# Earthworm Abundance and Carbon Cycling: Relationships in Northern Glacial Topography and Earthworm Species Type

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## Abstract

Invasive European earthworm colonization in the Northern United States has a detrimental effect on forest ecology by decreasing overall species diversity. The earthworm behaviors that cause this ecosystem decline are viewed beneficially in an agricultural context, and lead to a discrepancy in the anthropogenic consideration of earthworm effects. We studied the impact of topographical and vegetative cover type properties according to glacial geography on the population size of invasive earthworms at the University of Michigan Biological Station by conducting field surveys of earthworm abundance. A Wilcoxon t-test showed significant differences between the mean population count of earthworms at moraine and outwash locations, while linear regression indicated that soil temperature at a depth of 5cm was the strongest predictor of earthworm abundance. We also studied the carbon cycling of two earthworm species, *Lumbricus terrestris* and *Eisenia fetida*, within controlled terrariums. The earthworm terrariums demonstrated significantly higher soil carbon content that the control, confirmed by a single sample t-test. These findings support our assumption that invasive European earthworms are highly efficient carbon recyclers, and that their environmental distribution is impacted by topographical characteristics.

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## Abstract

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## Introduction

Endemic earthworms were extirpated from the Great Lakes region during the last ice age. All modern earthworms found in the Great Lakes region belong to invasive European species introduced to the area over the last five centuries (Tiunov *et al.*, 2006). Despite increasingly ubiquity throughout the Northeastern United States, earthworm activity is extremely detrimental to forest ecosystems, and has a massive impact on community structure and biodiversity (Frelich *et al.*, 2006). As concern for the preservation of Northern forest types grows, controlling the expansion of invasive earthworms throughout the Great Lakes region will be a major factor in natural resource policy and management (Hendrix & Bohlen, 2002).

Conventional perception views earthworms as beneficial environmental agents due to their extreme utility in agriculture. As highly efficient decomposers, earthworms are capable of bringing nutrients and soil organic matter to many different levels of the soil strata, and their castings influence soil aggregate formation and increase bulk density. (Sharma *et al.*, 2017). These qualities are extremely desirable in agricultural because they improve tilth, allowing for easier seasonal cultivation and root drainage, and increase short-term levels of nitrogen, potassium, phosphorous, and other nutrients which promote crop yield (Bhat *et al.*, 2017; Gliessman & Engles, 2007). The agricultural benefits of earthworms are likely part of the reason that invasive earthworms have colonized the Great Lakes region so aggressively; the transport of agricultural matter between locations is a strong agent of the spread of earthworms (Bohlen *et al.*, 2004). The advantageous characteristics of earthworms that make them so agriculturally sought after are the same characteristics that confer a negative effect on forest ecosystems.

Earthworms facilitate nutrient cycling at a rate which is unconducive to ideal uptake by all members of a forest community. They mix organic and mineral soil horizons, resulting in increased nitrogen leeching and lowered availability of phosphorous when these resources are brought to areas inaccessible by native root systems (Tinuov *et al.*, 2006; Bohlen *et al.* 2004). This alteration of the natural resource distribution creates competitive advantages among certain species that can quickly decimate forest diversity. Understory that depend upon forest floor detritus eaten by earthworms may be particularly effected by these changes, experiencing rapid increases in mortality rate upon earthworm introduction (Bohlen *et al.*, 2004). Northern

**Figure 2**: Scatter Plot of Surface Temperature (°C) and Average Worm Count

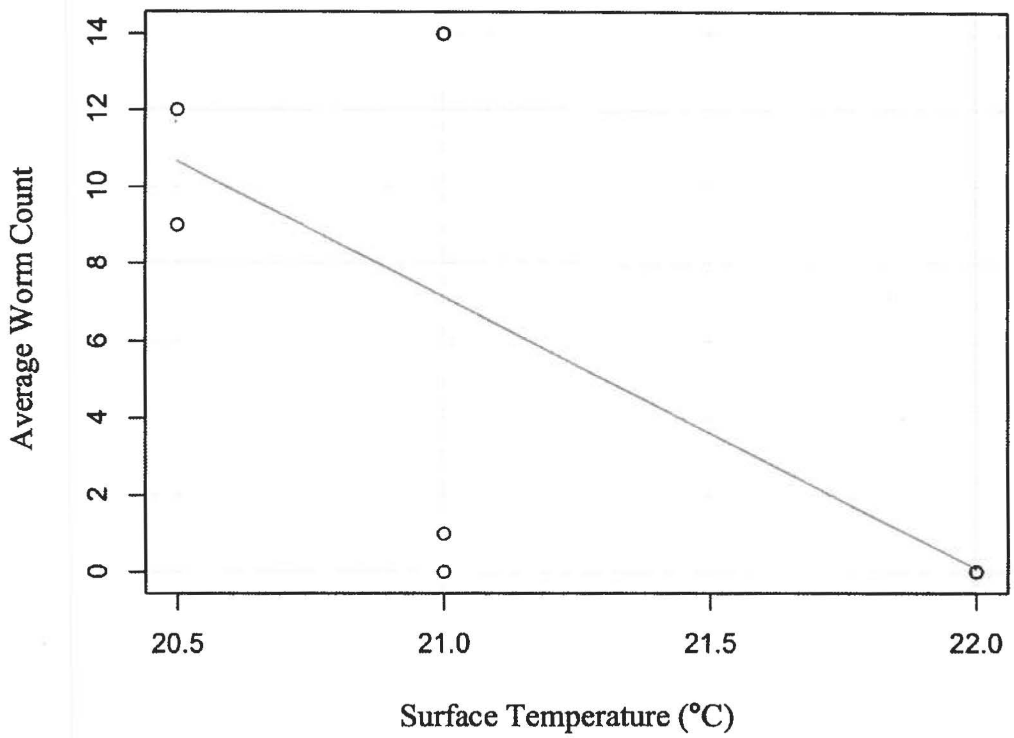
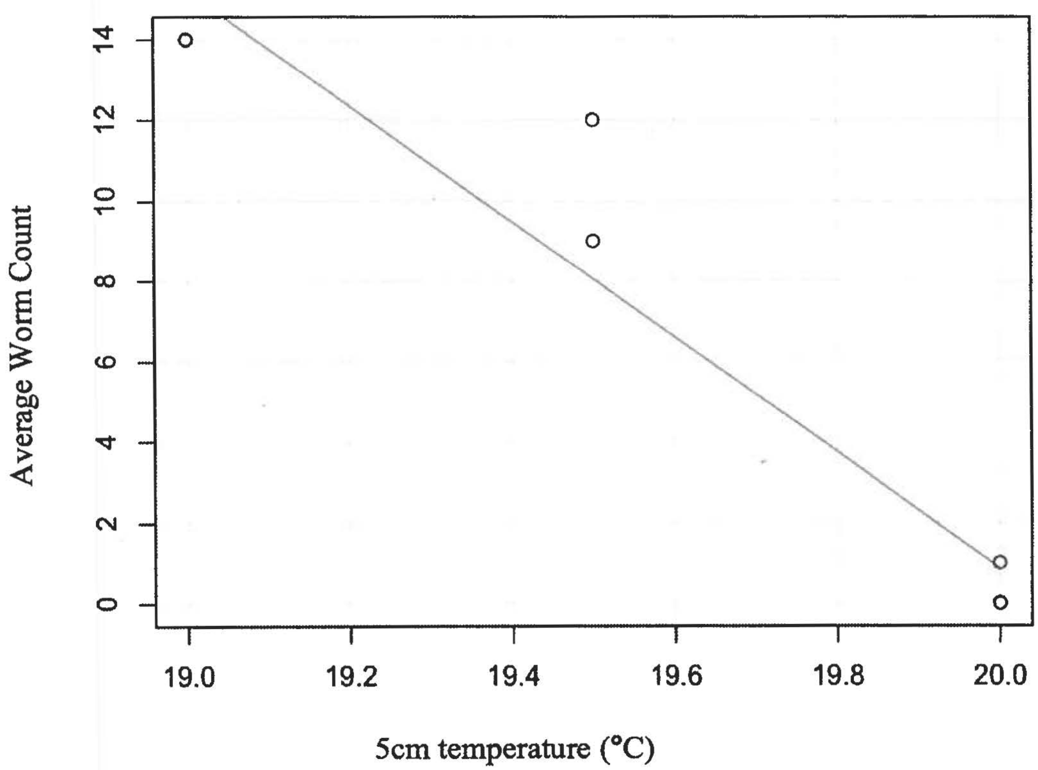



**Figure 3**: Scatter Plot of 5cm temperature (°C) and Average Worm Count



*Carbon Cycling*

The *Lumbricus terrestris* replicates had a mean carbon content of 6.445%, while the *Eisenia fetida* replicates had a mean carbon content of 7.195%. The control sample had a carbon content of 0.68%. The single sample t-test comparison of the population mean percent carbon of all worm replicates, 6.82%, to the 0.68 percent carbon value of the control resulted in a p-value of 0.0205, demonstrating a significant difference between the worm population mean percent carbon and the control value at an alpha level of 0.05. The paired t-test comparison of the difference in population mean percent carbon of the two worm species resulted in a p-value of 0.09271, demonstrating an insignificant difference in the population mean percent carbon of *Lumbricus terrestris* and *Eisenia fetida* at an alpha level of 0.05.

## Discussion

*Field Surveys*

Worm populations were significantly greater in both of the moraine locations than the outwash locations, suggesting a correlation between topographical characteristics and the extent of invasive earthworm colonization. The moraines were characterized by sandy loam soils and a pre-logging prevalence of hemlock (*Tsuga canadensis*) and Northern hardwoods, while the outwash locations possessed sandy soils and had a pre-logging prevalence of pines (*Pinus strobus, Pinus resinosa*), red oak (*Quercus rubra*), and hemlock (Tallant, 2017). Tiunov *et al.* noted that sandy acidic soil and pine presence discourage earthworm colonization, while hardwoods like sugar maple and loamy basic terrain promote their expansion (2006). Although our results confirm the cover type and soil trends observed in the Tiunov *et al.* study, they differ according to the relationship between pH levels and worm prevalence. Our second moraine location was the most acidic of all sites surveyed, exhibiting a pH level of 4.0, and also produced the greatest average number of worms. According to our linear regression, pH was thus a poor predictor of worm population sizes throughout our survey areas.

The strongest predictor of worm population size was the soil temperature at 5cm. Soil temperature at depth is highly influenced by ground cover and soil porosity, and could therefore be attributed to the differing plant communities and soil strata found between the moraine and outwash locations (Gliessman & Engles, 2007). Indeed, surface temperatures were lowest at the moraine locations, averaging 19.25 °C, and highest at the outwash locations with an average of 20 °C. Thicker ground cover in the moraine may shade the soil from absorbing sunlight, while the loamy soils retain water which raises the heat capacity of the soil (Fuchs). Tinuov *et al.* also noted the importance of temperature tolerance in determining which species are able to withstand environmental conditions found in the Northern United States (2006). Localized soil temperature differences may have a large impact in regulating earthworm colonization on UMBS property.

One determining factor of earthworm colonization that may be difficult to measure is the entry point and time of the foundational population members. Because earthworms move very slowly, their spread is extremely dependent on anthropogenic factors (Bohlen *et al.*, 2004). Although we did not examine human usage patterns near our survey sites in this experiment, they may have had a strong influence on localized population sizes. For example, our second moraine site exhibited the greatest average number of worms, and was located near a popular fishing site where bait such as earthworms may be frequently discarded.

*Carbon Cycling*

*Lumbricus terrestris* and *Eisenia fetida* lacked significant difference in the mean carbon content present in terrarium soils. This outcome was likely due to incomplete drying of terrarium samples before conducing carbon incineration, as residual water content in the samples would have altered the mass difference obtained from weighing the samples before and after burn off. The number of replicates used in our analysis was also low due to the contamination of one of the terrariums of both species during our sample preparations. Nonetheless, both species are active agents of carbon cycling. Due to the differences in epigeic and anecic worm species, we would expect *Lumbricus terrestris* to recycle carbon into deep soil strata at larger masses, while *Eisenia fetida* recycles large amounts of carbon close to the soil surface. Comparing the mean percent carbon recycled of the two species at particular soil depths in future experiments may lend greater resolution to this hypothesis, and may be a greater indicator of ecosystem niche than overall carbon content recycling.

Regardless of the differences between the two species, percent carbon present in the worm terrariums overall was significantly higher than the control. This result supports the paradigm that worms are strong agents of increasing soil organic matter. While these species may be appropriately coveted for their benefit to agriculture, such aggressive carbon cycling throughout the soil strata can be hugely detrimental to forest species unequipped to handle such rapid resource variation.

*Conclusion*

Localized variations in earthworm population sizes can be attributed to a wide variety of factors that interact complexly within forest ecosystems. Subsurface soil temperature is good predictor of how these factors ultimately impact earthworm distribution, and analyzing causal factors of soil temperature like ground cover and soil water retention will give us insight into the ongoing expanse of invasive earthworm colonization. Earthworms are keystone regulators of carbon and nutrient levels, and understanding the breadth of this impact on forest ecosystem diversity will be instrumental in weighing their agricultural benefit with negative impacts in policy and management.

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