IF YOU BUILD IT THEY WILL COME: DISPERSAL CAPABILITIES OF SOIL FAUNA
OUTLINE

- Why study soil fauna?
- Research interests: past & present
- Introduction to decomposer community and importance of soils
- Graduate work completed in Pinelands on soil fauna dispersion in a fragmented systems
- Questions/ Discussion
WHY STUDY SOIL FAUNA? AND SOILS IN GENERAL.... “POOR (wo)MAN’S TROPICAL RAINFOREST”

Soil is alive...
For example, in 1g of soil:
>100,000,000 bacterial cells
>11,000 species of bacteria
Also fungi and larger animals
IMPORTANCE OF DECOMPOSERS

Phthiracaridae (Box Mites)
Soil is the main medium for which N and C transformations occur (Anderson, 1988).

60-90% of terrestrial primary production is decomposed in the soil, which thus performs an important “ecological service” (Behan-Pelletier & Hill, 1983).

- Soil fauna contribute greatly to this process by:
  - Grazing on microbial biomass, which altered the rate at which organic matter breaks down.
  - Fragmenting organic matter and increasing its surface area for attack by microorganisms.
  - Controlling the grazing pressure of nematodes.
  - Mixing soil and organic matter and introducing microorganisms onto fresh organic matter.
  - Degradation of organic matter and mineralization of nutrients.
  - Controlling populations of pathogens.

**FUNCTIONAL ROLE OF DECOMPOSERS: ECOSYSTEM SERVICES**

- O horizon (loose and partly decayed organic matter)
- A horizon (mineral matter mixed with some humus)
- E horizon (light colored zone of leaching)
- B horizon (accumulation of clay from above)
- C horizon (partially altered parent material)
- Unweathered parent material.
Soils are alive so.....
Who’s there?

Mesofauna:
Soil predators, pathogens, herbivores

**FIGURE 4.3** Size classification of organisms in decomposer food webs by body width (Swift *et al.*, 1979).
Biodiversity below-ground supports biodiversity above-ground. The thin layer where soil and litter meet is especially crucial to this process.
There is an increasing awareness that the feedbacks among aboveground and belowground biota are major ecological drivers in terrestrial ecosystems.

Spatial patterning of soil biota and biotic activity can have important aboveground consequences, and this is apparent with regard to both plant community structure and the growth of individual plants.

Most simply, spatial heterogeneity in soil resources results in microhabitat diversity, which can promote species coexistence through greater resource partitioning.

**Figure 5.1.** Routes by which belowground organisms may influence aboveground organisms, as outlined throughout chapter 5. Arrows indicate direction of possible effects, and all groups of organisms identified in this figure are capable of either directly or indirectly influencing all other groups of organisms.

Wardle, D. 1963
Over 8,299 described Collembolan species, arranged into >670 genera, 31 families, 15 super families and 4 orders.

The cuticle, hydrostatic endoskeleton, tendons and muscles all work together to manipulate the body in such a way that propulsion is optimal.

The force and distance of the “spring” is equivalent to a human jumping over the Eiffel tower!!

Poduromorpha   Entomobryomorpha   Neelipleona   Symphyleona
The ultrastructure of the surface of Collembolan is one of the most striking features found in nature (Hopkin, 1997).”

**Fig. 1.** Diagram showing the surface sculpturing in the cuticle of *P. aquatica.*

**Sminthuridae cuticle near pore canal**

**Sminthuridae eye-like patches (8 ocelli)**

**Cuticle Patterning (Isotomidae)**
AFM images characterize the hardness and elasticity of the cuticular material. The 3D images of minor tubercles display. The height of the minor tubercles on Hypogasturidae.
Mites of the suborder Oribatida are the world’s most numerous arthropods living in the soil. Densities can reach hundreds of thousands/square meter!! They have long life cycles (K strategists) up to 7 years, females lay few eggs and many are parthenogenetic (no males). Slow metabolic rates, slow development and low fecundity, Oribatida are not capable of fast population growth and are usually restricted to stable environments, in contrast to opportunistic groups (Collembolan).

Oribatida comprise an important component of soil decomposers; their abundance, species composition and diversity in a particular habitat serve as good indicators of “soil health”.

ACARI: SOIL MITES
Predatory Mesostigmatidae Mite

Galumnoidea spp.

Neotrichozete spp.
FUNCTIONAL GROUPS OF SOIL FAUNA

- **Saprotrophs** (primary decomposers): Feed on non-living organic materials.
- **Fungivores** (secondary decomposers): Feed on living fungal hyphae and other microorganisms.
- **Generalist:** Feed on variety of resources and are not bound by digestive capabilities (i.e., Collembolan)
- **Predators:** Feed on smaller fauna and larvae forms of macroarthropods.
- **Phycophages/herbivores:** Feeding mainly on lichen, algae and plant tissues (not separated for this study).

- Trophic guild is determined by a variety of diagnostics, mostly by examining the mouth parts of the organism.
**RESEARCH INTERESTS: PAST & PRESENT**

- Boreal coniferous forest zone
- 86% of land area is forested
- Three main tree species: Scots Pine, Silver Birch, Norway Spruce
- EU Renewable Energy Directive:
  - 20% by 2020 CO\(_2\) reduction
- Impacts on soil health and ecosystem processes

Fig. 1. The equilibrium model. Rate = extinction (ascending curves) or immigration (descending curves). SPP. = number of species, $S_m$, $S_n$, $S_f$, and $S_n$ = equilibrium number of species for near small, near large, far small, and far large islands respectively (MacArthur and Wilson 1967).
A recent search of the Cambridge Scientific Abstracts database revealed over 1600 articles containing the phrase “habitat fragmentation.” (Fahrig, 2003)
Investigated the effects of habitat fragmentation on soil fauna communities within the Pine Plains located at the Warren Grove Gunnery Range.

Investigated the colonization abilities of soil fauna by created sterilized islands located in a “sandy matrix” of unfavorable habitat.

Spatial- Temporal effects of fragmentation on soil fauna.

Empirical research suggests that soil fauna diversity, density and species richness is reduced in fragmented systems. (Adetola & Ola-Adams, 2000)
TERRESTRIAL ISLANDS

- Research was conducted at Warren Grove Gunnery Range from July 2011 - July 2012, with the support of Drexel University students (opening and closing a lot of gates for me in order to do my research!)

- Terrestrial islands are created when a section of (forest or patch of vegetation) is separated from the main intact forest.

- Using soil fauna as my model organism group I tested to see if the effects of habitat fragmentation could be observed in a disturbed section of the W.G.G.R.
SURVEY DESIGN

- 12 regrowth islands
  - 3 Large + Close
  - 3 Large + Far
  - 3 Small + Close
  - 3 Small + Far
  - Mainland (intact) forest
  - Sandy matrix

- Soil fauna sampled bi-monthly July 2011 - July 2012
- 1 core / island/sampling event
- 3 cores from the mainland
- 3 cores from the sandy matrix
Devices to extract soil fauna are relatively simple and inexpensive ways to measure soil health and diversity.

1. Invert Soil Core in mesh sieve
   - Organic layer first

2. Soil fauna migrate downward
   - Due to desiccating conditions

3. Soil fauna collected in test tube

Time, patience and dedication are necessary to get through the taxonomy.
Natural Islands

Near Islands: 4.5-6.0 m*
Far Islands: 15.0-18.5 m*
Large Island: 1.60-3.25 m²
Small Islands: 0.50-1.10 m²

* Distance from main forest (south)

Island Area
Large Island: Checker
Small Island: Horizontal Lines

Island Distance:
Near: Circle
Far: Diamond
H1: Islands that are closer to the main forest will have higher population densities of microarthropods than small islands.

H2: Large islands will have higher population density and diversity.

H3: The main forest will have the highest density and diversity of microarthropods.
DISTANCE AND MEAN DENSITY OF SOIL FAUNA ON NATURAL ISLANDS

![Graph showing the mean number of fauna per year for islands at different distances. The black bar represents 'Close', and the gray bar represents 'Far'. The p-value is 0.49, and the F-value is 6.729.](image)
Fauna Density & Sample

Including MF & Sand:
P<0.0001*, F= 14.68

Excluding MF & Sand
P= 0.28, F= 1.146

Fauna Density & Sample Date:
P<0.0001*, F=8.03
TWO-WAY ANOVA OF MEAN NUMBER OF TAXA OBSERVED PER HABITAT TYPE

Interaction: 1.96% p = 0.88, F = 0.66
Date: 4.03%, p < 0.0001, F = 6.76
Habitat: 85.44%, p < 0.0001, F = 143.49

Mean # of taxa observed over one-year

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<th>Habitat Type</th>
<th># of taxa</th>
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<tbody>
<tr>
<td>Ig/ close</td>
<td>10</td>
</tr>
<tr>
<td>Ig/far</td>
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<td>sm/close</td>
<td>7</td>
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<tr>
<td>sm/far</td>
<td>15</td>
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EFFECTS OF NATURAL ISLANDS DISTANCE ON FUNCTIONAL GROUPS WAS NOT DETECTED.
MEAN DENSITY OF FAUNA INCREASES WITH AREA ON NATURAL ISLANDS

Mean density of fauna vs. Area

Mean # of Fauna/Year

2.5×10^5
2.0×10^5
1.5×10^5
1.0×10^5
5.0×10^4
0.0

0 2 4 6 8
Island Area (m2)

R^2 = 0.42*
P = 0.02*
F = 7.22*
Mean density of saprotrophs over time on different island sizes

- Large: $1 \times 10^4$
- Small: $2 \times 10^3$

P = 0.002*
F = 10.35
Microarthropods as a whole were positively related to island area. Densities of fauna appear to increase with area.

Saprotrophs were the only guild that showed a significant difference in population density and island area.

Predators, Fungivores, Generalists, and the unknown guild did not exhibit differences in their densities between island area.
PCA ANALYSIS OF SOIL FAUNA COMMUNITIES
Litter depth
Soil moisture %
Organic matter content
Fungal hyphal length
Soil respiration
Decomposition rate

Environmental parameters were analyzed by first testing whether there was a difference between habitat types. Differences between habitat types lead to linear regression analysis of population density and the parameter being investigated.
**Litter Depth vs Saprotrophs**

- $R^2 = 0.65$
- $P = 0.002$
- $F = 18.43$

**One-way ANOVA of Habitat and Litter Depth**

- $P = 0.004^*$
- $F = 37.01$

**Litter Depth vs Unknown Functional Group**

- $R^2 = 0.40$
- $P = 0.03$
- $F = 6.5$
Soil fauna density was positively related to CO$_2$ flux for both AM and PM measurements.

This measurement does not discriminate between biotic organisms (roots, microbes, fauna)

There was not a difference observed in rate of respiration between island sizes.
EXPERIMENTAL APPROACH TO ISLAND BIOGEOGRAPHY USING DEFAUNATED PATCHES

- Provide insight into the dispersal capabilities of microarthropods.
- Observe differences between taxa and their immigration success rate.
- Gain understanding as to which groups of soil fauna were likely the early colonizers of the natural islands.
CONCLUSIONS FROM NATURAL ISLAND SURVEY

- Soil fauna densities were highly correlated with island area.
- Saprotrophic mites & members of the unknown functional guild were positively correlated with litter depth.
- Other environmental parameters measured did not appear to drive soil fauna densities (SOM, % water content, & FHL).
- Species diversity decreased from Main Forest > Large > Small > sand matrix.
- Fauna collected from these islands had adequate time to colonize the islands and establish populations, however some species of collembolan were only observed in the main forest, possibly indicating limited dispersal capabilities across the sand matrix.
- The mainland and large & close islands communities appear to contain a different group of taxa compared to the other islands, which do not separate out when analyzed using PCA.
Thirteen patches of soil were collected from the main forest and dried in an oven at 70°C for 72 hours in an attempt to kill off any soil organisms present.

- 6 close islands
- 6 far islands
- 1 patch as control (exclusion cage)
- Soil fauna samples were collected bi-monthly from September 2011 - May 2012.
- Total of 5 sampling events
Wind dispersal of microarthropod was tested using sticky traps at distances of 7.0m away from main forest and 15.0m away from main forest.

Traps were left out in the field for 48h and were examined under stereomicroscopy.

Microarthropods were not present on any of the traps. Other flying insects were captured on the traps along with several ants.
Mean density of juvenile mites was regressed against the mean density of predatory mites. Each point represents the average # of fauna collected for each sample period.

Juvenile Mites & Predators on Near Islands

\[ R^2 = 0.82^* \]
\[ P = 0.03^* \]
\[ F = 15.66^* \]

Juvenile Mites & Predators on Far Islands

\[ R^2 = 0.06 \]
\[ P = 0.7 \]
\[ F = 0.18 \]
COMMUNITY ANALYSIS: STERILE PATCHES

F = 51.74, P < 0.0001

F = 28.69, P < 0.0001
ISLAND DISTANCE AND SOIL FAUNA COMMUNITY

MANOVA
Axis 1 F=2.0, P=0.163
Axis 2 F=0.22, P=0.608
Wilks' Lambda F=1.12, P=0.333
Certain taxa of collembolans were found only in the main forest, indicating that they may have limited dispersal capabilities.

Diversity within each patch increased with time, indicating that soil fauna are actively moving throughout the fragmented habitat.

Questions still remain: is this just passive dispersal or are they actively seeking out patches to serve as refuges as they move through a fragmented system?

- Pheromone trails?
Recent Time article asks an important question: What if the world’s soil runs out? (Time 12/14/2012)

- 40% of soils used in agriculture are degraded or seriously degraded
- Soils are being lost 10-40 times the rate at which it can be replenished. (We need our decomposers...healthy i.e. SOIL FAUNA)
- Soils are not part of the "sexy sciences" therefore little attention has been drawn to the massive extinction taking place right below our feet!
- Soils take thousands of years to form, yet we can destroy them in a matter of decades.
QUESTIONS/ DISCUSSION

Merci beaucoup!