Implications of climate change for invasive species

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About Me

Teaching:

- Quantitative Ecology: Application of statistical modeling to ecological problems
- Geographic Information Systems and Spatial Statistics: Understanding ecological problems in a spatial context

Current Research Projects

- UMass Cranberry Bog: Late water treatment – alternative to herbicide/pesticide application
- Spatial patterns of tree damage in Tampa FL during hurricane Irma

Invasion Ecology

- Northeast Regional Invasive Species and Climate Change Network (RISCC) evergladescisma.org

theroanokestar.com

lewisginter.org

Chat your thoughts:

What do you think is an example of a major pathway of invasive species introduction?

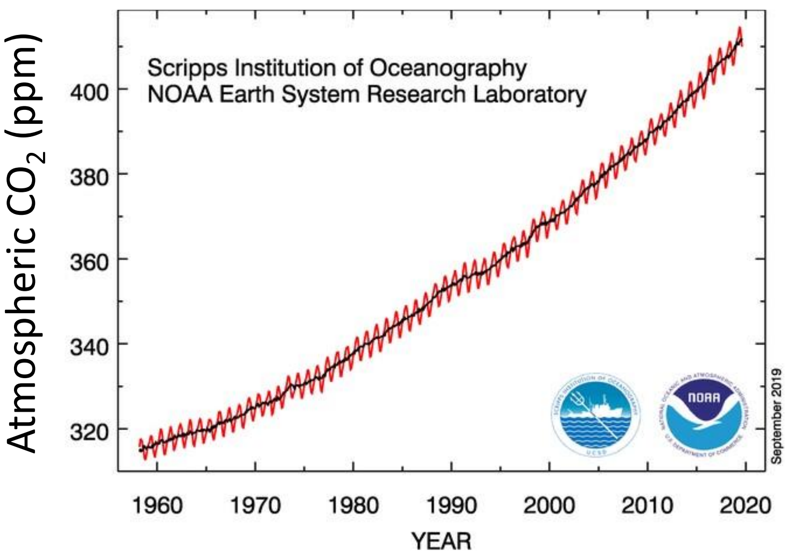
Bonus if you can identify the invasive species in the photos!

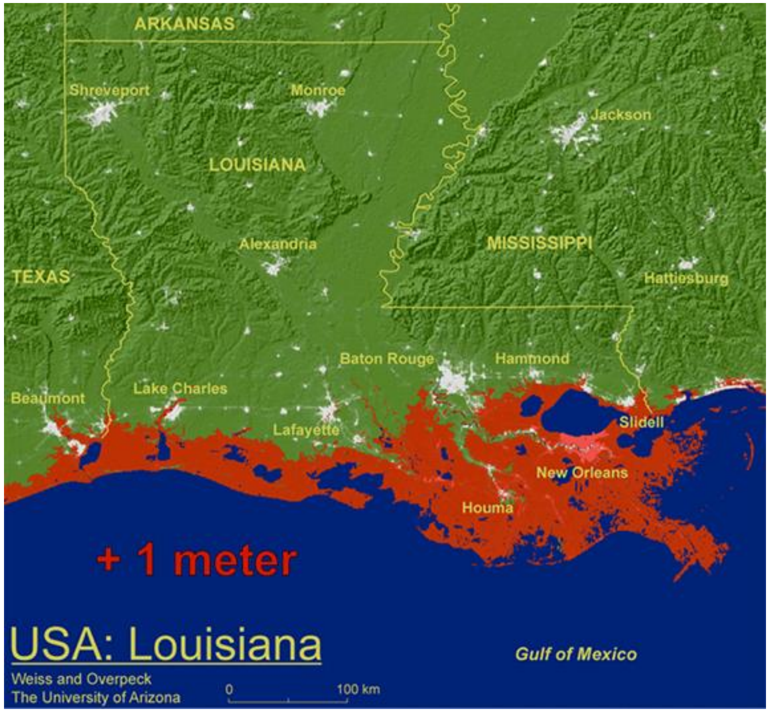
Invasive species are bad enough

Asian Carp (Image from Mississippi State University Extension)

Kudzu (texasinvasives.org)

Now we need to add climate change?





BACKGROUND

Let’s all get on the same page!

What is an invasive species?

'Invasive species' means, with regard to a particular ecosystem, a non-native organism whose introduction causes or is likely to cause economic or environmental harm, or harm to human, animal, or plant health.

(Executive order 13112)

Global Change Components

- Increased CO2
- Increased temperature
- Increased variability and extreme events
- Altered phenology

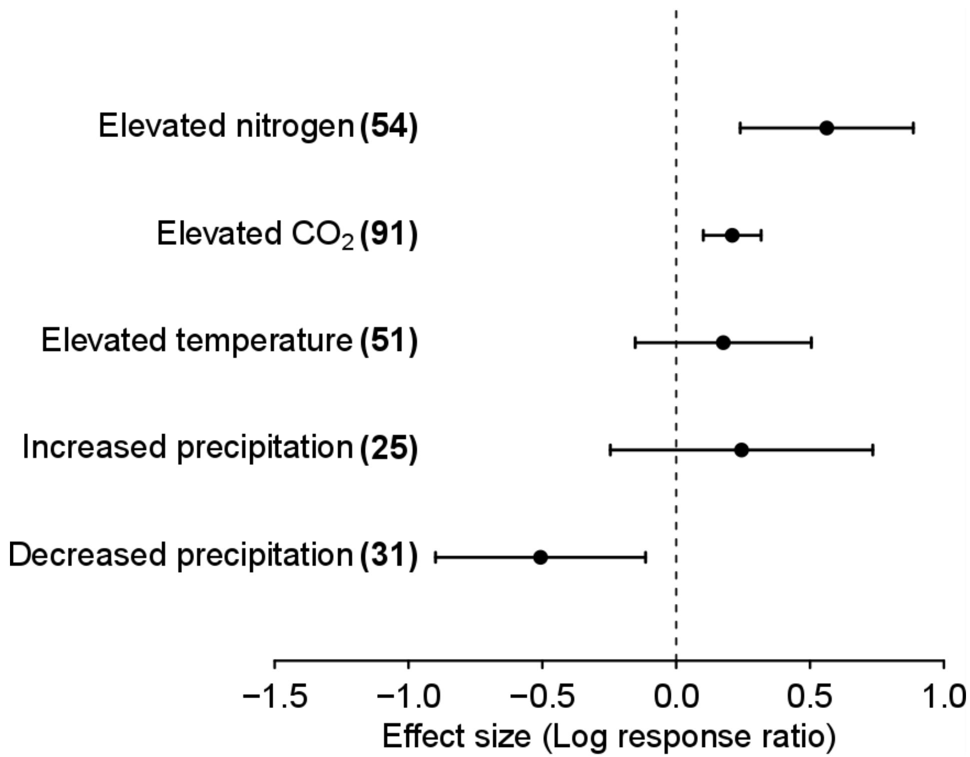


Figure S3 from Liu et al 2017

Global Change

Plants will respond to all aspects of global change

Global Change

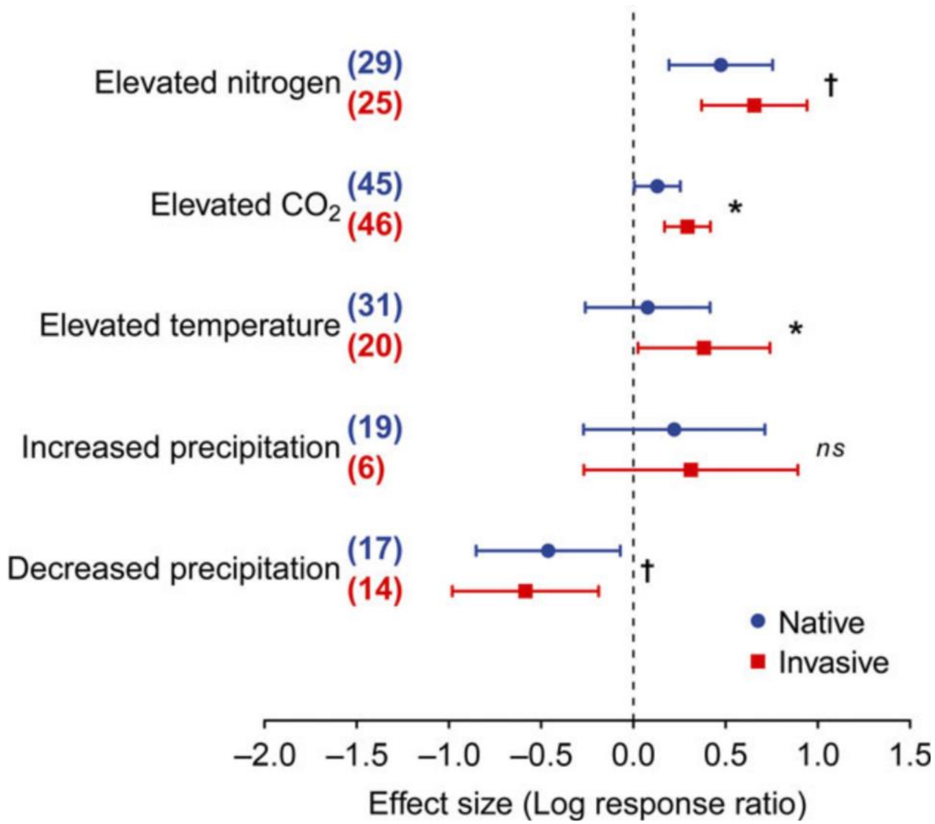


Figure 1 from Liu et al, 2017

But invasive plants may respond even more favorably than non-invasives.

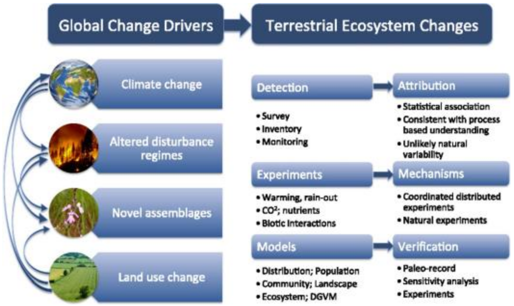


Fig. 1 – Franklin et al. 2016

El Niño and a record CO_2 rise

Richard A. Betts, Chris D. Jones, Jeff R. Knight, Ralph F. Keeling and John J. Kennedy

Carbon–concentration and carbon–climate feedbacks in CMIP6 models and their comparison to CMIP5 models

Vivek K. Arora[1], Anna Katavouta[2,3], Richard G. Williams[2], Chris D. Jones[4], Victor Brovkin[5,6], Pierre Friedlingstein[7],

Predicting plant invasions in an era of global change

Bethany A. Bradley[1,2], Dana M. Blumenthal[3], David S. Wilcove[4,5] and Lewis H. Ziska[6]

How Will Global Environmental Changes Affect the Growth of Alien Plants?

Jujie Jia[1,2], Zhicong Dai[3], Feng Li[1,2] and Yanjie Liu[4]*

Global change is complicated…

Feedbacks of Terrestrial Ecosystems to Climate Change*

Christopher B. Field,[1] David B. Lobell,[2] Halton A. Peters,[1] and Nona R. Chiariello[3]

Cross-scale Drivers of Natural Disturbances Prone to Anthropogenic Amplification: The Dynamics of Bark Beetle Eruptions

KENNETH F. RAFFA, BRIAN H. AUKEMA, BARBARA J. BENTZ, ALLAN L. CARROLL, JEFFREY A. HICKE, MONICA G. TURNER, AND WILLIAM H. ROMME

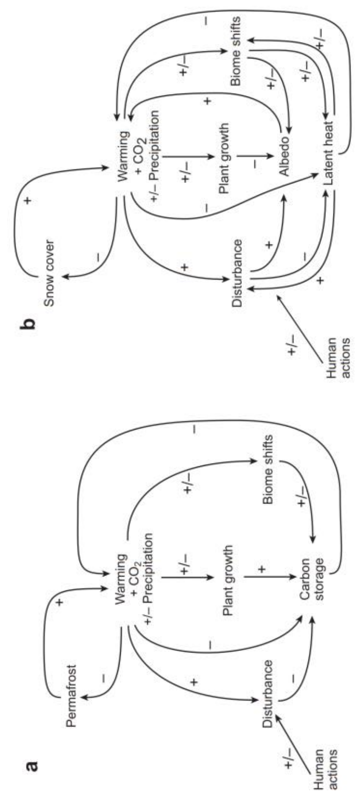


Fig. 1 – Field et al. 207

Climate Change and Disturbance: Multiple Feedbacks

Outline of topics

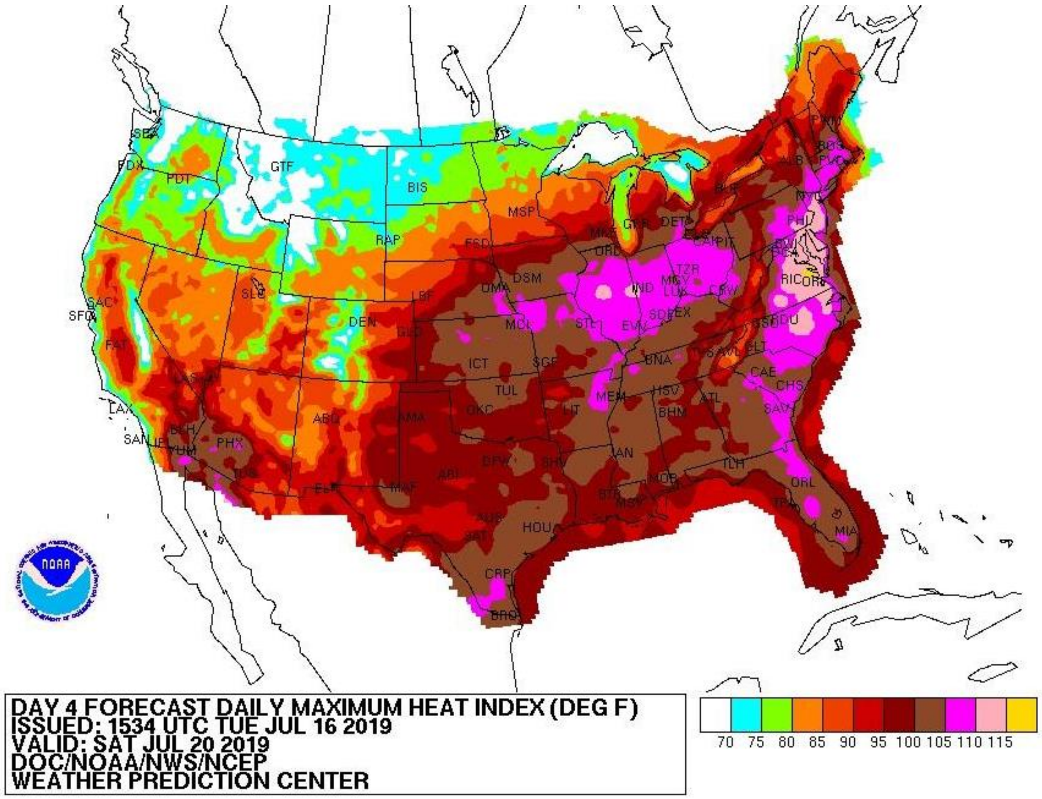
1. Rising temperature favors invasives
2. Climate change and range shifts
3. Climate variability creates disturbance
4. Plant response to rising CO_2
5. Management

Figure 1 in Bradley et al, 2010

TRENDS in Ecology & Evolution

1. Rising temperature favors invasives

Warming temperatures & longer growing seasons are '*virtually certain*' (IPCC, 2013)



https://www.weather.gov/twitter

Warming favors greater quantity and variety of forest pests

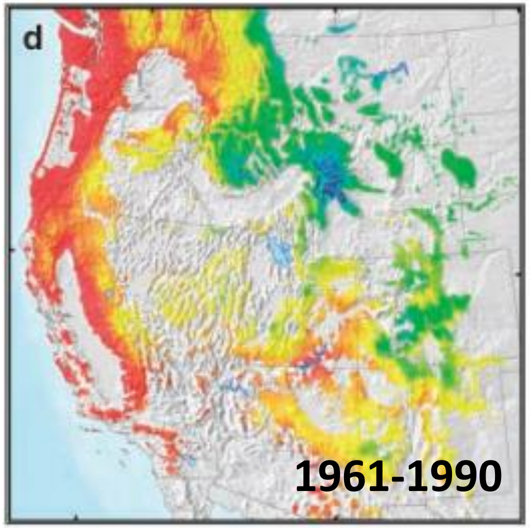
Most insect pests are ectotherms, relying on the environment for heat

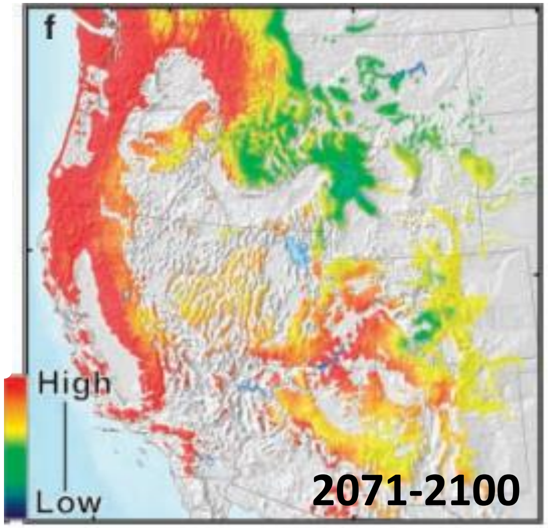
Warmer temperatures increase populations of defoliating insects and bark beetles

As the buds begin to open, winter moth caterpillars become free-feeders (feeding on expanding foliage and moving about from leaf to leaf). Note the penny at the bottom of the photograph that provides a scale for size. (Photo: R. Childs). UMass Extension

Forest pests have longer/more life cycles with warming

Mountain Pine Beetle kill – July 2009, Wyoming





Probability of over-wintering

Figures from
Bentz et al. 2010

Meta-analysis of experimental studies:
Rising temperatures favor invasive plants

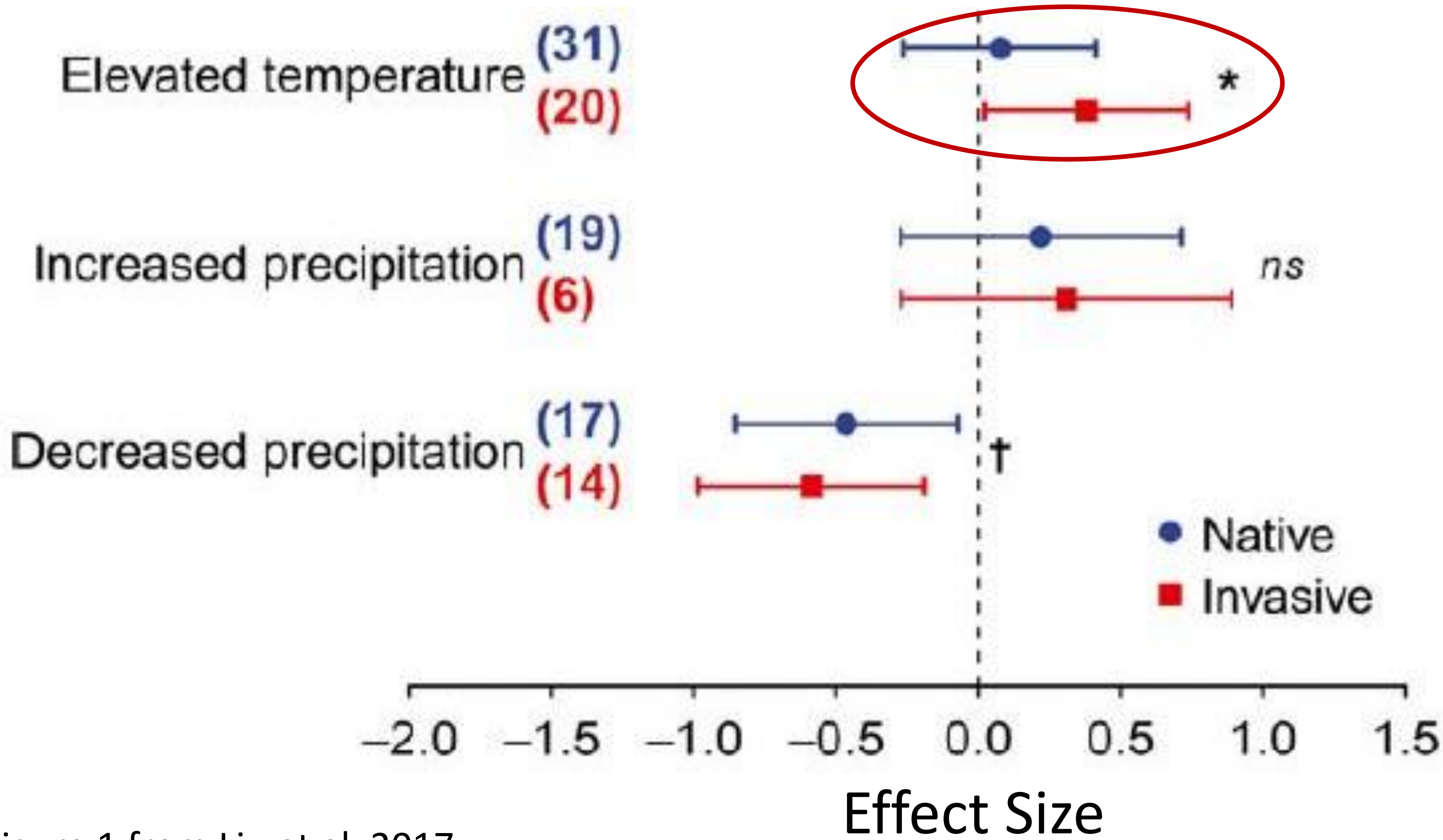
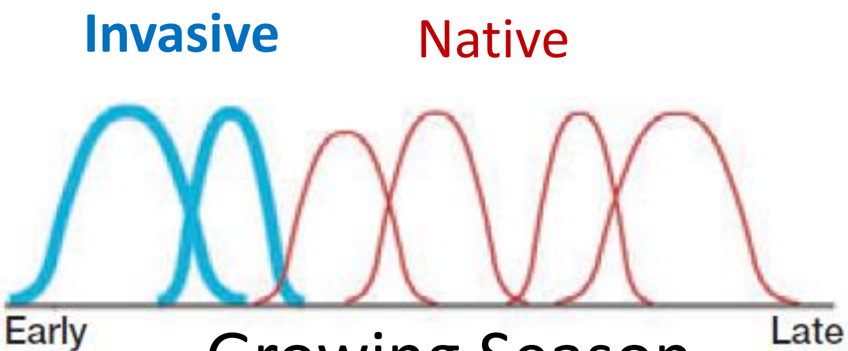


Figure 1 from Liu et al. 2017

Why? Priority Effects

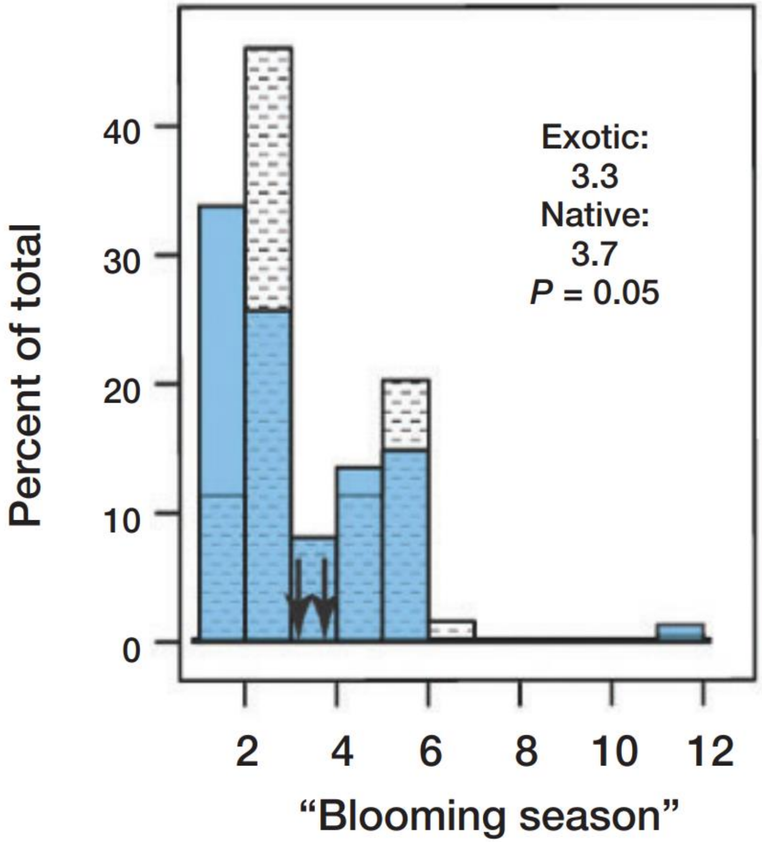
(The early bird catches the worm)



Growing Season

Adapted from figure 1 from Wolkovich & Cleland, 2011

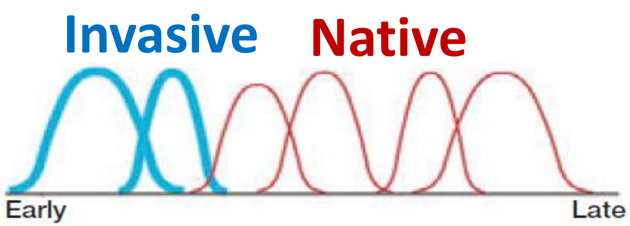
Japanese barberry *(B. thunbergii)*



Invasives bloom earlier

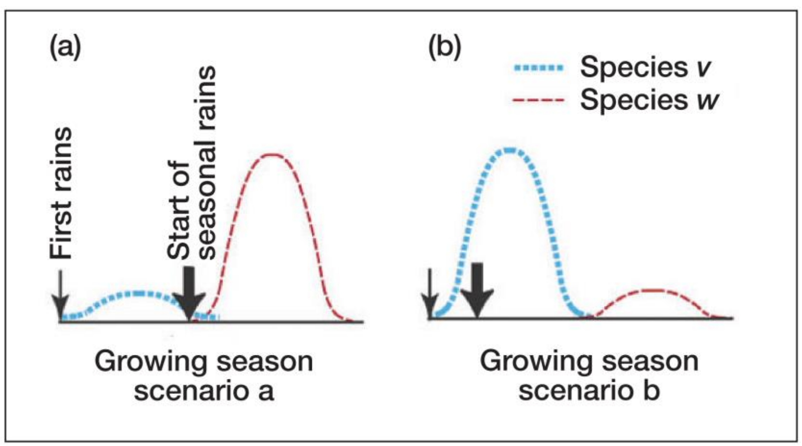
Figure 2 in W & C 2011

Priority Effects



Growing Season

Adapted from figure 1 from Wolkovich & Cleland, 2011



Wolkovich & Cleland, 2011: Figure 2

- A potentially risky bet-hedging strategy
- Global warming may make it less risky!
- Payoff is a vacant niche
- Plasticity and rapid evolution can help invasives with priority effects

Warming can alter phenology, advantaging rapid-adapters, or species with high plasticity

Favorable Climate Change Response Explains Non-Native Species' Success in Thoreau's Woods

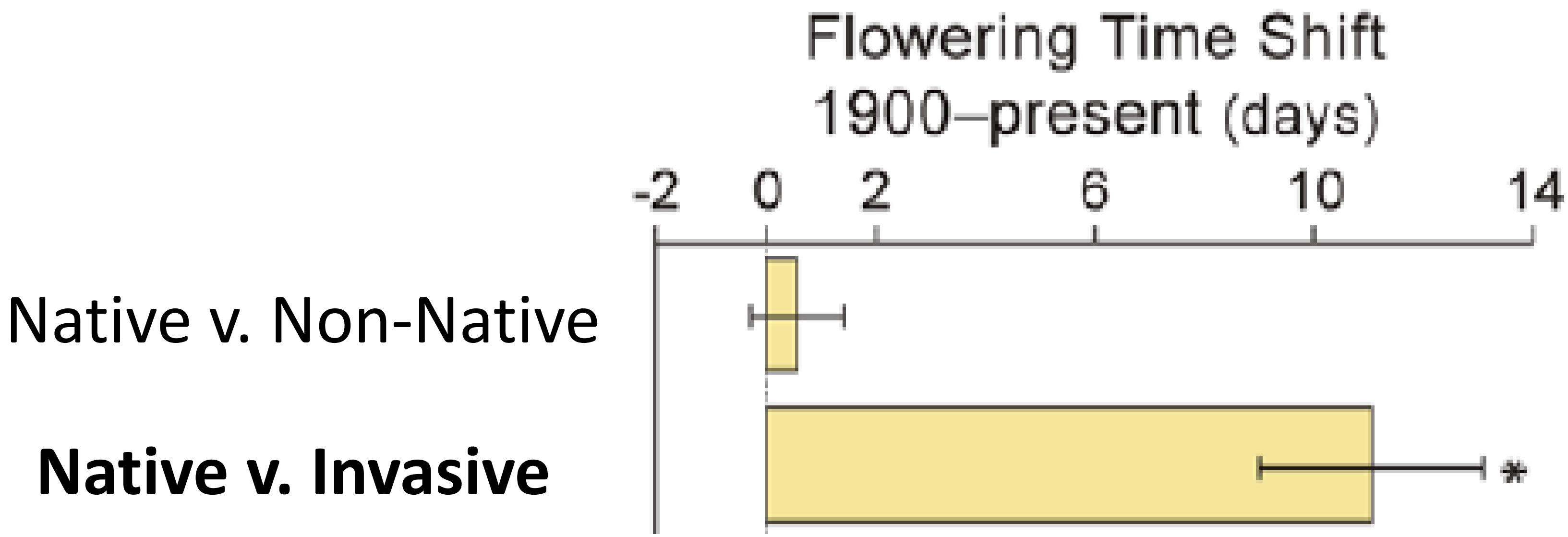
Charles G. Willis[1,2], Brad R. Ruhfel[1], Richard B. Primack[3], Abraham J. Miller-Rushing[4,5], Jonathan B. Losos[6], Charles C. Davis[1]*

Phylogenetic patterns of species loss in Thoreau's woods are driven by climate change

Charles G. Willis[a], Brad Ruhfel[a], Richard B. Primack[b], Abraham J. Miller-Rushing[b], and Charles C. Davis[a,1]

Willis et al., 2010a, b

Timing of invasive plant green-up and germination is more responsive to temperature



Temperature-responsive invasives are increasing in abundance

Willis et al., 2010

1. Rising temperature favors invasives

USA npn

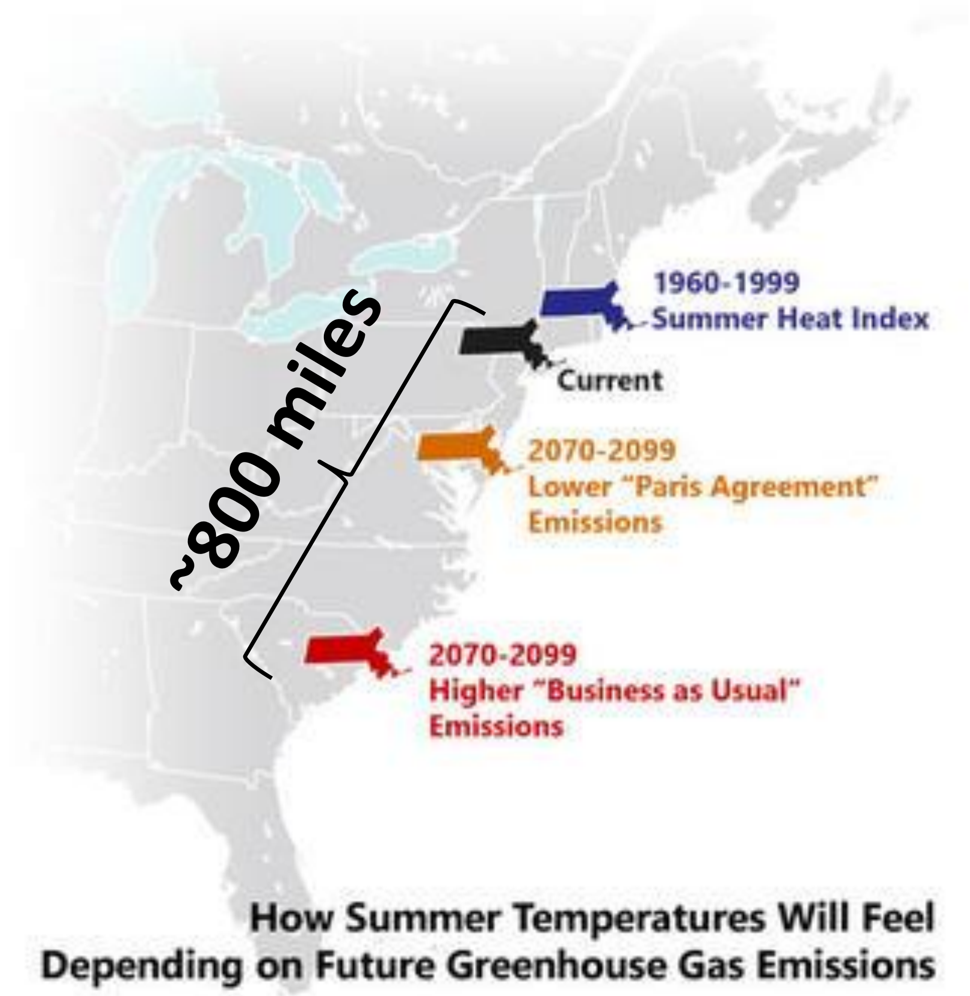
National Phenology Network

Take home points:

- Invasives take advantage of longer growing seasons by emerging early, or taking advantage of times that native plants are dormant.
- Direct temperature effects on invasive plant growth: biochemical processes usually happen faster at higher temperatures.

Climate change is happening *fast.*
Favors fast dispersing species

The Northeast is getting warmer!



How fast are native species moving?

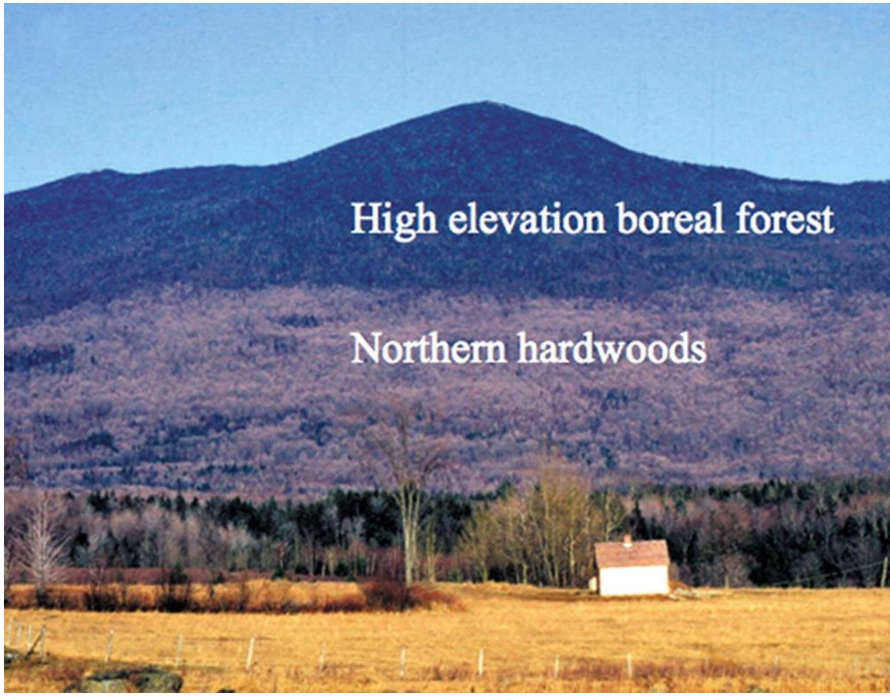
1964 to 2004: Measured forest composition in the Green Mountains

Northern hardwoods expanded upwards in elevation

Boreal forest contracted from lower elevation

Movement = ~ 600 ft upwards over 40 years

How fast? Not fast enough



Shifts in forest composition

Beckage et al. 2008

Instead, we're giving non-native and invasive species a head start via human-mediated dispersal

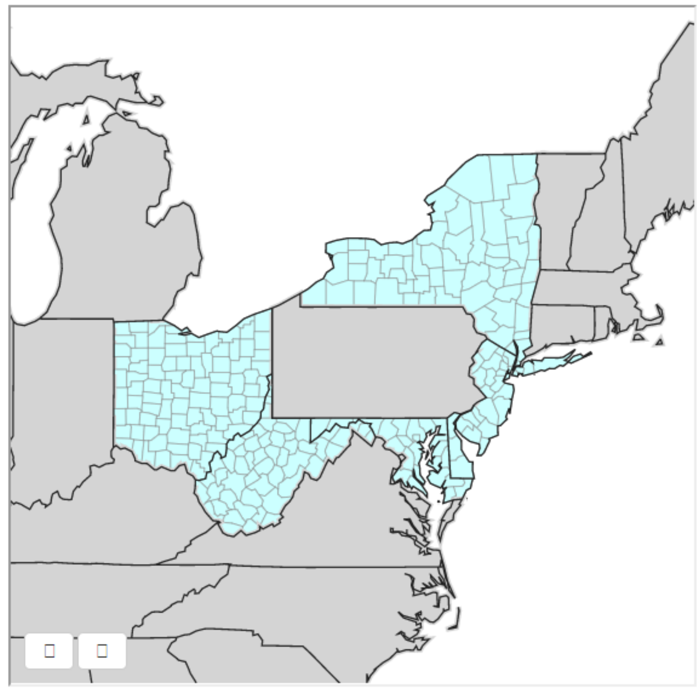
vs.

[Range Shift Listing Tool](https://www.eddmaps.org/rangeshiftlisting/): https://www.eddmaps.org/rangeshiftlisting/

Work led by Jenica Allen

In collaboration with

EDDMapS find · map · track



Download

Scientific Name
Arundo donax
Cenchrus setaceus
Centaurea melitensis
Conyza bonariensis
Digitaria violascens
Firmiana simplex
Genista monspessulana
Hypericum calycinum
Lagerstroemia indica
Ligustrum japonicum

Showing 1 to 10 of 18 entries

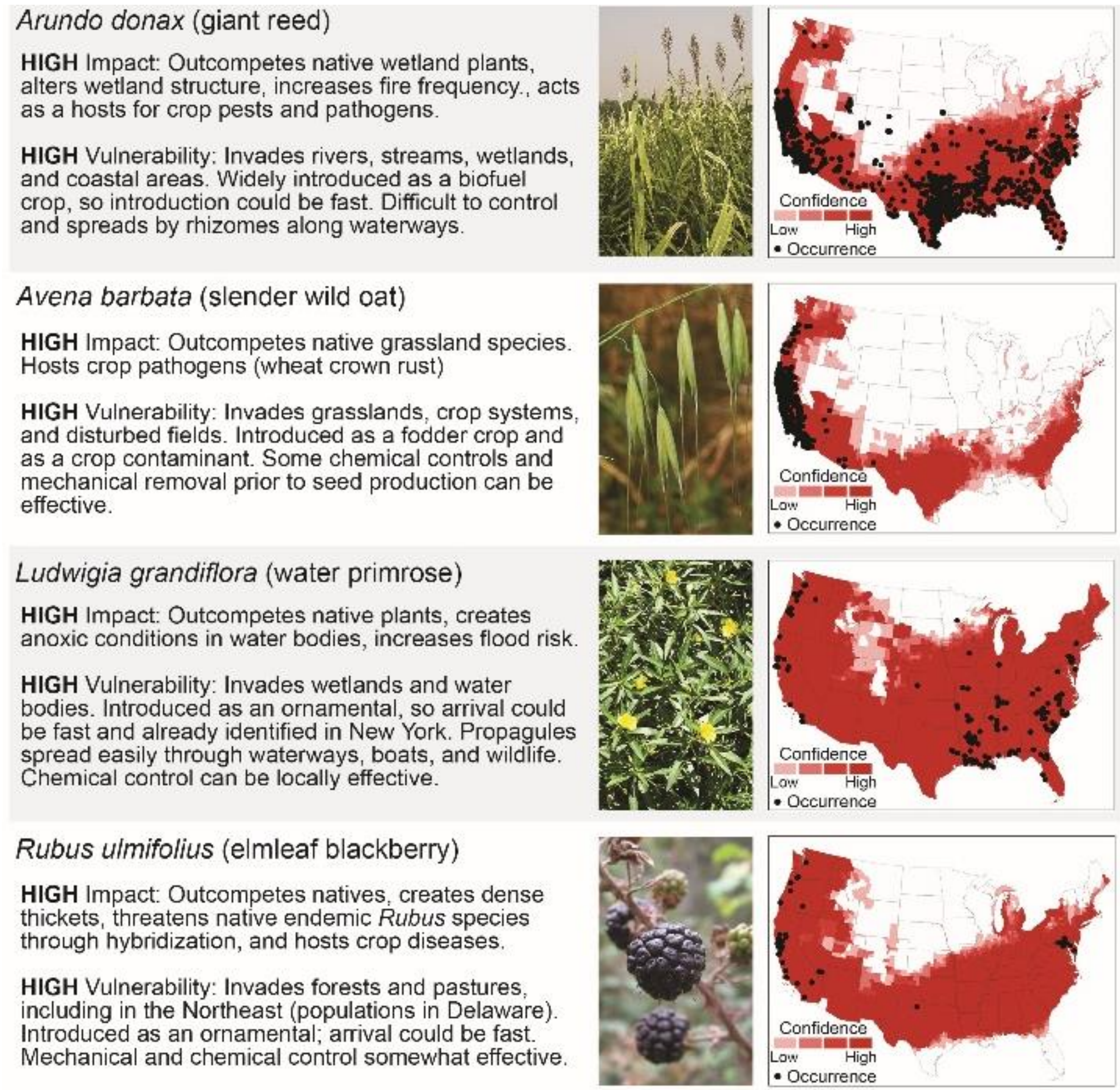
Northeastern IPM Center

Project funded by the Northeastern IPM Center through Grant #2014-70006-22484 from the National Institute of Food and Agriculture, Crop Protection and Pest Management, Regional Coordination Program.

Prioritizing state watch lists

Which species have the highest impacts?

Which species are likely to invade ecosystems in your region?

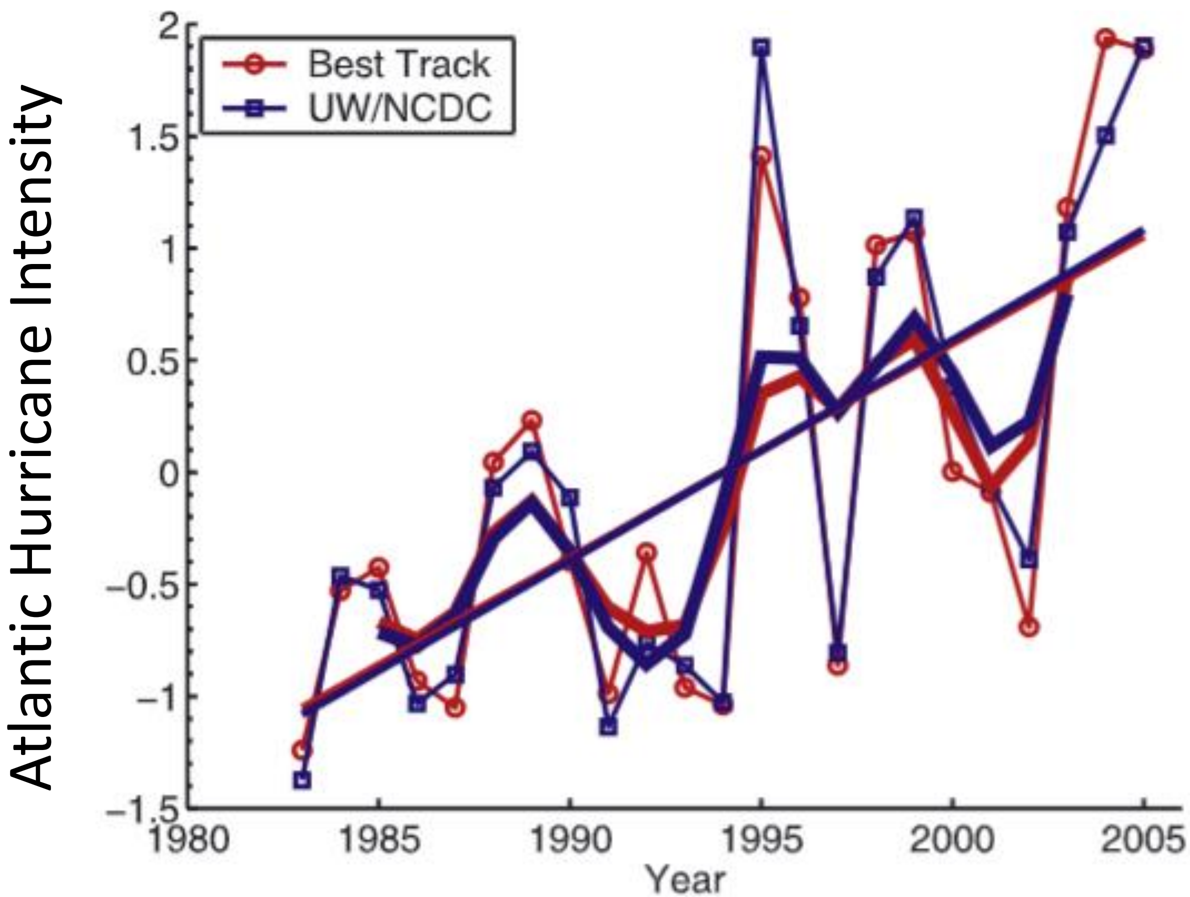


Take home point:

- Invasive species ranges are shifting – but, we have a chance to get ahead of some of them.

Ludwigia grandiflora

Climate change increases disturbance



Kossin et al. 2007

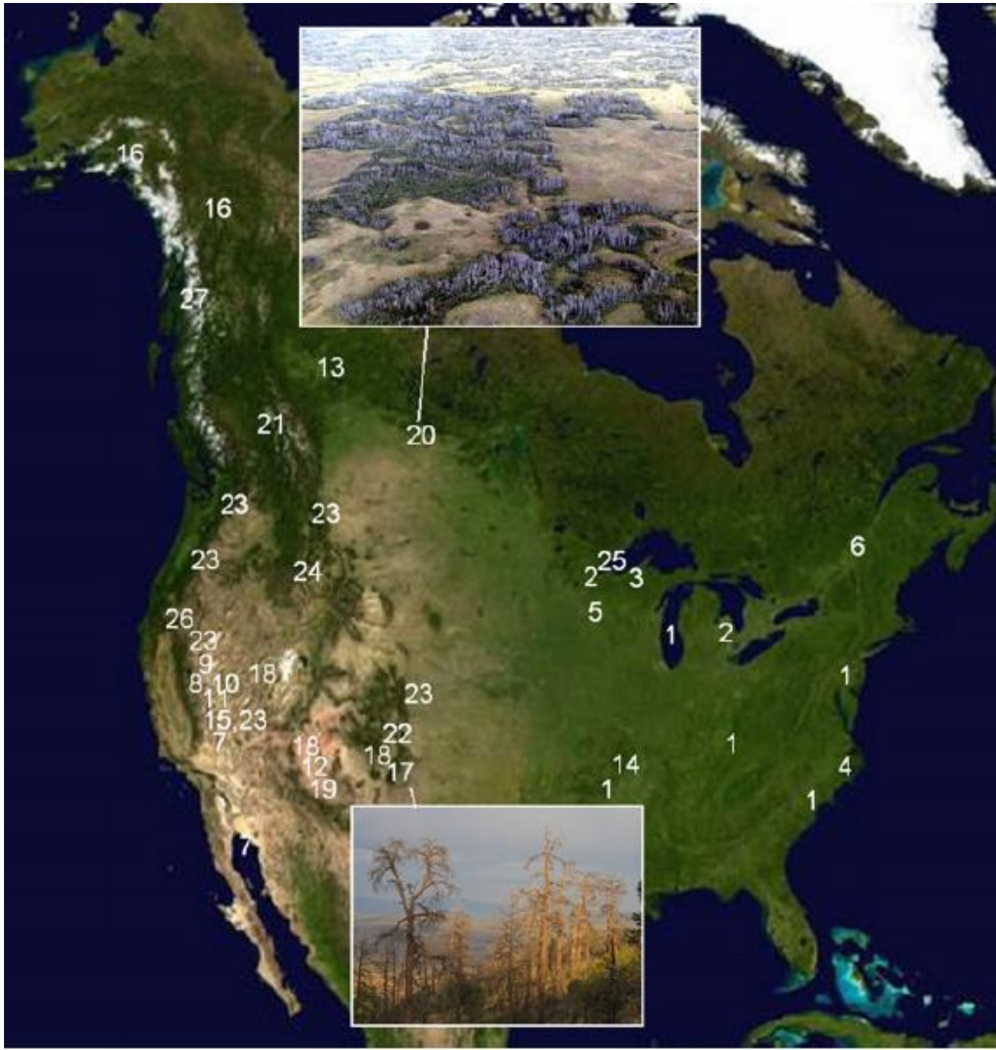
Extreme heat/drought also causes disturbance to native ecosystems

Western US:

Forest die-off linked to drought

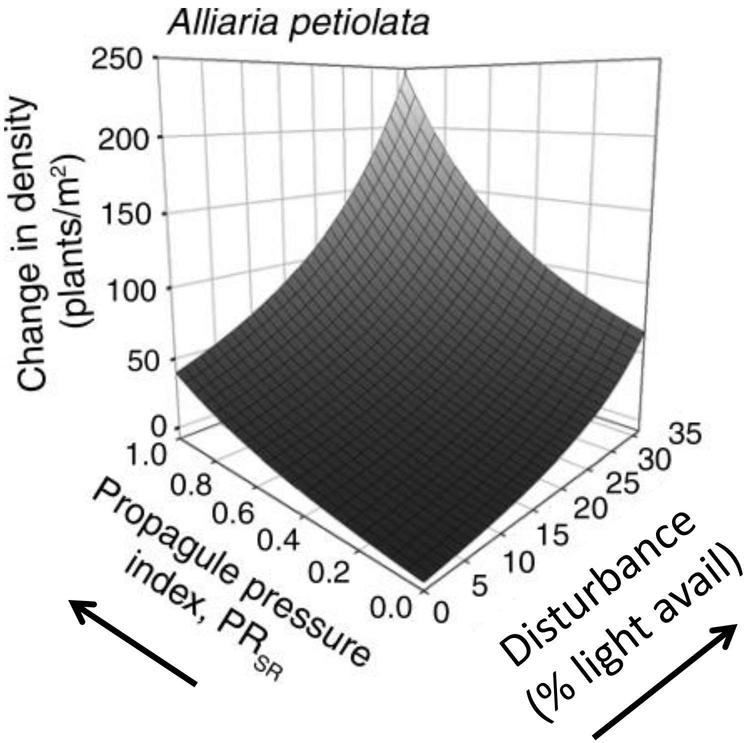
Eastern US:

Tree mortality tied to severe winter + hot summer



Allen et al. 2010

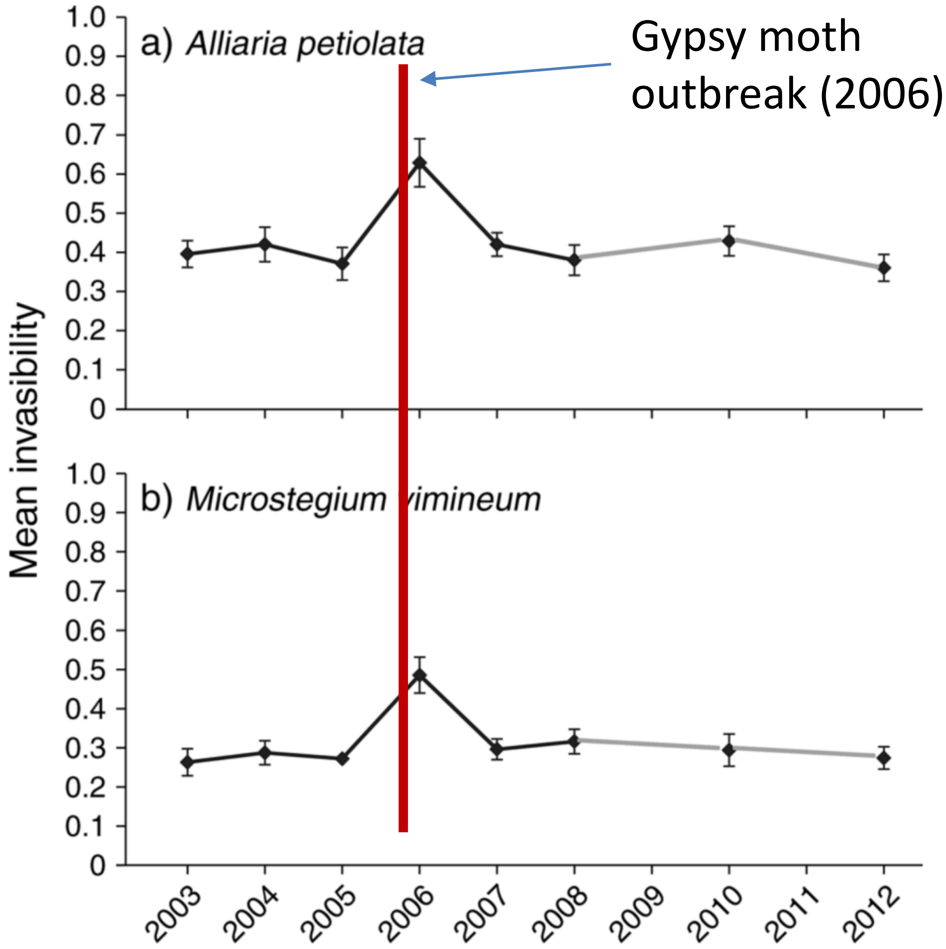
Invasive species thrive with increased disturbance



Eschtruth & Battles, 2009

Kudzu invasion at disturbed forest edge.
Source: Wikimedia

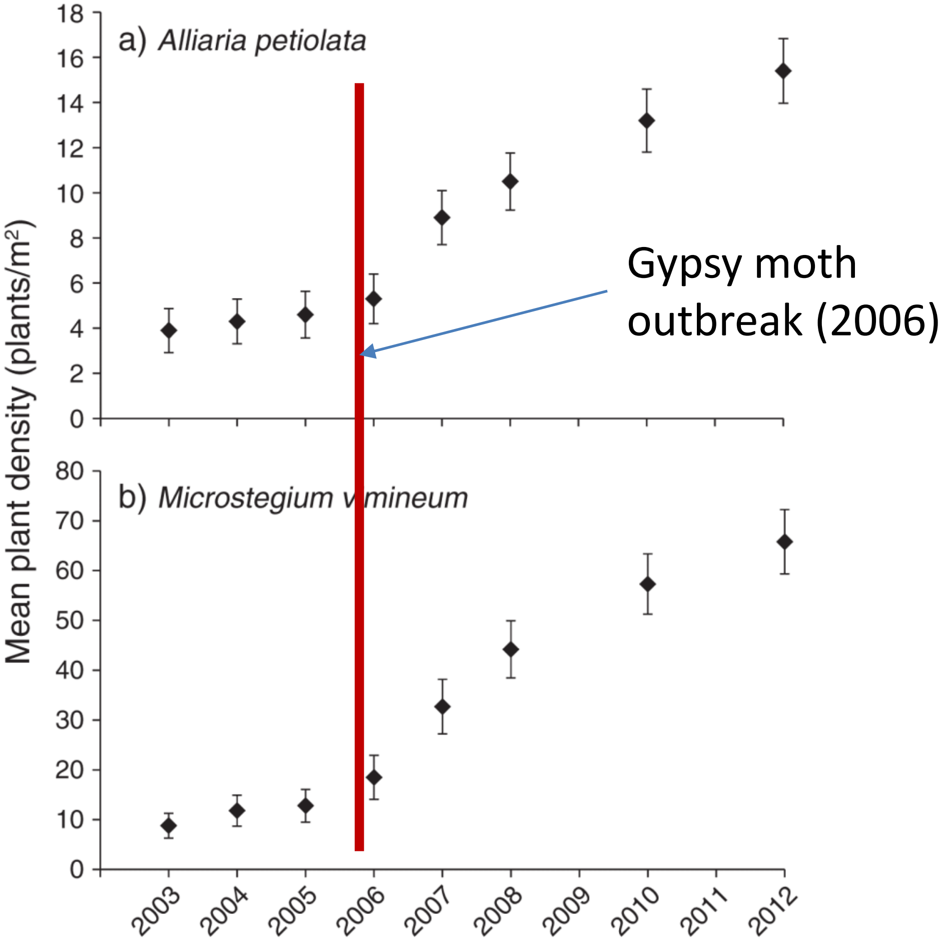
Small disturbances create invasibility windows



Propagule pressure, coupled with ephemeral forest canopy disturbance = big opportunity for invasives

Eschtruth and Battles 2014

Invasibility windows = persistent increase in invasives



"Although forests appear to recover quickly after ephemeral disturbances, these perturbations may have long-term impacts"

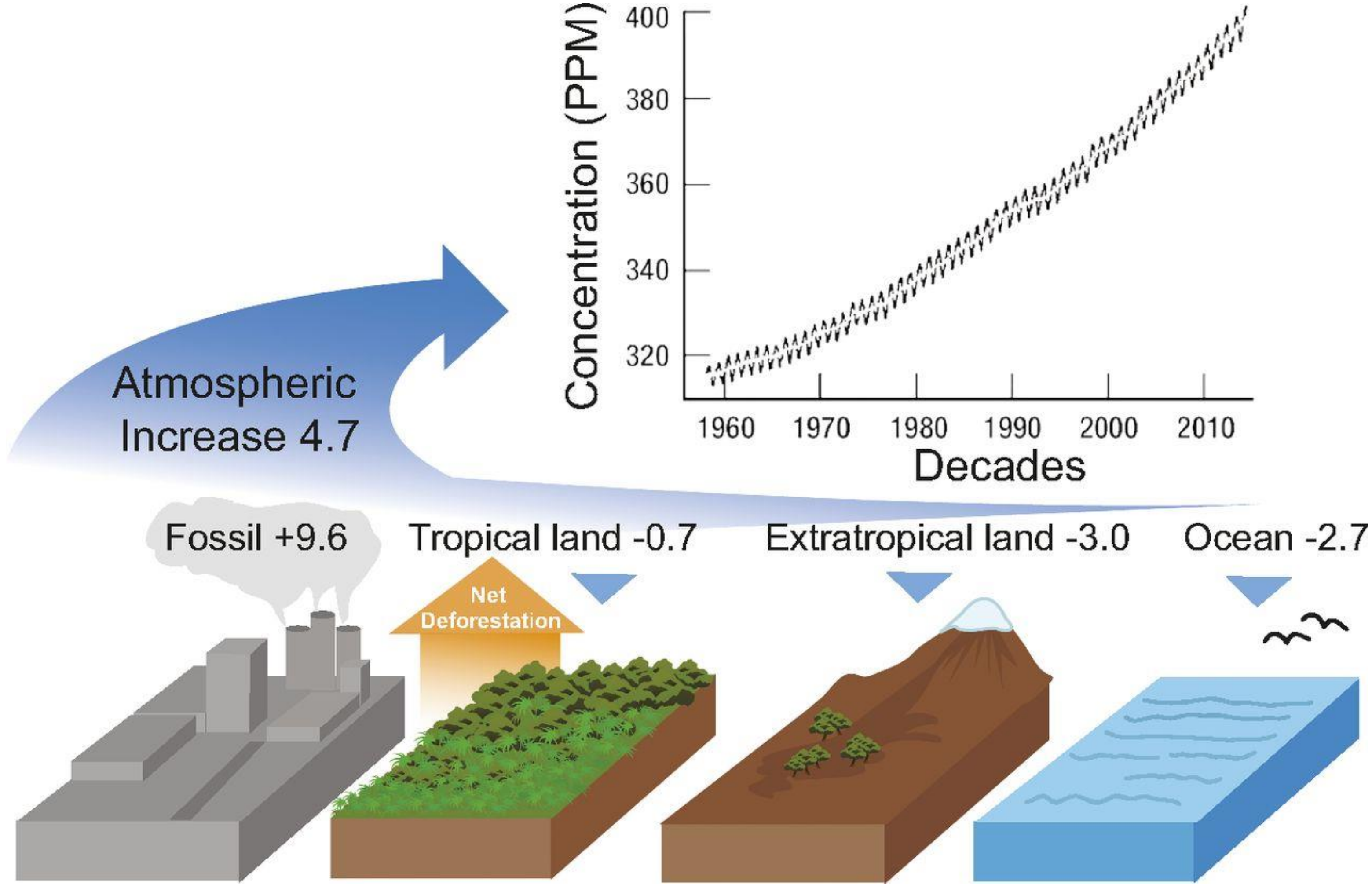
Eschtruth and Battles 2014

Take home point:

- Climate extremes create novel disturbance, harming native ecosystems and providing an opening for invasives

New Jersey Forest after Hurricane Sandy

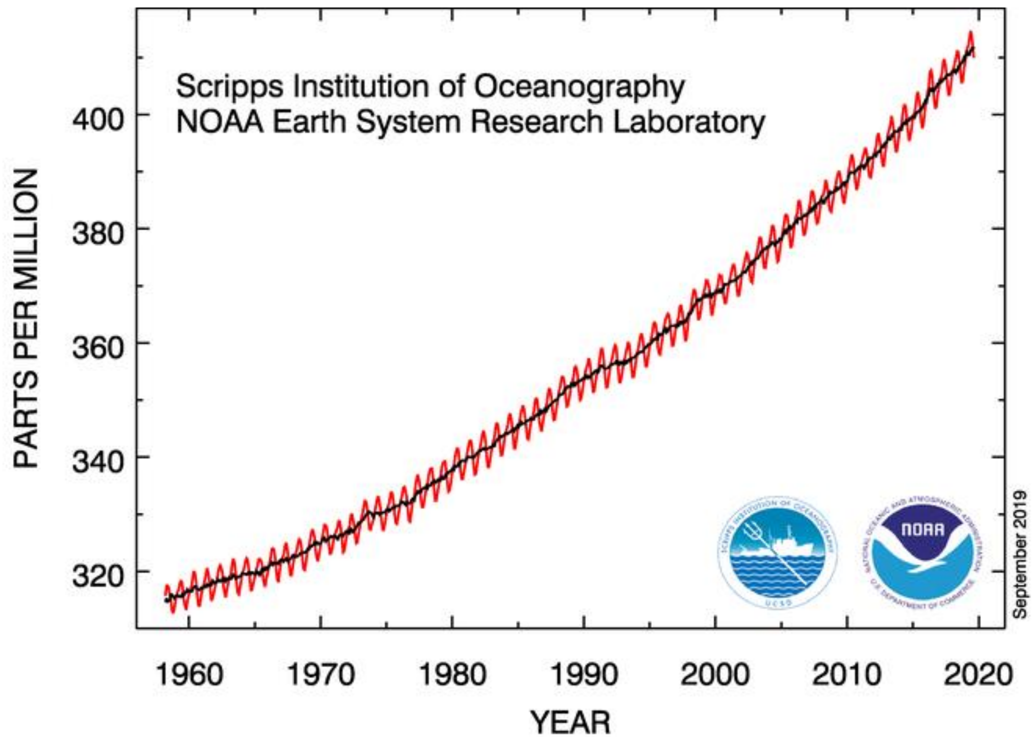
PLANT RESPONSES TO CO2



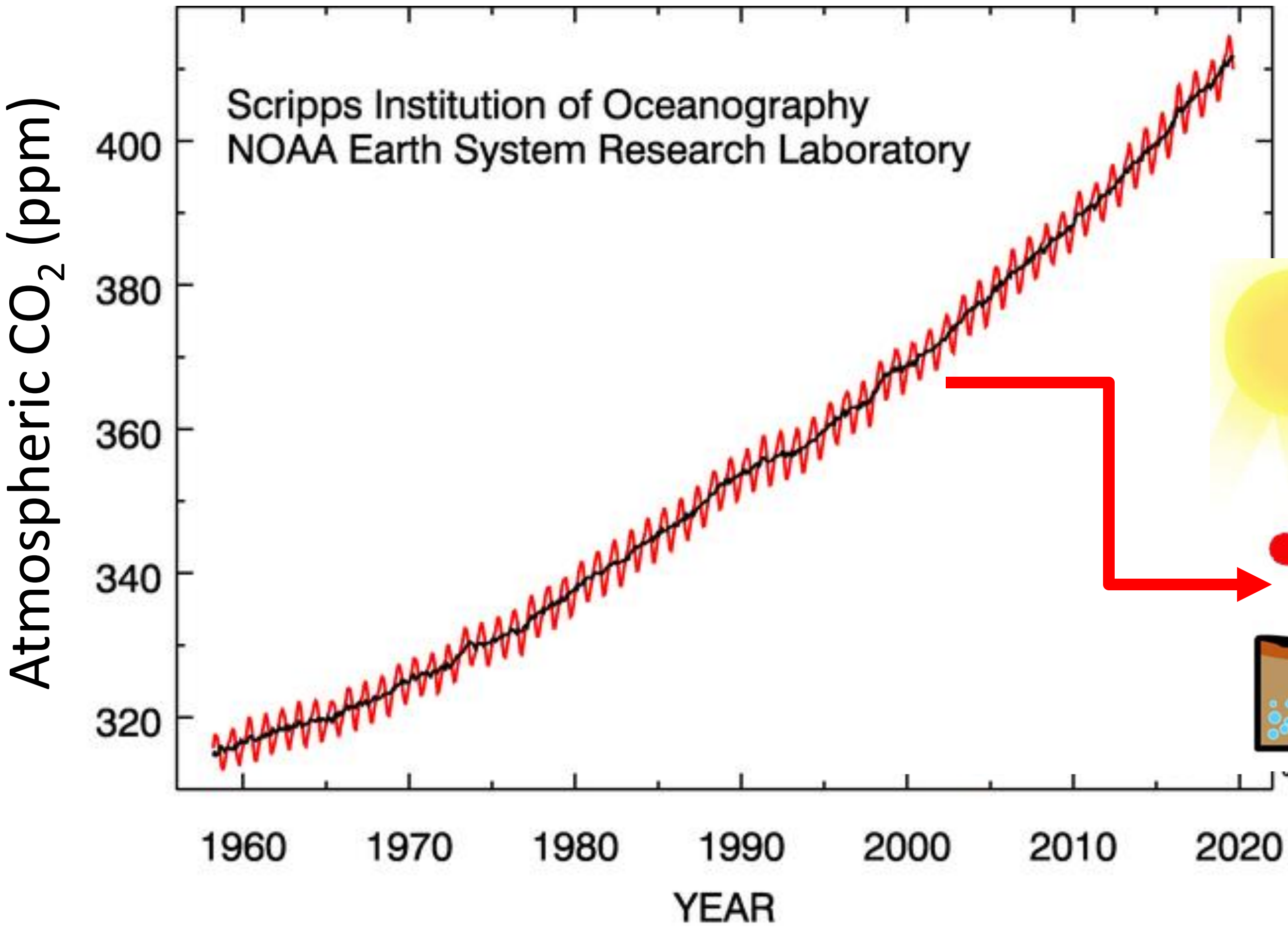
Sellers et al. Figure 1

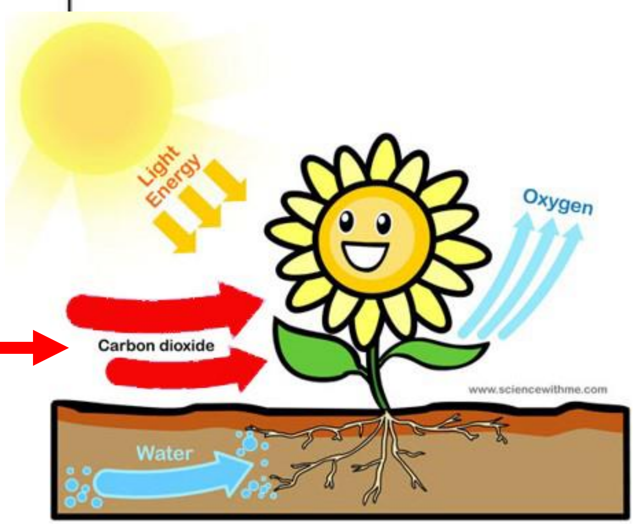
Increased CO2

- CO2 levels are rising at an accelerating rate.
- Plants with the C3 pathway are currently CO2 limited (Ziska et al. 2004)
  - These are 96% of all plants



Atmospheric CO_2 levels are rising





Plants do "better" with higher CO_2

[Instagram/Twitter]

The answer is not so simple…

There is abundant misinformation or misleading information

Plants do better with higher CO_2

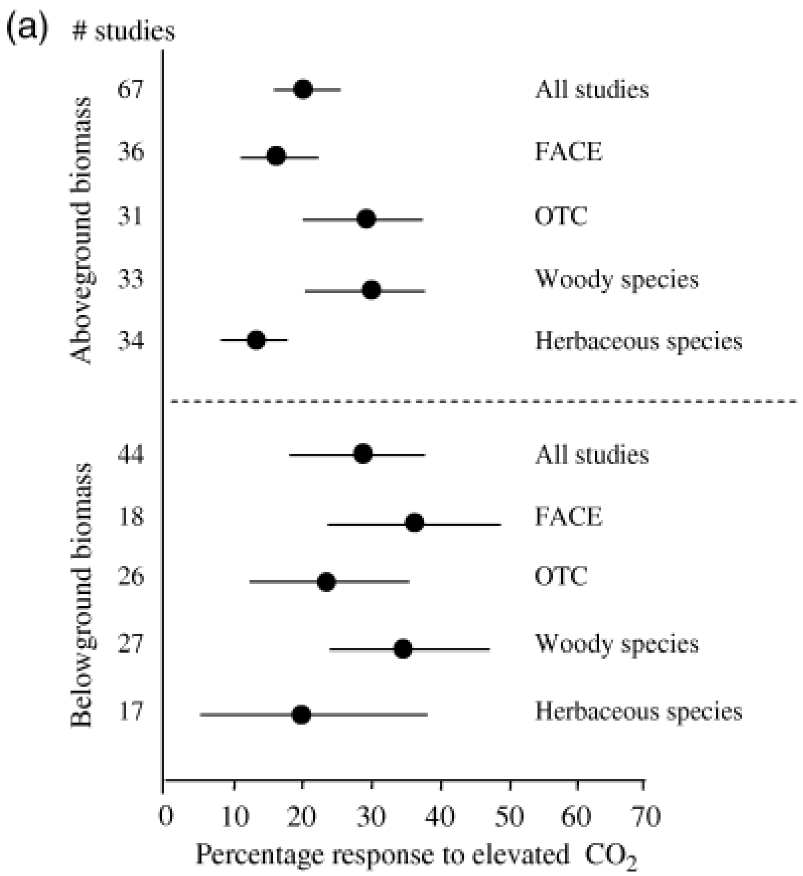
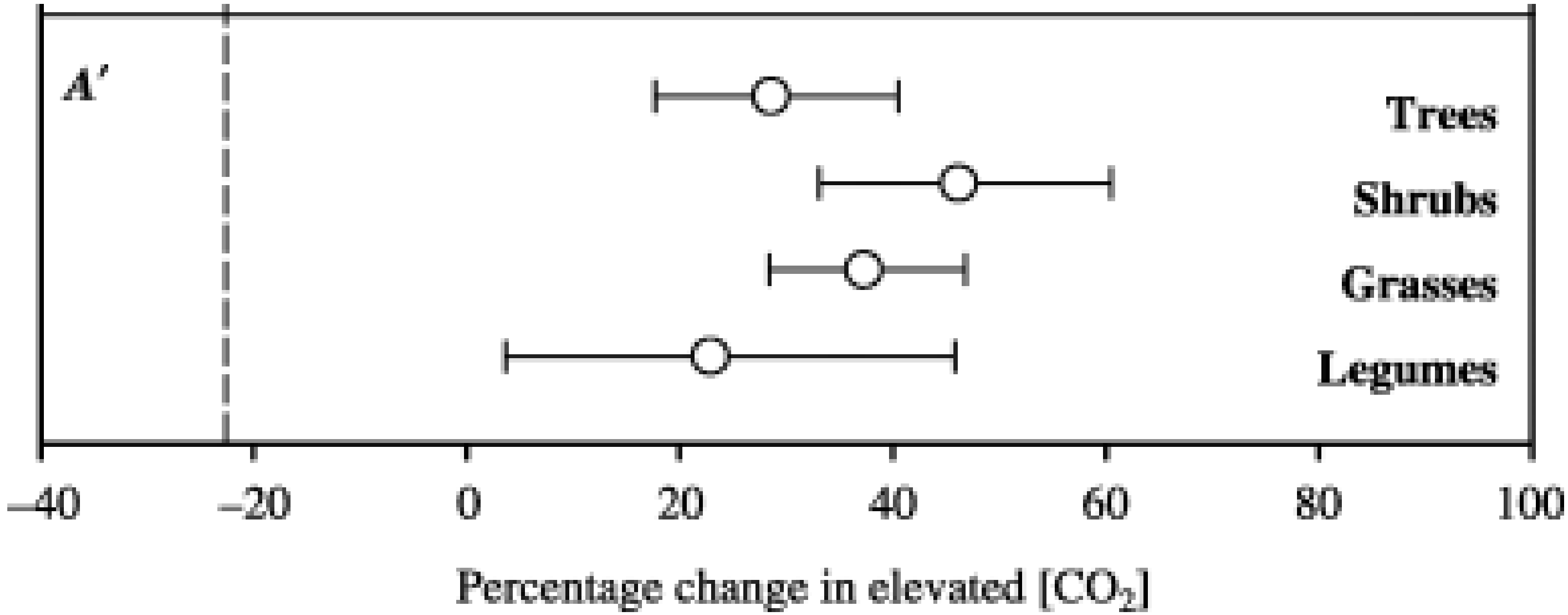


Figure 1 DeGraff et al 2004

Woody species have bigger gains in biomass accumulation

Figure 3 in Ainsworth and Long 2004



Plants do better with higher CO_2

Variation by group: photosynthetic rate

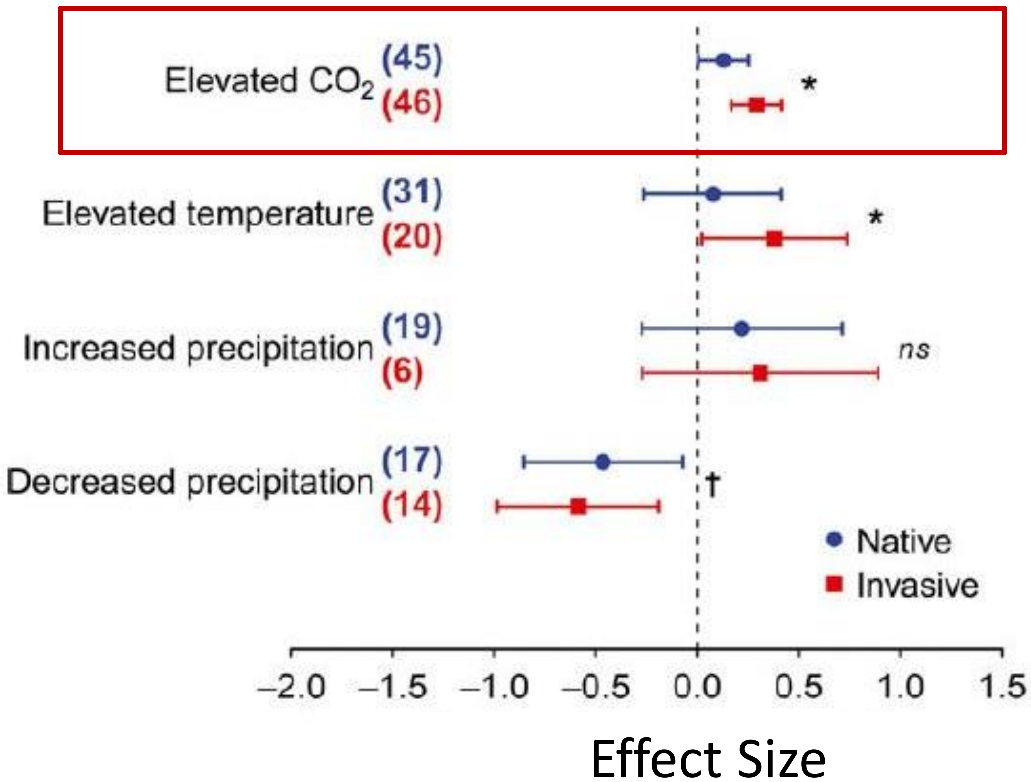
Plants do better with higher CO_2

Average increased growth		*Change to average plant*
Trees:	+50%	18% more flowers
Crops:	+35%	19% more fruits
Shrubs:	+20%	25% greater seed mass
Flowering herbs:	+15%	

Big variation by species, study, and functional group

Invasive plants do better still

- Comparative studies of invasive and native plants with rising CO_2 show that invasives perform better



Terrestrial invasive plants perform better than native plants with elevated CO_2

Liu et al. 2017

Invasive plants do better still

- Comparative studies of invasive and native plants with rising CO_2 show that invasives perform better
- Also, bigger & more roots = harder to kill

Canada thistle

Ziska et al. 2004

4. Plant response to rising CO_2

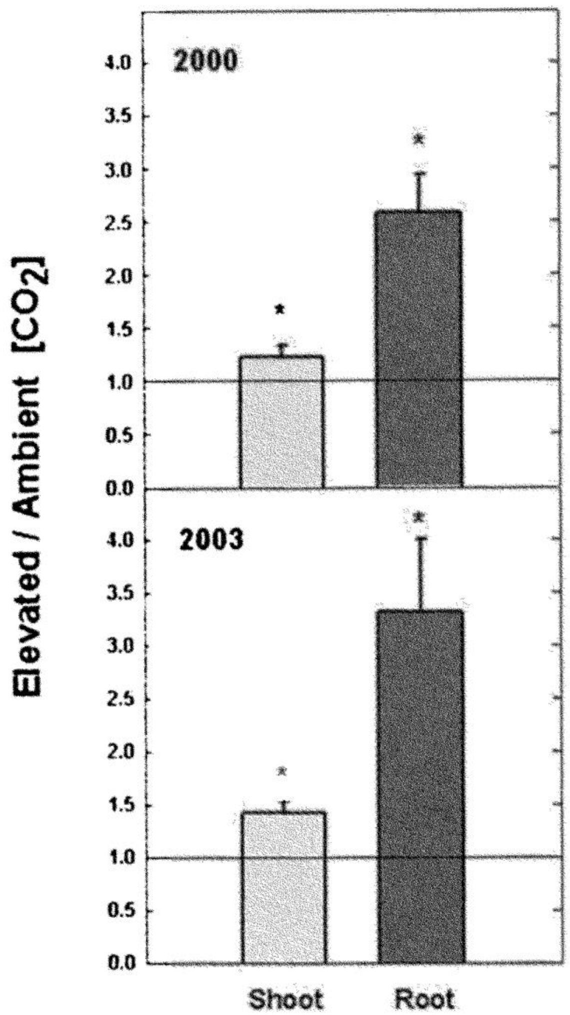


Figure 1 in Ziska et al. 2004

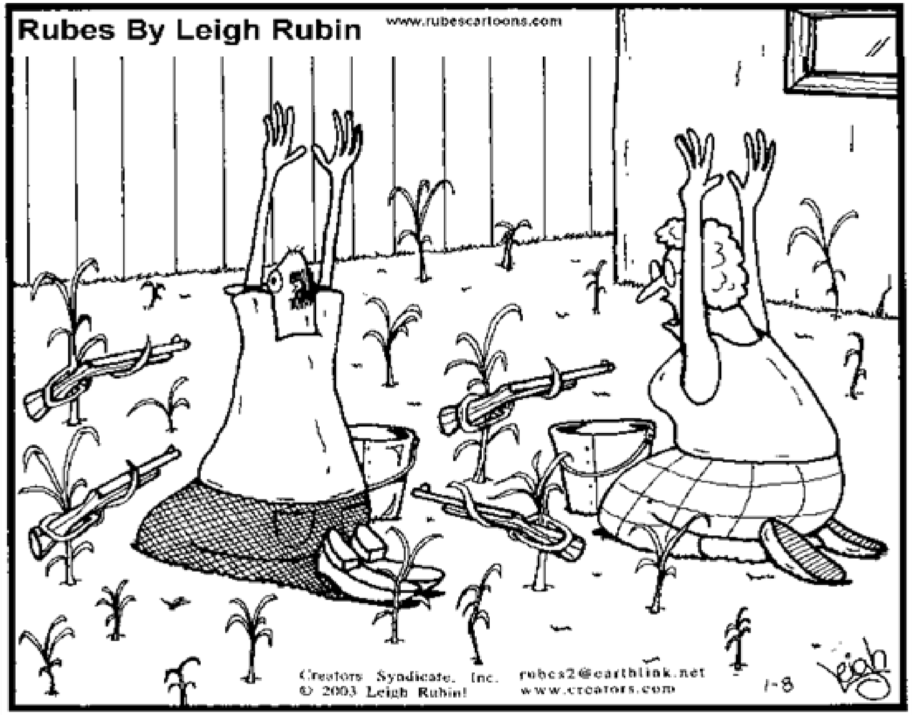
- Increased biomass in Canada thistle with higher atmospheric CO2. Root biomass more than doubled.

- Canada thistle can spread via root fragments.

- Could become a worse agricultural weed under increased CO2.

Take home points:

- All plants do better with higher CO_2, but relative improvements matter.
- Watch out for hardier invasives.



"We never should have waited this long ... Now the weeds have *completely* taken over."

Recap

- Invasives emerge earlier, have longer/more life cycles, and are more competitive with warming temperatures.
- Invasive species ranges are shifting – but, we have a chance to get ahead of some of them.
- Climate extremes create novel disturbance, which favors invasives.
- Invasive plants have a growth advantage with higher atmospheric CO_2.

Management Opportunities

- Phenology-based approaches
- Assisted migration

Phenology

- Budbreak/senescence are vulnerable times
- Times when invasives are active, but non-invasives are dormant or not actively growing are great opportunities for creative management.

The phenology of plant invasions: a community ecology perspective

Elizabeth M Wolkovich[1*] and Elsa E Cleland[2]

5. Management Implications and Opportunities

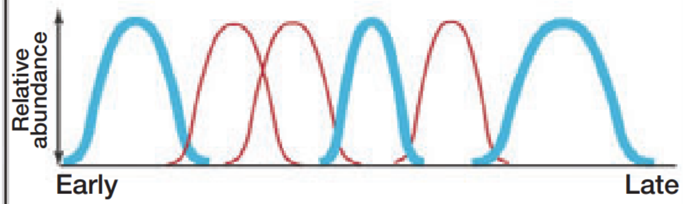
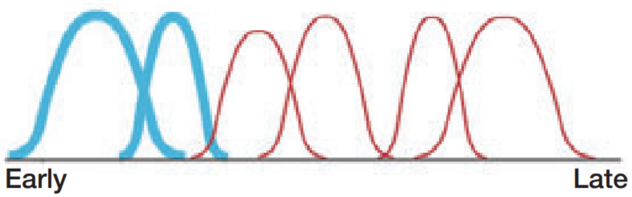
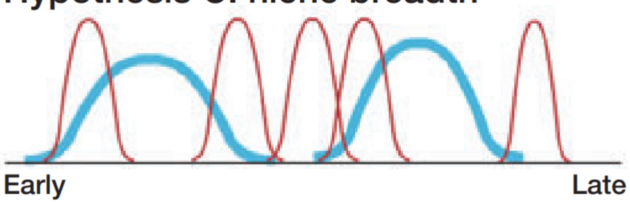
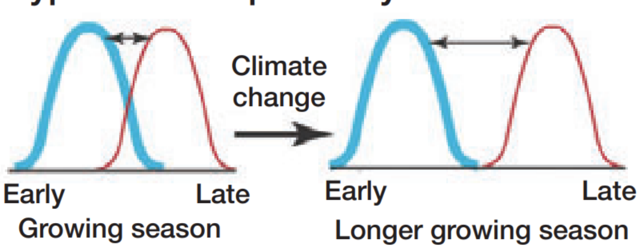
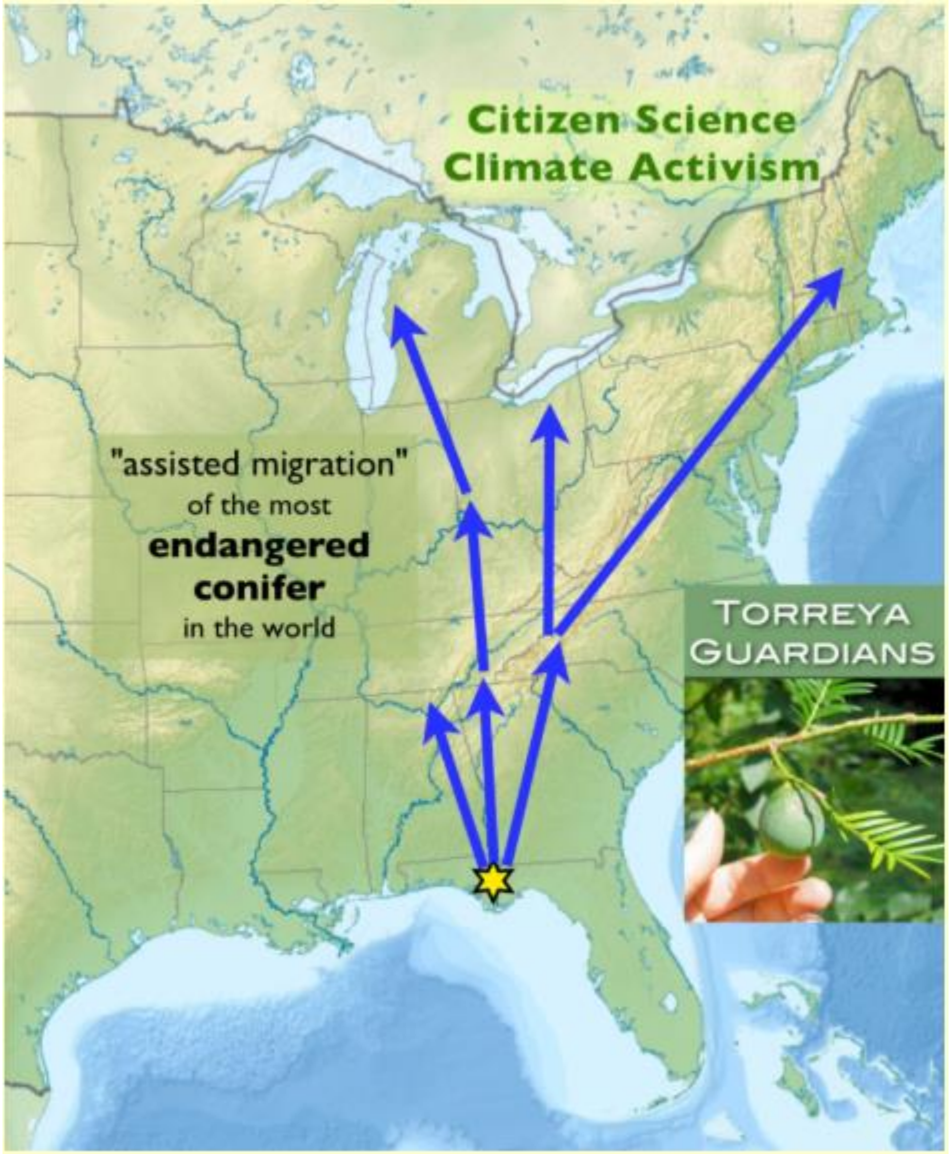
Hypotheses	Predictions	Management opportunities
Hypothesis A: vacant niche 	**A: vacant niche** Exotic species tend to leaf/bloom when native species are not in leaf/bloom	**A: vacant niche** Herbicide, grazing, fire and other removal programs targeted when exotic species are active and native species inactive
Hypothesis B: priority effects 	**B: priority effects** Exotic species leaf/bloom earlier than native species	**B: priority effects** Targeted removal programs in the early season
Hypothesis C: niche breadth 	**C: niche breadth** Length of leafing/ blooming period of exotic species is greater than for native species	**C: niche breadth** Targeted removal when exotic species are active and native species inactive
Hypothesis D: plasticity and climate 	**D: plasticity and climate** Leafing/blooming of exotic species varies across seasons, covaries with climate	**D: plasticity and climate** Management programs when climate events increase phenological gap between native and exotic species

Figure 1 in Wolkovich and Cleland, 2011

Solution? Assisted Migration

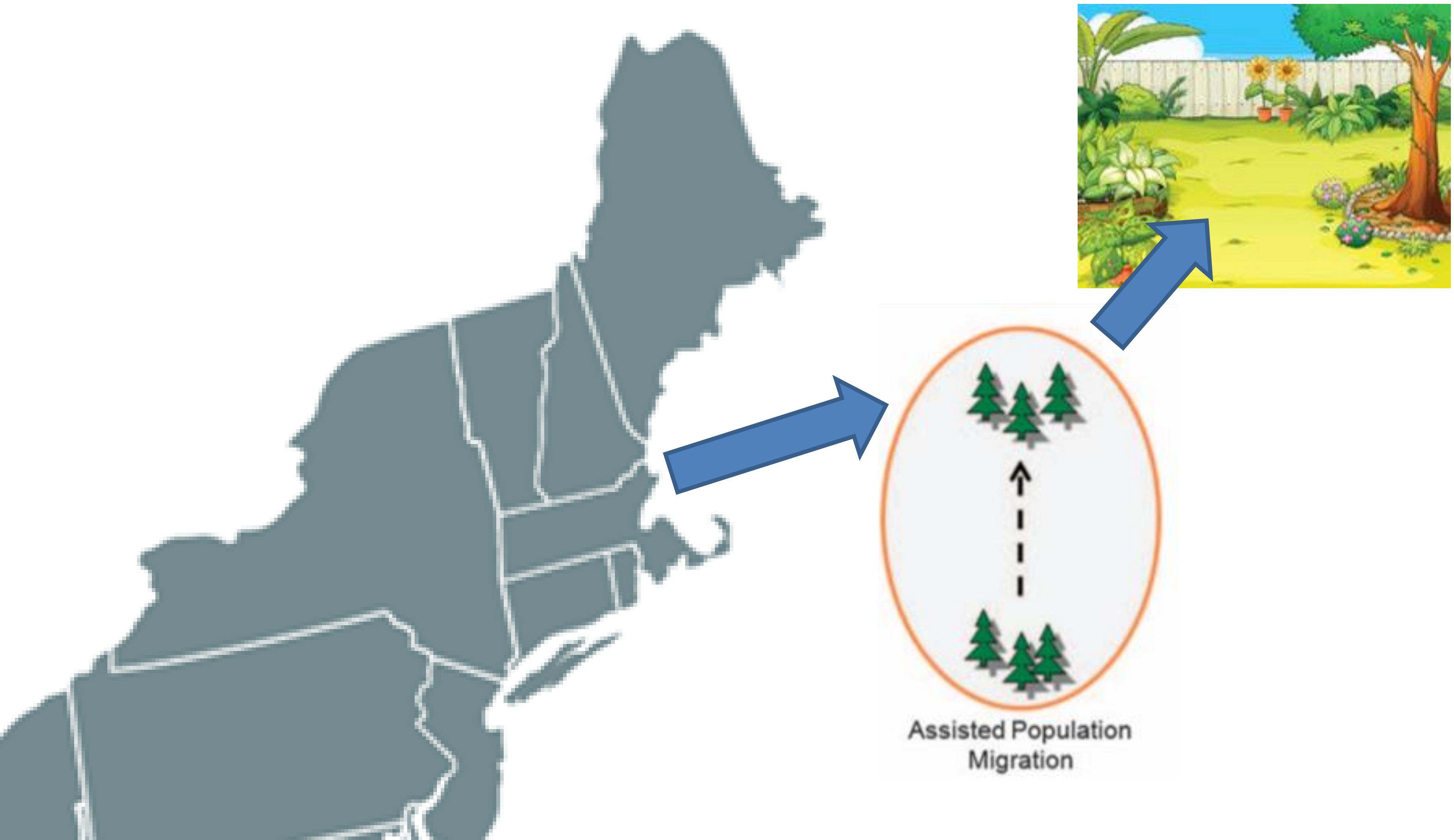
- The intentional introduction of species outside of their historic ranges into more climatically favorable regions



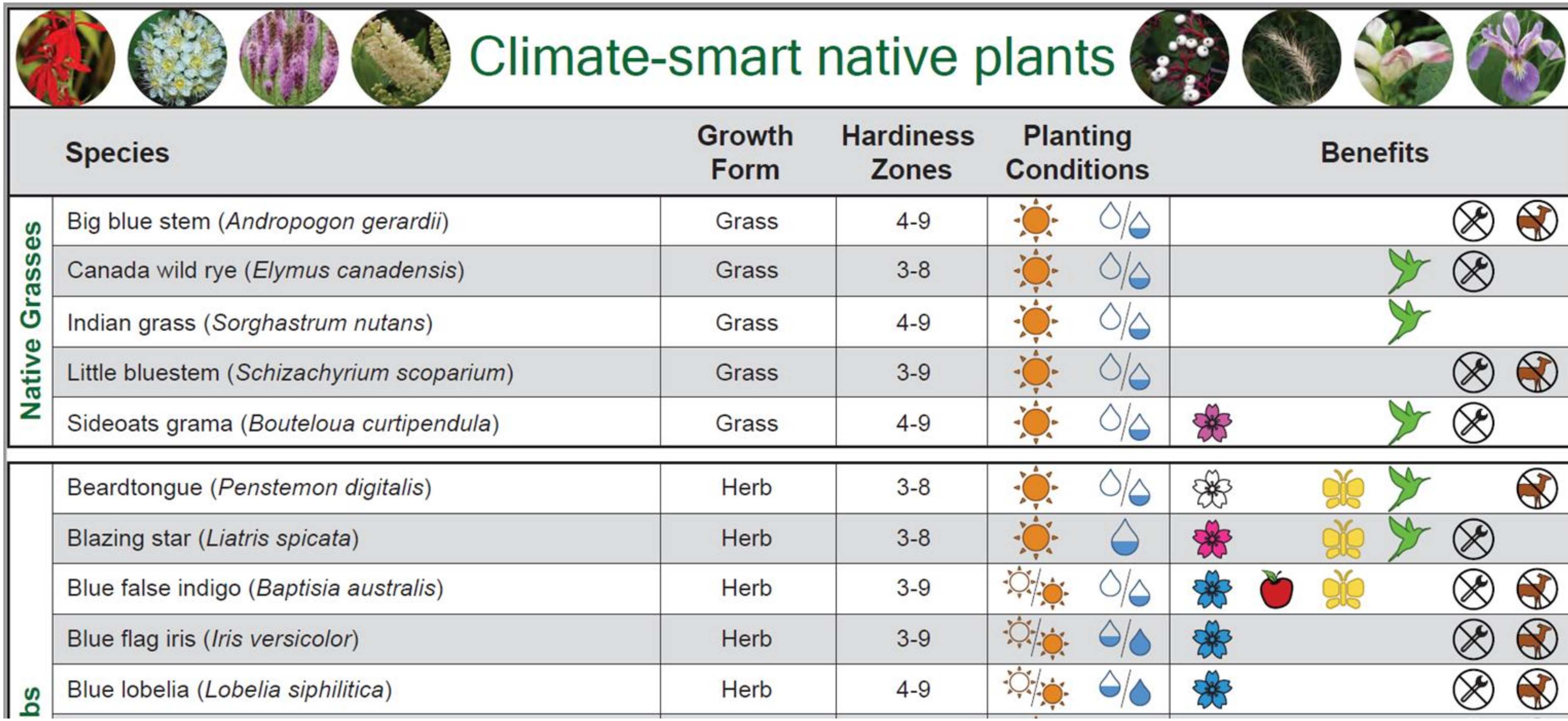
Assisted migration could refer to several different strategies

- Introducing warm-adapted populations to northern range margins

Within range shifts – gardens as ‘steppingstones’



Within range shifts – gardens as 'steppingstones'



Climate-smart native plants

	Species	Growth Form	Hardiness Zones	Planting Conditions	Benefits
Native Grasses	Big blue stem (*Andropogon gerardii*)	Grass	4-9		
	Canada wild rye (*Elymus canadensis*)	Grass	3-8		
	Indian grass (*Sorghastrum nutans*)	Grass	4-9		
	Little bluestem (*Schizachyrium scoparium*)	Grass	3-9		
	Sideoats grama (*Bouteloua curtipendula*)	Grass	4-9		
bs	Beardtongue (*Penstemon digitalis*)	Herb	3-8		
	Blazing star (*Liatris spicata*)	Herb	3-8		
	Blue false indigo (*Baptisia australis*)	Herb	3-9		
	Blue flag iris (*Iris versicolor*)	Herb	3-9		
	Blue lobelia (*Lobelia siphilitica*)	Herb	4-9		

https://www.risccnetwork.org/
management-challenges

We have the opportunity to have beautiful, climate resilient gardens that support biodiversity.

5. Management Implications and Opportunities

Download a Cheat Sheet!

risccnetwork.org

Northeast RISCC Management

Regional Invasive Species & Climate Change

Management Challenge

Double Trouble

Understanding risks from invasive species + climate change

Summary

Individually, invasive species and climate change are major threats to global ecosystems. Together they create new challenges for effective management. Before we can design management strategies to respond to this double trouble, we need to understand how these two forms of global change interact.

Why is risk higher in the Northeast?

All regions are likely to see interactions between invasive species and climate change (Figure 1). The Northeast is particularly vulnerable for the following reasons:

- Northerly latitudes are warming more than southerly latitudes, leading to more rapid environmental changes.
- Substantial urban and suburban development cause atmospheric CO_2 content to increase more rapidly in the Northeast compared to more rural areas, increasing the competitiveness of invasive plants.
- Trends towards more extreme precipitation are more pronounced in the Northeast than any other region of the U.S., increasing disturbance and stress to native ecosystems.
- Prevalent southerly invasives are shifting their ranges north, making the Northeast a future invasion hotspot.

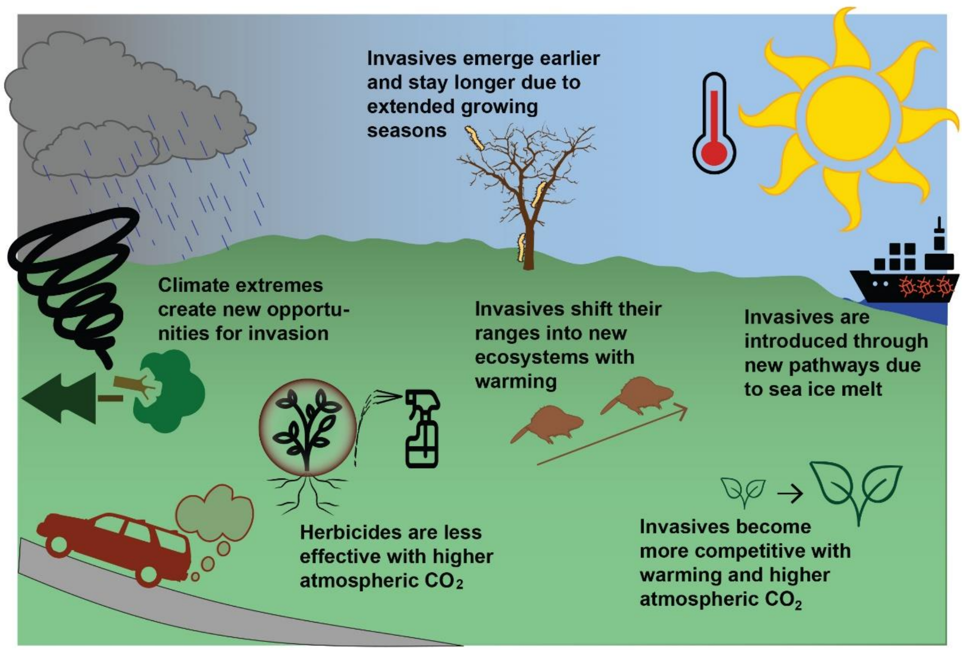


Figure 1. Major interactions between non-native invasive species and climate change.

Assisted Migration is Controversial!

A Framework for Debate of Assisted Migration in an Era of Climate Change

JASON S. McLACHLAN, JESSICA J. HELLMANN, MARK W. SCHWARTZ

Support Aggressive Assisted Migration

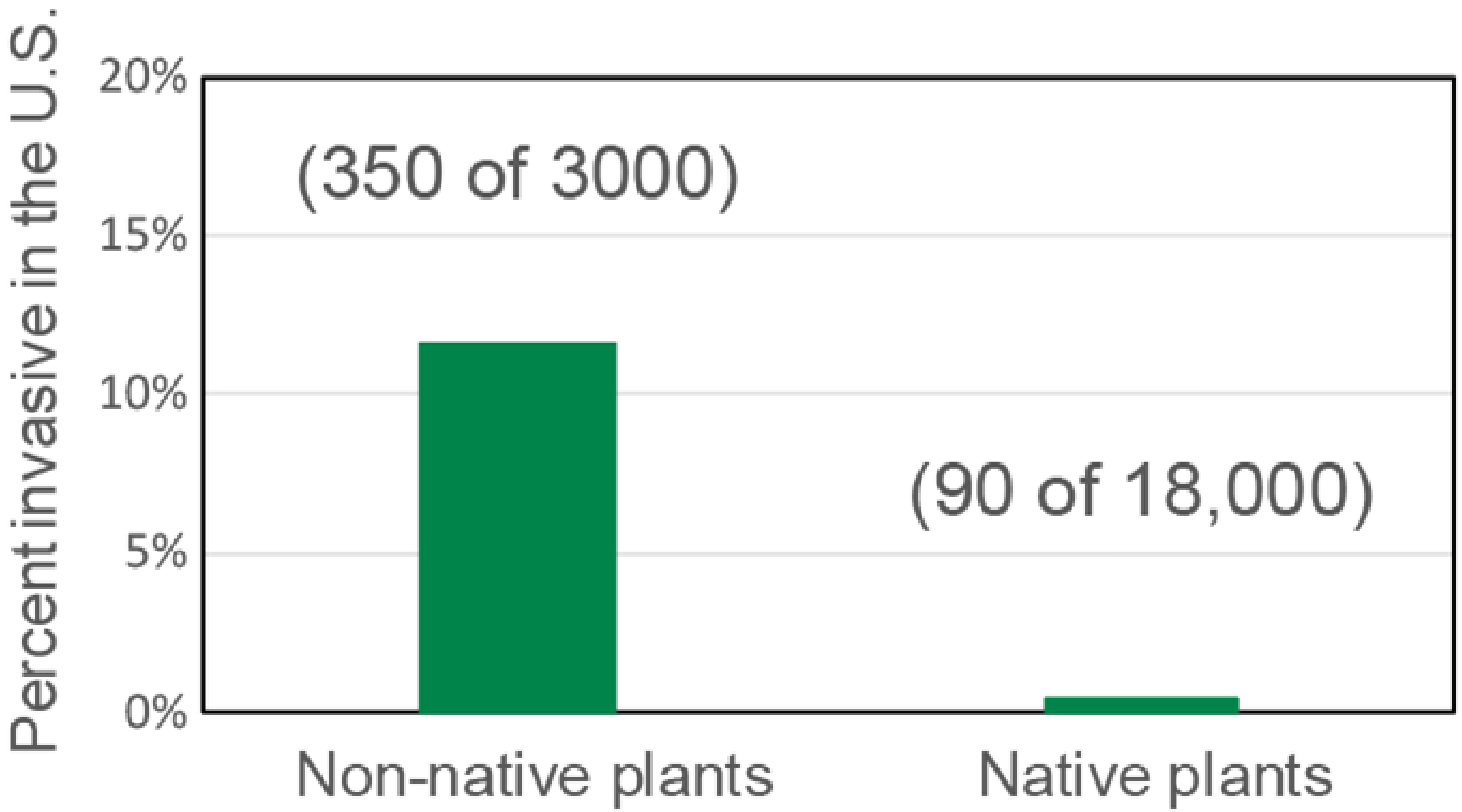
"I don't have a sense of what's normal. I do have a sense of species moving a lot through time."
— **Connie Barlow**, founder of the Torreya Guardians and a writer/naturalist with a background in evolutionary biology, as quoted in Nijhuis (2008).

Oppose Assisted Migration

"When it comes to introducing nonnative species, we have such overwhelming evidence of good ideas gone bad . . . and this isn't just The (Nature) Conservancy's policy, it's my personal policy. . . . it's very dangerous tinkering."
— **David Printiss**, manager of The Nature Conservancy reserve just south of Torreya State park, as quoted in Nijhuis (2008).

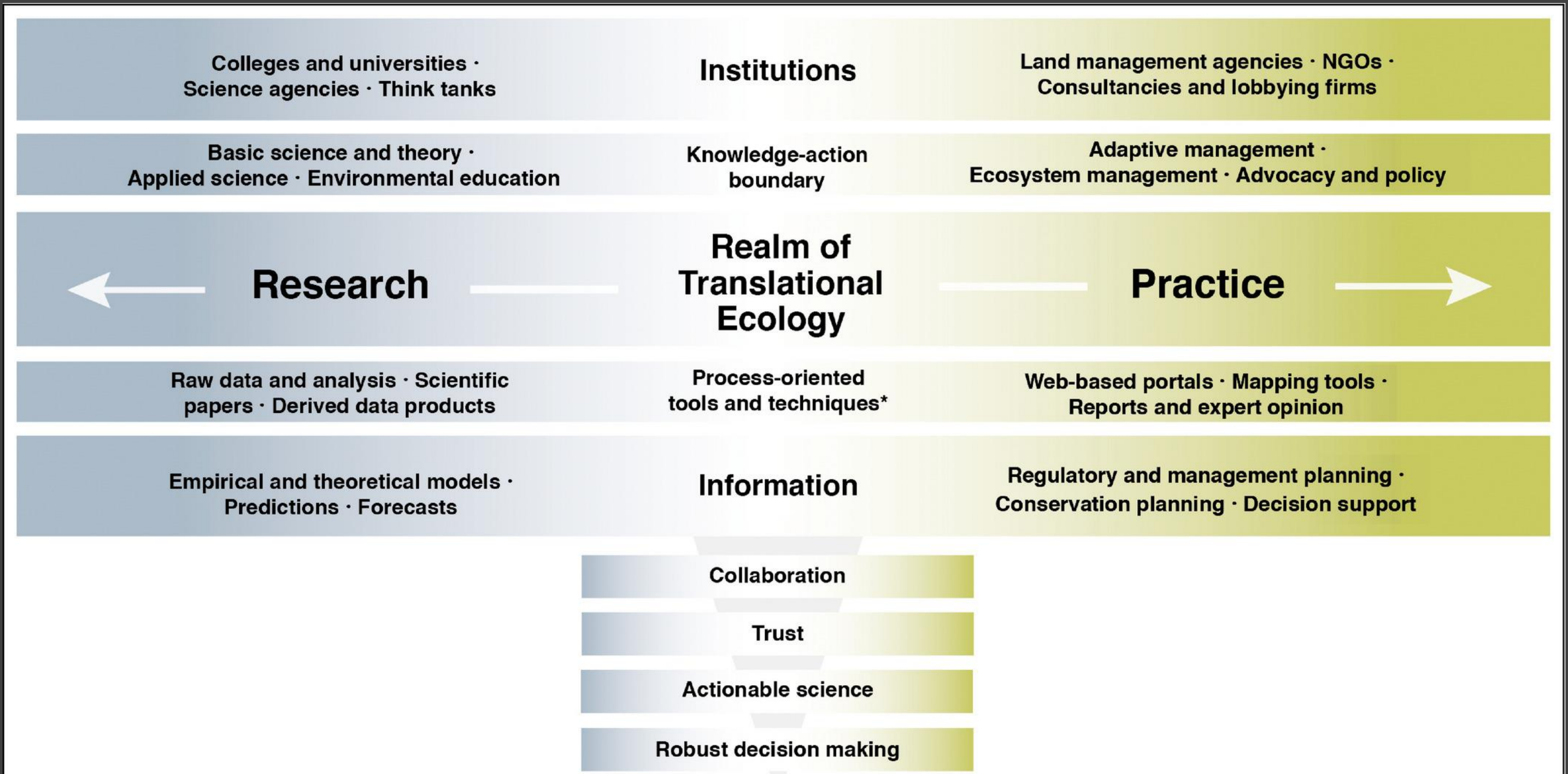
We're already doing assisted migration with nursery plants. But, most nursery plants are non-native.

Non-native plants are more likely to be invasive than native plants



Simberloff et al. 2012

TRANSLATIONAL ECOLOGY AND RISCC



Translational Ecology

- Enquist et al. 2017, Frontiers in Ecology & Environment

Northeast RISCC Management

Regional Invasive Species & Climate Change

Mission Statement:

The Northeast Regional Invasive Species & Climate Change (RISCC) Management Network aims to reduce the compounding effects of invasive species and climate change by **synthesizing** relevant science, **communicating** the needs of managers to researchers, **building** stronger scientist-manager communities, and **conducting priority research**.

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Translational Ecology: Actionable Science

Translational ecology (TE) is an approach in which ecologists, stakeholders, and decision makers work together to develop research that addresses the sociological, ecological, and political contexts of an environmental problem

Frontiers in Ecology and the Environment, Volume: 15, Issue: 10, Pages: 541-550, First published: 01 December 2017, DOI: (10.1002/fee.1733)

Northeast RISCC

Leadership Team

We support a network of ~ 450 invasive species managers

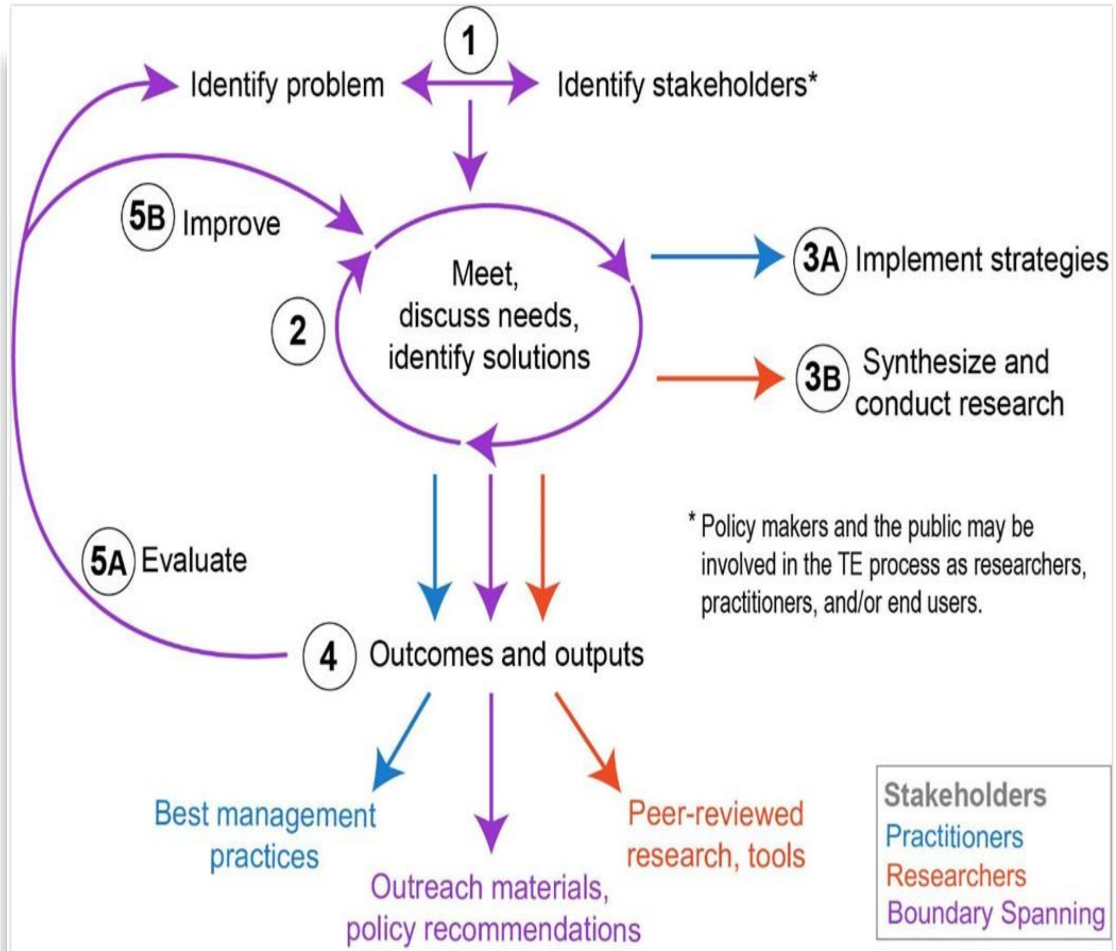
Northeast RISCC

So… What do we do at RISCC?

Northeast RISCC

Translational Invasion Ecology

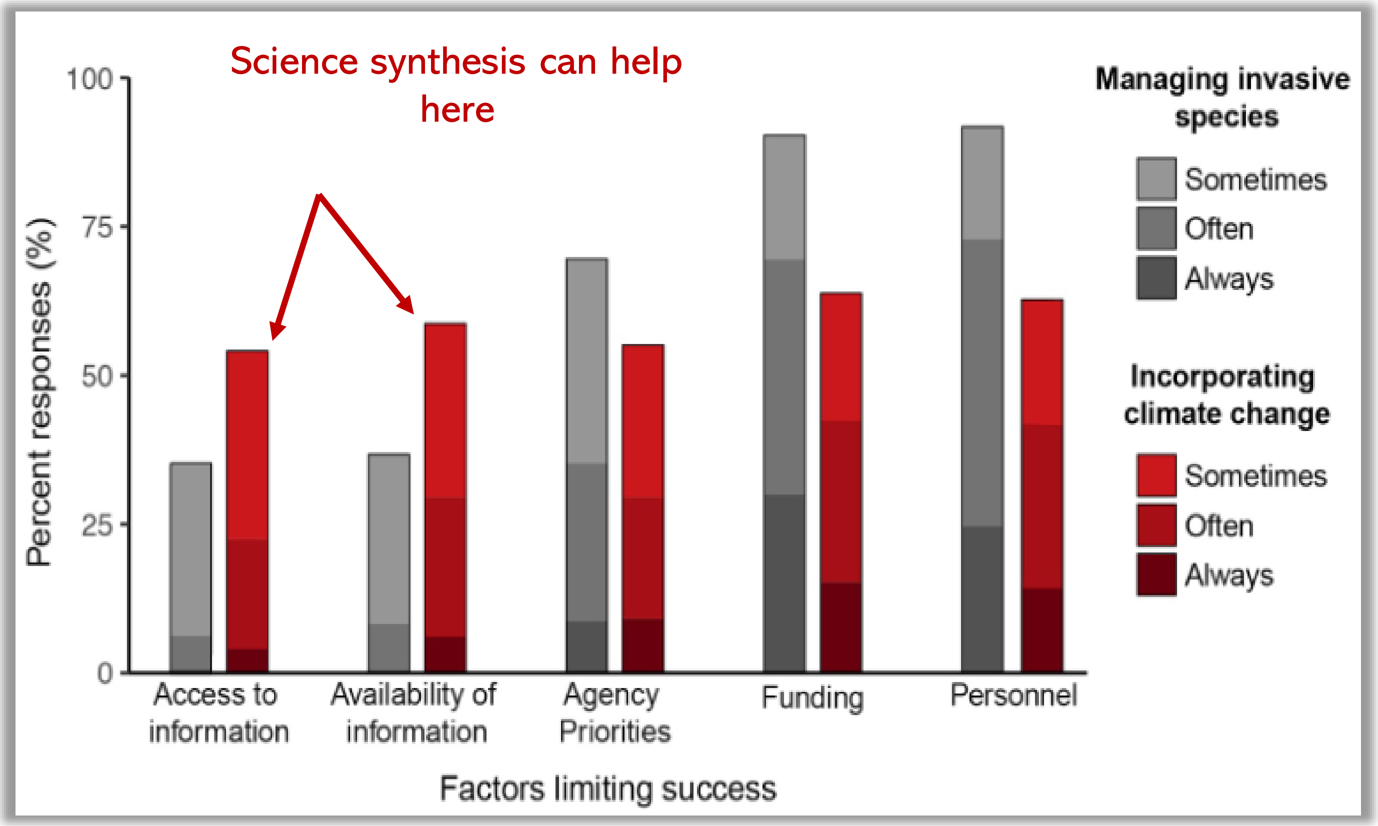
At RISCC, we apply principles of TE to the twin challenges of Invasive Species (IS) and Climate Change (CC)



Morelli et al *In Review*

Northeast RISCC

Synthesize The Science!



Beaury et al. 2020

Our survey revealed that a lack of information, or access to information, is a key barrier to including climate change in management actions.

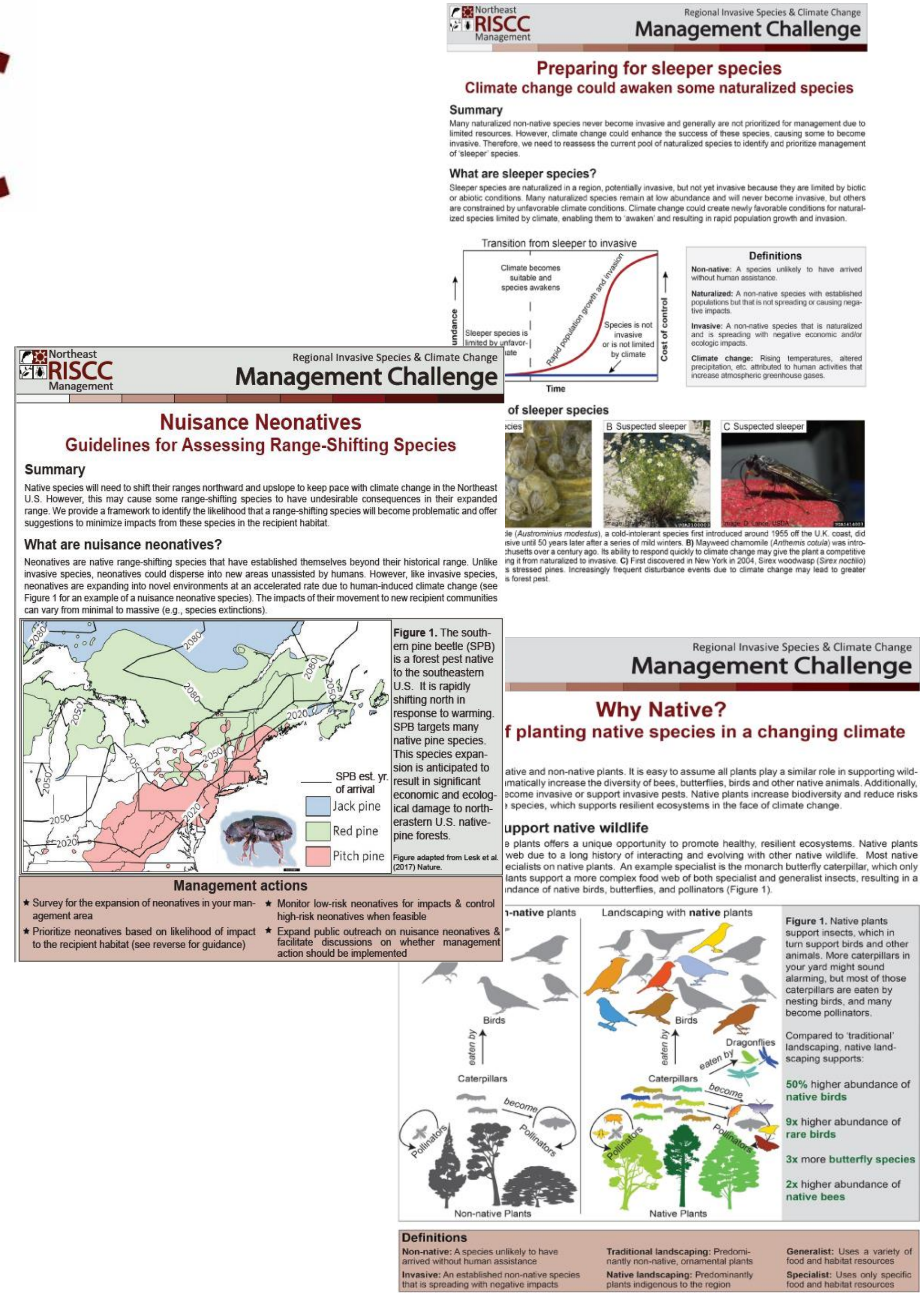
RISCC helps make information accessible and available to land managers.

Northeast RISCC

Synthesize The Science!

We create and distribute biweekly research summaries to our listserv.

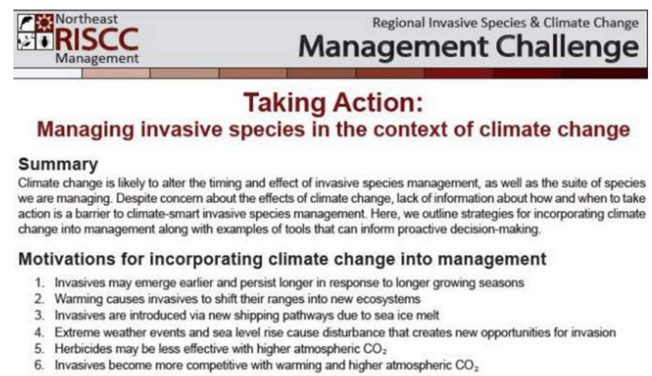
We produce semiannual, 2-page Management Challenges.



Share Knowledge and Needs

Sharing knowledge and needs of IS managers through workshops and surveys

Knowledge sharing leads to RISCC products.


Northeast RISCC Management

Regional Invasive Species & Climate Change
Management Challenge

Taking Action:
Managing invasive species in the context of climate change

Summary

Climate change is likely to alter the timing and effect of invasive species management, as well as the suite of species we are managing. Despite concern about the effects of climate change, lack of information about how and when to take action is a barrier to climate-smart invasive species management. Here, we outline strategies for incorporating climate change into management along with examples of tools that can inform proactive decision-making.

Motivations for incorporating climate change into management

1. Invasives may emerge earlier and persist longer in response to longer growing seasons
2. Warming causes invasives to shift their ranges into new ecosystems
3. Invasives are introduced via new shipping pathways due to sea ice melt
4. Extreme weather events and sea level rise cause disturbance that creates new opportunities for invasion
5. Herbicides may be less effective with higher atmospheric CO_2
6. Invasives become more competitive with warming and higher atmospheric CO_2

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Share Knowledge and Needs

What new invasive species are likely to emerge in your management area?

What types of native species are better choices for restoration?

How do we maximize treatments by adjusting timing?

How will treatment efficacy change and what alternative treatments work better?

Preventative Management

Recommendations:

- Plant species native to Eastern North America that are resistant to climate change (e.g., drought-tolerant, broad hardiness zones; Fig. 2).
- Develop watch lists and proactive management plans for invasive species predicted to shift into your region.
- Prioritize treatment of existing invasive species predicted to spread or increase in abundance with climate change.
- Monitor non-natives for increases in populations ('sleeper species').

Example: Tug Hill State Forest in NY planted native, warm-adapted trees to reduce future disturbance and resist invasions with climate change.

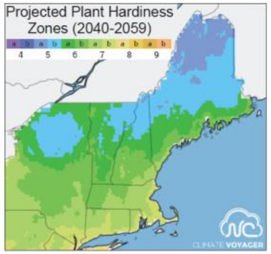

Fig 2. Climate Voyager maps future hardiness zones (climate.ncsu.edu/voyager/).

Treatment & Control

Recommendations:

- Time invasive species management with shifts in the growing season.
- Test new management techniques in the event that existing treatments become less effective with climate change.
- Identify and monitor for range shifting invasive species.
- Connect with managers, both locally and in other regions, about effective treatments for watch list species.

Example: Pesticides need to be applied quickly following the emergence of Gypsy Moth caterpillars. Optimal timing for control can be predicted based on climate (Fig. 3). Sign up with the NPN to be notified ahead of time.

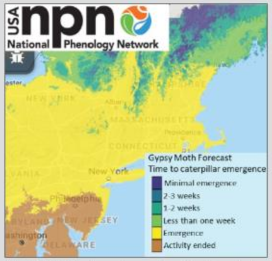

Fig 3. NPN phenology visualization tool (www.usanpn.org/data/visualizations).

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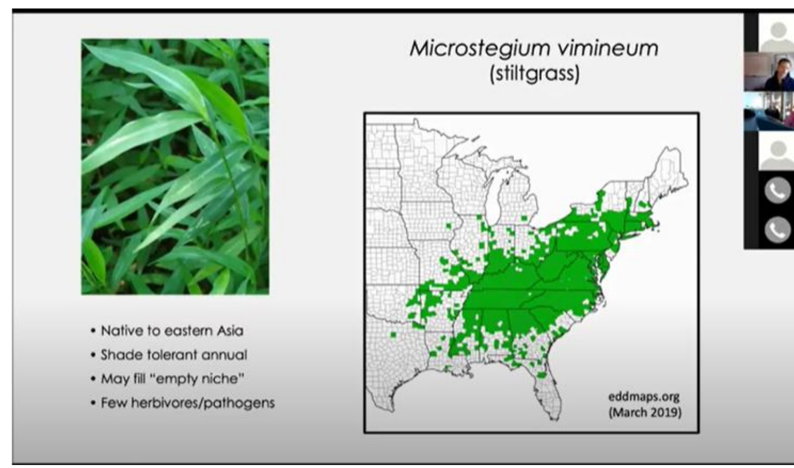
Build Community

Creating networking and one-on-one conversation opportunities

For example, webinars on range-shifting invasive species:

- **Advice from a manager**
- **Advice from a scientist**



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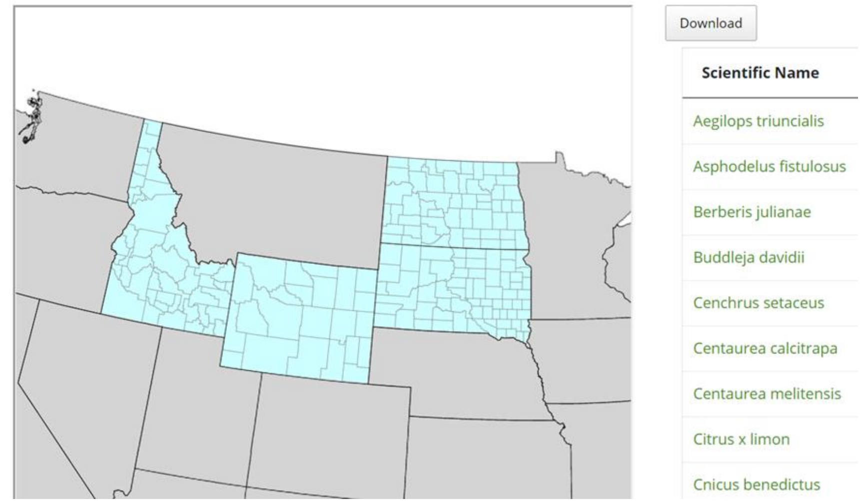


https://www.eddmaps.org/rangeshiftlisting/

Priority Research

Our research priorities include:

- Resilient Communities
- Range Shifting Species
- Biocontrol Efficacy

Work led by Jenica Allen

EDDMapS find • map • track

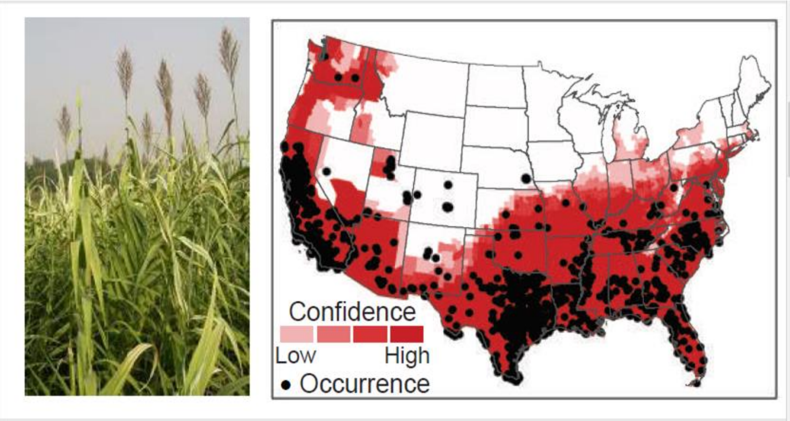
Northeast RISCC

Priority Research: Range Shifting Plants

Arundo donax (giant reed)

HIGH Impact: Outcompetes native wetland plants, alters wetland structure, increases fire frequency, acts as a host for crop pests and pathogens.

HIGH Vulnerability: Invades rivers, streams, wetlands, and coastal areas. Widely introduced as a biofuel crop, could arrive quickly. Difficult to control and spreads by rhizomes along waterways.



Northeast RISCC Management

Regional Invasive Species & Climate Change

Interested? Have a seat at our table!

Join us at:

risccnetwork.org

UMass Amherst

USGS science for a changing world

NYISRI New York Invasive Species Research Institute

Cornell University

NE CASC Northeast Climate Adaptation Science Center

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