

Life is a gloss on geography. And if you dig your fists into the earth and crumble geography, you strike geology. Climate is the wind of mineral earth's rondure, tilt and orbit modified by local geological conditions. The Pacific Ocean, the Negev Desert, and the rain forest in Brazil are local geological conditions. So are the slow carp pools and splashing trout riffles of any backyard creek. It is all, God help us, a matter of rocks.

The rocks shape life like hands around swelling dough. In Virginia, the salamanders vary from mountain ridge to mountain ridge, so do the fiddle tunes the old men play... These are not merely anomalous details. This is what life is all about: salamanders, fiddle tunes, you and me and things... No mountains and one salamander, one fiddle tune, would be a lesser world. No continents, no fiddlers. No possum, no soup, no taters. The earth without form, is void...

-- Annie Dillard, *Life on the rocks* (1982)

# Conserving Nature's Stage: Using geodiversity as a coarse-filter conservation strategy

Paul Beier



Geodiversity = diversity of edaphic, topographic, and related abiotic characteristics

8 June 2016



*Conservation Biology*. June 2015  
**Special Section: Conserving Nature's Stage**  
*(9 papers & editorial)*

# Conserving Nature's Stage: Using geodiversity as a coarse-filter conservation strategy

Part I: What is biodiversity, and why do we need coarse-filter strategies to conserve it?

Part II: Geodiversity is a good coarse-filter surrogate for biodiversity

Part III: Using Conserving Nature's Stage (geodiversity) in conservation planning

*Time for discussion after each part – or ask a question any time!*

# Biodiversity is the variety of life on earth...

Biodiversity includes

- species
- genetic diversity within species
- species interactions (competition, predation, and other things a zoo cannot provide),
- ecological processes (local extinction & recolonization, disturbance regimes such as fire)
- the evolutionary processes that generate new life

# Conservation means keeping all this stuff around...

- **species**
- genetic diversity within species
- species interactions (competition, predation, and other things a zoo cannot provide),
- ecological processes (local extinction & recolonization, disturbance regimes such as fire)
- the evolutionary processes that generate new life

But today I will focus on **species**, because the first rule of intelligent tinkering is to save all the parts (A. Leopold).

Part I: Biodiversity & coarse-filter strategies to conserve it<sup>6</sup>

# Conservation of biodiversity starts with conserving every species (keeping all the parts)

**Fine filter conservation:** directly trying to conserve individual species, e.g., Recovery Plans for species listed under the Endangered Species Act.



Fine-filter conservation would be our only strategy if we had perfect knowledge, but we don't even know where species are.

Taxon	# species	# (%) named	# (%) w/range maps <sup>a</sup>
Vertebrates	60,000	59,000 (98%)	40,000 (66%)
Arthropods	9 million	1 million (9%)	19,000 (0.2%)
Fungi	616,000	44,000 (7%)	50 (0.008%)
Plants	315,000	224,000 (71%)	21,000 (7%)

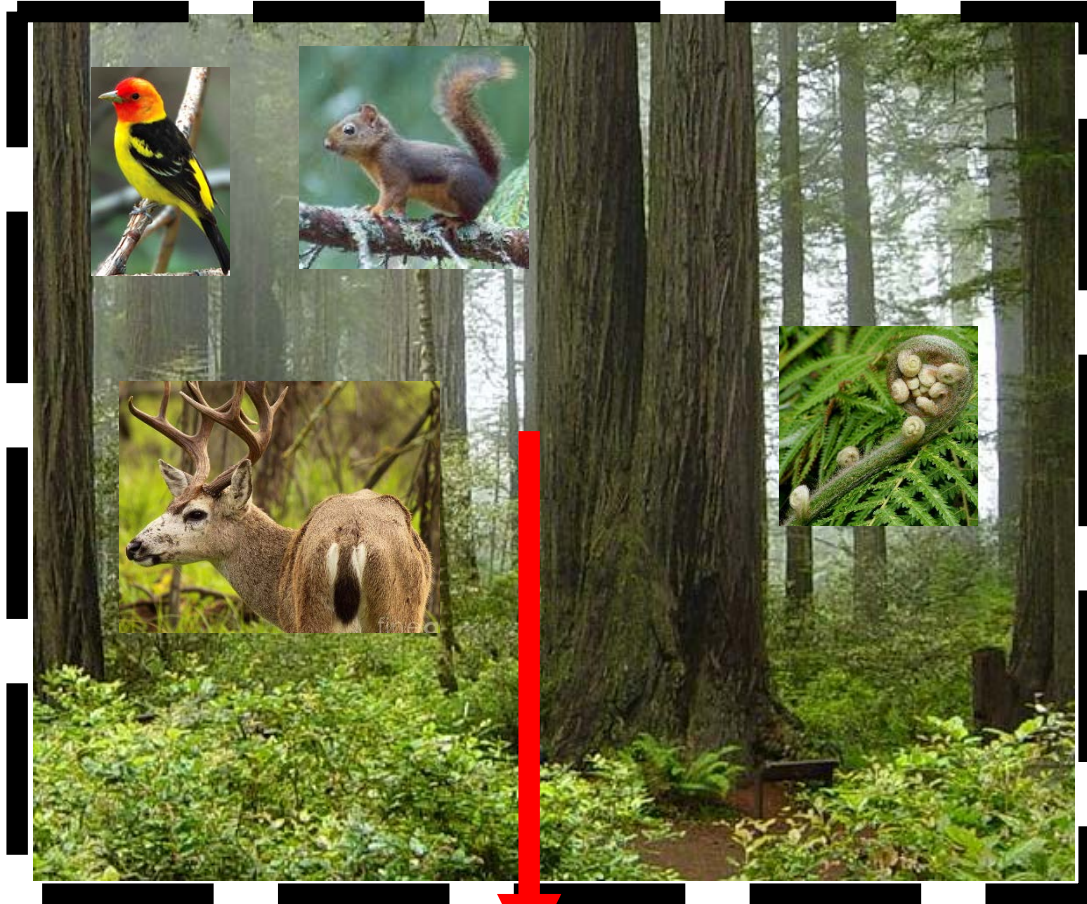
Mora et al. 2011 PLOS Biology

<sup>a</sup> A species occurs < **40%** of sites within its mapped range (Hurlbert & White 2005, Ecology Letters 8:319). **Range maps (Swiss cheese with 60% holes) do not really tell us where species occur.**

Part I: Biodiversity & coarse-filter strategies to conserve it<sup>8</sup>

# Coarse-filter conservation

e.g, TNC  
ecoregional  
plans aim to  
conserve  
10% to  
100% of  
each  
vegetation  
community.



The goal of  
the shortcut  
is to  
conserve  
(most)  
**species.**

**Coarse filter** is  
guaranteed to  
fail to conserve  
some species.

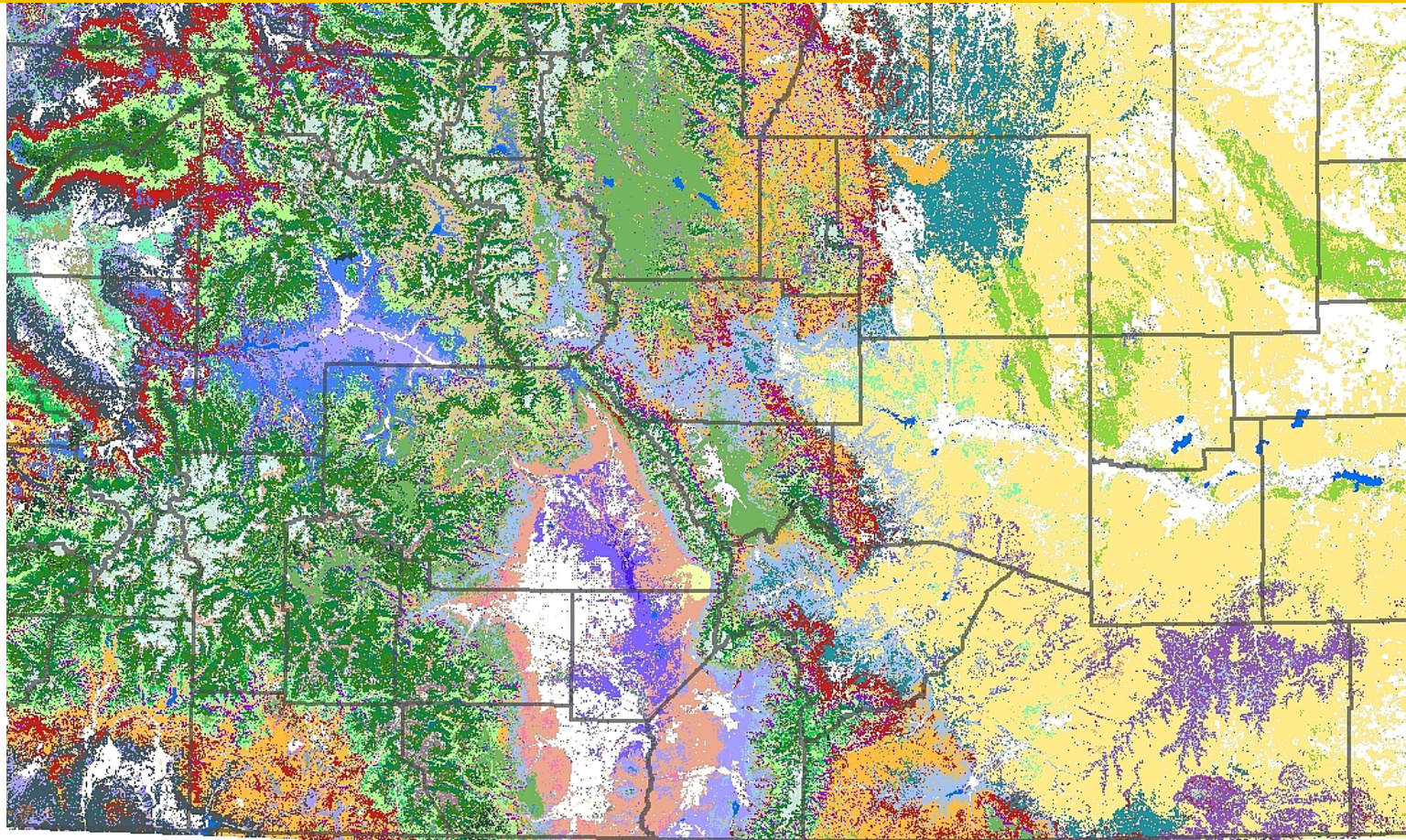
Photo: Michael Schweppe  
<http://www.flickr.com/photos/schweppe/21556590/>,



Part I: Biodiversity & coarse-filter strategies to conserve it<sup>9</sup>

# Our current coarse-filters = vegetation communities

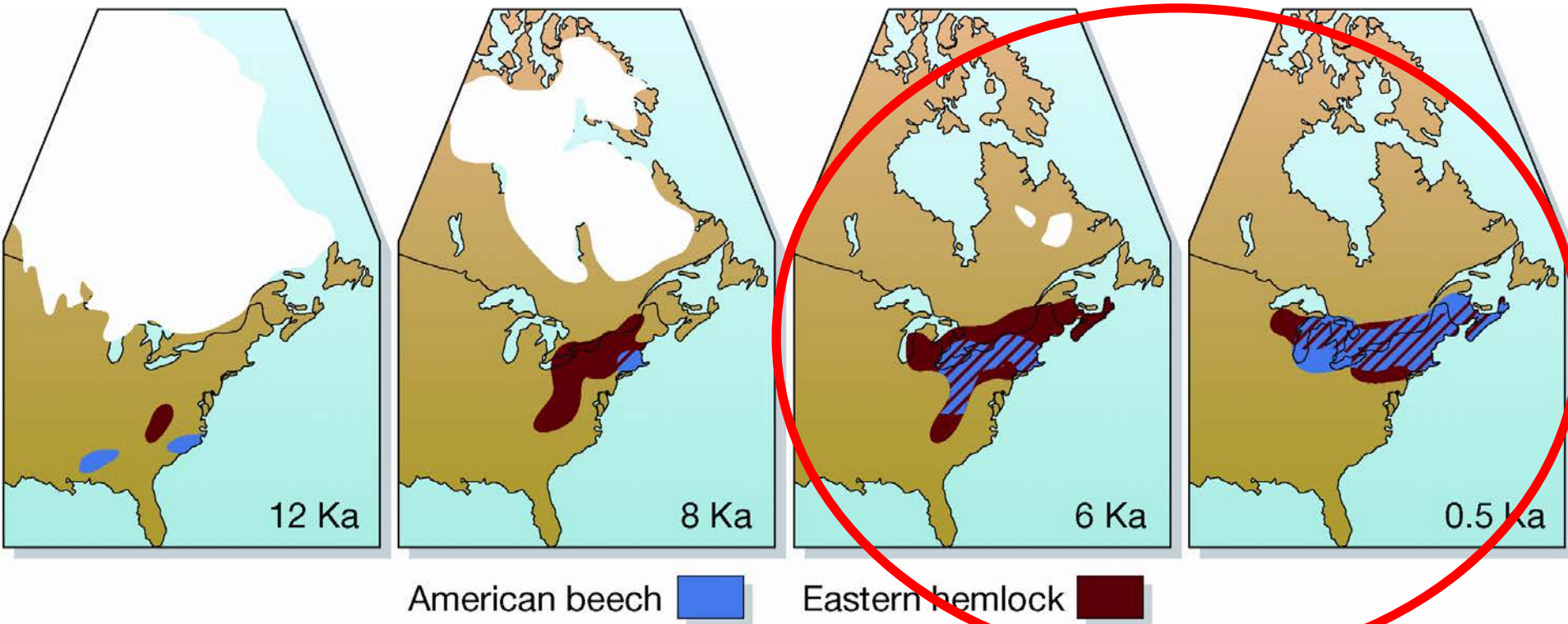
Example:  
68 Vegetation  
Communities  
of Colorado



Part I: Biodiversity & coarse-filter strategies to conserve it

# Vegetation communities are illusions of our short human memory.

Example: “American beech-Eastern hemlock” over 12,000 years of changing climate



**The most stable 6,000 years in the last 2.5 million years; these coincide with all of human history.**

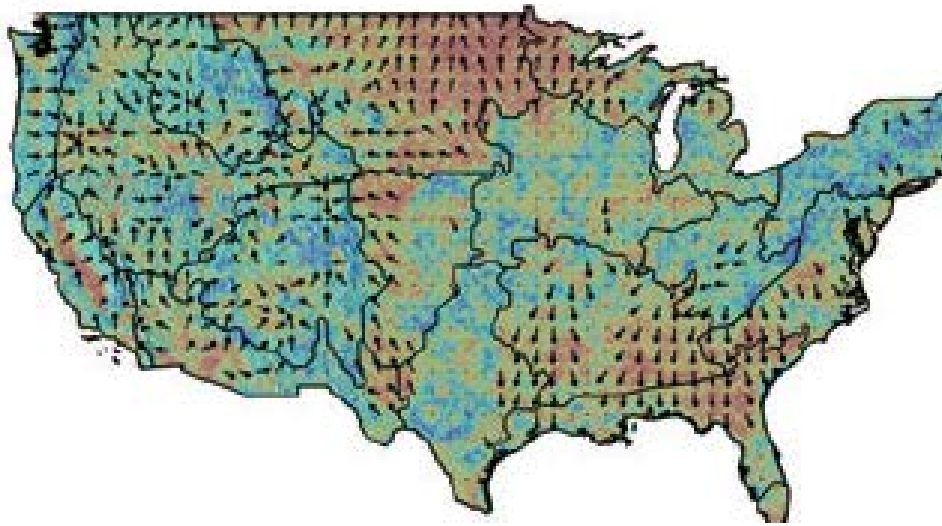
Even if projections of future climate are wrong (and they probably are wrong), biotic communities are and always have been unstable.

Gill et al. 2015. *Conservation Biology* *Special Section*.

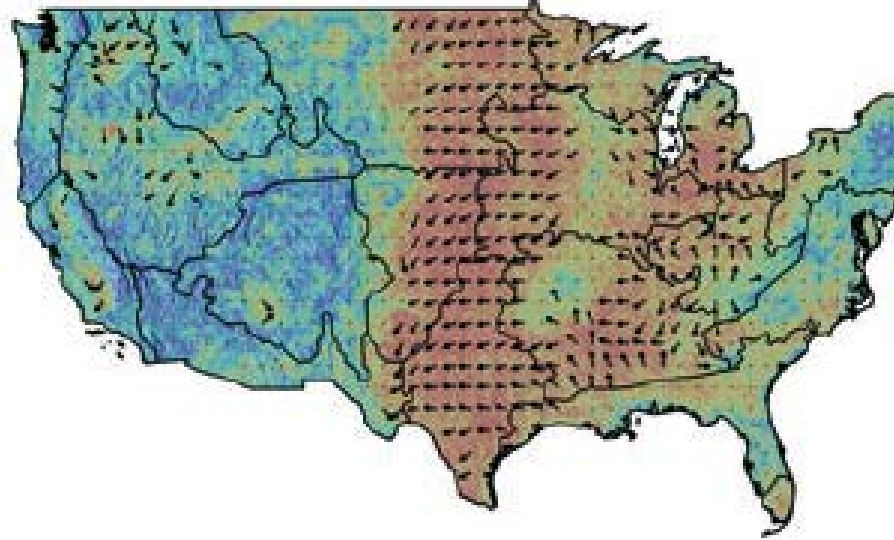
Part I: Biodiversity & coarse-filter strategies to conserve it<sup>12</sup>

# Recent (not projected) climate velocity 1915-2005

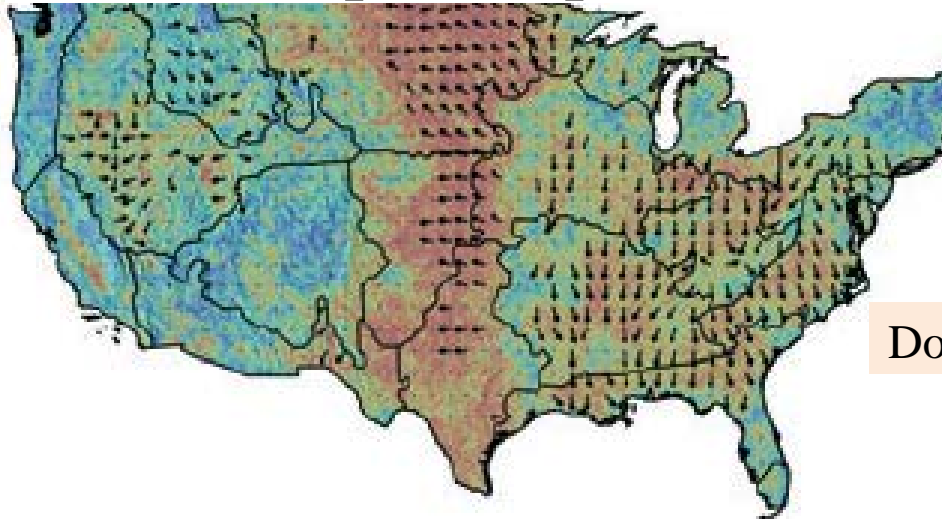
## Minimum temperature



## Climatic water deficit



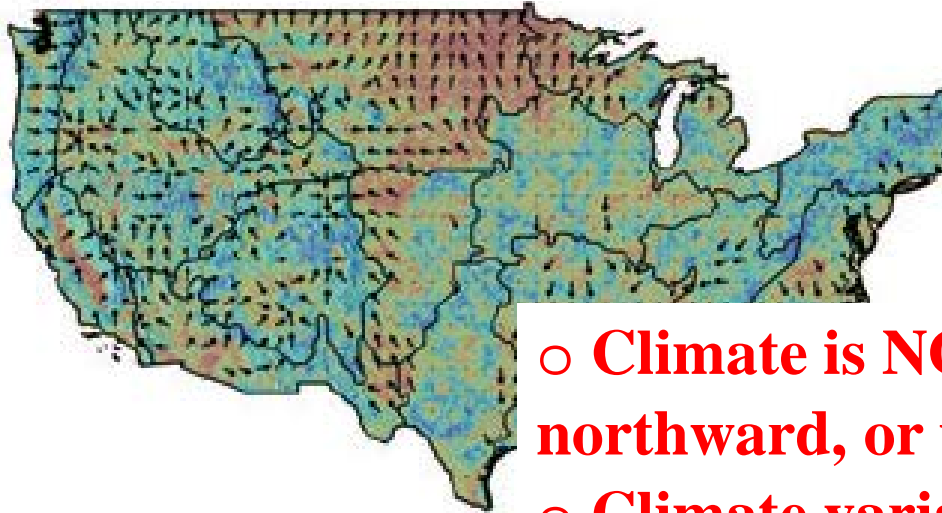
## Actual evapotranspiration



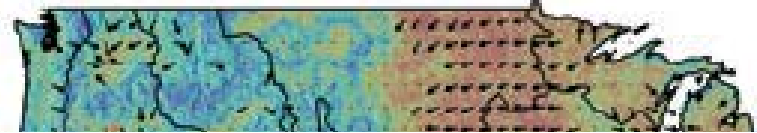
Dobrowski et al. 2013 Global Change Biol 19

# Recent (not projected) climate velocity 1915-2005

## Minimum temperature

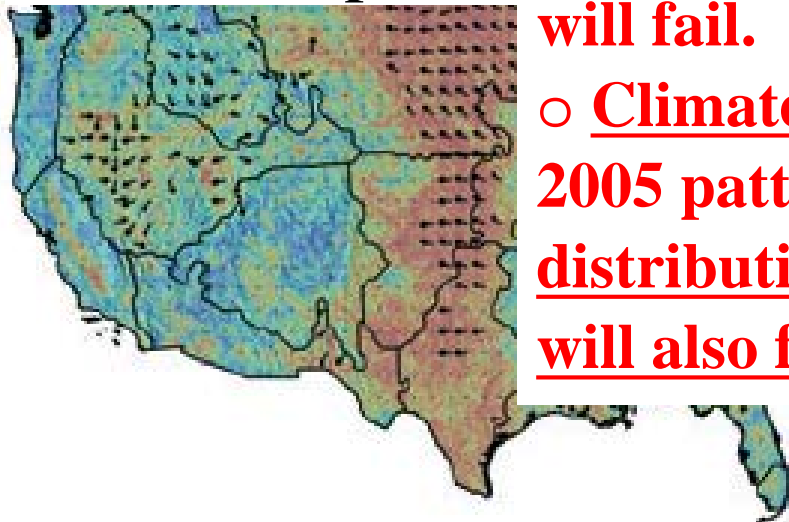


## Climatic water deficit



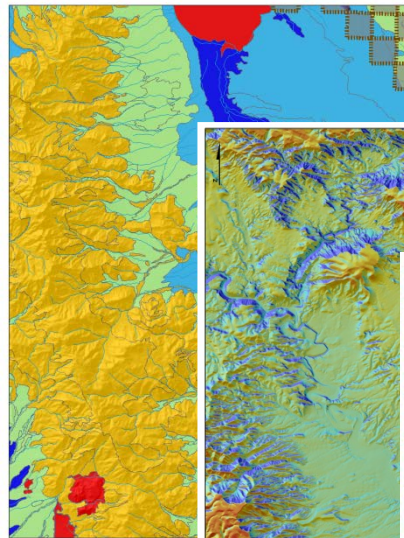
- **Climate is NOT consistently moving northward, or upward in elevation.**
- **Climate variables are NOT shifting in concert. Communities are reassembling and coarse filter will fail.**
- **Climate models do NOT hindcast these 1915-2005 patterns, and certainly can't predict species distributions for the next 90 years: the fine filter will also fail.**

## Actual evapotranspiration



# Geodiversity as a driver of biodiversity

Plants & animals are (and will be) a function of:



Soil properties

Solar insolation

Topographic position

Elevation

**Climate is changing (but at any spot, it's difficult to predict how).**

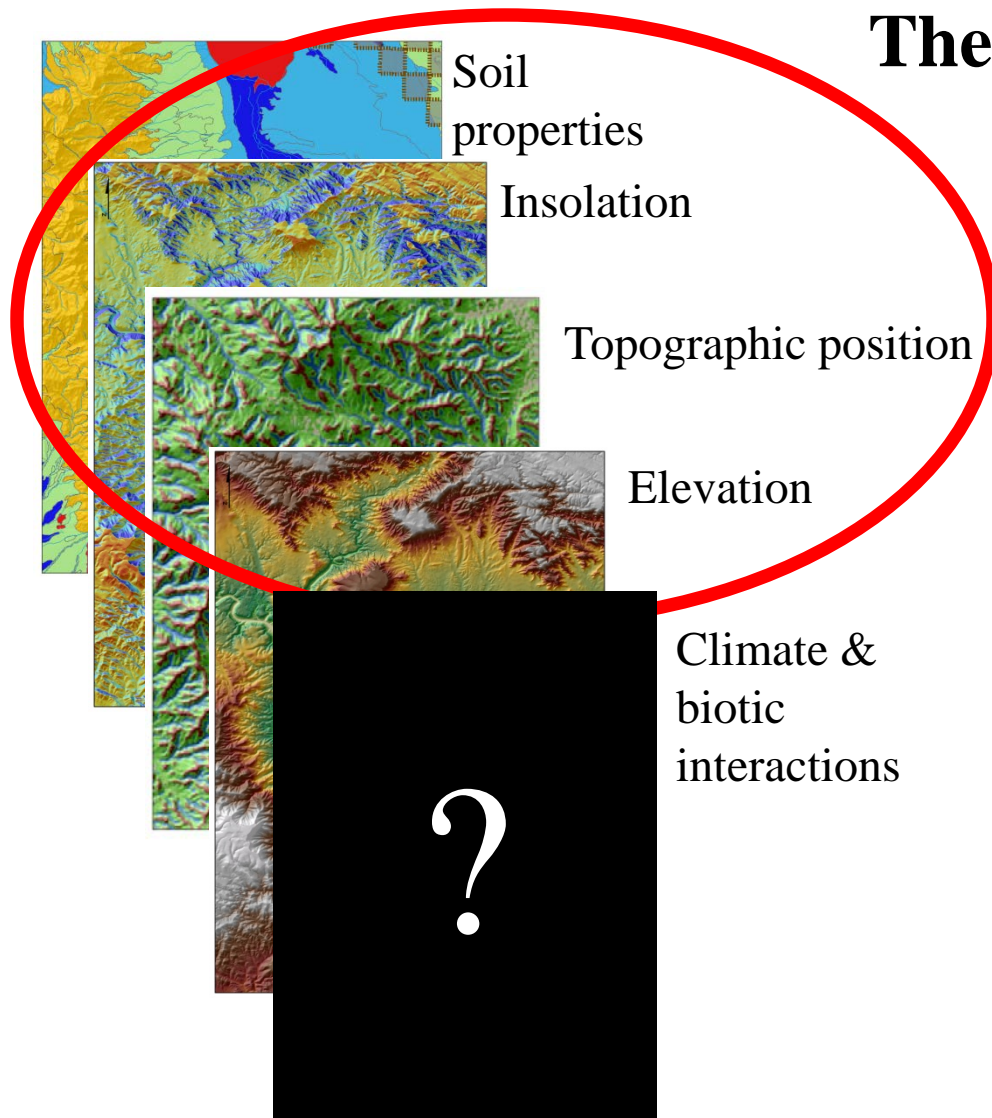
Climate & biotic interactions

# Geodiversity as a driver of biodiversity

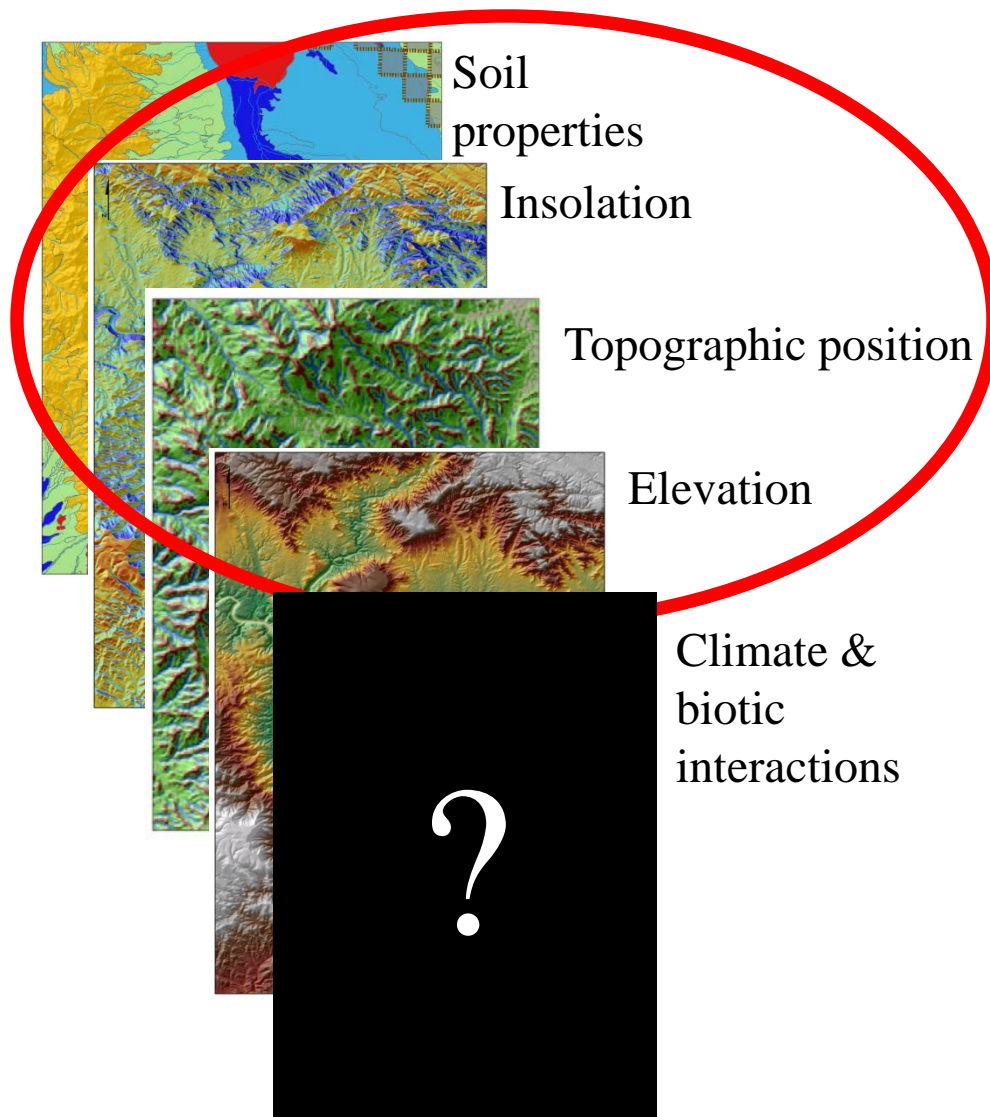
**These variables are stable.**

**They define enduring features.**

**Diverse physical environments support diverse species today, and interact with climate (today's or tomorrow's) to support plants and animals.**



# Conserving Nature's Stage

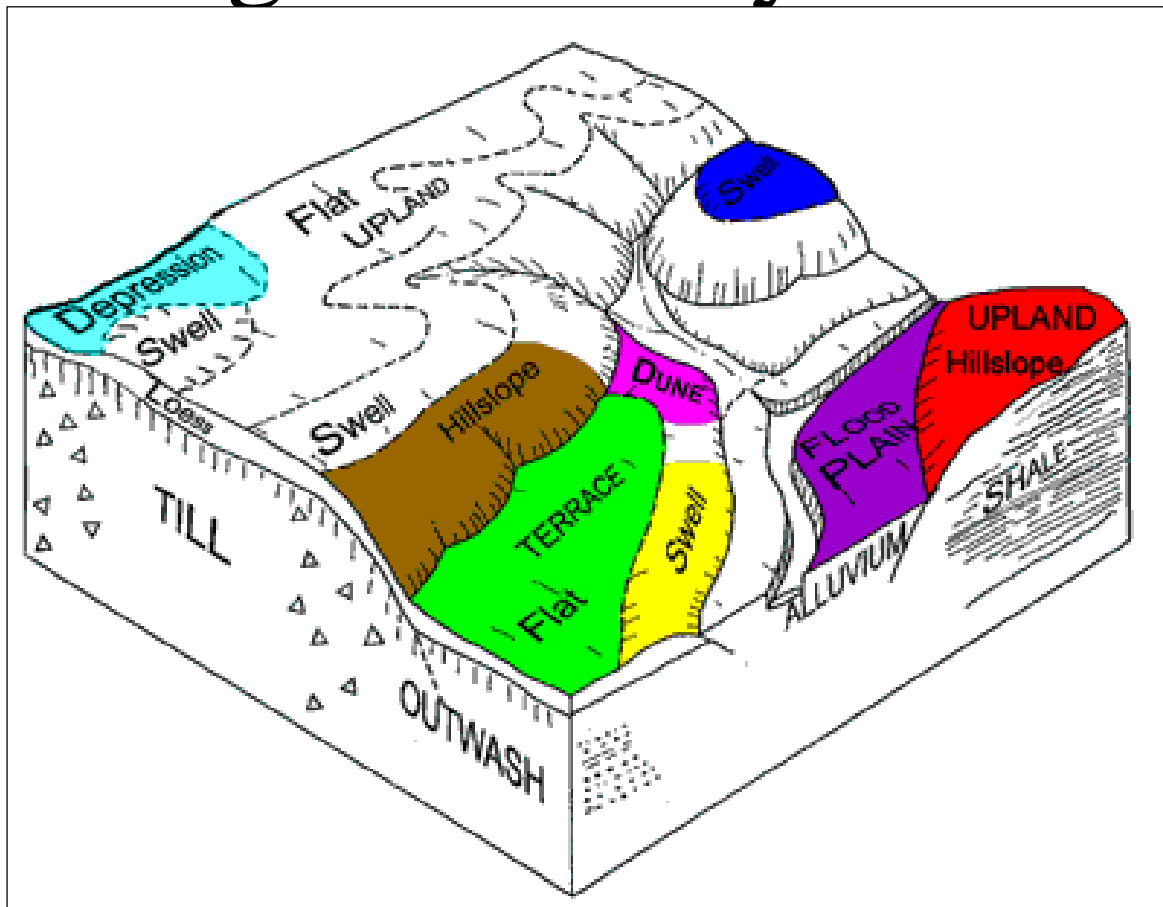


**“Conserve  
the arenas of biological  
activity rather than the  
vegetation communities  
that are the  
temporary occupants of  
those arenas.”  
(Hunter et al. 1988)**

(“enduring features” are also  
called “land facets” or  
“geophysical settings”)

# Conserving Nature's Stage: Conserve sites that span the full spectrum of geodiversity

Geodiversity is not an end in itself. It is a shortcut (surrogate) to conserve **species** (whose locations are not known).



Part I: Biodiversity & coarse-filter strategies to conserve it

# Conserving Nature's Stage:

## Geodiversity as a coarse-filter conservation strategy

**Discussion** of Part I: What is biodiversity, and why do we need coarse-filter strategies to conserve it?

Recap:

- Biodiversity includes species, genetic diversity, species interaction, & eco-evo processes.
- Fine-filter conservation is a species-by-species approach.
- We can't rely solely on fine filter because we haven't named most species, and we don't know where any of them are.
- Our current coarse-filter (vegetation communities) won't work in the long term because veg communities are & always have been ephemeral.
- Climate is changing, but we can't predict how.
- I advocate conserving enduring features as a new coarse filter

# Conserving Nature's Stage: Using geodiversity as a coarse-filter conservation strategy

- ✓ Part I: What is biodiversity, and why do we need coarse-filter strategies to conserve it?
- **Part II: Geodiversity is a good coarse-filter surrogate for biodiversity**

Part III: Using Conserving Nature's Stage (geodiversity) in conservation planning

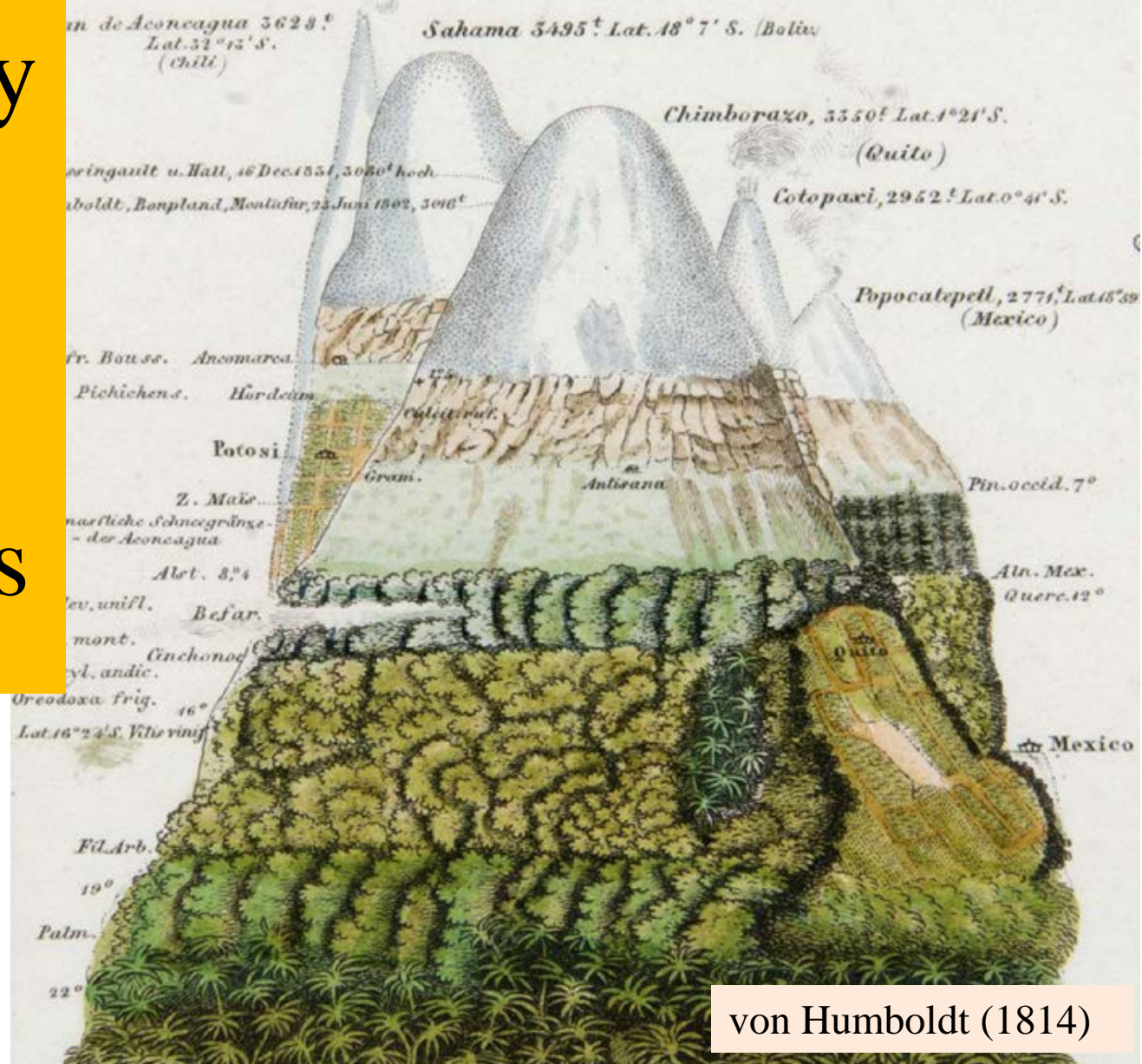
# Part II: Geodiversity is a good coarse-filter surrogate for biodiversity

## Evidence

- geodiversity is a major driver of species distributions
- close association between species & enduring features
- geodiversity has prevented extinctions for 2 m years
- speciation occurs at interfaces between enduring features
- site complementarity highly predictable from geophysical variables
- Selection-based tests (the evidence most relevant to conservation)

Part II: Geodiversity is a good surrogate for biodiversity<sub>1</sub>

Geodiversity  
is a major  
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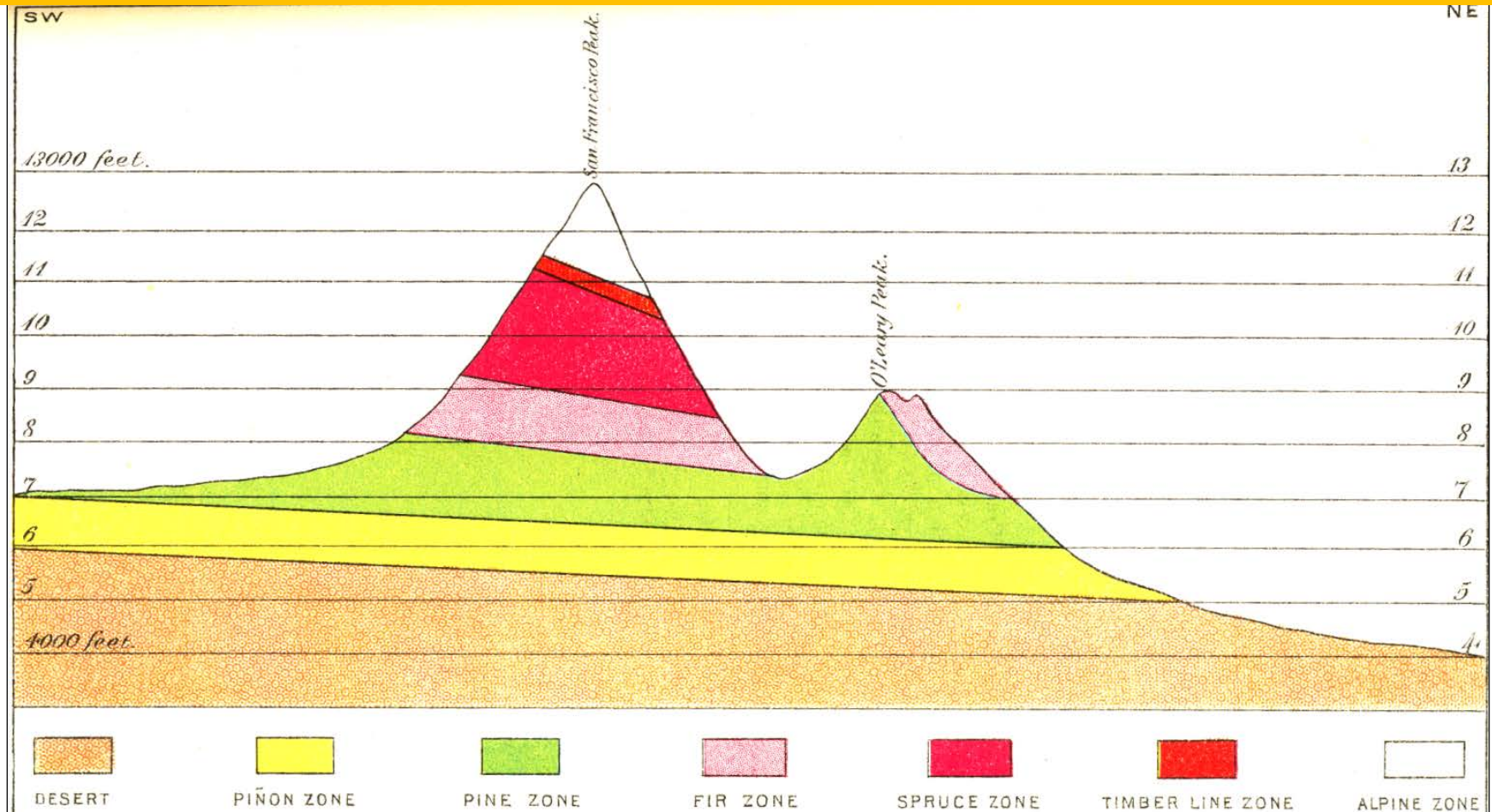


von Humboldt (1814)

Lawler et al. 2015. *Conservation Biology*. Special Section

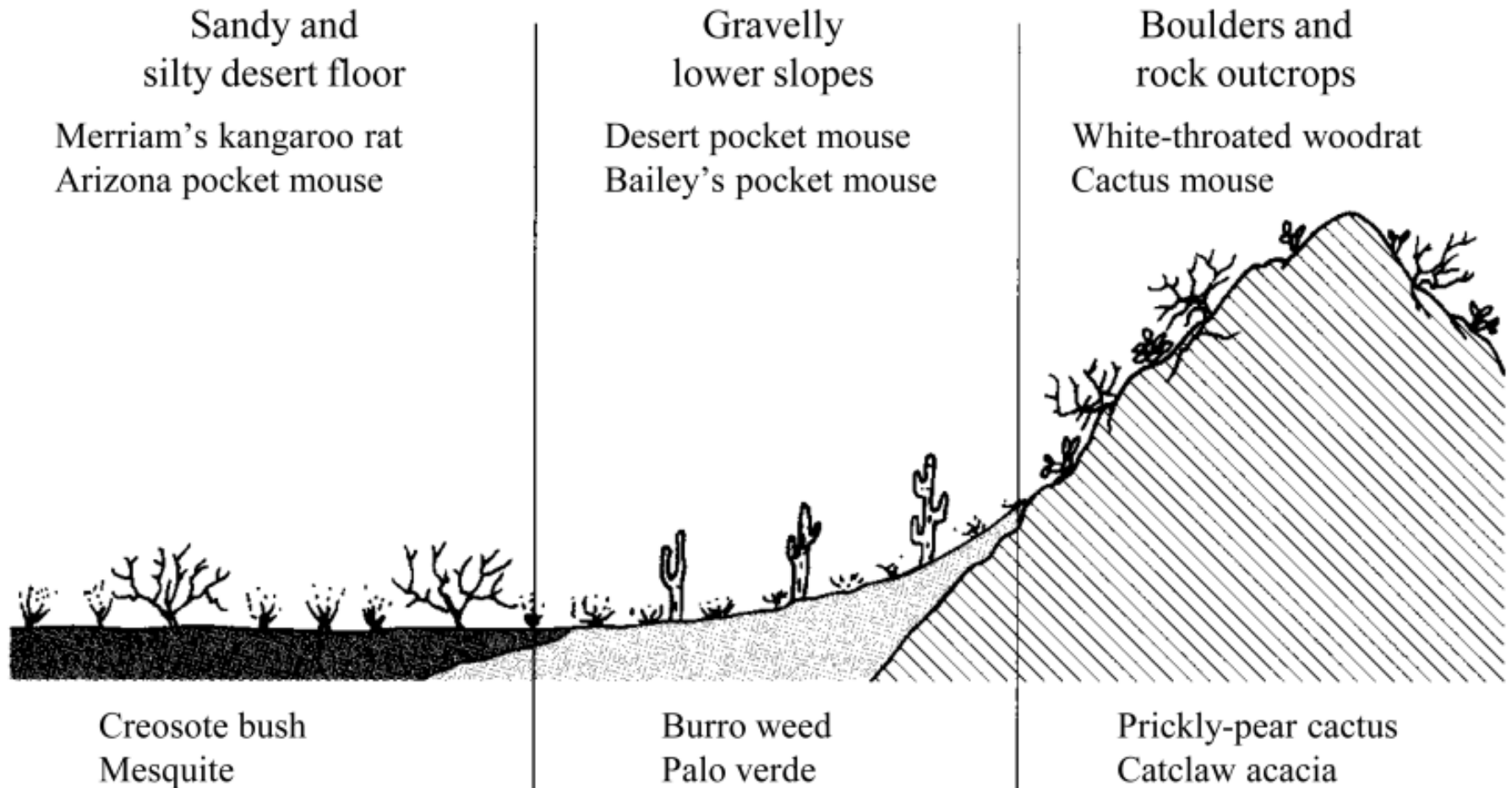
Part II: Geodiversity is a good surrogate for biodiversity<sub>2</sub>

# C. Hart Merriam (1890): Life Zones determined by elevation, aspect, & landform



Part II: Geodiversity is a good surrogate for biodiversity<sup>3</sup>

# Each type of enduring feature supports particular plants & animals



Vaughan. 1974. *Mammalogy* textbook

Part II: Geodiversity is a good surrogate for biodiversity<sup>24</sup>

Many species are endemic to **rare geofeatures**.

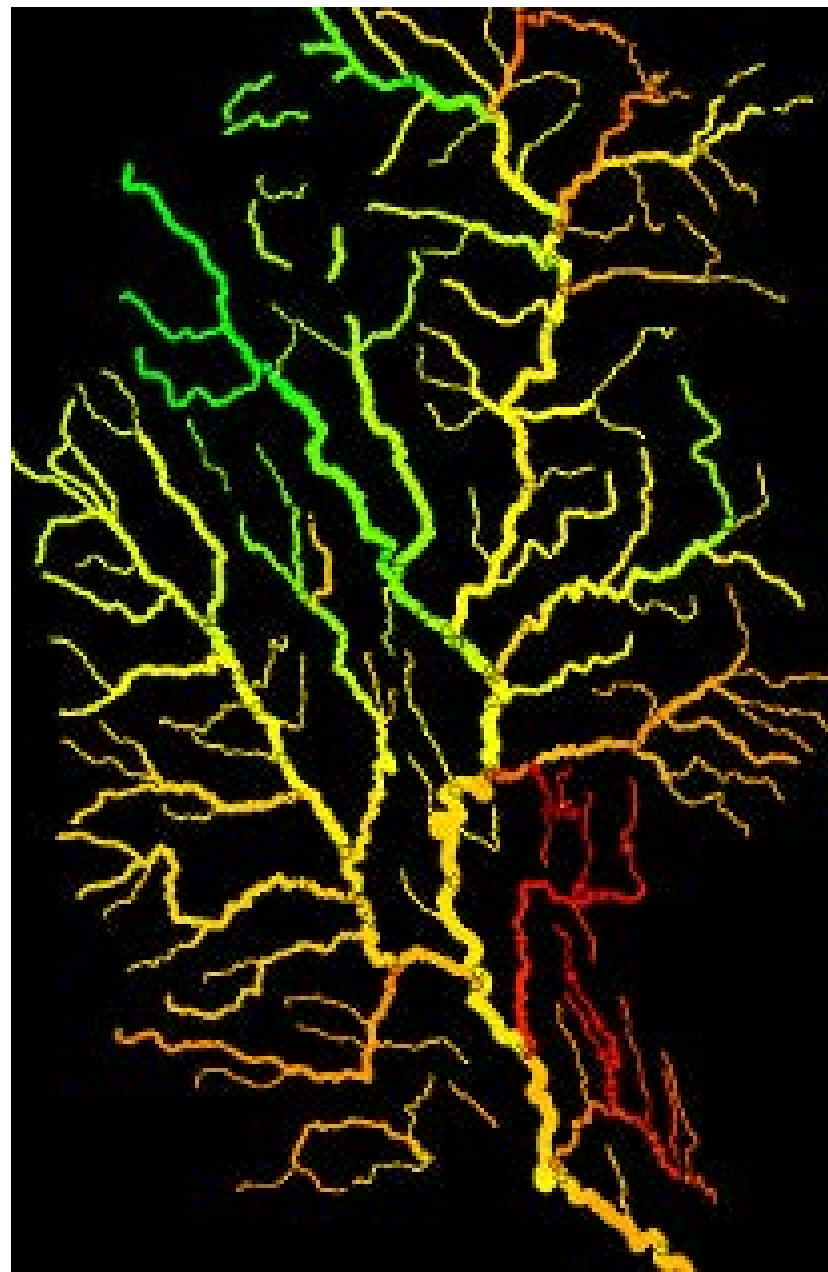
- a) caves
- b) cliffs & talus
- c) limestone pavement
- d) dunes
- e) frost sites
- f) tufa towers
- g,h) waterfalls
- i) river bars
- j) desert springs
- k) deep-sea thermal vents
- (Not shown) vernal pools, metalliferous soils (serpentine)



Hjort et al. 2015. *Conserv Biol* *Special Section*

Part II: Geodiversity is a good surrogate for biodiversity<sup>25</sup>

And MANY species depend on streams and use stream networks as travel corridors.



Part II: Geodiversity is a good surrogate for biodiversity<sub>6</sub>

Although past episodes of climate change (2.5 million years) produced many local extinctions, geodiversity apparently reduced the number of global extinctions caused by climate change.

Species persisted in, or moved to, suitable enduring features.

Example: areas of cold-air pooling provided refuge during warm periods.

Gill et al. 2015. *Conservation Biology* Special Section

Part II: Geodiversity is a good surrogate for biodiversity<sup>7</sup>

Speciation of plants & animals occurs  
at soil interfaces (especially between  
acidic & alkaline soils)  
and at interfaces between uplands &  
lowlands

Rouget et al. 2003. *Diversity & Distributions* 9

Part II: Geodiversity is a good surrogate for biodiversity<sub>8</sub>

Site complementarity (the ability of a site to add new species to the set of species already represented in a reserve network) is highly predictable from abiotic variables.

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Taxon	% variance in site complementarity explained by a model using abiotic explanatory variables
Amphibians	85%
Birds	85%
Mammals	78%

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Albuquerque & Beier. 2015. *J Biogeography* 42

Part II: Geodiversity is a good surrogate for biodiversity<sup>9</sup>

# Part II: Geodiversity is a good coarse-filter surrogate for biodiversity

## Evidence

- ✓ geodiversity is a major driver of species distributions
  - ✓ close association between species & enduring features
  - ✓ geodiversity has prevented extinctions for 2 m years
  - ✓ speciation at interfaces between enduring features
  - ✓ site complementarity highly predictable from geophysical variables
- We really need selection-based tests: If I design a reserve to span geodiversity, will I conserve a lot more species than in the same number of randomly-selected sites?



- (1) Tropical marine sites selected to span geodiversity would represent most species in 11 marine phyla.
- (2) Geodiversity was especially effective when the variables used to define geodiversity were weighted according to their influence on species turnover (estimated from another study).

Sutcliffe et al. 2015. *Conservation Biology* Special Section

Part II: Geodiversity is a good surrogate for biodiversity<sub>1</sub>

Across 400 published tests, abiotic surrogates represented plants well (median 26% better than random selection of sites).

**Selection-based test: YES  
(But only for plants, and 20% ain't great)  
(Lousy performance for animals)**

(2) Median shmedian... one type of abiotic surrogate performed much better than the median

Beier et al. 2015. *Conservation Biology*. Special Section

Part II: Geodiversity is a good surrogate for biodiversity<sub>2</sub>

# An unbinned abiotic surrogate: Environmental Diversity (Faith & Walker 1996)

Dataset	Improvement on # species represented (compared to random site selection)
Europe, reptiles	84%
Europe, amphibians	69%
Zimbabwe, plants	67%
Europe, vertebrates	40%
Arizona, birds	35%
Europe, birds	34%
Spain, birds	26%
Europe, mammals	No better than random

Beier & Albuquerque. 2015. *Conservation Biology*: 29:1401

Part II: Geodiversity is a good surrogate for biodiversity<sub>3</sub>

Environmental Diversity (one type of geodiversity surrogate) can prioritize sites to represent species, even when the planner has no data on where species are.

- Median efficiency of 38%.
- Inter-quartile range (30% to 68%) means low risk of a bad outcome.
- Abiotic data layers are freely available. In contrast, it is expensive to survey 100% of sites for the indicator taxon.

Beier & Albuquerque. 2015. *Conservation Biology*: 29:1401

Part II: Geodiversity is a good surrogate for biodiversity<sup>4</sup>

# Part II: Geodiversity is a good coarse-filter surrogate for biodiversity

## Discussion of the Evidence

- geodiversity is a major driver of species turnover
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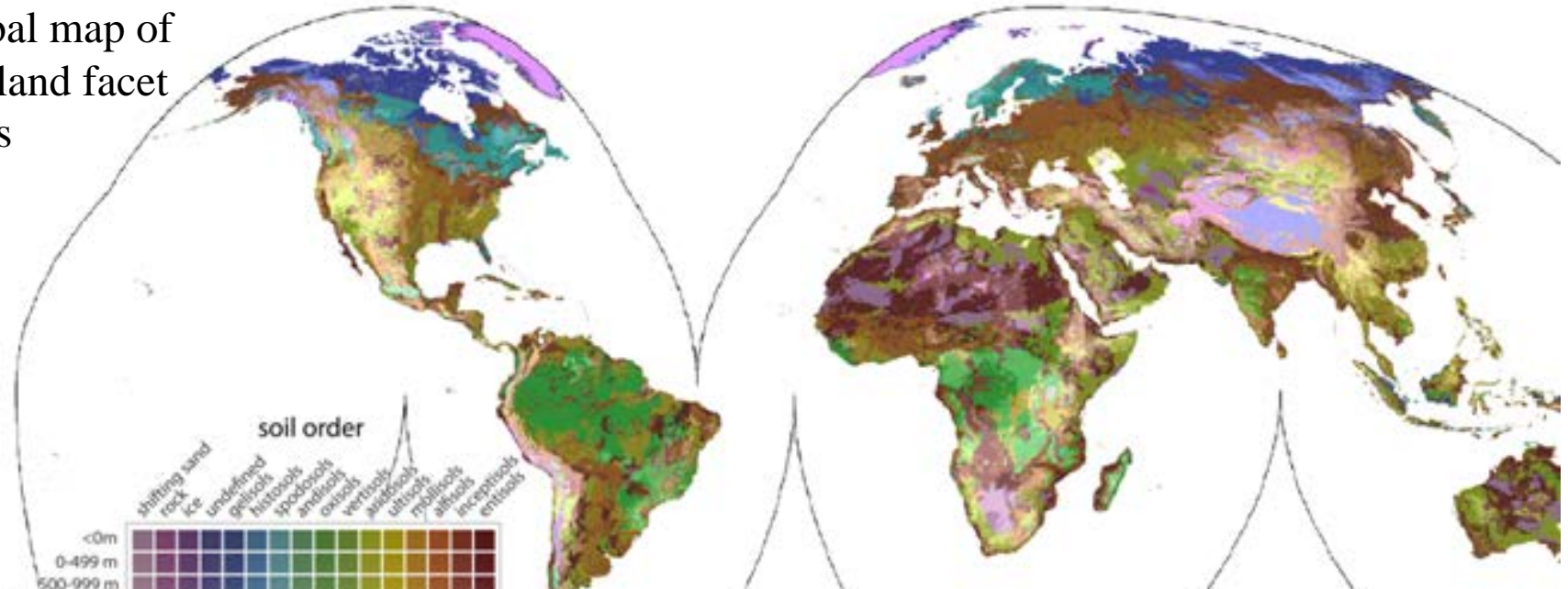
# Conserving Nature's Stage: Using geodiversity as a coarse-filter conservation strategy

- ✓ Part I: What is biodiversity, and why do we need coarse-filter strategies to conserve it?
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Part III: Using geodiversity in conservation planning

# Are we already conserving nature's stage?

Global map of  
176 land facet  
types



Some land facets are well protected, at least in some continents and countries.

In every region of the world, low elevation mollisols and vertisols (most productive for agriculture) are the least protected types.

Sanderson et al. 2015 *Conservation Biology* **Special Section**

Part III: Using geodiversity in conservation planning

Many government agencies have legal, political, and cultural mandates to conserve **species**.

Nonetheless, laws of the US & other nations, Forest Service planning rules, the National Fish Wildlife & Plant Climate Adaptation Strategy, the Convention on Biological Diversity, & Aichi targets **provide opportunities for governments to incorporate geodiversity into their decisions.**

Comer et al. 2015. *Conservation Biology*. **Special Section**

# Some ways to use geodiversity in conservation planning

When enrolling land for conservation, prioritize

- \* geosites like springs, vernal pools, metalliferous soils...
- \* streams and riparian areas, especially those that connect protected areas
- \* interfaces between acidic and alkaline soils
- \* low elevation mollisols and vertisols
- \* enduring features that are poorly represented in the region's conservation portfolio (may require GIS analysis)
- \* areas of cold air pooling (Daly et al. 2009. International Journal of Climatology)
- \* sites that can increase local topo-diversity, and thus allow short shifts in response to changing climate

## **To prioritize, NRCS might have to move from open to selective enrollment, with parcel-specific goals.**

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Conservation of biodiversity may require increasing protected land from 15% (current level) to >30% (perhaps 50%).

Across 8 case studies, adding geodiversity targets to a ‘traditional’ conservation plan (i.e., a plan designed to represent vegetation types & species) requires only a small increase in the total area prioritized & does not decrease the achievement of other targets.

Using geodiversity in a conservation plan is a low-cost type of bet hedging that should improve species representation, and might increase resilience to climate change.

Anderson et al. 2015. *Conservation Biology*. *Special Section*

Conserving Nature's Stage is a low-cost strategy to conserve species today given our ignorance about species. It may also prove useful for conservation in a changing climate.

Potential climate adaptation strategies:

- Enhance connectivity
- Enlarge protected areas
- Assisted colonization
- Mobile reserves
- Model shifting climate space
- **Conserve nature's stage**

Conserving Nature's Stage is a low-cost strategy to conserve species today given our ignorance about species. It may also prove useful for conservation in a changing climate.

Potential climate adaptation strategies:

- Enhance connectivity
- Enlarge protected areas
- Assisted colonization
- Mobile reserves
- Model shifting climate space
- **Conserve nature's stage**

Compared to some other strategies, Conserving Nature's Stage:

- **Does not rely on climate projections**
- **Does not require knowledge of responses of each species to climate change (or even knowledge of current species distributions)**
- **Uses data available for free everywhere on earth**

# Conserving Nature's Stage is *an* answer, not *the* answer

- It is a coarse filter approach. There will always be a need for fine-filter strategies for the species that fall through the coarse filter of geodiversity.

## Nonetheless

- Managers should prefer a plan that includes geodiversity over one that is based solely on current vegetation communities or known species locations.
- Biodiversity is not precisely mapped anywhere; geodiversity is precisely mapped everywhere.
- Managers skeptical of complex climate models (or even the fact of climate change) can use this strategy.
- Conserving geodiversity is likely to be one of the answers to the manager's need for options.

## Part III: Using geodiversity in conservation planning

## **Discussion:** using geodiversity to prioritize sites for conservation

- \* geosites like springs, vernal pools, metalliferous soils...
- \* streams & riparian areas, especially connecting protected areas
- \* interfaces between acidic and alkaline soils
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- \* areas of cold air pooling (Daly et al. 2009. International Journal of Climatology)
- \* sites that can increase local topo-diversity, and thus allow short shifts in response to changing climate

## **Discussion:** Advantages of geodiversity

- Adding geodiversity does not compromise other conservation goals
- Uses data freely available everywhere on Earth
- Does not use “house of cards” climate models

Part III: Using geodiversity in conservation planning

# Discussion



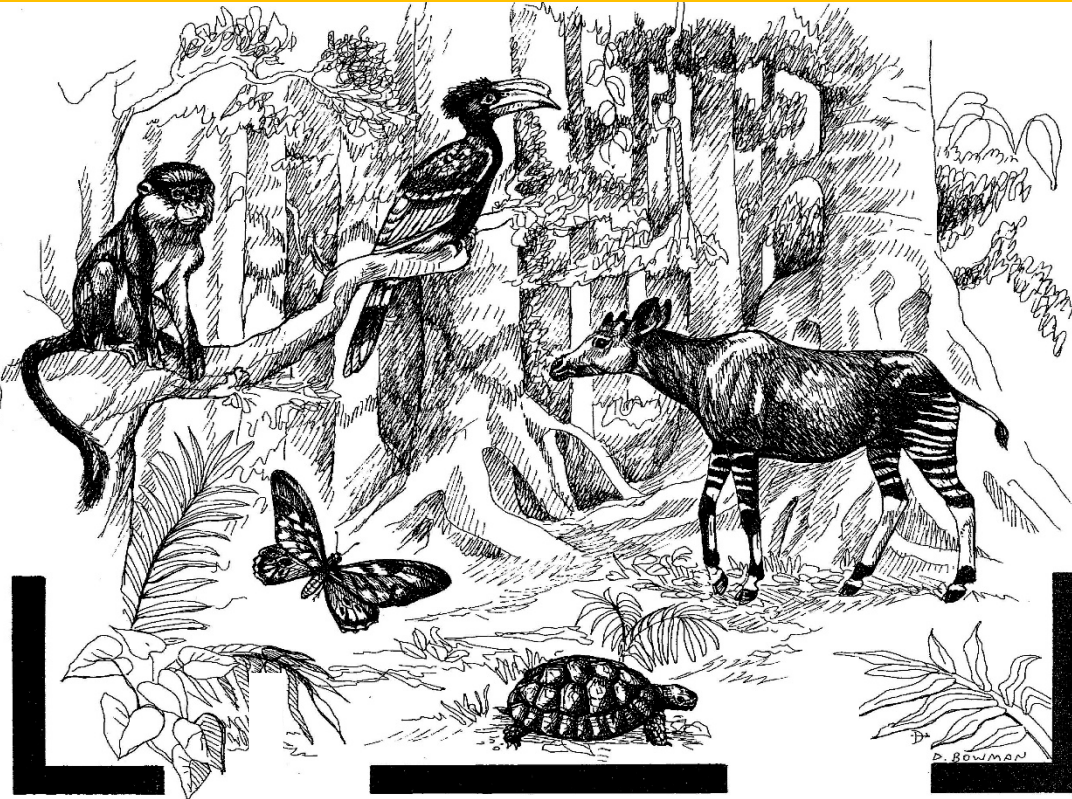
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The rocks shape life like hands around swelling dough. In Virginia, the salamanders vary from mountain ridge to mountain ridge, so do the fiddle tunes the old men play... These are not merely anomalous details. This is what life is all about: salamanders, fiddle tunes, you and me and things... No mountains and one salamander, one fiddle tune, would be a lesser world. No continents, no fiddlers. No possum, no soup, no taters. The earth without form, is void...

-- Annie Dillard, *Life on the rocks* (1982)

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