From Theory to Practice: How can the Principles of Ecological Resilience Inform Invasive Species Management?

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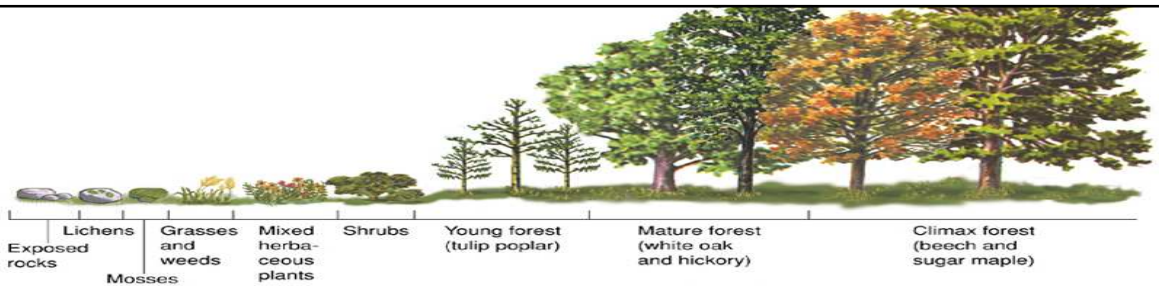
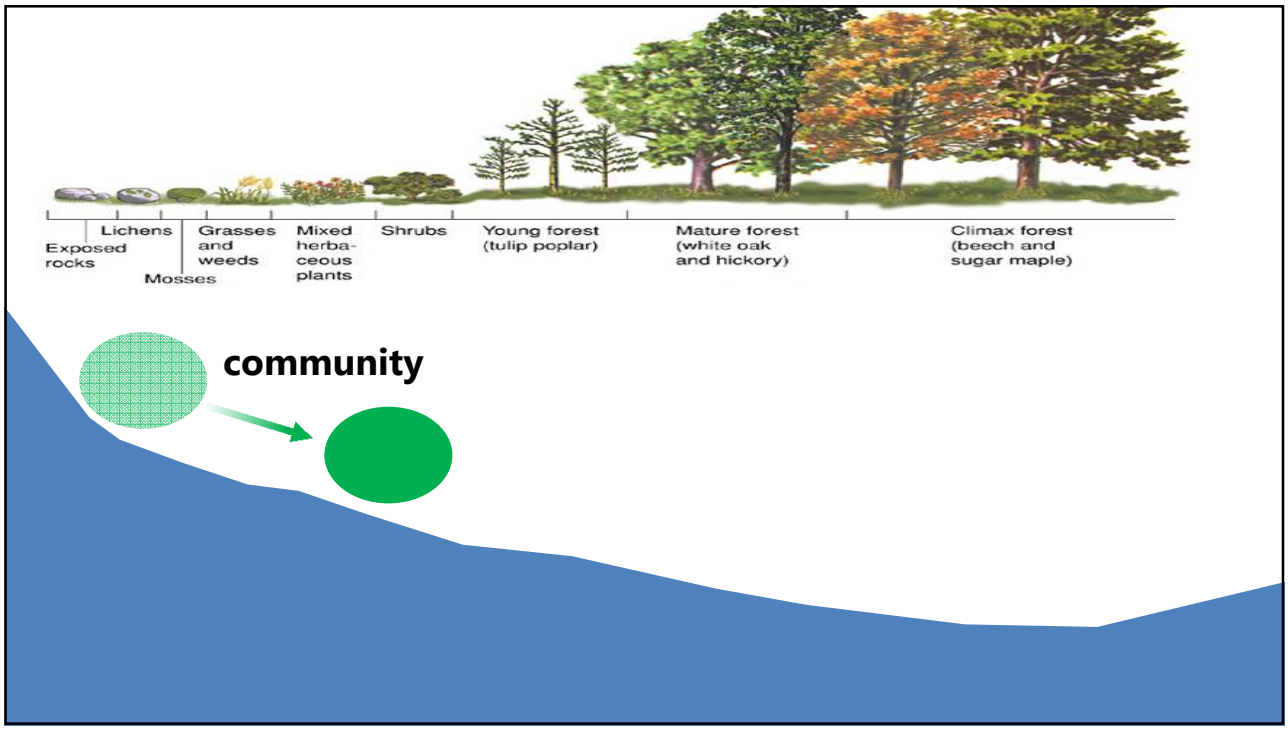
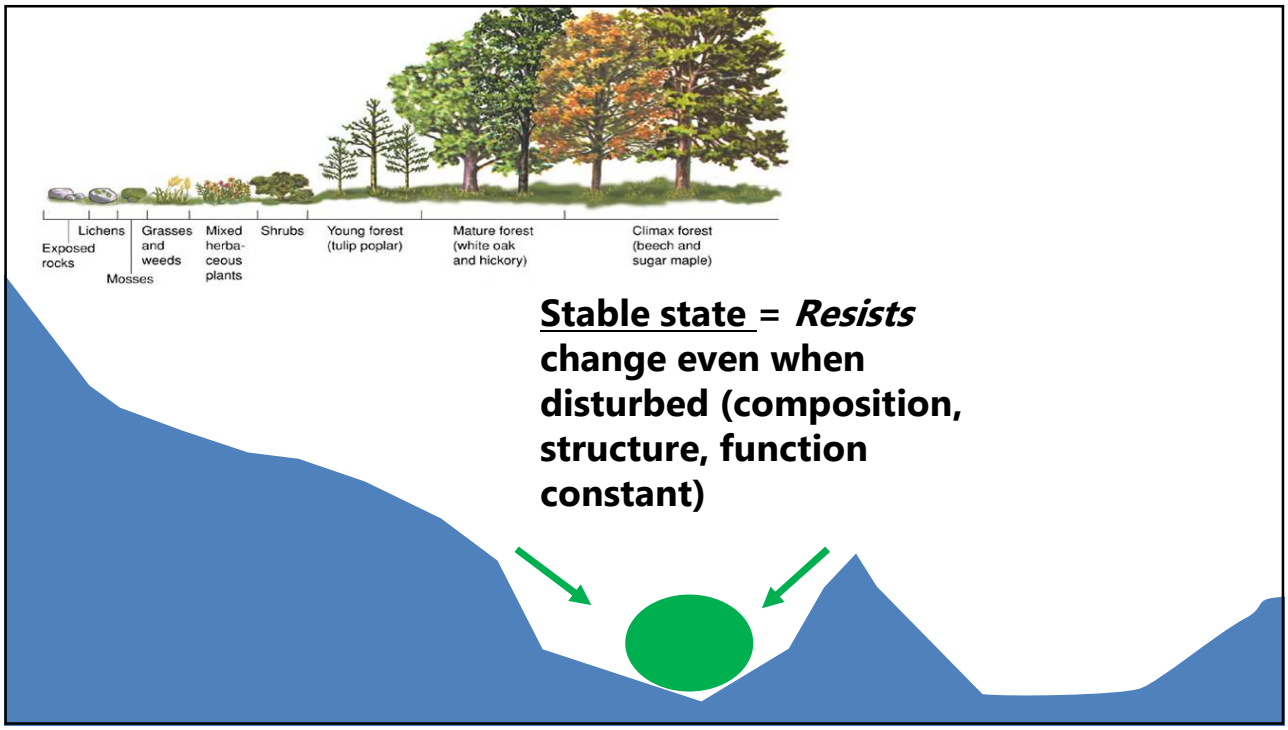


succession


Exposed rocks
Lichens
Mosses
Grasses and weeds
Mixed herba-ceous plants
Shrubs
Young forest (tulip poplar)
Mature forest (white oak and hickory)
Climax forest (beech and sugar maple)
community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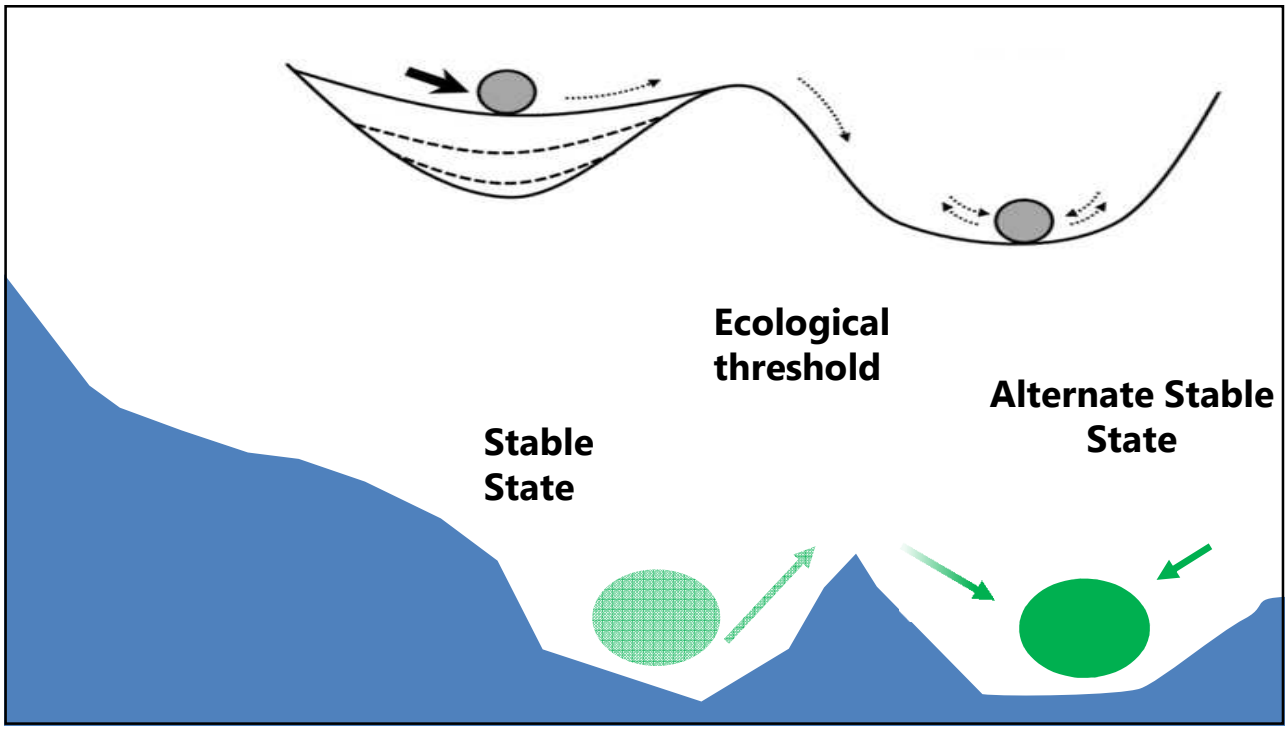
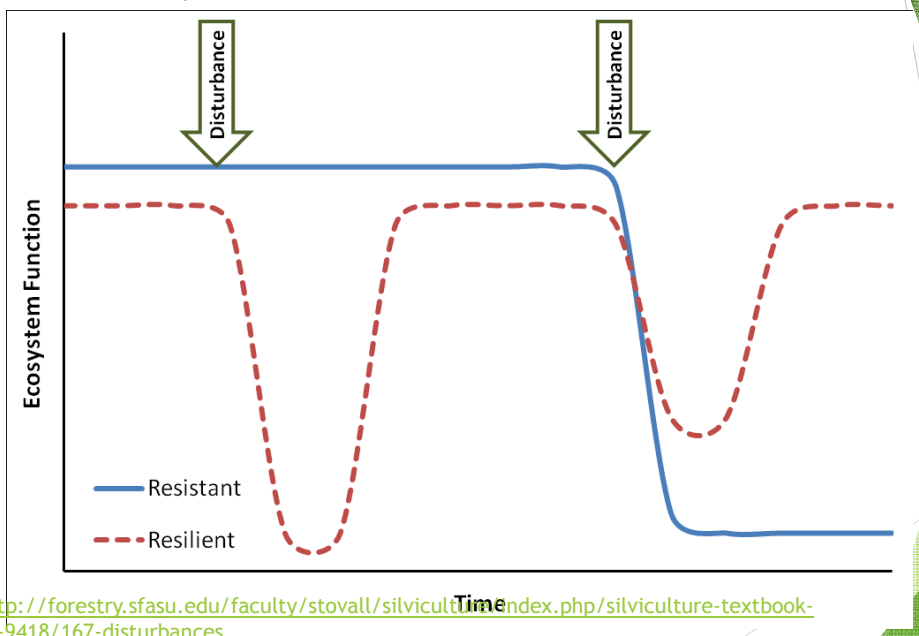
Stable state = *Resists* change even when disturbed (composition, structure, function constant)



- **Resilience** - Capacity of an ecosystem to ***regain*** its fundamental structure, processes and functioning when altered by stresses and disturbances
- **Resistance** - Capacity of an ecosystem to ***retain*** its fundamental structure, processes and functioning (or remain largely unchanged) despite stresses, disturbances or invasive species
- **Thresholds** - Boundaries in conditions leading to alternative stable states with different structure, processes and functioning and that do not return to the original state via self-organizing processes

Resilience vs. resistance



http://forestry.sfasu.edu/faculty/stovall/silviculture/index.php/silviculture-textbook-sp-9418/167-disturbances

On resilience

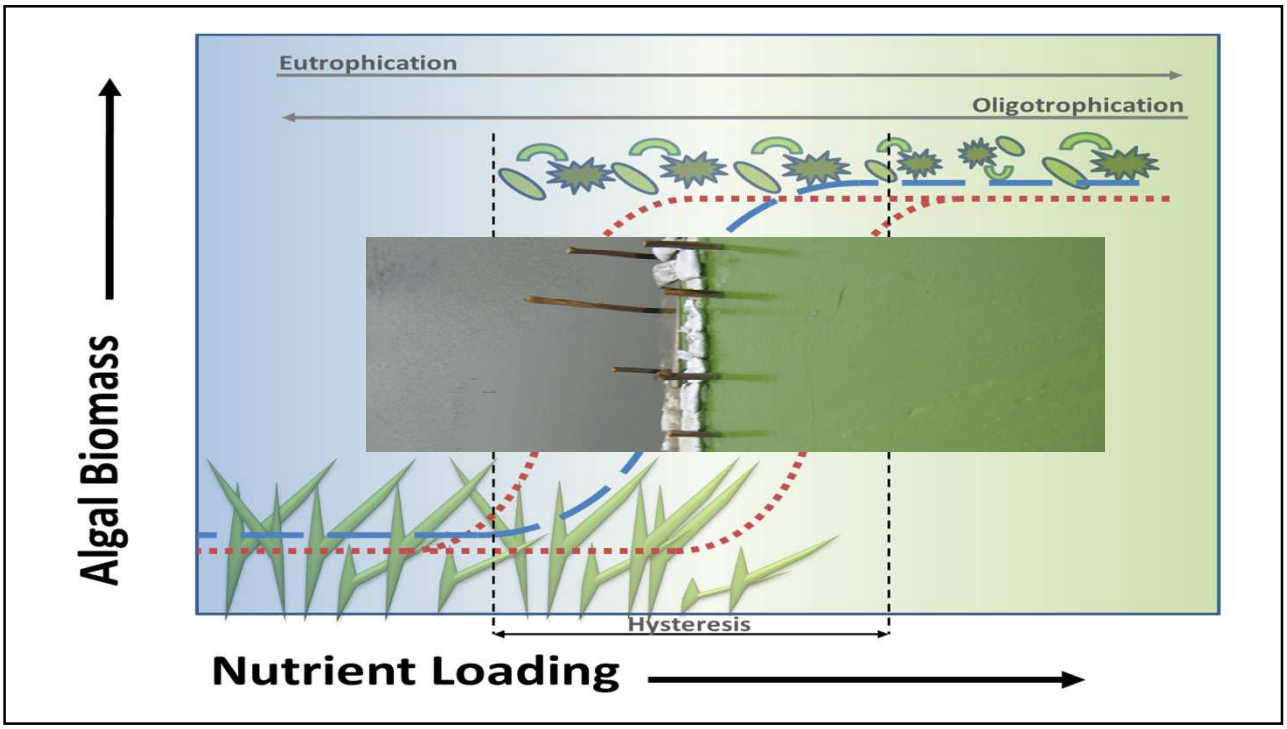
- Undesirable states can be very resilient
- Optimizing the capacity of a system to be resilient to one disturbance may increase its vulnerability to another
- Resilience ≠ not changing.
- Resilience *requires* change and disturbance to maintain its capacity to respond
- Command and control approach or optimization for one thing decreases resilience

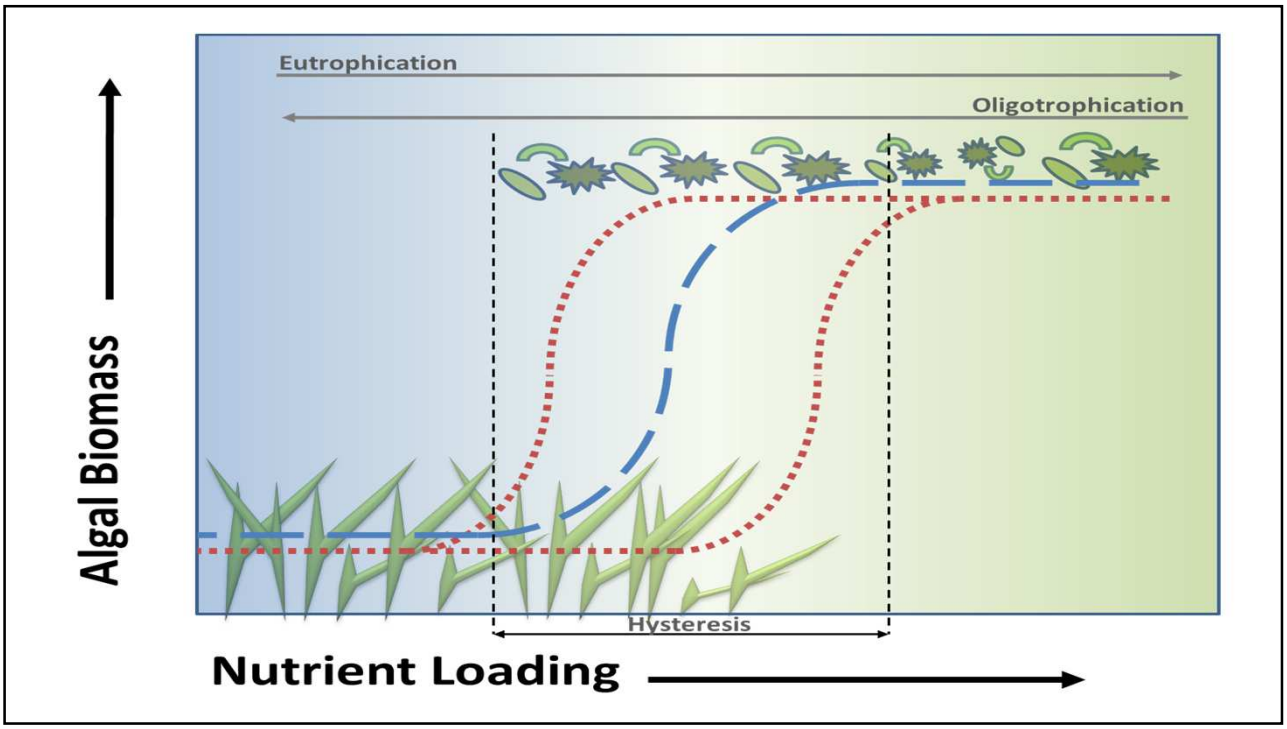
Examples of Ecological Thresholds that lead to Alternate Stable States:

- **Eutrophication in lakes**
- **Wetlands**
- **Salt marsh die-back**
- Sea urchin herbivory of kelp forests
- Wolves in Yellowstone
- Jamaican Reefs

…and many more

What are the key drivers?
Implications for measuring and managing ecosystems?


Eutrophication
Oligotrophication
Algal Biomass
Hysteresis
Nutrient Loading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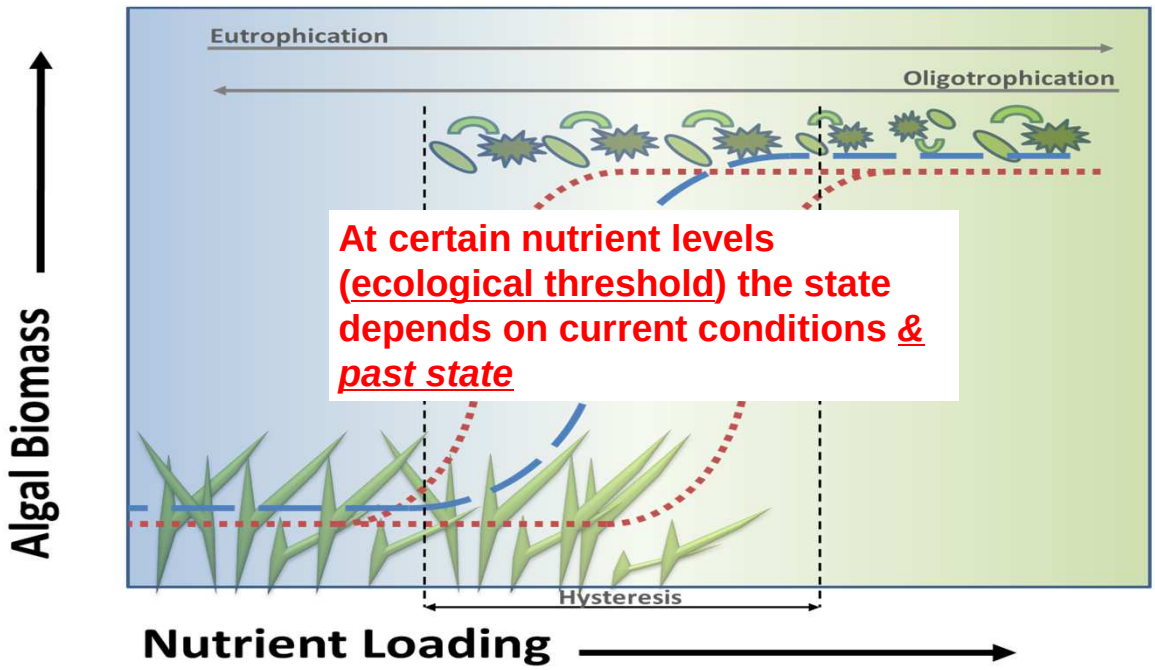

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Will mitigated wetlands ever be the same as "natural" wetlands?

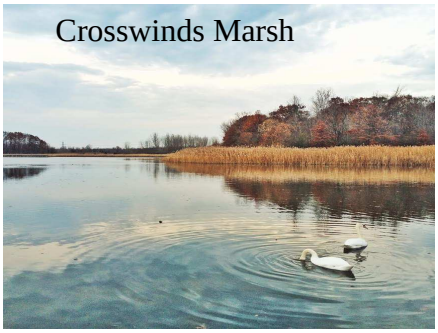
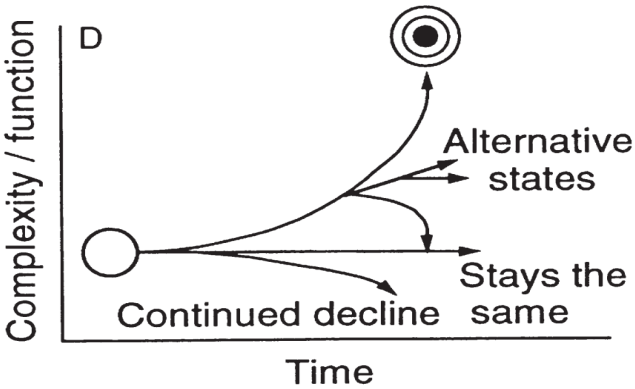


Photo credit: Jiayang Li



Zedler, J.B. and J.C. Callaway. (1999) Tracking wetland restoration: Do mitigation sites follow desired trajectories? *Restoration Ecology* 7.1, 69-73.

Alternate Stable States:
Diverse coastal sedge meadow &
Monodominant Cattails &/or Phragmites

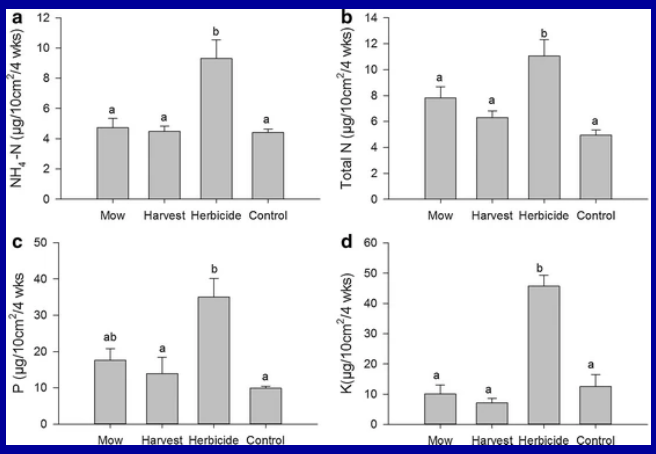
Woo & Zedler (2002) Can nutrients alone shift a sedge meadow towards dominance by the invasive *Typha glauca*?

- **"Aboveground biomass of *Typha* in the high nutrient addition treatment was more than double that for control plots…. In contrast, native graminoids did not respond to treatment, either in biomass or percent cover."**

See also: Zedler J (2009) Feedbacks that might sustain **natural, invaded and restored states** in herbaceous wetlands. In: Hobbs RJ, Suding KN (eds) *New models for ecosystem dynamics and restoration.* Island Press, Washington, DC, pp 236–258

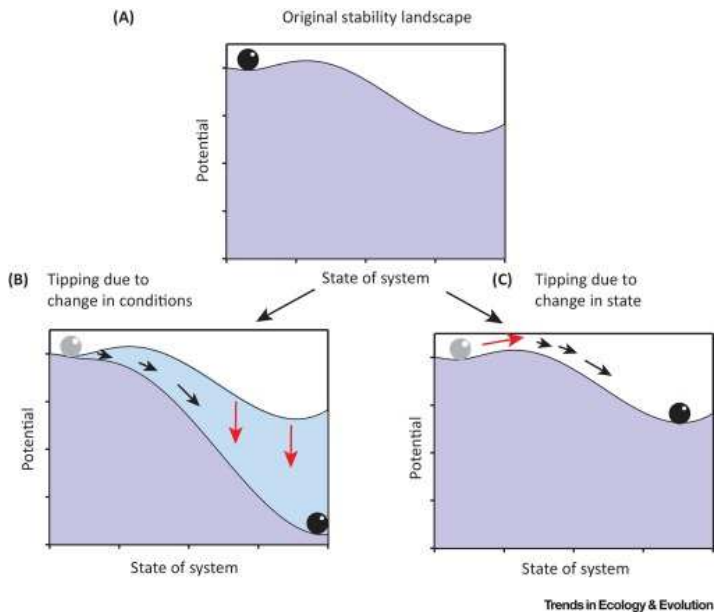
Herbicide management of invasive cattail (*Typha* × *glauca*) increases porewater nutrient concentrations

Beth A. Lawrence · Shane C. Lishawa · Yarency Rodriguez · Nancy C. Tuchman



***Herbicide application –> decay of leaf litter and roots + reduced uptake of nutrients = increased nutrient availability**

Lesson: What are the unknown/ unexpected thresholds?



van Nes EH, Arani BMS, Staal A, et al (2016) What Do You Mean, 'Tipping Point'? Trends in Ecology & Evolution 31:902-904. https://doi.org/10.1016/j.tree.2016.09.011

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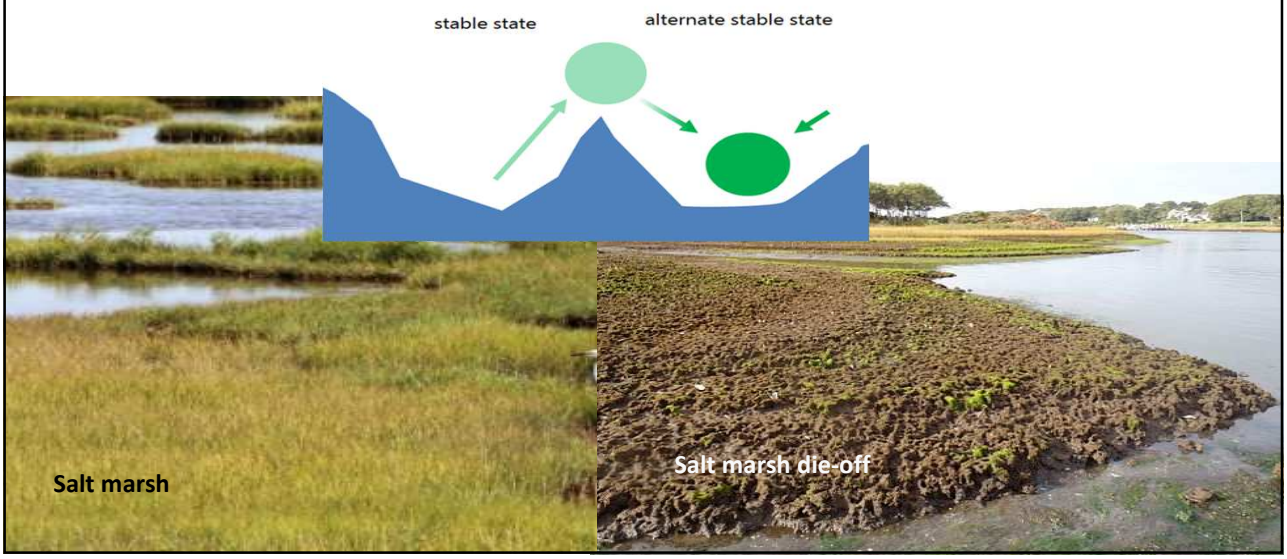
Salt Marsh: What is the ecological threshold?

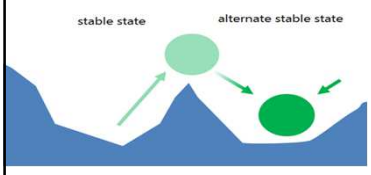
Watch: https://www.nsf.gov/news/special_reports/science_nation/purplemarshcrabs.jsp

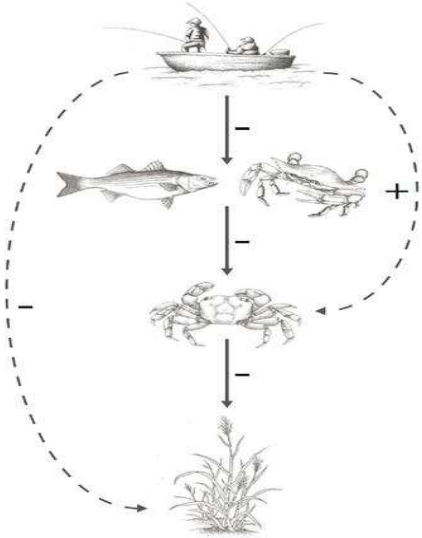


Salt Marsh: Consumer-driven alternate stable states

What is the ecological threshold?

But what facilitates return to salt marsh state?





Lesson: Sometimes the threshold is not what we want it to be

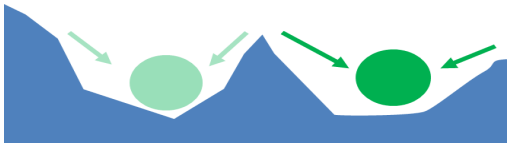
Indirect human impacts turn off reciprocal feedbacks and decrease ecosystem resilience

Mark D. Bertness · Caitlin P. Brisson · Sinead M. Crotty

- "Experimental addition of *Geukensia* [mussel] facilitators to creek banks accelerated *Spartina* [marsh grass] recovery,
- Mussel loss "limits recovery and the reciprocal feedbacks that drive community resilience."
- Reestablishment of facilitators = "a common, but generally overlooked… valuable restoration tool"

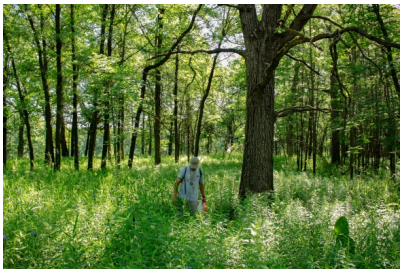
Resilient system

What are the implications of Resilience, Alternate Stable States, & Novel Ecosystems for restoration?



- When is it no longer the same community type?
- What causes the shift? Is it reversible?
- What is a resilience-based approach?

First step to resilience-based approach: Identify states & thresholds for your system



State transition

Open forests ⇄ Closed forests

no surface fire →

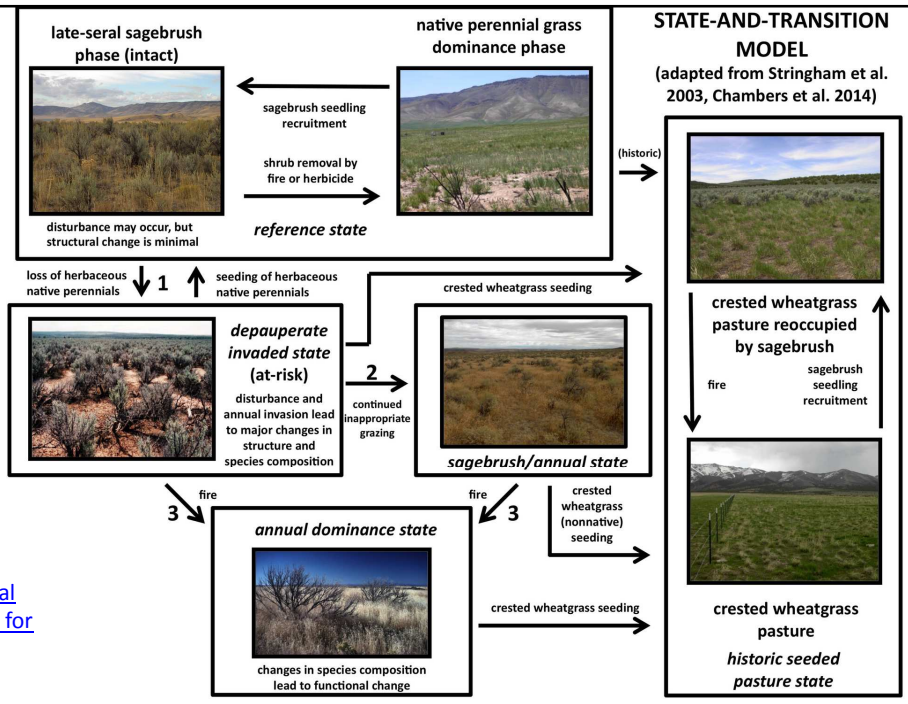
← surface fire

Increased fire-tolerant oak and pine species
Decreased tree density
Positive feedback that increases flammable conditions

Increased fire-sensitive tree species
Increased tree density
Positive feedback that increases fireproofing

Hanberry BB (2019) Recent shifts in shade tolerance and disturbance traits in forests of the eastern United States. Ecological Processes 8:32. https://doi.org/10.1186/s13717-019-0187-3

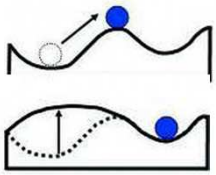
...and restoration actions to move from one state to the other



Jones et al. (2015) The potential of novel native plant materials for the restoration of novel ecosystems. Elem Sci Anth

For your ecoregion/area of management

- What are the alternate states?
  - How do they differ in resistance and resilience?
  - Which are desirable? Why?
- What are the **threshold** conditions that result in a transition from one state to another?
  - What are the **warning signals** of those thresholds?
- What are the **management actions** that
  - Cause a transition from one state to another?
  - Change the resistance or resilience of a state?



What is most challenging/unknown as you try to answer these questions?

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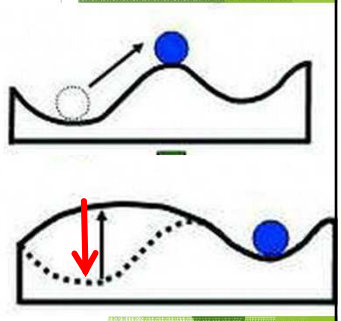
- **Resistance to Invasion-** Abiotic and biotic attributes and ecological processes of an ecosystem that limit the population growth of an invading species

What might **improve resistance** to invaders?

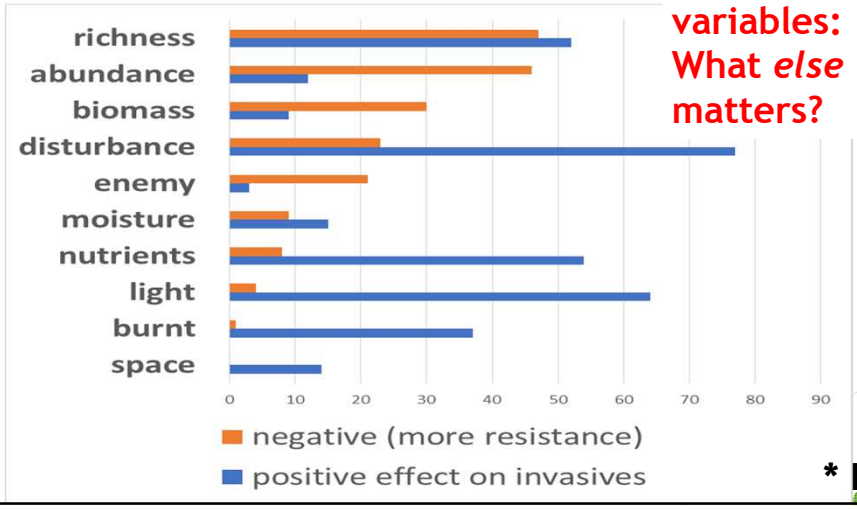
- **Mediate legacy effects of previous invaders**
- **Reduce nutrient availability**
- **Reduce potential for invasive species priority effects**
- **Promote diversity**
- **Match plant traits & functional groups to potential invaders**



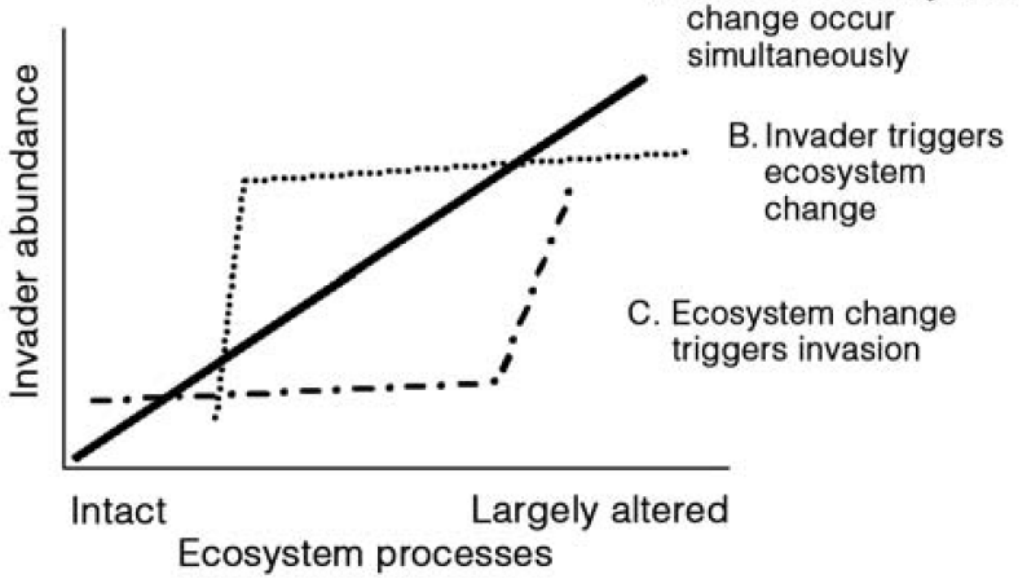
D'Antonio et al. (2016) Invasive Species and Restoration Challenges. In: Palmer MA, Zedler JB, Falk DA (eds) Foundations of Restoration Ecology. Island Press/Center for Resource Economics, Washington, DC, pp 216-244

Preliminary meta-analysis of over 500 studies*: **What are the native community traits that increase resistance or decrease vulnerability to invasive plants?**

Lots of other variables: What *else* matters?



*** Inés Ibáñez, et al.**



D'Antonio CM, Chambers JC (2006) Using Ecological Theory to Manage or Restore Ecosystems Affected by Invasive Plant Species. In Foundations of Restoration Ecology

Characteristic	Steady-state resource management	Resilience-based "ecosystem stewardship"
Reference point	Historic condition	Trajectory of change
Central goal	Ecological integrity	Sustain social-ecological systems and delivery of ecosystem services
Predominant approach	Manage resource stocks and condition	Manage stabilizing and amplifying feedbacks
Resources of primary concern	Species composition and ecosystem structure	Biodiversity, well-being, and adaptive capacity
Role of uncertainty	Reduce uncertainty before taking action	Embrace uncertainty: maximize flexibility to adapt to an uncertain future
Response to disturbance	Minimize disturbance probability and impacts	Disturbance cycles used to provide windows of opportunity

Chapin FS, Carpenter SR, Kofinas GP, et al (2010) Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends in Ecology & Evolution 25:241-249.