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Effect of metal contamination on microbial enzymatic activity in soil

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ABSTRACT

Anthropogenic metal contamination is a pervasive problem in many urban or industrial areas. The interaction of metals with native soil communities is an important area of research as scientists strive to understand effects of long-term metal contamination on soil properties. Measurements of free soil enzyme activities can serve as useful indicators of microbial metabolic potential. The goals of this study are to determine extracellular soil enzymatic activities with respect to corresponding metal concentrations within a site of long-term contamination. These data are examined to understand relationships between extracellular soil enzyme activities and persistent metal loads *in situ*. Here we present such results from a rare research opportunity at an un-remediated, urban brownfield in Jersey City, NJ, USA. The soils of the site developed over the last 150 years through the dumping of urban fill from New York City as well as industrial rail use. The site was abandoned and fenced in the late 1960s, and within it, there is a mapped gradient of metal concentration in the soils, including As, Pb, Cr, Cu, Zn, and V. We measured soil enzymatic potential (alkaline phosphatase, cellobiohydrolase, and L-leucine-amino-peptidase) across four plots within the site and at an uncontaminated reference site that is of the same successional age and geographic influence. We found the highest enzymatic activities for all three activities measured at the site with the greatest soil metal loads and a particularly strong relationship among enzyme activity and the metals V and Cr. Our results differ from many experimental studies that show decreased soil enzyme activity in soils experimentally treated with metals. The results may indicate the effects of long-term adaptation of soil communities within these metal contaminated soils.

1. Introduction

The global increase in human development is rapidly changing our world (DeFries et al., 2004), and has generated unique soils that vary in contaminant nature and concentration, moisture, and nutrient levels (Pouyat et al., 2007). The process of understanding how soil communities are affected by human impacts includes resolving differences in the structural and functional character of the biotic community. Within the soil, the presence and concentration of contaminants will modulate interactions between soil organisms (Krumins et al., 2015). Research on soil function, specifically enzymatic activity, in these systems is an increasingly important approach to a more holistic understanding of soils in contaminated environments.

In contaminated soils, the activity of the microbial community is intertwined with soil abiotic properties (Schimel et al., 2007). Functions like cellulose degradation or nitrogen cycling can be measured by using soil enzymatic activities as indicators (Burns et al., 2013). When microbial communities adjacent to industrialized sites were analyzed, they showed lower enzymatic function with higher soil metal loads (Wang et al., 2007) as well as lower community diversity (He et al., 2010). Lower enzymatic activities have also been observed when soil was experimentally contaminated with heavy metal loads. For example, Kandeler et al. (2000) showed lower urease, alkaline phosphatase, and xylanase activities for soils experimentally contaminated with Zn, Cu, Ni, V, and Cd compared to soils that were not experimentally contaminated.

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However, in other studies, high soil metal loads were associated with high enzymatic activities (Kzlkaya, 2004; Pascual et al., 2004), and in other studies, shifts in the microbial community composition and functioning were found with metal load (Zhang et al., 2007). These results highlight the complexity of the effect of heavy metal contamination on soil enzyme activities and the need to consider the experimental details of each study.

The goal of this research was to determine the relationship between elevated heavy metal concentrations in soil and extracellular enzyme activities that are proxy measures for nutrient cycling. To better understand relationships between persistent metal contamination and extracellular enzymatic activities, we have measured soil metal loads and determined the extracellular enzymatic potential of the soil across a gradient of heavy metal contamination within an unremediated urban brownfield. Further, we compare these results to those of a relatively uncontaminated reference site of similar successional age and geography, but very different historical usage. The results of this study will help answer an important question relevant in restoration ecology: What are the effects of long-term metal contamination on microbial nutrient cycling in soils?

2. Materials and methods

2.1. Site description

Our primary research site is located within Liberty State Park (LSP), Jersey City, NJ (40°42′16N, 74°03′06W), in the piedmont physiographic region of New Jersey (Fig. 1). The un-remediated soils of LSP have been given their own series designation by the USDA Natural Resource Conservation Service, the Ladyliberty Series (National Cooperative Soil Survey, 2012). Historically, intertidal mudflats and salt marsh characterized the area. Between 1860 and 1919 the area was filled with construction debris and municipal waste from New York City to build and develop the Central Railroad of New Jersey. Rail service through the terminal ran until 1967. It was abandoned until 1970 after which much of the area was remediated and established as a state park, now dominated by landscaped recreational areas. The most contaminated portion of the park, our study site, was fenced off from human use and access since 1969 and has not been remediated, restored, or managed.

The plant community is characterized by mid-successional temperate, deciduous forest growing in existing contamination. The forest is dominated by *Betulla populifolia* (gray birch), *Populus deltoids* (cottonwood) and *Populus tremuloides* (quaking Aspen). Other significant forest species encountered sporadically include *Prunus serotina* (black cherry) and *Acer rubrum* (red maple) (Gallagher et al., 2008). Plant community composition varies very little among the four sites with a slightly higher density of graminoids and herbaceous plants in the understory of some sites that are both of low and high metal load (notably sites 48 and 146, see Section 2.2). Those sites tend to have higher soil moisture (Table 1). Contamination caused by rail and industrial use at the site is primarily composed of heavy metals (As, Cr, Cu, Hg, Pb, Zn, V) (Gallagher et al., 2008) and, in isolated areas, organic pollutants. The organic pollutants have not yet been characterized. However, the exact source or origin of particular contaminants across the site will likely never be known. The research plots lie along a well-characterized soil metal gradient within the fenced and inactive portion of the park. Based on measurements in 2006 (Gallagher et al., 2008), the total soil metal loads at sites 48 and 43 are below the critical threshold level whereas levels at sites 14 and

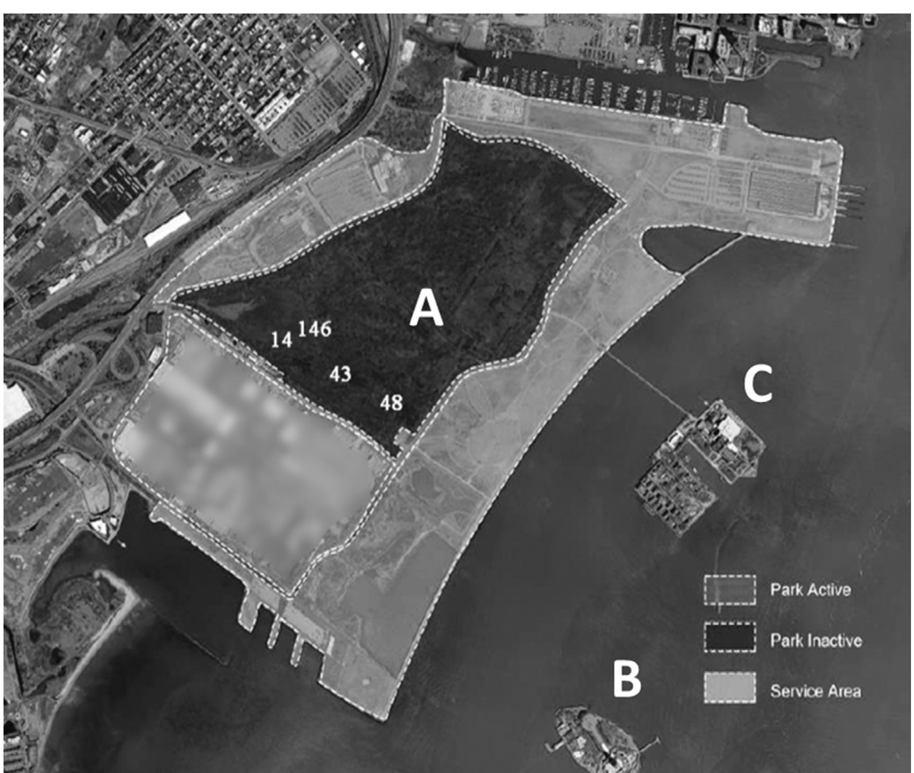

Fig. 1. Aerial view of primary research site, Liberty State Park (LSP) (A) with respect to the Statue of Liberty (B) and Ellis Island (C) in New York City Harbor. The four research sites are situated within the inactive portion of the park, and they are numbered 48, 43, 14 and 146 in increasing order of relative, overall metal contamination. As such, the sites lie along the southern boundary of the well-characterized brownfield (park inactive). Photo credit: Robison Aerial Inc.