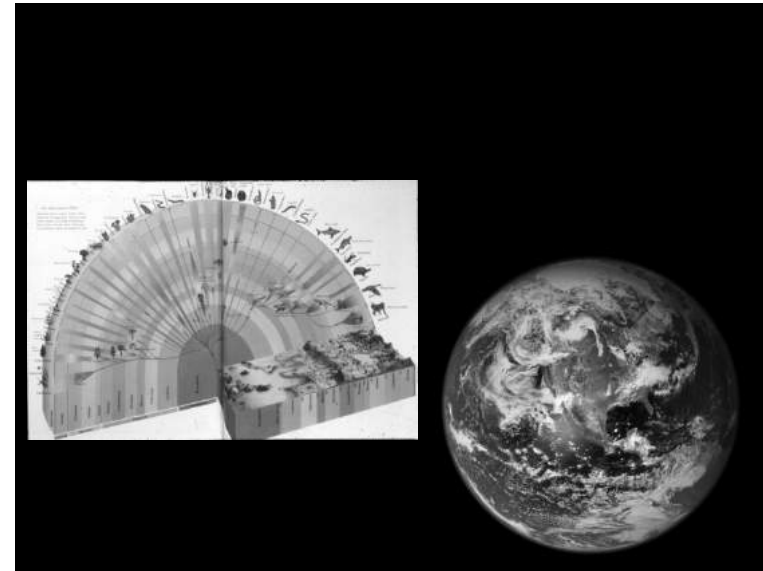


Future of Biogeography ... a global view



The Problem



Lisianthus habuenis Sytma 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



Lisianthus habuenis Sytma 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?



Lisianthus habuenis Sytsma sp. nov.



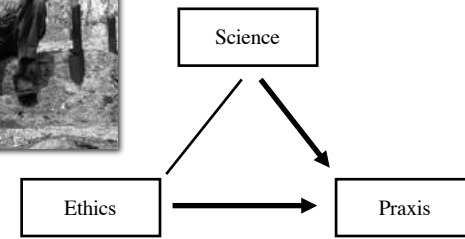
- What should our response then be? How should we then act?

Addressing the Problem



Cal DeWitt
Institute Environmental Studies
University of Wisconsin

"How does the world work?"



"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:

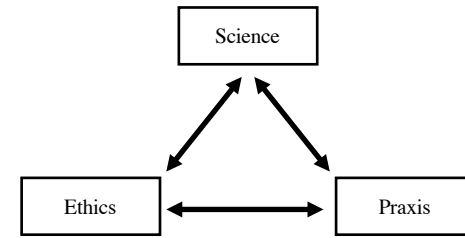
"Diversity is God's property, and we, who bear the relationship to it of strangers and sojourners, have no right to destroy it."
D.W. Ehrenfeld, 1988



Addressing the Problem

Biological Diversity

"How does the world work?"

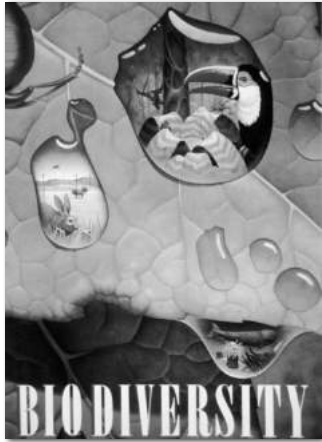


"What is right?"

"What then must we do?"

Addressing the Problem

Biological Diversity

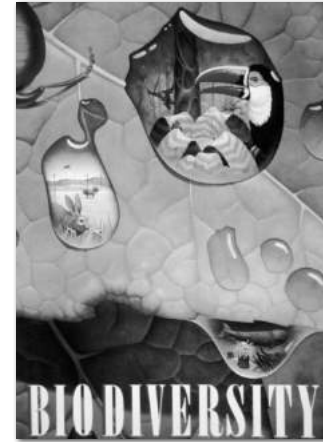


"How does the world work?"

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, 4×10^5 flowering plants



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

How much biological diversity is there?

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



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



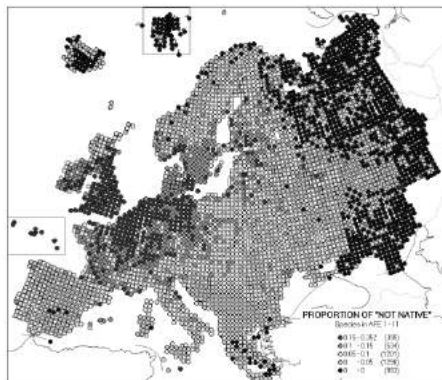
How does biological diversity go extinct?



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

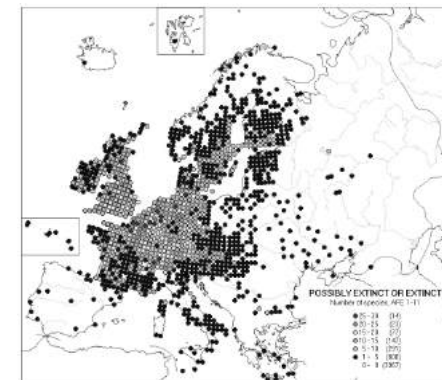
How does biological diversity go extinct?

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



How does biological diversity go extinct?

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



How does biological diversity go extinct?

- Habitat fragmentation



Midwest oak savanna



Chicago wet prairies

How does biological diversity go extinct?

- Habitat fragmentation



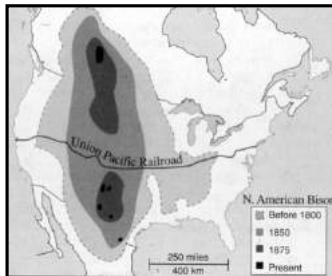
South Florida coastal scrub



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

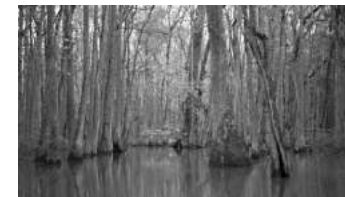
How does biological diversity go extinct?



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

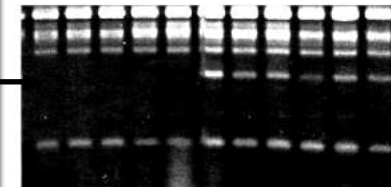


Figure 1. Photo showing the polymorphism at 530 bp produced in the ILL population of *Agalinus skinneriana* using primer AB-26. Lanes 1-5 represent ILL individuals, Lanes 6-10 are individuals from CHL-ZILC and Lane 11 is an individual from HPP.

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?

- Climate change

"IN HIS BOOK, *WORLDS IN THE MAKING*, ARRHENIUS FIRST DESCRIBES THE "HOT-HOUSE" THEORY OF THE ATMOSPHERE."



Svante Arrhenius
1859-1927

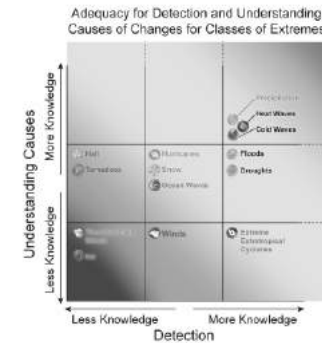
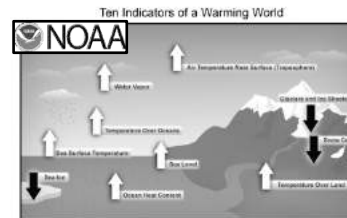
"ARRHENIUS ARGUED THAT VARIATIONS IN TRACE ATMOSPHERIC CONSTITUENTS COULD INFLUENCE THE EARTH'S HEAT BUDGET."



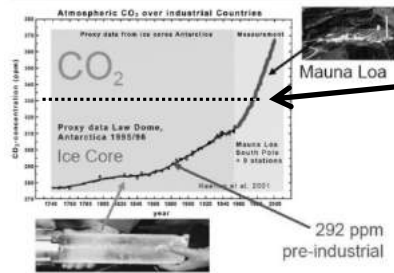
- Climate change: the problem of correlation and causation



- Climate change: the problem of averages and variation



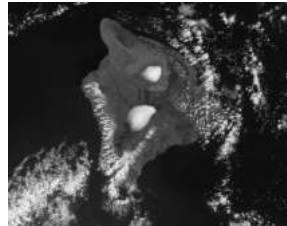
How does biological diversity go extinct?



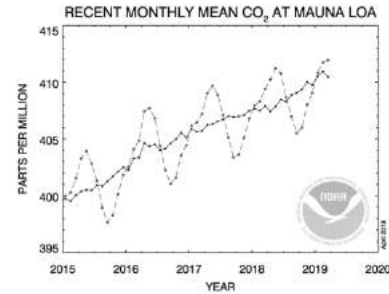
- Climate change
- Highest CO₂ concentration in Pleistocene was 330 ppm

270 year CO₂ 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?

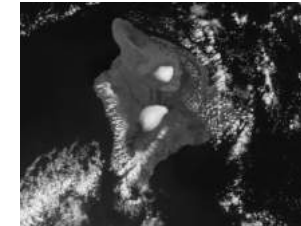


- Climate change

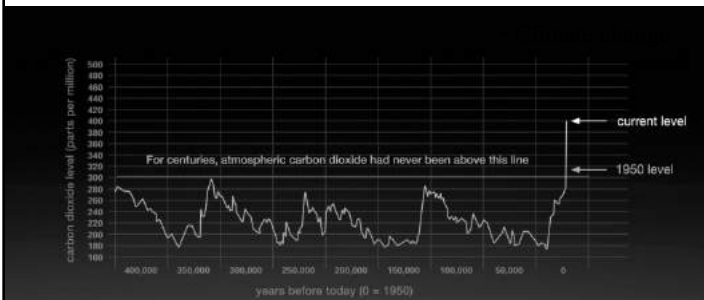
May 2, 2019 CO₂ concentration 414 ppm

Last 4 years' CO₂ concentration increasing from 400 ppm to 412 ppm

Measured at top of Mauna Loa

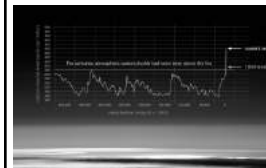


How does biological diversity go extinct?



Pleistocene oscillations

- Climate march – Saturday April 29, 2017



Future of Biogeography



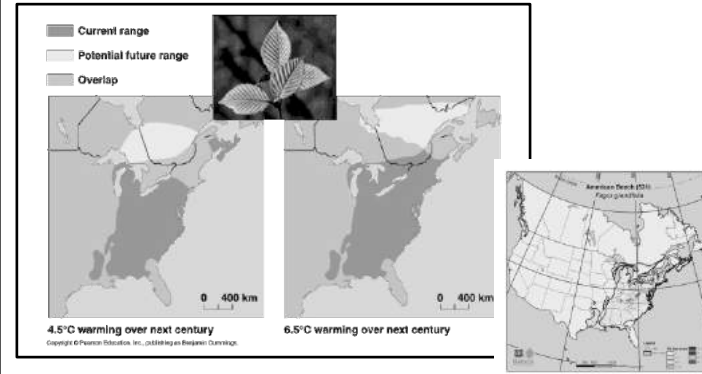
Consequences of climate change?

1. Vegetation shifts - the American beech model: what temperature effect with CO₂ doubling?



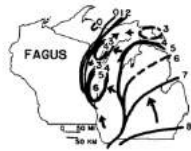
Fagus grandifolia
American beech

Future of Biogeography

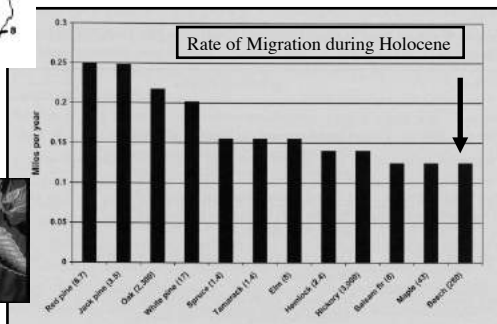


1989 *Science* paper based on doubling of CO₂

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

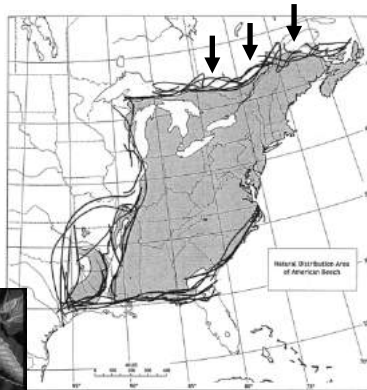


Present distribution of American beech

- a re-analysis by Karen Jankowski (2001)

Future of Biogeography

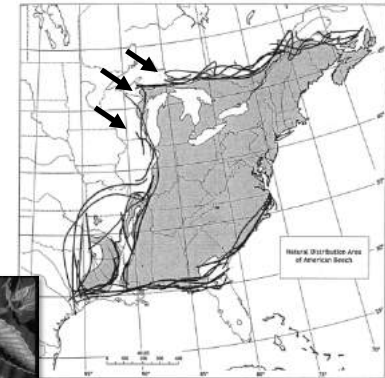
NORTH
 annual temp range: 58.5°F
 growing degree days: 1326
 spring frost date: 6/1-6/5
 fall frost date: 9/15
 January temp: 10°F
 July temp: 64°F
 continentality: 50 to <60%
 spring precip'n: 5"
 min. recorded temp: -44°F
 mean minimum temp: -40°F
 growing season: 100 days
 nights at/below 32°F: >180
 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: boreal/temperate



Present distribution of American beech
 "climate envelope"

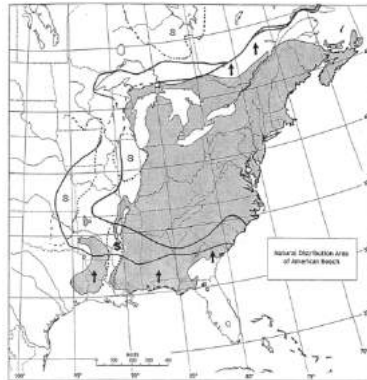
Future of Biogeography

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: 30-30°F
 days with >.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



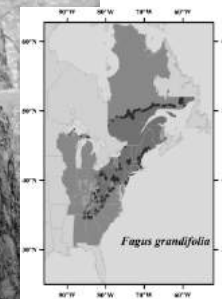
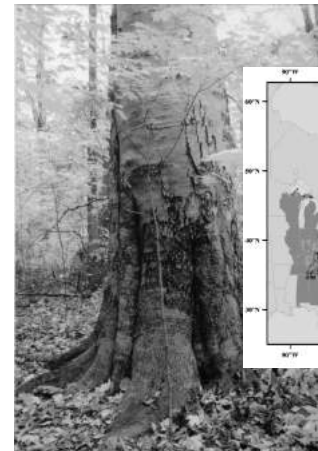
Present distribution of American beech
 "climate envelope"

Future of Biogeography



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

Future of Biogeography



Legend:
 - Both methods project a suitable climate
 - Both methods project an unsuitable climate
 - 6-scenario method projects an unsuitable climate whereas the 27-scenarios project a suitable climate
 - 6-scenario 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

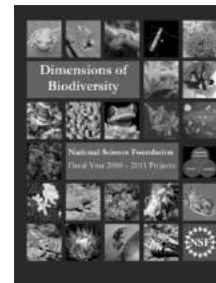


Epifagus virginiana
Beech drops
(root parasite only on American beech)

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

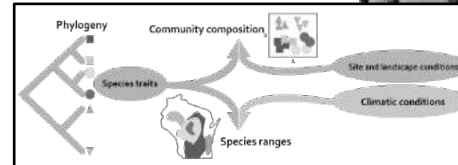
Beech drops must track beech migration or go extinct.

Future of Biogeography



Consequences of climate change?

2. Can Wisconsin flora shift with climate shifts?



Future of Biogeography

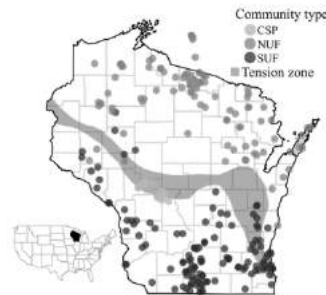
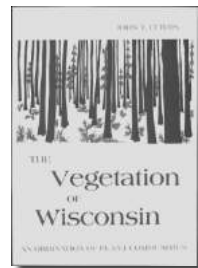


Fig. 1 Locations and community types of the 266 sites resampled across Wisconsin. Sites are colored by community types: northern upland forest (NUF), southern upland forest (SUF), and pine barrens of the central sand plains (CSP). The historical location of the tension zone designated by Curtis (1959)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

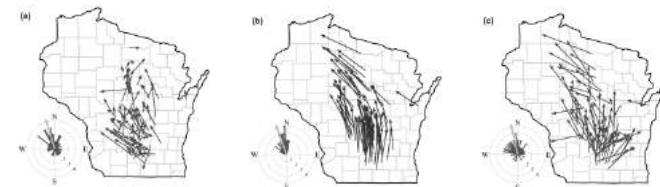
Consequences of climate change?

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

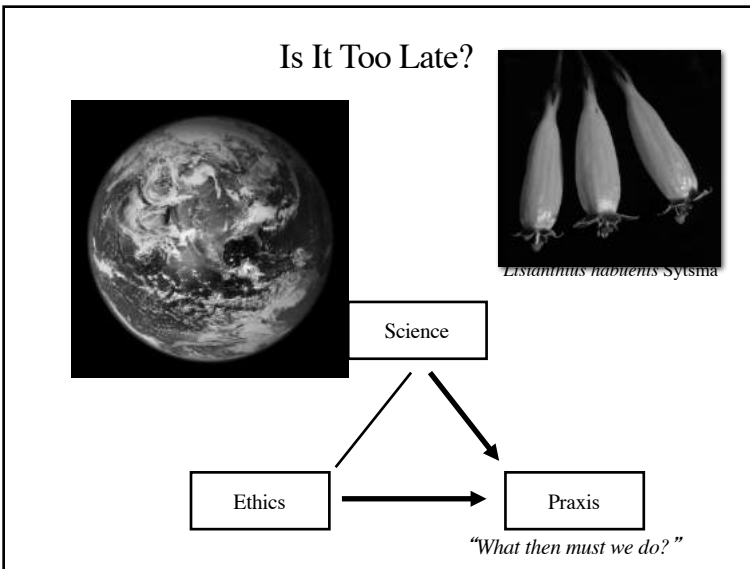
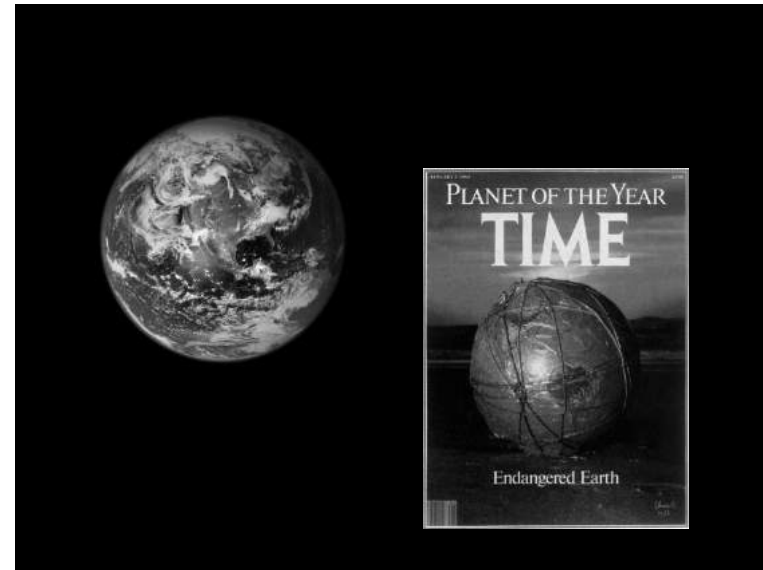
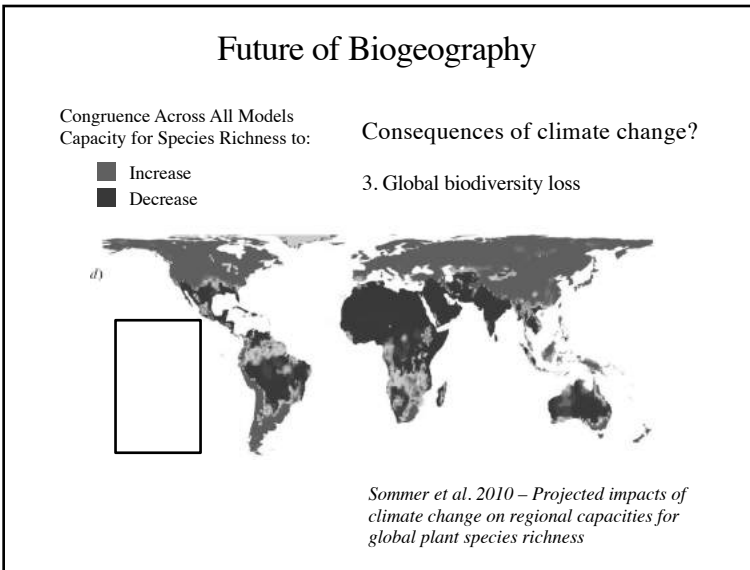


(a) Shifts in 78 species' distributions from 1950s – 2000s

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

(c) 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





Where do we go from here?

The future of our biota? . . .

A collage of images related to zoological parks and botanical gardens. It includes a sign for Henry Vilas Zoo, a garden scene with a pond, a scene with a gazebo, and a scene with a sign for Henry Cabot Lodge.

Zoological parks & Botanical gardens

