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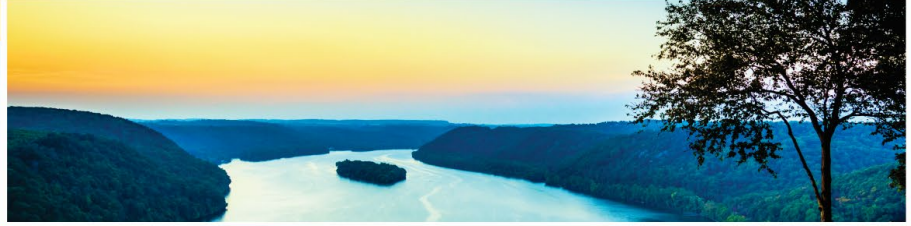
Bureau of Watershed Restoration and Nonpoint Source Management



Invasive Plant Species: Implications for Restoration Success and Water Quality Improvements

Section 319 Virtual Watershed Planning and Implementation Meeting

Melissa M. Harrison, PWS

May 22, 2023

Overview

A

B

C

D

- General overview of invasive plant species
  - Complexity of studying them in aquatic/semi-aquatic ecosystems
- Not-so-obvious impacts of invasive plant species
- How their impacts may affect the success of a restoration project
- Recent developments – Japanese Knotweed
- Conclusion

A – Japanese Knotweed *(Fallopia japonica,* syn. – *Reynoutria japonica*); B – Japanese Stiltgrass *(Microstegium vimineum);* C – Reed Canarygrass *(Phalaris arundinacea)*; D – Japanese Barberry *(Berberis thunbergii)*
Photo Credits: (A, B) DEP 2004, (C,D) https://gobotany.nativeplanttrust.org/

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Invasive Plant Species – Definition and Interest

- A species that has been introduced by humans, accidentally or intentionally, outside its native range **and** has negative impacts on biodiversity, ecosystem services, or human wellbeing (IUCN.org)

How are they different?

What makes them so successful?

What makes them tick?

How exactly are they able to do what they do?

What can we expect following an invasion, how is it going to affect the ecosystem?

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The Answer…

- Not straightforward – a lot of variability
- Infamous response:

IT DEPENDS…

What do you mean MS. SCIENTIST – you should know the answer if you're giving this presentation…

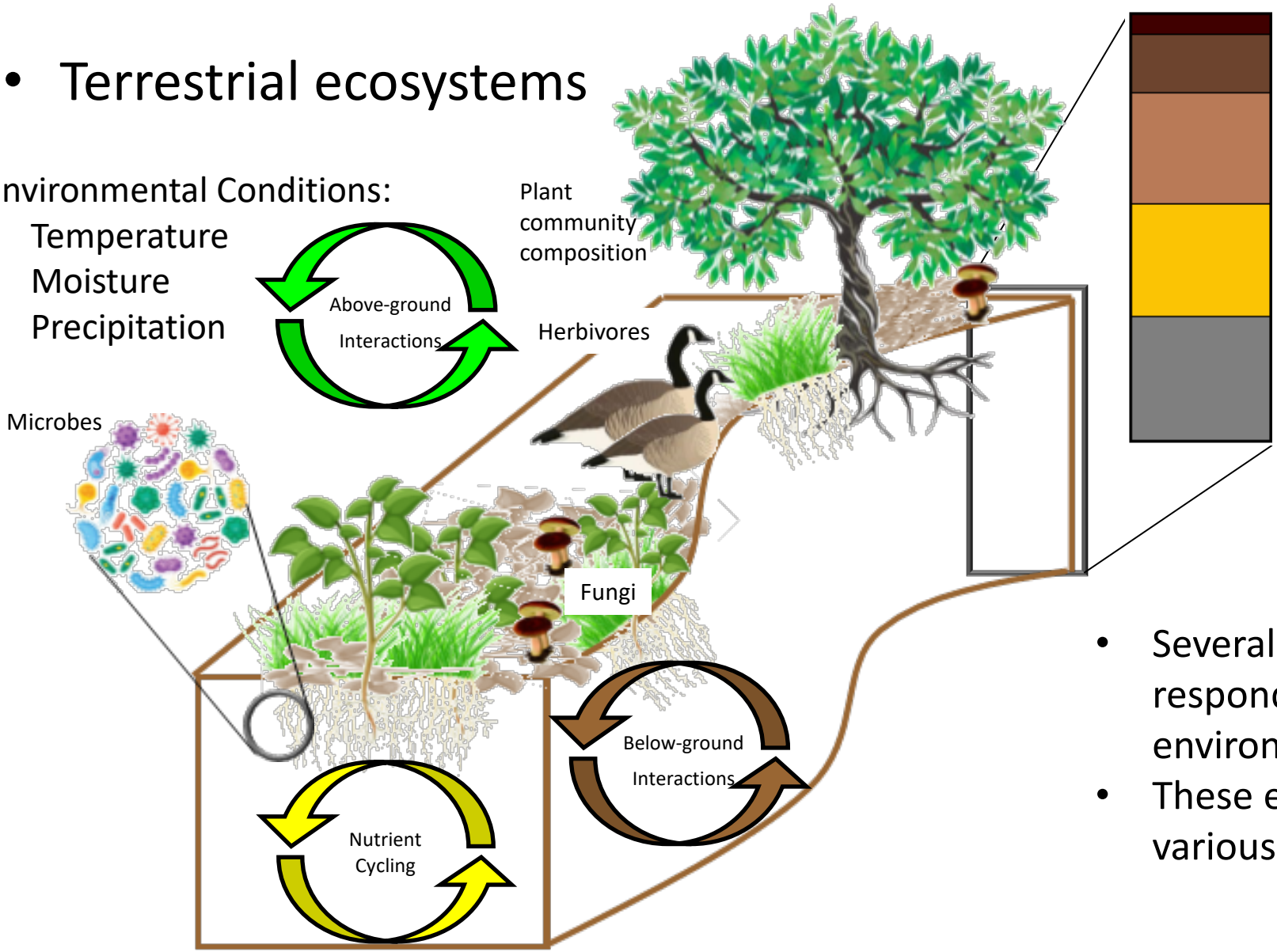
Why does it depend?

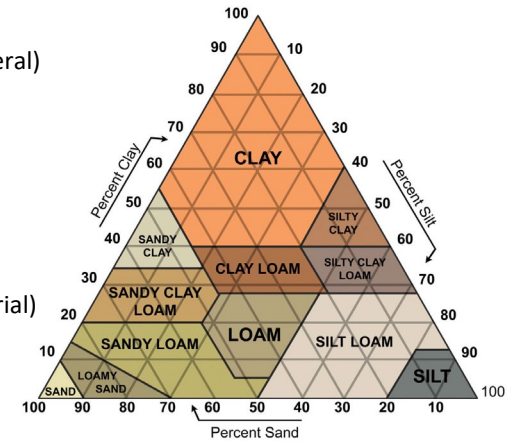
- Ecosystem interaction complexity

Complexity of Aquatic/Semi-Aquatic Ecosystems

- Terrestrial ecosystems

Environmental Conditions:
- Temperature
- Moisture
- Precipitation





Soil type and characteristics

- Several elements can affect how a plant responds to, and performs within, its environment.
- These elements are often interconnected in various ways.

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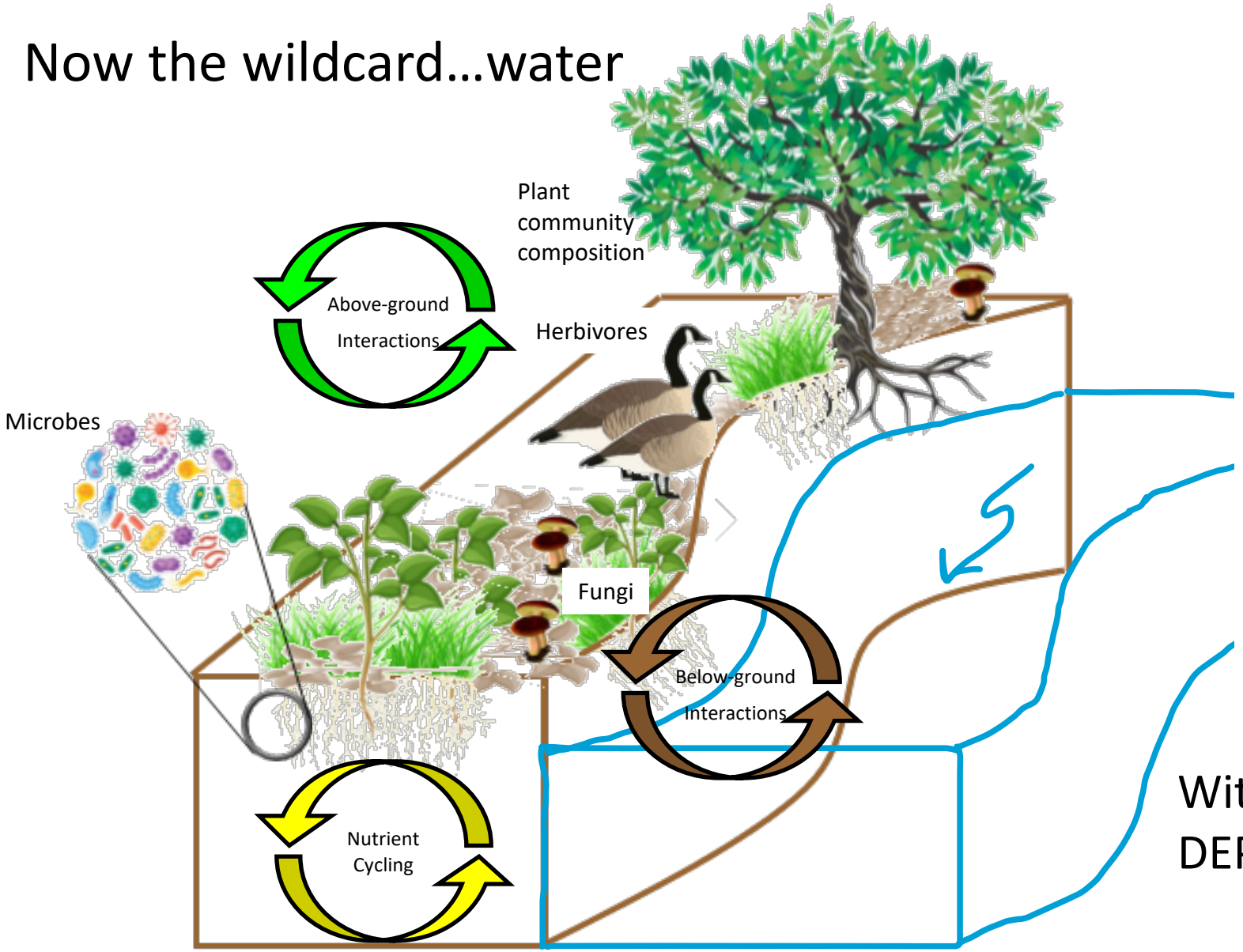
Complexity of Aquatic/Semi-Aquatic Ecosystems

- Now the wildcard…water



Added variables:

- Flooding
- Salinity
- Water temperature
- Transported pollutants and sediments
- Hydrologic regime
- Interaction of soil and water chemistry (pH, conductivity, etc.)
- Anoxic soil conditions
- Effects of drying and rewetting on nutrient cycling and nutrient availability

With all of that in mind…I guess “IT DEPENDS” is an acceptable answer…

Inherent Vulnerability to Invasion

- Riparian and wetland ecosystems are inherently susceptible to invasion
- Naturally function as landscape filters
  - Accumulate debris – creates canopy gaps
  - Subject to influx of nutrients, sediments, and other pollutants
  - Subject to frequent disturbances
- Nearby watercourse acts as an invasive species superhighway

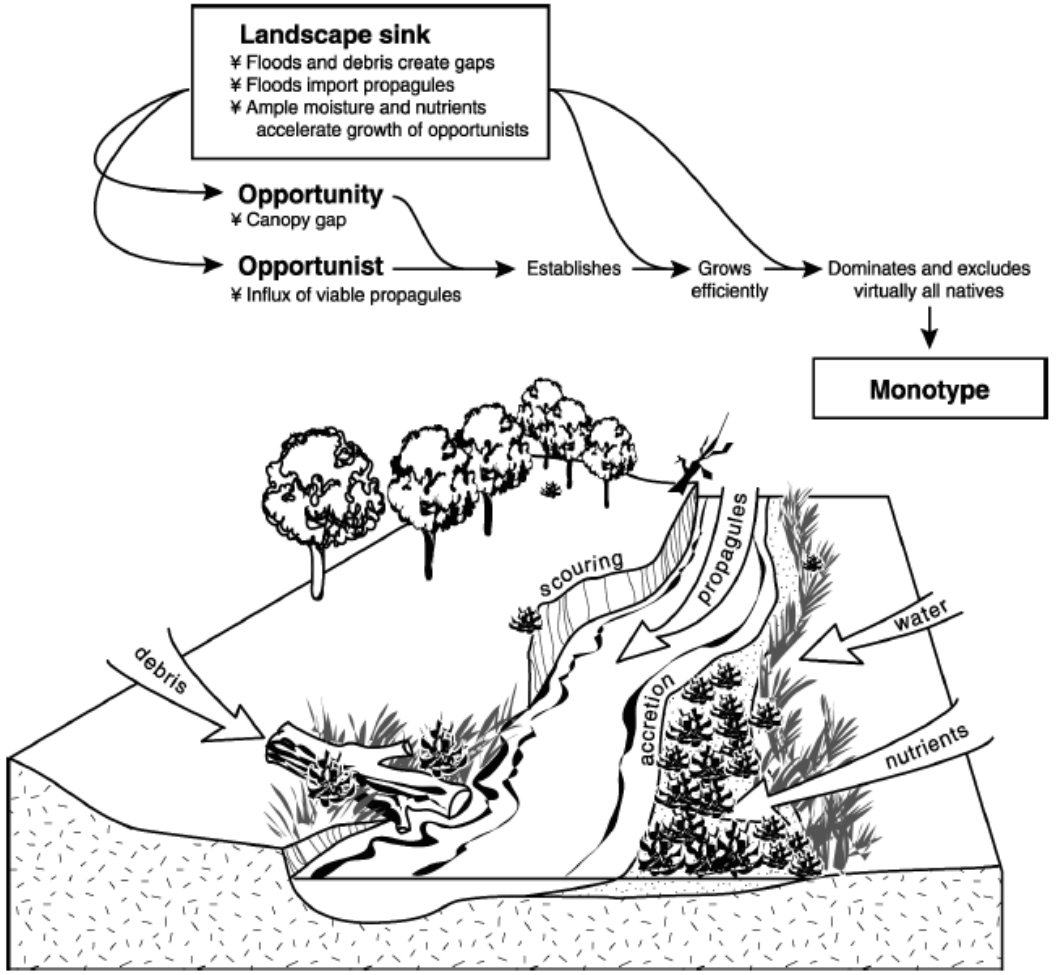


FIG. 6. Conceptual model showing how wetland position (as a landscape sink) has multiple influences on the formation of monotypes by wetland invasive plants: (1) Landscape sinks are subject to inflowing debris and flooding, which create canopy gaps that create opportunity for invasion, (2) floods bring in propagules (seeds, viable plant fragments, floating mats) of opportunistic species, and (3) flooding supplies water and nutrients that accelerate invasion and formation of monotypes. The opportunist is often one that initiates growth early in spring and grows tall quickly (*e.g.*, *P. arundinacea*, which grows efficiently, producing high plant volume per unit biomass *via* hollow stems and aerenchyma). Illustrated by K. Elliot.

Zedler and Kercher 2004

Impacts of Invasive Plant Species

- So they're here…what now?
- Commonly known impacts:
  - Displacement of native species
  - Establishment of monotypic stands
  - Reduced ecosystem biodiversity
- Lesser known impacts:
  - Alteration of nutrient cycling and nutrient availability, nutrient leaching
  - Alteration of soil structure
  - Changes to soil microbiota

Impacts of Invasive Plant Species: Plant Litter

- All plants produce some sort of litter…what makes invasive plant litter so special?
  - Quantity
  - Quality
    - Chemical composition
    - Nutrient content
    - Lignin content
    - C:N ratio
- "High-Quality" litter – high nutrient content, low C:N ratio, low lignin content, low concentrations of secondary (phenolic) compounds

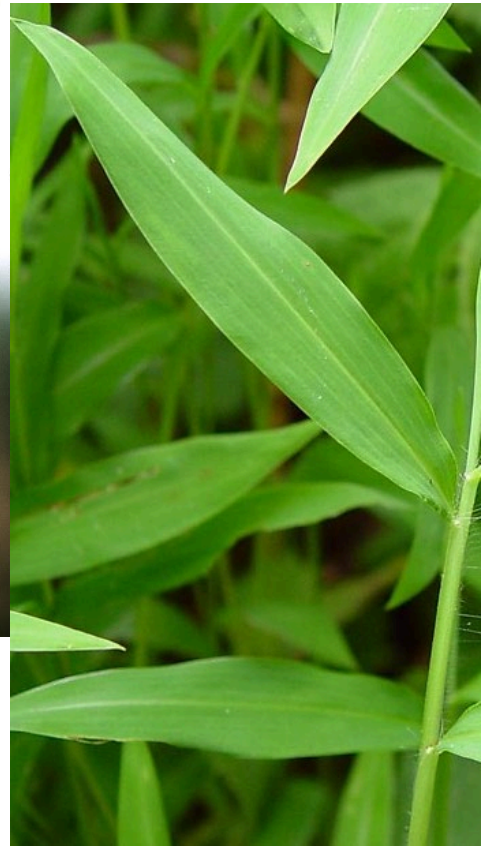


Photo Credits: (Right Top) https://www.minnesotawildflowers.info/grass-sedge-rush/reed-canary-grass; (Right Bottom) https://crcwma.org/index.php/2015/09/05/japanese-stiltgrass-microstegium-vimineum/; (Left Top) https://gobotany.nativeplanttrust.org/species/phalaris/arundinacea/; (Left Bottom) https://gobotany.nativeplanttrust.org/species/microstegium/vimineum/

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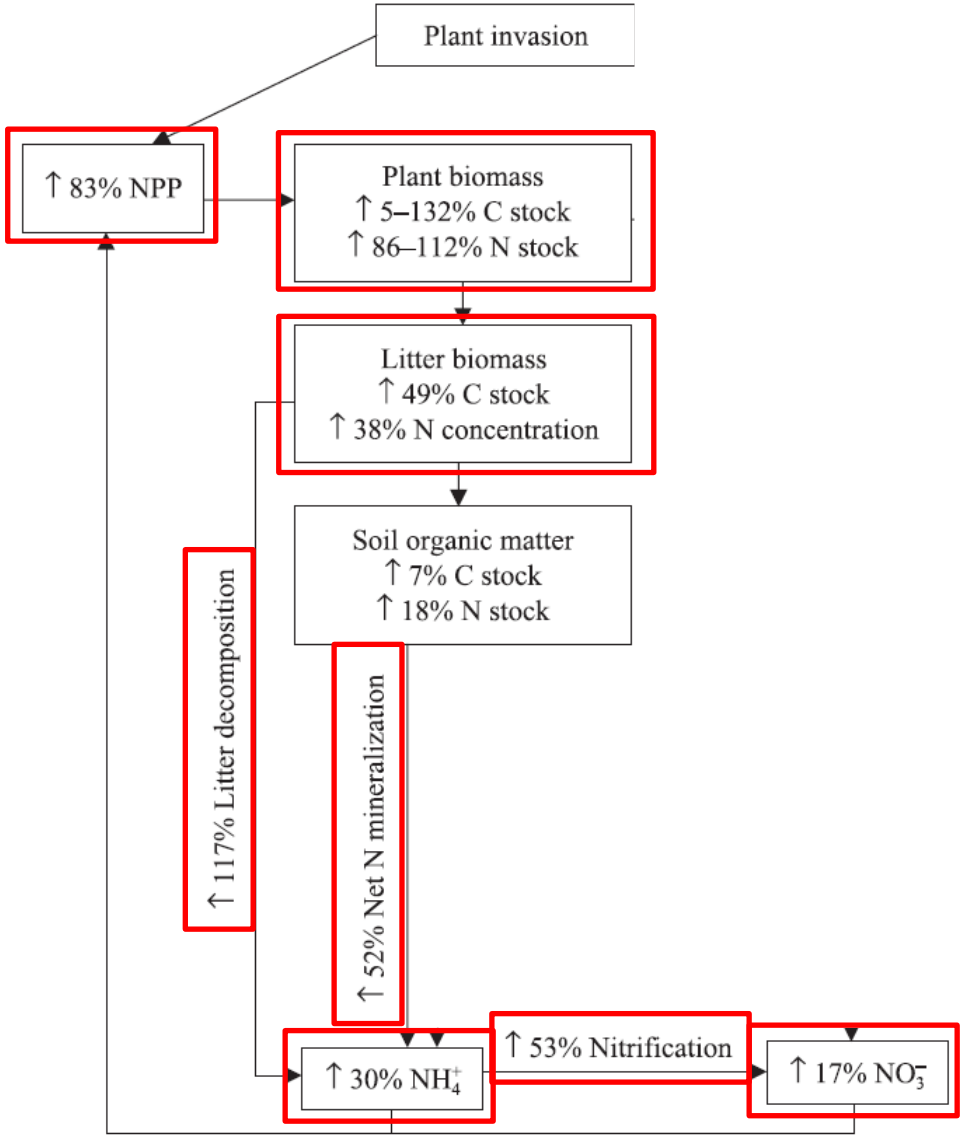
Impacts of Invasive Plant Species: Plant Litter Quality

- Quality of invasive plant litter often differs from natives
  - Higher nutrient concentrations
  - Lower lignin content
  - Lower C:N ratio
- Faster decomposition rate
- Increased nutrient availability in the system
- Accelerated nutrient cycling
- Effects can vary depending on the functional differences between the invader and the native species it is replacing (N-fixing vs. non N-fixing)



Liao et al. 2008

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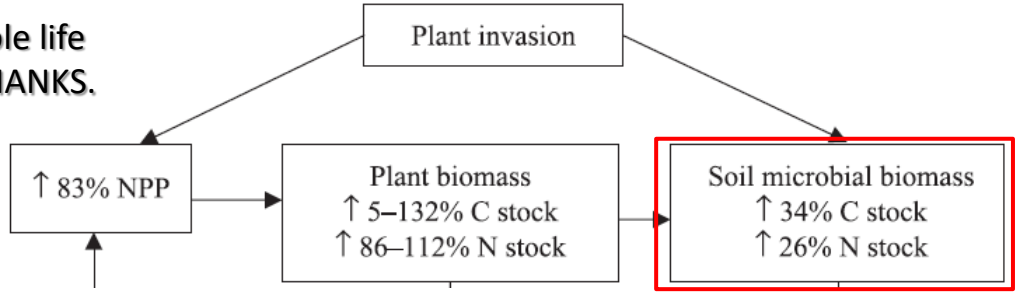
Impacts of Invasive Plant Species: Microbe Interactions

- Did you know?
  - 1 g of soil can contain 5,000 – 10,000 species of microorganisms?!

I could have gone my whole life without knowing that…THANKS.

- Effects of invasive plants on soil communities (direction and magnitude) are site-specific
- Invasive plants can affect soil biota in two ways:
  - Litter Inputs
  - Rhizosphere Effects
- Litter – increased litter quantity that is of higher quality = all-you-can-eat buffet for soil microbiota.



Liao et al. 2008

Table 1 Percent changes of soil biota and their functions in response to litter and rhizosphere effects of plant invasion. Data were shown with mean ± 95% CIs

	Percent changes ($e^{RR} - 1$) × 100%	
Variables	Litter effect	Rhizosphere effect
Biomass		
Microbes	27.52 ± 34.31	6.28 ± 10.63
Bacteria	16.07 ± 11.84	−12.06 ± 15.45
Fungi	−2.87 ± 29.20	4.20 ± 20.77
AMF	—	36.18 ± 34.40
MBC	14.65 ± 21.26	−29.20 ± 58.44
Abundance		
Soil invertebrates	71.48 ± 85.81	−40.37 ± 98.45
Detritivores	119.31 ± 76.30	—
Herbivores	—	−55.03 ± 98.31
Microbivores	89.38 ± 33.25	−14.49 ± 67.27

Zhang et al. 2019

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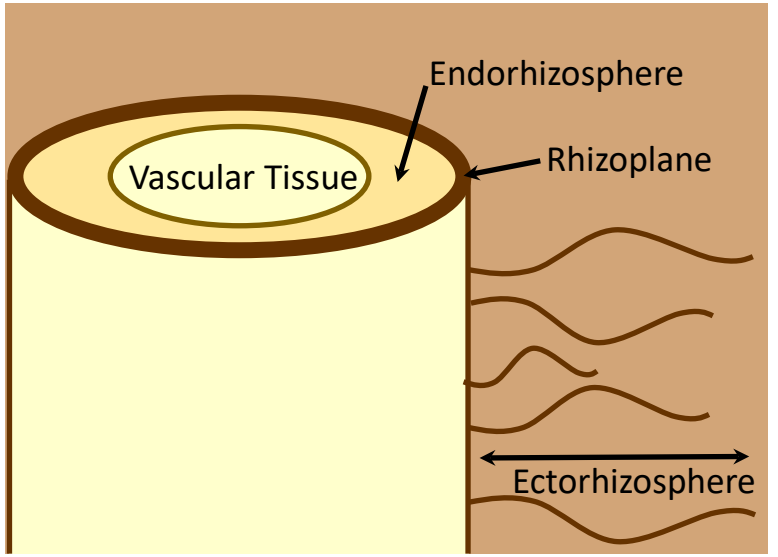
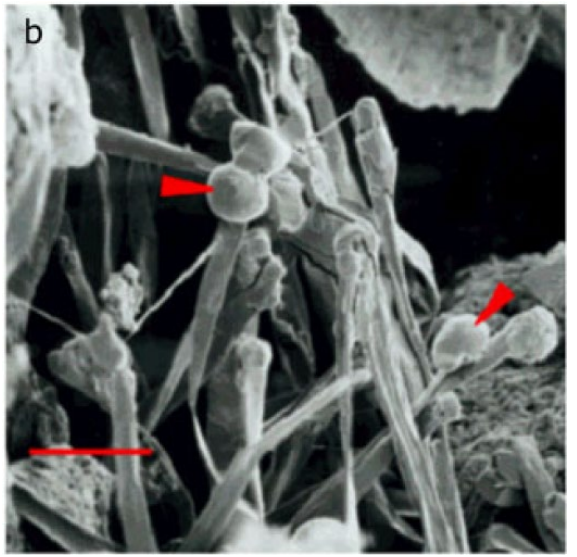
Impacts of Invasive Plant Species: Microbe Interactions

- Rhizosphere: area of chemical, biological, and physical influence generated by root growth and activity (McNear 2013)
  - Endorhizosphere – area **in** the root where microbes fed by root derived compounds may colonize
  - Rhizoplane – root surface and associated soil particles
  - Ectorhizosphere – area surrounding the root where microbes fed by root-derived compounds may colonize
- Rhizosphere effects
  - Root exudates: secretions (active), diffusates (passive)
    - High and Low Molecular Weight
  - Root-biota interactions





McNear 2013

Impacts of Invasive Plant Species: Microbe Interactions

- Root exudate cocktails of invasive plant species can be novel in comparison to native species
  - Unique organic acids, allelochemicals, hormones, enzymes, etc.
- Substances the ecosystem hasn't encountered and adapted to
- Novel compounds can disrupt the ecosystem in favor of the invasive
  - Changes to soil communities
  - Altered nutrient cycling

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Zhang et al. 2019

Photo Credit: https://www.grainger.com/know-how/equipment-information/kh-laboratory-beaker-guide

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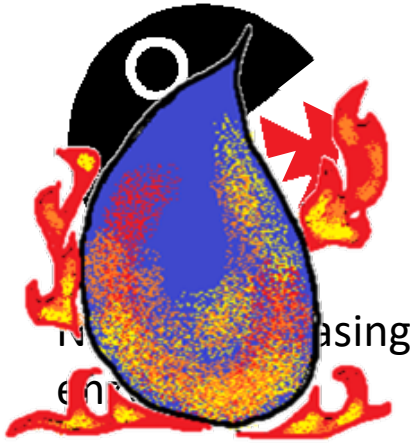
Impacts of Invasive Plant Species: Soil Interactions

- Plants affect soil chemistry and structure
  - Physically – root system growth and expansion
    - Pores and root channels
  - Chemically – root exudates, soil enzymes
    - Alter pH
    - Alter nutrient availability
- Chemical interactions
  - Nutrient releasing enzyme activity
  - Acidifying the rhizosphere
  - Releasing compounds that bind to others in the soil and release the attached nutrients.

Photo Credit: https://phys.org/news/2015-04-hormones-root-growth-revealed.html

Impacts of Invasive Plant Species: Soil Interactions



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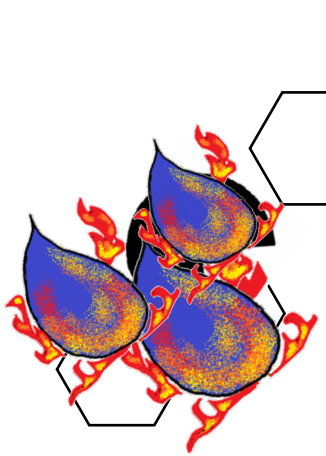
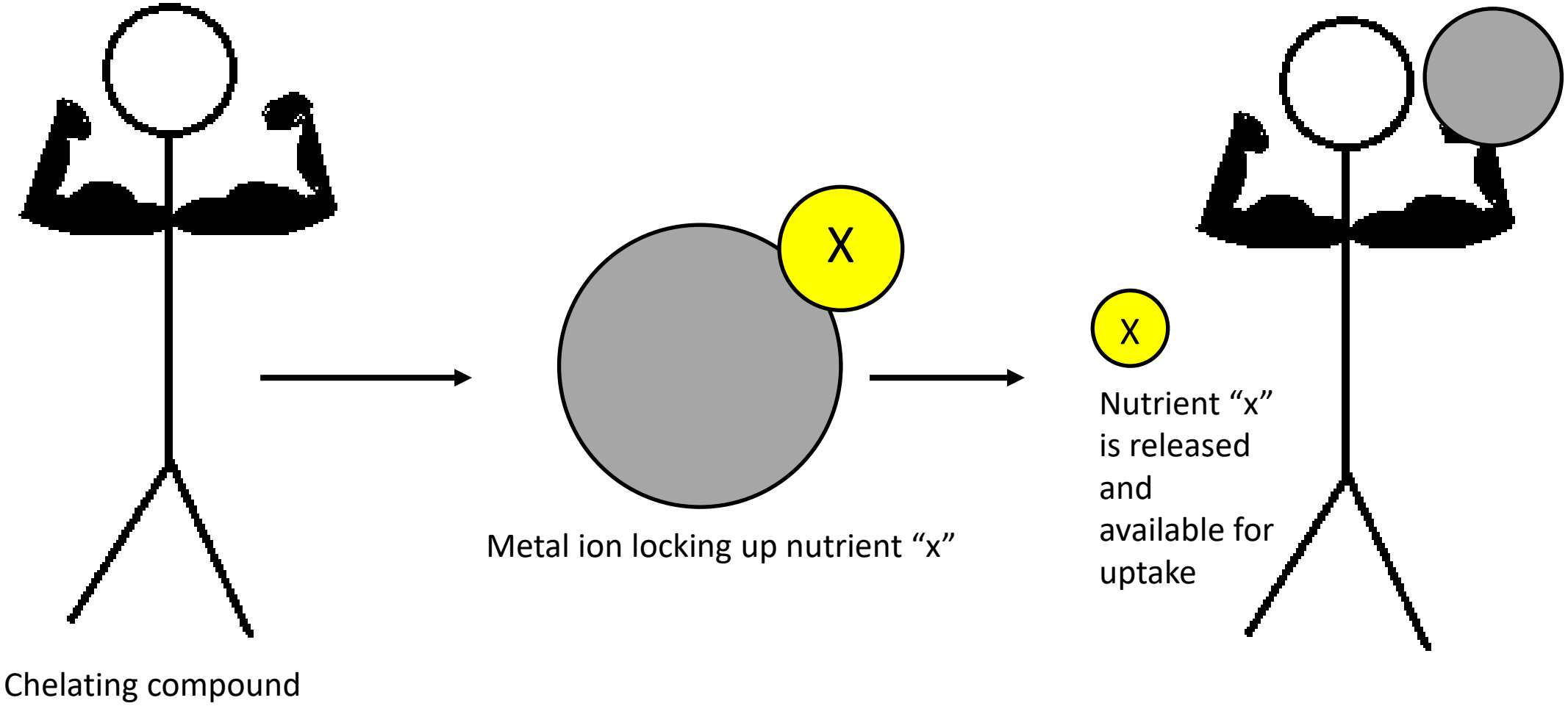
Organic Acid



Smaller, more readily usable compound with attached nutrient “x”

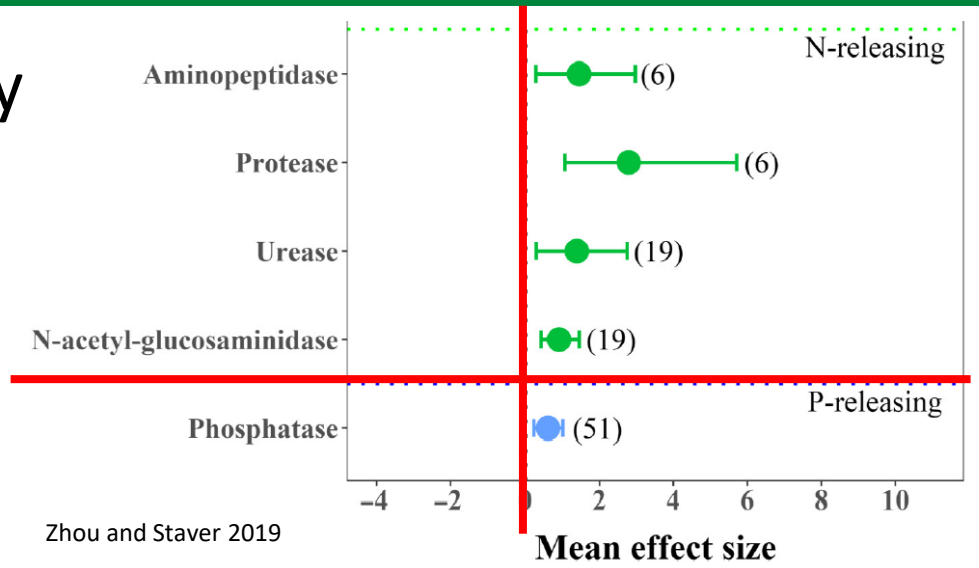
Complex compound with attached nutrient “x”

Impacts of Invasive Plant Species: Soil Interactions

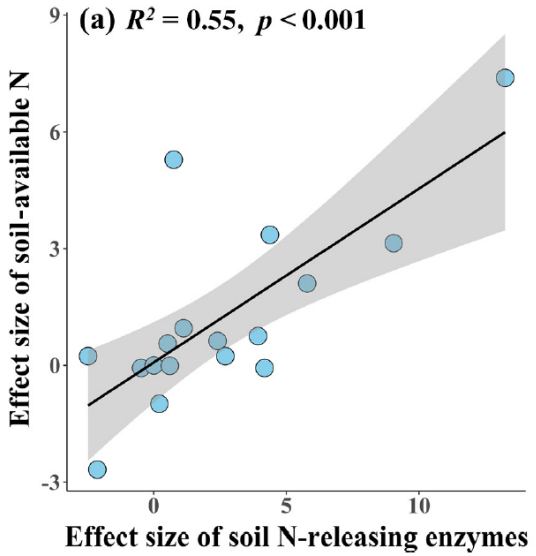


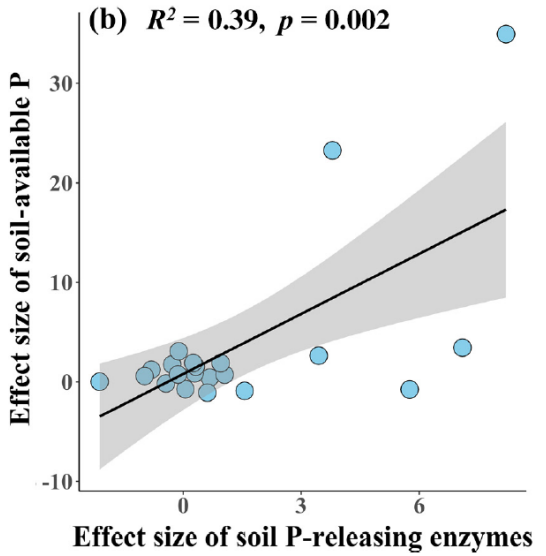
Impacts of Invasive Plant Species: Soil Interactions

- Invaded systems tend to have increased activity of soil enzymes that release N and P than noninvaded systems
  - ↑ 23 – 69% (Zhou and Staver 2019)
- Increased nutrient availability – likely linked to increased enzyme activity.
- Exact pathway for the increased enzyme activity is unclear – combination?
  - Litter inputs → increased microbe activity → increased production of enzymes by microbes
  - Root exudates → direct enzyme release / release of compounds that stimulate microbial activity → increased production of enzymes by microbes



Zhou and Staver 2019





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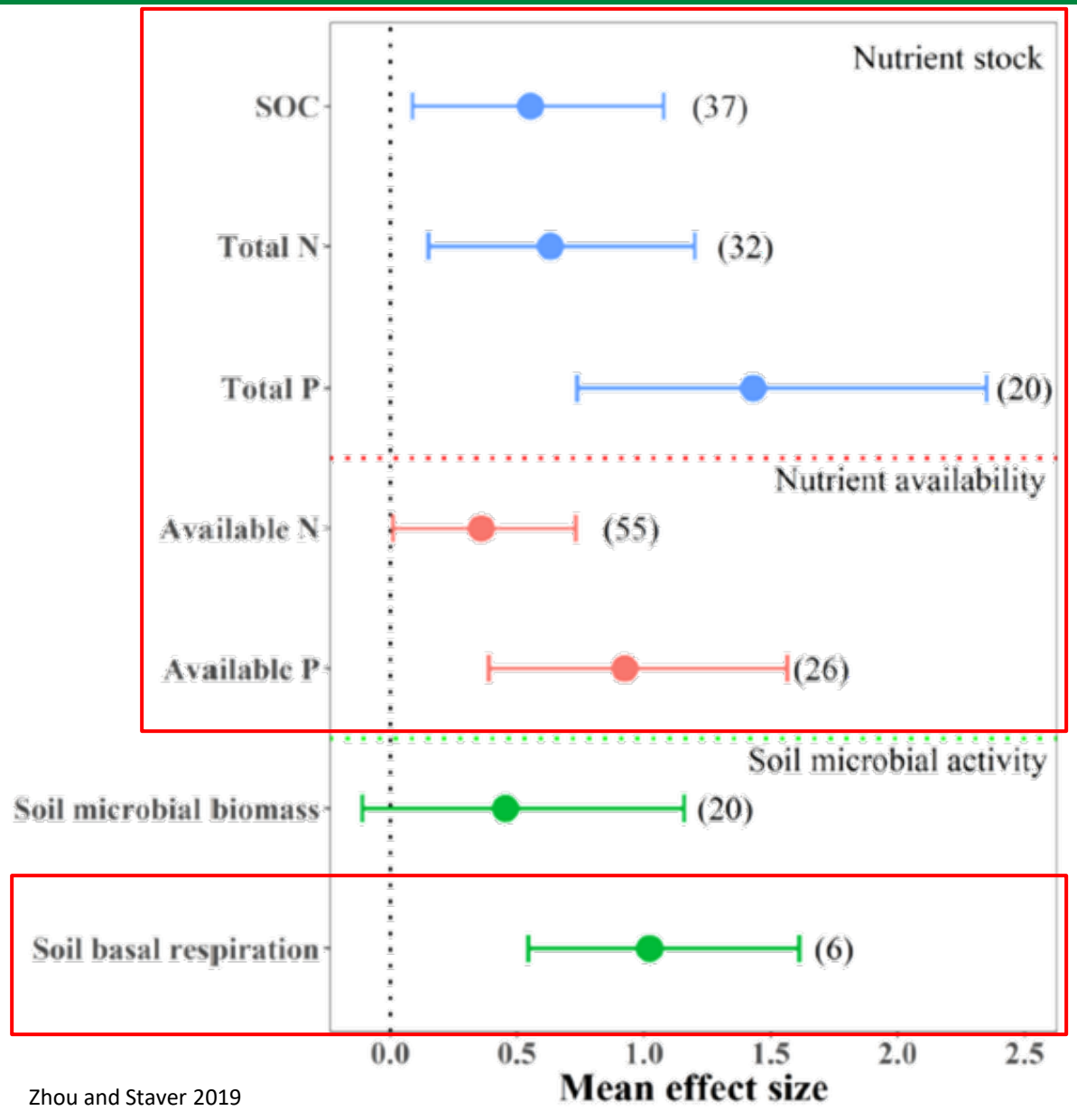
Impacts of Invasive Plant Species: Soil Interactions



Zhou and Staver 2019

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The Big Picture: Ecosystem Implications

- Invasive plant species can alter the chemical inputs into streams
  - Nutrient cycling – nutrient availability
    - **Nutrient leaching from soils**
  - Adjacent soil chemistry
  - Litter deposition
- Changes to erodibility
- Changes to macroinvertebrate communities
  - Diversity
  - Abundance

Photo Credit: (Top) https://www.nps.gov/cuva/learn/nature/japanese-knotweed.htm
(Bottom) https://dep.wv.gov/wwe/getinvolved/sos/pages/macros.aspx

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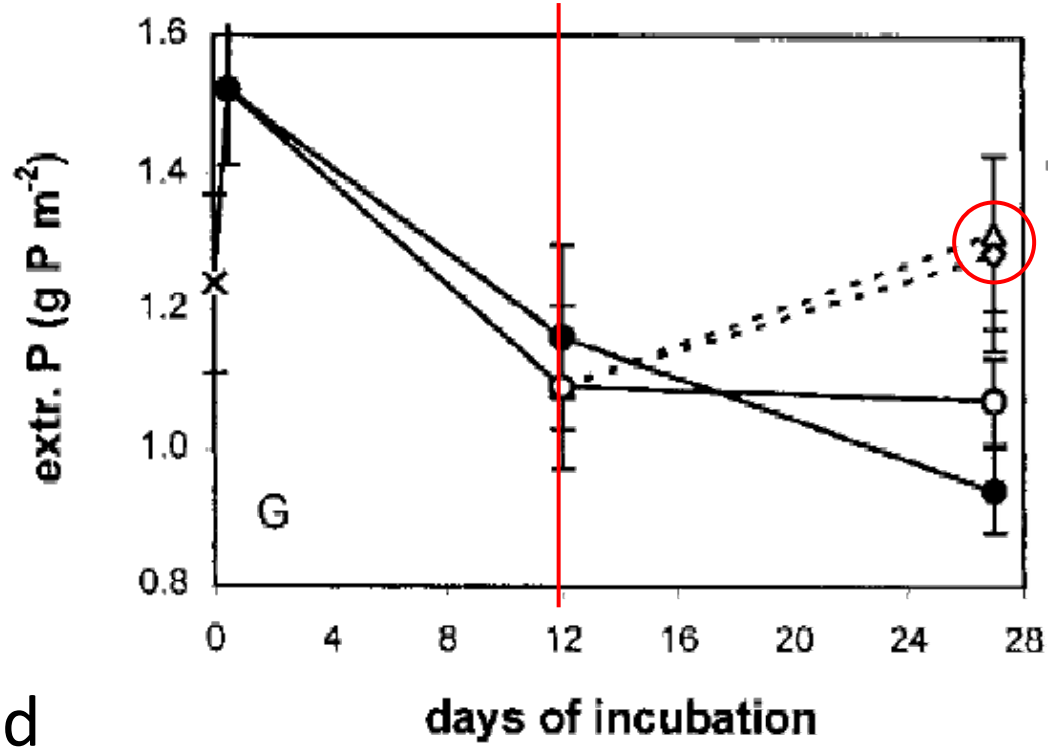
Ecosystem Implications: Nutrient Leaching

- Soils near streams experience periods of drying, re-wetting, or are always in contact with water
  - Oxic and anoxic conditions
- Nutrient cycling processes are affected by hydrology and availability of oxygen
- (Venterink et al. 2002) – Looked at effects of soil drying and re-wetting on nutrient release and availability
  - ↑ denitrification (release of N into atmosphere, occurs in anoxic conditions)
  - no effect on available N for plants/microbes
  - ↑ available P



x field cores,
• constant wet cores,
◯ dried cores,
Δ dried cores after 12 days re-wetted with distilled water,
◊ re-wetted with sulphate-enriched water.

Venterink et al. 2002 (adapted)

Ecosystem Implications: Nutrient Leaching

- Invasive plants can increase nutrient availability in the soil → this can lead to increased nutrients in the stream
- Autumn (*Elaeagnus umbellata*) and Russian Olive (*Elaeagnus angustifolia*)
  - Soil water and/or stream nitrate concentrations (NO_3^-) increased in invaded areas
  - Ammonium (NH_4^+) concentrations did not increase
- Excess nitrate and/or phosphorus can impact water quality
  - **<u>Can potentially affect a project's ability to meet load reduction goals</u>**
  - Potential for stream eutrophication if the watershed is densely populated with N-fixing invasive plant species

Photo Credit: (Top) https://gobotany.nativeplanttrust.org/species/elaeagnus/umbellata/
(Bottom) https://gobotany.nativeplanttrust.org/species/elaeagnus/angustifolia/

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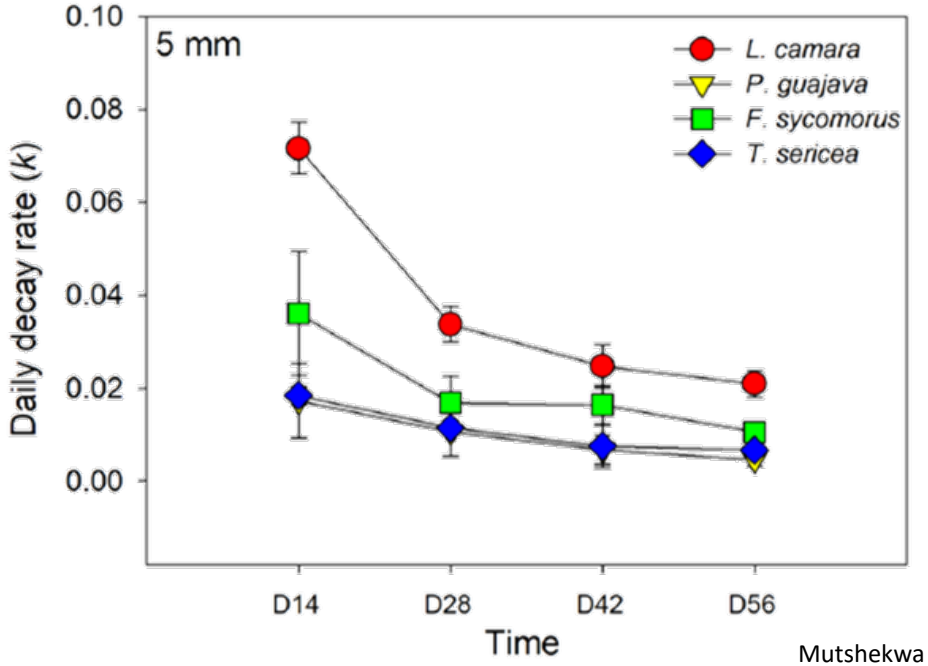
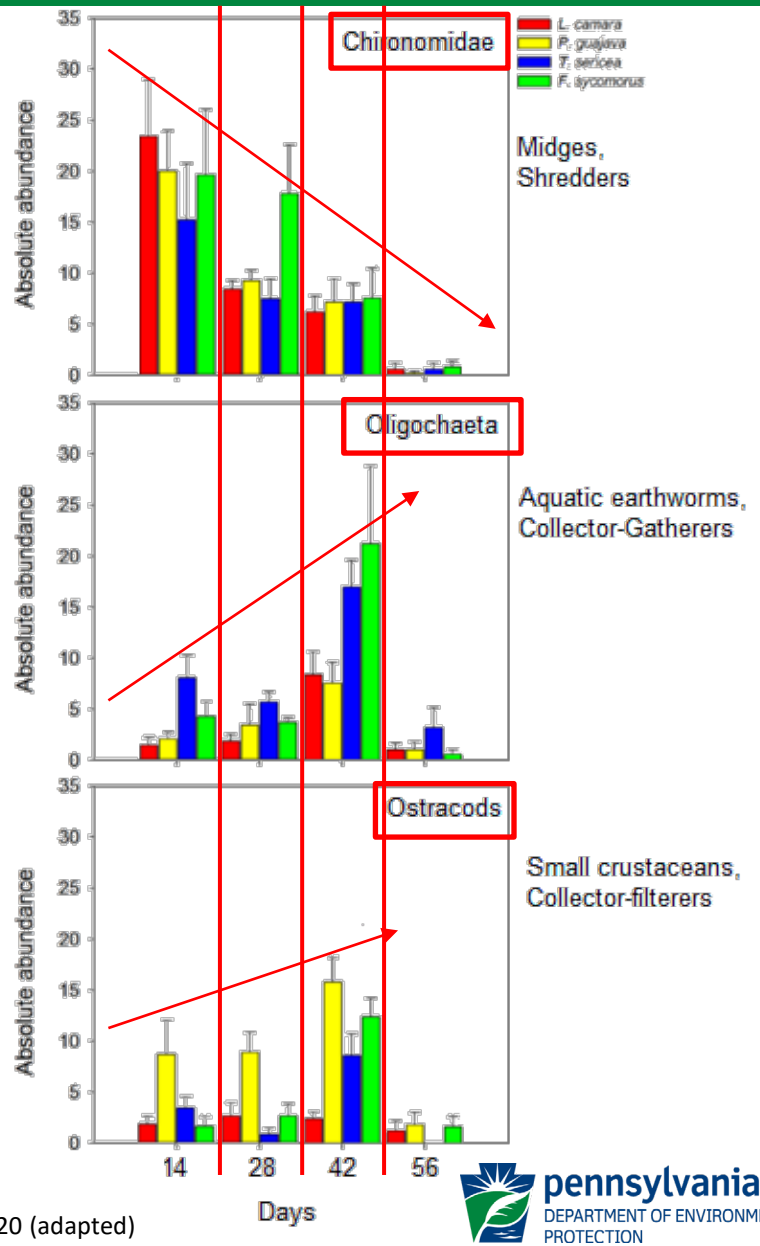
Ecosystem Implications: Macroinvertebrates

- Abundance of macros on invasive plant litter was sometimes higher than native litter
- Different macros responded differently over time
- Diversity was not significantly different
- Litter decomposition rate was variable between native and invasive plants
- Missing piece…
  - Litter Quality





Mutshekwa et al. 2020 (adapted)

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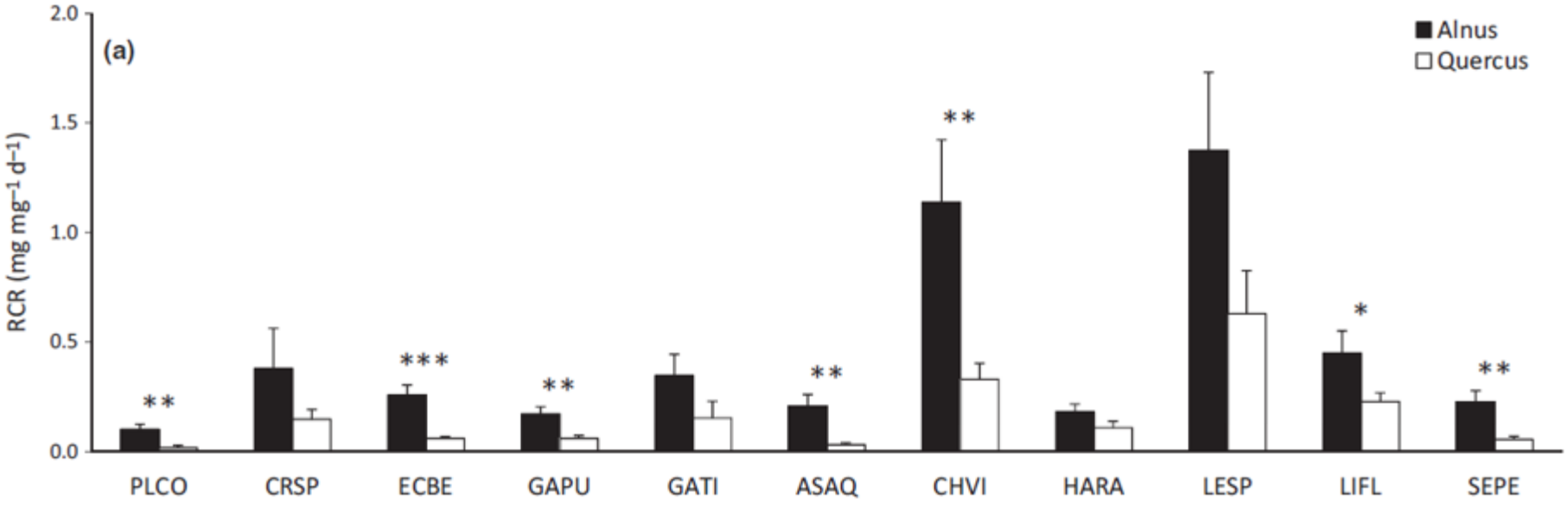
Ecosystem Implications: Macroinvertebrates

- (Santonja et al. 2018) Compared amount of litter consumed by macros when given high vs. low quality litter
- Black Alder (*Alnus glutinosa*) vs. English Oak (*Quercus robur*)
  - Alder – more N, less lignin, less phenolics, lower C:N ratio than oak – "High Quality"
- Average consumption 3x higher for Alder litter
  - Some macro spp. consumed more or approximately equal amounts



Santonja et al. 2018

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Ecosystem Implications: Macroinvertebrates

- So, the macros are eating the invasive litter…what's the problem?
  - Duration
  - Food Variety
- Native plant litter is available for a longer period of time
- Invasive plant litter is available for a shorter period of time
- Reduced plant diversity in invaded systems → fewer "longer-lived" food sources
- Change food variety → potential changes for certain groups of macros → shifts in the community
  - **<u>Potential implications for the IBI score</u>**
- Important to note: Impacts are variable and site-specific

Photo Credit: https://www.petmd.com/cat/symptoms/head-tilt-cats


Photo credit: https://www.everydayhealth.com/diet-nutrition/diet/bananas-nutrition-facts-health-benefits-recipes-risks/


Photo credit: https://soothingfood.com/different-types-of-fruits/

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Ecosystem Implications: Erodibility

- Changes to plant community structure, vegetation characteristics, and density all affect sedimentation and erosion processes
  - Height, stem diameter, rigidity
- Plants differ in rooting depth and structure
  - Invasive dominance → uniform rooting depth, ↑ risk of erosion

McNear 2013 (adapted)

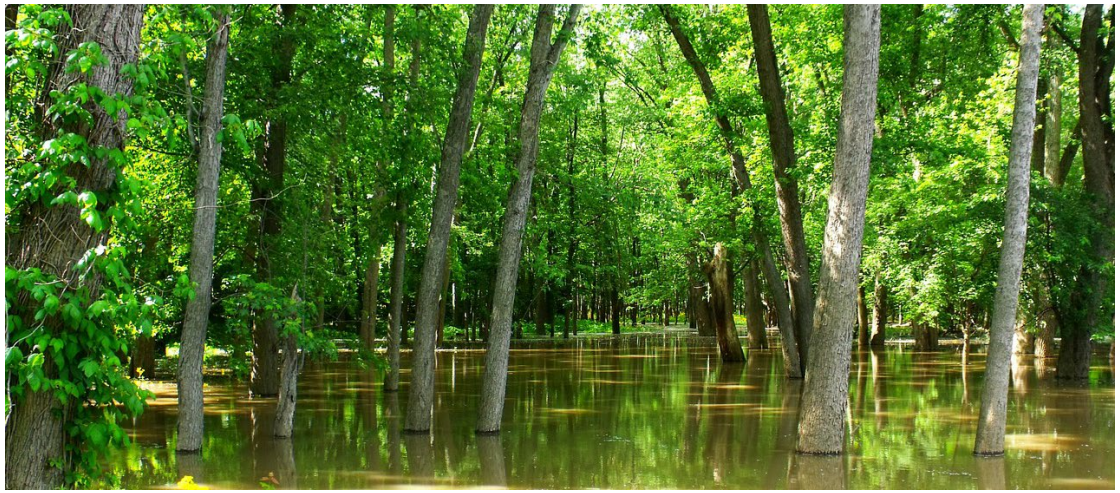

Photo credit: https://www.yellowstonelandscape.com/blog/the-effects-of-standing-water-and-flooding-on-trees-and-landscape-plants

Photo credit: https://thegrassoutlet.com/how-do-i-fix-my-lawn-after-it-floods/

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Case Study: Japanese Knotweed

- Concern that Japanese Knotweed may increase the rate of erosion along streambanks
  - Primarily an issue during the winter and early spring
- After leaves die back, sparse standing biomass leaves bare soil exposed
- Uniform, shallow root depth
  - Fragile roots that lack root hairs
- Up to this point – observational accounts and inferences, lack of empirical evidence
- Body of literature is growing
  - Mix of preliminary data and peer-reviewed studies

Photo credit: https://southwalesknotweedremoval.co.uk/spot-japanese-knotweed-winter/

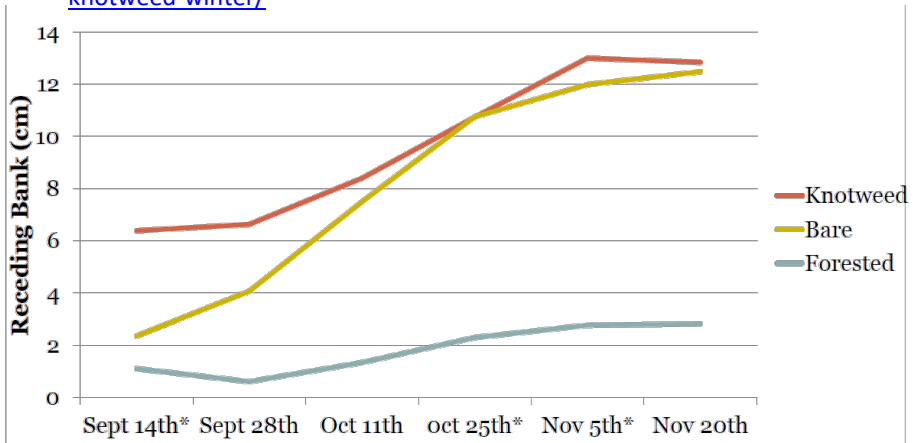

Figure 2: Rate of stream bank erosion compared to different vegetative buffers.

Secor et al. 2013

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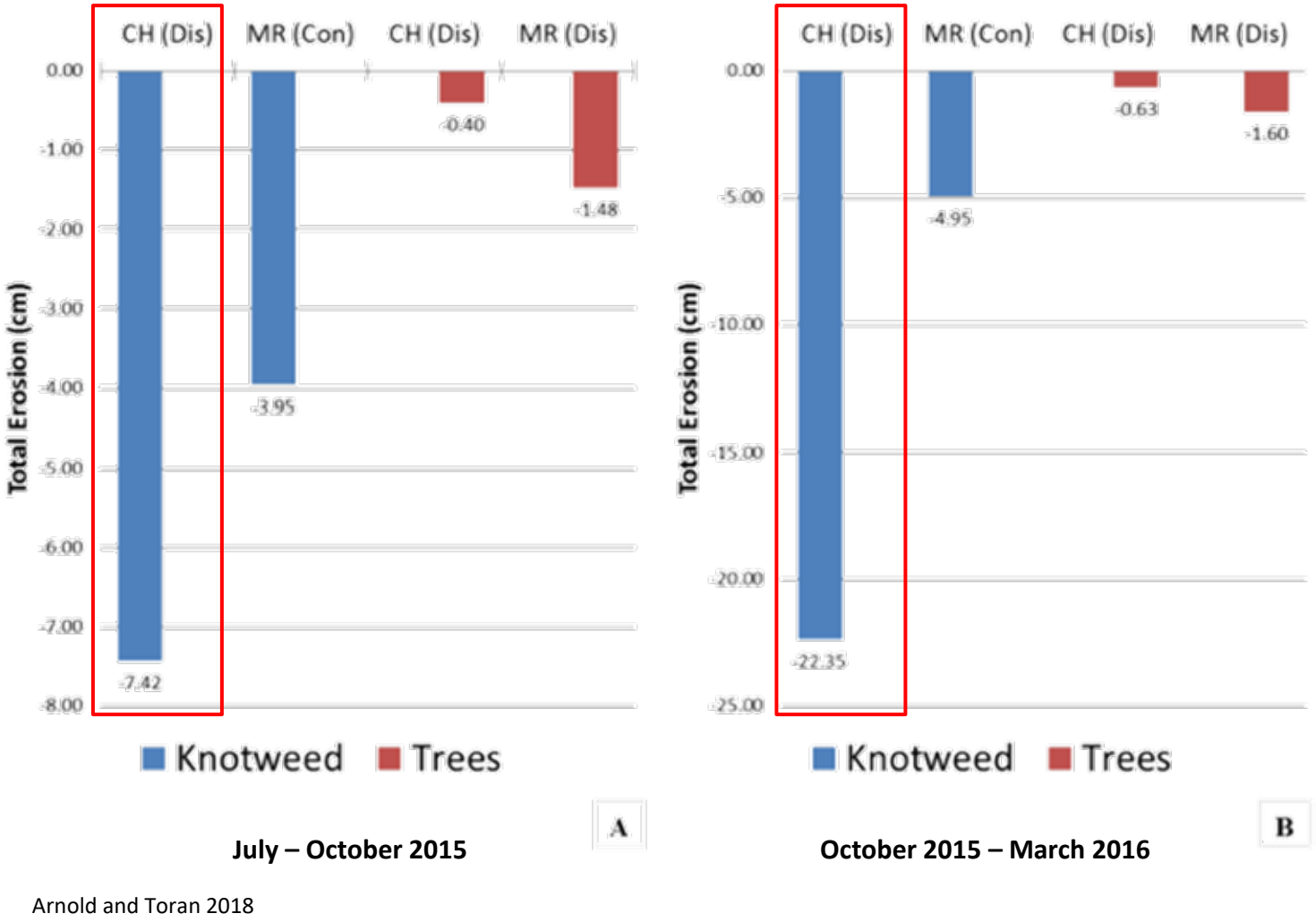
Case Study: Japanese Knotweed

- Arnold and Toran 2018 – experimentally examined knotweed and its effects on erosion
- Highest erosion → incised streambanks dominated by knotweed

Photo Credit: https://www.nps.gov/cuva/learn/nature/japanese-knotweed.htm



Arnold and Toran 2018

- Lowest erosion → incised streambanks dominated by trees

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Conclusion: Implications for Restoration Success

- Streams and their associated projects are monitored and assessed based on water chemistry, macros, and habitat
- Invasive Plant Impacts - Key Points:
  - ↑ nutrients leached into the stream → can affect a project's ability to achieve **nutrient load reductions**
  - Shifts in macroinvertebrate communities over time → can potentially affect the stream's **IBI score**
  - ↑ erodibility of the banks → can work against a project's ability to achieve **sediment load reductions** and affect the project's resiliency/longevity in the face of extreme weather events

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Conclusion: Prevention and Early Detection is Key

- Prevent invasive species establishment
  - Make sure construction equipment is clean prior to entering the site
  - Exercise due diligence if topsoil will be needed from offsite
  - Obtain seed mixes from certified, reputable companies
- Conduct regular monitoring
  - Address invasive establishment quickly
- Understand your invader
  - Not all management strategies are created equal

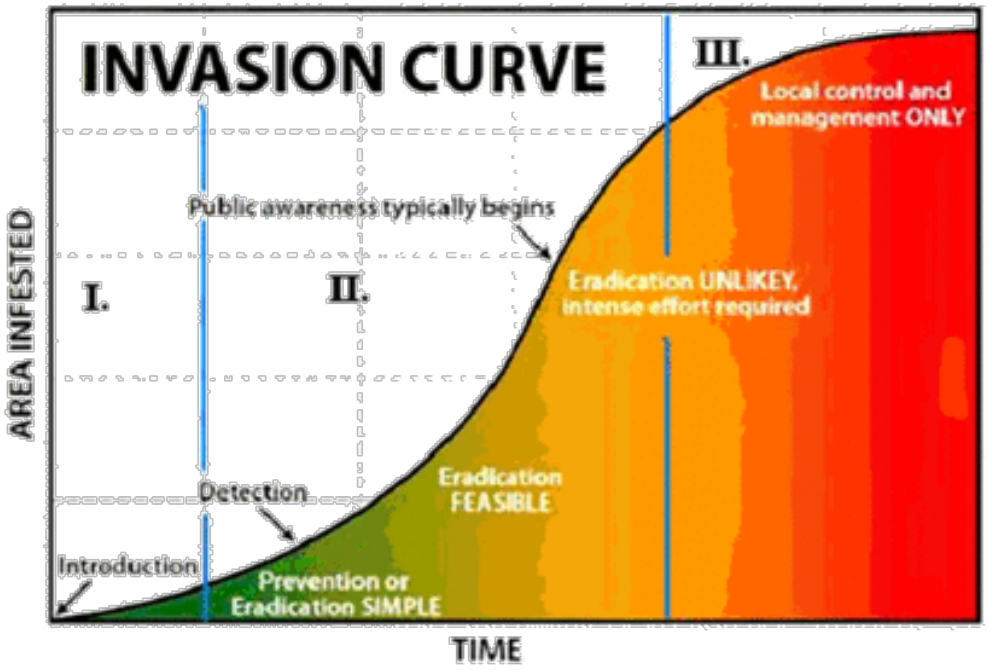

Image Credit: https://chautauqua.cce.cornell.edu/environment/invasive-nuisance-species/invasion-curve

Questions?

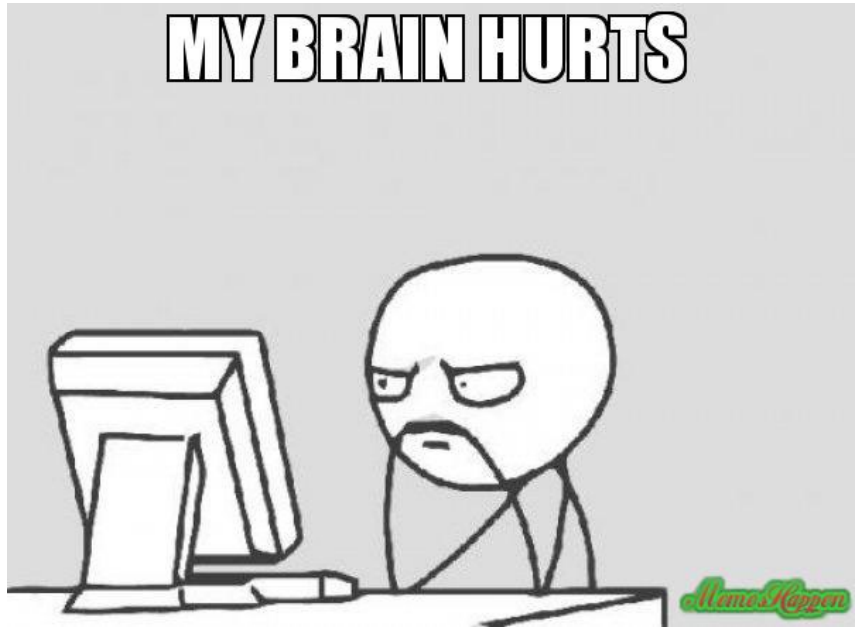

Image Credit: https://memeshappen.com/meme/112687/My-brain-hurts

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