Amynthas agrestis: Invasive Impacts on Forest Soils and Seedlings
Why did I do it?

• Public misconceptions
• Many unanswered questions
  • Are worms killing plants?
  • What are the soil chemistry changes?
  • What are the long-term effects?
  • What is the rate of spread?
  • What are the density effects? How much is too much?
• Need for applied field research on invasive species
A. *agrestis*— ‘Jumping Worms’

- Significant ecosystem impacts
  - Potential changes to soil properties
  - Increased litter decomposition
  - Reduction in micro-fauna
  - Produce large quantities of casting material that changes the physical, chemical, and biotic properties of the topsoil
Jumping Worms Taxonomy

- Previous understanding – primarily one species
  - *Amynthas agrestis*

- Closely-related complex
  - *Amynthas* group (primarily *A. agrestis* and *A. tokioensis*)
  - *Metaphire hilgendorfi* (Formerly *Amynthas hilgendorfi*)

- One or more species often found in close association

- Refer to *Amynthas/Metaphire* complex as jumping worms

- Common names: Snake worms, Alabama jumpers, crazy worms
States with confirmed jumping worm populations
Role in ecosystem

Jumping worms

Earthworms in the Ecosystem

Anecic
- Fresh litter feeder
- Soil dweller
- Pigmented skin
- Digs deep, vertical, unbranching burrows
- Large size

Epigeic
- Litter dweller, feeder
- No burrows
- Pigmented skin
- Small size

Endogeic
- Soil feeder
- Mineral soil dweller (0-50 cm)
- No skin pigmentation
- Creates a network of horizontal, branching burrows
- Small to medium-sized

Three major ecological groups of earthworms have been identified based on the feeding and burrowing behaviors of the different species.

Anecic burrows may reach depths up to two meters!
Soil signature
Past research on leaf litter

**Effects of non-native Asian earthworm invasion on temperate forest and prairie soils in the Midwestern US**

Jiangxiao Qiu and Monica G. Turner

**Table 1** Leaf litter and soil nutrient properties included in the study and the corresponding hypotheses regarding the effects of invasive Asian earthworms

<table>
<thead>
<tr>
<th>Response</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf litter</td>
<td></td>
</tr>
<tr>
<td>Litter cover (%)</td>
<td>-</td>
</tr>
<tr>
<td>Foliage litter mass (g/m²)</td>
<td>-</td>
</tr>
<tr>
<td>Litter depth (mm)</td>
<td>-</td>
</tr>
<tr>
<td>Soil nutrient pools</td>
<td></td>
</tr>
<tr>
<td>Soil organic matter (%)</td>
<td>+</td>
</tr>
<tr>
<td>Total C (%)</td>
<td>+</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>+</td>
</tr>
<tr>
<td>Total C:N ratio</td>
<td>+</td>
</tr>
<tr>
<td>Available P (ppm)</td>
<td>+</td>
</tr>
<tr>
<td>Nitrate (NO₃⁻) (mg N kg⁻¹soil)</td>
<td>+</td>
</tr>
<tr>
<td>Ammonium (NH₄⁺) (mg N kg⁻¹soil)</td>
<td>+</td>
</tr>
<tr>
<td>Dissolved organic C (mg C kg⁻¹soil)</td>
<td>+</td>
</tr>
</tbody>
</table>

Soil responses were measured at three depths from the surface (i.e., 0–5, 5–10 and 10–25 cm)

In the hypothesis column, “+” indicates expected positive and “−” negative effects of invasive earthworms
Research Questions

1) Do tree species mediate the effects of *Amynthas agrestis* on soil carbon and nutrient cycling, soil structure, and leaf litter decomposition rates?

2) Are *Amynthas agrestis* impacts on litter decomposition rates direct or indirect?

3) Do the above effects vary with *Amynthas agrestis* density?

4) What are the direct and indirect effects of *Amynthas agrestis* on tree seedling growth and survival?
Research Design: Density Impacts to Forest Soil Types

- 4 intact soil cores per forest type
- PVC cores 20 cm X 25 cm
- 4 cores-paired with density treatment
  - Control - no worms
  - Low - add 1 A. agrestis
  - Medium - add 3 A. agrestis
  - High - add 6 A. agrestis
- 5 Forest type x density treatment replicates
Mesocasm Field Study

- 80 cores
- Density study
- Monitored weekly
- Moisture
- Disturbance
Mesocasm Analysis

- Decomposition rate
- pH
- Soil aggregate size distribution
- Wet aggregate stability
- Total C, N, and C: N
- Available phosphorus (first two Hedley fractions)
- Microbial biomass C
- DOC (extraction with 0.5M $\text{K}_2\text{SO}_4$)
Post treatment
Large Mesh Decomposition Rate

- Buckthorn
- Sugar Maple
- White Oak
- White Pine

Number of worms vs. Large mesh decomposition rate (% lost)
pH Analysis

Post Data Analysis for pH

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>F Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest type</td>
<td>32.03</td>
<td>&lt;0.000001</td>
</tr>
<tr>
<td>worms</td>
<td>1.819</td>
<td>0.1829</td>
</tr>
<tr>
<td>x</td>
<td>1.148</td>
<td>0.3377</td>
</tr>
</tbody>
</table>
### Carbon Analysis

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>0%</th>
<th>1%</th>
<th>3%</th>
<th>6%</th>
<th>12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buckthorn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar Maple</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Oak</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Pine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### F value and P value

<table>
<thead>
<tr>
<th></th>
<th>F value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest type</td>
<td>1.7102</td>
<td>0.1798</td>
</tr>
<tr>
<td>Worms</td>
<td>0.0020</td>
<td>0.9649</td>
</tr>
<tr>
<td>Species interaction</td>
<td>0.8512</td>
<td>0.4718</td>
</tr>
</tbody>
</table>
Nitrogen Analysis

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>F value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>forest type</td>
<td>1.950</td>
<td>0.3243</td>
</tr>
<tr>
<td>worms</td>
<td>0.1457</td>
<td>0.7041</td>
</tr>
<tr>
<td>species interaction</td>
<td>0.5941</td>
<td>0.6215</td>
</tr>
</tbody>
</table>

The graph shows the percentage of nitrogen for different soil types and species. The x-axis represents the soil type (buckthorn, sugar maple, White oak, White Pine), and the y-axis represents the percentage of nitrogen. The error bars indicate the variability in the data.
### C:N Ratio

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>F value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>forest type</td>
<td>2.46207</td>
<td>0.1124</td>
</tr>
<tr>
<td>worms</td>
<td>0.03527</td>
<td>0.8519</td>
</tr>
<tr>
<td>species interaction</td>
<td>0.30768</td>
<td>0.7368</td>
</tr>
</tbody>
</table>

**Diagram:**

- **Soil Type:** buckthorn, sugar maple, White oak, White Pine
- **C:N ratio** range from 0 to 18
- Bars represent different treatments (0, 1, 3, 6)
Carbon Mineralization

![Graph showing C Mineralization for different soil types.](image)

<table>
<thead>
<tr>
<th>Forest type</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worms</td>
<td>0.00575</td>
<td>0.93981</td>
</tr>
<tr>
<td>Forest type</td>
<td>1.63106</td>
<td>0.20111</td>
</tr>
<tr>
<td>x</td>
<td>2.23101</td>
<td>0.09461</td>
</tr>
</tbody>
</table>
P Total

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>0</th>
<th>1</th>
<th>3</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>buckthorn</td>
<td>60</td>
<td>80</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>sugar maple</td>
<td>140</td>
<td>120</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>White oak</td>
<td>80</td>
<td>100</td>
<td>90</td>
<td>70</td>
</tr>
<tr>
<td>White Pine</td>
<td>80</td>
<td>100</td>
<td>90</td>
<td>70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>F Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest type</td>
<td>2.4758</td>
<td>0.080433</td>
</tr>
<tr>
<td>worms</td>
<td>1.604</td>
<td>0.210579</td>
</tr>
<tr>
<td>x</td>
<td>4.8759</td>
<td>0.004407</td>
</tr>
</tbody>
</table>
Soil Aggregates

2mm-4mm

.25mm-.5mm

.5-1mm

.053mm-.25mm

The Morton Arboretum
Wet Aggregate Stability

Forest Soil Types

- buckthorn
- sugar maple
- white oak
- white pine

Percentage of Aggregate Stability

<table>
<thead>
<tr>
<th>Forest Soil Types</th>
<th>0 worms</th>
<th>6 worms</th>
</tr>
</thead>
<tbody>
<tr>
<td>buckthorn</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>sugar maple</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>white oak</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>white pine</td>
<td>80%</td>
<td>80%</td>
</tr>
</tbody>
</table>

F-statistic and P-values:

- Forest type: F = 5.7643, P = 0.007184
- worms: F = 6.4261, P = 0.022063
- x: F = 1.2862, P = 0.313051
## Research Design: Tree Seedlings

### Soil treatment

<table>
<thead>
<tr>
<th></th>
<th>Unmodified soil</th>
<th>Worm-modified soil</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Negative control:</strong></td>
<td>No worm Unmodified soil</td>
<td>No worm Modified soil</td>
</tr>
<tr>
<td><strong>Direct effect:</strong></td>
<td>1 worm Unmodified soil</td>
<td>1 worm Modified soil</td>
</tr>
<tr>
<td><strong>Indirect effect:</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Seedlings
- White oak
- Sugar maple
- White pine
- Common buckthorn

Each seeding will receive treatment and will be replicated 5 times.
Collaborated with UW-Madison Arboretum
Confirmed Species Populations

Open bare spots
Measurements: Seedlings

Prior to and at the end of the experiment, measurements to be taken on:

- Diameter
- Height
- Above and belowground biomass of each seedling
Seedling harvest
Soil signature

Nutrient availability
Competitive advantage
Biomass

Relative Change in Biomass by Soil Type

F=6.11; P=0.001
Relative Change in Height by Soil Type

- Bucketthorn
- Sugar Maple
- White Oak
- White Pine

Percent Height Change

Uninvaded vs. Invaded
Relative Change in Diameter by Soil Type

<table>
<thead>
<tr>
<th></th>
<th>Uninvaded</th>
<th>Invaded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buckthorn</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Sugar Maple</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td>White Oak</td>
<td>-10</td>
<td>-20</td>
</tr>
<tr>
<td>White Pine</td>
<td>-15</td>
<td>-25</td>
</tr>
</tbody>
</table>
Dry Fine Roots

Relative Change in Dry Fine Roots by Soil Type

- Buckthorn
- Sugar Maple
- White Oak
- White Pine

Legend:
- Uninvaded
- Invaded
Take home points

• Need to continue research
• Delimit distribution
• Understand density impacts
• Nutrient cycling
• Management
  – Natural areas
  – Collections
Research Team

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Jennifer Fratterigo, Ph.D., Assistant Professor in Natural Resources and Environmental Sciences, University of Illinois

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UW-Madison Arboretum

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