Historical Lead Contamination Linked to Atmospheric Deposition is Associated With Declines in Ectomycorrhizal Diversity and Shifts in Fungal Community Composition

Chance R. Noffsinger | P. Brandon Matheny

Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, Tennessee, USA

Correspondence: Chance R. Noffsinger (chancenoff@gmail.com)

Received: 25 November 2024 | **Revised:** 25 February 2025 | **Accepted:** 3 March 2025

Handling Editor: Tatiana Giraud

Funding: This study was supported by the U.S. National Science Foundation (award DEB 2030779); Breedlove, Dennis Fund at the University of Tennessee Herbarium; Carlos C. Campbell Memorial Fellowship; and research support from the Department of Ecology and Evolutionary Biology at UT.

Keywords: endangered ecosystem | forest soil | functional traits | fungal guilds | metal contamination | saprotrophic fungi

ABSTRACT

Ectomycorrhizal and saprotrophic fungi respond differently to changing edaphic conditions caused by atmospheric deposition. Within each guild, responses can vary significantly, reflecting the diversity of species and their specific adaptations to environmental changes. Metal contaminants are often deposited onto earth's surface through atmospheric deposition, yet few studies have assessed the relationship between soil metal contamination and fungal communities. The goal of this study was to understand how soil metal contamination and other edaphic factors vary across the spruce-fir ecosystem in the Southern Appalachians and influence fungal diversity and function. Here, we characterize soil fungal communities using high-throughput sequencing of the ITS2 gene region and found that higher soil lead (Pb) concentrations were associated with lower fungal diversity. Ectomycorrhizal fungi were less diverse (specifically hydrophilic ectomycorrhizal functional types) at plots with elevated soil Pb concentrations, while saprotrophic fungi were less diverse at plots with elevated soil carbon:nitrogen ratios. Fungal community composition was significantly influenced by pH, Pb, and spatial factors. This study identifies important relationships between fungal diversity and soil Pb concentrations and indicates variable responses of genera within well-defined ecological guilds. Our work highlights the need to characterize poorly understood taxonomic groups of fungi and their function prior to further environmental degradation.

1 | Introduction

Atmospheric deposition is a major pathway through which sulfur dioxide and nitrogen (N) oxides are introduced into terrestrial ecosystems via rain, particles, and gases. This process increases inorganic N, potentially leading to N saturation and forest ecosystem decline. Elevated N and sulfur deposition alter soil properties by reducing pH and depleting essential nutrients, while increasing carbon (C) storage (Vitousek et al. 1997; Schwartz et al. 2022). Acidification, driven by the addition of nitric acid and biological processes like nitrification (Schindler et al. 1985; Schuurkes and Mosello 1988; Johnson et al. 1990), solubilises metals such as aluminium (Al) and lead (Pb), making them bioavailable (Babich and Stotzky 1979; Bojórquez-Quintal et al. 2017). These metals can inhibit root growth, decrease nutrient uptake, and ultimately reduce photosynthetic capacity, forest biomass, and biodiversity, contributing to tree mortality (Shortle and Smith 1988; Schulze 1989; Cronan and Grigal 1995; Aber et al. 1998). Such impacts are particularly severe in mountain ecosystems that