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Metals and their isotopes: An opportunity to study insect ecology and physiology?

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Insects have the largest biomass of terrestrial animals, contribute to invaluable ecosystem services and migrate across continents transporting seeds, spores, genes and pathogens between ecosystems. Anthropogenic activities are exposing insects to elevated levels of toxic metals and are altering the bioavailability of many essential metals. Despite the fundamental role of metals in insect biogeochemistry, the response of insects to environmental changes in metal availability remains understudied relative to that of vertebrates. Additionally, metals and their isotopes have shown the potential to develop new tools to study insect mobility, physiology or reproduction. Understanding the pathways of metal incorporation in insect tissues and mechanisms of isotope fractionation is thus crucial to apply metal isotope science to biological, ecological or toxicological questions in entomology. We conducted a diet-switching experiment on monarch butterflies [Danaus plexippus] with controlled larval and adult diets to evaluate the sources of metals and metalloids, strontium isotopes, and lead isotopes to insect tissues over a period of 8 weeks. Some of those metals (e.g., Ca) showed differences with sexes likely related to the different routing of metals in reproductive organs hosted by specific tissues. Some metals bioaccumulated from the adult diet (e.g., Ni, Zn) or from external dust and aerosols (e.g. Al, Fe, Pb) and some showed little changes throughout adult life (e.g., Ba, Sr, Ti). Adding an isotope dimension refined the interpretations. For example, lead isotopes showed rapid changes after emergence with a clear signal of exogenous lead incorporation from local anthropogenic sources. Lead isotopes have a strong potential to integrate pollution exposure in mobile insects providing a critical metric to investigate population response to metal pollution or to track pollution sources along a migratory path. Strontium isotopes confirmed their potential utility for reconstructing the area of larval development of an individual, as they mostly remained preserved in wing tissues throughout adult life. Calcium elemental and isotopic fractionation track the partitioning of Ca between tissues and reproductive organs based on sex. This preliminary study only scratches the surface of how metals and their isotopes could advance our knowledge of insect biology with implications for conservation, pollination and ecosystem services.