Identifying restoration practices and landscape variables that increase native plant establishment and mitigate plant invasion

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Invasive species are a global threat to biodiversity

Global econ. cost: **$423B**

60% of extinctions driven solely or partly by invasive species

Interfere with restoration goals

IPBES 2023

Can stream restoration encourage invasion?

Disturbance creates establishment opportunities

Increase in “free space”

Soil disturbance

Research Questions

- Determine restoration techniques and environmental factors of existing stream restoration projects that limit invasion of non-native plant species and facilitate native plant establishment.

  - Compare the vegetation community of restored with un-restored stream reaches.

  - Provide recommendations on stream restoration techniques and planting practices that facilitate native plant establishment and minimize colonization of invasive plants.

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Hypotheses

Invasive plant colonization will be correlated with increased resource availability and increased disturbance.

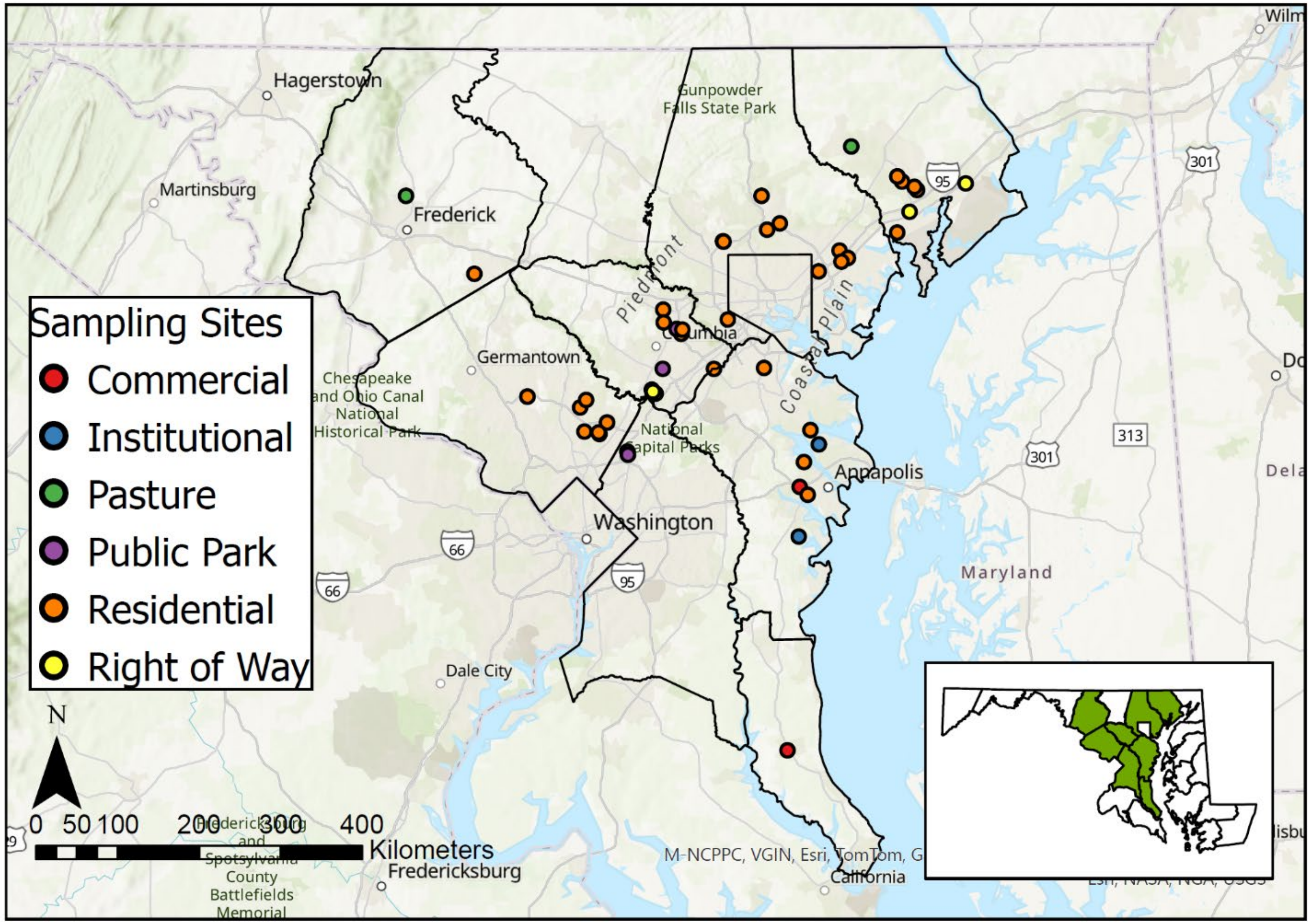
Restored reaches will have greater invasive plant cover than unrestored reaches.

Study Design

46 paired sampling streams (n=92)

- Restored reach
- Unrestored reach

6 sampling points/stream along 100 m reach (n=600)



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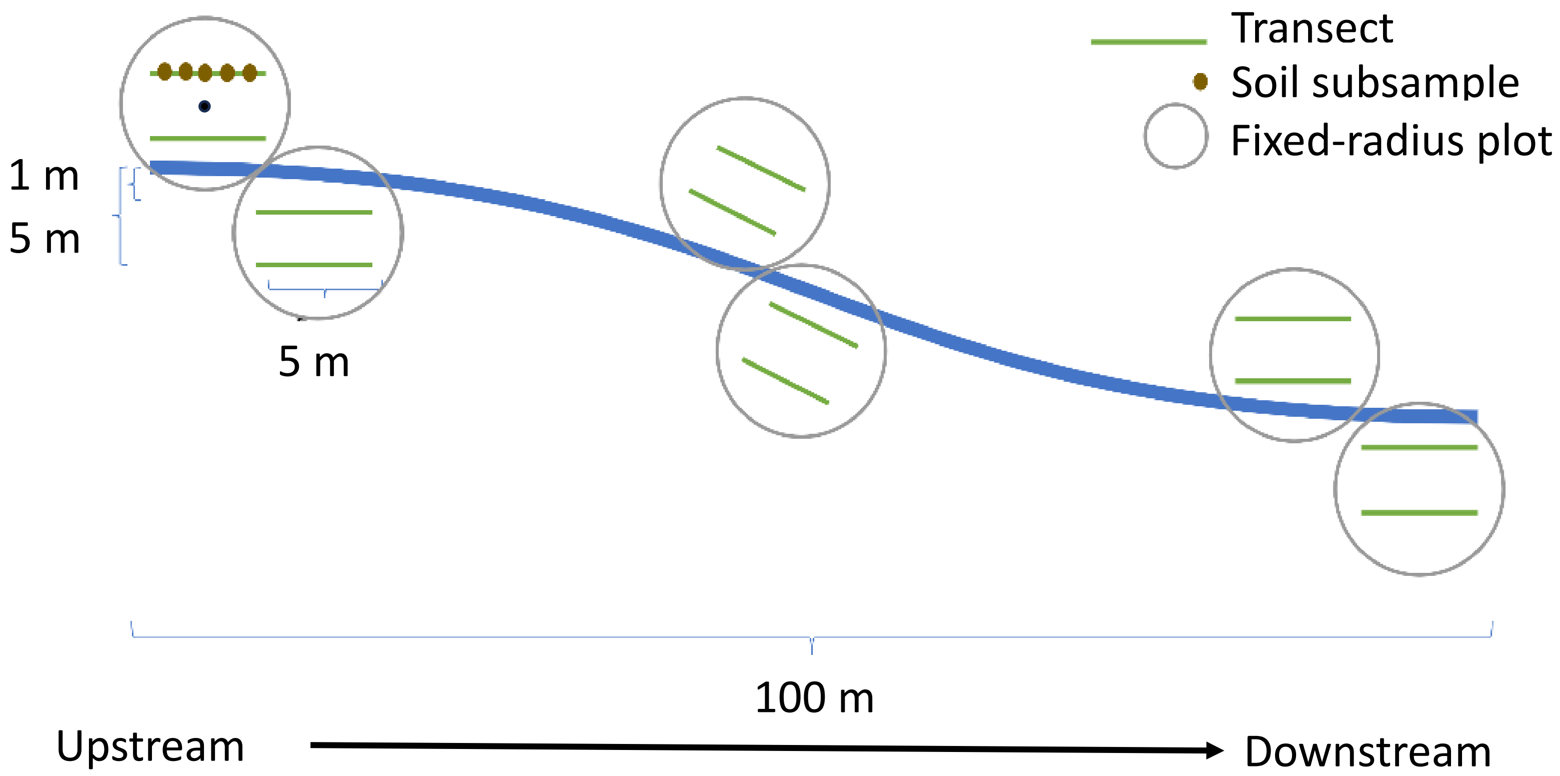
Vegetation and Soil Sampling



2 transects/point
(n=12/stream)

5 soil samples/transect
(n=60/stream)

1 fixed-radius plot/point
(n=6/stream)

Species Indices

- Using non-native* and native species

- $$Nonnative\ \ Species\ Index = \frac{\left(\frac{nonnative\ species\ richness}{overall\ species\ richness}\right) + \left(\frac{nonnative\ species\ cover}{total\ cover}\right)}{2}$$

- NNSI = Non-native species index (USDA PLANTS)
- NSI = Native species index (USDA PLANTS)

*93% of non-native species observed are also considered invasive by US-RIIS

Utilizing paired design to reduce noise

Unrestored

0.33

-0.67

Restored

0.52

-0.32

$NNSI_{U-R}$ -0.19

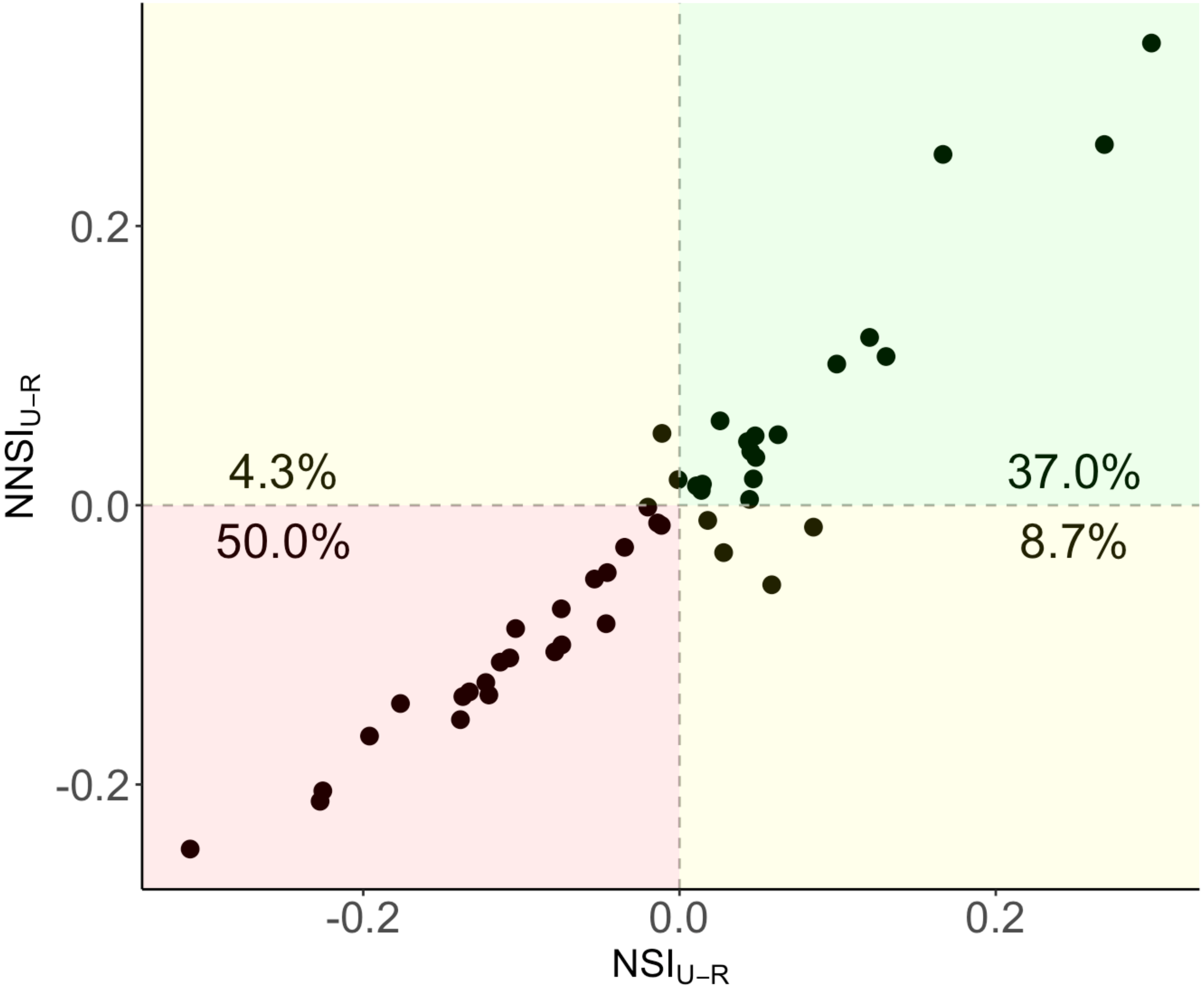
NSI_{U-R} -0.35

Potential Revegetation Outcomes

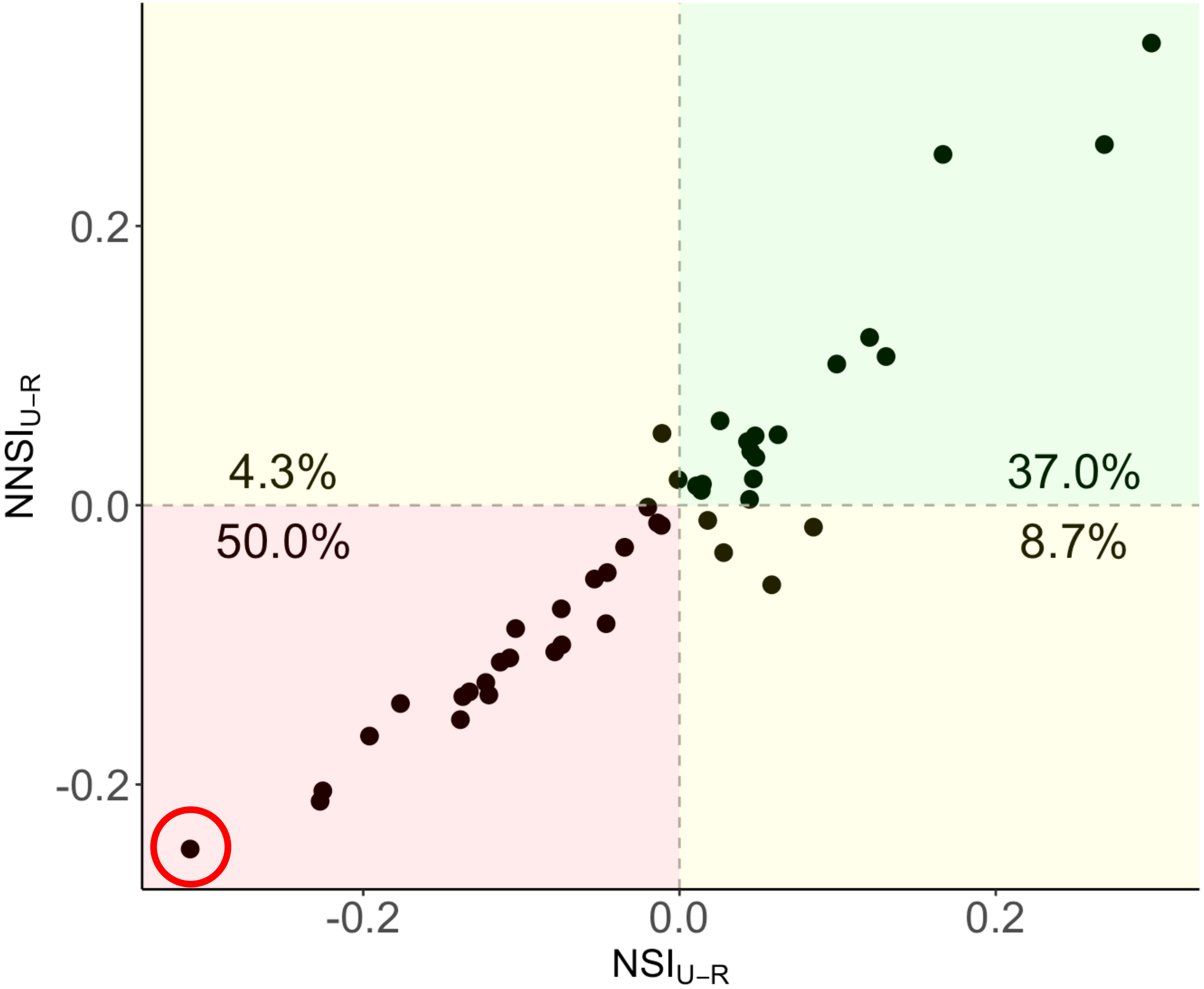
	↓ native species richness and cover	↑ native species richness and cover
↓ non-native species richness and cover	**Bad** Lower richness and cover of native species and greater richness and cover of non-native species	**Good** Greater richness and cover of native species and lower richness and cover of non-native species
↑ non-native species richness and cover	**Ugly** Lower richness and cover of native species and greater richness and cover of non-native species	**Bad** Greater richness and cover of native species and greater richness and cover of non-native species

Results

Stream restoration worsens plant invasion in most cases



Example: poor outcome



Species coverage of a poor outcome

Restored: 27 native species, 15 non-native species

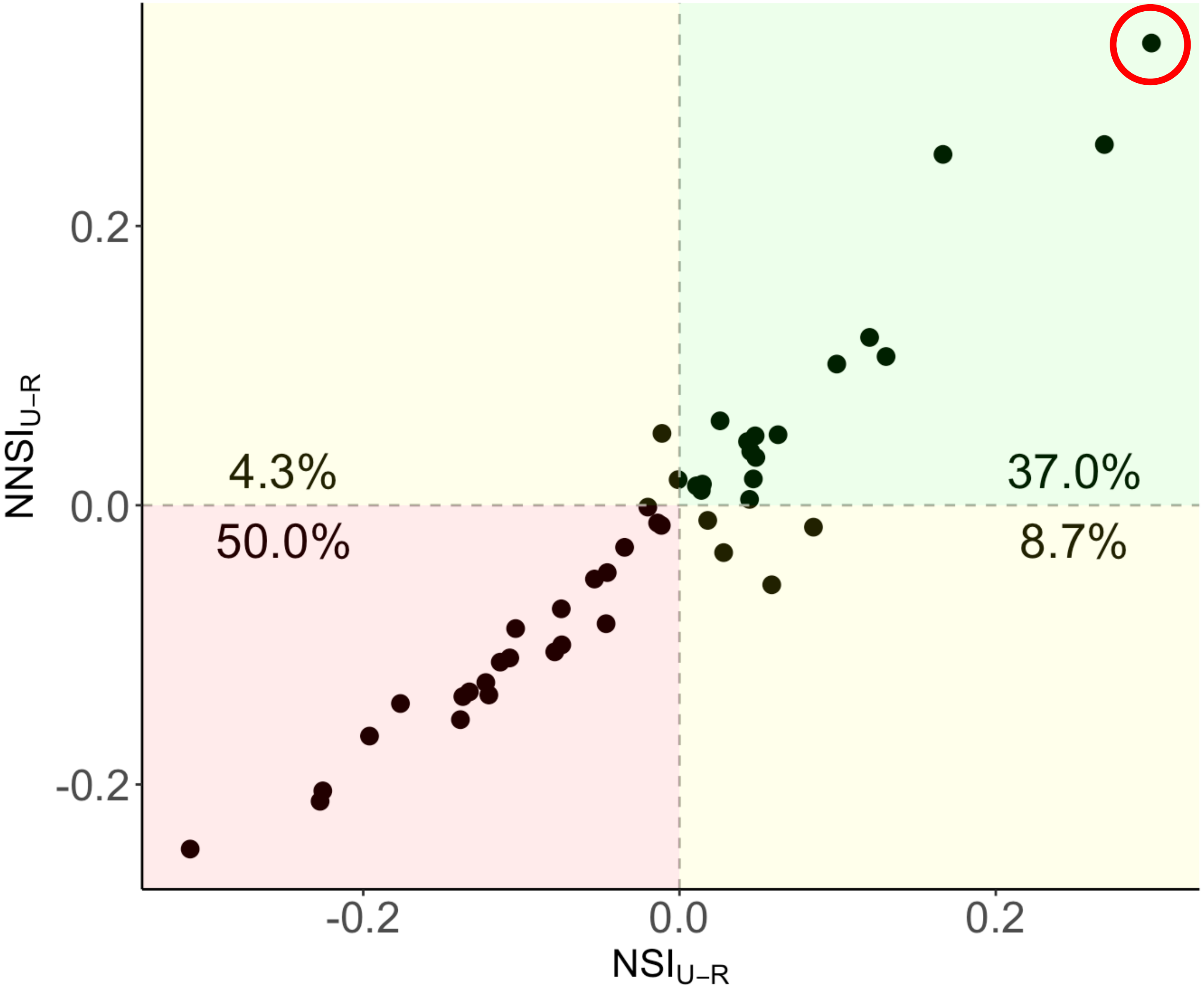
Species	% Coverage
Japanese stiltgrass*	24.3
Red maple	14.1
Redtop*	8.5
American elm	6.3
Sugar maple	5.7
Ground ivy*	3.7
Ostrich fern	3.1
Multiflora rose*	3.1
Violet spp.* (maybe)	2.7
Skunk cabbage	2.3

Unrestored: 28 native species, 8 non-native species

Species	% Coverage
Tulip poplar	24.5
American hornbeam	20.9
New York fern	19.1
Red maple	6.8
Ground ivy*	4.9
Blackgum	4.0
White oak	3.3
Red oak	3.3
Japanese barberry*	1.8
Pignut hickory	1.6

*non-native

Example: desired outcome



Species coverage of a desired outcome

Restored: 22 native species, 10 non-native species

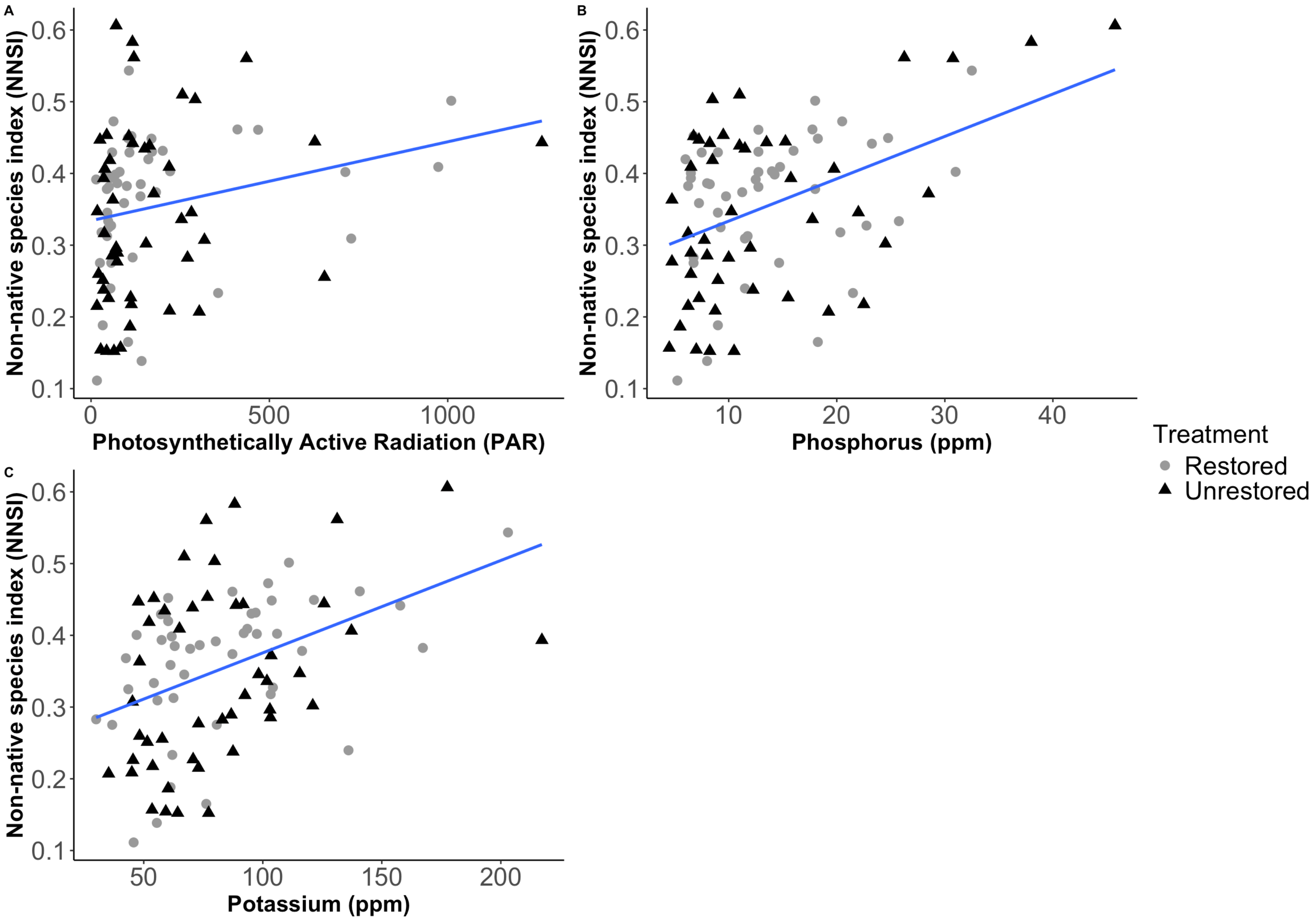
Species	% Coverage
Tulip poplar	20.7
English ivy*	13.4
Sycamore	12.9
Sweetgum	9.7
Red maple	7.3
White ash	4.4
Japanese honeysuckle*	4.3
Scarlet oak	3.9
Poison ivy	3.7
White oak	3.7

Unrestored: 15 native species, 15 non-native species

Species	% Coverage
English ivy	23.0
Boxelder	7.8
Tree-of-heaven*	7.6
Porcelainberry*	6.7
Japanese knotweed*	6.3
American elm	5.8
Chinese wisteria*	5.5
Sweet autumn clematis*	4.2
Amur honeysuckle*	3.8
Tulip poplar	3.2

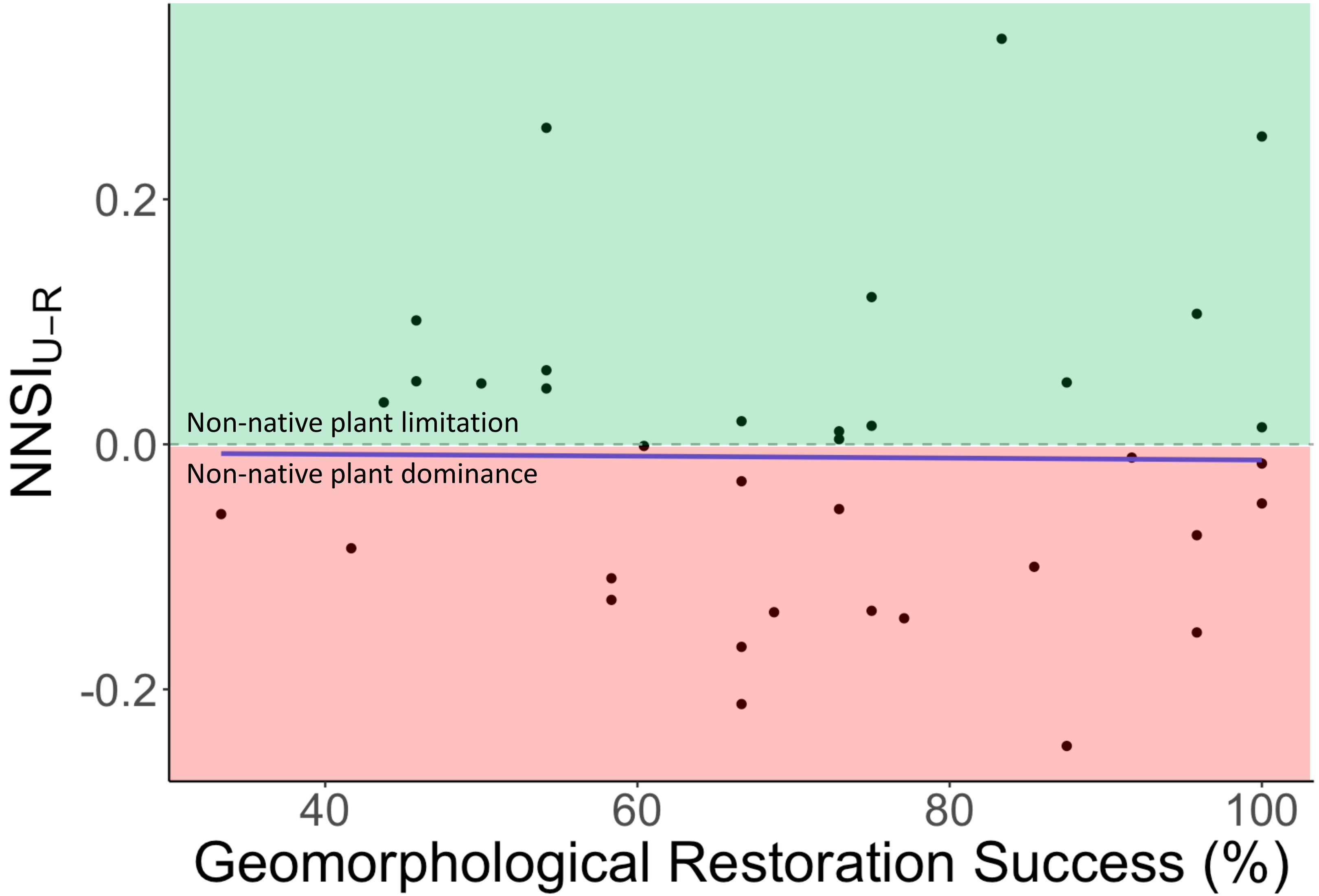
*non-native

Resources impacted invasion overall BUT did not differ between restored and unrestored sites



Time since restoration did not impact invasion

Invasion is unrelated to geomorphological outcomes




In most cases, restoration has worsened invasion…
but the outcomes are unrelated to geomorphology or resource availability

Disturbance

Tree removal

- Increase in space and light availability

Soil disturbance

- Increase in space and nutrients
- Stimulates the seedbank

https://www.jmu.edu/news/facmgt/2015/09/09-heroic-stream-restoration.shtml

Urban context

Most restoration sites studied are in urban areas

Invasive plant material readily available in urban areas

Will look more into influence of landscape context in next analyses

No relationship between geomorphology and vegetation outcomes

Monitoring geomorphology offers no insight into the vegetation community

Possible to improve geomorphology without also improving the vegetation

Research Questions

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Hypotheses

Surrounding landscape context (e.g., area of watershed in urban/ag) will be a driver of invasion.

Projects that limit disturbance to the soil and leave mature trees will have lower invasion.

Restoration Project Attributes

Project construction length

Project goals

Design approach

Monitoring/management

Limits of disturbance

ConYear	Design Plans	Design Report	As-Built Plans	Monitoring Report	Design Firm	Project Goal
2007	☑	☐	☐	☐	CCJM, Ecosite, Brightwat	
2013	☑	☐	☐	☐	USACE Baltimore, MD	BS, EC, Habitat
2003	☑	☐	☐	☑	Greenhorne & O'Mara	BS
2012	☑	☑	☐	☑	KCI	BS
2016	☑	☐	☑	☑	Century Engineering	FC
2013	☑	☐	☑	☐	McCormick Taylor	
2012	☑	☐	☐	☑	JMT	Mitigation
1995	☐	☐	☑	☑	Brightwater	Mitigation
2015	☑	☑	☑	☐	KCI	MS4, WQ
2000	☐	☑	☑	☑	Greenman-Pedersen, Co	BS, EC, Habitat,
2004	☑	☐	☐	☑	Ecotone	Mitigation
2013	☑	☑	☑	☑	KCI	
2014	☐	☐	☑	☑	RK&K	MS4
2013	☑	☑	☑	☑	Parsons Brinckerhoff	BS, EC, Habitat
2012	☑	☐	☐	☑	Coastal Resources, PB	Mitigation, BS,
2012	☑	☐	☐	☑	Coastal Resources, PB	Mitigation, BS,
2010	☑	☑	☑	☑	PB Americas, Coastal Res	BS, WQ
2015	☑	☐	☐	☐	CPJ Associates	
2006	☐	☐	☑	☐	Underwood & Associates	
2009	☑	☐	☐	☑	KCI	BS, Habitat
1999	☑	☐	☐	☑	Environmental Systems /	BS, Habitat
2013	☑	☑	☑	☑	KCI	BS

Planting plans

- How many layers of vegetation were planted?
- Were mature trees left within LOD?
- Was vegetation selected by zone?
- For how many years was the project monitored?
- Was there an invasive species management plan?
- Was a reference model used?
- Does the planting list reflect the natural community type?
- What is the proportion of native/non-native/invasive stems planted?
- What was the stem/seed density planted?

Project status

Field sampling complete

Manuscript drafted for first objective

Finish analyses for second objective:

Landscape context

Project attributes

Planting plans

Thanks to…

Chesapeake Bay Trust

MARYLAND CB TRUST Protect the Chesapeake

MARYLAND DEPARTMENT OF NATURAL RESOURCES

MONTGOMERY COUNTY MARYLAND 1776

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Chesapeake Bay Program
Science. Restoration. Partnership.

NATIONAL FISH AND WILDLIFE FOUNDATION
NFWF

ANNE ARUNDEL COUNTY MARYLAND

Invasive Species
COLLABORATIVE AT VIRGINIA TECH

VT FRALIN LIFE SCIENCES INSTITUTE
GLOBAL CHANGE CENTER
VIRGINIA TECH.

VT COLLEGE OF AGRICULTURE AND LIFE SCIENCES
SCHOOL OF PLANT AND ENVIRONMENTAL SCIENCES
VIRGINIA TECH.

What are the take home points? What does this mean for me?

Translation slides by Joe Berg

Restored sites studied had higher NNI species

- Since tree clearing allows more room and sunshine to stimulate plant growth, and soil disturbance stimulates seed establishment and releases nutrients, both apparently favoring NNI species over native species
- as a practitioner I want to minimize my projects LOD and tree removal
- as a regulator/reviewer, I want to minimize tree clearing and ground disturbance, and maybe extend the monitoring period for control of NNI species

- Next Steps
  - Evaluation of planting plan influence on plant community quality
  - How design approach influences plant community condition

Questions?

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