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Earthworms, grasshoppers, and old-field ecosystems

Research Highlights

- Earthworms and grasshoppers alter soil nutrient cycling and plant growth.
- The combined impacts of earthworms and grasshoppers can be predicted by their individual effects.
- Soil nutrient stocks and plant community resilience explain why the combined effects of earthworms and grasshopper don't have synergistic effects on old-field ecosystems.

Research Summary

Over the past three years, I have spent the early spring and late fall counting earthworms at the Yale-Myers Forest in Northeastern, CT. Earthworms are not native to Connecticut, but have been distributed throughout the state by anglers, gardeners, and anyone who has moved soil around. Non-native earthworms are particularly abundant in and around old farmsteads making old-fields a good place to find and study them. Earthworms increase the decomposition of leaf litter, increase soil nutrient availability, and often stimulate plant growth. These effects are seen as a good thing in farm fields, gardens, and their native range in Europe, but can be disastrous to the plants and animals in North American forests adapted to earthworm-free conditions [1,2].

While my springs and falls have been dedicated to earthworms, my summers have been focused on plants and the grasshoppers that grown up *en masse* to eat them. Grasshoppers are abundant in Connecticut old-fields and one generalist species called the red-legged grasshopper is the most common of them all. Being a generalist, the red-legged grasshopper will readily eat grasses, legumes, and forbs reaching high densities [3]. Grasshoppers, like other herbivores, can reduce the amount and quality of plant growth. Grasshoppers can also indirectly increase soil nutrient cycling because plants try to grow back their lost leaves by mining nutrients from the soil [5]. So like earthworms, grasshoppers can influence the growth of plants and the availability of soil nutrients.

Research Summary, cont.

Since earthworms and grasshoppers both change plant growth and soil nutrients, ecologists have suggested that their combined impacts should drive major ecosystem change [6]. The theory is that if both animals stimulate nutrient cycling and plant growth, then the nutrient recycling rate should increase as plants are replaced by those that can grow quickly in high nutrient conditions. These nutrient rich plants should decompose faster and thereby recycle nutrients into already nutrient-rich soils. Overall, we should see different plant types and lots of available nutrients in places with both grasshoppers and earthworms.

I studied earthworms and grasshoppers to test the hypothesis of faster nutrient cycling. I've been carefully adding and removing them from cages to maintain areas of high and low abundance. I've measured plant growth, soil nutrient levels, and soil microbial activity to document their individual and combined impacts. I tested whether the combination of grasshopper and earthworm individual effects predict their true combined effect. Surprisingly, they did. I found strong evidence for the individual impacts of grasshoppers and earthworms promoting soil nutrient cycling, but no evidence that these impacts were synergistic as our hypothesis claimed.

So why didn't strong feedbacks between grasshoppers and earthworms materialize? Thankfully, I have data that can help answer that question. First, nutrients that recycle from decomposing leaves do not travel uninterrupted to growing plant roots. Much of the flow can be bound up in the soil to form organic matter that slowly releases nutrients and buffers the synergistic feedback [7]. Second, the plant species that establish within field patches don't necessarily turnover very quickly even if nutrient availability increases. As a consequence, the priority gained by the plants that arrived first can prevent the wholesale changes in plant growth and nutrition that are necessary to cause strong feedbacks. So, soil buffering and resilient plant communities can make the combined grasshopper-earthworm effects weaker than we might have thought.

What does this mean for our management of forest or field ecosystems? I'd argue it is good news, because it suggests that the plant communities in these ecosystems can be resistant to synergistic changes for at least a few years. This does not offset the drastic changes earthworms cause in forests where they've never been, nor does it confirm that feedbacks never develop given decades to incubate. However, it suggests that the impacts of gaining or losing an herbivore or decomposer species can be assessed individually, at least at first. My data suggest that the possibility of herbivore-decomposer feedbacks doesn't negate the value of management decisions made based on studying individual effects.

For further information see:

1 Dobson, A. & Blossey, B. Earthworm invasion, white-tailed deer and seedling establishment in deciduous forests of north-eastern North America. *Journal of Ecology* **103**, 153-164 (2015).

2 Bohlen, P. J. *et al.* Non-native invasive earthworms as agents of change in northern temperate forests. *Frontiers in Ecology and the Environment* **2**, 427-435, (2004).

3 Schmitz, O. J., Beckerman, A. P. & Obrien, K. M. Behaviorally mediated trophic cascades: Effects of predation risk on food web interactions. *Ecology* **78**, 1388-1399, (1997).

4 Burghardt, K. T. & Schmitz, O. J. in *Trophic Ecology: Bottom-up and top-down interactions across aquatic and terrestrial systems* (eds T. Hanley & K.J. La Pierre) (Cambridge University Press, 2015).

5 Hamilton, E. W. & Frank, D. A. Can plants stimulate soil microbes and their own nutrient supply? Evidence from a grazing tolerant grass. *Ecology* **82**, 2397-2402, (2001).

6 Wardle, D. A. *et al.* Ecological linkages between aboveground and belowground biota. *Science* **304**, 1629-1633 (2004).

7 Buchkowski, R. W., Schmitz, O. J. & Bradford, M. A. Nitrogen recycling in coupled green and brown food webs: weak effects of herbivory and detritivory when nitrogen passes through soil. *Journal of Ecology* **0** (2018).