THE DETERMINATION OF VARIATIONS IN CALCIUM AND ARTHROPOD ABUNDANCE IN RESIDENTIAL YARDS ALONG AN URBAN TO RURAL GRADIENT

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Abstract. Rapid urbanization at regional and global scales necessitates an understanding of these newly formed urban habitats. Previous studies indicate that regional and local scale deposition contributes a significant amount of calcium to soils in urban areas. Calcium is known to limit the growth of soil isopods and studies have shown that soil isopod abundances are higher in urban than in rural forest patches. While these studies have focused on forested areas along an urban to rural gradient, residential areas have not been investigated though they are the dominant land use in urban areas. This study addresses the following questions: Does calcium vary in residential soils i) regionally across an urban to rural land use gradient and ii) locally within yard patches (front yard, backyard, proximity to road, and home) and iii) do isopod abundances correspond with soil Ca concentrations? The sites used in this study correspond with the Neighborhood Nestwatch network in the Washington D.C and Baltimore Metropolitan areas. Calcium levels were more than two-fold greater in suburban sites than the other land use types. Isopod abundance in urban areas was highest, and pH significantly correlated with calcium levels in the soil. The results suggest that calcium levels and arthropod abundance are being affected by more than local and regional deposition.

INTRODUCTION

The urban ecosystem, we realize, becomes more and more important to study as the world continues to change around us. Slightly less than half of the world's population now resides in cities, but this is projected to rise to nearly 60% in the next 30 years (Picket et al. 2001). In the U.S alone close to 80% of the population lives in urban areas (US Census 2000). 70% of prime farmland is in the path of rapid development and in the '90s alone, more than 3 million acres of open space (including farmland and forests) were developed (USDA). This rapid change toward urbanism has environmental consequences. Studies show that acid deposition acidify terrestrial ecosystems resulting in diverse impacts including the loss of species and accelerated leaching of nutrients, such as Ca^{2+} (Likens 2004). The primary source of acid rain is the combustion of fossil fuels and in an urban environment these emissions are released in high volume. A study conducted by M.M. Makholm and DJ Mladenoff showed Ca^{2+} was found in lower concentrations where there was a high amount of pollution and, subsequently, a lower pH (2005). The urban ecosystem, therefore, with its high pollution, could potentially contain calcium deficient soils.

Calcium is essential to many living organisms as part of the food web and deficiencies could have many effects. The food web is an interconnected relationship where all species, including humans, interact with one another (Faeth et al. 2005). Insectivorous and granivorous (seed eating) birds require calcium-rich material for eggshell formation in addition to their normal foods (Graveland and Van Gijzen 1994). The calcium is provided by woodlice (Isopoda), millipedes (Diplopoda), and snails. Though tits and pipits use mainly snail shells as their source of calcium; flycatchers, wren and robins consume woodlice and millipedes (Bures and Weidinge 2003). A study done by J.Graveland and R. van der Wal revealed that calcium deficiency in soils effected snail abundance resulting in a low reproductive success in tits (1996). The study showed that birds that lacked calcium resulted in egg shell defects. Pete Marra of the Smithsonian Environmental Research Center (SERC) observed that birds in an urban ecosystem have thinner egg shells than birds in the rural counterparts.

Soil inveterbrates could potentially be an indicator of calcium content in soils. Snails, slugs, woodlice and millipedes favor soils high in calcium (Lavellle et al. 2001), because they use the calcium to develop their exoskeleton. Abundance of these soil invertebrates has been shown to be affected by the levels of calcium. Snail density has declined on calcium-poor soils over two decades but not on calcium-rich soils (Graveland 1996). Earthworms contain around 50% more calcium, nitrogen, phosphorus, potassium and bacteria than the surrounding soil and have three glands that secrete calcium carbonate ($CaCO_3$) naturally (Nardi 2003). It was also shown in a study conducted by Katalin Szlavecz earthworm density and biomass were approximately eight times higher in urban areas compared to rural areas. Though the relationship between calcium and soil invertebrates is well documented, extensive research of calcium content in these soils is limited.

Calcium concentration can be altered due to individual management of land. Lime is a compound of calcium or calcium and magnesium capable of counteracting the harmful effects of an acid soil on lawn grasses (Collier 1984). Of the three types of lime, ground limestone and calcic limestone ($CaCO_3$), almost pure calcium carbonate, is used 95% of the time in the United States (Collier 1984).

Calcium is also released by sources in urban ecosystems such as atmospheric deposition and infrastructure (roads, buildings, sidewalks). In cities where construction is a daily event, airborne particulate matter resulting from building implosion composes of 57% calcium (Beck et al. 2003). Deposition of atmospheric particles represents another important source of pollutants and nutrients in urban areas. In a study conducted by Richard Pouyat (2000), water-extractable dust deposition was higher in calcium in urban sites, and as distance from the city increased the concentration of calcium decreased. Although sources for calcium are known in these urban sites, there is no data relating the high levels of calcium from the atmosphere and infrastructure to the level of calcium in soils in residential neighborhoods.

The purpose of this experiment was to determine if calcium varied regionally along an urban to rural gradient and/or locally within yard patches, and to determine if macro-invertebrate abundances vary with calcium and/or along an urban to rural gradient.

MATERIALS AND METHODS

The study was conducted from June 4th – August 12th 2005.

Site Selection

All sites were part of an ongoing volunteer citizen science program called Neighborhood Nestwatch that is operated through the Smithsonian Environmental Research Center (SERC) in Edgewater, MD. A sub sample of sites used by Roukes (in press 2005) to measure lead concentration in birds along an urban to rural gradient was used. The sites were chosen out of a pool of over 200 households in Maryland, Washington D.C. and Virginia.

The urban-rural land use gradient was categorized into based on population density (number of individuals per square mile-U.S. Census Bureau 2000) and put into four land use types: Eight sites Inner Urban (>8,000); Four sites Outer Urban (8,000 – 2,000); Four sites Suburban (2,000 – 300); and Seven Rural (< 300).

General Yard Layout

Earthworm Extraction

25 X 25cm quadrats were sampled at three different yard patches (front, back and road) per site. A record of site characteristics including soil moisture, soil temperature, leaf litter depth, and slope were taken. Each quadrat was cleared of debris, leaf litter and plants. If leaf litter was thick, it was checked for earthworms and other insects

and arthropods before clearing. Two gallons of 0.05% formalin solution was prepared using 1/2 snap cap vial of formaldehyde added to each gallon of water. The formalin was slowly poured onto the ground to avoid runoff. The earthworms were collected and placed into a zip-lock bag filled with clean water. After two gallons were poured and earthworm collection was finished, leaf litter and debris were returned to the surface. Earthworms were counted and weighed. Earthworms were killed in 80% ethanol and preserved in 4% formalin solution. Earthworm biomass was analyzed along the land use gradient.

Soil Arthropod Collection

At each yard patch arthropods were collected in plastic or glass containers. After 30 minutes, collection ceased, containers were labeled with quadrat number and put into a cooler. Arthropods were later separated and categorized by functional group (detritivores, carnivores, etc). The number of individuals for each functional group was recorded and the samples were then frozen. Arthropod abundance along the land use gradient was analyzed.

Soil Sampling

Soil samples were taken using a stainless steel sampling probe at five different yard patches (front lawn, back lawn, and three quadrats) using a zigzag pattern. Approximately 15-20 soil cores were taken at 0-10cm depth. Soil was stored in a paper bag, labeled with the date, address and patch type or quadrat number. Patch area was measured using a wheel device. A "footprint" of the house was also measured. Samples were stored at the lab and remained in the bag until dry. Soil was also taken at all locations to measure pH. pH was measured using a pH meter. Calcium concentrations were determined along the land use gradient using a plasma mass spectrometer.

RESULTS

Calcium varied significantly across the land use gradient. The largest value of calcium concentrations was found in the suburban sites; 479.7g/kg (figure 1). The calcium concentration value in inner urban sites was 280.9g/kg, outer urban 187.5g/kg and rural 185.5g/kg.

Calcium varied between the five site patches but the results are not significant (ANOVA $p>0.05$) (figure 2). The concentration of calcium was highest at the road patch and lowest in the back lawn.

Of all the isopods collected, 47% were in inner urban areas, 25% in rural, 16% in outer urban and 12% in suburban (figure3). Of the total amount of arthropods found, 40% were found in inner urban areas, 27% in rural, 20% in inner urban and 13% in suburban (figure 4). Thirty five percent of the millipedes were found in outer urban areas, 28% in inner urban, 26% in rural and 11% in suburban (figure 5).

Earthworms were found in all land use types and there is no significant difference in biomass between them. The biomass was largest in the rural sites; 69.33g/m^2, next in suburban sites; 38.92g/m^2, outer urban; 33.92g/m^2, and inner urban; 21.97g/ m^2 (figure 6).

DISCUSSION

With respect to the variations along the land use gradient, I had expected to see the highest amount of calcium in the urban areas as past studies had shown for certain forested patches. The variation shows the highest amount of calcium in the suburban areas, though urban areas still show high levels of calcium. Very few of the residents I talked with lime their property and as a result addition of calcium via management with lime was ruled out. (It should be noted that this was not a random sample and all of the residential sites are part of the Neighborhood

Nestwatch program. A study including samples at random residential sites is needed). Within these residential areas, however, there are differences from past studies. The high levels of calcium might be explained by higher amounts of salting in these areas as compared to others. Patch variation shows that calcium is highest at the road patch which is what I would expect if salting played a role. However, the findings in patch variation are not significant so no definitive conclusions can be made. The variations shown, though, indicate that something more is affecting calcium levels than regional and/or local patterns of deposition.

Isopods were found in the highest abundance in inner urban areas which is consistent with other data. I observed isopods in inner urban areas along concrete sidewalks and on concrete stairs yet there was no significant correlation with calcium. Isopods may still be affected by levels of calcium as the levels in all four land use types may have been higher than the level that would indicate.

Earthworms, millipedes, and all arthropods show no significant difference along the land use gradient. The earthworms were collected early in the season so certain species that mature and grow large would not have when they were collected. This might have had an impact on the data if they were collected later. Earthworms are a known food source for certain birds, and though egg shells were found to be thin in these urban areas, there is no indication that there is a lack of calcium or earthworms. Lead levels have also been found to be high in urban areas and it is possible that this is where the problem is. Millipedes and other arthropods do not show a significant response to the environmental differences along the land use gradient supporting the idea that their habitat similarity plays a more important role.

ACKNOWLEDGEMENTS

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APPENDIX

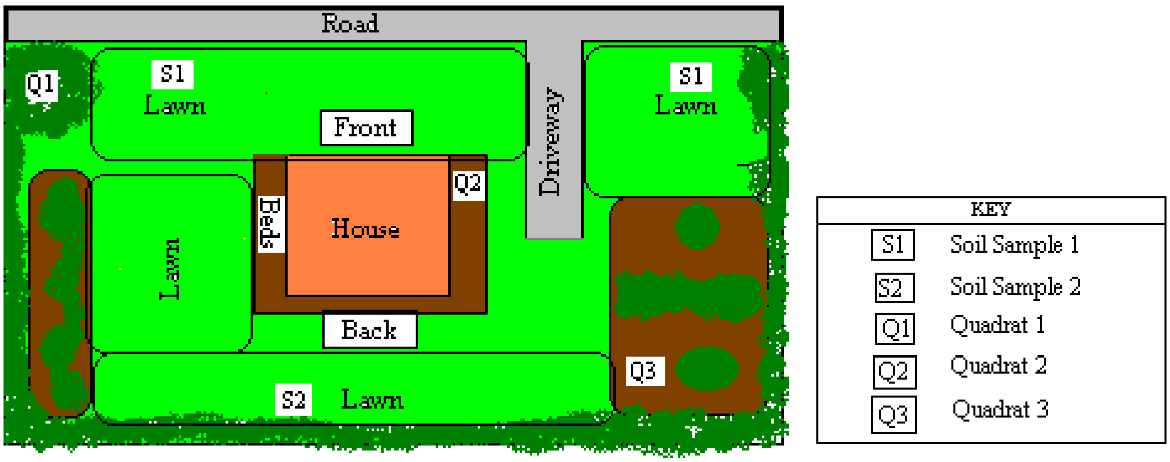

FIGURE 1: General Yard Layout and Patch Delineation and Definition

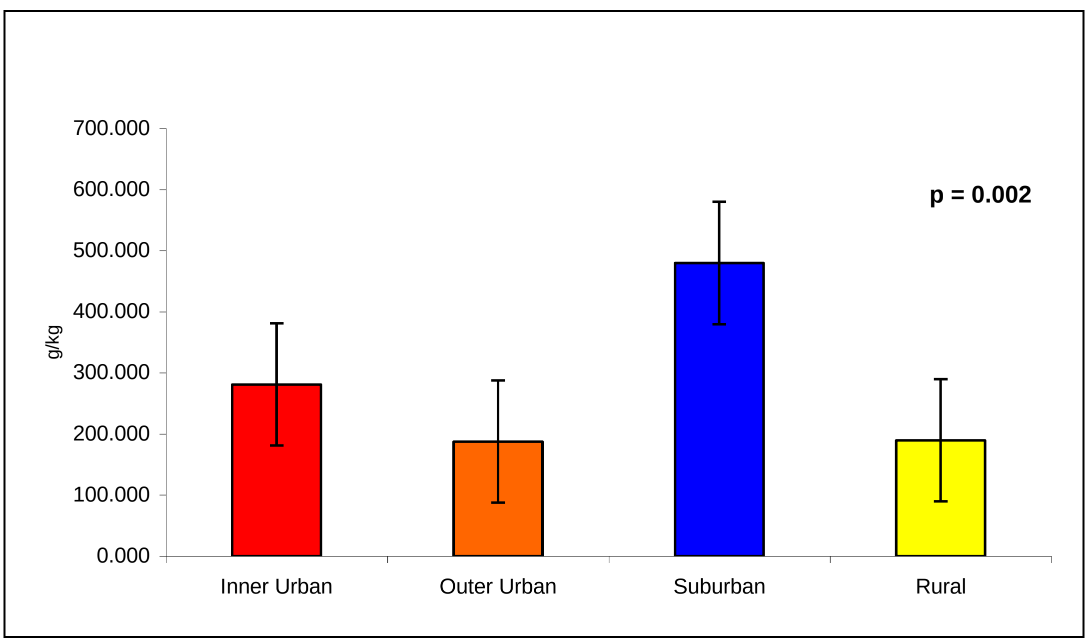

FIGURE 2: Calcium Variation by Land Use

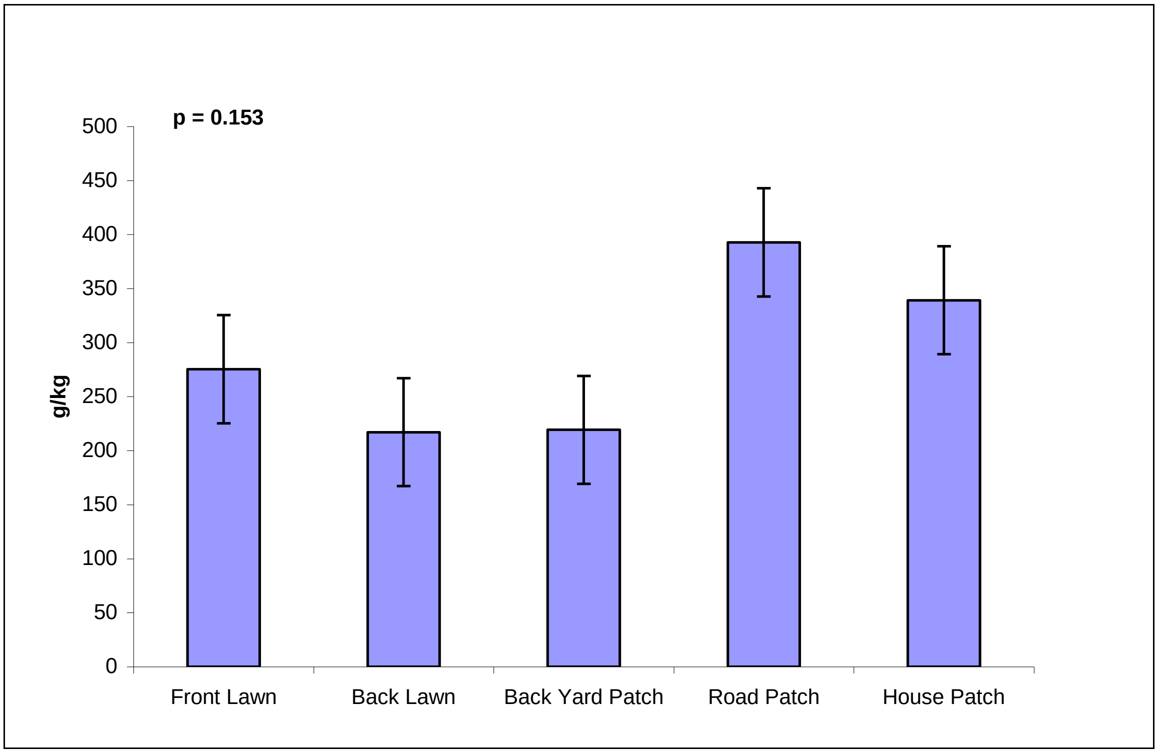

FIGURE 3: Local calcium variation

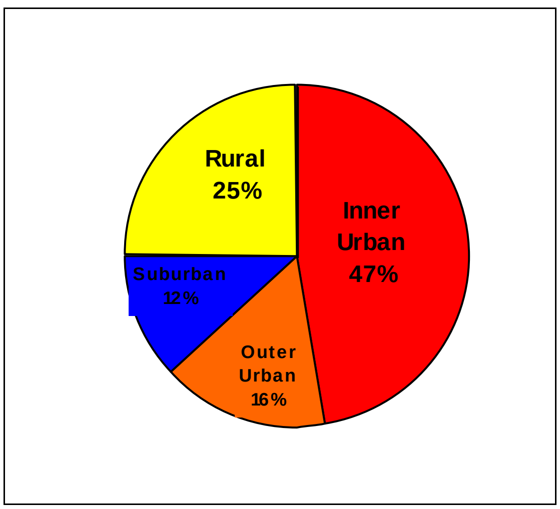

FIGURE 4: Percent Isopod Abundance by Land Use

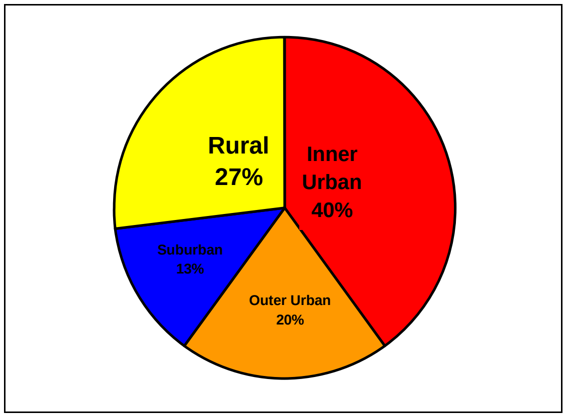

FIGURE 5: Percent Arthropod Abundance by Land Use

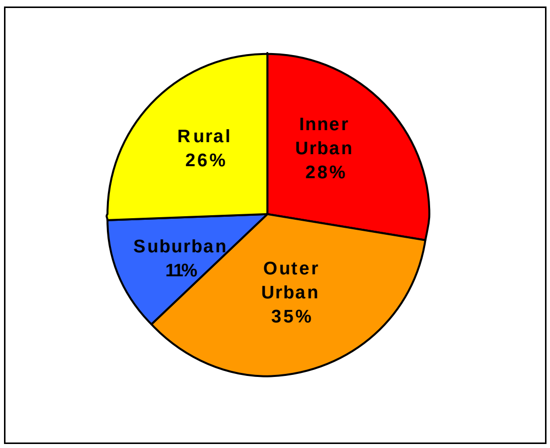

FIGURE 6: Percent Millipede Abundance by Land Use

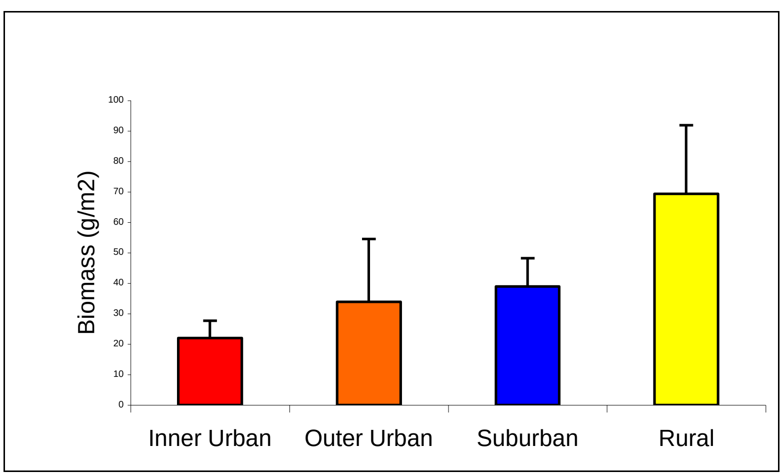

FIGURE 7: Mean Earthworm Biomass