Do Invasive Earthworms Impact Water Quality?

NRCA Student: Ben Vermilyea[1]

Community Partners: James Fischer[2] and John Markelon[1]

[1]Litchfield High School; [2]The White Memorial Conservation Center, Inc.

ABSTRACT

Introduced earthworms have been implicated in changing several ecological processes that impact northern forest ecosystems. We explored the impact that introduced earthworms are having on forest soils along two headwater streams; one streambank exhibited a heavy invasion of earthworms while the other did not. We measured earthworm abundance, soil bulk density, water percolation at soil surface, soil erosion along the stream banks, and water chemistry parameters (dissolved oxygen and conductivity). In the invaded streambank, we observed significantly more earthworms and significantly higher bulk density. We did not observe any significant differences between the two streambanks in the remainder of assessments. We explored how many potential samples would be needed to observe a statistically significant pattern by performing a power analysis. Although we did not observe significant patterns that indicate how earthworms contribute to water quality disturbance, our power analysis suggests that it may be feasible to detect significant differences by increasing our sample size.

INTRODUCTION

Introduced earthworms are changing the soil conditions of northern forest of North America (Bohlen et al., 2004). Connecticut earthworms are primarily introduced species that are endemic to Europe and Asia (Reynolds, 1973). Earthworms are often attributed with changing the structure of forest soils by consuming the leaf litter layer and incorporating subsoil (a.k.a. mineral) layers, thereby increasing the soil's bulk density (Wironen and Moore, 2006). Soil bulk density is a measurement of soil compaction or, rather, the amount of space between soil particles. Higher bulk density means there is less space for air or water to occupy, thereby decreasing water percolation and increasing water run-off along the soil surface (Douglas and Crawford, 1993). Increased water run-off near watercourses and waterbodies could increase the impacts of soil erosion and thereby decrease water quality.

Measuring soil erosion and water run-off are challenging to quantify. Traditionally, Gerlach Troughs are used for these measurements but are expensive to replicate (Larson et al., 2012). We developed a novel method that is inexpensive and seems easy to replicate after our initial trial.

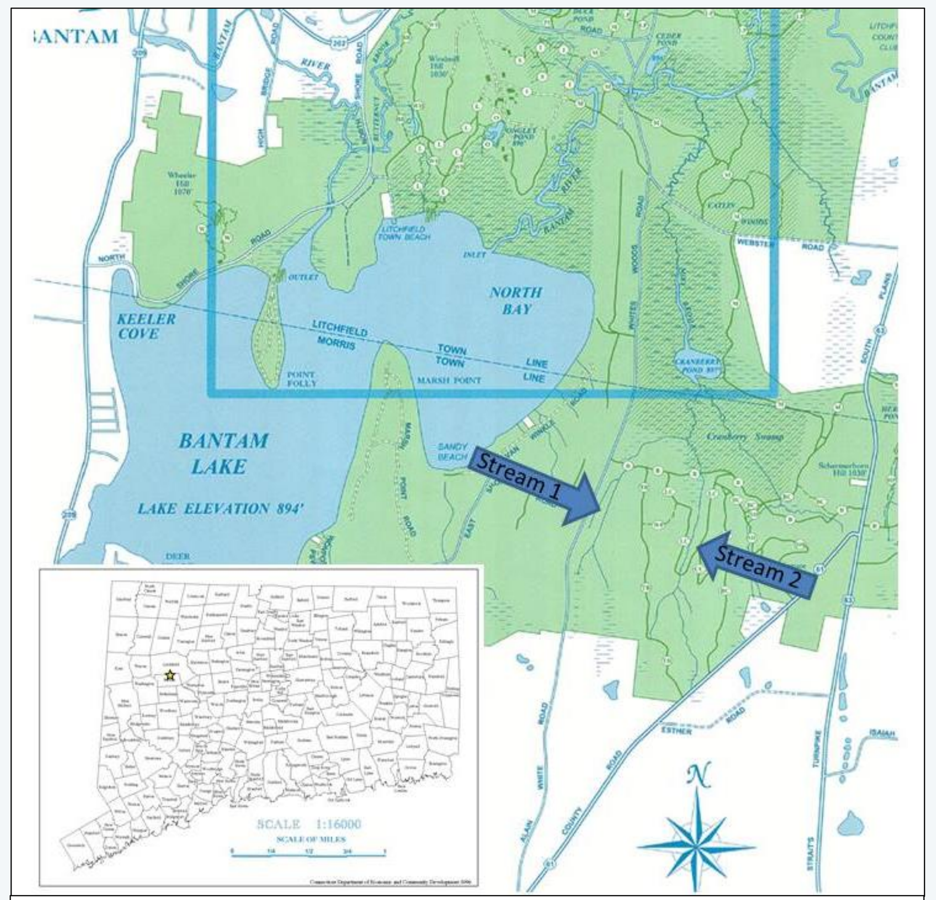

Figure 1: Map of the two streams and surrounding area.

Figure 2: Mixing mustard solution.

Figure 3: Hammocks installed on the bank of stream one.

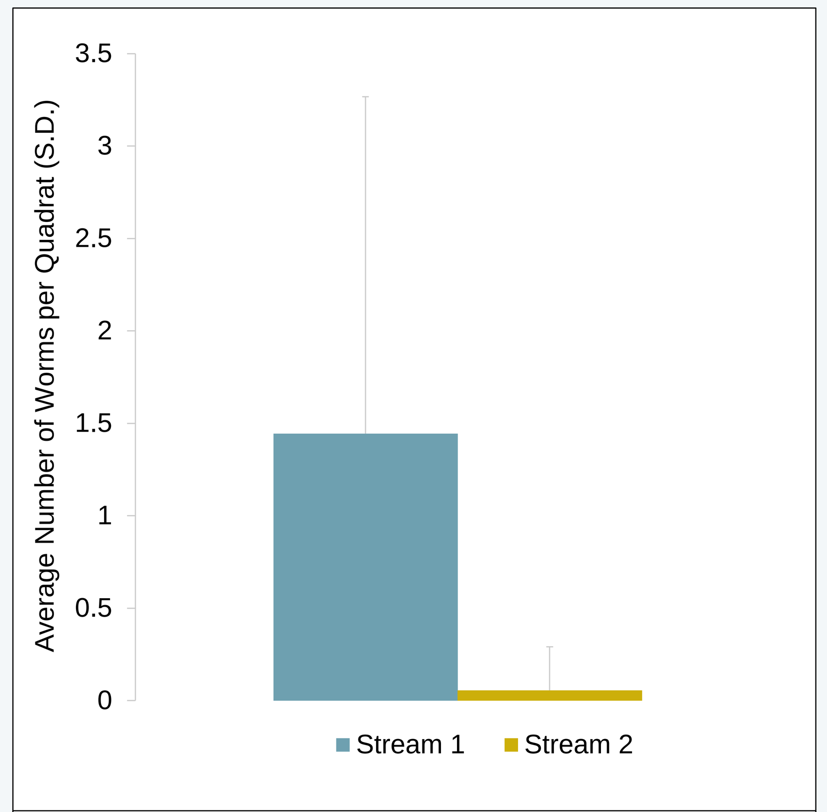

Figure 4: The number of earthworms collected at each site.

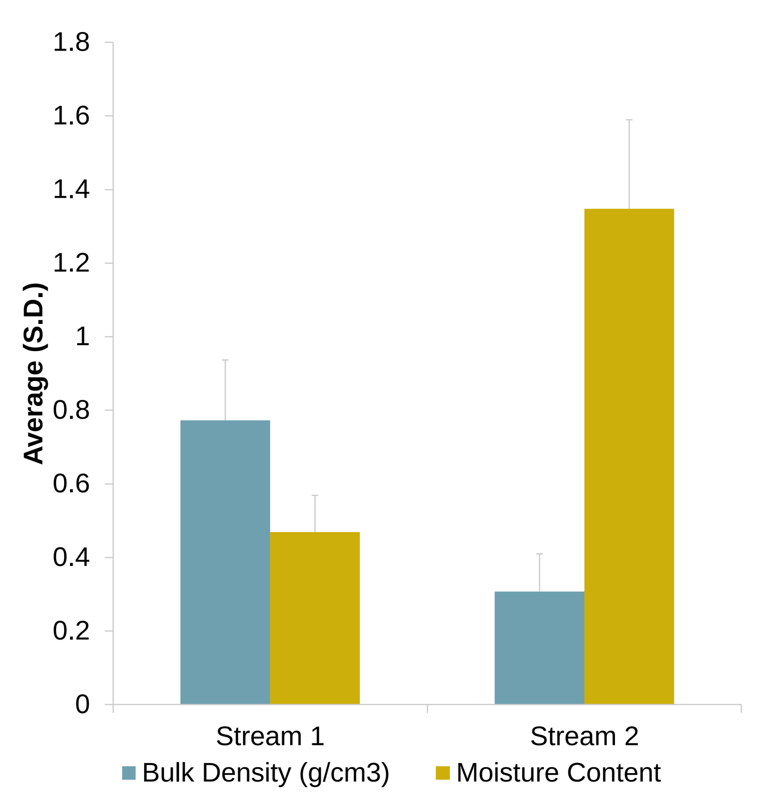

Figure 5: Soil parameters along the two headwater streams

MATERIAL AND METHODS

Study Area

- A total of two intermittent headwater streams were selected and located south of Cranberry Pond in White Memorial Foundation, Morris, Litchfield Co., CT (Fig.1).
- The tree canopy consisted mainly of sugar maple *(Acer saccharum)*, red maple *(Acer rubrum)*, northern red oak (*Quercus rubra*), yellow birch (*Betula alleghaniensis*) and some eastern white pine *(Pinus strobus)*.
- Prior sampling indicated that one of the stream banks is populated by invasive earthworms, and the understory consisted mostly of Japanese barberry (*Berberis thunbergii*), multi-flora rose (*Rosa multiflora*), winged euonymus (*Euonymus alatus*), and goutweed (*Aegopodium podagraria*). Along the second stream, few worms and little evidence of their presence was detected compared to the other stream; here the understory consisted of ferns (Pteridophyta), goldthread *(Coptis trifolia)*, and many tree seedlings associated with the canopy species.

Data Collection Protocol and Analysis

- A total of six primary sampling sites located 20 meters apart and parallel to each stream. All further samplings were collected within 5 meters of the streambank. All data were collected between September and early December 2015.
- Worms were counted and collected for a total of three samples at each sample site by pouring a mixture of 40 g of ground yellow mustard mixed with 3.79 l of water within a 0.25 m^2 frame (Fig. 2).
- A total of three O-horizon samples were collected at each sample site to calculate bulk density and soil moisture. We collected a soil sample by inserting a PVC collar with a diameter of 5.08 cm and 7.09 cm long. Samples were massed prior to drying and then massed again. Bulk density is the dry weight of the sample divided by the sample volume. The difference of the wet and dry weights of the soil samples calculates soil moisture.
- A total of twelve surface soil percolation tests were measured on both streams. Percolation was tested by inserting a PVC pipe measuring 58.0 cm in length and 10.16 cm in diameter into the ground 5.0 cm, pouring 3.79 l of water, and immediately timing how much water was displaced in 15 min. or we recorded the time when the volume was completely drained.
- Dissolved oxygen in water was measured using the modified Winkler method with a LaMotte Dissolve Oxygen Test Kit #5860-01 (LaMotte Company, Chestertown, MD).
- Water conductivity was measured with a Vernier Conductivity Probe (Vernier Software & Technology, Beaverton, OR).
- Cloth hammocks were used to collect sediment runoff after rain storms. Each hammock consisted of white polyester Georgette measuring 0.41 x 0.15 m and were attached to bamboo rods with stainless steel safety pins and stuck into the stream bed along the edge of the streambank. Hammocks were weighed prior to installation and after the precipitation event to the nearest 0.01 g after drying (Fig. 3).
- Student t-test and other data analyses were performed using Microsoft Excel 2010.

ACKNOWLEDGEMENTS

Thank you to James Fischer from White Memorial for the countless hours that he spent working on this project with me. Thank you to John Markelon from Litchfield High School for providing materials needed for the completion of this project and for first introducing me to NRCA. Thank you to Laura Cisneros of UCONN/NRCA for her support of this project. Thank you to my parents for providing me with the transportation back and forth and for motivating me to complete the field experience and the community project.

RESULTS

- There were significantly more worms observed along Stream 1 than Stream 2 (p-value = 0.0025, t-stat = 3.2071) (Fig. 4).

Soil Parameters: Bulk Density, Percent Moisture, & Percolation

- The soils along Stream 1 had a significantly higher bulk density than along Stream 2 (p-value = 4.9 * x^{11}, t-stat = 10.2015) (Fig. 5).
- The soils along Stream 2 contained a greater percentage of moisture than in Stream 1 (p-value = 9.11 * x^{13}, t-stat = 14.2344) (Fig. 5).
- There was no significant difference observed between the stream soils percolation tests (p-value = 0.3374, t-stat = 0.4321).

Soil Erosion

- The amount of soil erosion along both streams was not significantly different after both rain events; first rain event (p-value = 0.1049, t-stat = 1.2965), second rain event (p-value = 0.2938, t-stat = 0.5476) or when we combined the measurements (p-value = 0.2402, t-stat = 0.7110) (Fig. 6).
- Power analysis conducted post hoc inferred that we would need 441 samples (power = 0.8) to observe a significant difference between streams using the combined measurements (Fig. 7).

Water Chemistry

- Dissolved Oxygen was observed as 9.8 and 9.4 mg/l in the invaded versus the native streambanks, respectively.
- Conductivity averaged 176.15 μS (S.D. = 40.23, n = 2) in the stream invaded by earthworms versus the naïve streambank, which averaged 168.00 μS (S.D. = 1.27, n = 2).

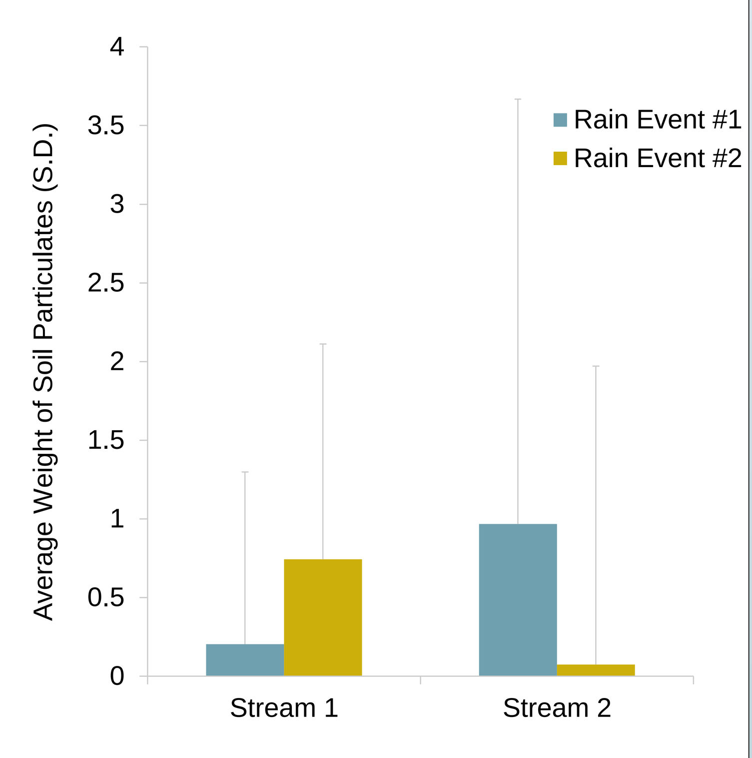

Figure 6: The weight of the soil particulates collected in the hammocks.

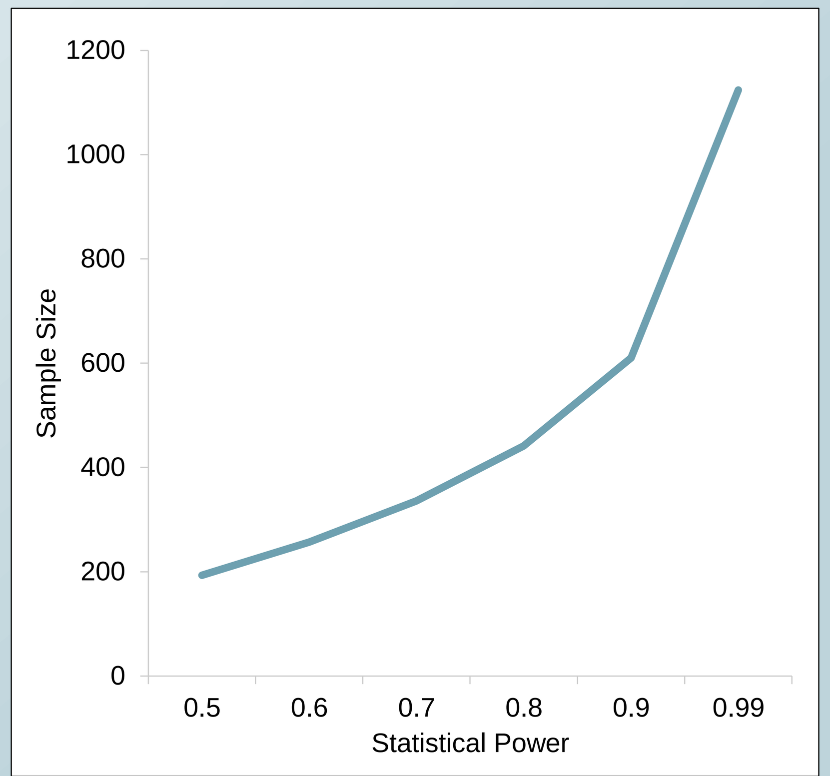

Figure 7: Power analysis was used to estimate a sample size needed .

CONCLUSIONS

Earthworm density inhabiting the streambanks of these two headwater streams was different. Introduced earthworms compacted the forest soils and changed the soil moisture content near these headwater streams. Although we did not observe significant differences between soil erosion caused by changes in run-off, our power analysis suggests that we might observe significant results if we had a larger sample size. We feel that this sampling effort is achievable and will explore this in future projects. We have not thoroughly tested the hammock method. Future work is needed to calibrate this technique, including, for example, measuring the amount of area that is effectively sampled by each hammock replicate.

Although we did not observe any differences in water chemistry parameters between the streams, land use near each stream could influence the water chemistry (Corsi et al., 2010). A municipal road parallels the earthworm invaded stream and conductivity could be impacted by repetitive annual applications of road salt each winter. Future projects will need to account for differences in land use practices near streams while exploring the impact of non-native earthworms on water quality parameters.

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