Surprising impacts of earthworms on old forests

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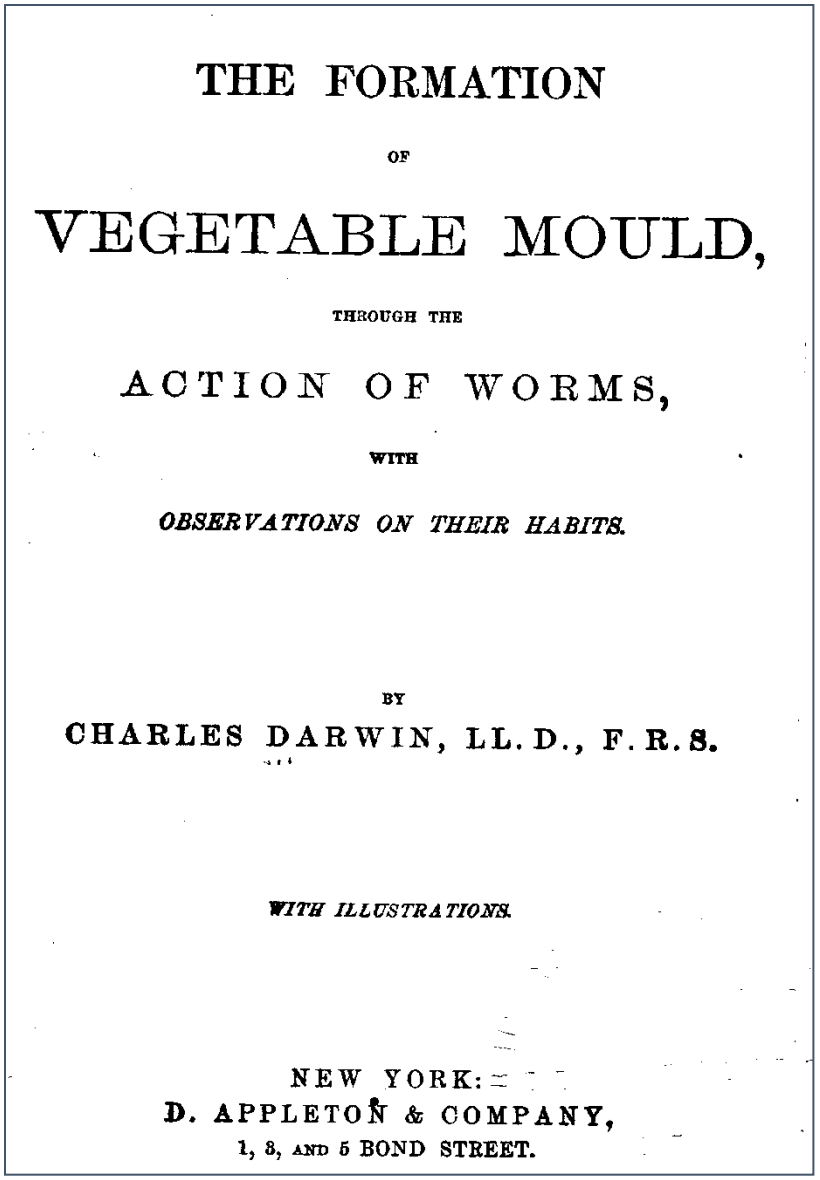
UNIVERSITY OF MINNESOTA

Invasive earthworms are a conservation problem for old-growth hardwood forests because they:

- Degrade the soil
- Exacerbate effects of climate change
- Interact with deer to disrupt plant communities

Giant blue earthworm, Sri Lanka, and Giant Gippsland earthworm, Australia

Currently ca 6000 species
Phylum: Annelida
Class: Clitellata
Subclass: Oligochaeta
Order: Opisthopora



THE FORMATION

OF

VEGETABLE MOULD,

THROUGH THE

ACTION OF WORMS,

WITH

OBSERVATIONS ON THEIR HABITS.

BY

CHARLES DARWIN, LL.D., F.R.S.

WITH ILLUSTRATIONS.

NEW YORK:
D. APPLETON & COMPANY,
1, 3, AND 5 BOND STREET.

"It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly organized creatures."

-Charles Darwin, 1881

Global worming

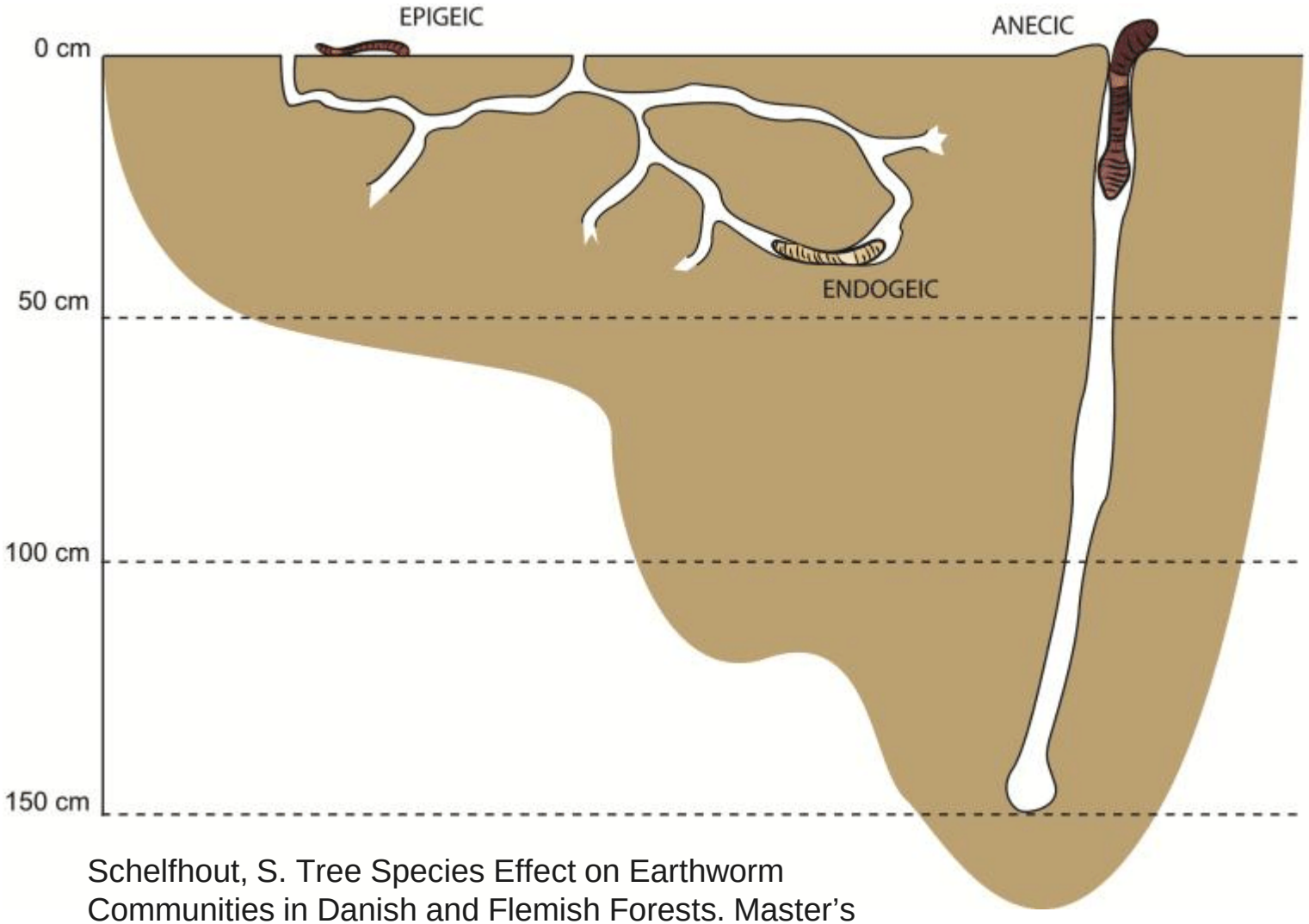
Hendrix et al. 2008
Annu Rev Ecol Evol Syst

The NE US has a ‘first wave’ of earthworm invasion from Europe, and a ‘second wave’ of jumping worms from Asia

Figure 1

Global distribution of indigenous and introduced species within earthworm families in each biogeographic realm (modified from Reynolds 1994, with data from Gates 1982, Jamieson 1981, Omodeo 2000, Sims 1980).

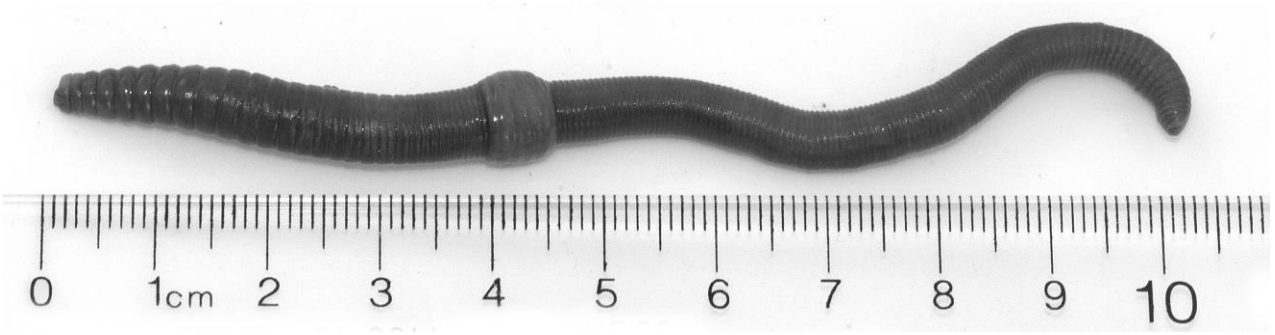
Ecological classes of earthworms and burrow types



Schelfhout, S. Tree Species Effect on Earthworm Communities in Danish and Flemish Forests. Master's Thesis, Ghent University, Ghent, Belgium, June 2010.

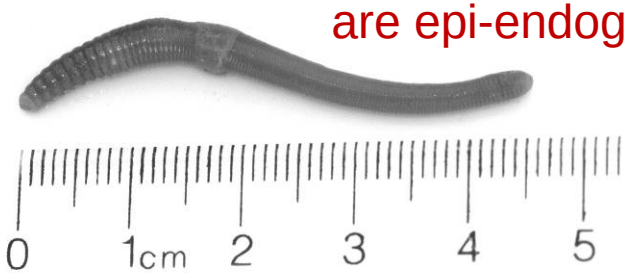
Common European earthworm species and ecological groups

Epigeic: *Dendrobaena octaedra*

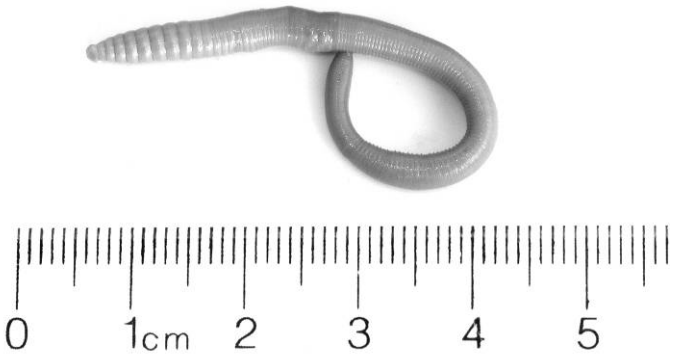


Anecic: *Lumbricus terrestris* (nightcrawler)

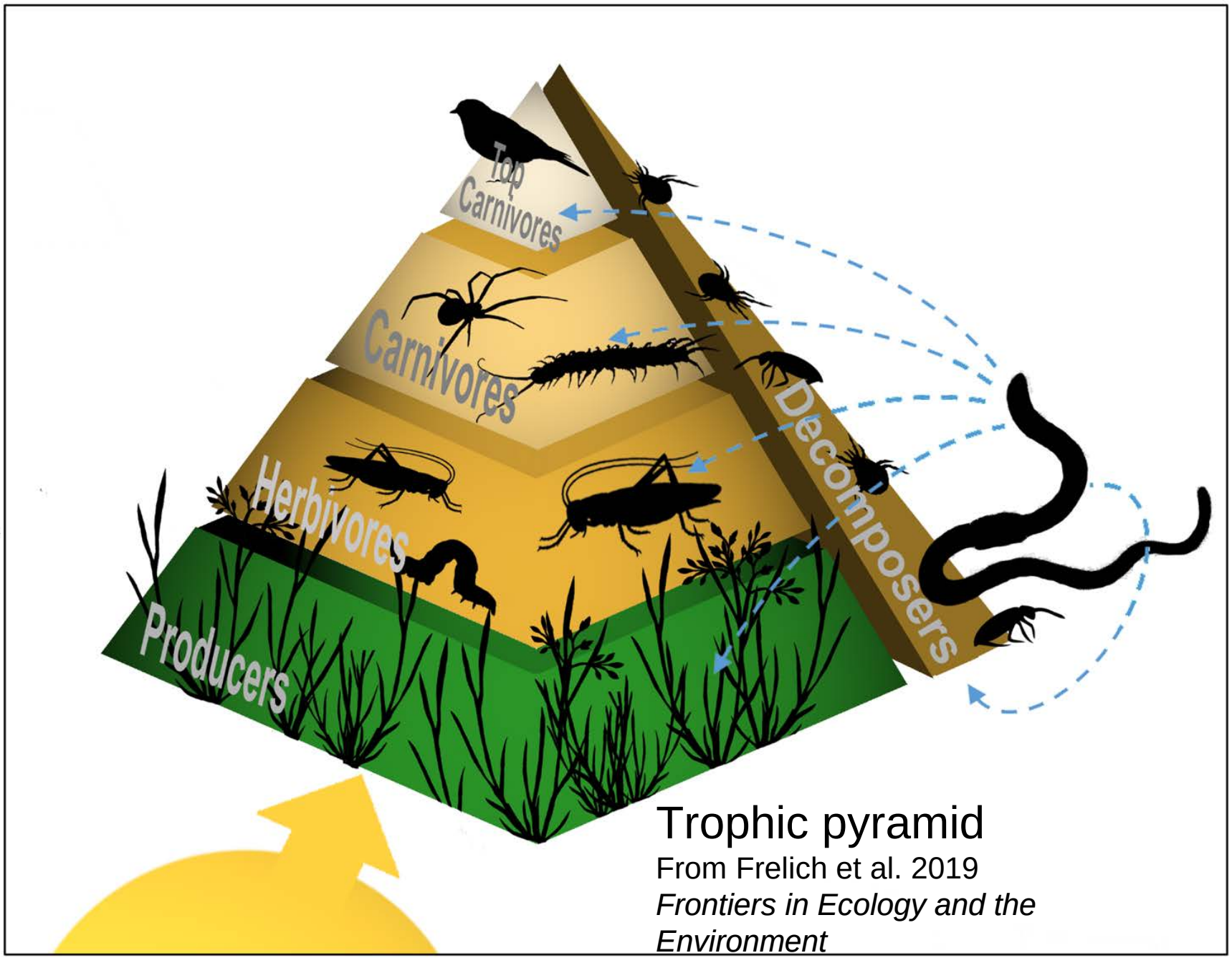
Jumping worms are epi-endogeic



Epi-endogeic: *Lumbricus rubellus*



Endogeic: *Aporrectodea caliginosa*



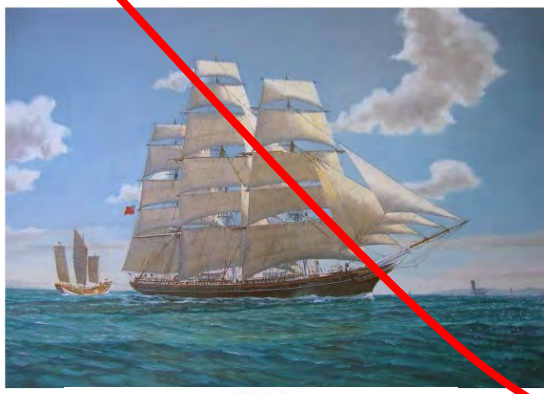
Trophic pyramid

From Frelich et al. 2019 *Frontiers in Ecology and the Environment*

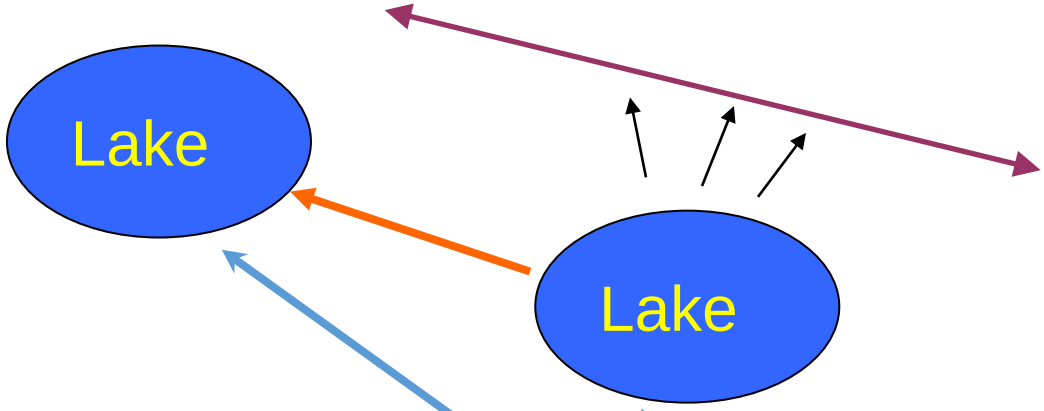
European earthworms move very slowly on their own, however they:

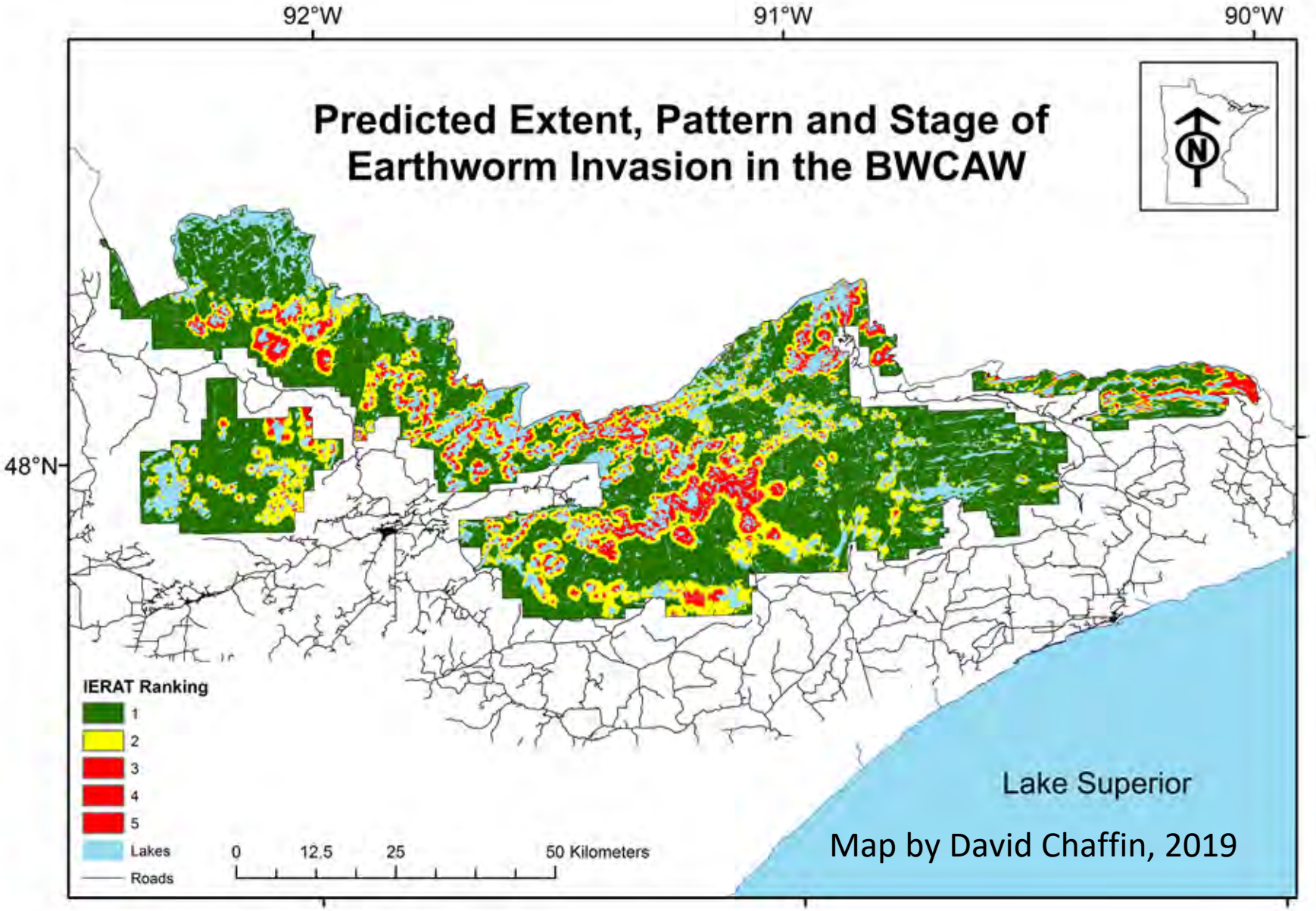
- Are transported long distances via potted plants and live fishing bait
- Move on their own from lakeshores (small black arrows)
- Are moved by logging equipment, ATVs and hikers along trails.

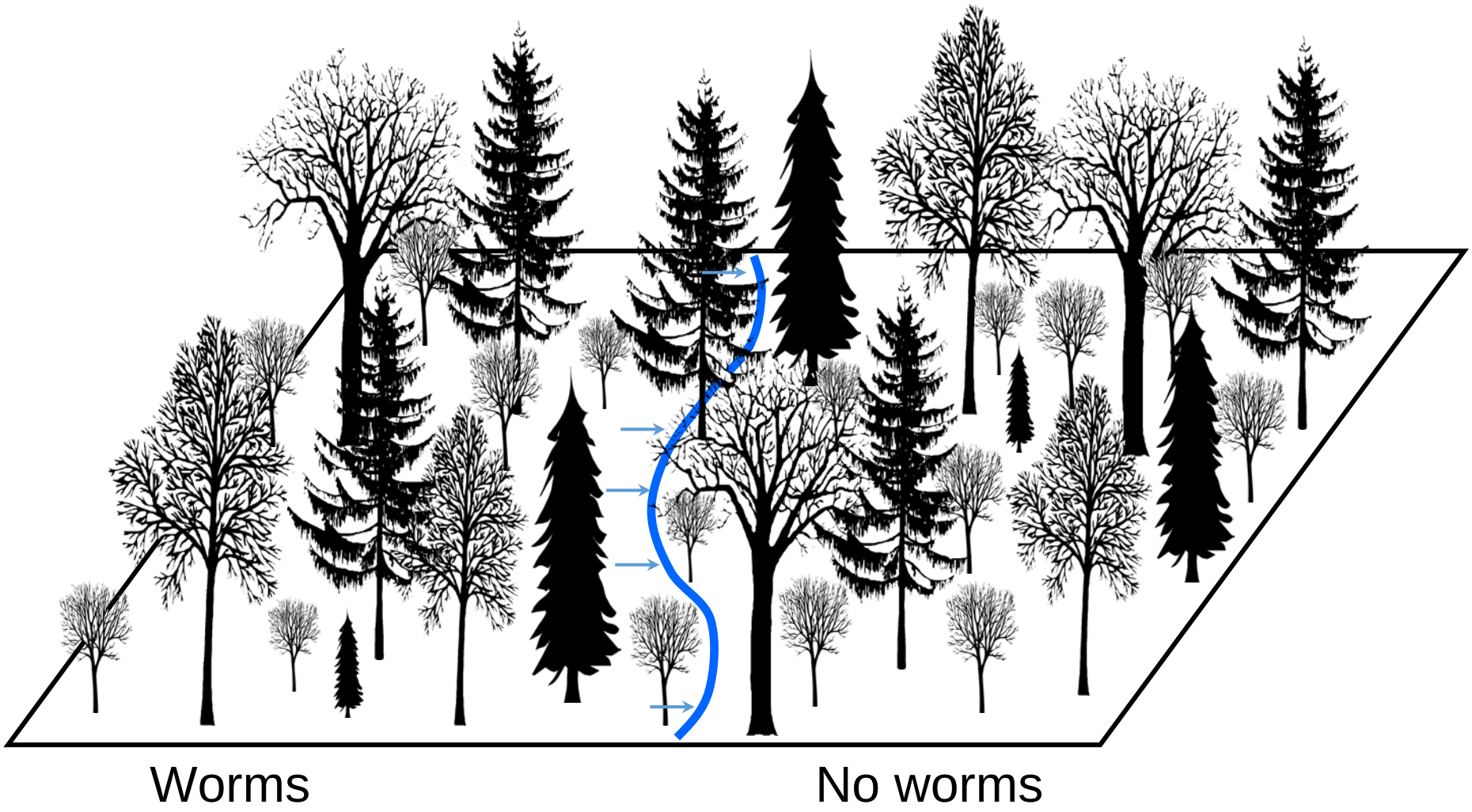
Europe



North America




92°W
91°W
90°W
48°N
Predicted Extent, Pattern and Stage of Earthworm Invasion in the BWCAW
N
IERAT Ranking
1
2
3
4
5
Lakes
Roads
0
12.5
25
50 Kilometers
Lake Superior
Map by David Chaffin, 2019



Leading edge of invasion earthworm studies

Sampling earthworms in the field

Photos: Alex Roth

Five stages of invasion

Stage 1
Worm free

Stage 2
Epigeic only

Stage 3
Endogeic and epi-endogeic invade

Stage 4
Increasing Biomass and a few *L. terrestris*

Stage 5
High biomass,
L. terrestris dominated

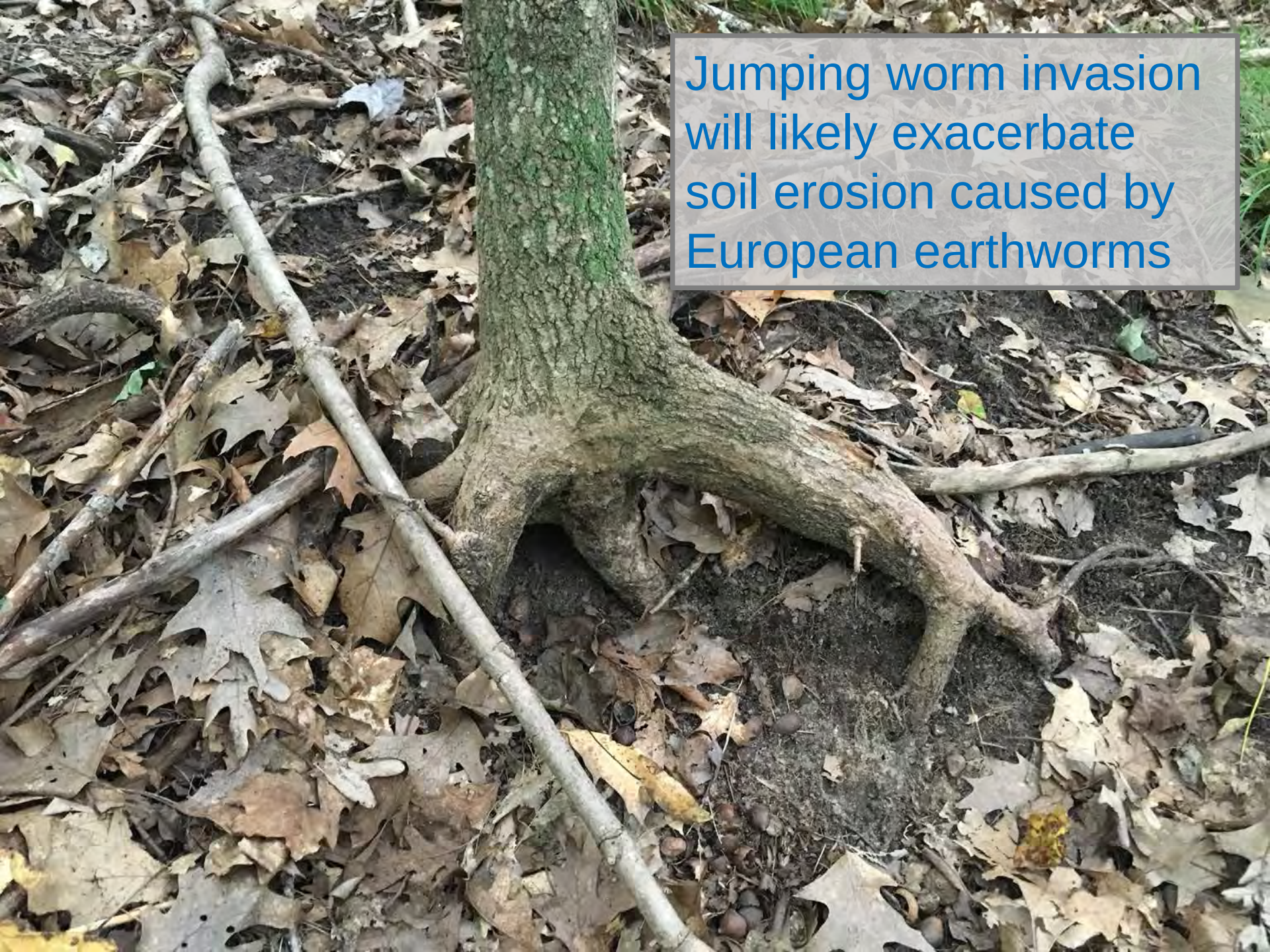
Loss, Hueffmeier, Frelich, Host, Sjerven and Hale. 2013
Natural Areas Journal 33: 21-30

Earthworms eat the leaf litter on the forest floor

Stage 2, *Dendrobaena* only

Stage 3, + *Aporrectodea ssp.* and *L. rubellus*

Stage 5, + *L. terrestris*


Jumping worm invasion will likely exacerbate soil erosion caused by European earthworms

Ecosystems
DOI: 10.1007/s10021-014-9814-0

ECOSYSTEMS

Invasive Earthworms Deplete Key Soil Inorganic Nutrients (Ca, Mg, K, and P) in a Northern Hardwood Forest

Kit Resner,[1] Kyungsoo Yoo,[1]* Stephen D. Sebestyen,[2] Anthony Aufdenkampe,[3] Cindy Hale,[4] Amy Lyttle,[1] and Alex Blum[5]

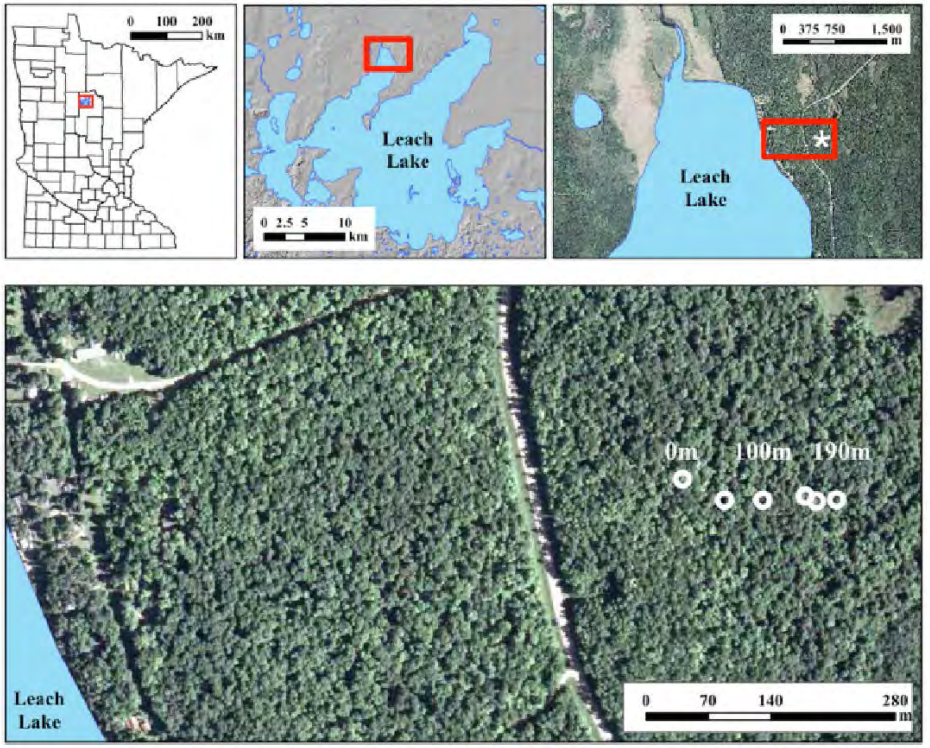
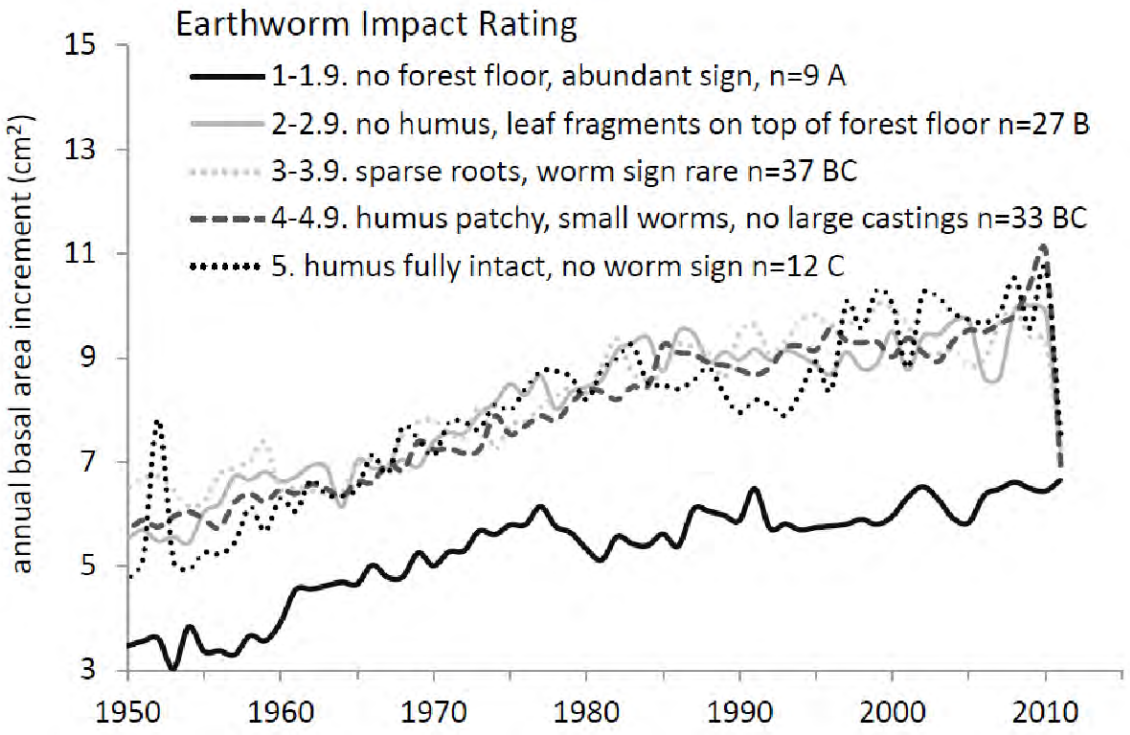
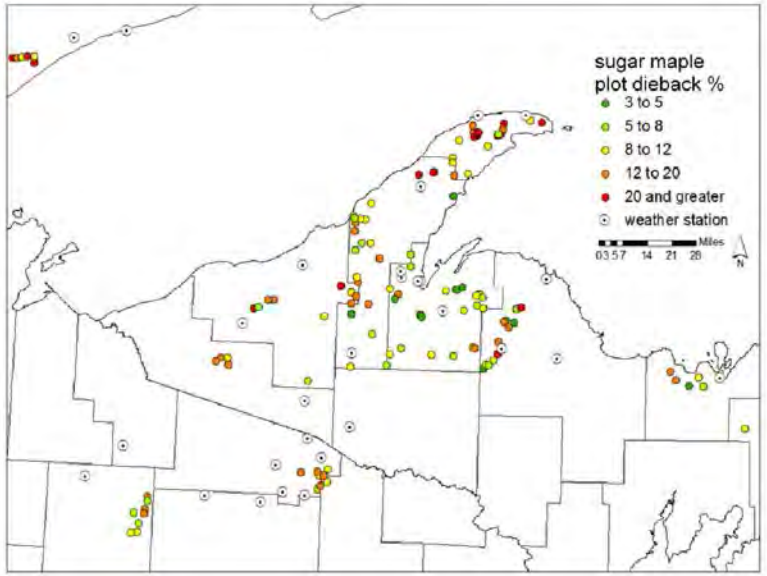


Figure 1.1. Sugar maple crown dieback in Keweenaw County, MI, 2009. Photo by Tara Bal





Earthworms were a significant factor in sugar maple dieback in a study of 120 plots in MI, WI, and MN

Bal et al. 2018, *Biological Invasions*

Photo: Dave Hansen, University of MN

Effects on plant species richness, before earthworm invasion…

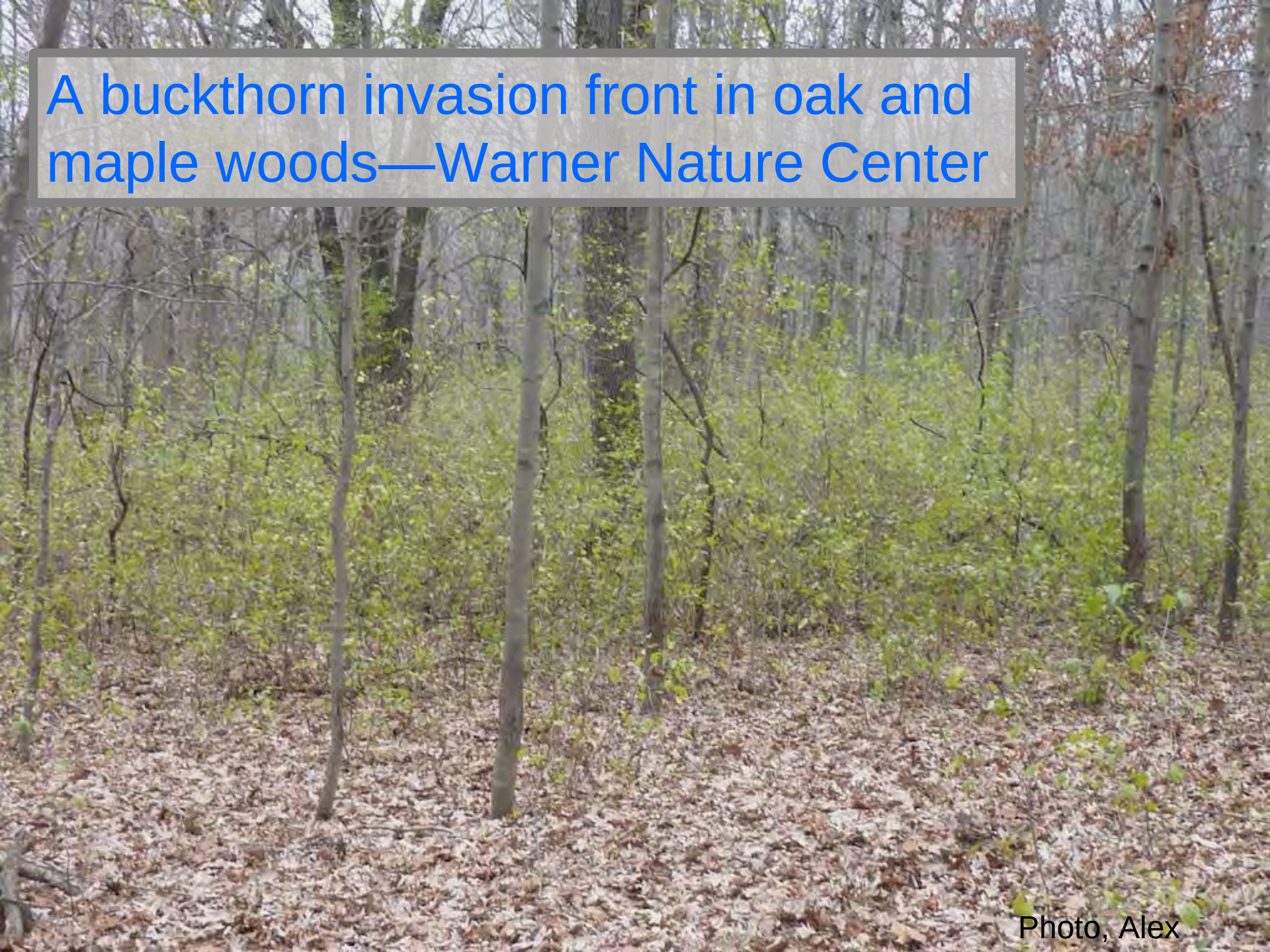
Photo: Dave Hansen, University of MN

…and after earthworm invasion, seedling density down by 98%

Earthworm impacts on plants

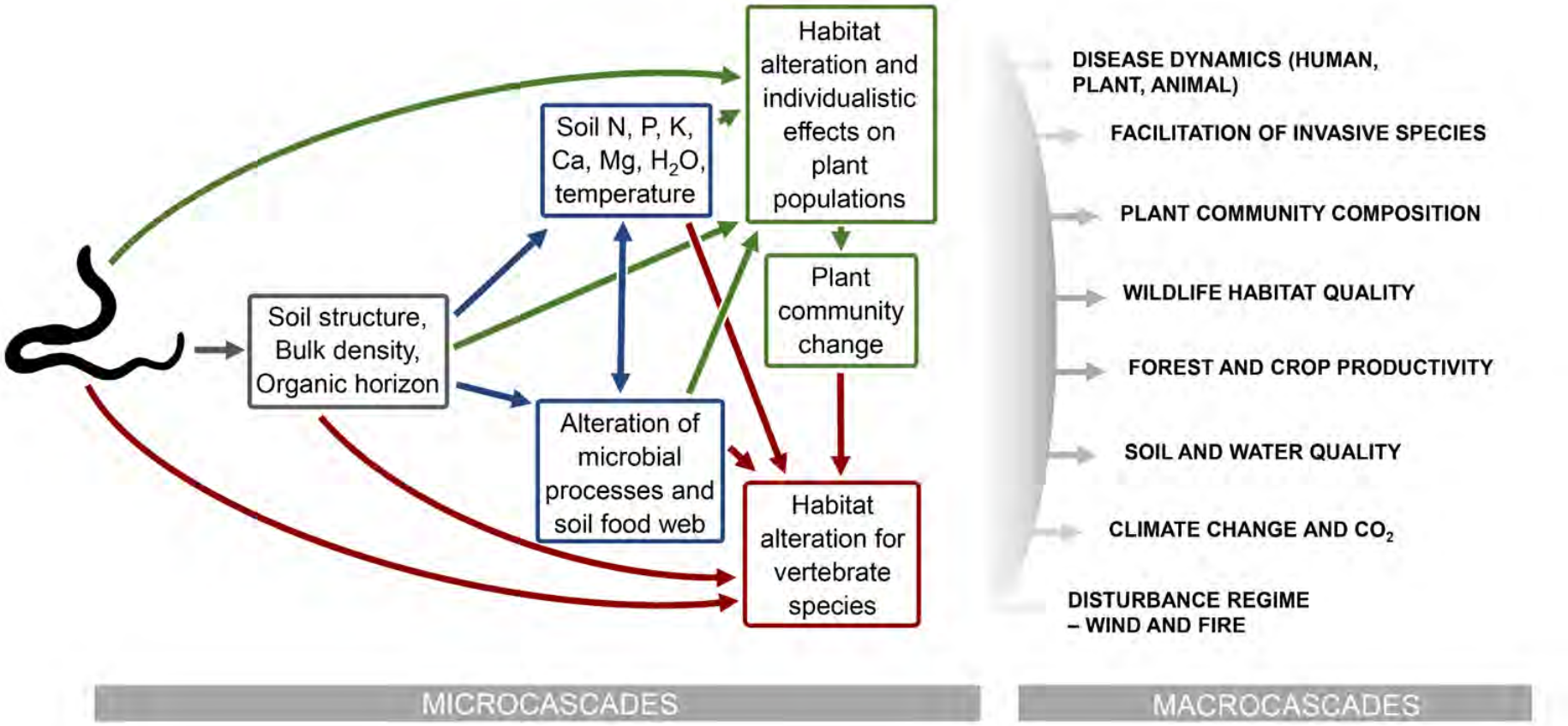
Losers:
Orchids, trillium, sweet cicely, yellow violet, twisted stalk and others

Winners:
Sedge, grass
Jack-in-the-pulpit

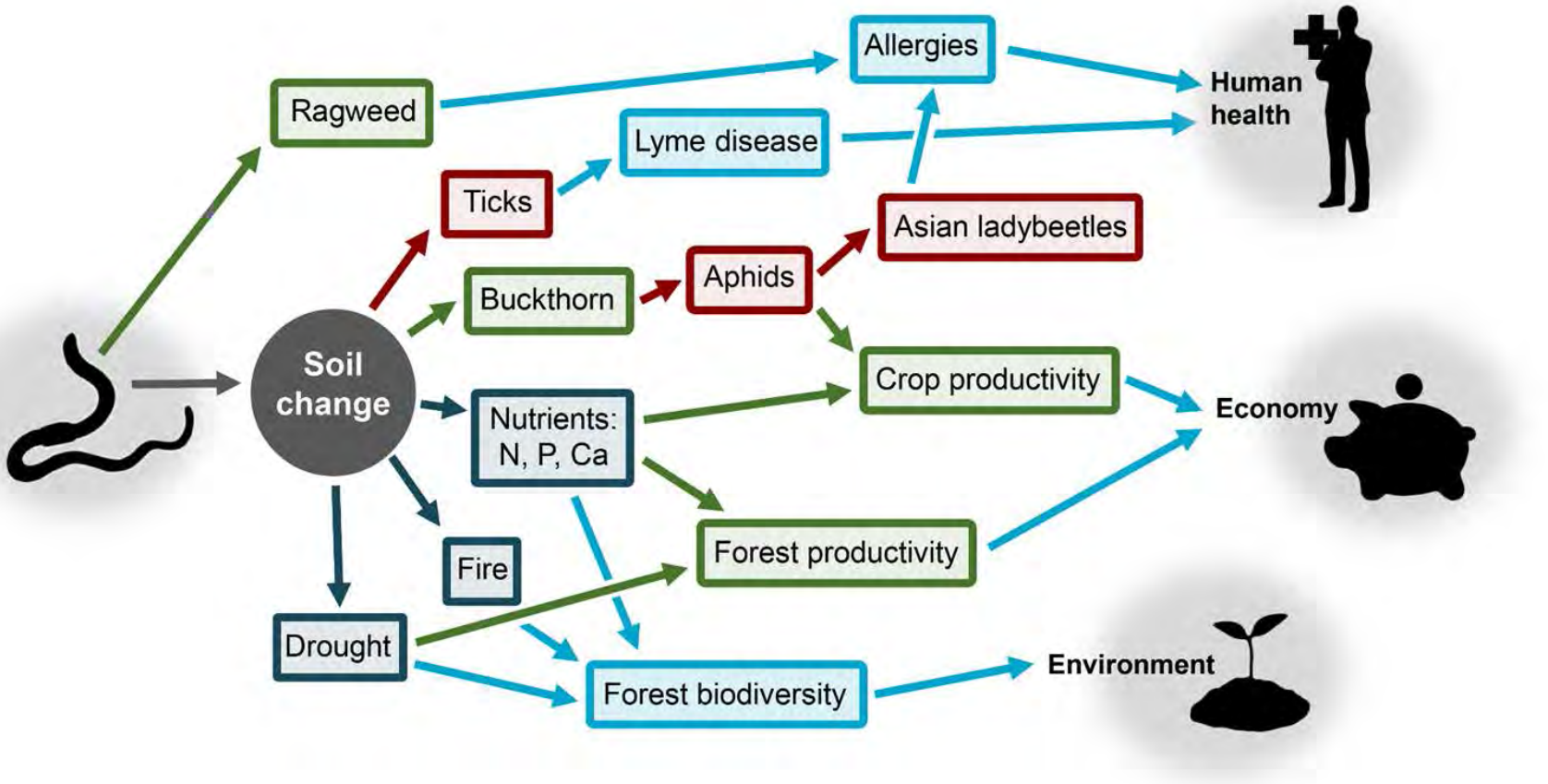

A buckthorn invasion front in oak and maple woods—Warner Nature Center
Photo, Alex

Invasive plants that may be facilitated by earthworm invasion:

- Buckthorn (common and glossy)
- Garlic mustard
- Tatarian honeysuckle
- Black swallowwort (*Cynanchum*)
- Japanese barberry
- Hemp nettle (*Galeopsis tetrahit*)
- *Veronica* ssp.
- Stiltgrass (*Microstegium*)

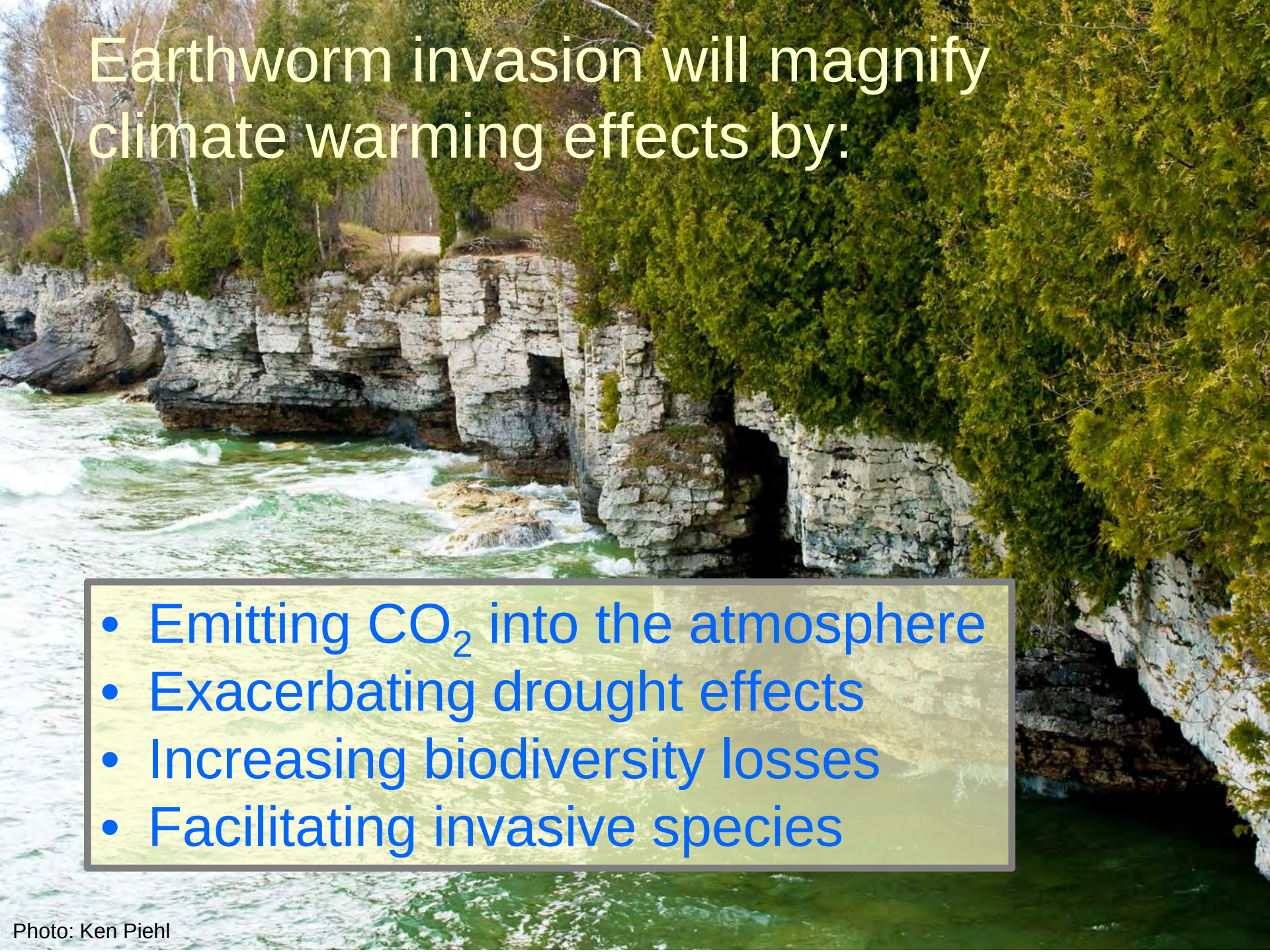


Direct effects of earthworms on soil structure, with cascading impacts on soil function, plant and animal habitat (microcascades), leading to issues of concern to society (macrocascades) From Frelich et al. 2019, *Frontiers in Ecology and the Environment*



Cascade complexes caused by earthworm invasions affecting human health, the economy and environment

From Frelich et al. 2019, *Frontiers in Ecology and the Environment*



Earthworm invasion will magnify climate warming effects by:

- Emitting CO_2 into the atmosphere
- Exacerbating drought effects
- Increasing biodiversity losses
- Facilitating invasive species

Photo: Ken Piehl

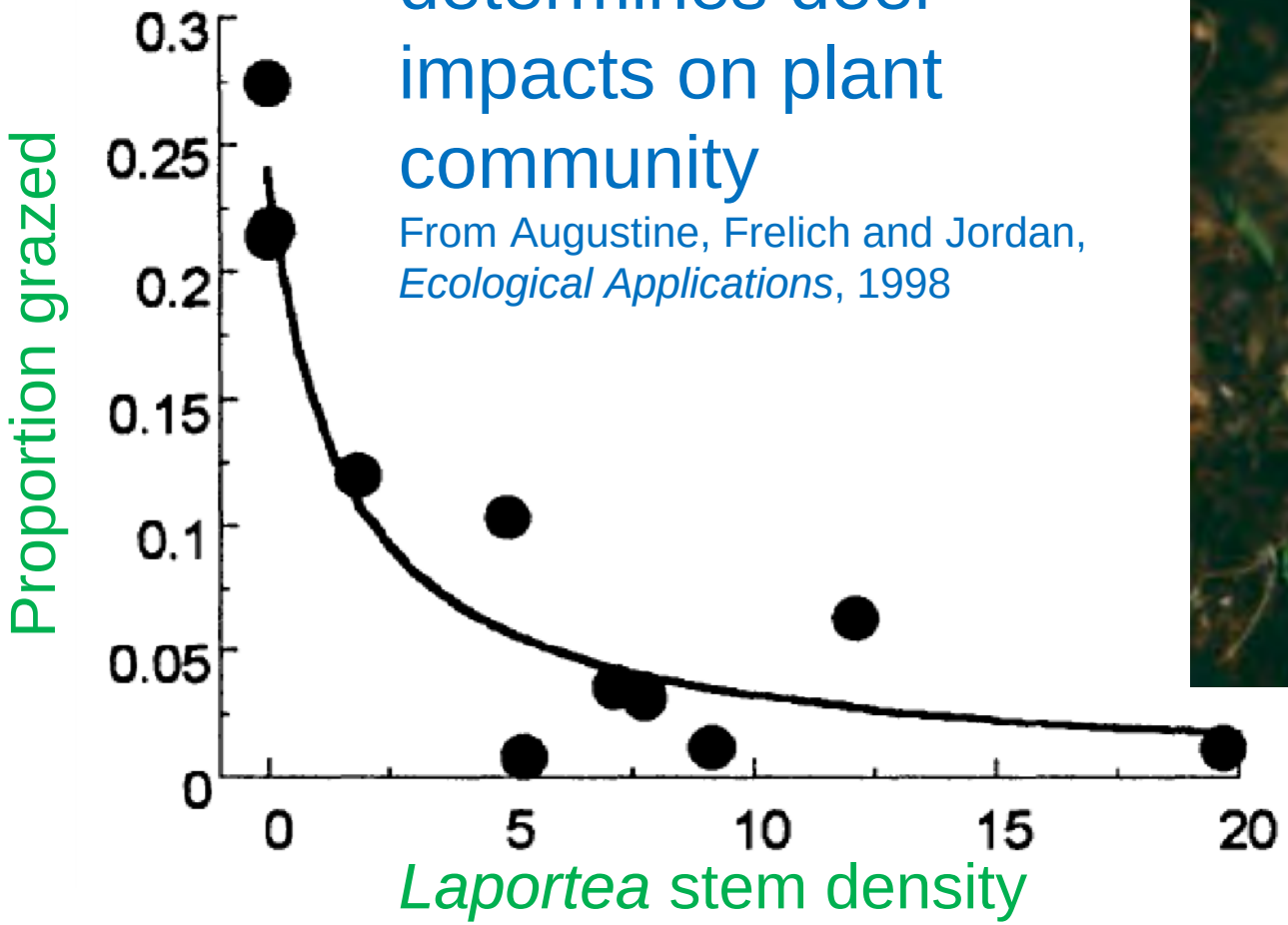
Two-way deer and invasive earthworm interactions in hardwood forests

David Augustine research on impacts of deer overabundance—deer density measurement with cameras

Alternate states study with wood nettle—David Augustine and Lee Frelich

Deer to plant ratio determines deer impacts on plant community

From Augustine, Frelich and Jordan, *Ecological Applications*, 1998



The more earthworms lower plant density, the easier it becomes for deer to locally eliminate plants

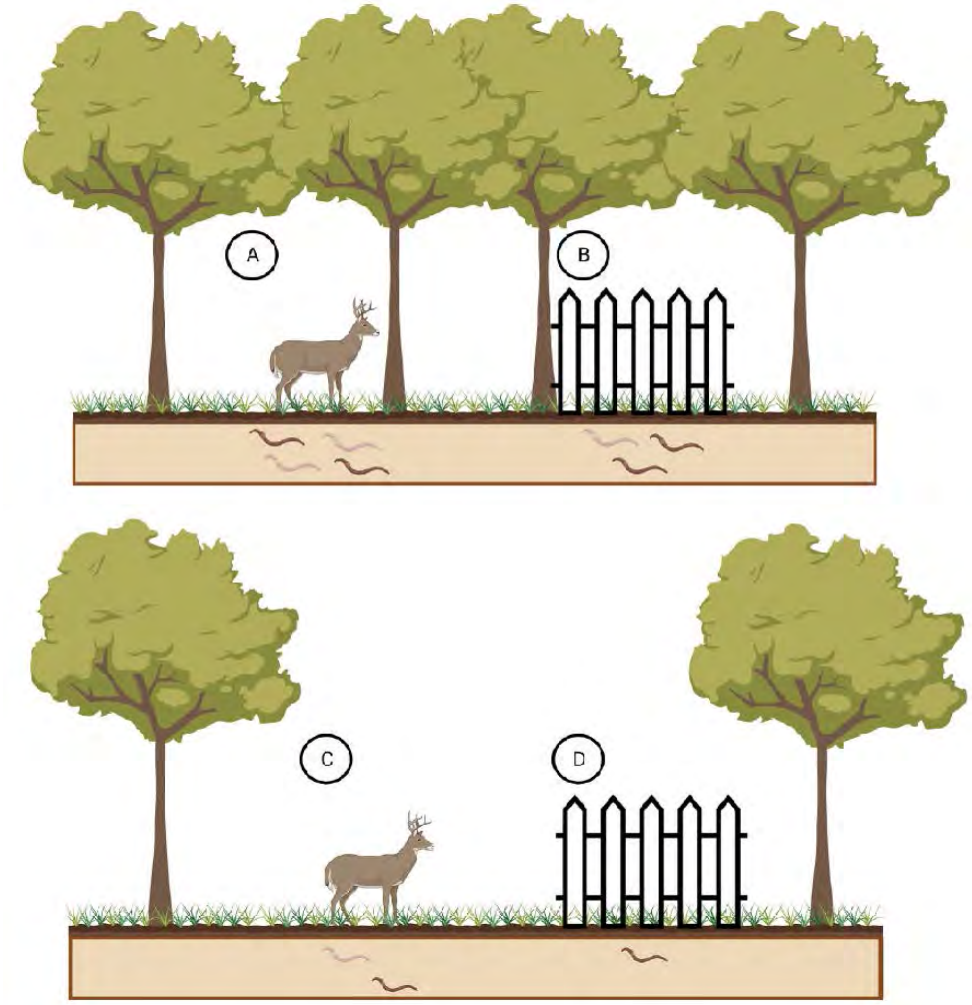
Thresholds for plant density needed to tolerate deer grazing

From Augustine, Frelich and Jordan, *Ecological Applications*, 1998

Low deer
40 plants/acre

Medium deer
400 plants/acre

High deer
2,400
plants/acre

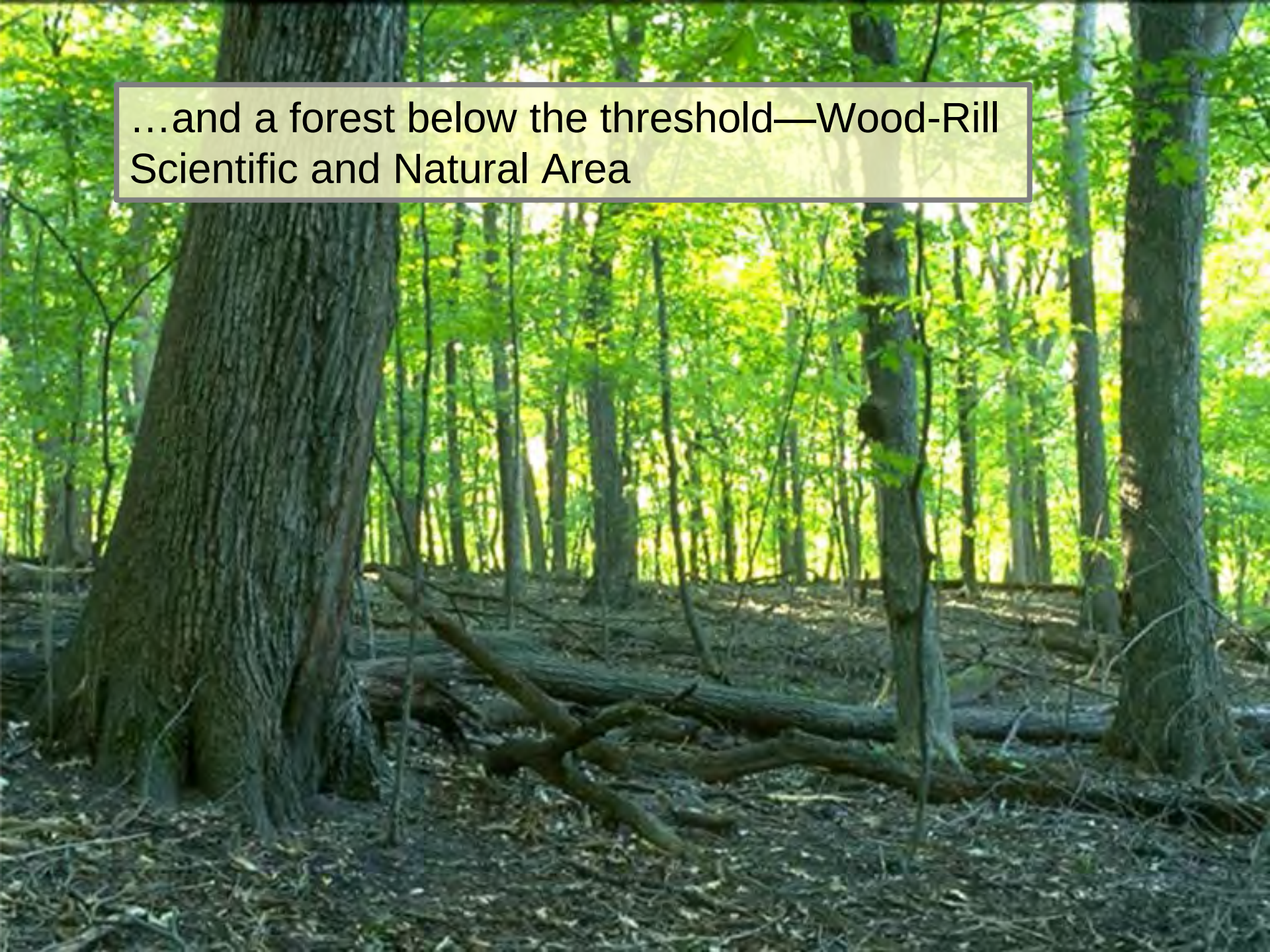


Deer also increase earth-worm density

Wisconsin northern hardwoods experiment: Worms were most abundant under forest canopy with the presence of deer. Reed et al. 2023 *Ecology*

Invasive earthworms reduce plant density, raising deer:plant ratio and deer impacts; deer also increase earthworm density


A maple forest in the Cannon River Wilderness
with plant density above the plant:deer threshold


…and a forest below the threshold—Wood-Rill Scientific and Natural Area

Asian worms or jumping worms

- 14 species in North America
- *Amynthas* and *Metaphire* species
- Move around in mulch
- More aggressive than European worms
- Mostly annual species—survive winter as eggs/cocoons

Annular clitellum
vs
Raised clitellum

Clitellum close to head—
start at segment 14 or 15
vs
Further from head,
start at segments 23-32,
depending on species

Jumping worms live in the top 2 inches
and create a layer of loose granules

Soil granule size depends on species:
Metaphire hilgendorfi > *A. Agrestis* > *A. tokioensis*

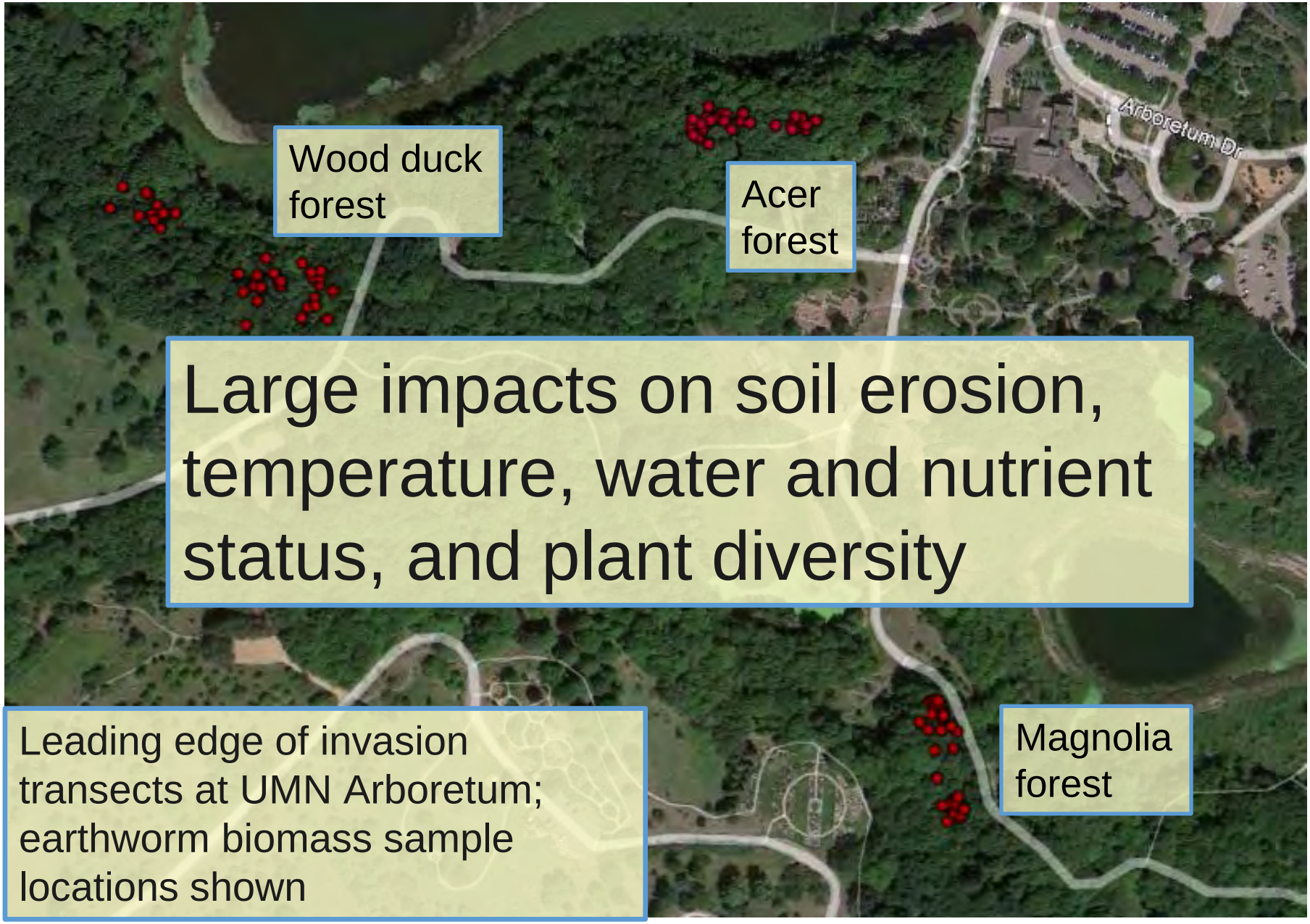

Wood duck forest
Acer forest
Arboretum Dr
Large impacts on soil erosion, temperature, water and nutrient status, and plant diversity
Leading edge of invasion transects at UMN Arboretum; earthworm biomass sample locations shown
Magnolia forest

Photo: Bob Leverett

Questions ?

MITPP
C
Bruce and Ruth Dayton
Darby and Geri Nelson
Olseth Family Foundation

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