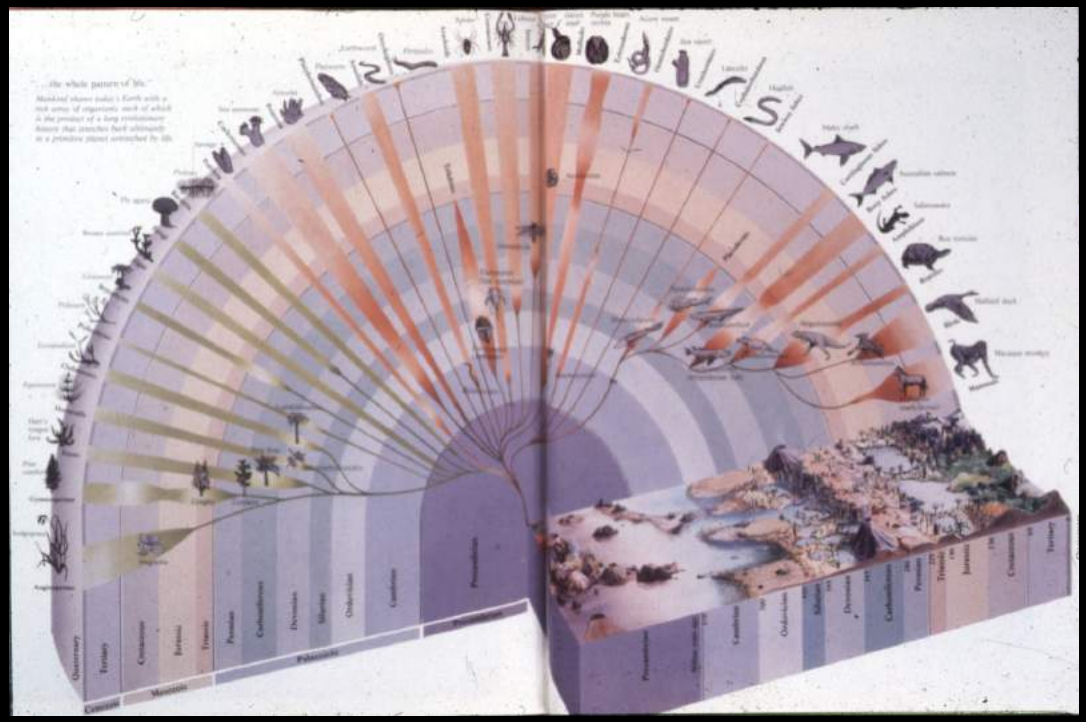
Future of Biogeography
. . . a global view . . .

Future of Biogeography

- Earth ***is*** a dynamic place
- Speciation and extinction ***are*** natural parts of the history of biota



The Problem

Lisianthius habuenis Sytsma sp. nov.

- New species endemic to one lowland cloud forest peak, Cerro Habu, central Panama - described in 1983

The Problem

• On a return trip in 1985, the forest - and the species - were gone; one of the 13,800 species of plants E.O. Wilson had projected to disappear in the last century

Lisianthius habuenis Sytsma sp. nov.

• New species endemic to one lowland cloud forest peak, Cerro Habu, central Panama - described in 1983

The Problem

• Should we care? Do we have an economical, ecological or ethical responsibility?

• What do we know about extinction? How does it happen? What are the ecological repercussions?

Lisianthius habuenis Sytsma sp. nov.

• What should our response then be? How should we then act?

Addressing the Problem

Cal DeWitt
Institute Environmental Studies
University of Wisconsin

"How does the world work?"

Science

Ethics

Praxis

"What is right?"

"What then must we do?"

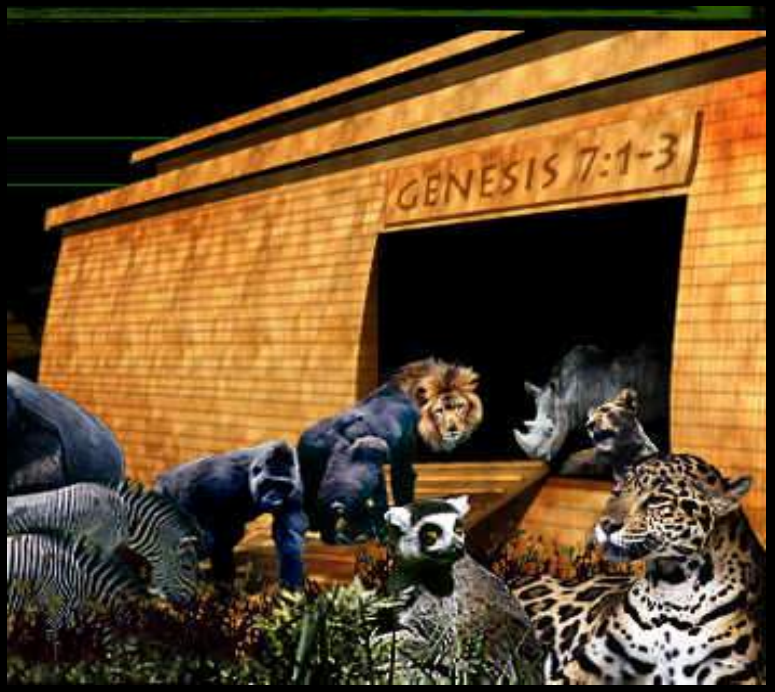
From: DeWitt, C. B. 1998. Science, Ethics, and Praxis: Getting it All Together.

Addressing the Problem

- "*It is inconceivable to me that an ethical relation to land can exist without love, respect, and admiration for land, and a high regard for its value. By value, I of course mean something far broader than mere economic value; I mean value in the philosophical sense.*" Aldo Leopold, 1949

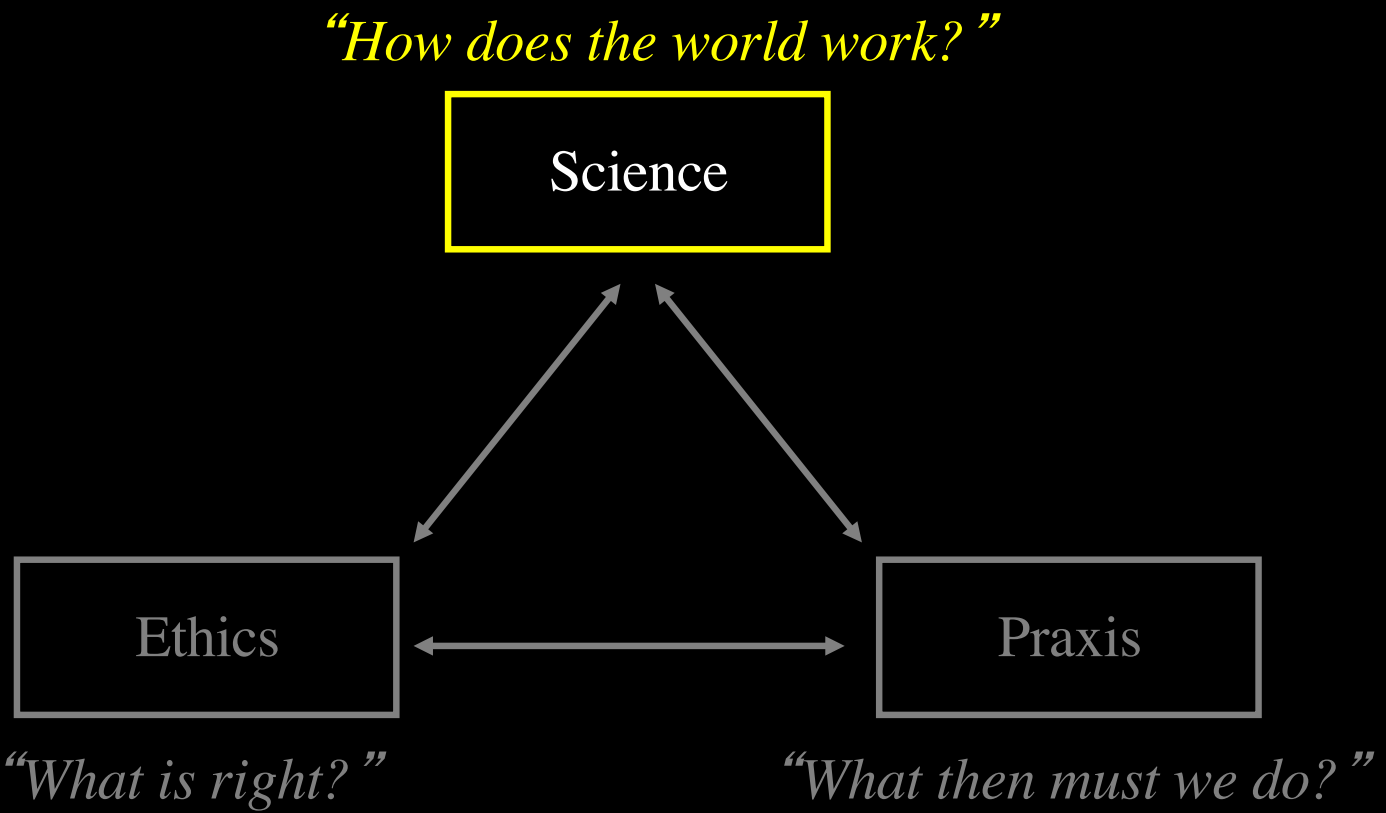
- The Judeo-Christian Stewardship Environmental Ethic makes us accountable to God for conserving biodiversity:

"*Diversity is God's property, and we, who bear the relationship to it of strangers and sojourners, have no right to destroy it.*"
D.W. Ehrenfeld, 1988



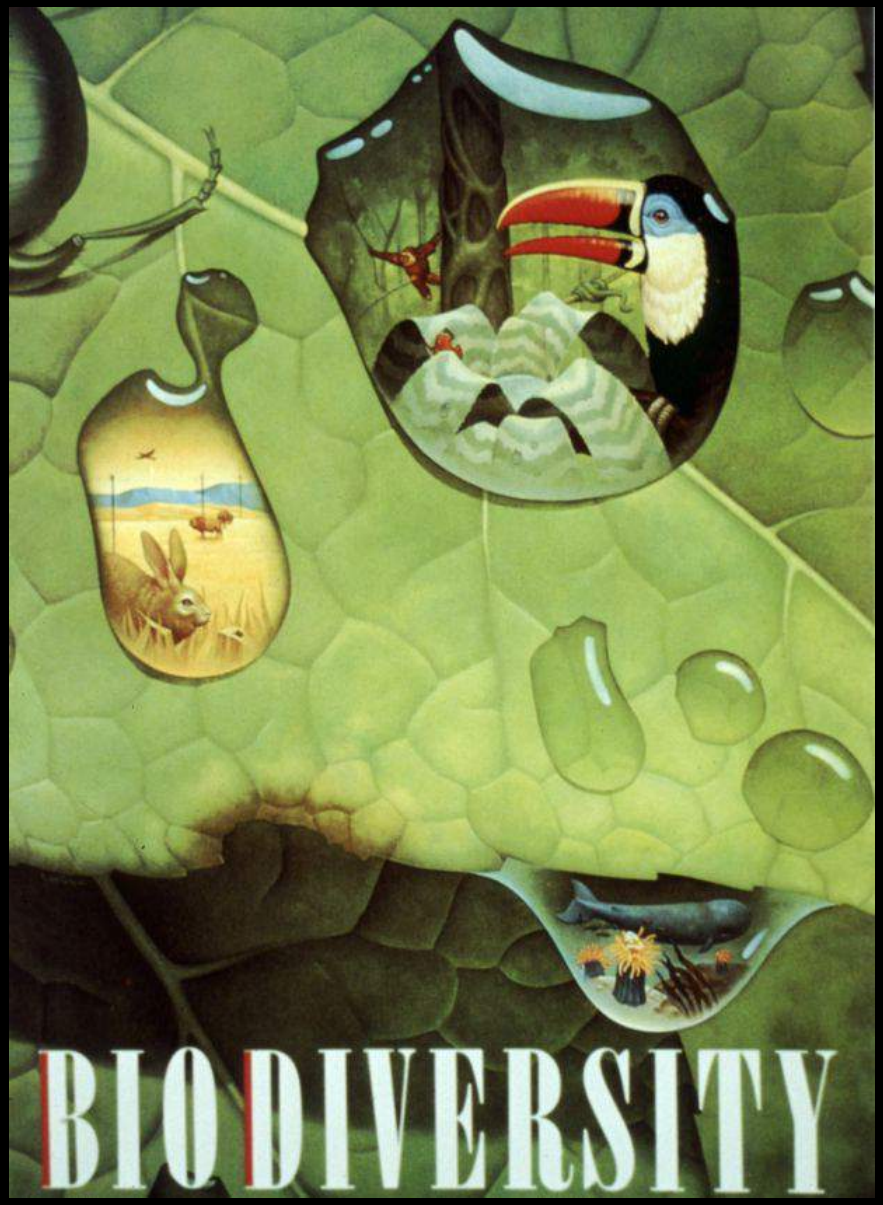
Addressing the Problem

Biological Diversity



Addressing the Problem

Biological Diversity

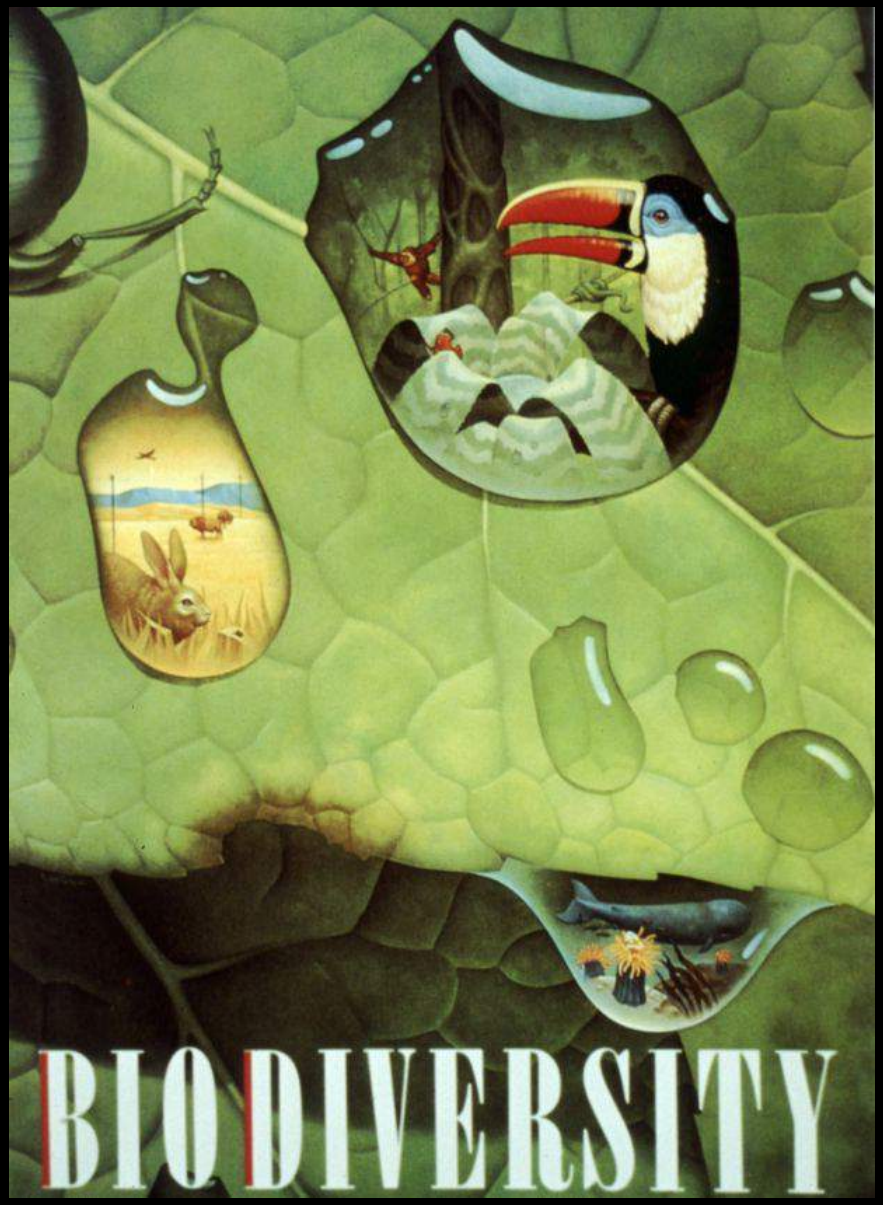


"How does the world work?"

Science

1. How much BioDiversity is there?
2. Where does that biodiversity live?
3. How fast is it going extinct?
4. How do species become endangered or go extinct?

How much biological diversity is there?



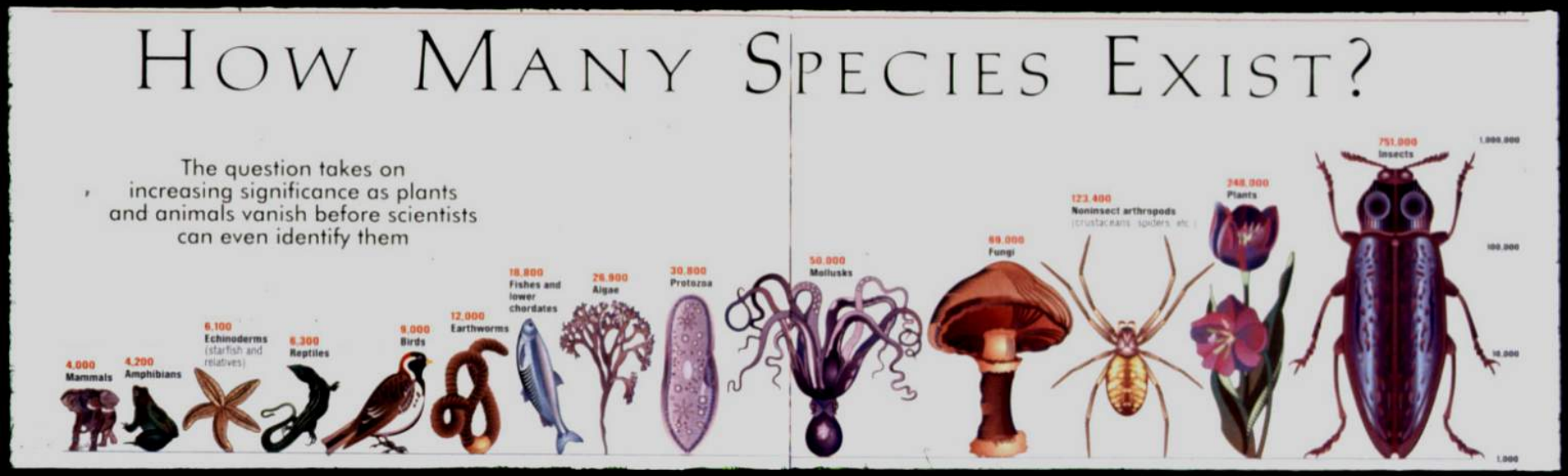
• The term "BioDiversity" was born during the National Forum on BioDiversity, held in Washington D.C. in 1986

Biodiversity = variation

- genes
- populations
- species
- communities
- ecosystems

How much biological diversity is there?

- 1.4 million living species of all kinds of organisms have been named
- 750,000 are insects, 250,000 are plants, 41,000 are vertebrates
- The remainder consists of a complex array of invertebrates, fungi, algae, and microorganisms
- Absolute number is likely to exceed 10 million



How much biological diversity is there?

- Gene diversity
- 1000 bacteria, 10^4 fungi, 4 X 10^5 flowering plants

- gray wolf DNA sequences would fill all 15 editions of the *Encyclopaedia Brittanica* since 1768

How much biological diversity is there?

- Gene diversity
- 1000 in bacteria, 10^4 in fungi, 4 X 10^5 in flowering plants

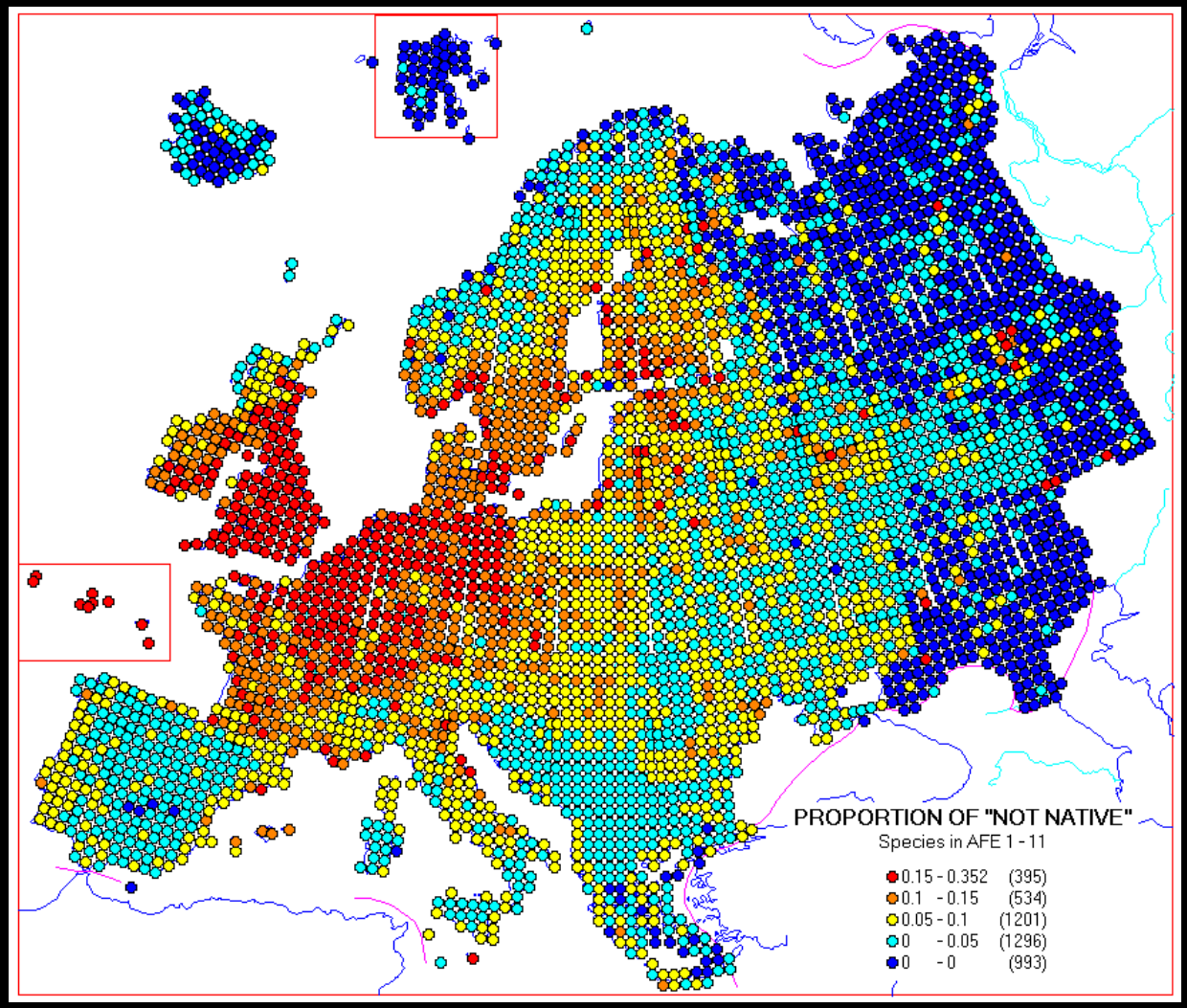
- . . . and 10X that in the coastal redwood from your Greenhouse Tour

How does biological diversity go extinct?

- “Weeds”, invasives
- Habitat fragmentation
- Climate changes

How does biological diversity go extinct?

- Strong link between areas of ‘weed’ concentrations and extinction hot spots



How does biological diversity go extinct?

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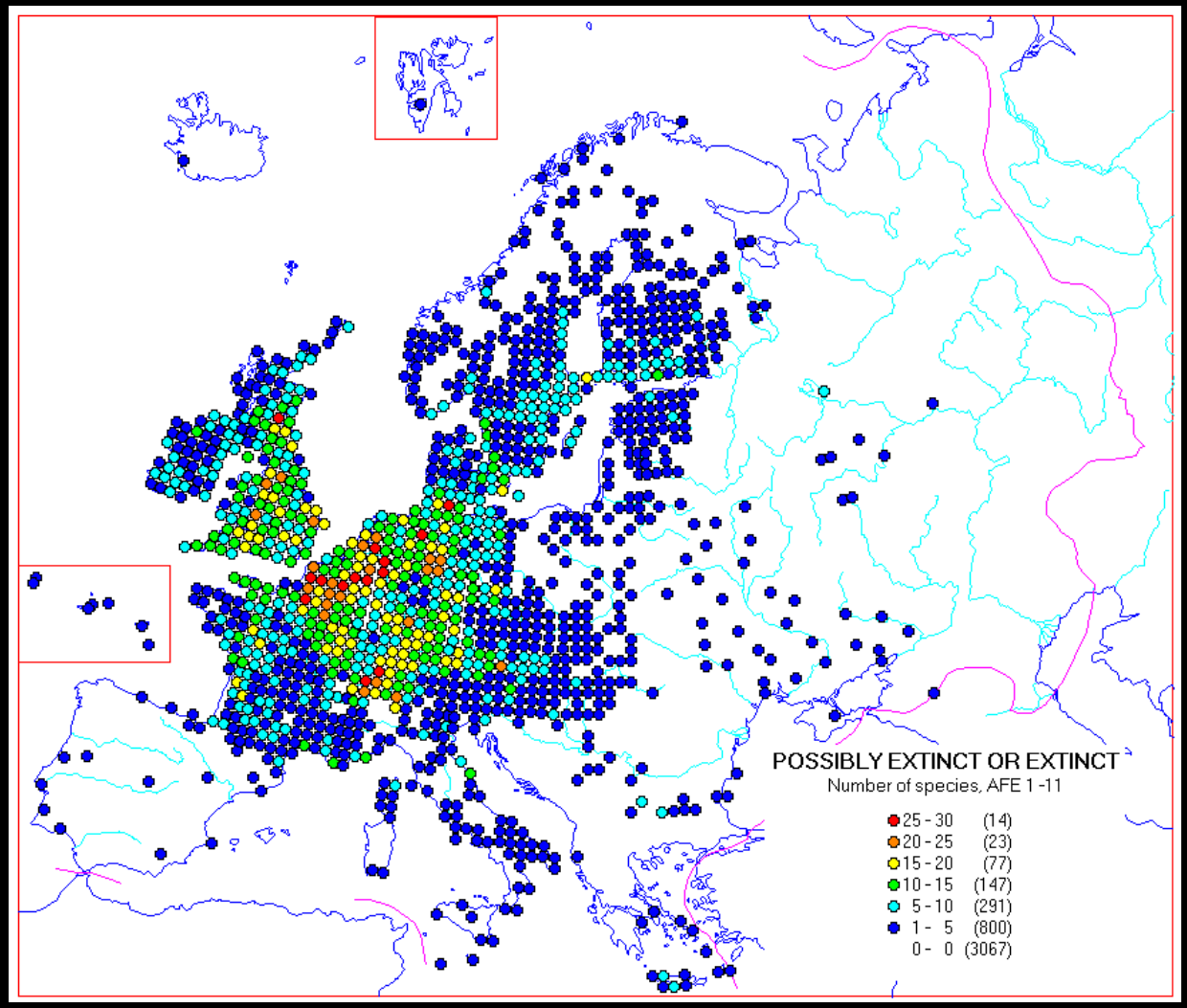


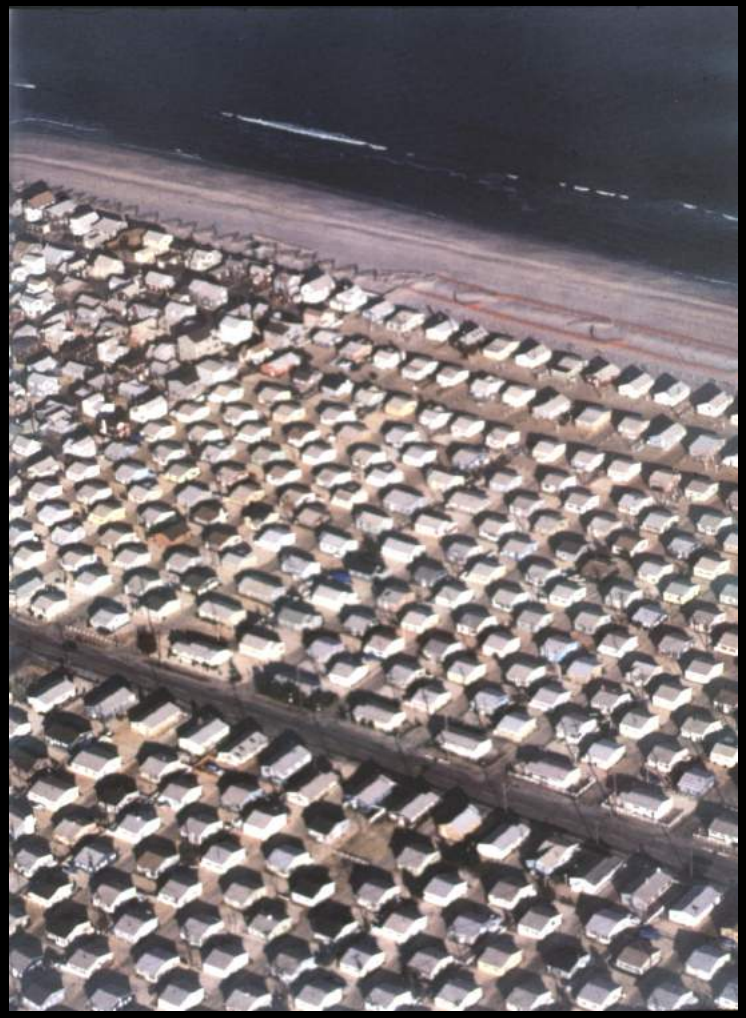
How does biological diversity go extinct?

Midwest oak savanna

- Habitat fragmentation

Chicago wet prairies

How does biological diversity go extinct?

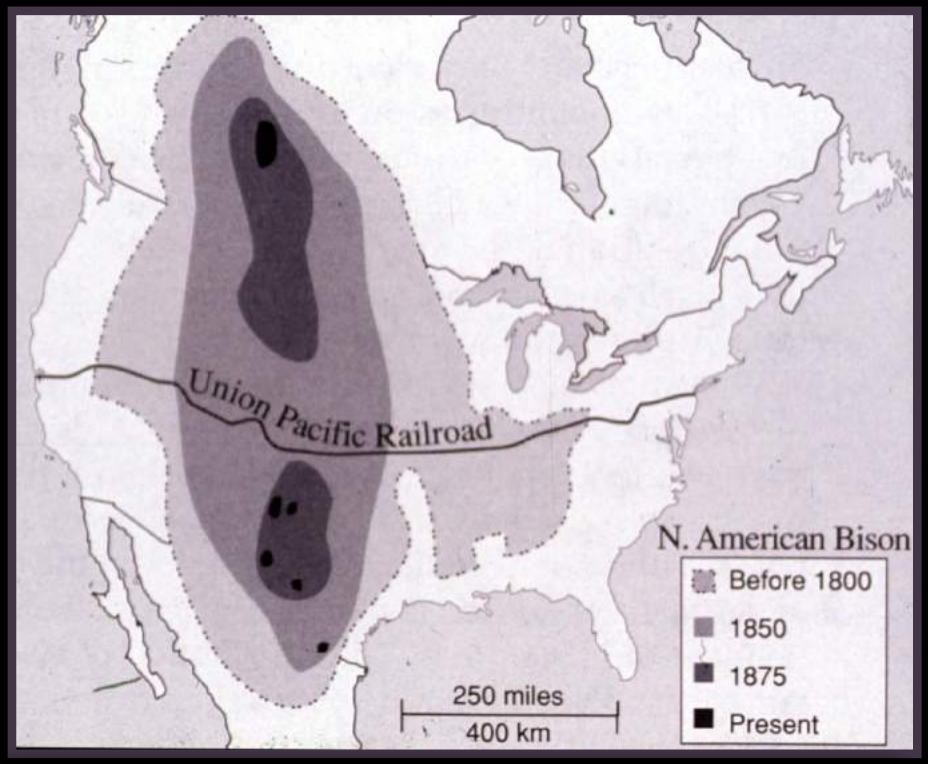


South Florida coastal scrub

- Habitat fragmentation

Florida Everglades

How does biological diversity go extinct?

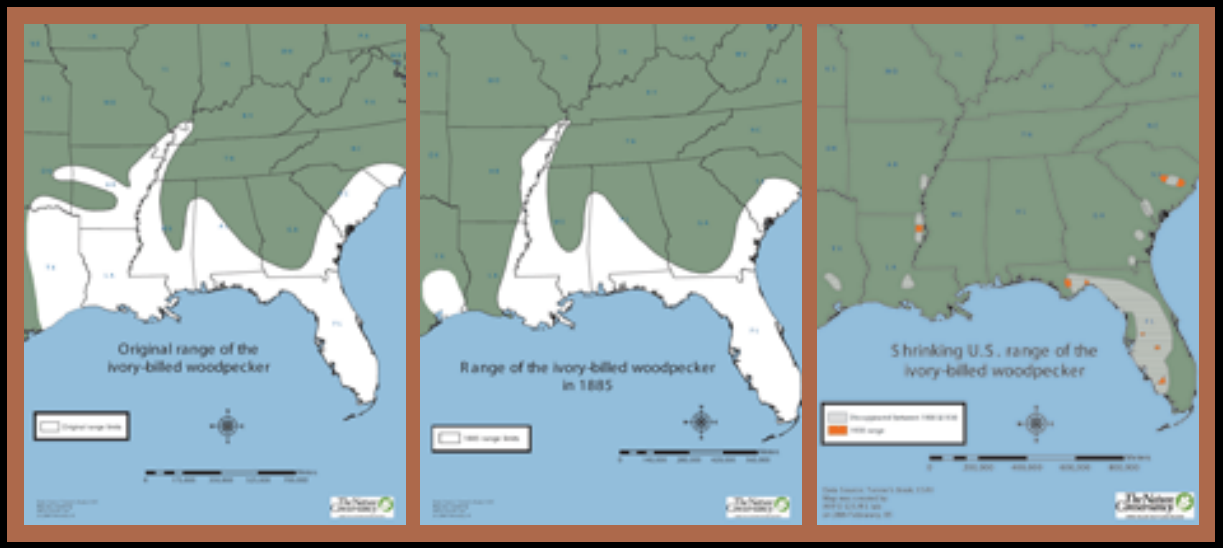


- Habitat fragmentation

Completion of the Union Pacific Railroad in 1869 had dramatic impact on the distribution of the American bison

How does biological diversity go extinct?

Ivory-billed woodpecker-
considered extinct since 1944



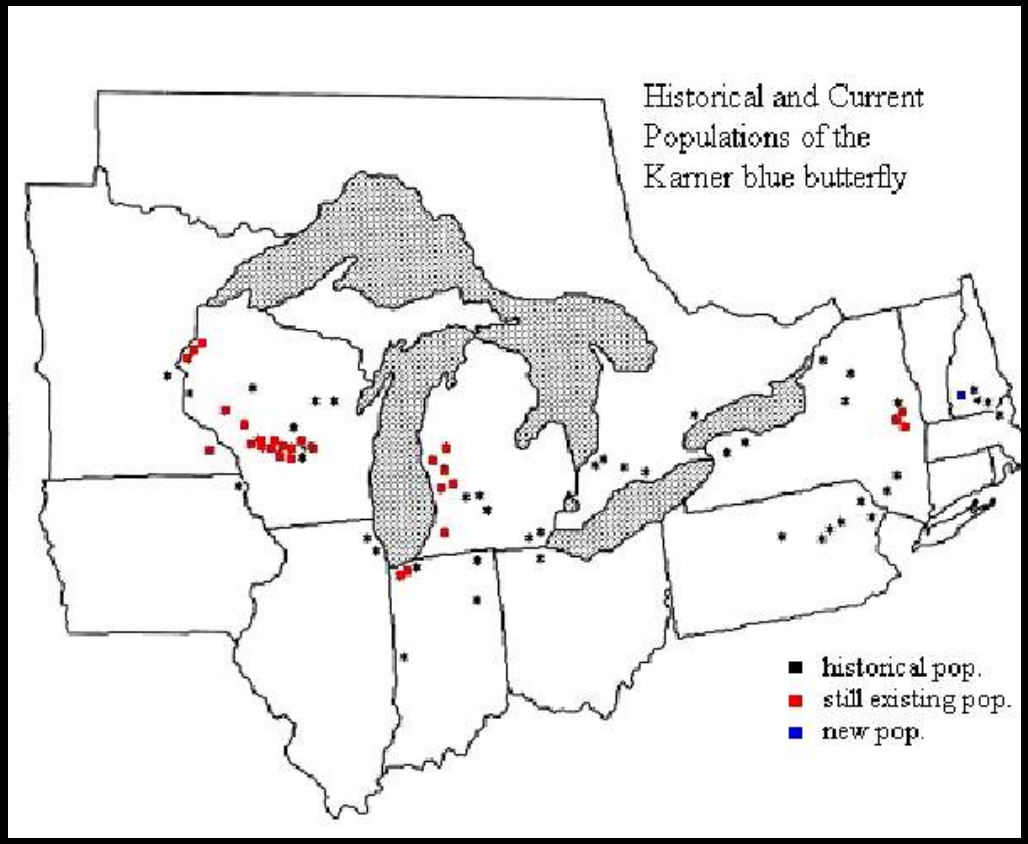
Island nature of its habitat today — swamp forest
[Arkansas 2004, Florida 2005, Louisiana/Mississippi 2017]

How does biological diversity go extinct?

Deforestation and oak savanna/prairie use for agriculture have largely made many Great Lake ecosystems simply experiments in "island biogeography"

How does biological diversity go extinct?

The endangered Karner Blue is restricted to disappearing oak savanna habitat in the Great Lakes region with its larval stages dependent on a single species of plant - *Lupinus perennis*



How does biological diversity go extinct?

- Cumulative effect is degradation of genetic diversity or severe genetic bottlenecks

Agalinus skinneriana
Purple false foxglove

Threatened (4 states) in Great Lakes region - restricted to south facing dry prairies

How does biological diversity go extinct?

- Cumulative effect is degradation of genetic diversity or severe genetic bottlenecks

- DNA fingerprinting, however, reveals practically no genetic variation

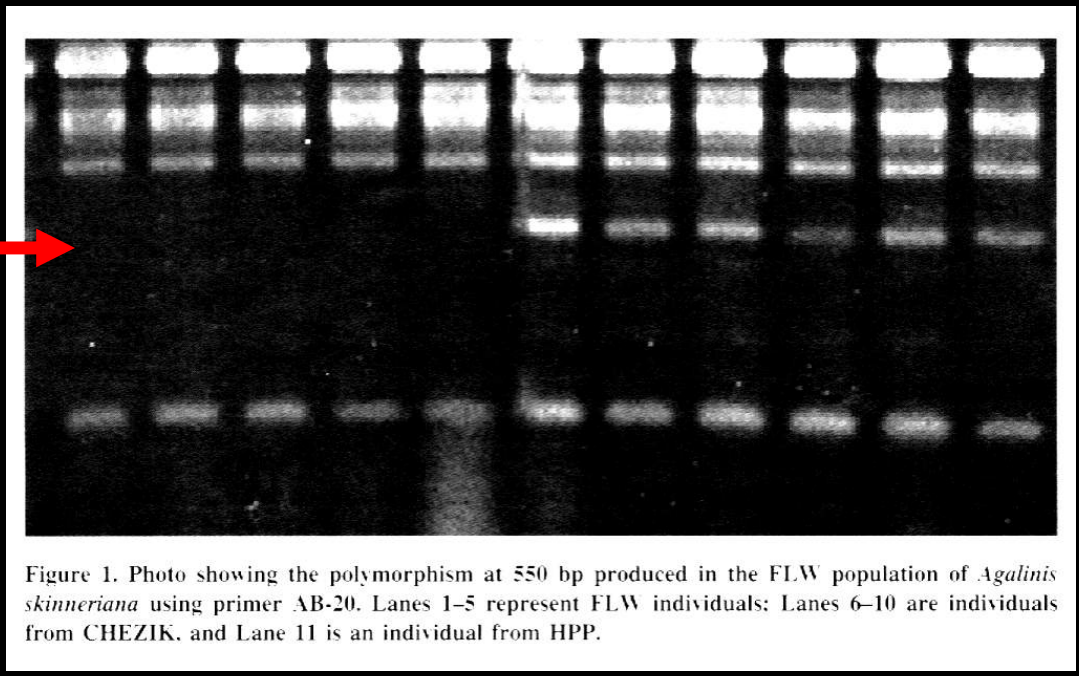


Figure 1. Photo showing the polymorphism at 550 bp produced in the FLW population of *Agalinis skinneriana* using primer AB-20. Lanes 1–5 represent FLW individuals; Lanes 6–10 are individuals from CHEZIK, and Lane 11 is an individual from HPP.

Kercher & Sytsma (2000) in *Natural Areas Journal*

How does biological diversity go extinct?

As predicted by the theory of island biogeography, prairie patches inventoried in southern Wisconsin in 1950 and again in 2000 showed significant loss of species diversity during the 50 year interval (Leach and Givnish, 2001) - extirpation

As expected, moth-pollinated species such as the prairie fringed orchid were one of the first to disappear

Platanthera leucophaea
Prairie-fringed orchid

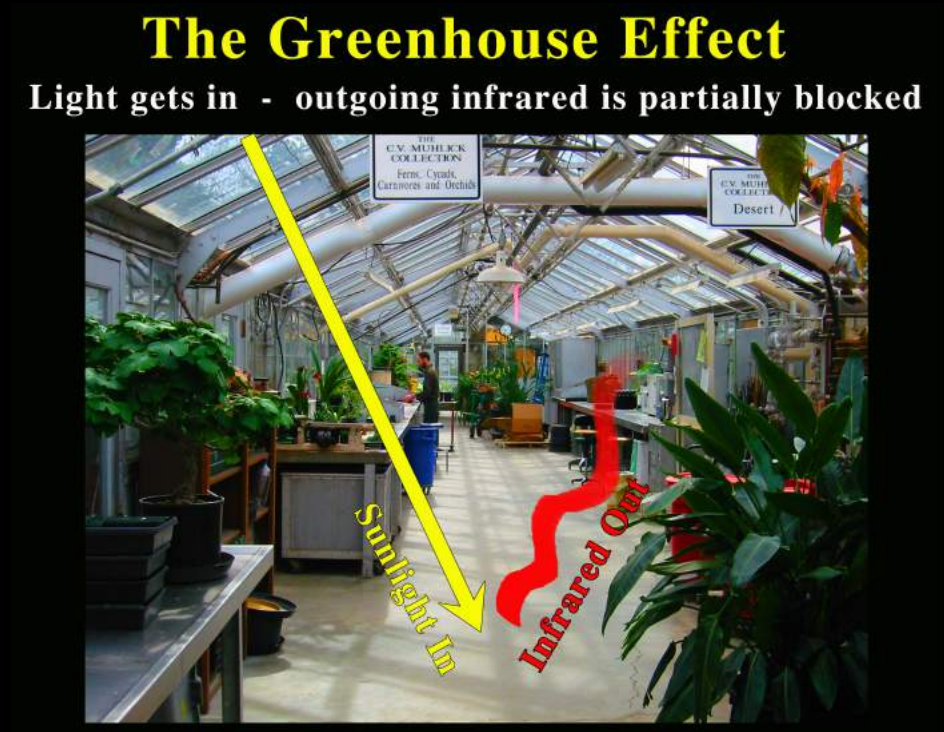
How does biological diversity go extinct?

"In his book, *Worlds in the Making*, Arrhenius first describes the "hot-house" theory of the atmosphere."

Svante Arrhenius
1859-1927

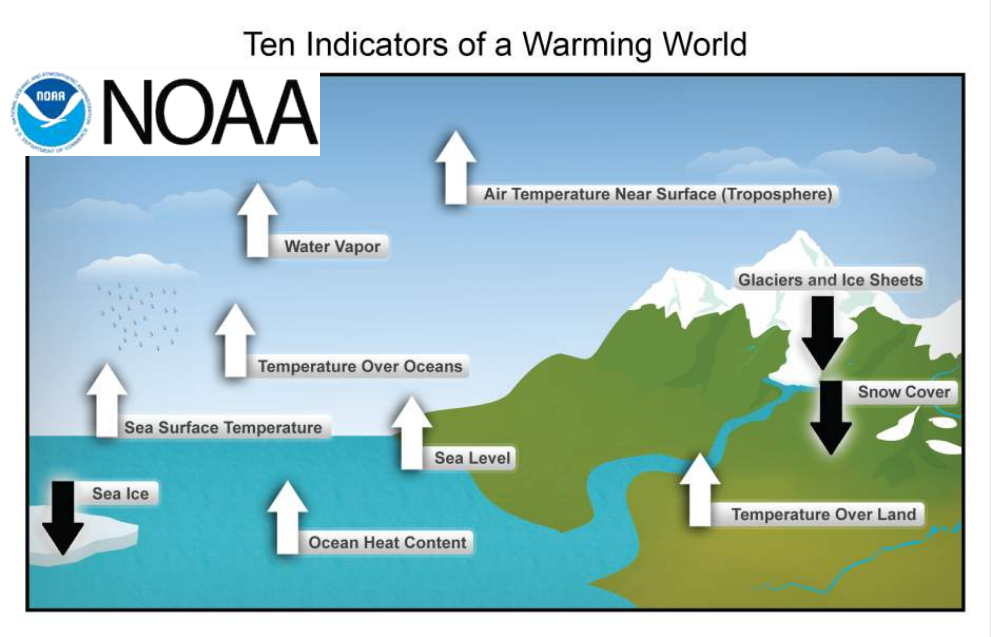
"Arrhenius argued that variations in trace atmospheric constituents could influence the Earth's heat budget."

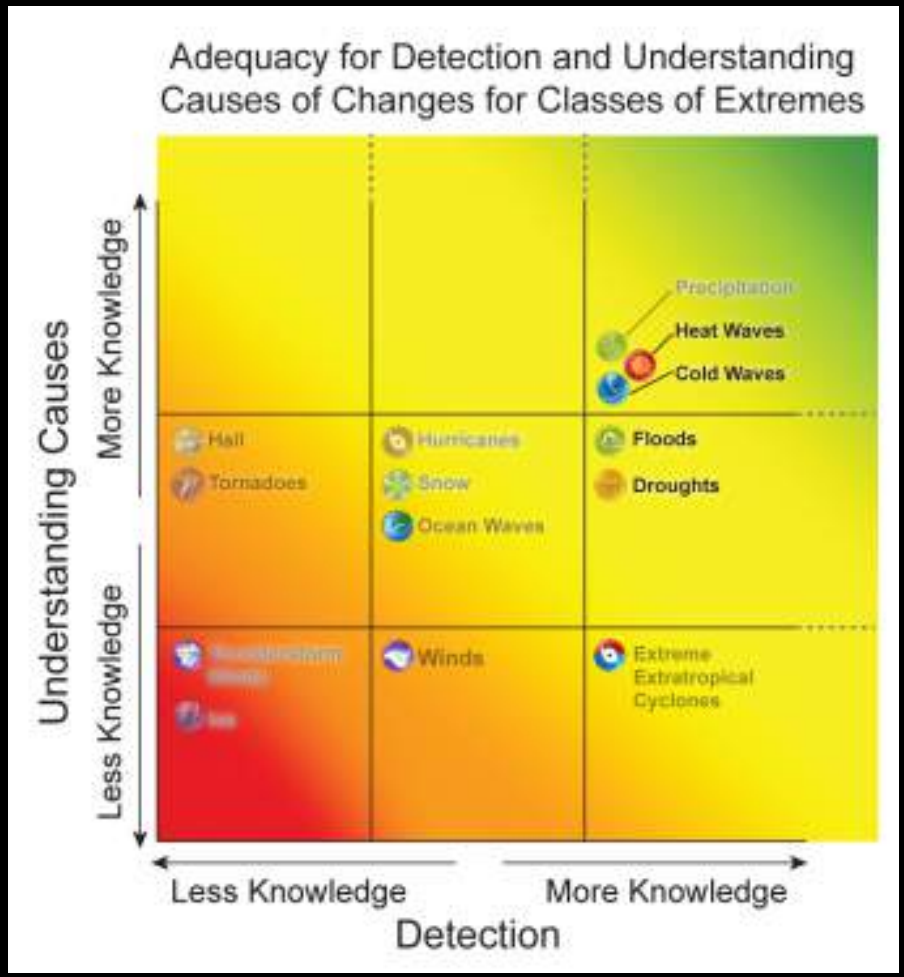
- Climate change



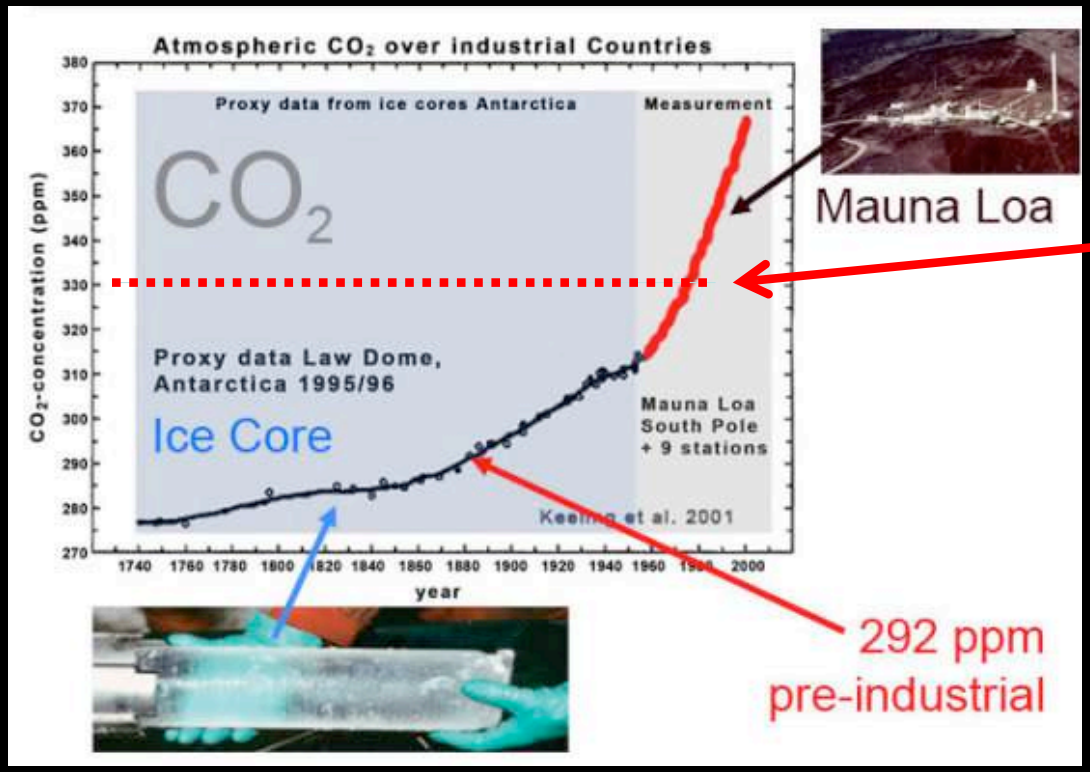
- Climate change: the problem of correlation and causation

- Climate change: the problem of averages and variation





How does biological diversity go extinct?



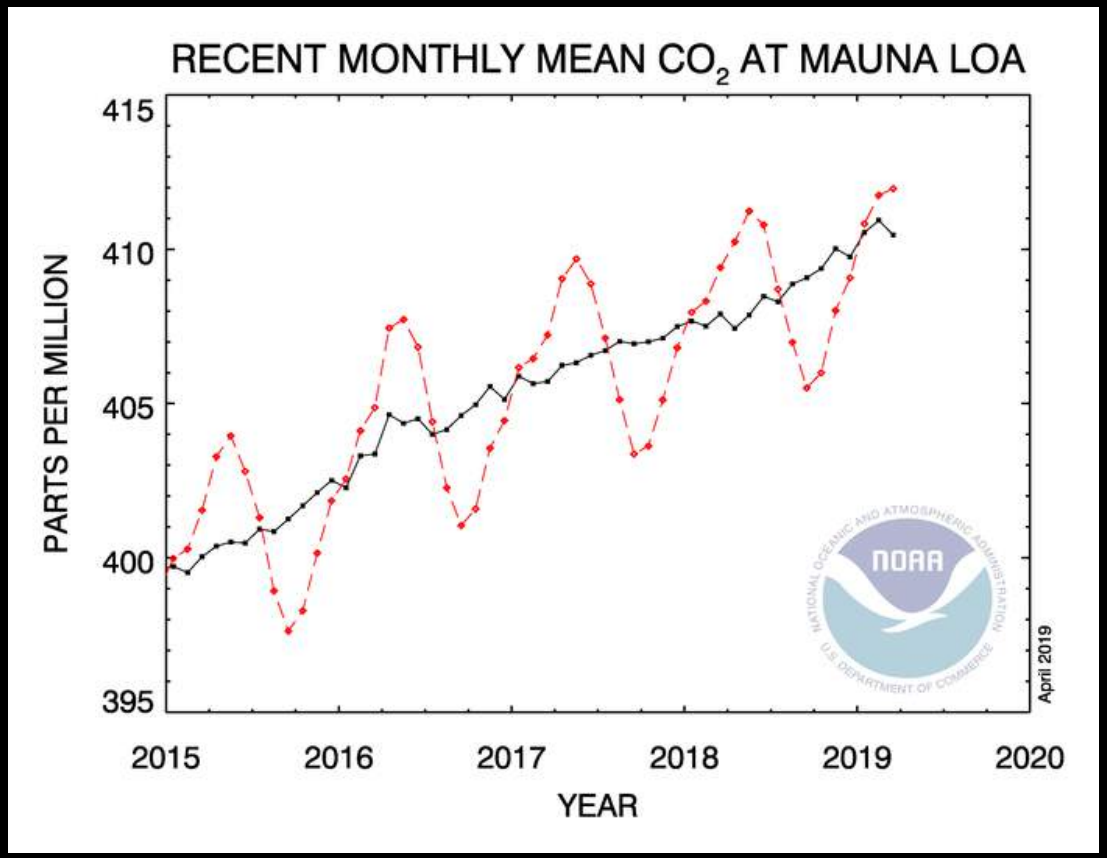
- Climate change

Highest CO_2 concentration in Pleistocene was 330 ppm

270 year CO_2 concentration increasing from 277 ppm to 370 ppm (2007)

Measured at top of Mauna Loa, Hawaii and in Antarctic ice

How does biological diversity go extinct?



Last 4 years' CO_2 concentration increasing from 400 ppm to 412 ppm

Measured at top of Mauna Loa

- Climate change

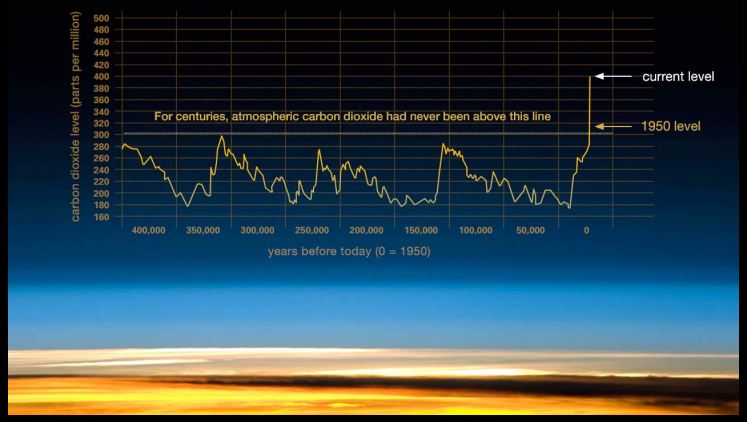
May 2, 2019 CO_2 concentration 414 ppm

How does biological diversity go extinct?

- Climate change

Pleistocene oscillations

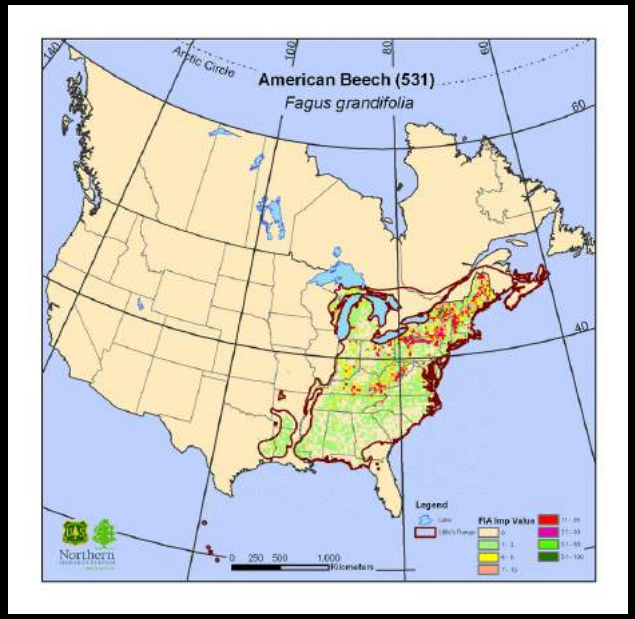
- Climate march – Saturday April 29, 2017



Future of Biogeography

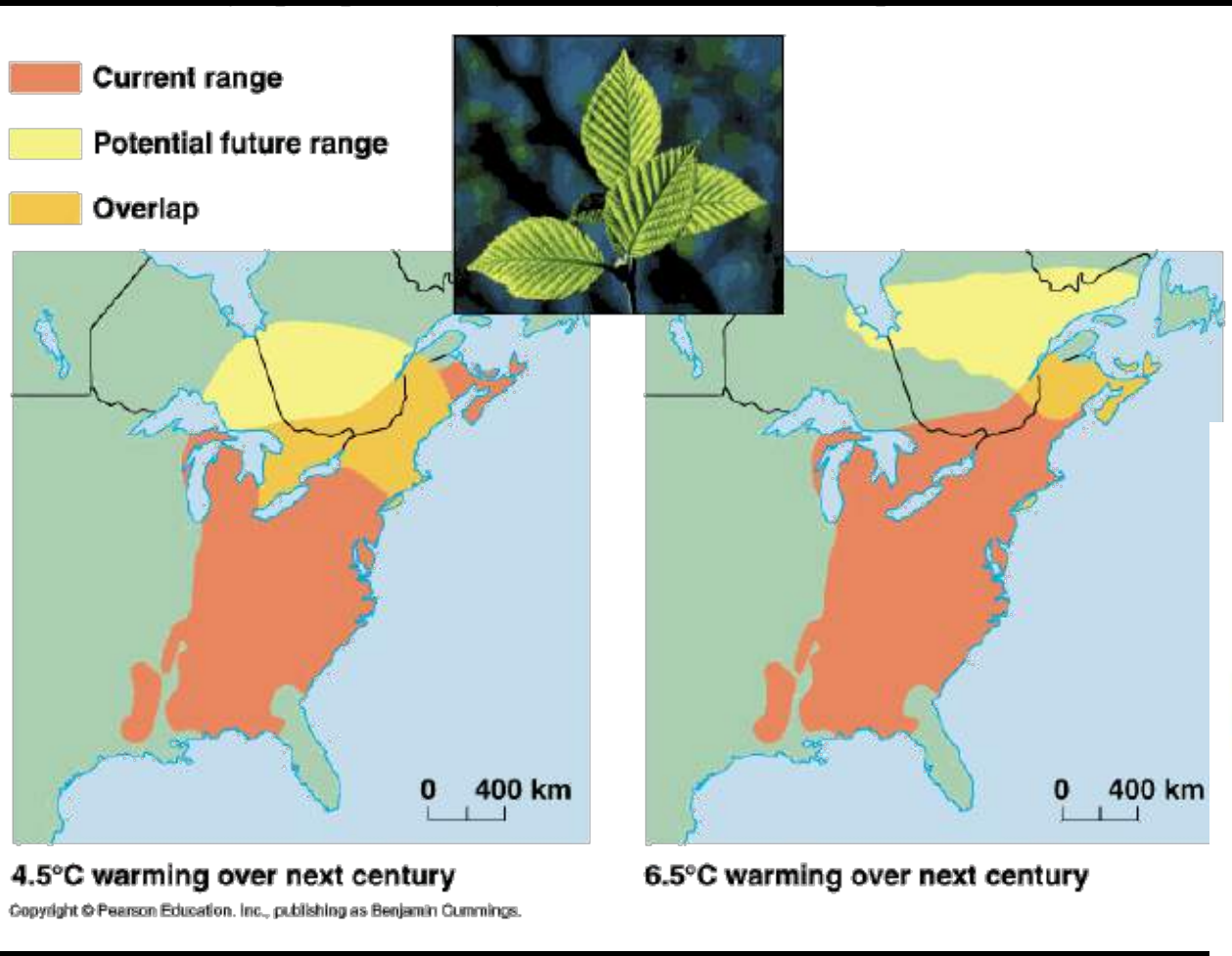
Consequences of climate change?

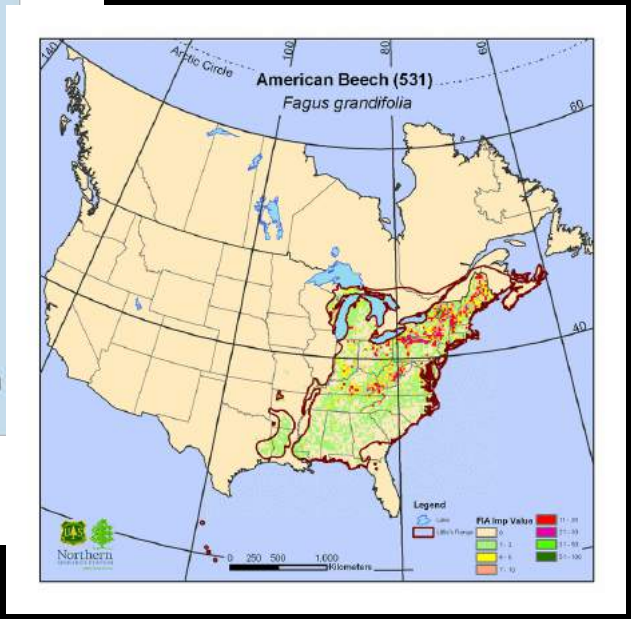
1. Vegetation shifts - the American beech model: what temperature effect with CO_2 doubling?



Fagus grandifolia
American beech

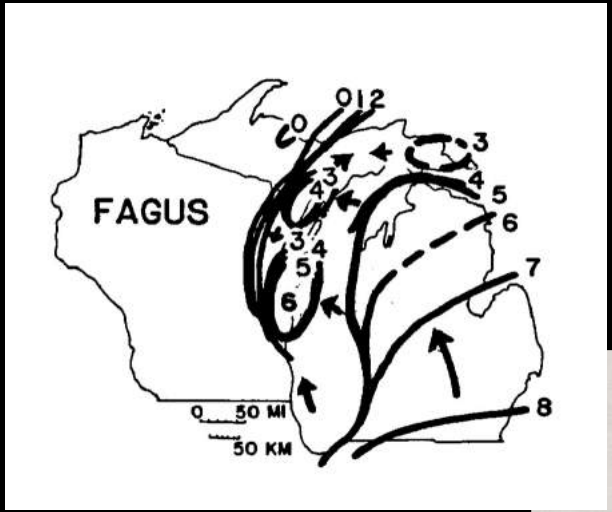
Future of Biogeography



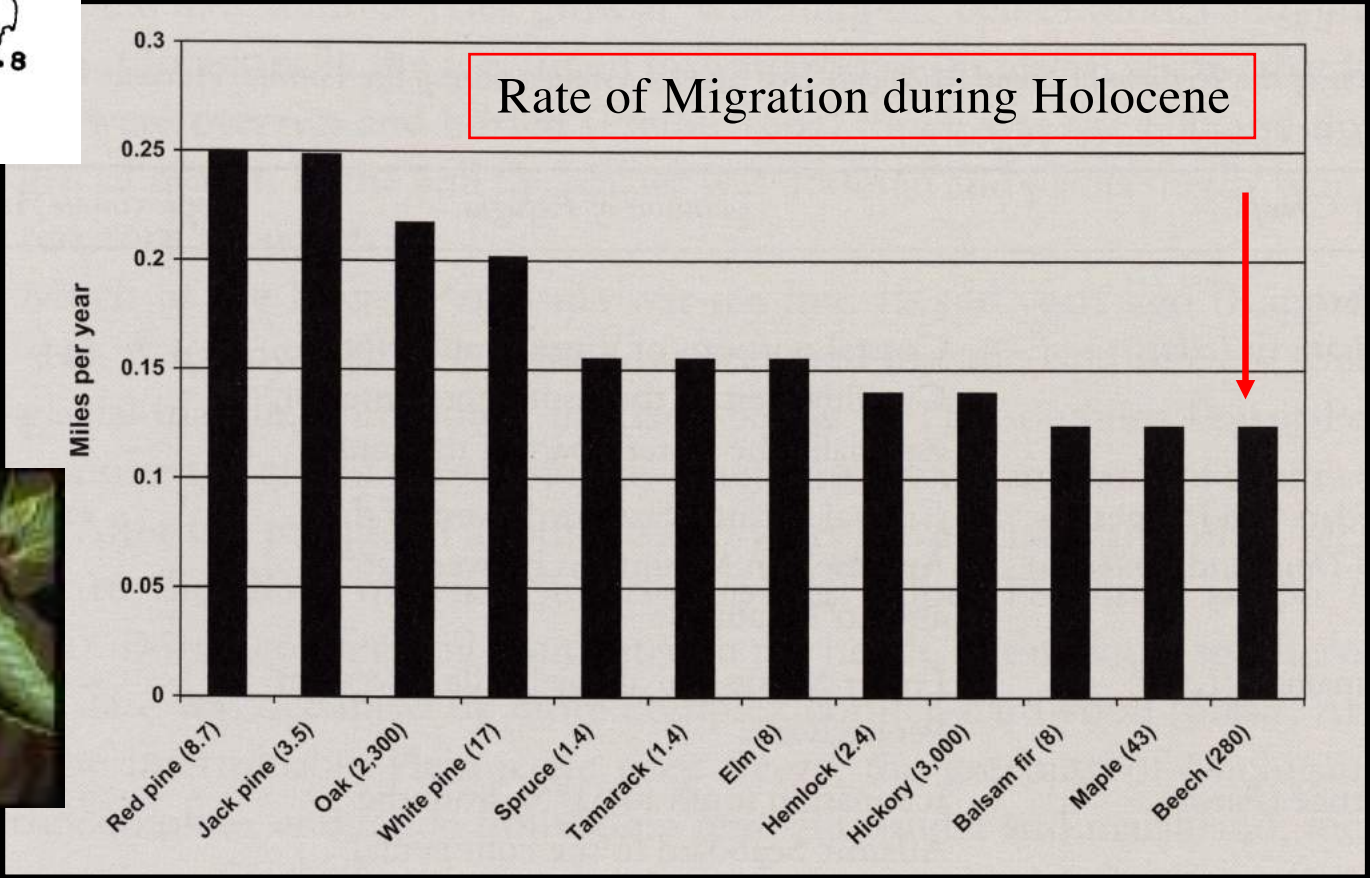


1989 *Science* paper based on doubling of CO_2

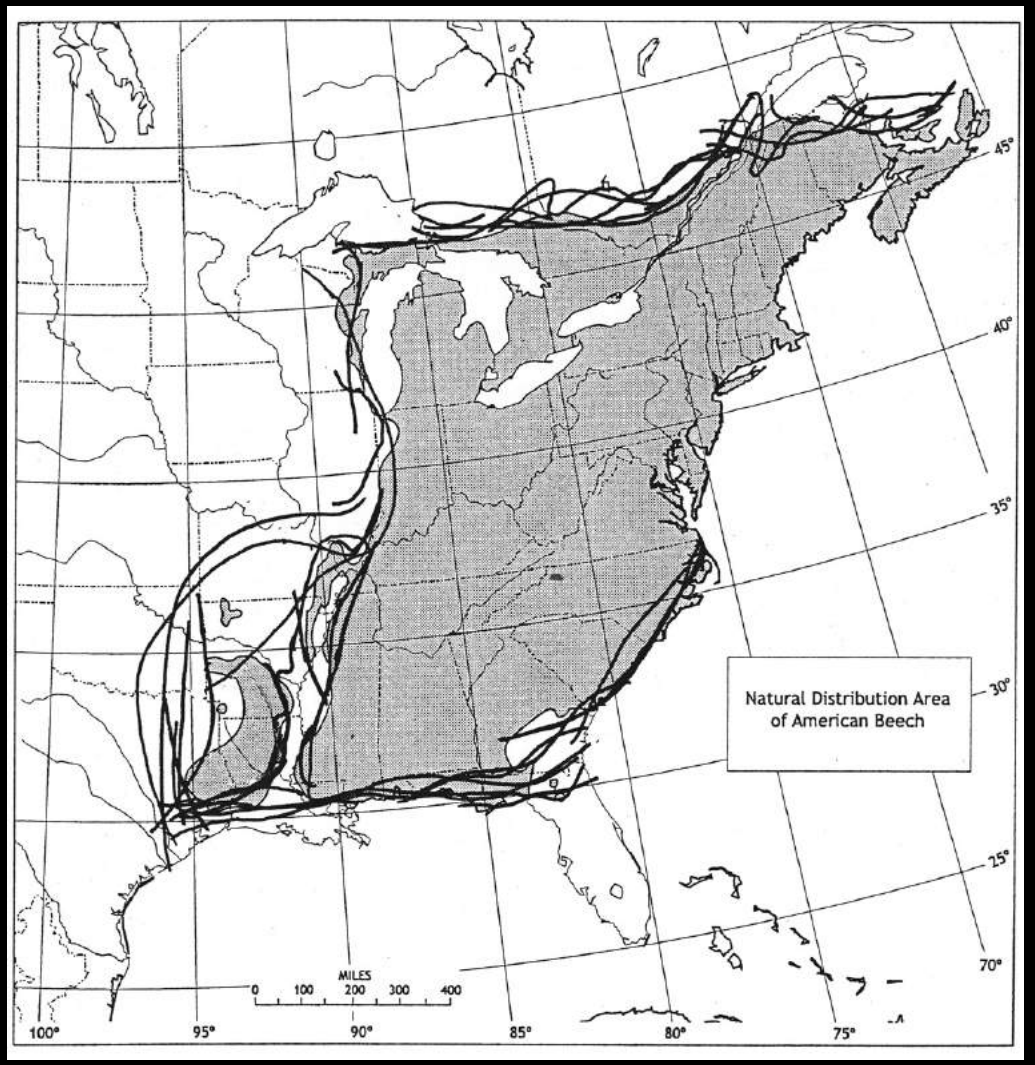
Future of Biogeography



- but American beech is a *very slow* migrater
- can it keep pace with the projected vegetation shift with global warming?



Future of Biogeography



Present distribution of American beech

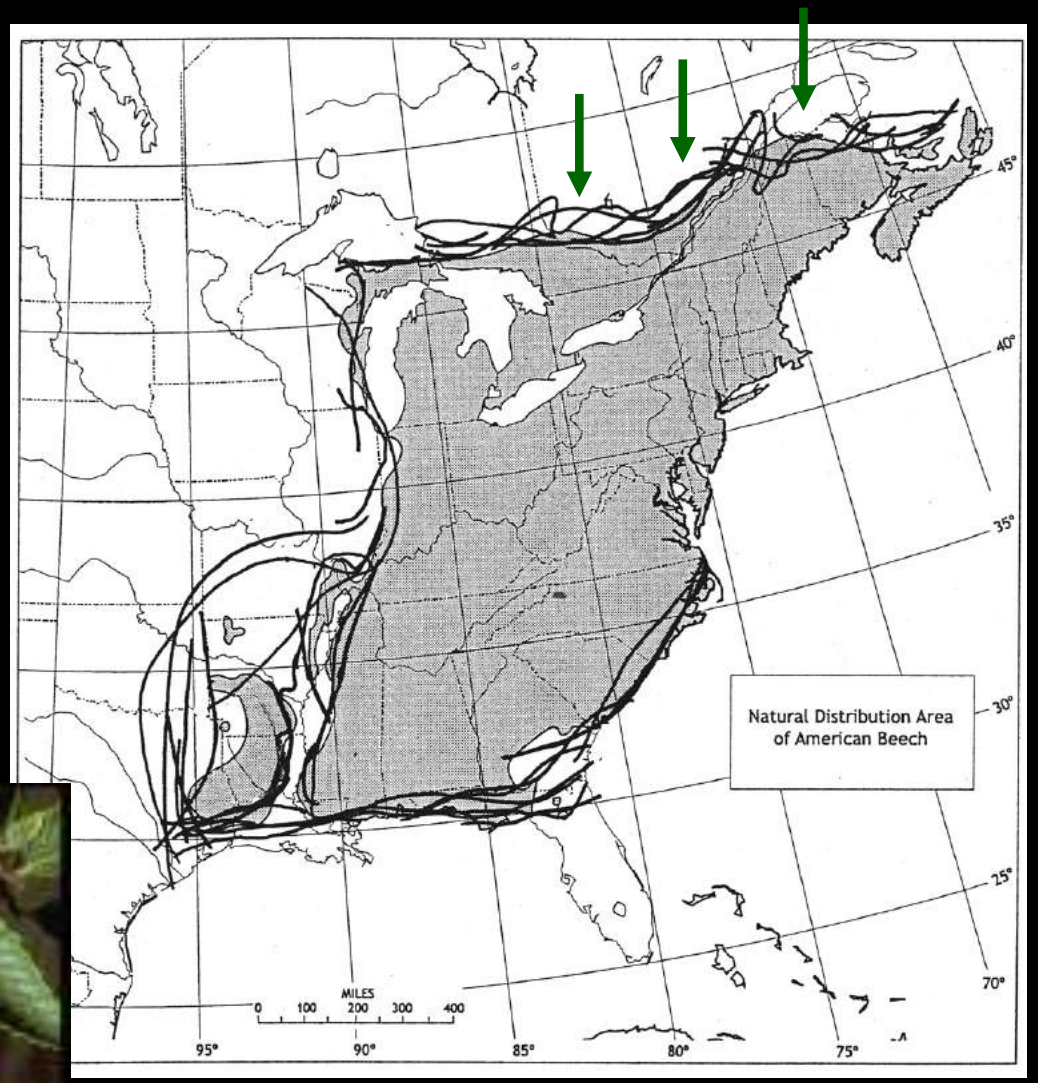
- a re-analysis by Karen Jankowski (2001)

Future of Biogeography

NORTH

annual temp range:58.5°F
growing degree days:1326
spring frost date: 6/1-6/5
fall frost date: 9/15
January temp: 10°F
July temp: 64°F
continentality: 50 to<60%
spring precip'n: 5"

min. recorded temp: -44°F
mean minimum temp: -40°F
growing season: 100 days
nights at/below 32°F: >180
actual evapotranspiration: 20"
mean annual precip'n: 30"
mean maximum temp: 90°F
mean annual temp: 40°F
mean annual snowfall: 100"
soils: podzols
soil climate:boréal/perhumid



Present distribution of American beech

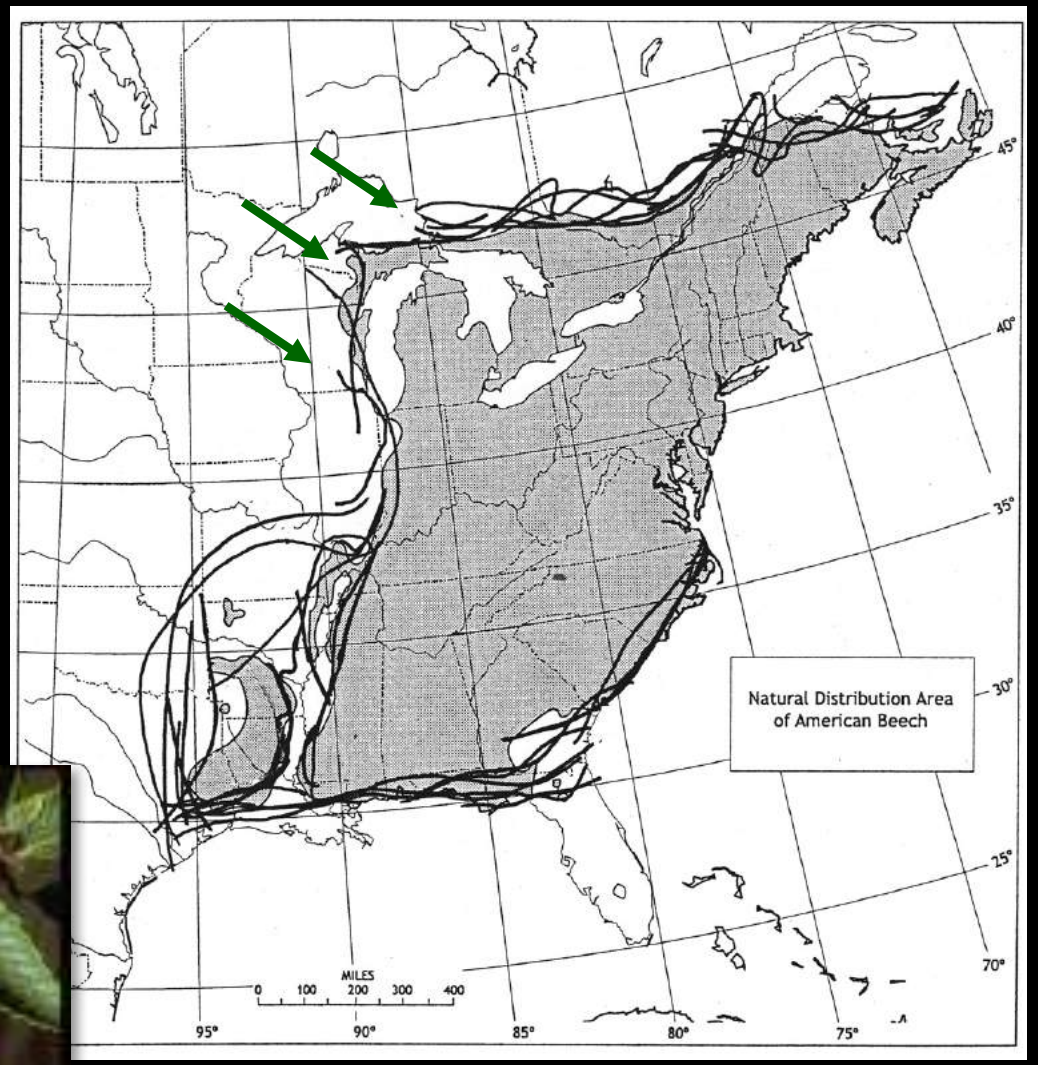
"climate envelope"

Future of Biogeography

NORTHWEST

min. recorded temp: -40°F
annual temp range:49.5-54°F
spring frost date: 6/1
continentality: 50%
days w/>.01" precip'n:120
mean min. temp.: -30°F

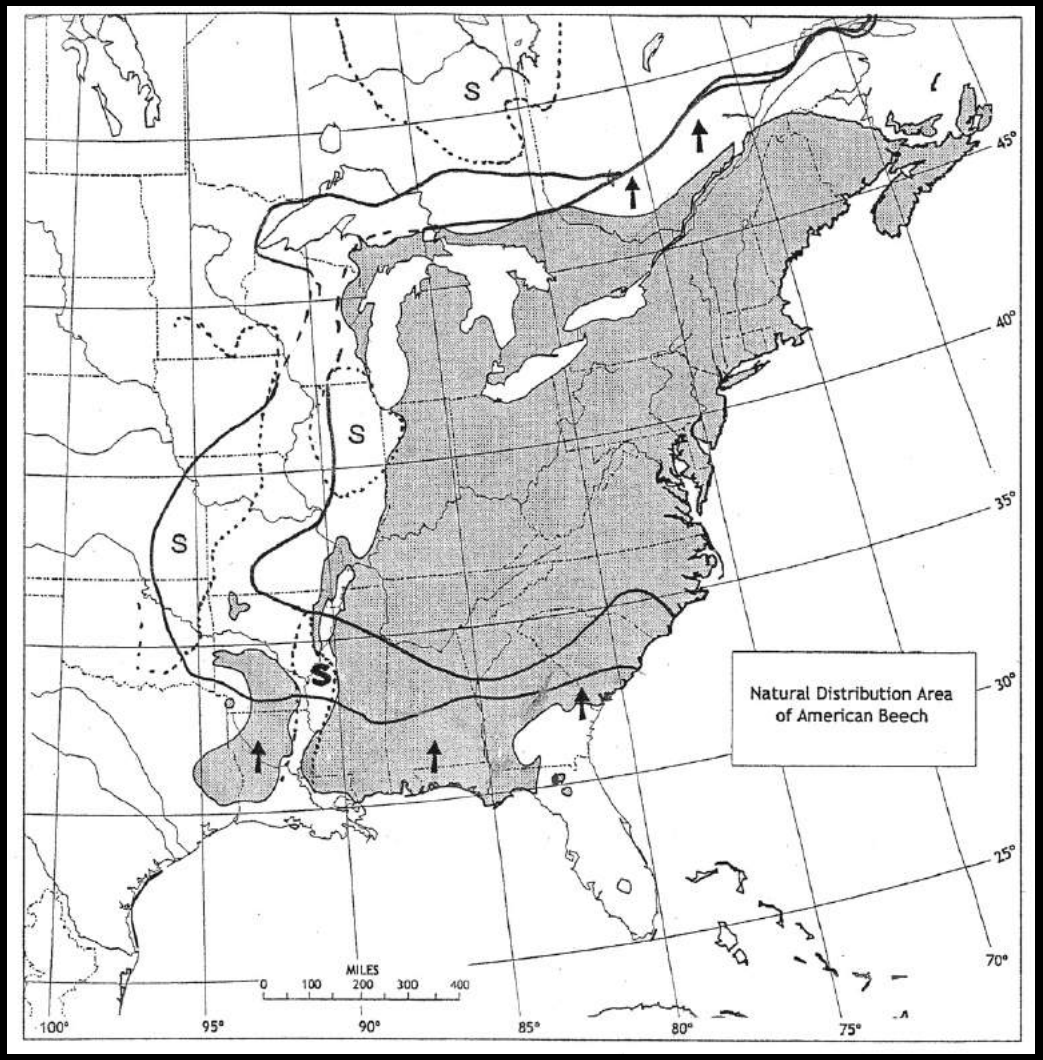
nights at/below 32°F: 180
mean January temp: 10º20°F
days with .25-.5" precip'n: 30-40
frequency of aridity: < 25%
mean annual precip'n: 30"
actual evapotranspiration:20-25"
moisture index: >1.0
mean annual temp: 40°F
(fall frost date: 9/15-10/1)
soils: podzols, luvisols
soil climate:boreal/humid



Present distribution of American beech

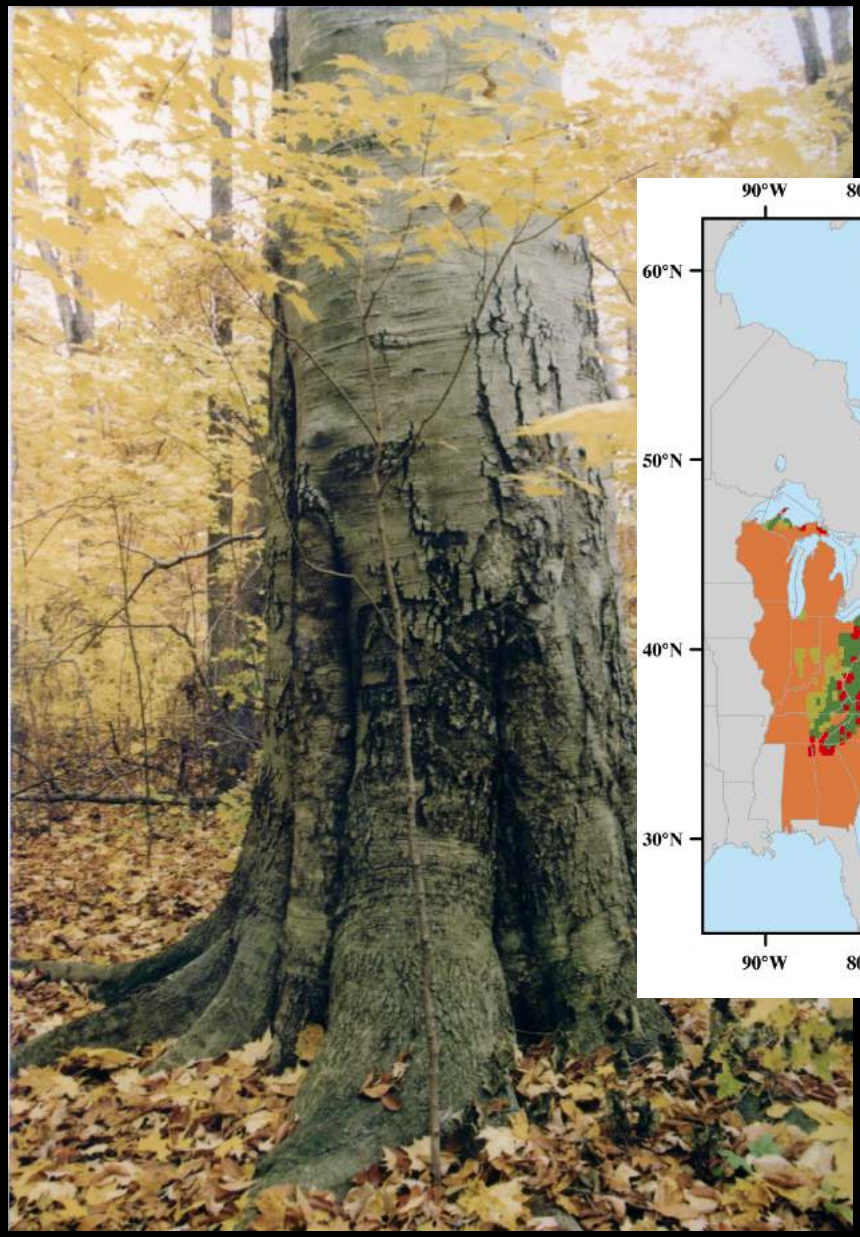
"climate envelope"

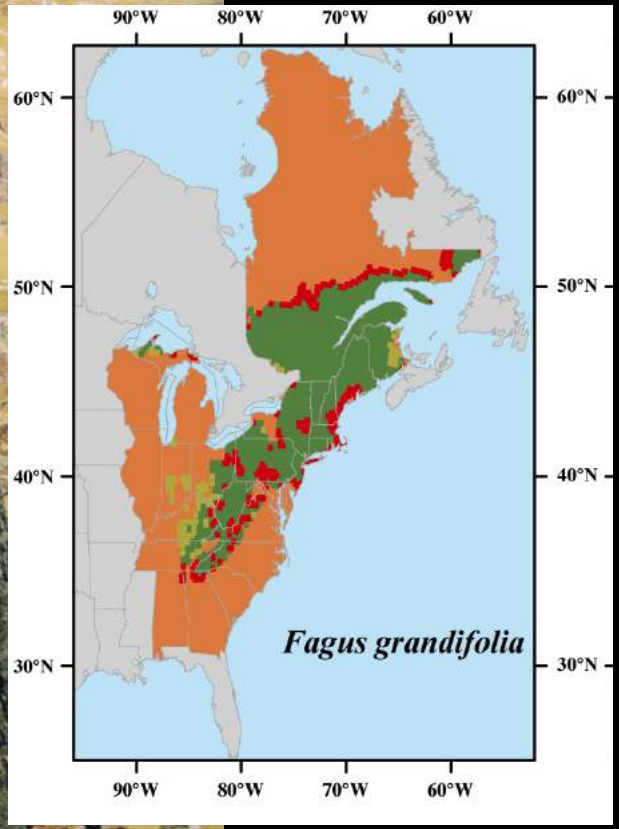
Future of Biogeography



Projected distribution of American beech based on its climate envelope and two models of global warming

Future of Biogeography





Both methods project a suitable climate

Both methods project an unsuitable climate

k-means method projects an unsuitable climate whereas the 27 scenarios project a suitable climate

k-means method projects a suitable climate whereas the 27 scenarios project an unsuitable climate

Casajus et al. 2016

Projected distribution of American beech based on its climate envelope and two models of global warming

Future of Biogeography

Epifagus virginiana

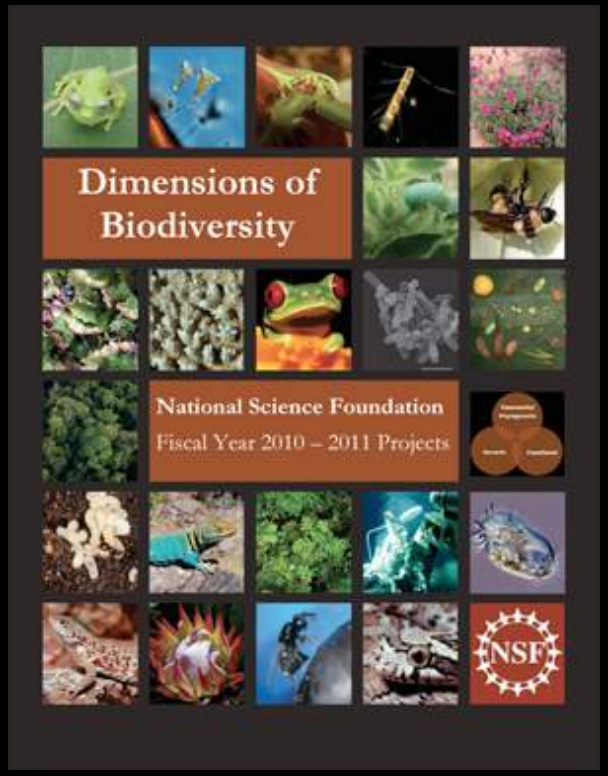
Beech drops

(root parasite only on American beech)

No matter what projection of beech distribution is invoked, whole vegetation units (and soil!) need to migrate.

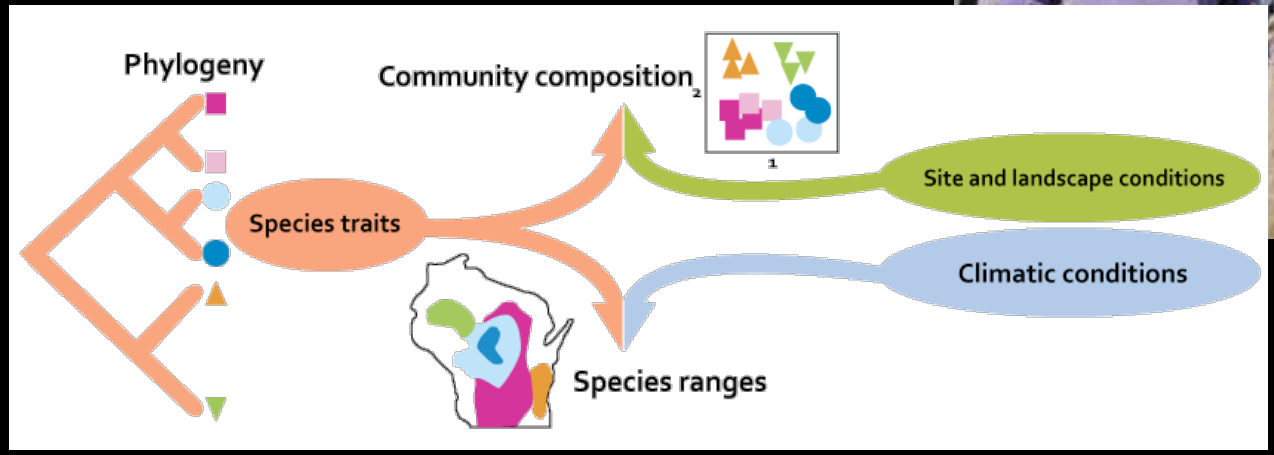
Beech drops must track beech migration or go extinct.

Future of Biogeography



Consequences of climate change?

2. Can Wisconsin flora shift with climate shifts?



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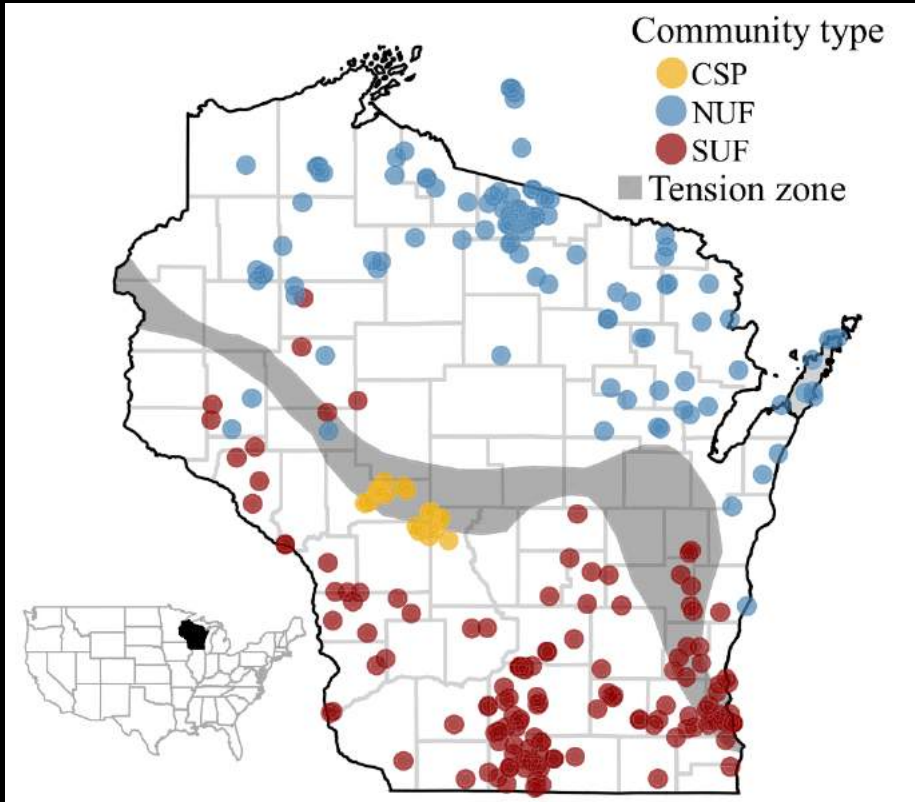
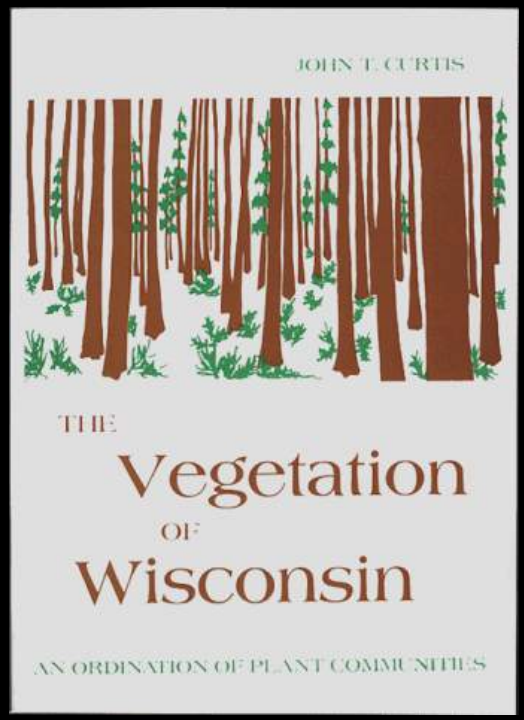


Fig. 1 Locations and community types of the 266 sites resampled across Wisconsin. Sites are colored by community types: northern upland forest (NUF), southern upland forest (SUF), and pine barrens of the central sand plains (CSP). The historical location of the tension zone designated by Curtis (1959) is shown in gray.

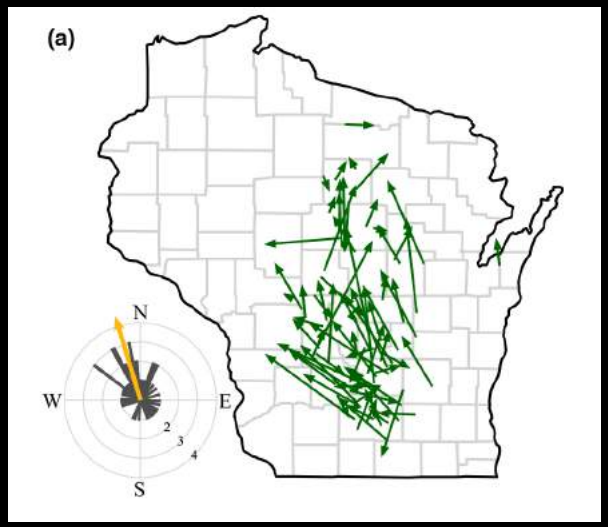
Consequences of climate change?

2. Can Wisconsin flora shift with climate shifts?

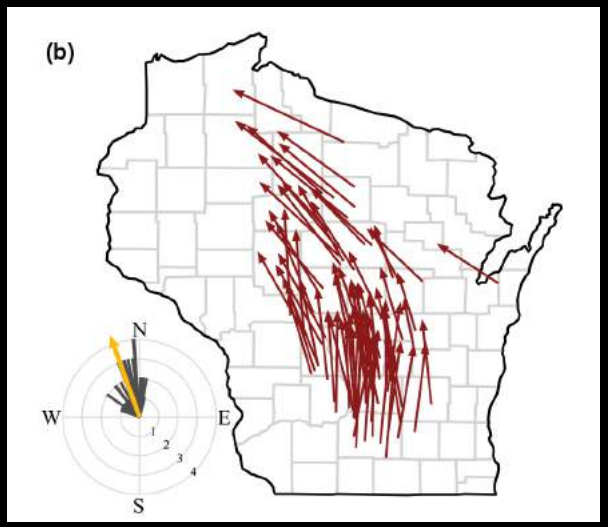


Ash et al. 2017 – Tracking lags in historical plant species' shifts in relation to regional climate change

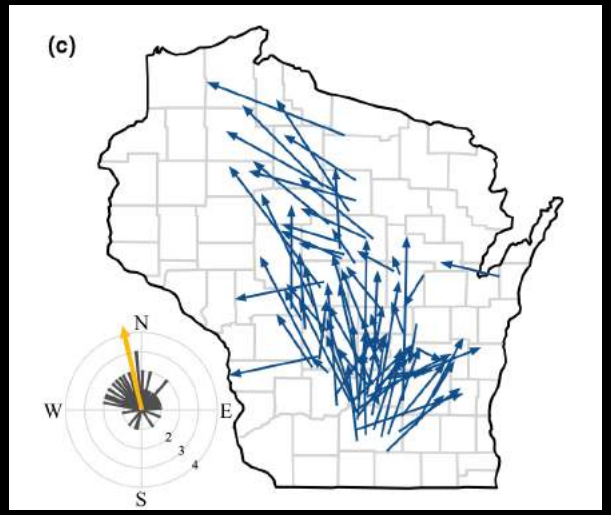
Future of Biogeography



Shifts in 78 species' distributions from 1950s – 2000s



Shifts in climate envelope of 78 species from 1950s – 2000s



Lag in geographic shift relative to climate shift of 78 species

Ash et al. 2017 – Tracking lags in historical plant species' shifts in relation to regional climate change

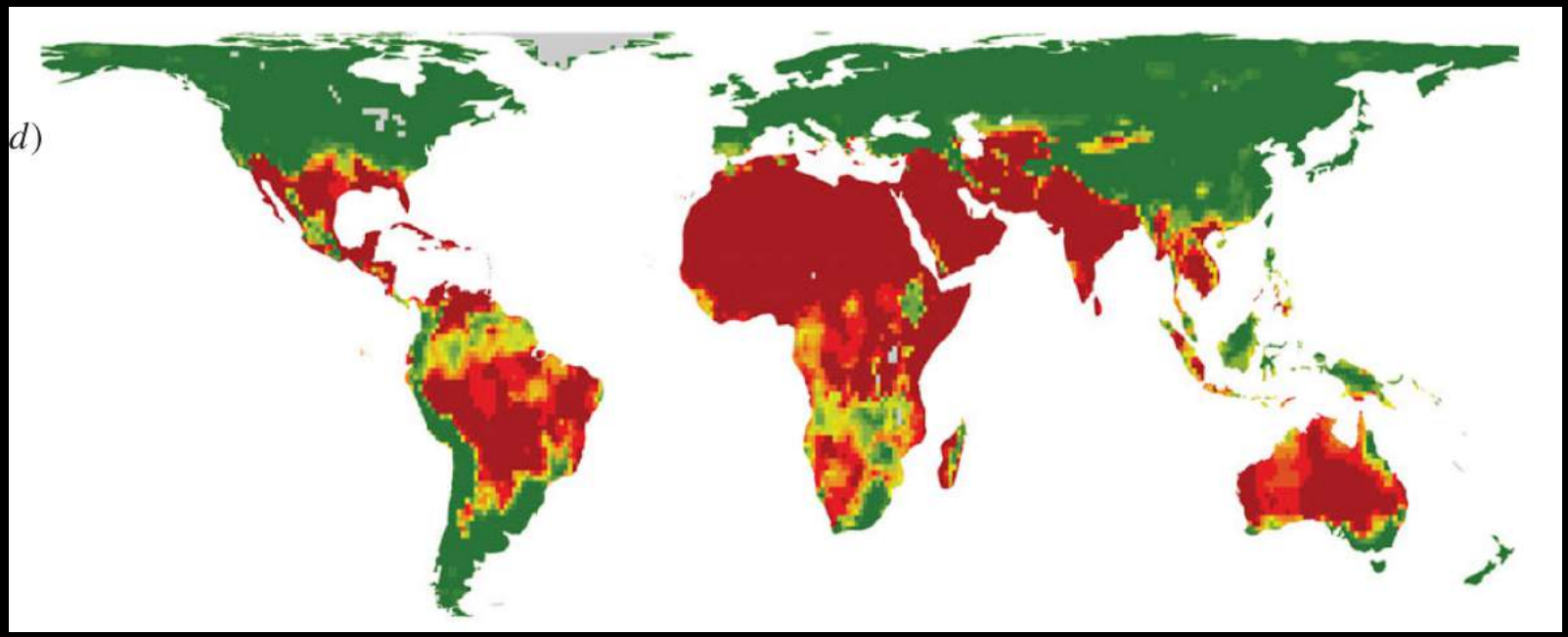
Future of Biogeography

Congruence Across All Models
Capacity for Species Richness to:

- Increase
- Decrease

Consequences of climate change?

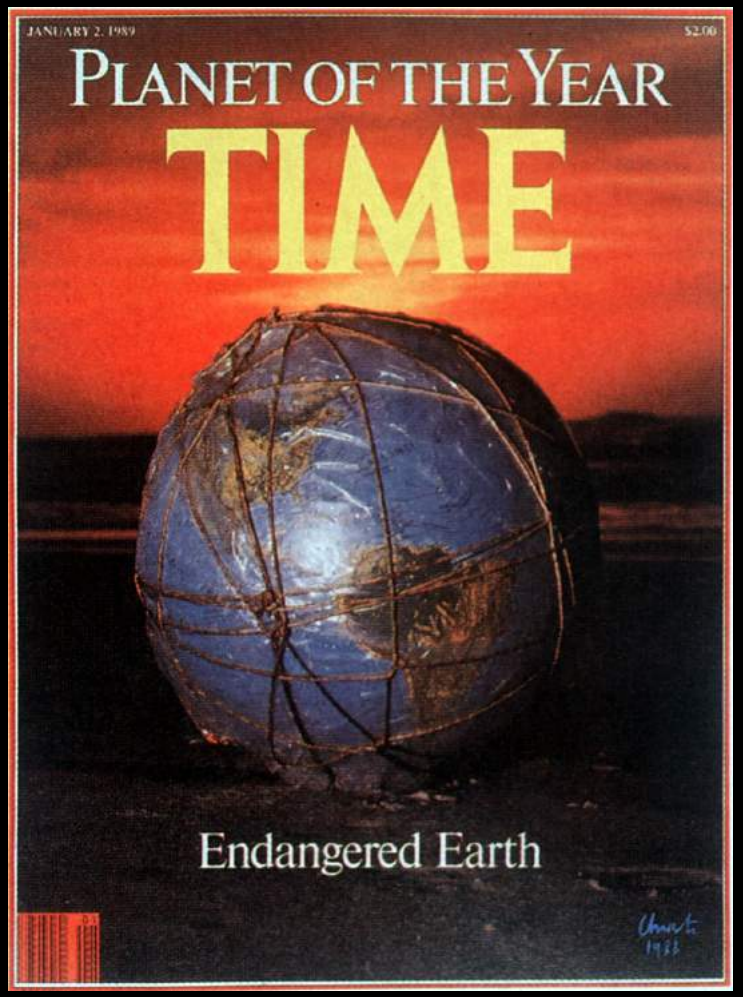
3. Global biodiversity loss



Sommer et al. 2010 – Projected impacts of climate change on regional capacities for global plant species richness

Where do we go from here?

Time Magazine in 1989 labelled our Earth - "Planet of the Year" - the endangered earth



and, in the 30 years since, it has become increasingly so.

Is It Too Late?

Lisianthius habuenis Sytsma

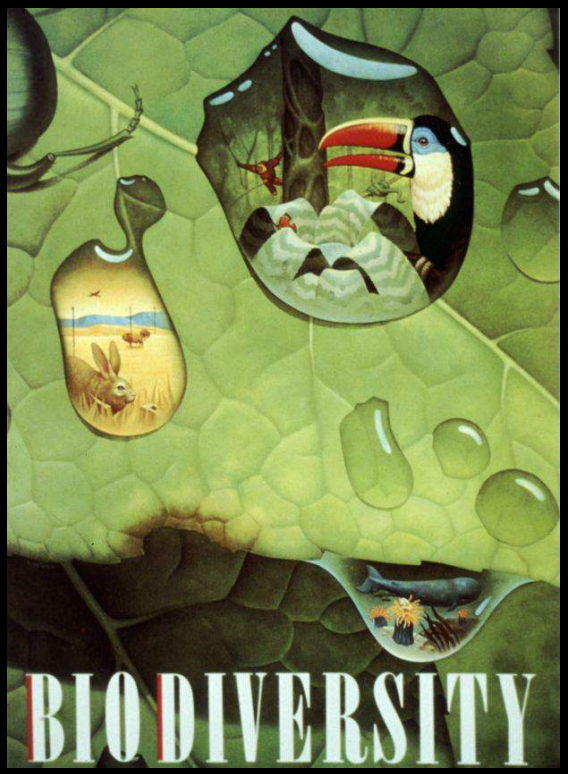
Science

Ethics

Praxis

"What then must we do?"

Where do we go from here?



"For better or worse, we find ourselves charged with responsibility for a gigantic, dispersed Noah's ark; what we do next will determine what can be saved. Will we act as responsible stewards of the many organisms that share the Earth with us?"

P.H. Raven and G. Prance in *Save the Earth*

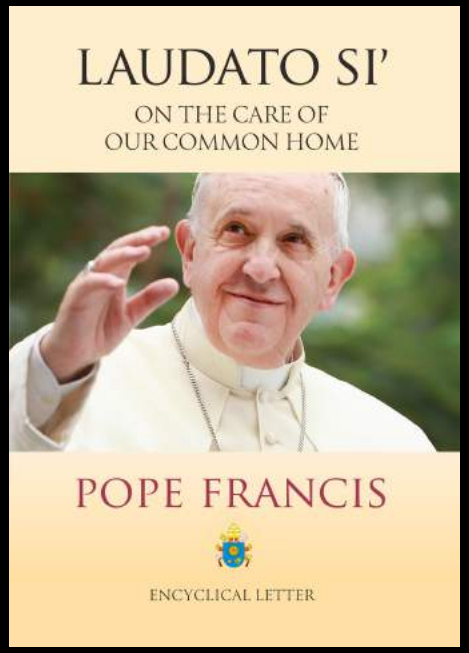
Where do we go from here?

We need a new generation of the "conservation voice"

Rachel Carson

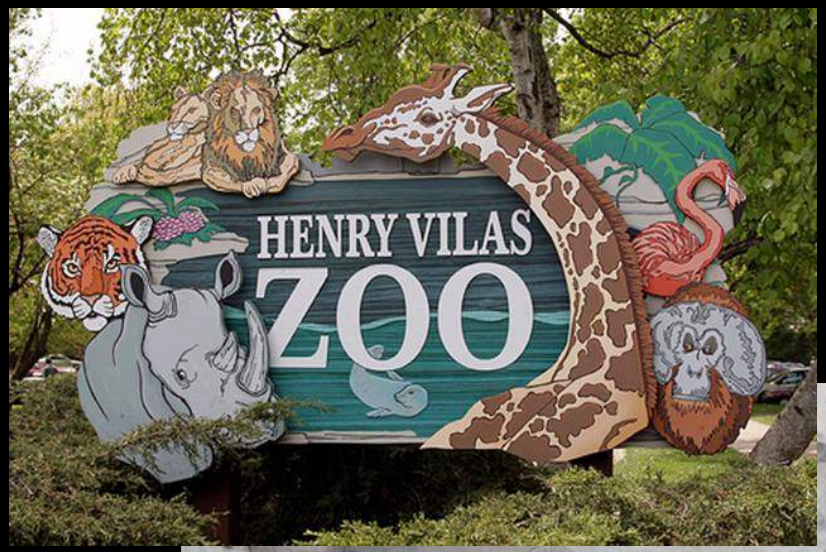
E. O. Wilson

Peter Raven



Pope Francis

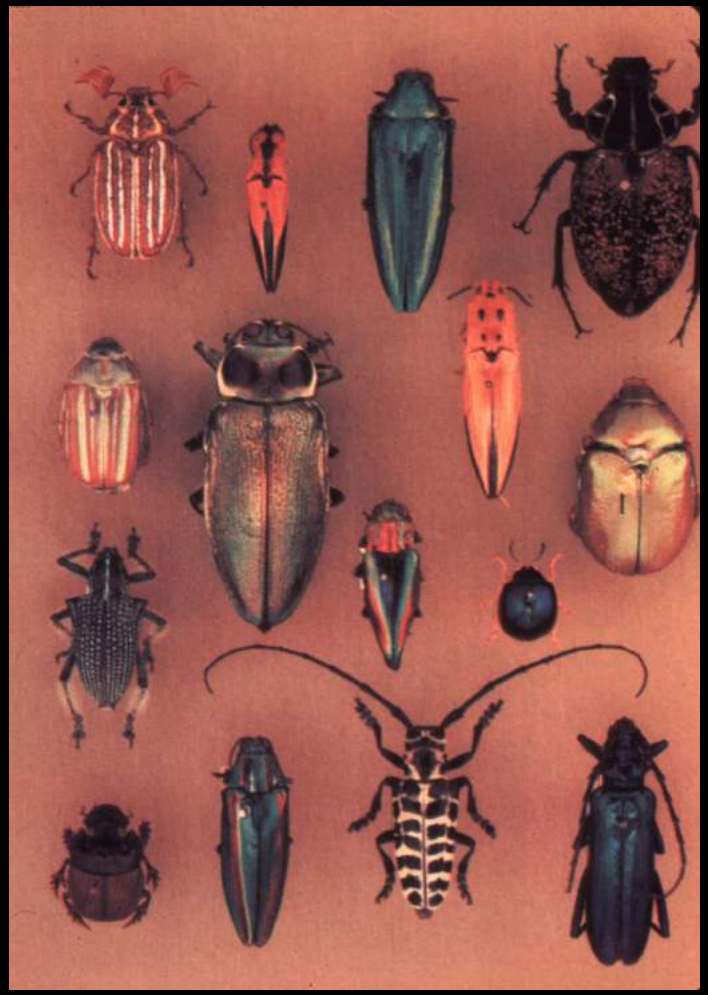
Where do we go from here?



The future of our biota? . . .

Zoological parks & Botanical gardens

Where do we go from here?



Or only this? - museums and herbaria