important vectors of non-essential metal(loid) contamination in fairy and slender-billed prions.

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