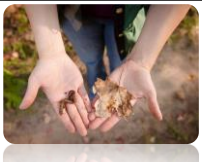
*Got worms? That might be a problem!*
Investigating Impacts of Non-Native Earthworms in Hardwood Forests



**Tara L. Bal, PhD, CF** tlbal@mtu.edu
**Assistant Professor, Forest Health**

Virtual Woodland, Water, and Wildlife Conference
March 3, 2021, 11:30am-12:00pm (est)

Michigan Technological University
College of Forest Resources and Environmental Science

1

*Earthworm Problems – In 4 parts*

- Background – Why Worms?
  - Canopy Dieback and Declines
- Ecosystem Factors
  - "Sideways Cascade" Impacts
- Worm Info
  - Identification, Sampling
- Management Strategies
  - What folks can do!

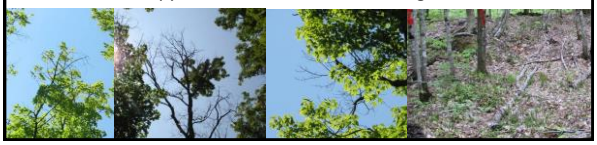
2

Michigan Technological University is located within Ojibwa (Chippewa) homelands and ceded-territory established by the Treaty of 1842, the shared lands and waters of Native American nations in *Gakiiwe'onaning* (Keweenaw Bay), *Gete-gitgaaning* (Lac Vieux Desert), *Mashkii-ziibing* (Bad River), *Odaawaa-zaaga'iganing* (Lac Courte Oreilles), *Waaswaaganing* (Lac Du Flambeau), *Miskwaabikong* (Red Cliff), *Wezaawaagami-ziibiing* (St. Croix), *Zaka'aaganing* (Sokaogon Mole Lake), *Nagaajiwanaag* (Fond du Lac), *Misi-zaaga'iganiing* (Mille Lacs), and *Gaa-mitaawangaagamaag-ininiwag* (Sandy Lake).

3

## Part 1 - Maple Decline on the Radar

- Severe dieback in UP MI by area foresters, beginning ~2005
  - MI, WI DNR Forest Health Highlights, ~2012-15
- High Value of Sugar Maple
- Concern about management induced dieback?
- Loss of canopy = $ loss, concern for future regen

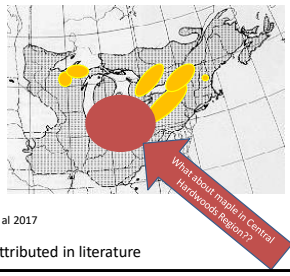


4

## Sugar Maple Failure - Decline

Where has this been studied? (examples)

- **RESEF network, Quebec, Canada**
  - Duchesne et al, 2005
- **Adirondacks, NY**
  - Gardescu 2003, Jenkins 1999
- **Hubbard Brook Exp. Forest, NH**
  - Juice et al, 2006
- **Alleghany National Forest, PA**
  - McWilliams et al, 1996
- **Chequamegon-Nicolet NF, WI**
  - Powers, Nagel 2009
- **Upper Peninsula, MI**
  - Matonis et al, 2011, Donovan 2005, Bal et al 2017




*Many different* conditions and factors attributed in literature

5

## Dieback Defined

*Dieback*: loss of portions of a crown due to a single factor

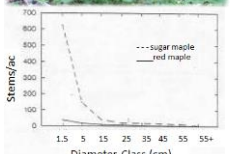
*Decline:* loss of vigor and growth and eventual mortality due to a combination of **predisposing**, **inciting**, and/or **contributing** factors

(Manion 1991; Houston 1992)

6

## Sugar Maple Ecology

- Keystone Species
- Classic shade tolerant
- Selection Silviculture
- Natural regen.
- Large #'s seeds every 2-3 years
- Can survive >30 yrs at <1m height
- Common, 150,000/acre seedlings




Dukes Research Forest, Marquette, MI Jenkins 1997

7

## Reported SM Canopy Dieback Etiologies

- soil nutrition and moisture
- extreme weather events
- atmospheric deposition
- highway salt
- defoliating insects- i.e. pear thrips
- management activities
- sugar maple borer
- *Armillaria* spp. and decay

Horsley et al., 2002; Houston 1992; Whitney 1999: Bailey et al., 2004

8


9

Hazel Swamp Rd, Houghton County, MI, 2010

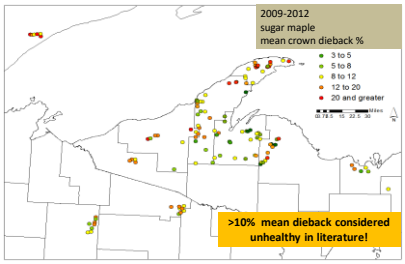
10

Lizzardo Rd, Keweenaw County, MI, 2009

11

## Sugar Maple Dieback Monitoring

Crown & Bole
Growth and Climate
Sapstreak
Soil Nutrients
Foliage Nutrients
Regeneration Counts
Herbaceous Comp.
Forest Floor Condition*
Ownership, Mgmt




12

## Factors Related to Regeneration

Mean SM regeneration counts (2009-2012)

**Modeled plot and edaphic variables (n=65):**

| Significant Variables | p value | Trend Direction |
|---|---|---|
| Mean SM Tree Height | <0.001 | + |
| Seedling Mortality Rating | 0.001 | + |
| Soil Calcium | 0.002 | + |
| Soil Potassium | 0.004 | - |
| Soil Ca/Al ratio | 0.039 | - |

*No beech or exotic invasives in majority of sites.
**Did not include deer density.

13

## Factors Related to Canopy Dieback

Mean SM crown dieback (2009-2012)

**Modeled plot and edaphic variables (n=65):**

| Significant Variables | p value | Trend direction |
|---|---|---|
| Forest floor rating (worms) | 0.009 | + |
| Soil Carbon | <0.001 | + |
| Soil Manganese | <0.001 | - |
| Herbaceous Cover | <0.001 | - |

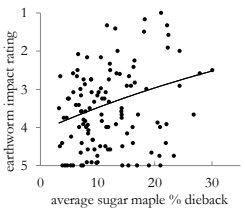
14

## Modeled Relationships with Dieback

**Forest floor rating (earthworm impacts) compared to plot dieback, (p=0.014)**

1 = heavy impact

5 = no impact



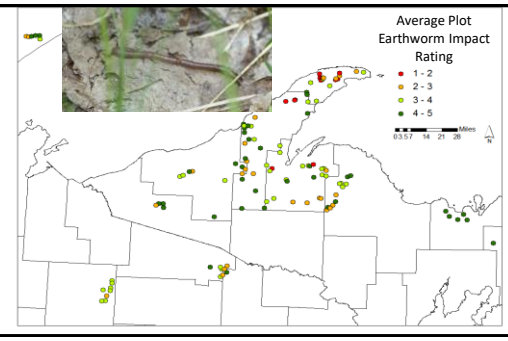

15

## How were earthworm impacts measured?


**Forest Floor Condition, Earthworm Impact Rating Scale (Lilleskov, USFS)**

| Rating | Description of class characteristics |
|---|---|
| 1 | No forest floor. Previous year's litter over mineral soil. Worm sign abundant. |
| 2 | No humus, large old leaves under litter. Worm sign present or absent. Roots absent. |
| 3 | No humus. Small leaf fragments, larger old leaves present. Sparse roots. Some worm sign, but rare large casting piles. |
| 4 | Humus patchy, may be mixed in soil. Some roots, but not thick. Small worms may be found in the forest floor, but no large castings or middens. |
| 5 | Humus fully intact. Roots present in humus and leaf fragments. Forest floor coherent when picked up with intact recognizable layers. No worms or worm sign present. |

16

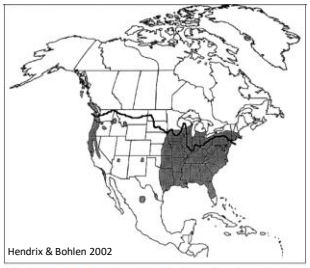



17

## Part 2 –Ecosystem Factors

18

## Earthworm natural range in North America

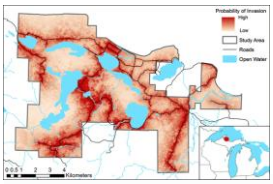


Hendrix & Bohlen 2002

*Figure 1. Approximate distributions of Nearctic earthworms in eastern and Pacific regions of North America in relation to Wisconsinan glacial margins (heavy line). Shaded areas represent combined ranges of approximately 100 species, some tentative and some with very limited distribution. See Fender (1995), Fragoso and colleagues (1995), James (1995), and Reynolds (1995) for detailed distribution maps.*

19

## Mapping Invasions




Predicted probability of invasion for *L. terrestris* across Huron Mountains, Upper Peninsula, Michigan. Model parameters include *road proximity, soil pH, and land cover*

Shartell et al 2013

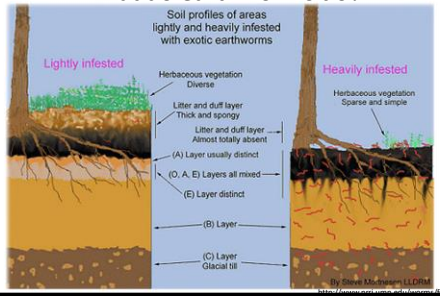
**Predicting Invasions**

*"91.7% and 98.9% of sugar maple habitat" will be invaded within 100-years, from roads or timber harvest, respectively*

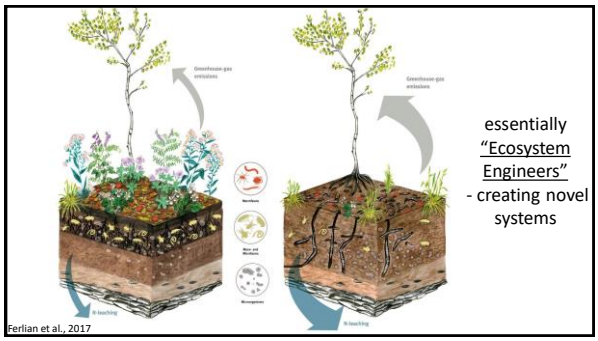
Gundale et al 2005

20

## What do earthworms do?




21

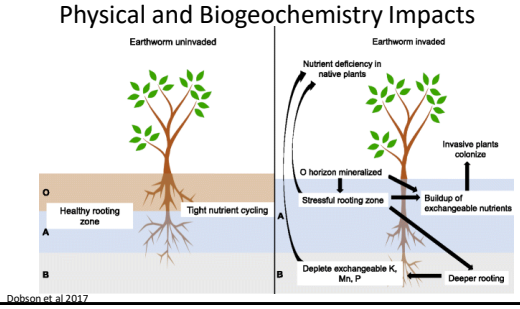


essentially
"Ecosystem Engineers"
- creating novel systems

Ferlian et al., 2017

22

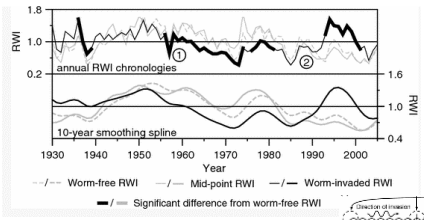
## Physical and Biogeochemistry Impacts



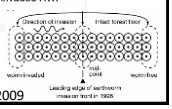

Dobson et al 2017

23

## Detection of Worm Invasion in Tree Rings




- Pulse, and deterioration
- More sensitive to drought



Larson et al 2009

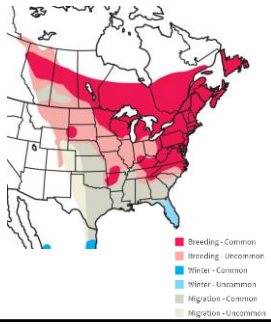
24

Ground-nesting birds

Ovenbird

*Seiurus aurocapilla*


"teacher, teacher, teacher"




25

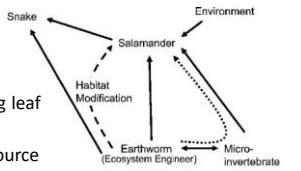
*Ovenbird nests in earthworm-free forests (left, arrow pointing to nest opening) are well-concealed. In areas with invasive earthworms (right), nests are less concealed and therefore more vulnerable to predators. (Photos by Scott Loss)*

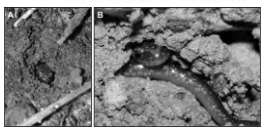
Loss, S. R., & Blair, R. B. (2011). Reduced density and nest survival of ground-nesting songbirds relative to earthworm invasions in northern hardwood forests. *Conservation Biology*, *25*(5), 983-992.

26

## Salamanders

- Salamanders declined exponentially with decreasing leaf litter volume
- Declines in arthropod food source
- Variable impacts – areas with native/invasive earthworms

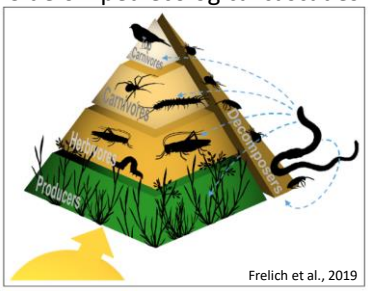



Red backed salamander in Lumbricus burrow. Ransom 2012

27

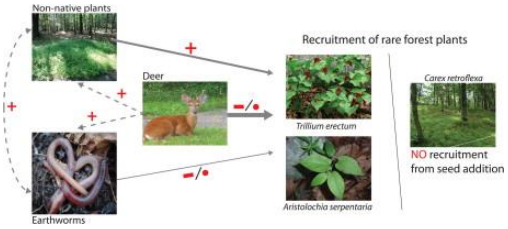
## Side-swiped ecological cascades




Frelich et al., 2019

28

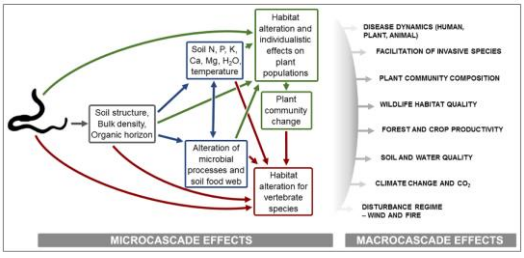
## Deer + Worms + exotic plants = not good…




Davalos et al 2015 Interactive effects of deer, earthworms, and non-native plants on rare forest plant recruitment. *Bio Conservation*

29

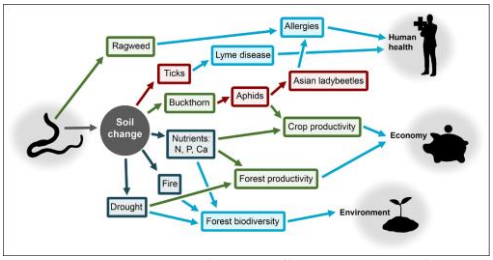
## Micro effects lead to Macro effects




Frelich et al., 2019

30

## Micro effects lead to Macro effects




Frelich et al., 2019 "ultimately affect societal well-being"

31

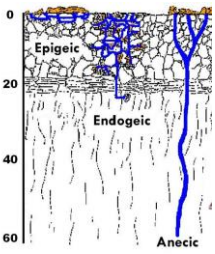
## Part 3 - Worm sign?

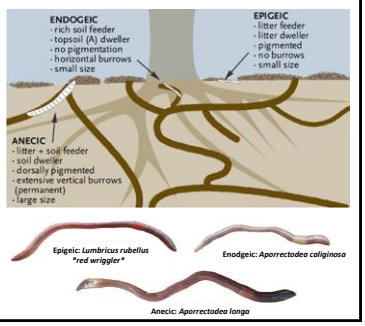
32

## Earthworm sign


33

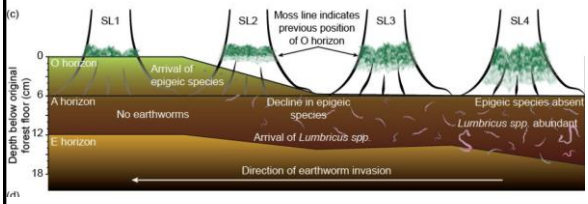
## Ecological Groups




34

## Invasion progression, shifting groups




Larson (pers comm)

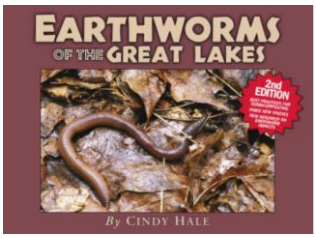
35

## Not every worm is everywhere!

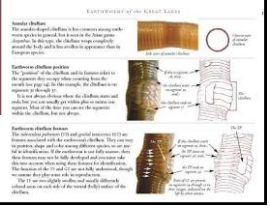
- And they don't all do the same thing!
  - ~15-30 species in GL region
  - ~100+ in southern US
  - 1000s species worldwide
- Continuous introductions…
  - New species
  - Genetic variability
  - Different impacts

Anecic: *Lumbricus terrestris*
*nightcrawler*


36




- Background Info
- Useful Anatomy Overview
- Identification Guides
- Dichotomous Key



**ISBN-10 :** 097920061X

37

## More Online References

Great Lakes Worm Watch
- http://nrri.umn.edu/WORMS/default.htm

Canada Worm Watch
- https://www.naturewatch.ca/wormwatch/


38

## Other methods for sampling

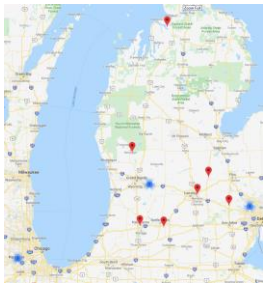
- Forest Floor Rating*
- Flip and strip
- Digging
- Midden counts
- Mustard solution
  - 1 gallon jug to ~1/3 cup dry mustard powder slowly over about 1sq ft

39

Some important worms to look for


40

Reported In Michigan since 2008




Midwest Invasive Species Information Network 10.19
misin.msu.edu

41

42

## Part 4 – Practical worm management?

- Chemicals that kill all worms? No…
- Worm killing-fungi, bacteria? No…
- Some sand granules so sharp that slice through worm guts
  - soil amendment?


**Eliminate fishing bait dumps**
**Inspect nursery plants and soil**
**Responsible vermiculture**
**Practice worm BMPs**

43

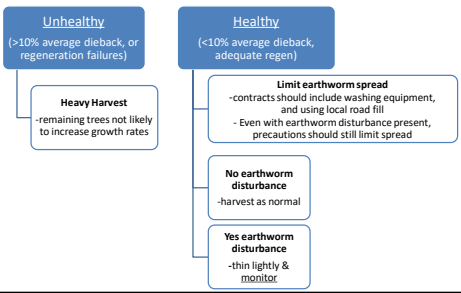
## Earthworm BMPs (Best Management Practices)

- Powerwash equipment between sites
- Boot scrubbers at trailheads
- Public Awareness
- Use local road grading materials
- Site selection – supplemental planting – fertilize – consider rotation length
- Identify and Monitor earthworms
  - record impacts

***Bottom Line: Options available to attempt resolving issues but uncertainty exists***


44

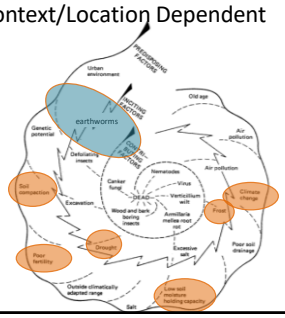
## Potential Silvicultural Decision Tree for Sugar Maple Stands




45

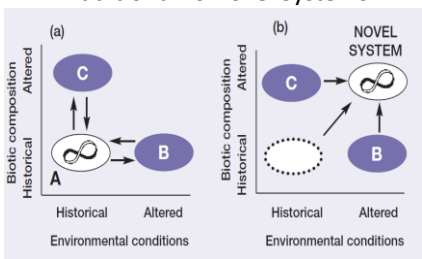
## Forest Impacts are Context/Location Dependent

- Length of time since invasion?
- Worm Species present?
- Deer facilitation
- Invasive plants
- Soil physical/chemical properties
- Mycorrhizae
- Invertebrates/wildlife impacts
- "Mesophication"
- "Acerfication" or "Maple-ization"




46

## Traditional vs Novel Systems

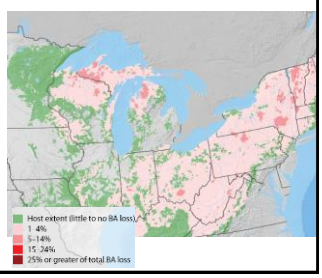



**Seastedt, Hobbs, Suding** (2008) **Management of novel ecosystems: are novel approaches required?** ***Front Ecol Environment*** **6(10): 547–553**

47

## Future Maple Decline Research Plans

- Revisiting sites, 10+ years
- Examining Risk Models
  - National Insect and Disease Forest Risk Assessment, USDA)
  - Worms, deer, climate change, defoliators…
- Impacts on sap chemistry




48

## Wrapping Up

- Spread the word!
  - Need for incorporation of earthworm impacts in forest data collection, potentially silvicultural prescriptions
- Many large, interdisciplinary, landscape-scale questions still to be asked
  - What about other major forest tree species?
  - Ecosystem Engineers = Novel Systems

49

## Acknowledgements


- Co-PIs and Co-Authors: Andrew Storer, Marty Jurgensen, Dana Richter, Michael Amacher, Yvette Dickinson
- Graduate Students: Julie Grinstead, Shelby Lane-Clark
- Field Support: American Forest Management Inc, MI DNR, Ottawa NF, Hiawatha NF, Chequamegon-Nicolet NF, Superior NF
- Funding: GMO Renewable Resources LLC., USDA Forest Service Evaluation & Monitoring Program, USDA NIFA McIntire-Stennis, MTU CFRES, MTU Research Excellence Fund, Ecosystem Science Center


Ecosystem Science Center

DNR

FOREST SERVICE UAS

AMERICAN FOREST MANAGEMENT, INC.

GMO Renewable Resources

USDA

NIFA

Michigan Technological University
College of Forest Resources and Environmental Science

50


51

## Additional References for More Information


- Bal, et al., 2018. Evidence of damage from exotic invasive earthworm activity was highly correlated to sugar maple dieback in the Upper Great Lakes Region. Biological Invasions. 20(1): 151-164. DOI: 10.1007/s10530-017-1523-0
- Bal, et al., 2015. Nutrient stress predisposes and contributes to sugar maple dieback across its northern range: a review. Forestry 88 (1): 64-83.
- Bohlen, et al., 2004. Non-native invasive earthworms as agents of change in northern temperate forests. *Frontiers in Ecology and the Environment* 2:427-435.
- Drouin, et al., 2016. Linkage between exotic earthworms, understory vegetation and soil properties in sugar maple forests. *Forest Ecology and Management* 364:113-121.
- Frelich, et al., 2019. Side-swiped: ecological cascades emanating from earthworm invasions. *Frontiers in Ecology & Environment* doi:10.1002/fee.2099.
- Krist et al. 2015. 2013-2027 National Insect and Disease Forest Risk Assessment (NIDRM). https://www.fs.fed.us/foresthealth/technology/pdfs/2012_RiskMap_Report_web.pdf
- McCay & Scull. 2019. Invasive lumbricid earthworms in northeastern North American forests and consequences for leaf-litter fauna. *Biol Invasions* 10.1007/s10530-019-01959-1


52