EARTHWORMS IN FORESTS

Produced jointly by:
University of Vermont &
Vermont Department of Forests, Parks & Recreation
With support from:
Northeastern States Research Cooperative

Where Are They From?

All earthworms in Vermont are non-native.

Approximately 12,000 years ago the state of Vermont was covered by glacial ice. This event removed any native earthworms which may have evolved with our forests.

Earthworms were inadvertently imported with soil and plant materials from Europe and Asia. They have continued to be imported purposefully as fishing bait and for use in gardens and composting.

Earthworms have been spread across the landscape in waterways and by the movement of plants, soil, and compost due to human agricultural and horticultural practices.

Many forests converted from agriculture have residual earthworm populations. Forests without this land use history, such as forests at higher elevations, developed without earthworm populations and so are at the most risk for change with invasion.

Earthworms feed on organic matter and are capable of altering soil chemistry and the physical and microbial environment of soils.

Earthworms in forests can be detrimental to plant growth.

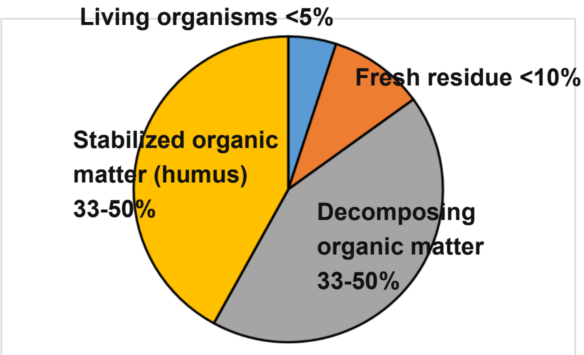
Earthworms abundant

Earthworm feeding eliminates the soil organic layer essential to understory vegetation.

Earthworms absent

Without earthworms abundant soil organic layer supports growth of understory vegetation.

Forest Floor Organic Matter



The forest floor includes a layer of organic matter in different stages of decomposition. Without earthworms, the proportions might be similar to this graph.

Survey Results

Studies at the University of Vermont have included statewide surveys to learn what species are present and where they are found. Earthworms in Vermont are typically found in hardwood forests where the leaf litter is more digestible than the waxy needles and acidic soils of conifer forests. Some species of epigeic earthworms have been noted in coniferous forests, but this is a rare occurrence.

Surveying for earthworms in forest soils

Earthworm Identification

Groupings Based on Feeding Behavior

Epigeic: earthworms live and feed on the forest floor, rarely burrowing into mineral soil, contributing minimally to soil aggregation. These species are very small, dark in color, and are often the first to appear at the beginning of an invasion event.

Endogeic: earthworms found mainly in the mineral layers of the soil. They are largely responsible for soil aggregation due to their consumption of organics associated with mineral soils. These species are small to medium in size and, because they live underground in mineral soil horizons, are non-pigmented, appearing light pink or gray.

Epi-Endogeic: earthworms feed on the forest floor and organic rich mineral soils, and mix the organic and mineral horizons. These species are usually medium in size and due to their size and feeding activity can significantly affect forests. These species are typically pigmented, but may not be as dark as the small epigeic species.

Anecic: earthworms make deep, vertical burrows. They take organic matter from the forest floor and pull it deep into their burrows, burying organic matter in the subsoil. They are pigmented, quite large, and may plug their burrows with partially digested leaf material making small piles on the soil surface.

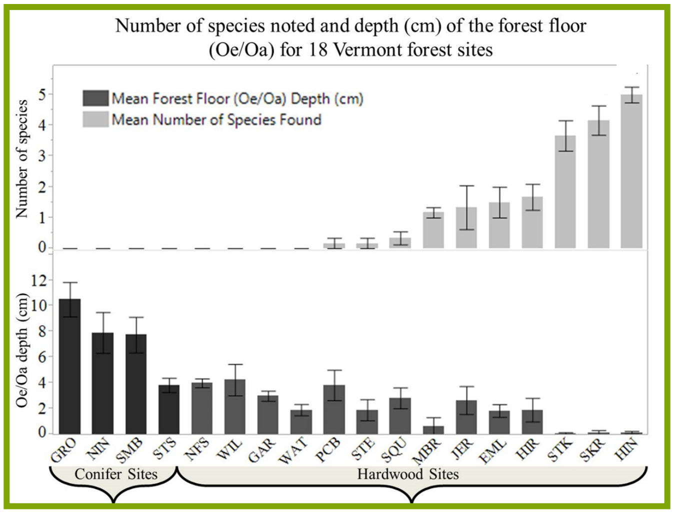
Earthworm Species Now Found in Vermont

Epigeic Worms	Epi-endogeic species	Endogeic species	Anecic worms
Dendrobaena octaedra *Dendrodrilus rubidus* *Lumbricus festivus* *Lumbricus castaneus* *(Eisenia foetida)* *(Perionyx excavates)*	*Lumbricus rubellus* *Amynthas agrestis* *(Amynthas tokyoensis)* *(Amynthas hilgendorfi)*	*Apportectodea tuberculate* *Apporectodea rosea* *Apporectodea longa* *Apporectodea turgida* *Apporectodea trapezoids* *Octolaseon cyaneum* *Octolaseon tyrtaeum* *Allobophora chlorotica*	*Lumbricus terrestris*

Species in parentheses are present in Vermont, but were not found in our 2012-2014 forest survey.

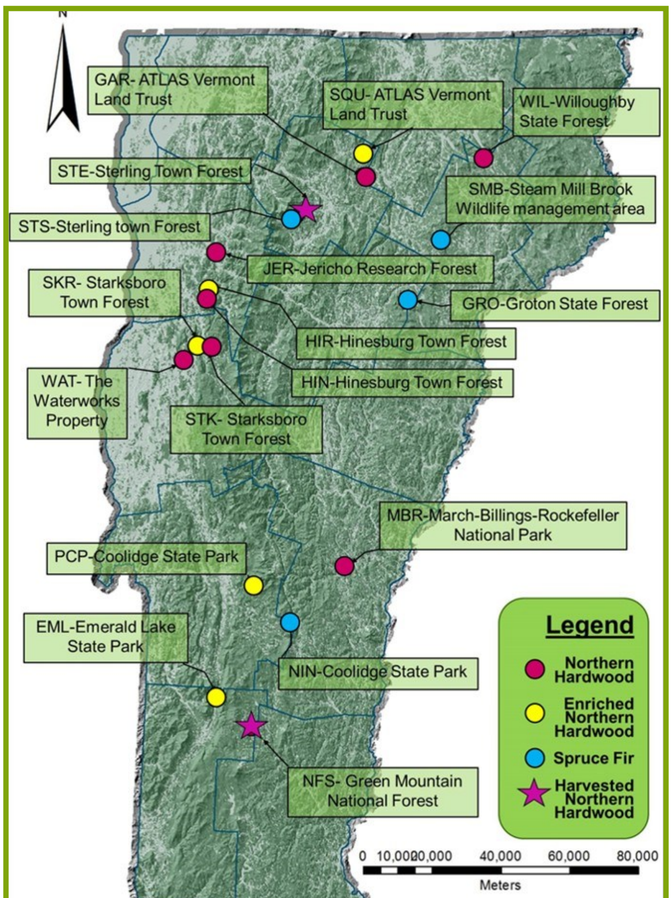
Research Findings

Sites with the highest worm density and species richness had a history of agricultural land use.



Earthworm presence in northern forests: impact on distribution of soil carbon within aggregate fractions' M.E. Knowles, PSS, UVM, 2015.

Study sites with many earthworm species had smaller amounts of organic matter on the forest floor.



Sites of earthworm and soil carbon study.

Earthworm Study

A survey of earthworm invasions into forests found 15 species present (see previous page). An additional 4 (listed in parentheses) are known to occur in Vermont but were not found during this survey. At 18 study locations (see map at lower left), counts of earthworms were made along with measures of soil organic matter and mineral soil carbon. Land use histories were used to match earthworm survey results with information about past agricultural uses.

Earthworm presence is extensive across Vermont forests. Sites with high earthworm diversity have reduced forest floor depth (soil organic layers) and higher mineral soil carbon (organic matter moved deeper in soil).

Forest Impacts

The forest floor is the medium in which native seedlings germinate and grow. Earthworms disrupt this fertile seedbed and make forests more prone to invasion by non-native plant species, which often inhabit disturbed soils. Unlike garden soils, forest soils are part of the natural ecosystem and serve many functions that depend on a diversity of soil organisms. As non-native animals, earthworms change many of these functions.

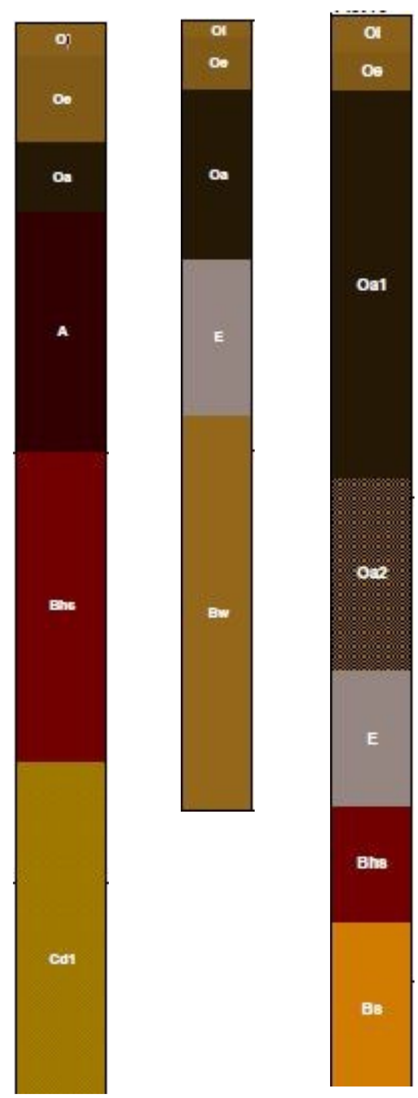
- Earthworms create less favorable soil conditions for plant regeneration and growth.
- Through feeding, earthworms reduce organic matter on the forest floor, replacing these organics with castings (coated digested excrements) which don't absorb water and lead to drier, warmer soil conditions, prone to erosion.
- Soil ingestion by earthworms creates changes in proportions of decay organisms (i.e. shifting from fungi to bacteria) impacting many decomposition processes.
- They reduce fungi populations, especially specialized fungi such as mycorrhizae that assist plants with water and nutrient absorption, resulting in poor soil health and reduced plant growth.
- As competitors, earthworms can reduce the presence of soil arthropods (e.g. insects).
- Earthworms bioaccumulate heavy metals and may introduce them into the forest food web affecting wildlife.

Soil Carbon Primer

Carbon that is fixed by plants as cellulose, starch, lignin or other organic compounds is transferred to the soil through dead plant matter, including dead roots, leaves, and trees. The amount of carbon in plant material can be substantial. For example, nearly half the dry weight of tree trunks is carbon. Soil organisms decompose dead plant material and carbon is respired back to the atmosphere as carbon dioxide or methane, depending on the availability of oxygen in the soil. Some carbon compounds easily digested by soil organisms are considered less stable forms of soil carbon which may be respired rapidly into the atmosphere. The structure of some organic compounds make it difficult for many soil organisms to obtain energy from them. This makes them less likely to be respired and more stable in soil. Carbon compounds may also bind tightly to mineral soils. This binding creates an environment where carbon may become physically inaccessible to microbial communities, stabilizing it regardless of its chemistry.

The carbon content of soil is a major factor in its overall health. Soil carbon improves the physical properties of soil. It increases the cation-exchange capacity (CEC) and water-holding capacity, especially in sandy soil, and it contributes to the structural stability of clay soils by helping to bind particles. Soil organic matter (SOM), of which carbon is a major part, holds a great proportion of nutrient cations and trace elements that are of importance to plant growth. SOM prevents nutrient leaching, and is integral to the organic acids that make minerals available to plants. It also buffers soil from strong changes in pH, and increases the moisture content of a soil.

Our Vermont forest soils have been affected by historical land use practices that have, in some areas, resulted in reduced soil carbon (SOC). Although exact quantities are difficult to measure, human activities have caused substantial losses of SOC. Many agricultural fields have been converted back to forests and , over time, forest soils are rebuilding carbon storage, but this is a slow process and replenishment is dependent on soil characteristics and activity of soil organisms, as well as forest management practices.



Soil profiles showing differences in depth of organic horizons (Oi, Oe, Oa).

Potential Role for Earthworms In Carbon Sequestration

Soil Carbon Changes Due to Earthworms

Carbon Loss

The forest floor, besides performing important ecosystem functions, accounts for a significant proportion of total forest soil carbon. Earthworm respiration alone does not account for much carbon loss from soil. Rather, earthworms increase the growth and respiration of decay organisms. Through soil mixing earthworms aerate the soil. Then decay organisms are exposed to fresh organic matter, and more carbon is emitted to the atmosphere in the process of decomposition.

Carbon Stabilization

In the earthworm gut, organic matter and mineral soil particles form aggregates called castings. Within these castings there are micro—and macro-aggregates. Aggregates are often very stable, and contain a high amount of the originally ingested organic matter. It has been found that this stable aggregation physically protects the carbon within, forming a stabilized pool of carbon in the soil.

Earthworm castings.

Earthworms ingest organic matter (carbon) on the forest floor and relocate that carbon to lower mineral horizons.

In the earthworm's gut, organic matter and mineral soil particles form aggregates.

Northern forests have the potential to sequester some of the carbon emitted by human activities. A large portion of forest carbon storage is belowground. Losses of carbon from past land use, especially those associated with tilled agriculture, have persisting negative effects on carbon stores. Due to this influence, much of the northern forest with a history of past agricultural use is experiencing a net gain in soil carbon. However, most studies document short term carbon losses after an earthworm invasion, primarily through the indirect impact earthworms have on the decomposition rates of these soils. Other research suggests that earthworm-created stable aggregates may reduce carbon losses through the long term physical protection of carbon, specifically within microaggregate (<250 μm) structures.

Regardless of the potential role of earthworms in carbon sequestration, they adversely affect soil structure, reduce organic matter, alter seed beds for regeneration, and negatively impact other forest processes.

Earthworm Impacts Summary

Reduce forest floor organic matter

Relocate carbon lower in soil profile

Reduce herbaceous layer

Alter seed bed

Change forest habitat structure, possibly affecting salamanders and birds

Alter soil temperature, moisture, and water filtration

Beware

Crazy snakeworms (*Amynthas species*) are particularly invasive. They are in the epi-geneic earthworm group and are reported to invade and consume organic matter rapidly.

Forest Management Tips

Earthworms are here to stay. Forest management planning should include strategies to minimize impacts on forest health.

Avoid practices that spread earthworms into untreated soil or compost. Not all forests have all species of earthworms, so minimizing the movement of soil from one location to another can reduce additional infestations. Nursery trees with root balls should be inspected before planting.

Be aware of signs that earthworms are present and affecting forest soils and forest health. Look for earthworm casts, diminished organic layer depth, or a forest devoid of understory plants. Forests near fishing areas may be especially vulnerable due to discarded earthworm bait.

Increase soil carbon by increasing the amount of organic matter on the forest floor. Leaving branches on the forest floor after a harvest is one way to stock up on organic matter.

Consider promoting tree species with deep taproots, especially on sites with low organic matter or sandy soils. Providing organic matter deeper in the soil may increase the amount of stable carbon for plant use.

Additional Resources

Vermont Soil Carbon Study: http://www.uvm.edu/~soilcrbn/
Vermont Invasive Pests: http://www.vtinvasives.org/
Soil Quality in Vermont http://fpr.vermont.gov/forest/ecosystem/soil_quality
Worm identification: http://www.nrri.umn.edu/worms/identification/index.html

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This project was supported by the Northeastern States Research Cooperative through funding made available by the USDA Forest Service. The conclusions and opinions in this paper are those of the authors and not of the NSRC, the Forest Service, or the USDA.

FPR -2016—01