Novel Ecosystems: Backyard to Landscape

Society for Ecological Restoration Mid-Atlantic Chapter

College Park, Maryland

March 29, 2013

Revised April 15, 2013

Marilyn Jordan Ph.D.

Senior Conservation Scientist

The Nature Conservancy on Long Island, NY

The Nature Conservancy.

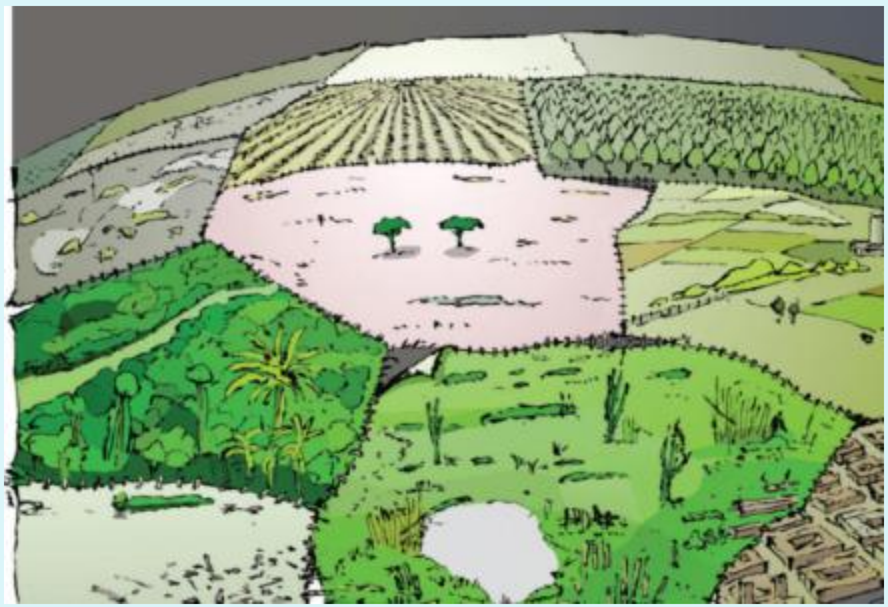
Protecting nature. Preserving life.

Novel ecosystems recently recognized: ***No-analog*** *combinations of species and/or environmental conditions*

Ariel Lugo. 1992. Comparison of Tropical Tree Plantations with Secondary Forests of Similar Age (Puerto Rico)

Joe Mascaro. 2008. Limited native plant regeneration in novel, exotic-dominated forests on Hawai'i

As though working through the five stages of grief, more and more ecologists are reluctantly accepting that we live in a human-dominated world. And some are discovering that patchwork ecosystems might even rival their pristine counterparts. *Emma Marris*



Marris, E. 2009. Ragamuffin Earth. *Nature News Feature* Vol 460, p. 450-453

Marris. 2010. The New Normal. Conservation Magazine 11(2):12-17

Identical articles

Novel Ecosystems: hope or hype?

Scrubby, untended, feral, worthless weed patches?

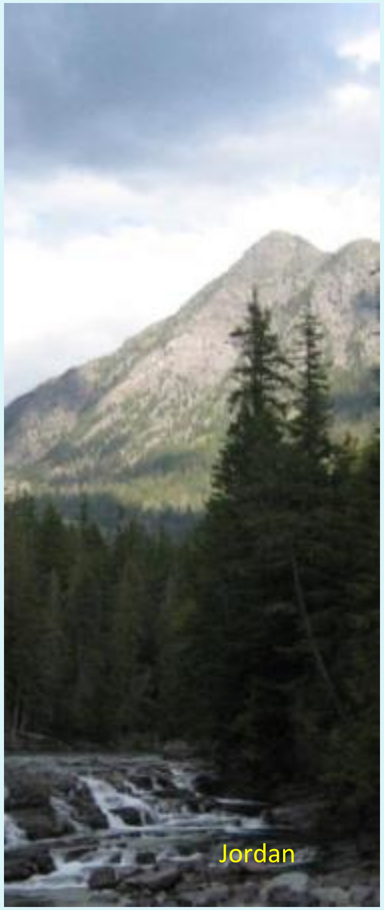
- OR -

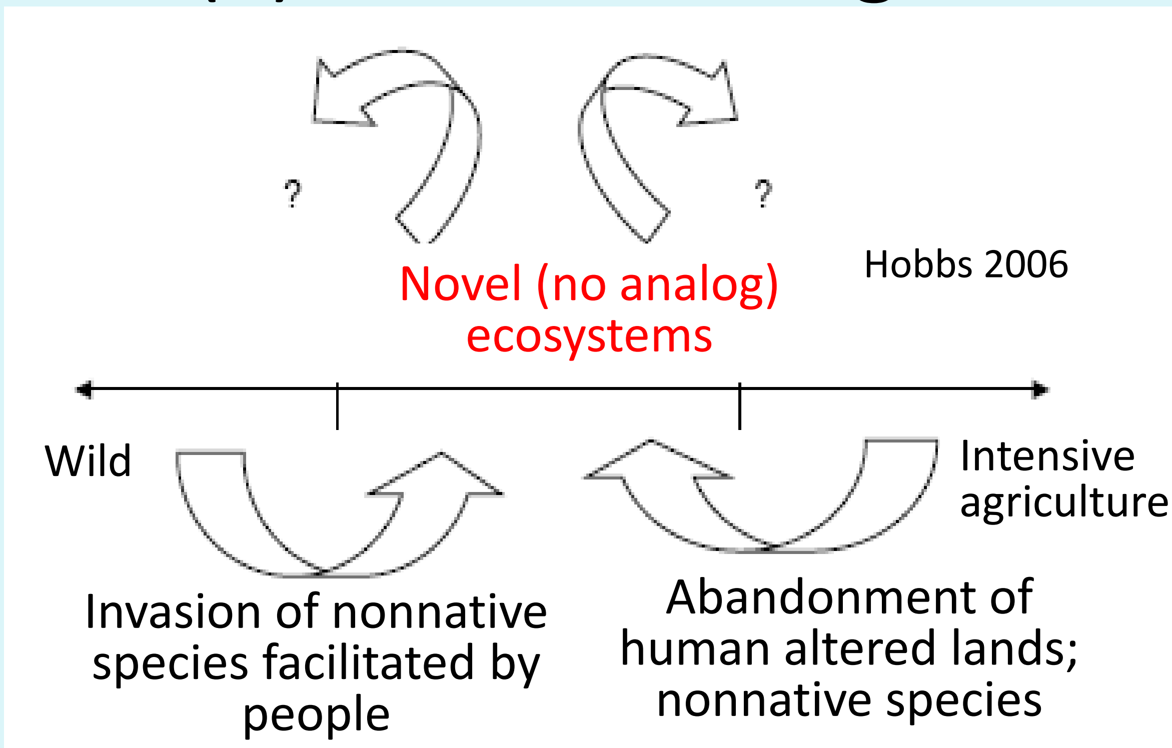
Valuable functional habitats?

Rival "pristine" counterparts?

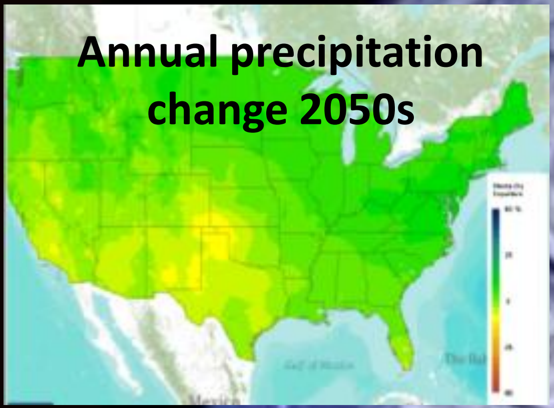
Producers of ecosystem services for people?

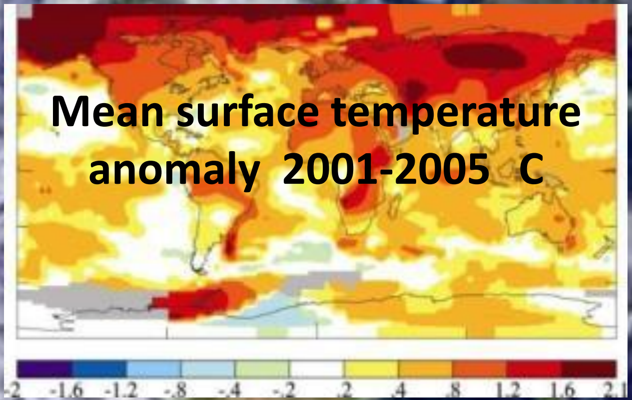
Created by: (1) Invasion and/or extinction (2)Land use changes





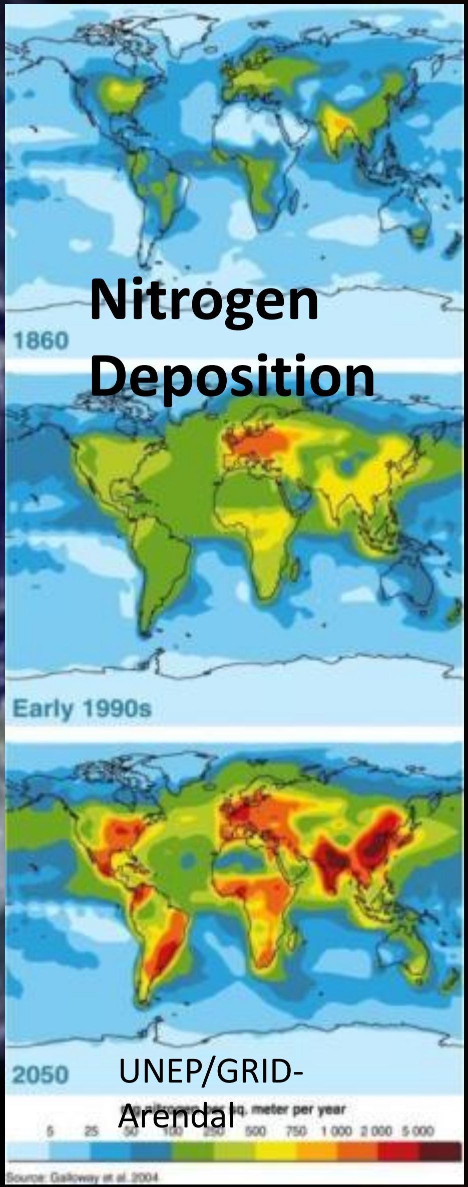
Created by (3) global changes



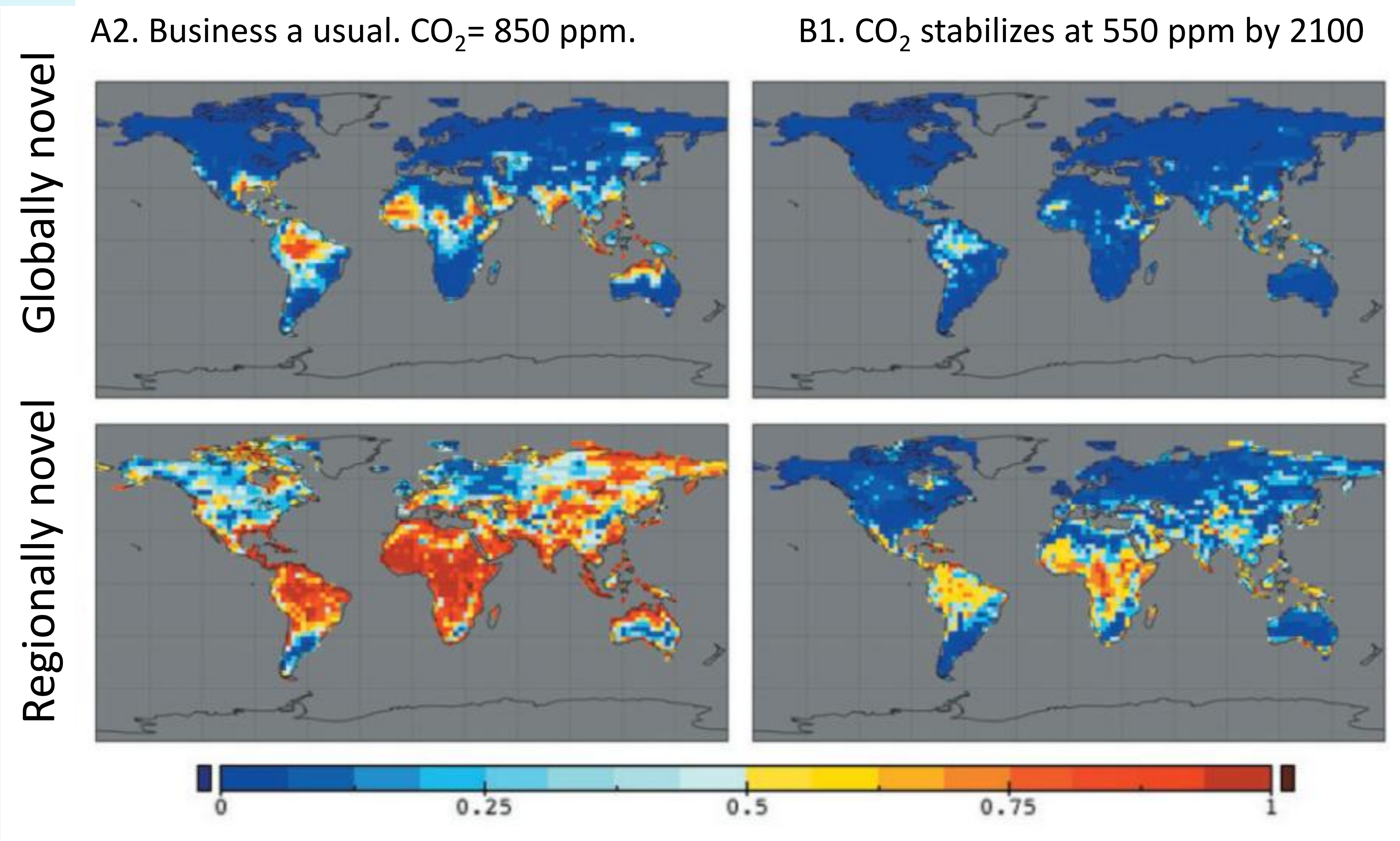


CO_2

Ocean acidification



No-analog climates



Fraction of climate models predicting no 2080s climate match with 1980-1999 climates.

Williams and Jackson. 2007. Novel Climates, no-analog communities… Front. Ecol. Environ. 5(9)475-482.

Ellis' definition of novel ecosystems:

Unused lands embedded within settlements, croplands, rangelands and seminatural anthromes:

- They cover ~37% of the ice-free terrestrial globe.
- "Used" + "Seminatural" >75%

http://ecotope.org/anthromes/

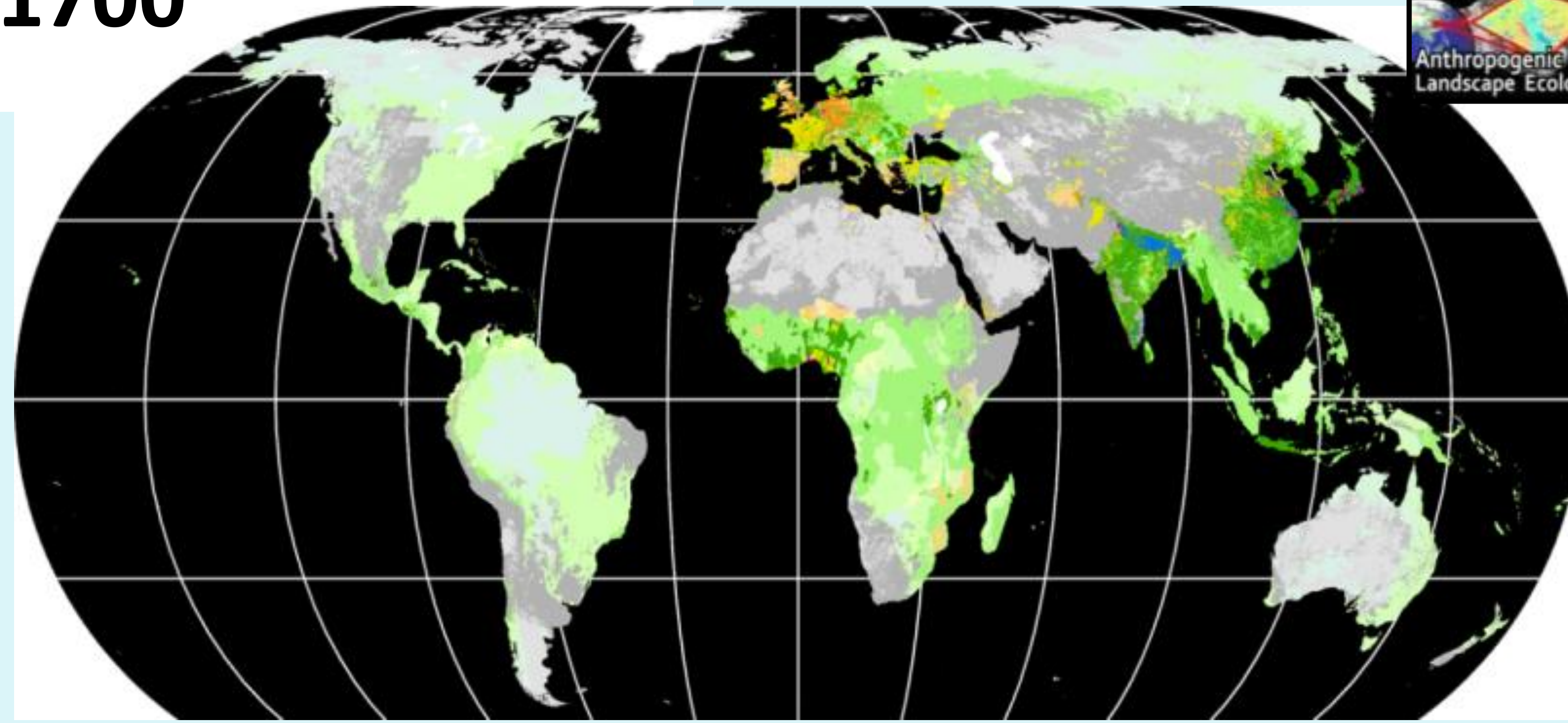
Ellis et al. 2010. Anthropogenic transformation of the biomes, 1700 to 2000. Global Ecology & Biogeography. Univ. MD, Anthropogenic Landscape Ecology

How did the biosphere become anthropogenic?

Ellis et al. 2010

Laboratory for Anthropogenic Landscape Ecology

1700



Used | ***Seminatural*** | **Wild**

Dense Settlements
Urban | Dense settlements

Villages
Rice | Irrigated | Rainfed | Pastoral

Croplands
Residential (Irrigated, Rainfed) | Populated | Remote

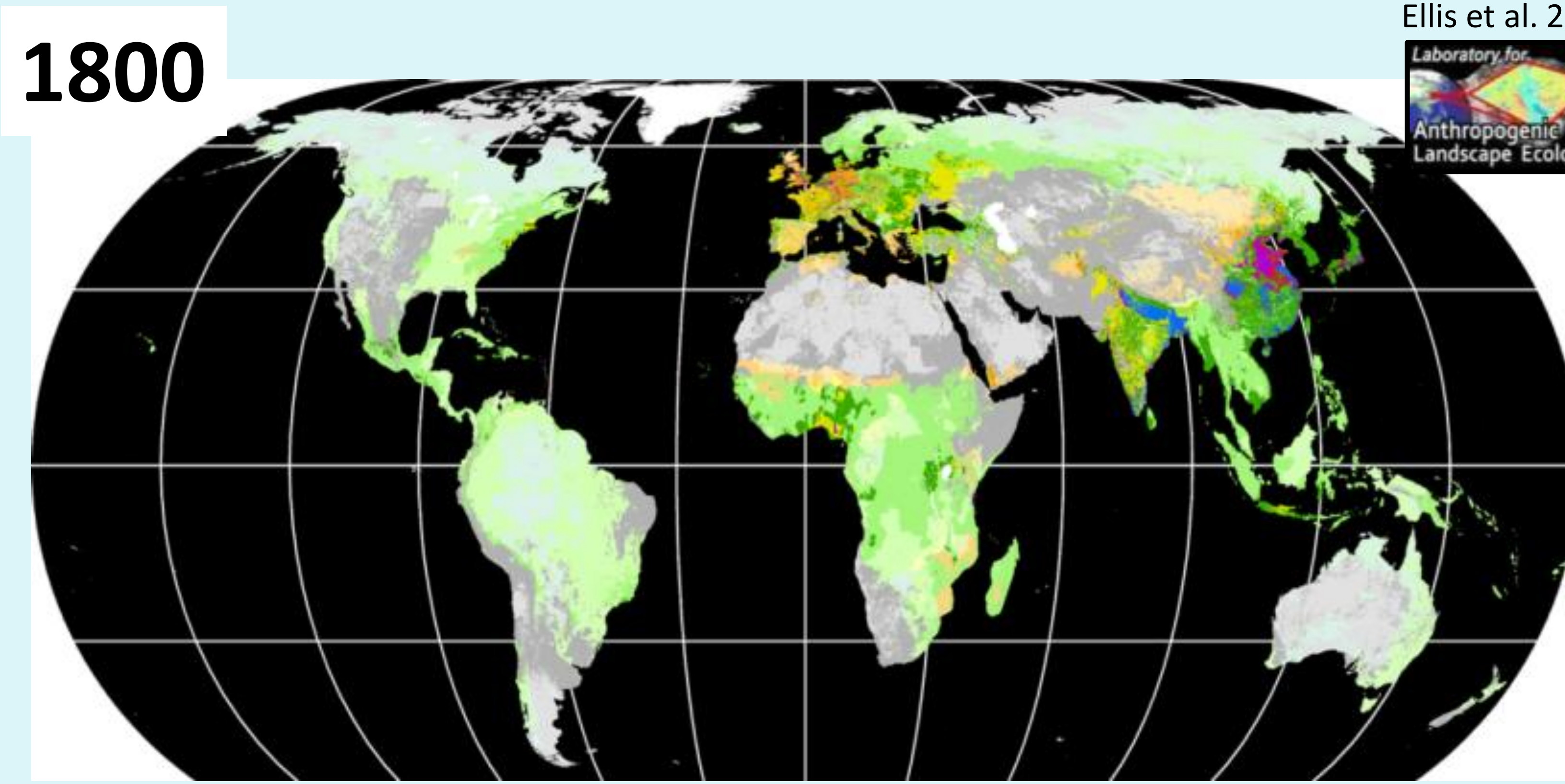
Rangelands
Residential | Populated | Remote

Seminatural
Woodlands (Residential, Populated, Remote) | Treeless & Barren

Wildlands
Woodlands | Treeless & Barren

How did the *biosphere* become anthropogenic?

Ellis et al. 2010



Used | *Seminatural* | **Wild**

Dense Settlements: Urban, Dense settlements

Villages: Rice, Irrigated, Rainfed, Pastoral

Croplands: Residential (Irrigated, Rainfed), Populated, Remote

Rangelands: Residential, Populated, Remote

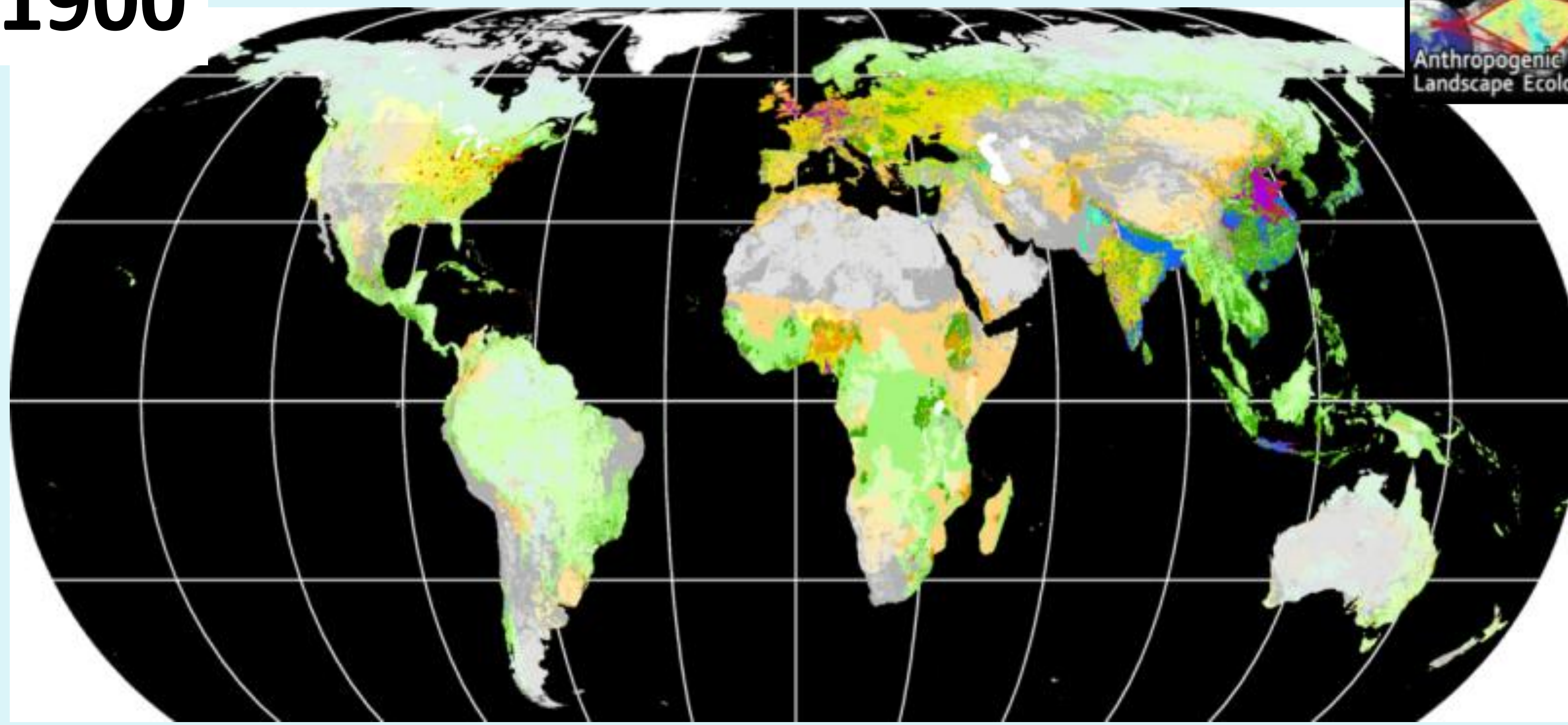
Seminatural: Woodlands (Residential, Populated, Remote), Treeless & Barren

Wildlands: Woodlands, Treeless & Barren

How did the biosphere become anthropogenic?

Ellis et al. 2010

1900



Used	Seminatural	Wild

Dense Settlements — Urban, Dense settlements

Villages — Rice, Irrigated, Rainfed, Pastoral

Croplands — Residential (Irrigated, Rainfed), Populated, Remote

Rangelands — Residential, Populated, Remote

Seminatural — Woodlands (Residential, Populated, Remote), Treeless & Barren

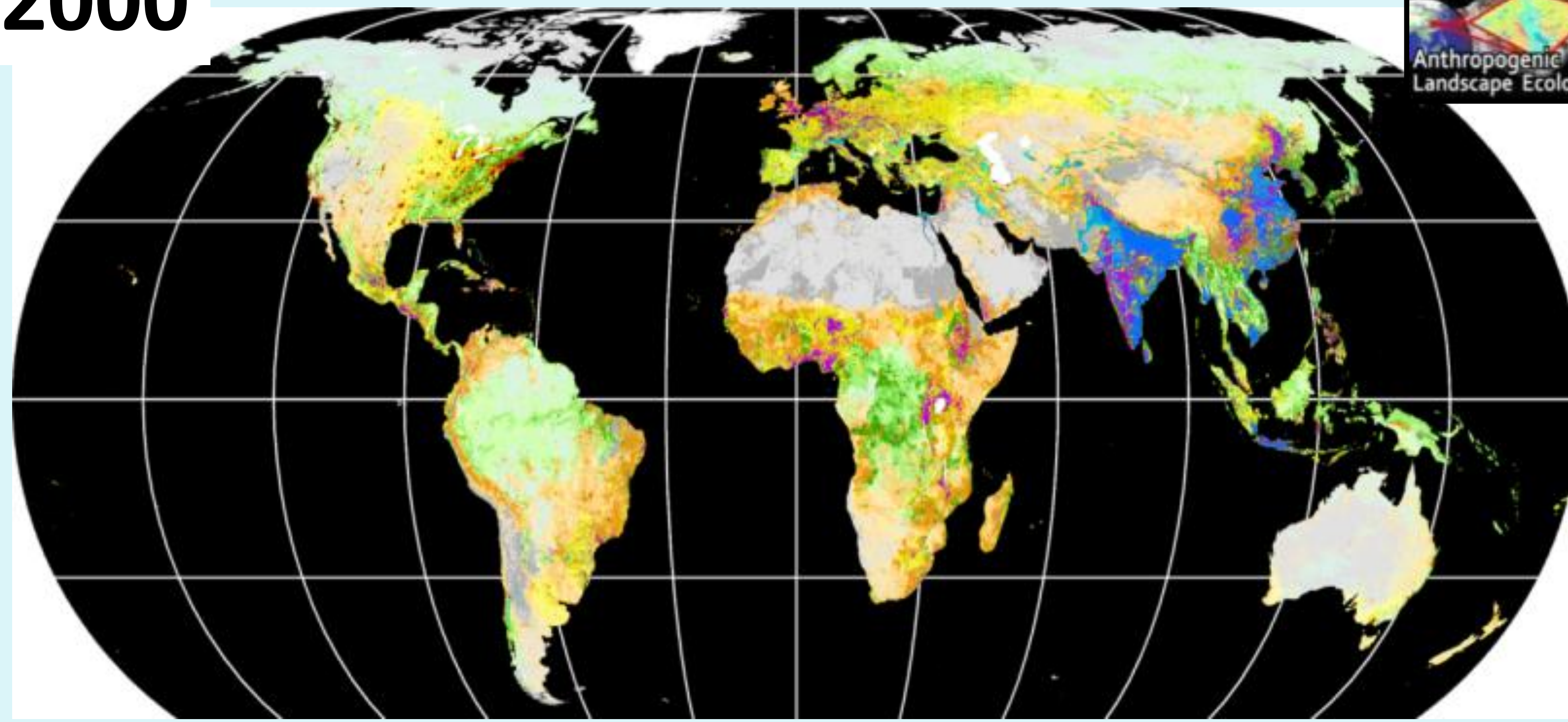
Wildlands — Woodlands, Treeless & Barren

How did the biosphere become anthropogenic?

Ellis et al. 2010

Laboratory for Anthropogenic Landscape Ecology

2000



Used	**Seminatural**	**Wild**

Dense Settlements: Urban, Dense settlements

Villages: Rice, Irrigated, Rainfed, Pastoral

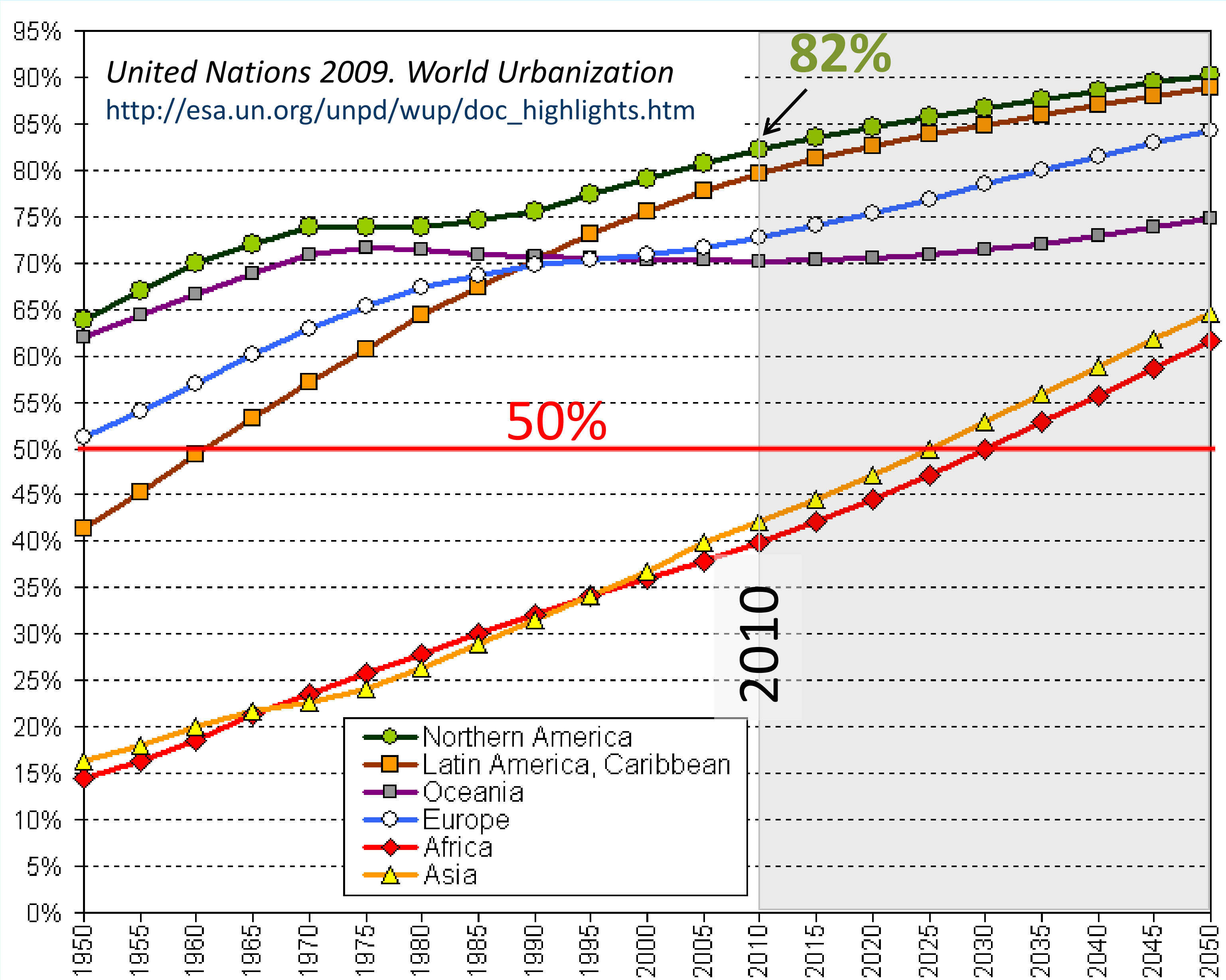
Croplands: Residential (Irrigated, Rainfed), Populated, Remote

Rangelands: Residential, Populated, Remote

Seminatural: Woodlands (Residential, Populated, Remote), Treeless & Barren

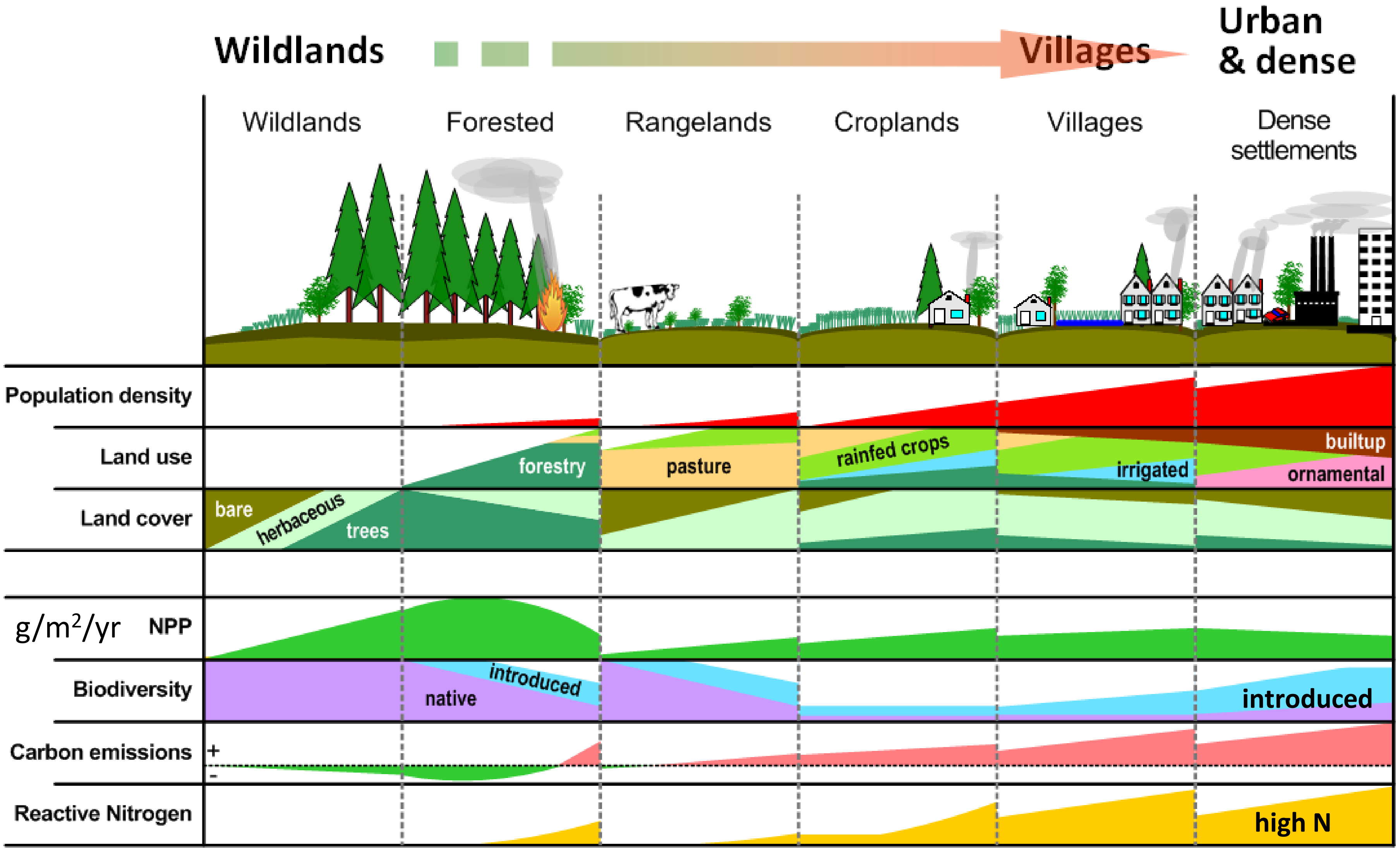
Wildlands: Woodlands, Treeless & Barren

Human population increasingly urban



N. America
Latin America
Europe
Oceana
Asia
Africa

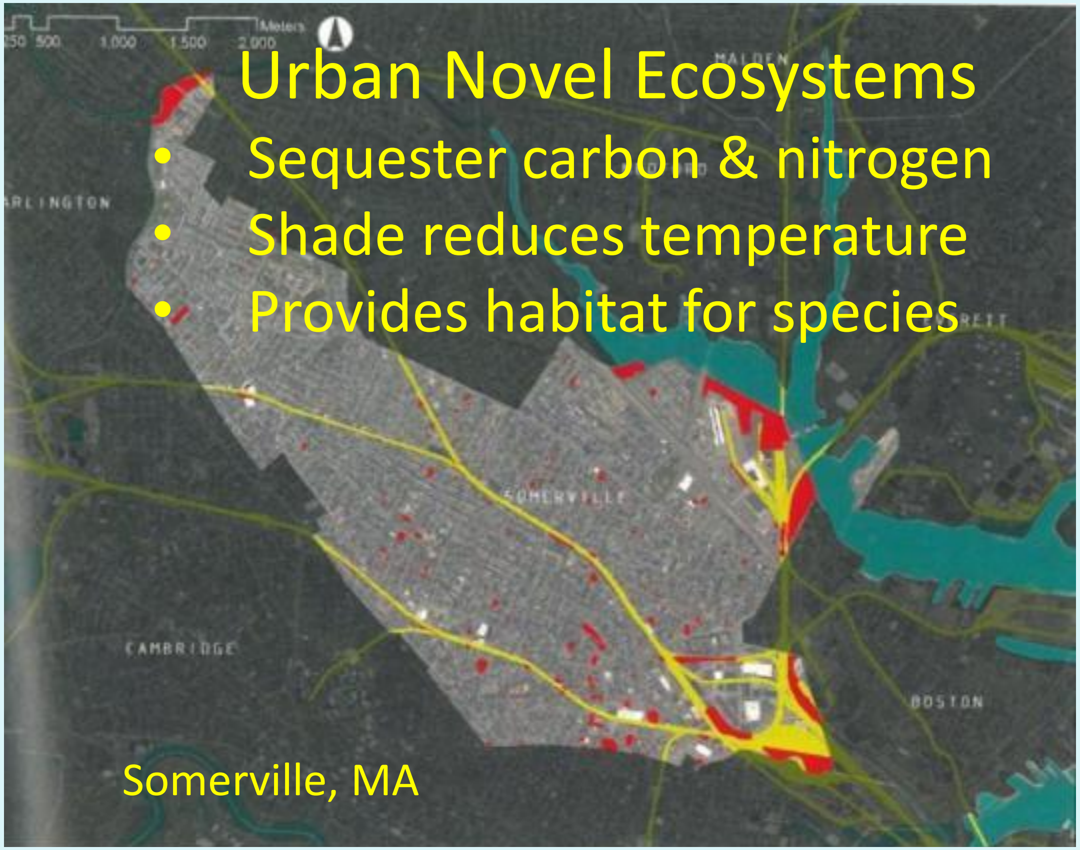
Anthropogenic Biomes: Conceptual Model



Ellis & Ramankutty (2008)

Urban Novel Ecosystems

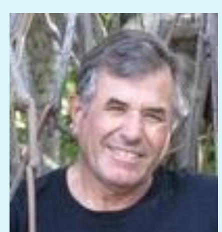
- Sequester carbon & nitrogen
- Shade reduces temperature
- Provides habitat for species



Somerville, MA

Spontaneous vegetation = ≥ 9.7% of land area
Vacant and industrial lots = Red
Railroad ROWs (40 ft from centerline) = Yellow

Peter Del Tredici. 2010. Wild Urban Plants of the Northeast. Arnold Arboretum, Harvard




Urban forest (Del Tredici)

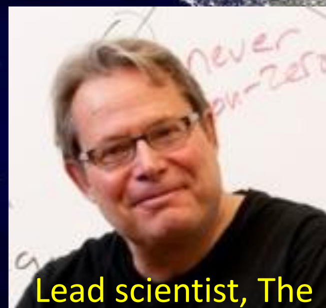

Phragmites: Loading dock (Del Tredici)


Quaking aspen (Del Tredici)

Other examples

Conservation in the Anthropocene

Breakthrough Journal *2:26-36* **http://thebreakthrough.org**



Lead scientist, The Nature Conservancy

Santa Clara University

Science Communi-cations, TNC

Peter Kareiva, Michelle Marvier and Robert Lalasz

By its own measures, conservation is failing. Biodiversity on Earth continues its rapid decline… we are losing many more special places and species than we're saving… Conservation will likely continue to create parks and wilderness areas, but…the bigger questions [are]what will we do with <u>the rest of It –</u> working landscapes, urban ecosystems, plantations…

Novel Ecosys tems

Attributes of Novel Ecosystems

- Heavily influenced by humans (but not intentionally managed)
- New combinations of species
- Introduced/non-native species
- Environmental change/new abiotic conditions/species migrations
- Ecosystem function & services altered
- All ecosystems/all scales: terrestrial, fresh water, estuarine, and marine

No native plan t species in this woodland

Jacobs

Ecosystem function

Processes affecting energy and materials (amount, forms, distribution, fluxes, import/export).

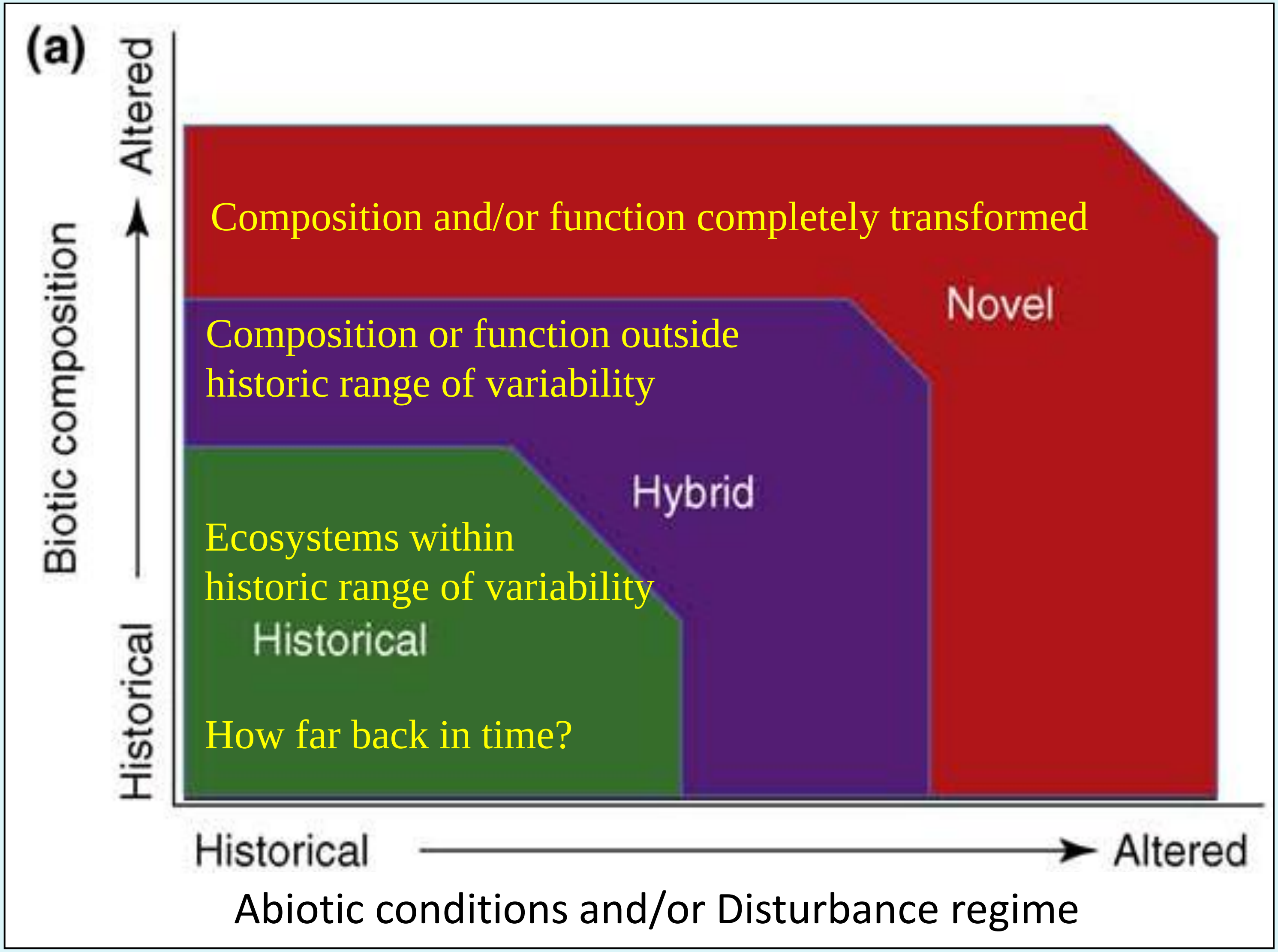
- Primary production
- Soil chemistry
- Nutrient & carbon cycling
- Decomposition

Ecosystem services = produce resources

- Provisioning: food (pollination, seed dispersal etc.)
- Soil: Generate and preserve and renew fertility
- Mitigate drought and floods
- Protection from erosion
- Purify air and water
- Support human health (physical and mental)
- Contribute to climate stability
- Maintain biodiversity

Types of Ecosystems

Hobbs et al. 2009. Novel ecosystems: implications for conservation and restoration. Trends Ecol. & Evol. 24 (11)

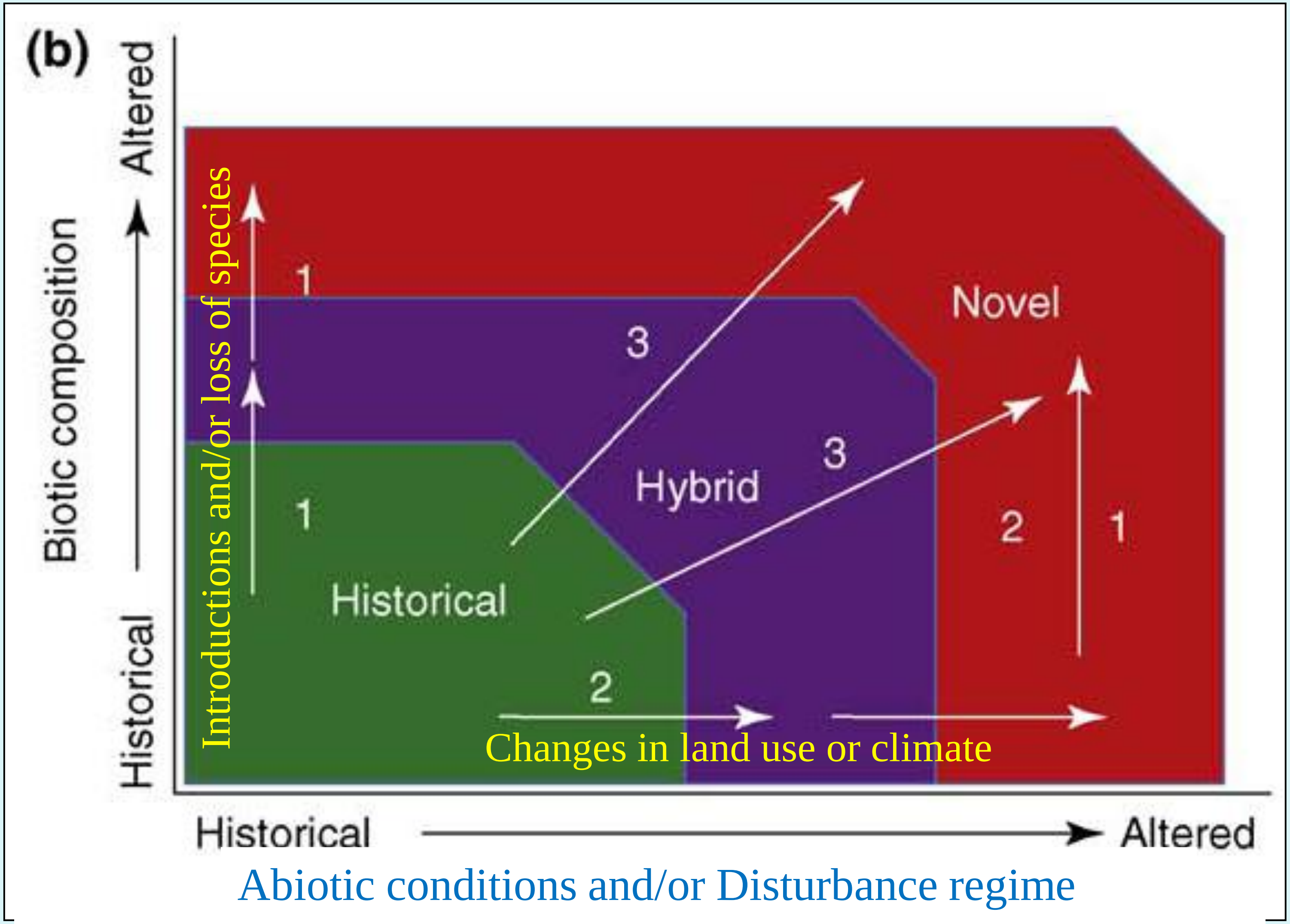


Text in yellow or blue Times New Roman font added by M. Jordan

Types of Ecosystems

Hobbs et al. 2009. Novel ecosystems: implications for conservation and restoration. Trends Ecol. & Evol. 24 (11)

Text in yellow or blue Times New Roman font added by M. Jordan

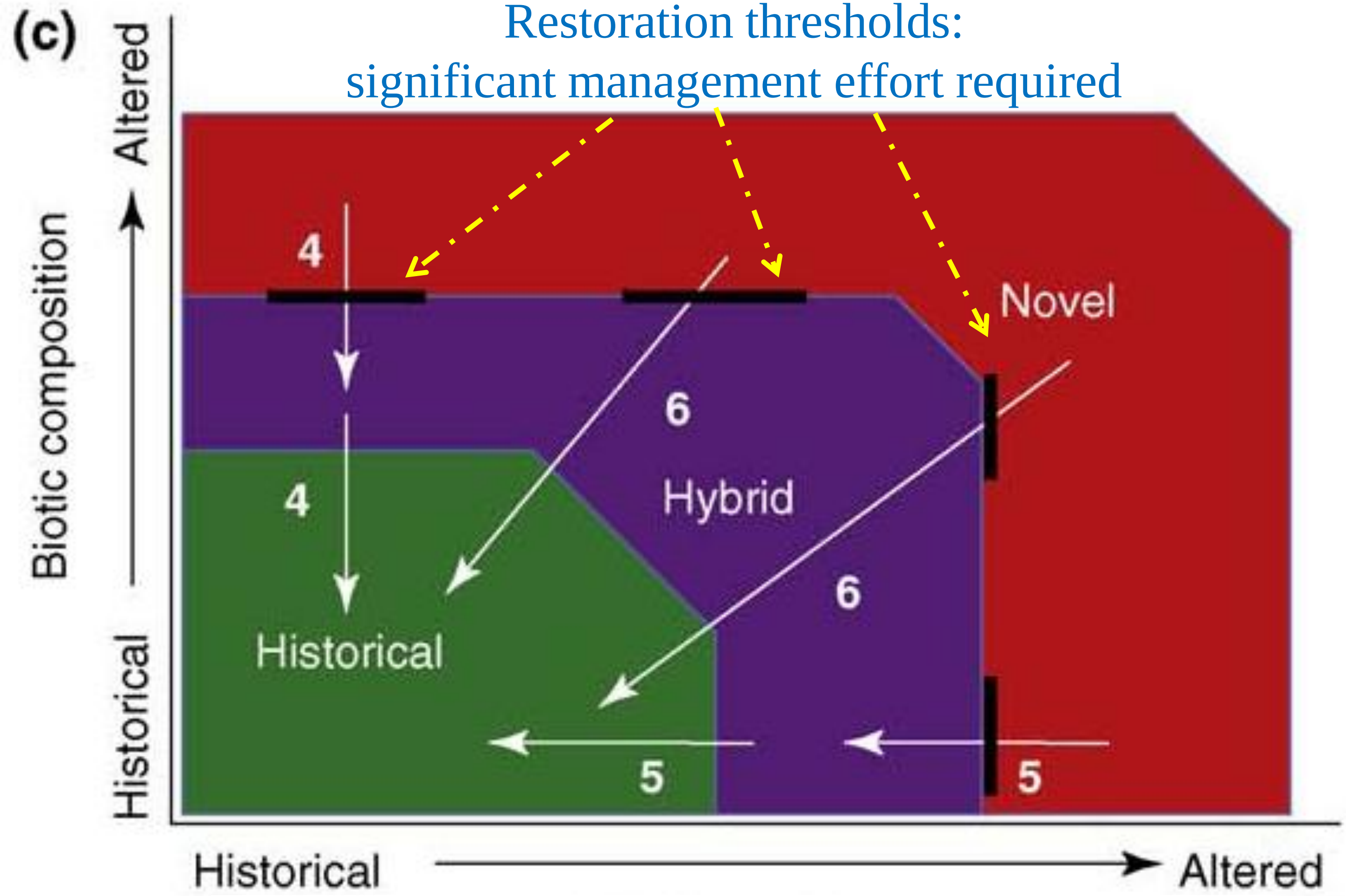


Climate, land use, nutrient loading, fire regime, hydrology, etc .

Types of Ecosystems

Hobbs et al. 2009. Novel ecosystems: implications for conservation and restoration. Trends Ecol. & Evol. 24 (11)

Restoration thresholds:
significant management effort required



Abiotic conditions and/or Disturbance regime

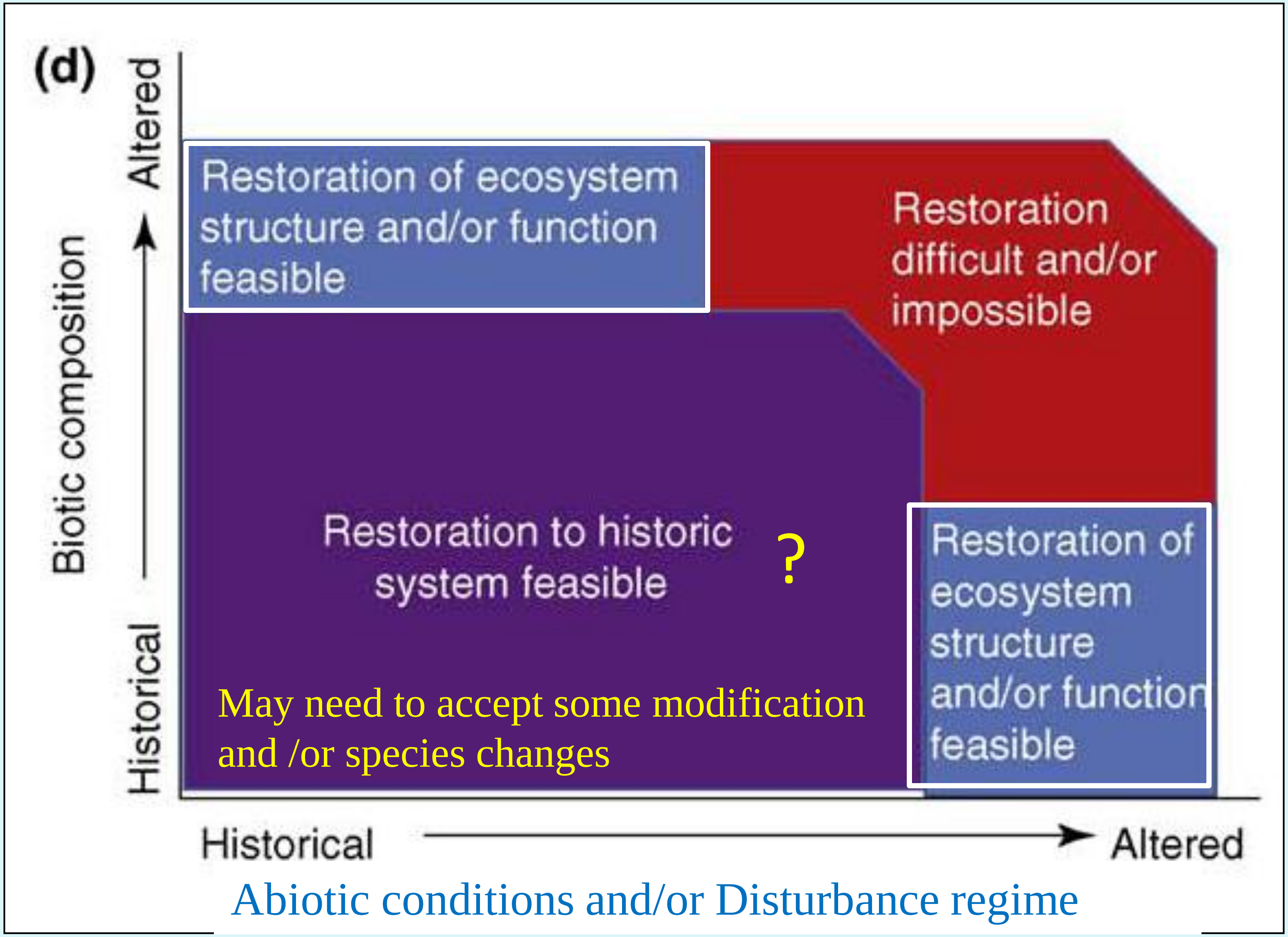
Climate, land use, nutrient loading, fire regime, hydrology, etc .

Text in yellow or blue Times New Roman font added by M. Jordan

Types of Ecosystems

Hobbs et al. 2009. Novel ecosystems: implications for conservation and restoration. Trends Ecol. & Evol. 24 (11)

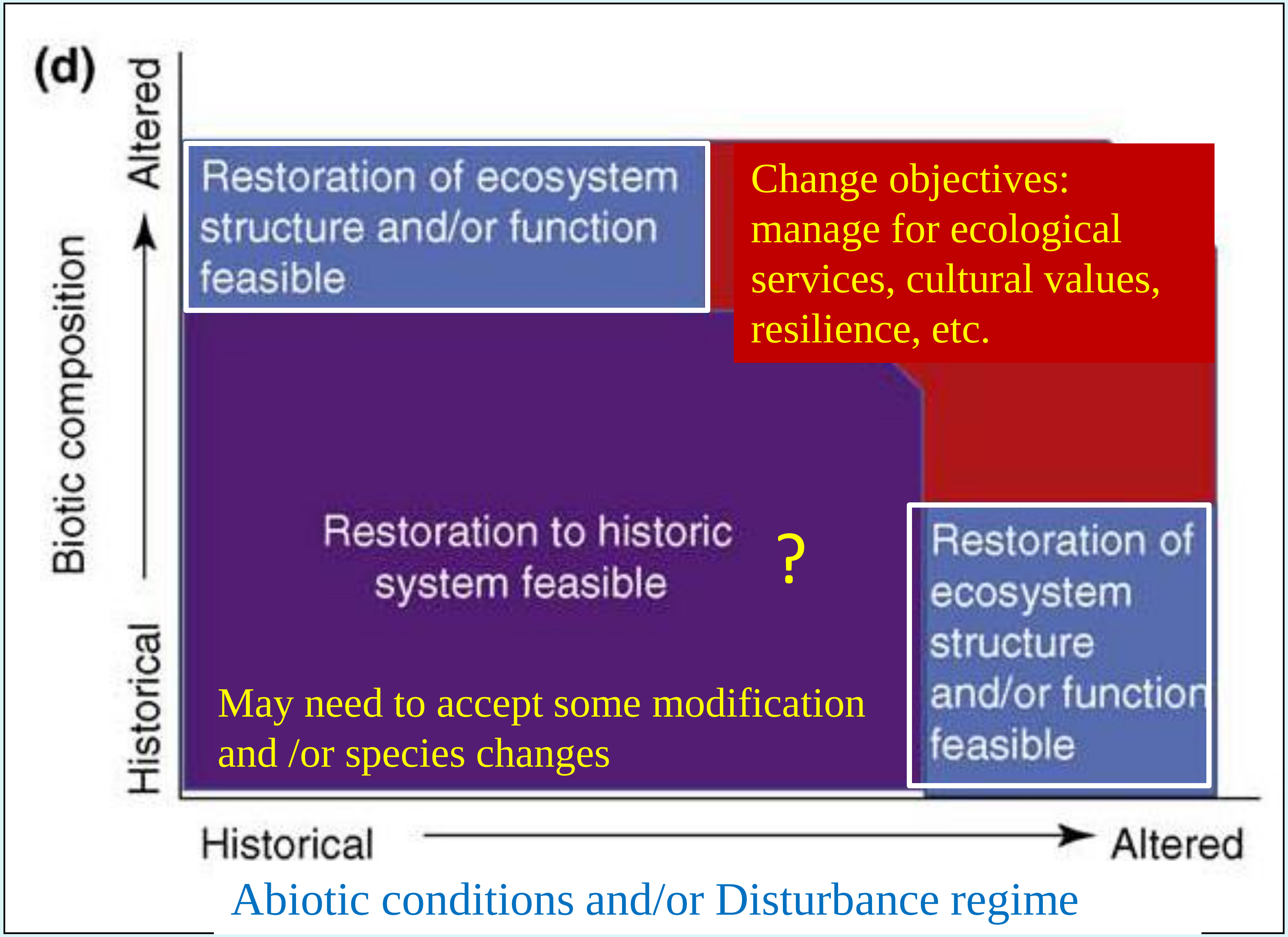
Text in yellow or blue Times New Roman font added by M. Jordan



Types of Ecosystems

Hobbs et al. 2009. Novel ecosystems: implications for conservation and restoration. Trends Ecol. & Evol. 24 (11)

Text in yellow or blue Times New Roman font added by M. Jordan



Questions about novel ecosystems

- Will you know it when you see it? How to recognize a novel ecosystem?
- How novel is the ecosystem: How to quantify "novelty?"
- How to recognize thresholds to stable alternative steady states?
- What are appropriate goals for restoration &management?
- How should novel ecosystems be managed: novel challenges and novel approaches? Yes but NOT "anything goes."

Introduced *Calamagrostis epigeios* in Liberty State Park, NJ. Claus Holzapfel Rutgers and NJIT

What do we know and what should we do?
A literature "mashup"

Effects of invasive species on:

- native species
- communities
- ecosystem function
- food webs

Extinction and evolution

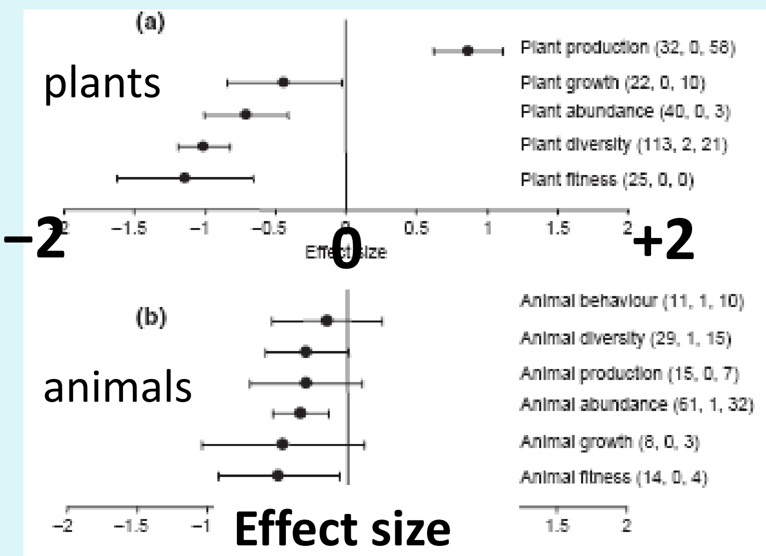
How to manage or restore?

- Information and tools
- Stakeholders and values

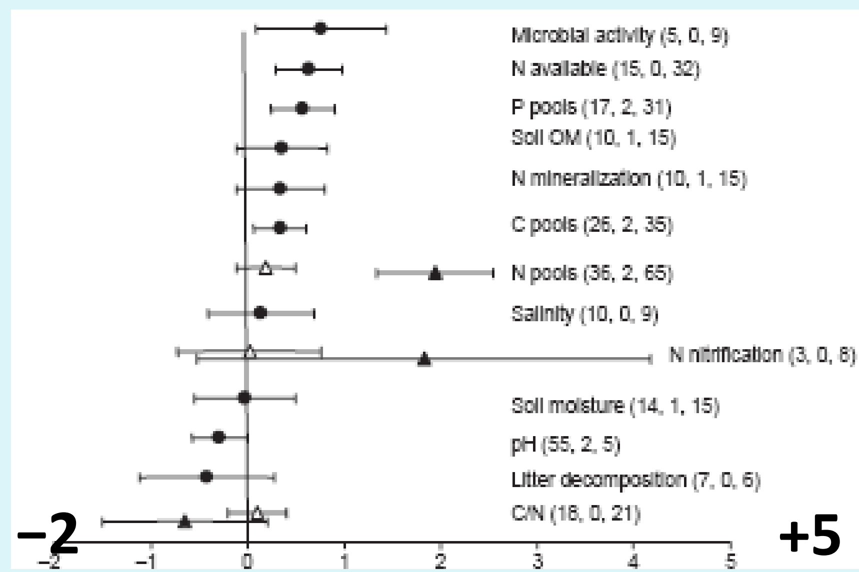
Ecological effects of invasive alien plants: species, communities & ecosystem function

Vila et al. 2011. Ecological impacts…. meta-analysis. Ecology Letters
199 articles, 1041 field studies, 135 alien plant taxa, species-communities-ecosystems.

1. Alien plants had <u>significant effect in 11 of 24</u> types of impacts.
2. <u>Magnitude and direction varied</u> within & between types.
3. On average: Abundance & diversity resident species <u>decreased</u>;
4. Primary production and several ecosystem processes <u>increased</u>.



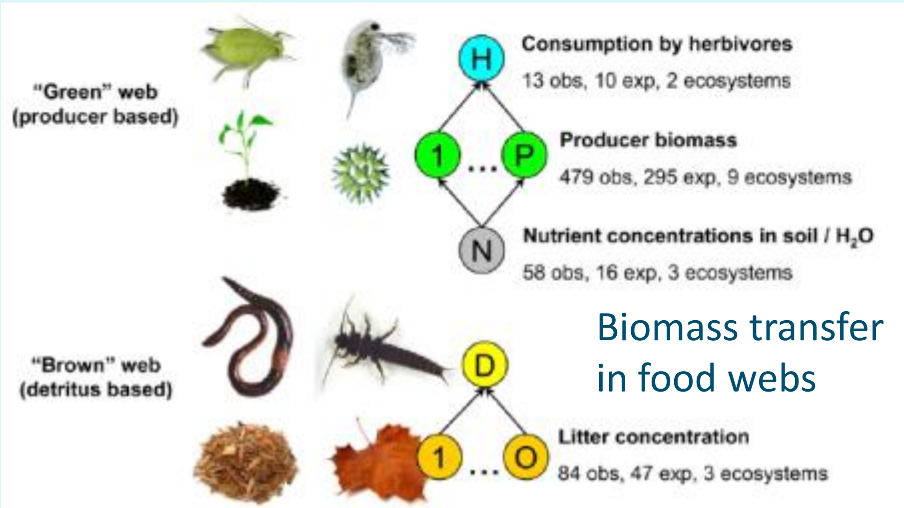
Species & communities



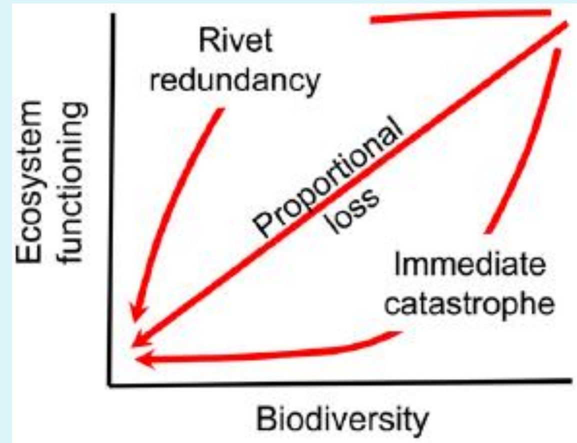
Ecosystems

Ecological role of primary producers

Reducing diversity reduces: biomass, nutrient uptake efficiency, possibly (not always) primary production?



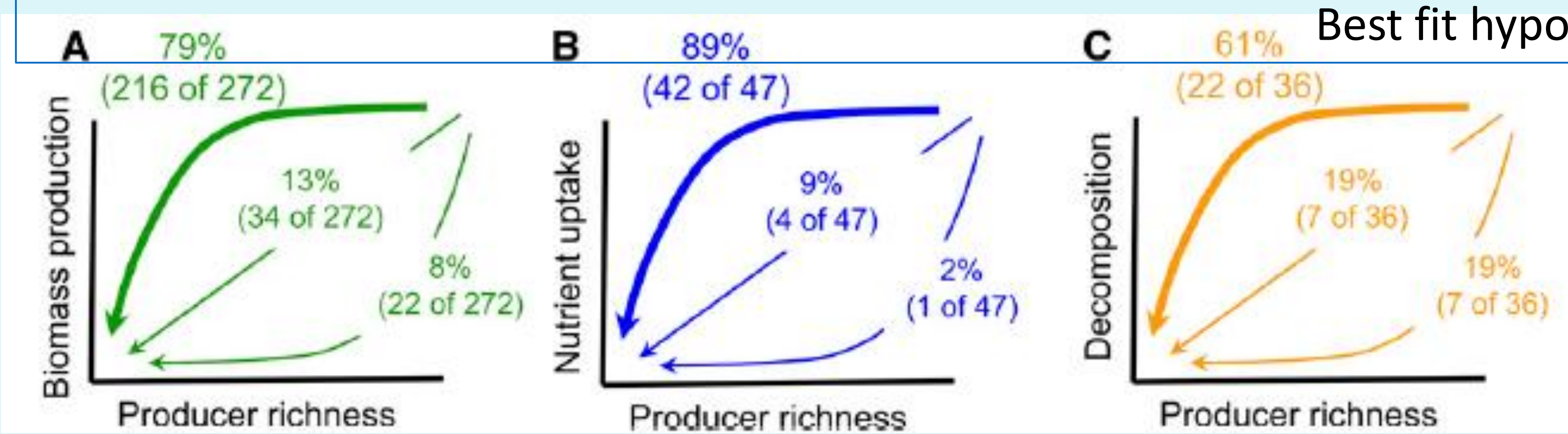
Biomass transfer in food webs



Ehrlich's "airplane analogy"

Meta-analyses192 peer reviewed papers, 574 independent manipulations of species richness

Best fit hypothesis



Cardinale et al. 2011. The functional role of primary producer diversity… Am.J.Bot 98

Eight questions about invasions and ecosystem function (what do we know?)

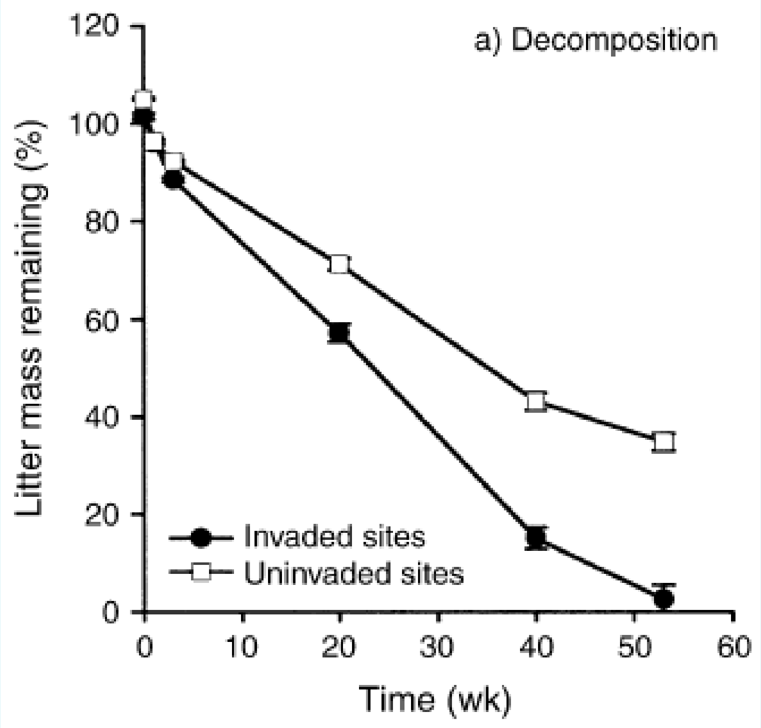
Strayer, D.L. 2012. Ecology Letters 15

1. **Can species invasions affect ecosystem functioning?**
   YES absolutely. Changes are varied and can be large.
2. **How frequently** (what fraction of invaders) affect eco fn?
   Unknown; 3—30% good enough estimate.
   How many ecosystems affected? Not studied; ~widespread.
3. **Which invasions change ecological function?**
   Much research; Hard to predict—be *very careful about new introductions*. Functionally distinct species; trait spectrum.
4. **Which eco functions most often or severely affected?**
   Little studied; mostly plants, typically speed up cycling limited materials.

Eight questions about invasions and ecosystem function (what do we know?)

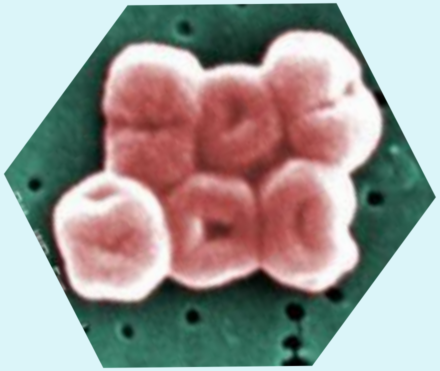
Strayer, D.L. 2012. Ecology Letters 15

5. **How are eco function changes related to changes in populations/communities?**
   Populations & Communities studied; ecosystems not much.
6. **How do effects on eco function change through time?**
   Unanswered. Increase, decrease or both?
   Short term annoyance or profound problem?
7. **How do invasions interact with anthropogenic changes?**
   Common, strong & varied. Climate change, nutrients…
8. **Which eco function changes can be managed or mitigated & which are unmanageable? A general answer?**
   Little studied. (1) Control invader – OR – Manage undesirable effects (human effects on target ecosystem function)



Litter decomposition is more rapid in invaded sites.
Ashton et al. 2005. Ecological Applications

Belowground changes and microbial communities in invaded sites are poorly known – and very important.

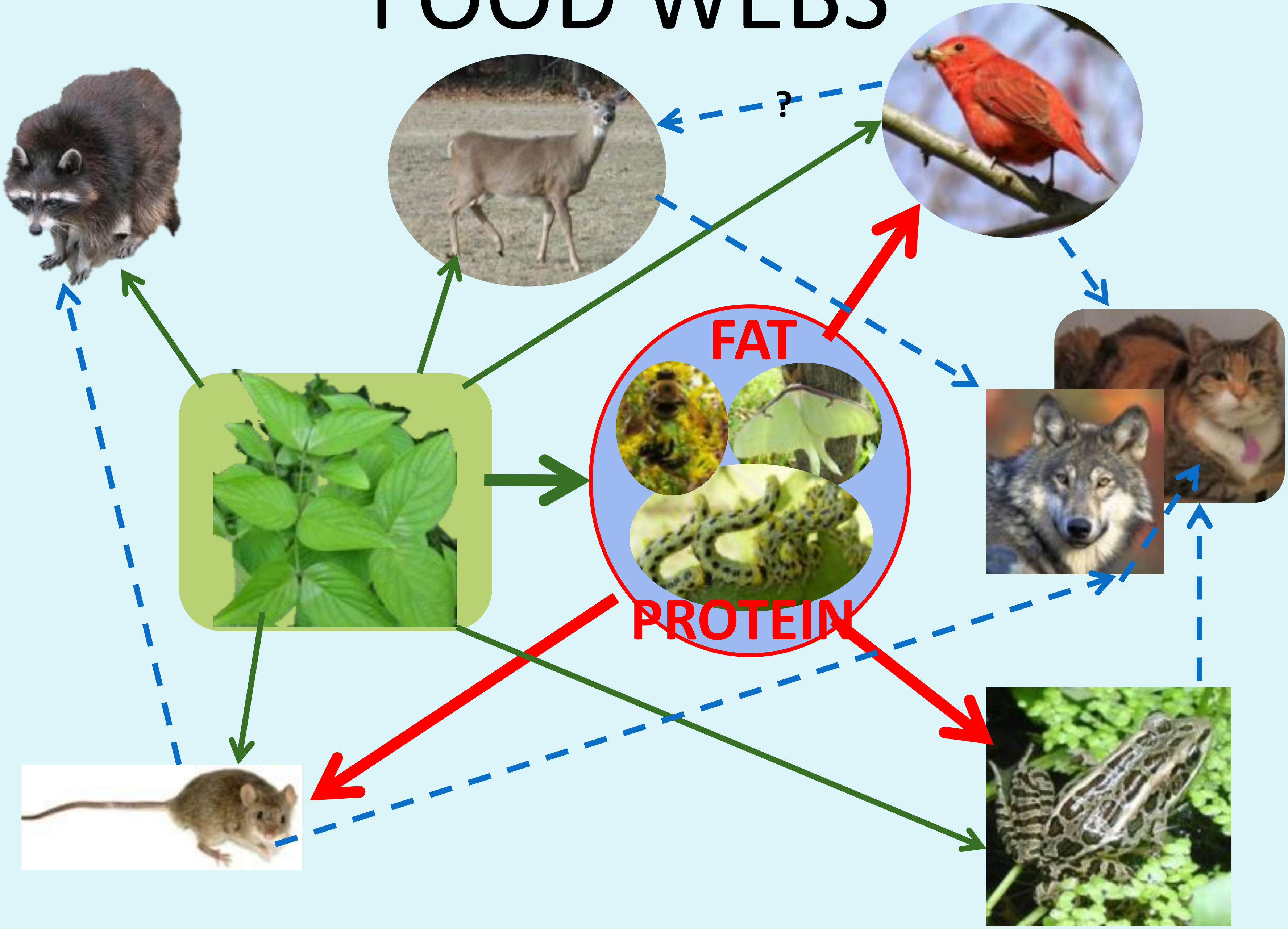


Acinetobacter.baumannii. Encyclopedia of Life, public domain from the Public Health Image Library. Photographer: Janice Haney Carr.

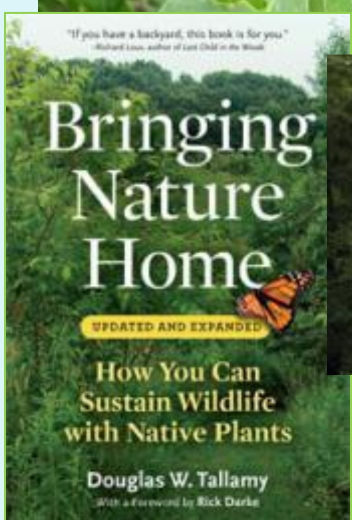
Also poorly known: Effects on Food Webs

Jordan

FOOD WEBS



Many insect species – even generalists – are able to eat relatively few plant species



COMMON SECONDARY METABOLIC COMPOUNDS FOUND IN THE LEAVES OF PLANTS

Chemical Class	Plant Sources
Glycosides	
cyanide glycosides	almonds, cassava, lima beans
iridoid glycosides	*Plantago*, *Lagochilus*, *Incarvillea*
cardenolides	milkweeds, *Isoplexis*, *Digitalis*
glucosinolates	broccoli, cauliflower, rapeseed
Phenols	
coumarins	Tonka bean, lavender, licorice
tannins	oaks, beech, hickory
lignins	grasses
Terpenes	
cucurbitacins	cucurbits, candytuft
limonoids	neem, *Carapa*
saponins	yucca, daisies, horse chestnut
Alkaloids	
benzylisoquinoline	poppy, *Colchicum*
pyrrolizidine	composites, legumes
quinolizidine	*Lupinus*, *Nicotiana*, *Conium*
nicotine	tobacco, eggplant, tomato

Douglas Tallamy. 2007. Bringing Nature Home. Timber Press

Moth & butterfly species – even generalists – are able to eat relatively few plant species

Native plants

plant species used to feed luna moth larvae

No surviving larvae 18 days

Non-native plants:

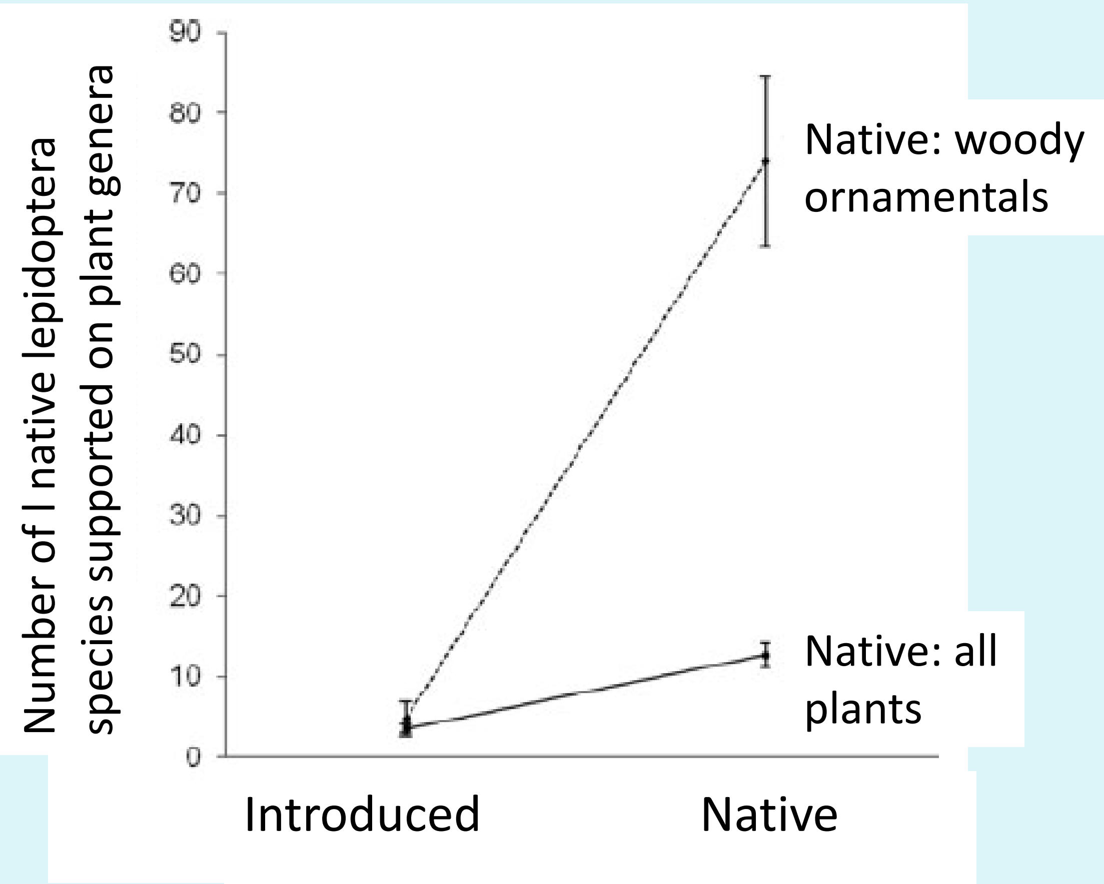
No surviving larvae on all plant species except 22% biomass on hoary alyssum

Sweetgum preferred native

Mean biomass (g) of Luna moth larvae

Tallamy, Ballard and D’Amico. 2009. Biological Invasions

Nonnative plants reduce diversity (and biomass) of native Lepidoptera (butterflies & moths)

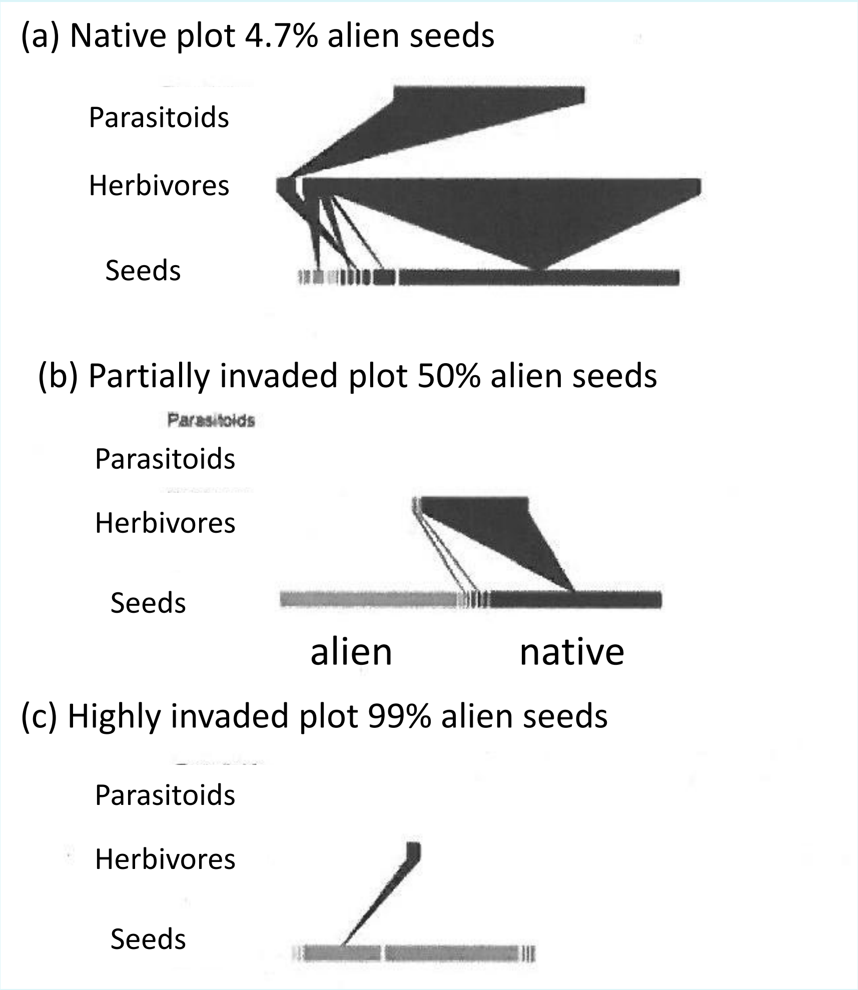


Bars are standard errors

Other types of insects??

Tallamy & Shropshire. 2009. Conservation Biology

Replacement of native plants with non-native ornamentals results in significant bottom-up reductions of energy available for seed predation food webs.



SEED EATING INSECT FOOD WEBS from plots with different levels of alien plant invasion.

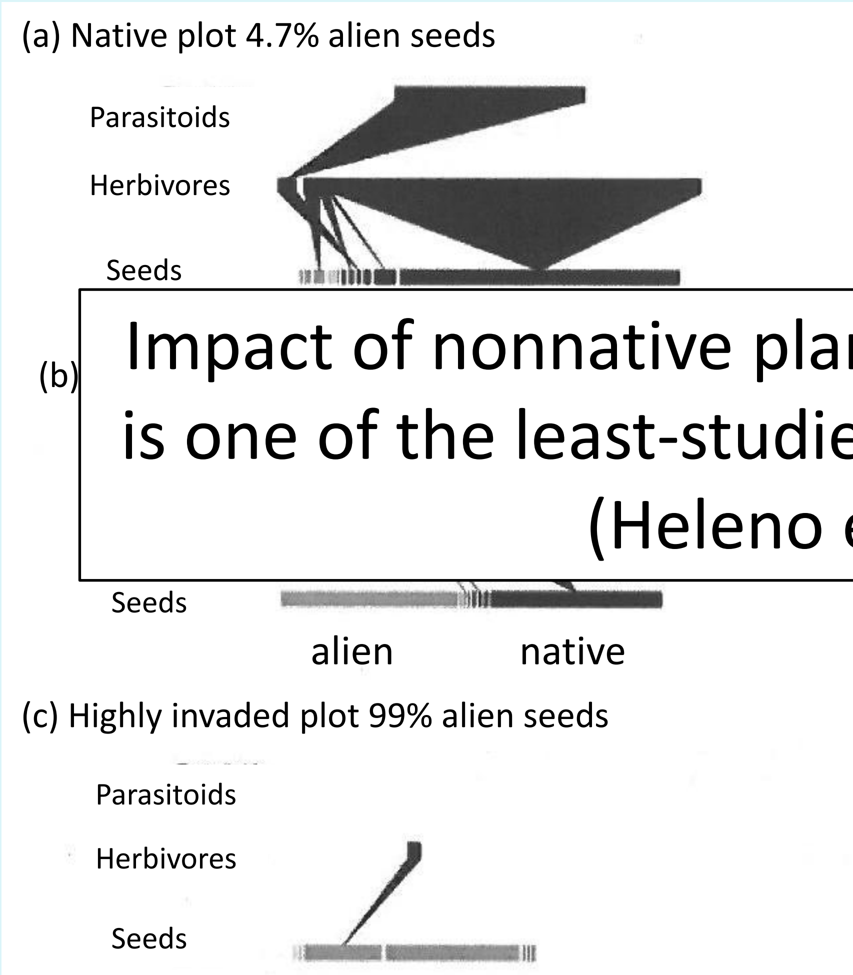
- Each bar = one species of plant.
- Area of triangles = relative number of insect species attacking lower level.

67% of insect biomass in seed-predation food webs will be lost if native forest is replaced by alien vegetation.

Azores

Heleno et al. 2008. Effects of alien plants…food web approach. Cons. Biology 23(2):410-419

Replacement of native plants with non-native ornamentals results in significant bottom-up reductions of energy available for seed predation food webs.



SEED EATING INSECT FOOD WEBS from plots with different levels of alien plant invasion.

- Each bar = one species of plant.
- Area of triangles = relative number of

Impact of nonnative plants on higher trophic levels is one of the least-studied areas of invasion biology (Heleno et al. 2008).

Azores

Heleno et al. 2008. Effects of alien plants…food web approach. Cons. Biology 23(2):410-419

Bug splat indicator

odyclub.com http://rvtravel.com/blog/rvnow/2007/10/take-rv-windshield-postmortem-bug.html

Species losses due to human land use, global change & invasions: The Diversity – Stability Debate*

Species & functional groups capable of **differential responses** to damp oscillations + **Redundancy** (several species do the same job) =

Resilience and adaptability to climate change & anthropogenic disturbance.

i.e. “the insurance effect.”

But – Field tests at scale of food webs and ecosystems are few.

McCann 2000. The diversity-stability debate. Nature 405.

Worldwide decline of specialist species: toward a global functional homogenization?

- Global change is leading to a replacement of specialist species by generalist species.
- Functional homogenization could alter ecosystem function/services.
- Functional diversity = biodiversity indicator (better than extinction).

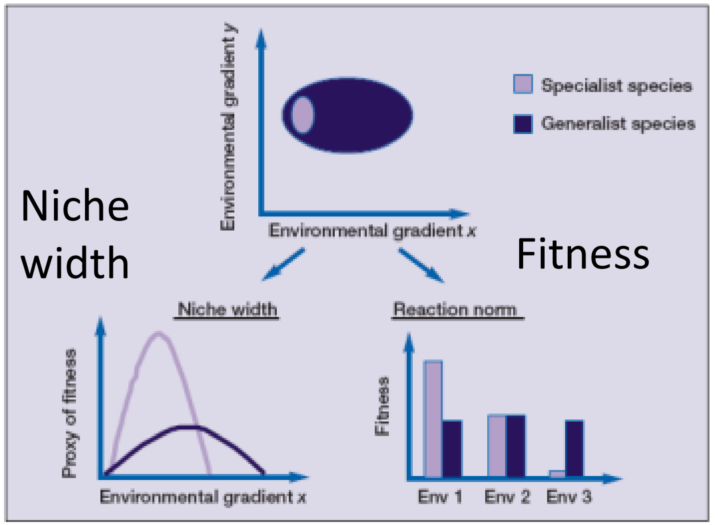
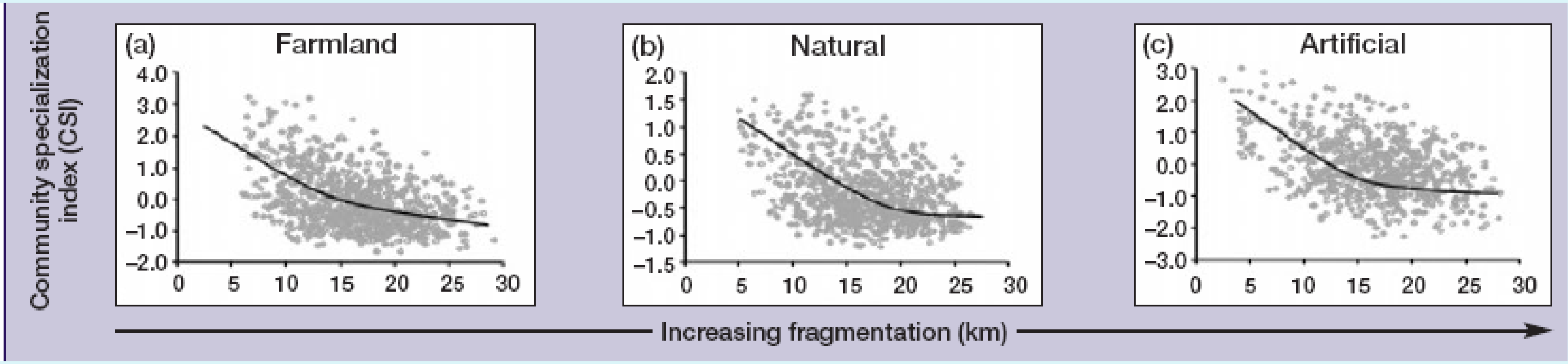


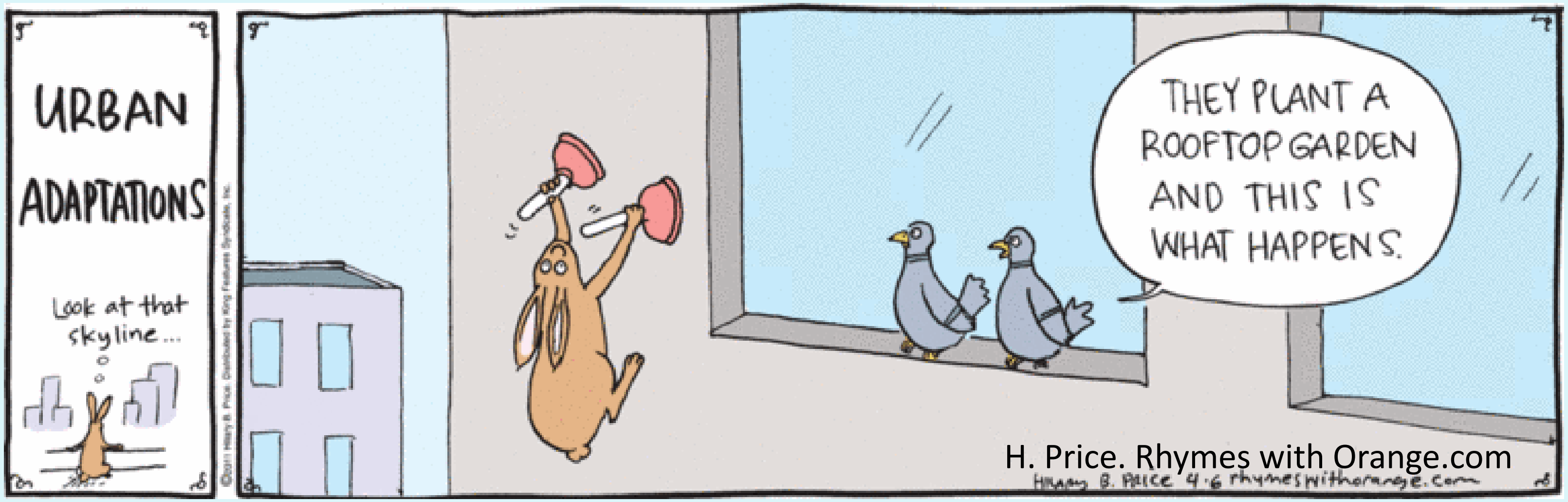
Figure 1. Concept of the ecological niche and two different measures of it. Env = environment.



Clavel, Julliard and Devictor. 2011. Worldwide decline of specialist species: toward a global functional homogenization? Frontiers 9(4):222-228

Are native species and ecotypes becoming <u>functionally</u> extinct?

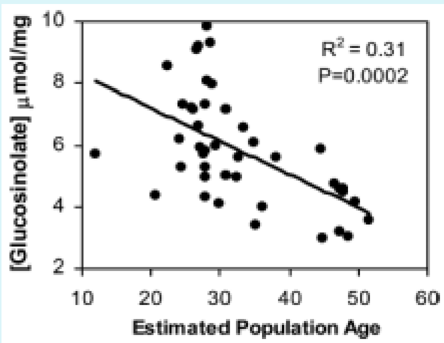
Are we losing the diverse genetic material needed for evolution?



Rapid adaptation to urban rooftop gardens?

You can't evolve if you are extinct.

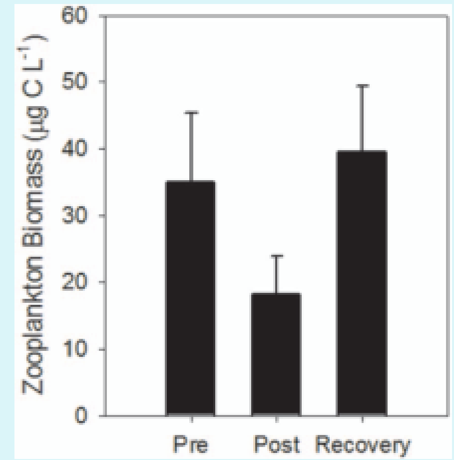
Will evolution be the solution?
Coevolution & Adaptation



With time lower concentrations of toxic compounds are found in areas invaded by garlic mustard.

Lankau et al. 2009. PNAS 106(32).

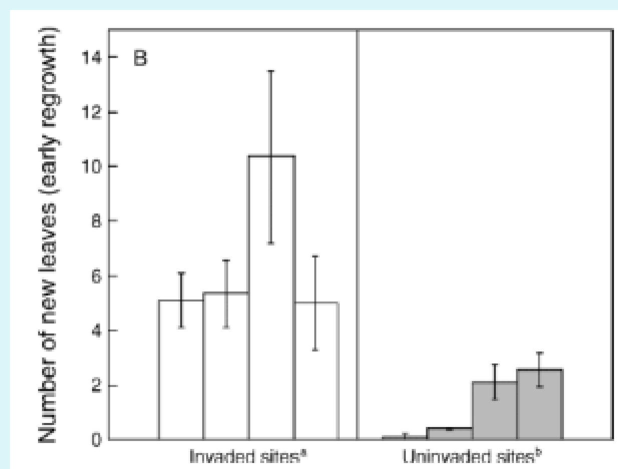
Lankau. 2010. Biol. Invasions



Zooplankton have recovered to levels before zebra mussel invasion of the Hudson River, NY

Pace et al. 2010. Ecosphere

Native big squirreltail growing with nonnative cheatgrass become more competitive.



Leger 2008. Ecological Applications

Will evolution be the solution?

	Number of herbivore species supported		
Non-native plant species	Homeland	Novel	Years since introduction
Phragmites austrlis	170	5	>300
Eucalptus stelloleta	48	1	100
Opuntia ficus-indica	16	0	250
Clematis vitalba	40	1	100
Melaleuca quinquenervia	406	8	120

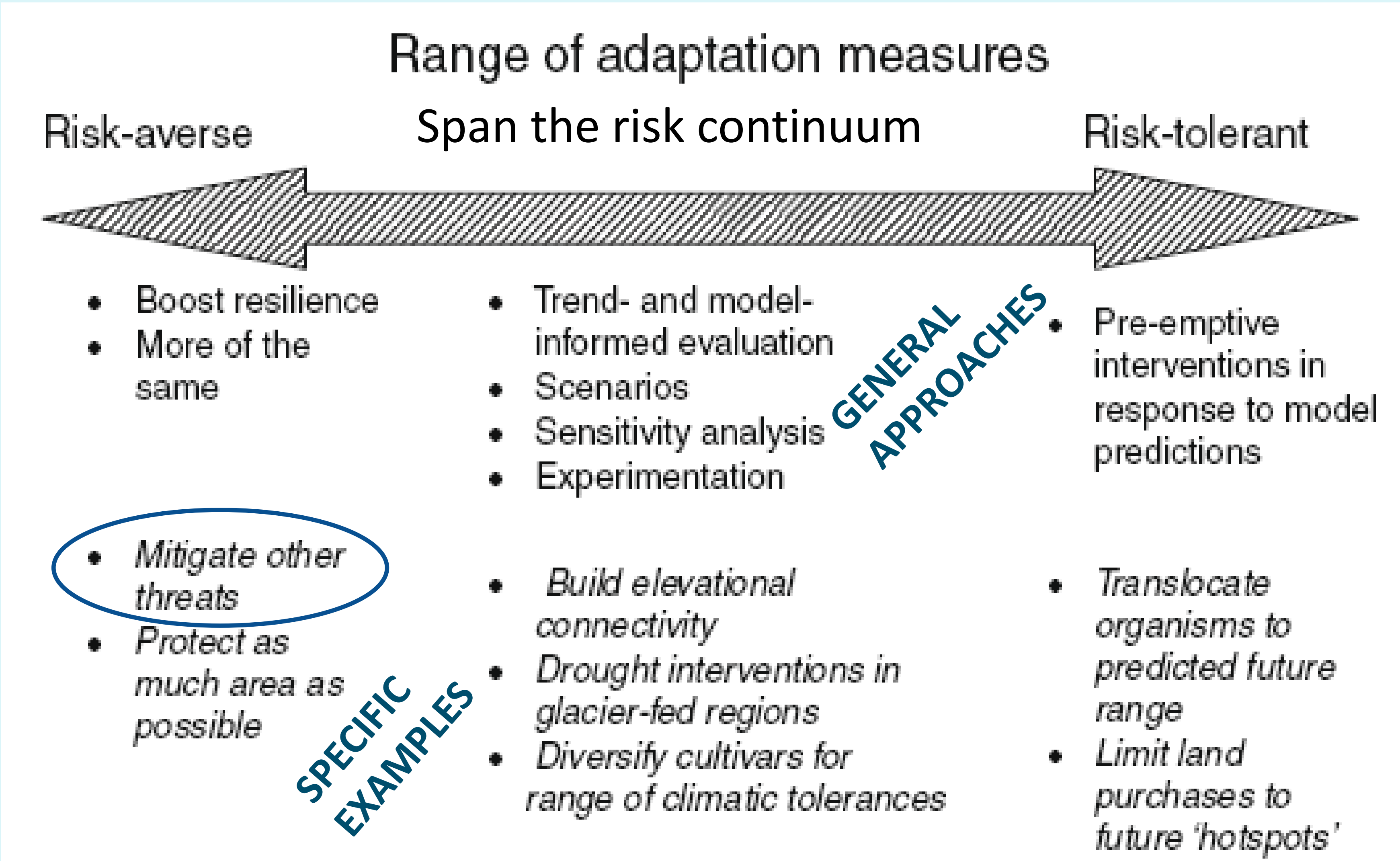
Data from Tallamy 2007. Bringing Nature Home. Timber Press

What is a land manager to do?

Climate Adaptation

Heller and Zavaleta. 2009.

Biodiversity management in the face of climate change: A review of 22 years of recommendations. Biological Conservation 142:14-32



Mitigate Other Threats

Change ≠ Degradation (Threat)*

Degradation = (semi)permanent deterioration of physical habitat quality (human caused alterations):

- Loss of habitat area
- Nutrient depletion or pollution
- Erosion
- Chemical contamination
- Fragmentation
- Altered water flow regimes

Some invasive species may be a cause as well as a symptom: Ecosystem engineers; Drivers not passengers

Prevent/remove degradation. Don't fight the <u>symptoms</u> – address the <u>causes</u>.

*Thanks to Bortman, Poiani and Anderson

Mitigate Other Threats

Change $\neq$ Degradation (Threat)*

Adaptive Change = adjustments in species composition, structure or processes in response to a new set of environmental conditions:

- Temperature
- Precipitation
- Disturbance

Common sense?

Do not involve degradation of physical habitat quality.
Usually not reversible by human action.

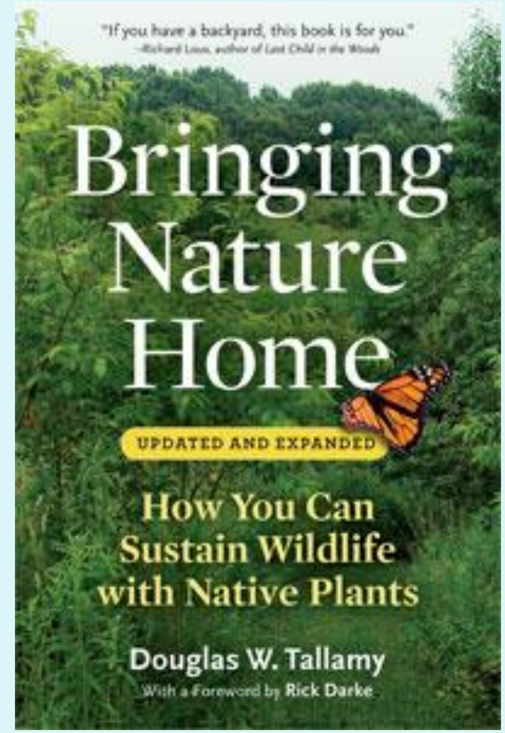
Do NOT fight inevitable change! Let evolution/adaptation/recovery happen!

*Thanks to Bortman, Poiani and Anderson

Douglas Tallamy

Professor & Chair of Entomology and Wildlife Ecology, University of Delaware.

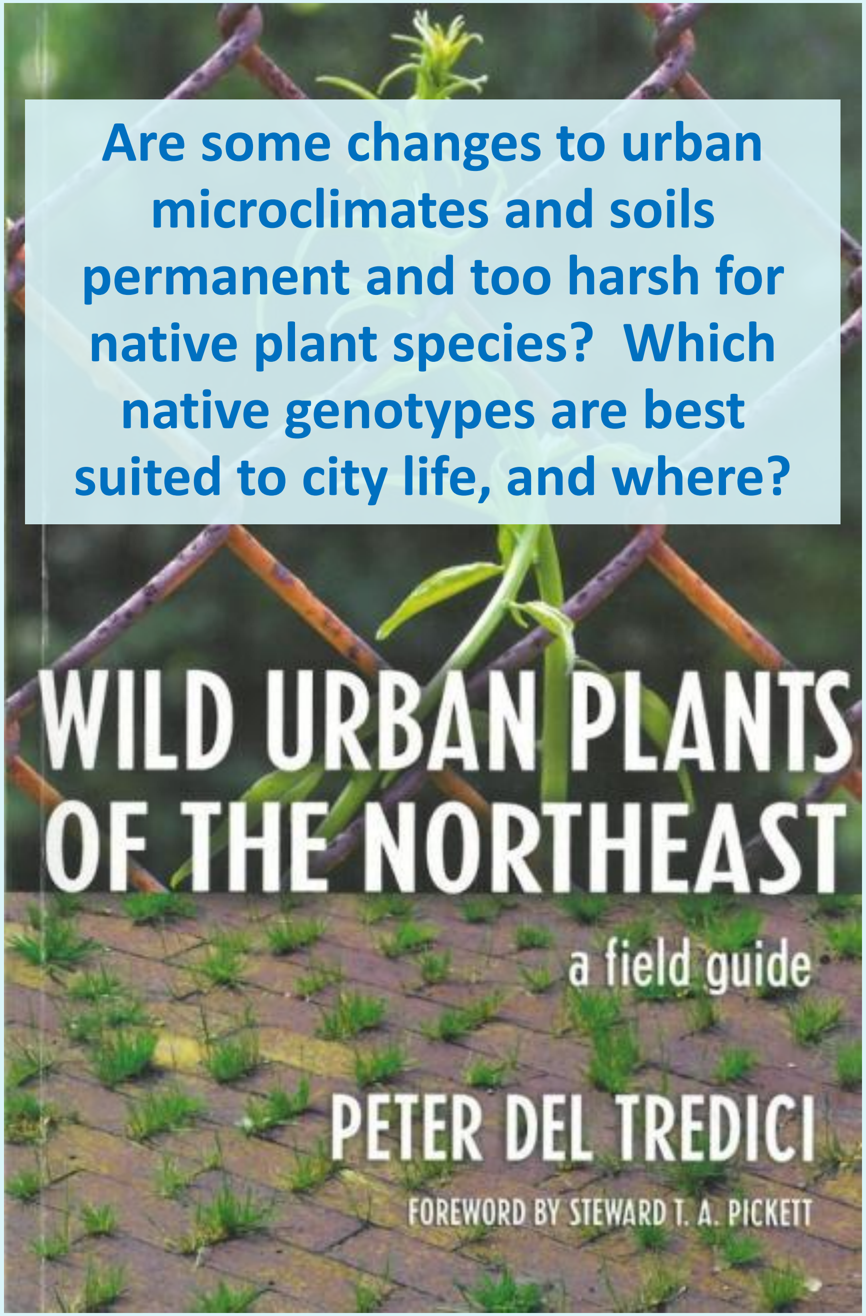
Use native plants and fight Degradation



- Food webs in greatly altered novel ecosystems are highly simplified and degraded with low species diversity, leading to global functional homogenization.
- Many native plant genotypes <u>can</u> survive in cities.
- Try them first and make urban environments less harsh.

Personal communication April 5, 2013

Are some changes to urban microclimates and soils permanent and too harsh for native plant species? Which native genotypes are best suited to city life, and where?



Peter Del Tredici

Senior research scientist
Arnold Arboretum
Harvard University

Understand and love wild urban plants: pre-adapted to urban conditions

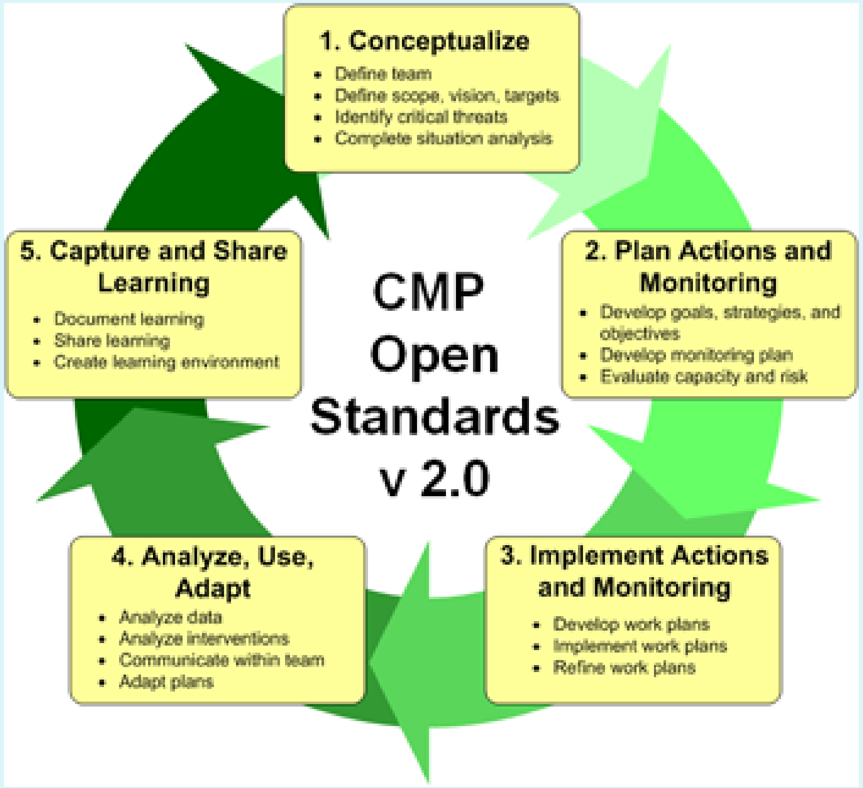
Accept change

Use an adaptive management approach

Conservation Measures Partnership
Open Standards for the Practice of Conservation
Adaptive Management Software for Conservation Project

https://miradi.org/

these standards are meant to provide the principles, tasks, and guidance necessary for the successful implementation of conservation projects.
"wizards" guide through process



Core members: African Wildlife Foundation (AWF), The Nature Conservancy (TNC), the Wildlife Conservation Society (WCS) and the Worldwide Fund for Nature/ World Wildlife Fund (WWF).

Floristic Quality Assessment

- Requires a list of all species at a site
- C = Coefficient of conservatism for each species = *A measure of the propensity for species to occur in human-disturbed versus least-altered habitat*.

  Nonnative species = 0 (if you want to include them)

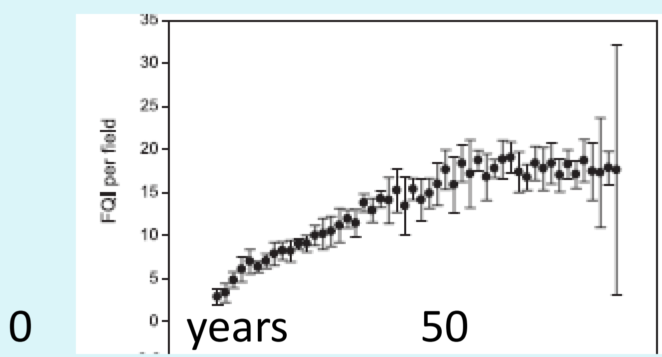
  Cosmopolitan, widespread native species = low scores 1+

  Rare native species = high scores up to 10

Mean C = ∑C/S (S = number of *all* species)

Floristic Quality Assessment Index = FQAI= ∑C/S x √S = ∑C/√S

Can weight with additional factors (e.g. wetland status)



Old field succession after abandonment in New Jersey. Maximum # fields = 10

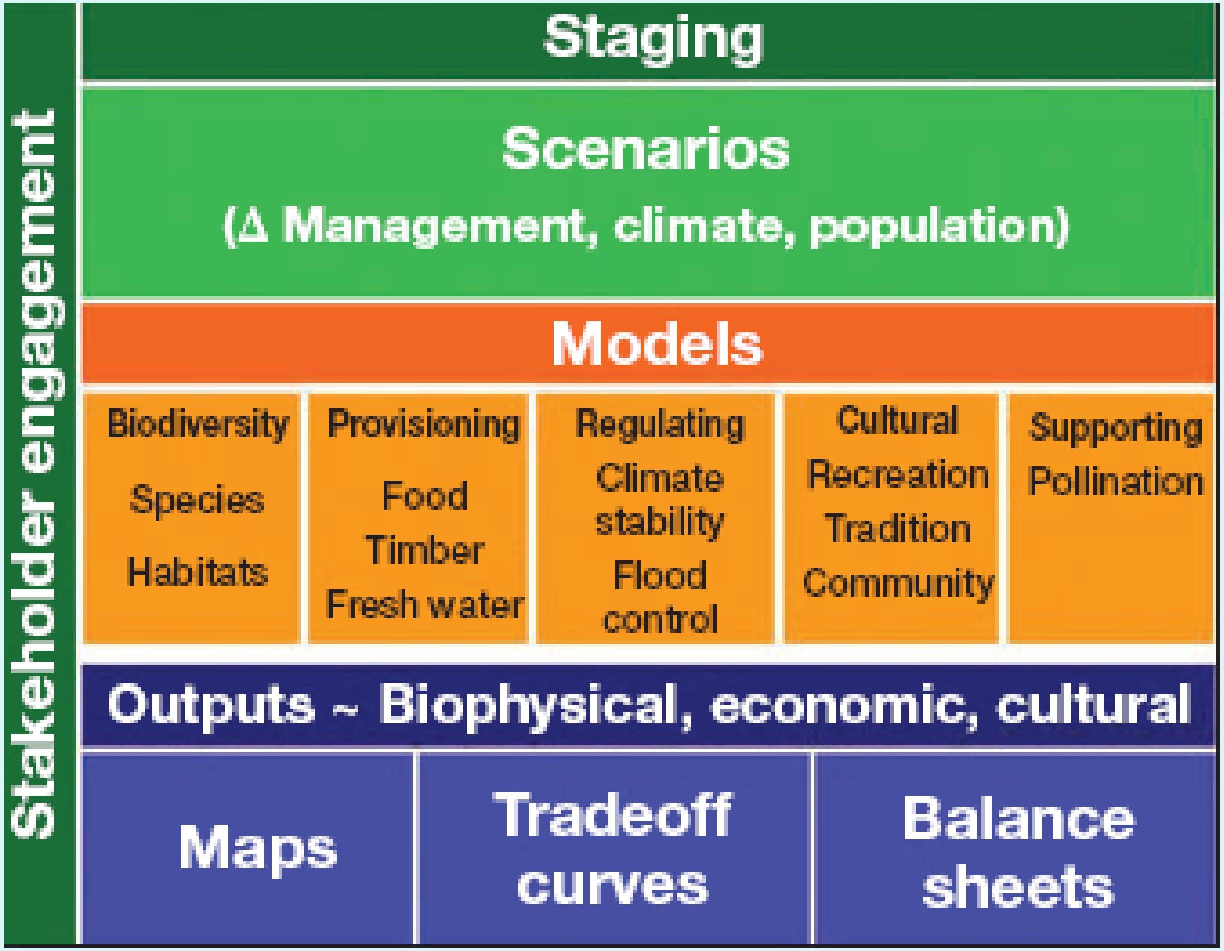
Spyreas et al. 2012. Successional trends in Floristic Quality. J. Appl. Ecol. 49

Value of Ecosystem Services: Landscapes

Natural Capital Project: http://www.naturalcapitalproject.org/

InVEST: A tool for Integrated Valuation of Ecosystem Services and Tradeoffs

the leading tool for incorporating natural capital into decisions



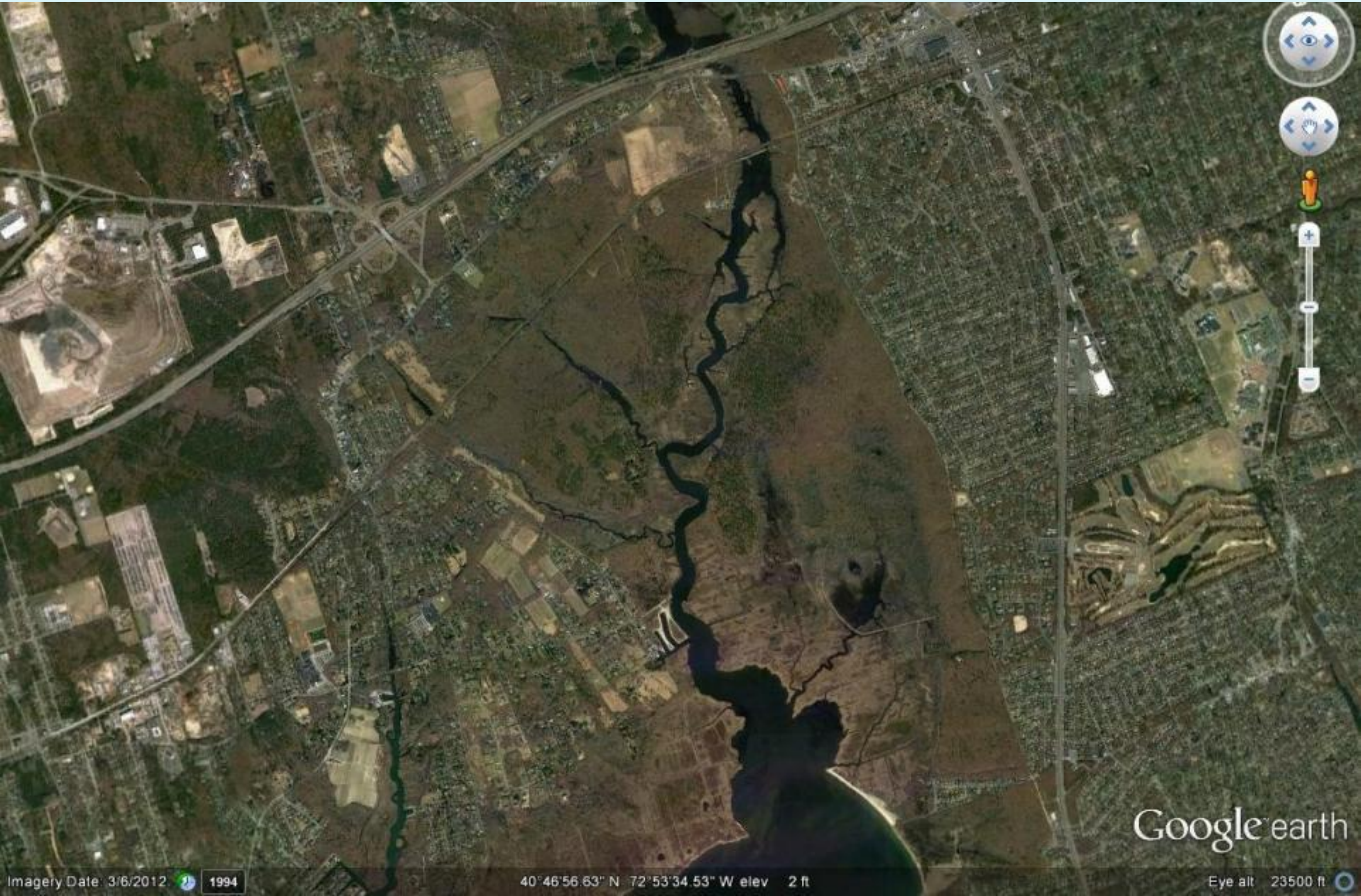
Daily et al. 2009. Ecosystem services in decision making: time to deliver. Front Ecol Environ 7 (1)21-28

Whole ecosystem approach:

Include the (often novel) matrix of lands and waters in which conventional protected areas are embedded.

- **Large enough** to sustain key ecological processes, allows for organism movement, and includes human communities.
- **Manage the matrix** in which protected conservation areas are embedded (*including backyards*).
- Work at multiple **scales**.
- Manage for **connectivity**
- Include strategies for maintaining **ecosystem function and ecosystem services.**
- Tie **policy** solutions to place.
- **Include the needs of people.**
- **MONITOR and share knowledge.**

Manage the matrix



Manage the matrix at all scales

HABITATS

- Shrink lawns.
- Encourage use of more native plants in backyards & restorations.
- Leave leaf litter in place for insect habitat.

LANDSCAPES

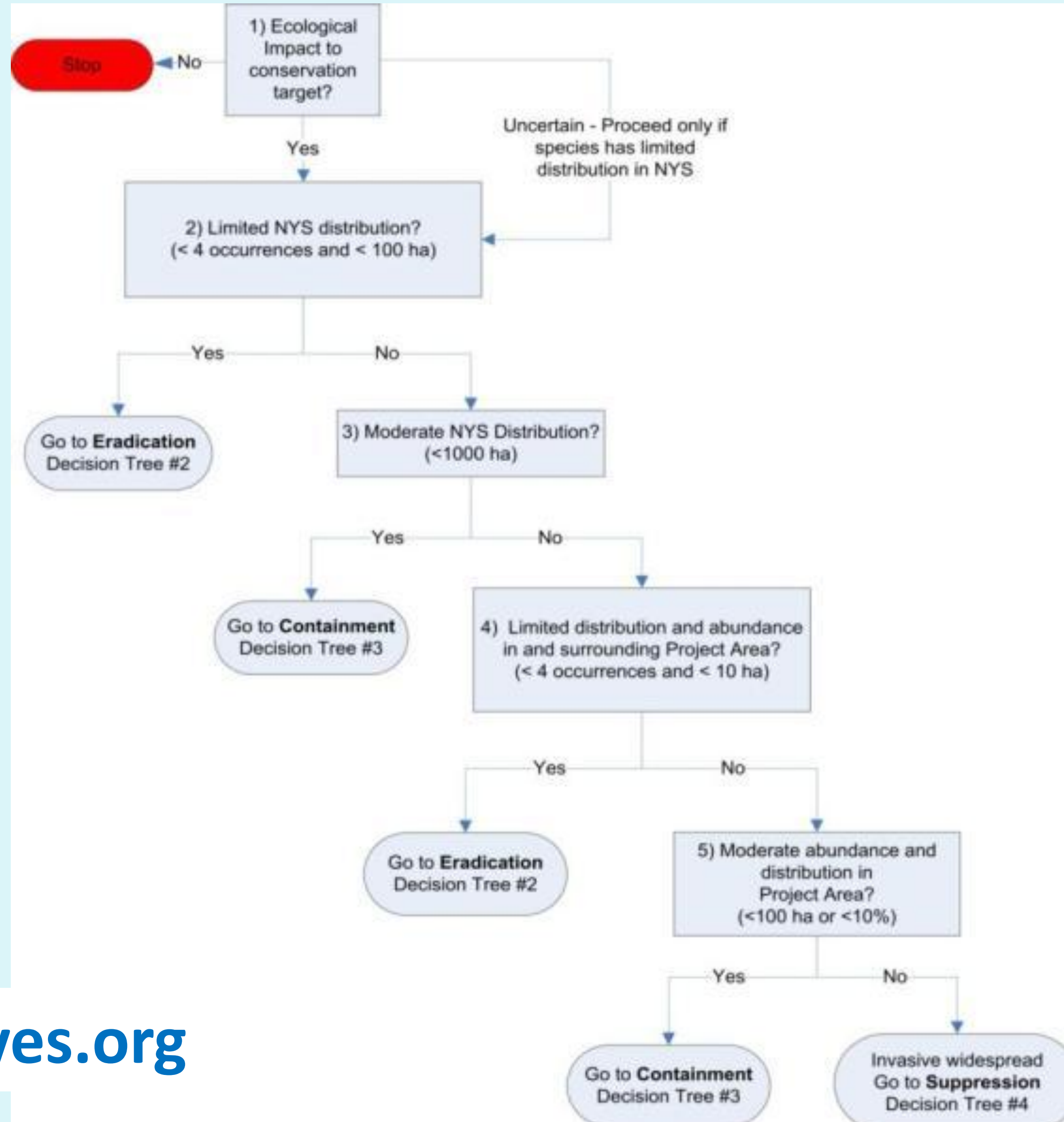
- Allow sale of only non-invasive plant species and cultivars.
- Reduce stresses (e.g. excess nutrients; dams; pollution; erosion; disturbance; excessive deer browse; etc.).
- Natural areas in developments.
- Green infrastructure???


Manage non-native plants?
focus on conservation outcome,
not only on killing weeds.
“Ecosystem engineers,” “Transformers,” the
“Drivers” that dominate and degrade ecosystems
because of their traits, not the “passengers” that
dominate as a result of human habitat degradation.

Invasive Plant Management Decision Action Tool

<u>Decision trees</u> to select best invasive plant management strategy (TNC NYS)

- Eradication
- Containment
- Exclusion
- Suppression
- STOP (not feasible)



http://imapinvasives.org

How to live with the invasive species we can't (shouldn't?) control?

- Maintain **refugia** for native species and genotypes.
- Manage **processes** that favor natives (fire, hydrology).
- Eliminate or reduce **causes** and facilitators of invasion (shoot deer).

- Restoration: use seed material from **competitive native species** and ecotypes adapted to competition with non-natives.
- **Accept a rehabilitated and/or mixed novel community with desirable functions.**

John Randall; TNC California

Uncertainty and Surprises

Limits to science: portray range of possible outcomes; indicate uncertainties.

Engage with diverse stakeholders early – They may not all agree!

Larson et al. 2013 Managing invasive species amidst high uncertainty and novelty. Trends Ecology Evolution (in press)

SUCCESS = DIVERSE, RESILIENT, FUNCTIONAL ECOSYSTEMS

HANDS OFF – ACCEPT CHANGE	MANAGE – RESIST CHANGE
VALUES: Don’t meddle; let “Nature” be in charge. •Evolution, change & recovery •Species change & migrate •Ecological function maintained? •Scare resources used wisely •Solutions are long term	**VALUES: Heal the earth; engage people in the solution.** •Native biodiversity is maintained •Species losses minimized •Ecological function maintained? •Socio-economic benefits •Environmental ethics developed
FEARS: Unknown and unpredictable consequences. •Undesirable results (invasives increase, lose natives and/or ecosystem function, etc.) •Socio-economic losses •Permanent habitat degradation?	**FEARS: Change is bad. Lose species and communities.** •Results are only short term •Perpetual mgmt commitment •Physical & chemical treatments may worsen habitat degradation •Expensive; lost opportunity cost

FAILURE = LOWDIVERSITY, UNSTABLE, UNPRODUCTIVE

Diagram structure derived from Barry Johnson. 2005. Polarity Management: A Summary Introduction

SUCCESS = DIVERSE, RESILIENT, FUNCTIONAL ECOSYSTEMS

HANDS OFF – ACCEPT CHANGE

MANAGE – RESIST CHANGE

ACTIONS: Accept the novel and adapt

Reduce causes of physical & chemical degradation & human stresses:

- Restore natural flows
- Reduce pollution/nutrients
- Increase connectivity
- Reduce excessive deer populations
- Restore top predators
- Ameliorate climate impacts

ACTIONS: Fight change, manage for historical condition

Active management:

- Remove invasive species
- Add/augment tolerant native species
- Assist species migration
- Maintain missing natural processes
- Reduce excessive deer populations

Start

EARLY WARNING

- Loss of specialist species
- Ecosystem services diminish
- Increased variance of ecological health indicators

EARLY WARNING

- Actions increasingly futile/costly
- Native species become invasive when moved to new locations
- Degradation worsens

MONITOR , LEARN, SHARE!

FAILURE = LOWDIVERSITY, UNSTABLE, UNPRODUCTIVE

Diagram structure derived from Barry Johnson. 2005. Polarity Management: A Summary Introduction

…conservation cannot promise a return to pristine, prehuman landscapes…What conservation could promise instead is a new vision of a planet in which nature -- forests, wetlands, diverse species, and other ancient ecosystems -- exists amid a wide variety of modern, human landscapes… and forge a more optimistic, human-friendly vision…

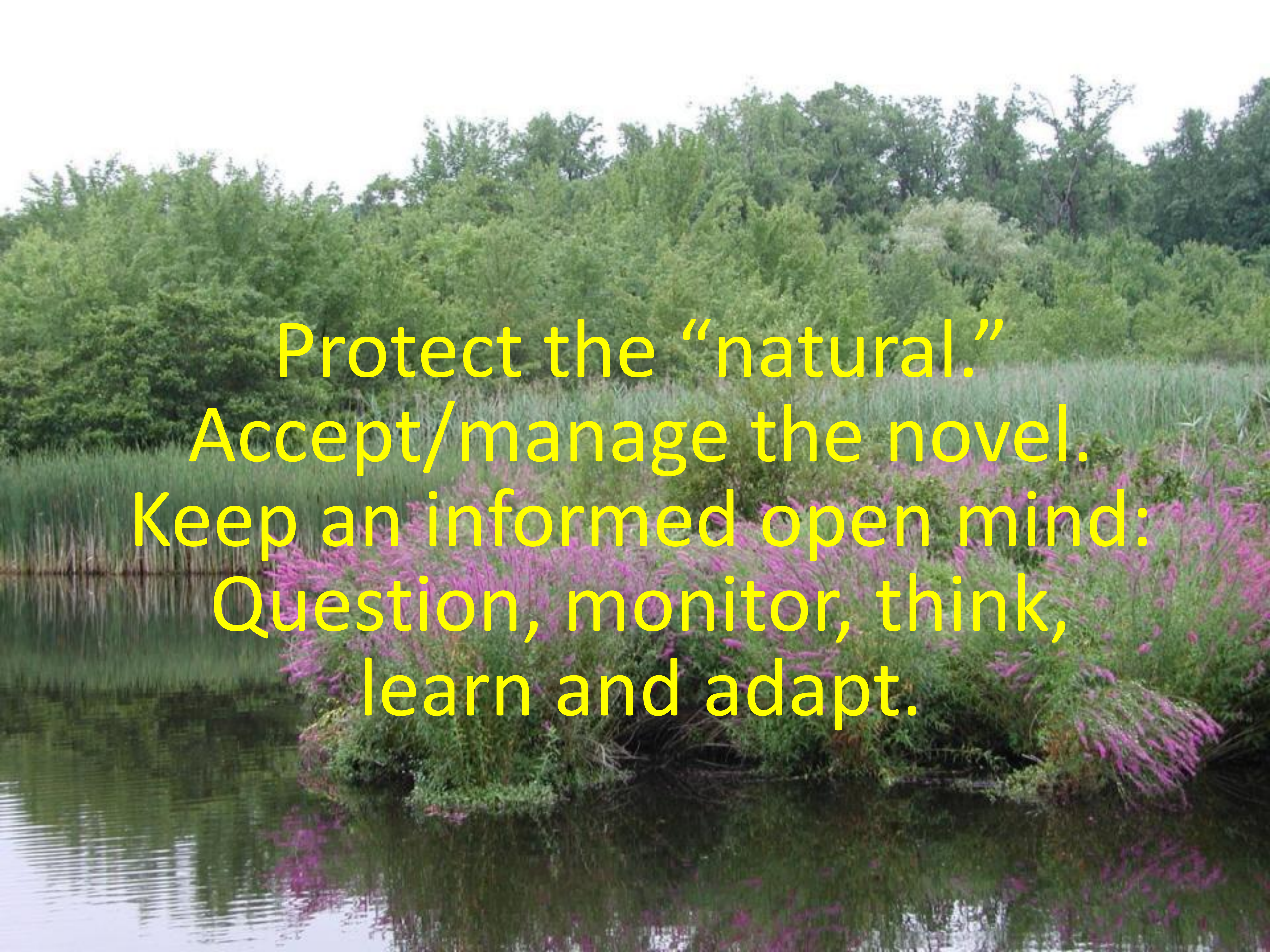
Debate at
http://thebreakthrough.org

Hope in the age of man?

"Yes we live in the anthropocene – but that does not mean we inhabit an ecological hell… We have a duty as a species to protect and manage [the earth]with love and intelligence. It is beautiful still…"

Marris, Kareiva, Mascaro and Ellis. Hope in the age of man. Op-Ed New York Times, December 7, 2011

Responses April 10-11, 2012: http://dotearth.blogs.nytimes.com


Protect the “natural.”
Accept/manage the novel.
Keep an informed open mind:
Question, monitor, think,
learn and adapt.