Gauging Ecosystem Response to Climate Change

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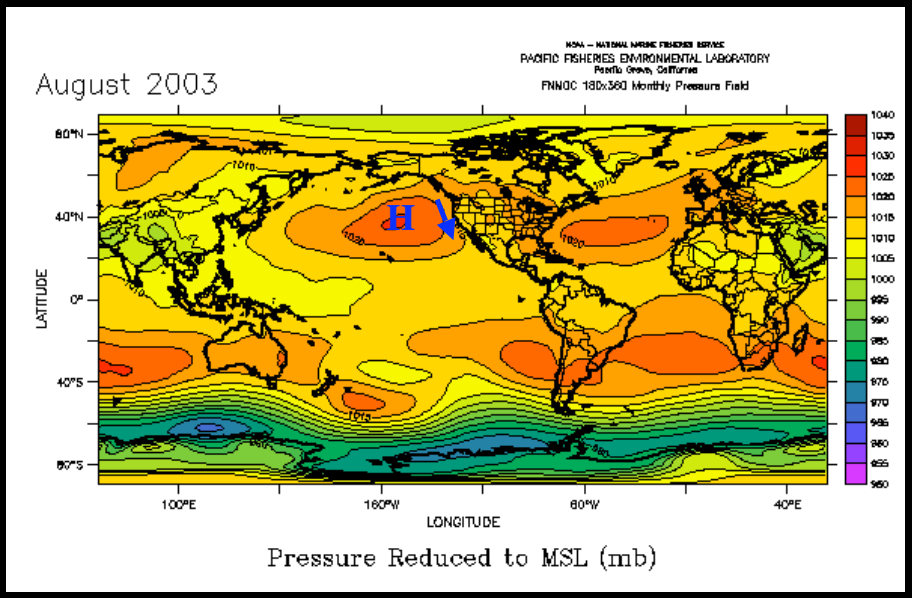
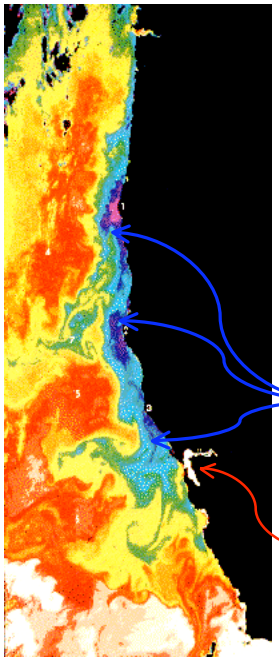
Why preserve biodiversity?

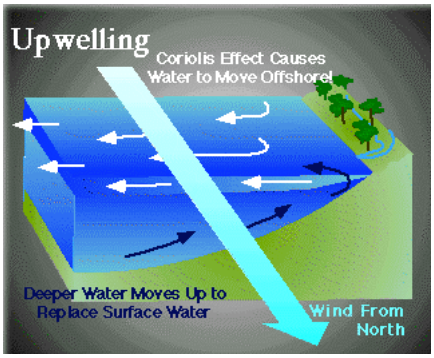
- Ecosystem services
  - Role in hydrologic cycle
  - Role in carbon cycle
  - Role in filtering pollutants, etc.
- Source of natural products/pharmaceuticals
- Quality of life
- Hold answers to questions of our origins and our nature

Analysis in deep time: reveals the powerful effects of climate change on ecosystems

~10–15 million years ago: strengthening of the North Pacific summer high pressure led to persistent upwelling



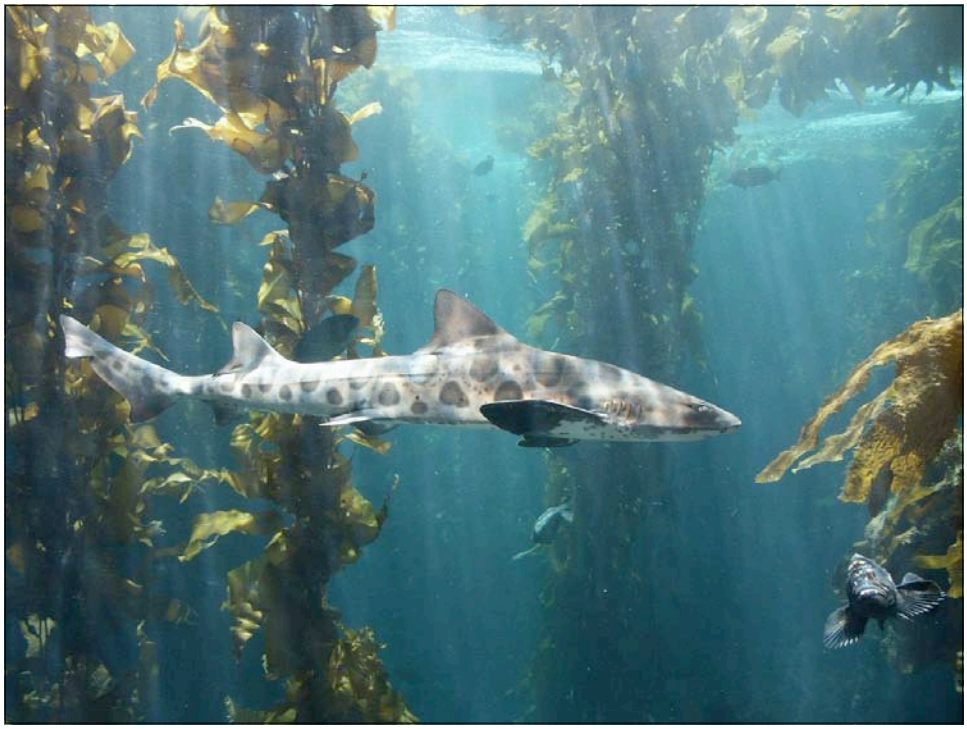




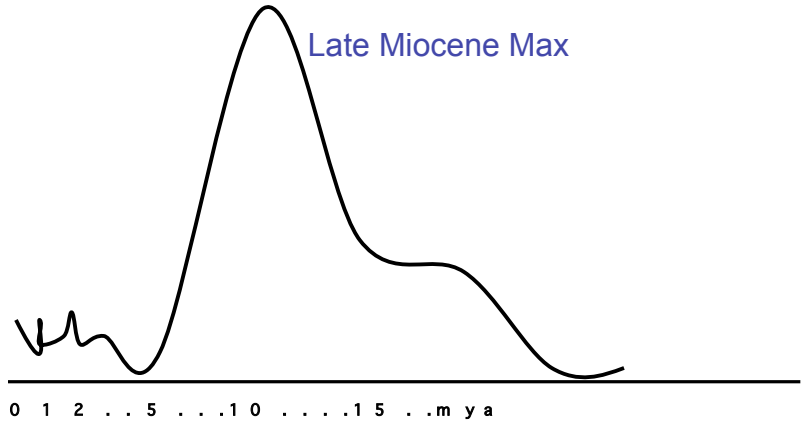
Coastal Upwelling – cold, nutrient rich water surfaces at the coast

San Francisco Bay

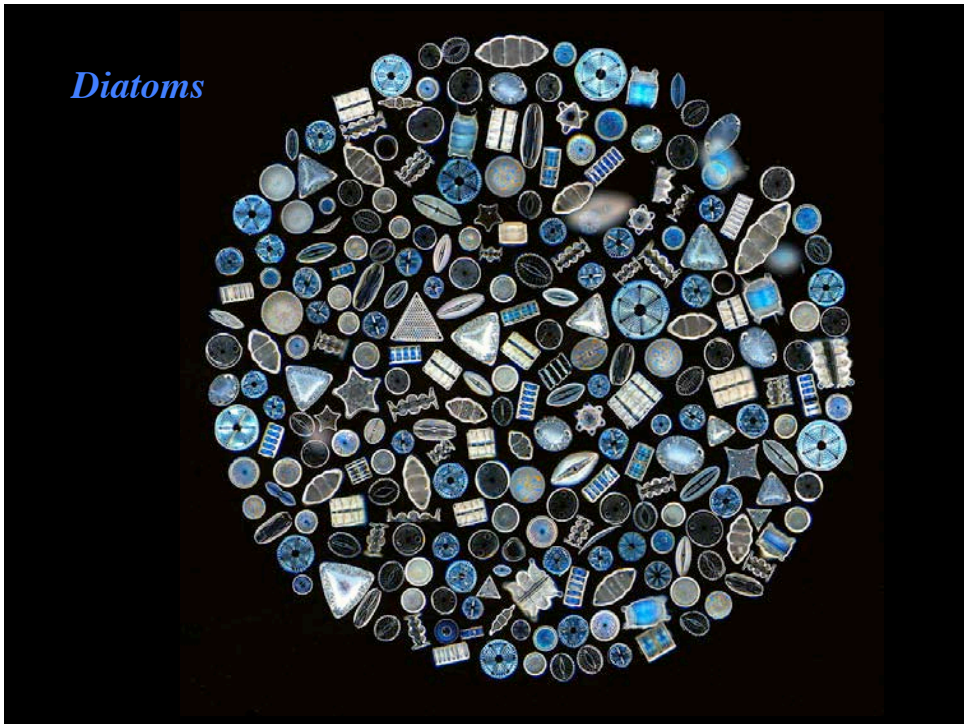
Kelp forest



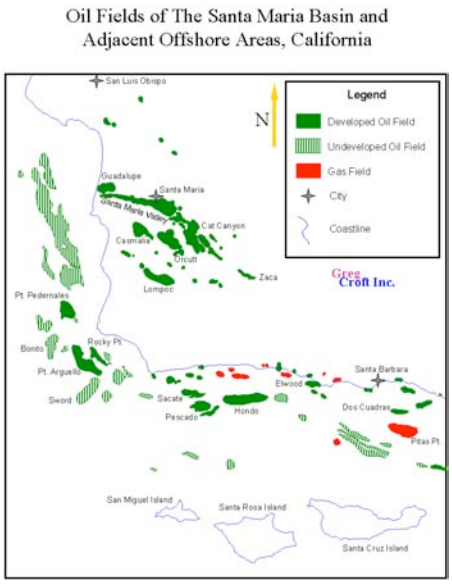
Diatom accumulation in the north Pacific: proxy for biological productivity



Barron (1998); Barron *et al.* (2002); Barron & Baldauf (1990)



Southern CA oils – derived from the Miocene diatoms



How are species going to respond to climate forcing?

- **D**ie – how severe is current crisis?
  – what controls extinction probability?
- **A**dapt – how fast?
  – how easily: what is genetic potential for change?
- **M**igrate – if so, where to and why?
  – (how design nature reserves?)
- **N**ada – the ability to weather the change

Different approaches

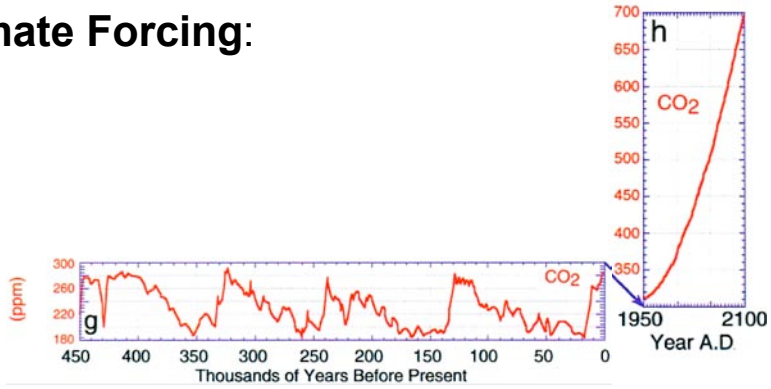
1) Historical records
2) Modeling
3) Experimental manipulation
4) Fossil record

In applying these approaches, what else do we learn?

Long-term goal

Develop a general theory of the biotic response to climate/global change

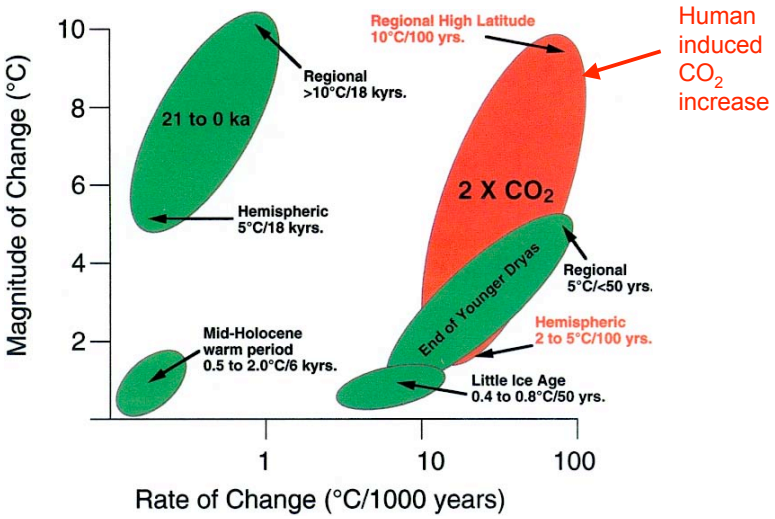
Climate Forcing:



CO_2 change over the last 450,000 years, the last ~4 glacial (lower CO_2) – interglacial cycles (higher CO_2)

Jackson, S.T. and J.T. Overpeck 2000. *Paleobiology*

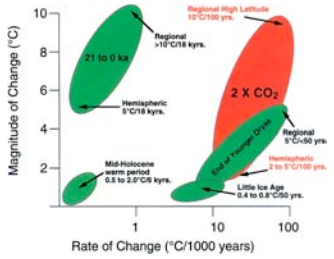
How severe are the projected changes compared to the Ice Age changes?



Human induced CO_2 increase

Jackson, S.T. and J.T. Overpeck 2000. *Paleobiology*

Three differences between now and the emergence from the last Ice Age:



1) Biota has not experienced both the high rates *and* magnitudes of CO_2 increase in the recent past.
2) CO_2 is increasing now; in the Ice Ages it dropped.
3) Human pressure is *much* more intense.

Jackson, S.T. and J.T. Overpeck 2000. *Paleobiology*

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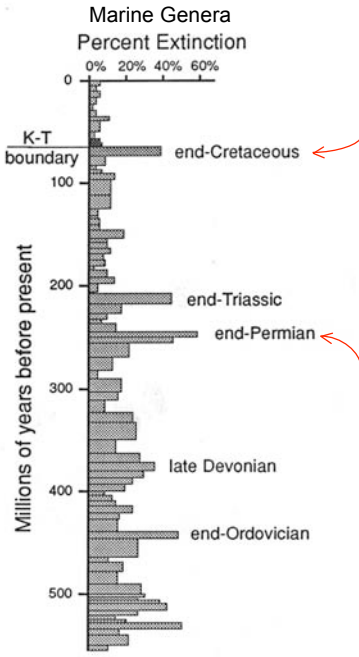
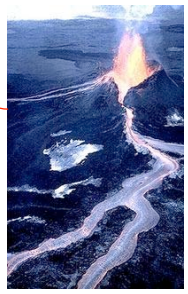
Are we in a 6th mass extinction?

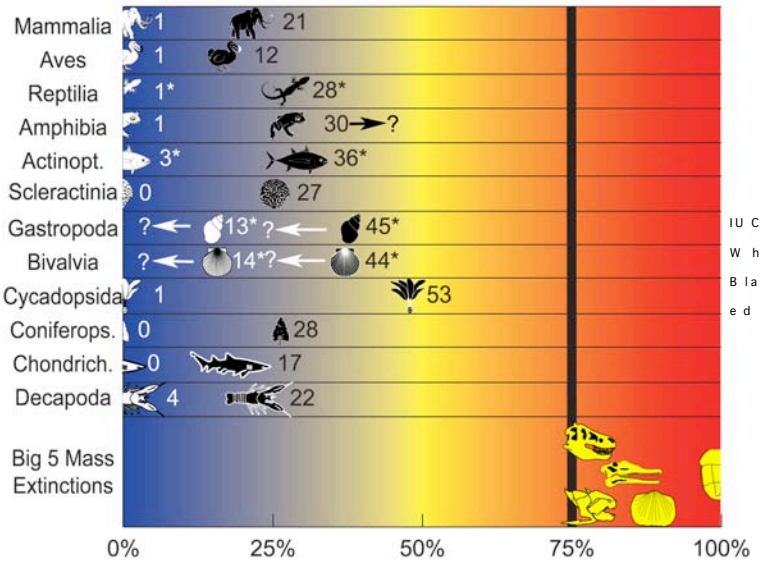
Extinction on Geological Timescales

- Ubiquitous
- Five exceptional events (the “big 5”)



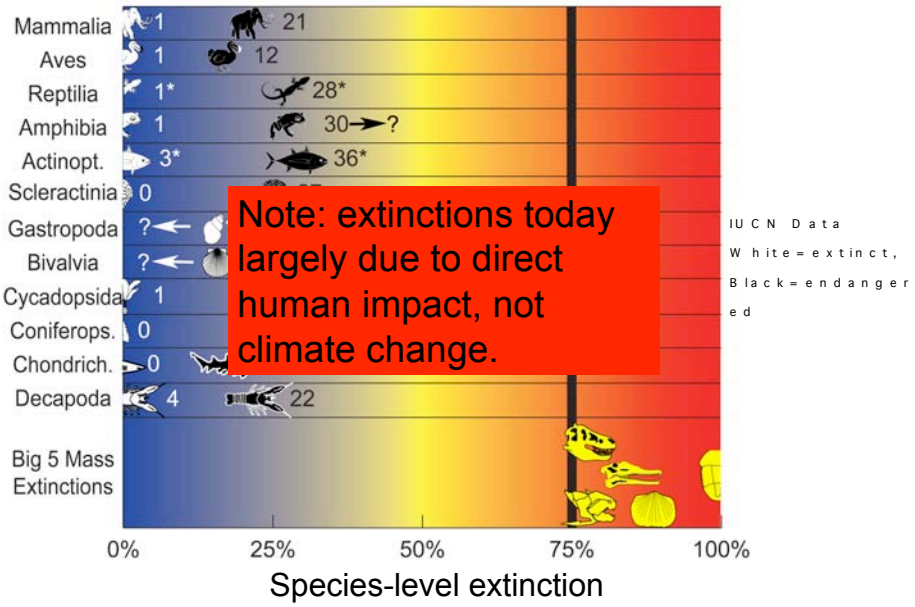


Are we in a 6th mass extinction? By magnitude, NO.

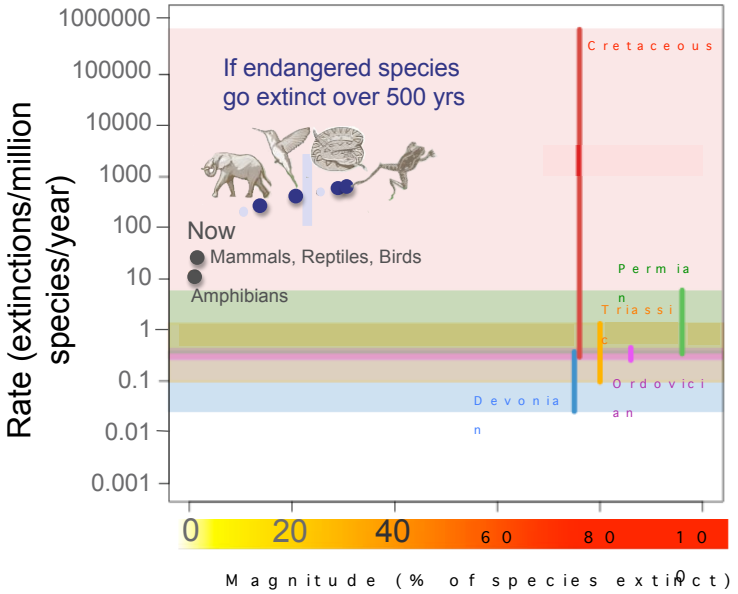


IUCN Data
White=extinct,
Black=endangered

Are we in a 6th mass extinction? By magnitude, NO.



Are we in a 6th mass extinction? By rate, YES.



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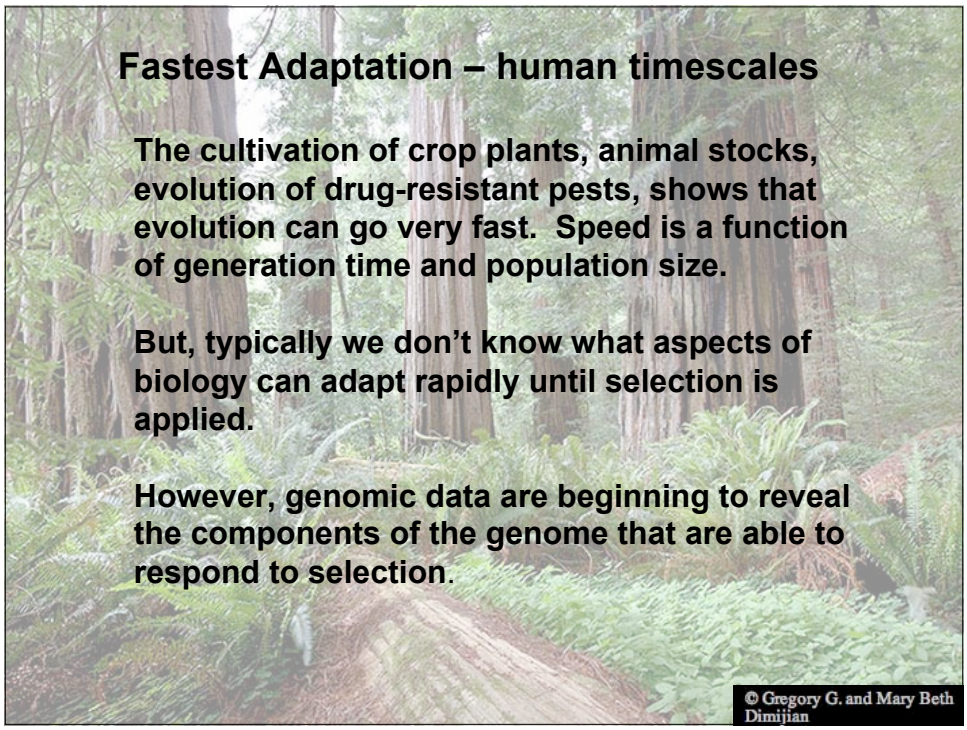
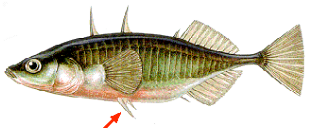
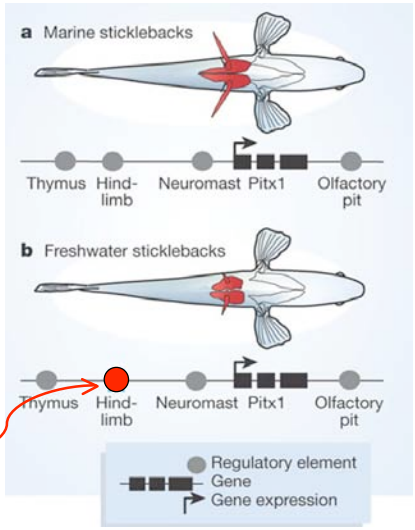


Adaptation – on historical timescales

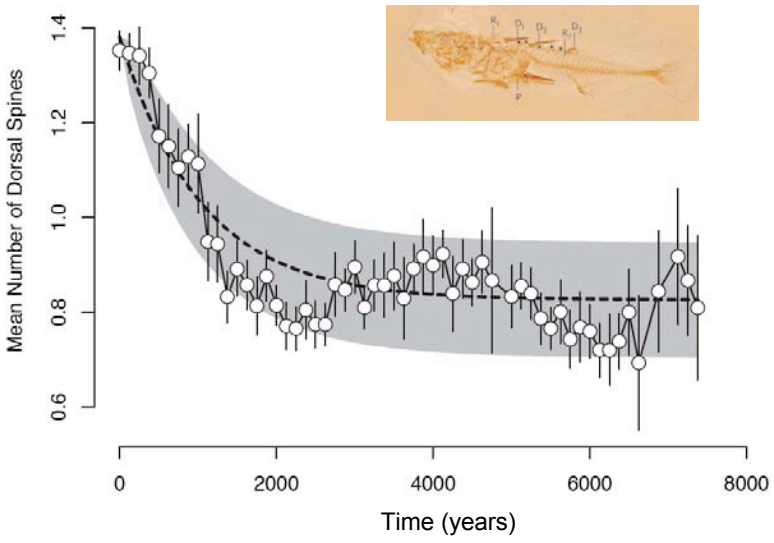
Glacial retreat created new rivers; sticklebacks invaded, typically with the loss of their spines …



Turns out this is easy to do genetically – all you have to do is damage one genetic control element



In fossil record can measure rate of change: adaptive change 50% complete in ~1,000 years



Hunt, Bell, Travis (2008) *Evolution*

Adaptation – on geological timescales

"Ardi" is 4.4 million years old: the long road to *Homo sapiens*

Tim White (and colleagues), UC Berkeley

Adaptation – on geological timescales

Most adaptive change involves altering a complex genetic architecture – so innovation is *very* slow …

"Ardi" is 4.4 million years old: the long road to *Homo sapiens*

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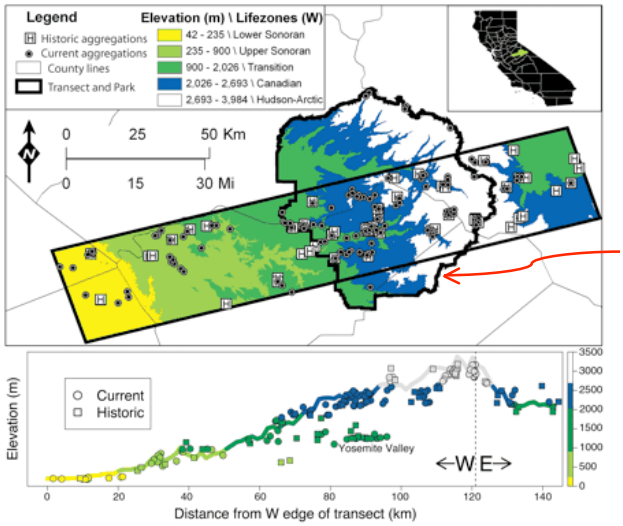
How have species ranges changed in ~80 years?

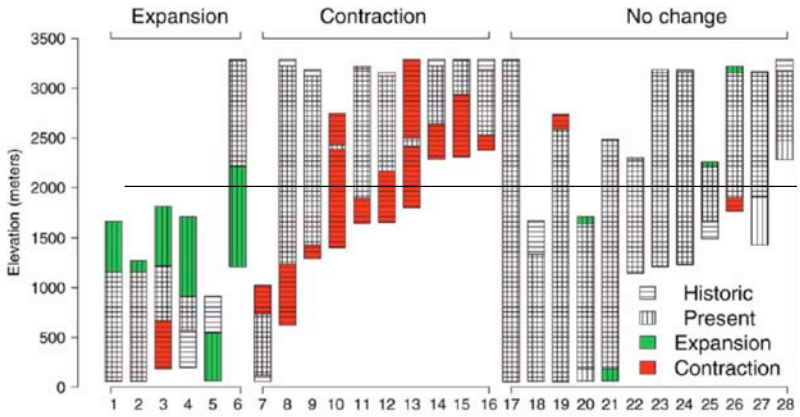
Grinnell resurvey project historical: 1914-1920



Berkeley survey (MVZ) in vicinity of Yosemite

C. Moritz et al., *Science* 322, 261-264 (2008)

Changes in elevational range in ~80 years



1. California

16. Alpine chipmunk

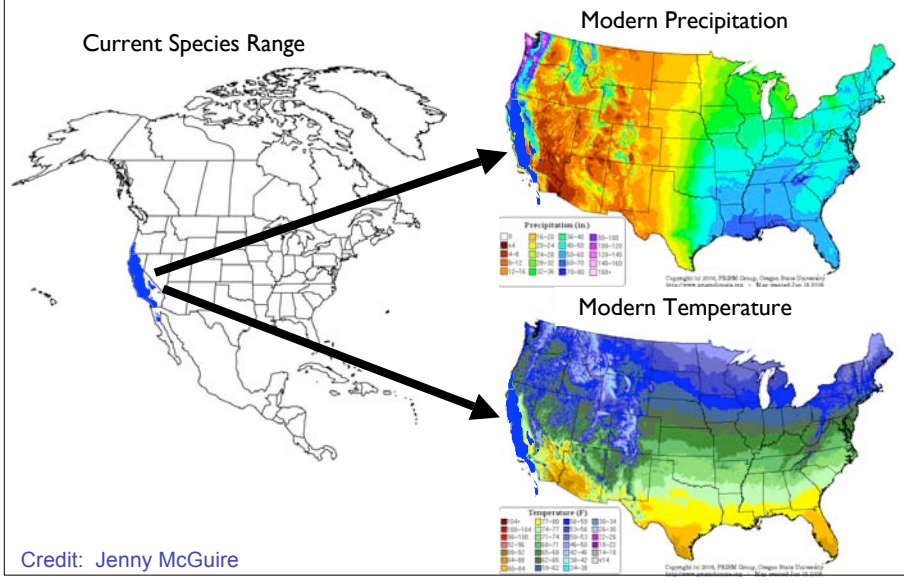
C. Moritz et al., *Science* 322, 261-264 (2008)

Inferring future geographic ranges: Ecological Niche Modeling

Current Species Range

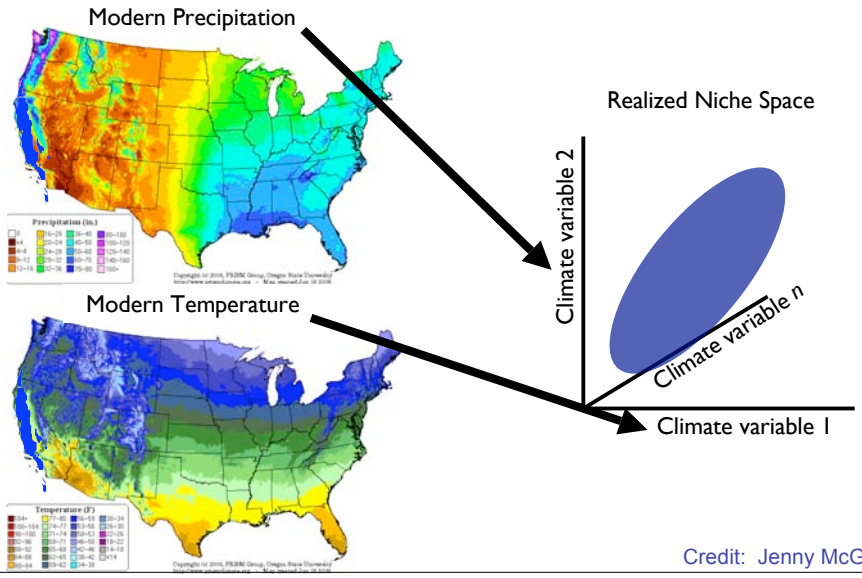
Credit: Jenny McGuire

Inferring future geographic ranges: Ecological Niche Modeling



Credit: Jenny McGuire

Inferring future geographic ranges: Ecological Niche Modeling



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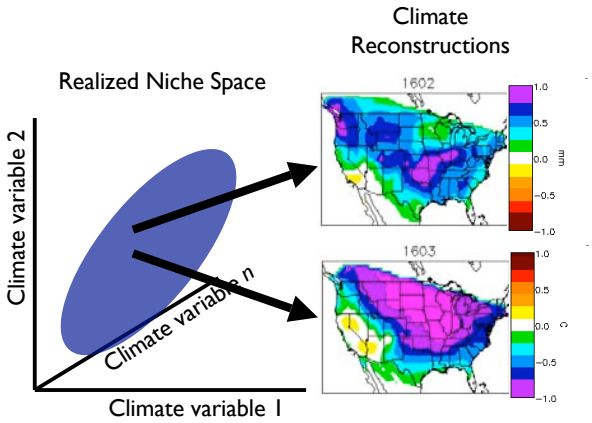
Inferring future geographic ranges: Ecological Niche Modeling



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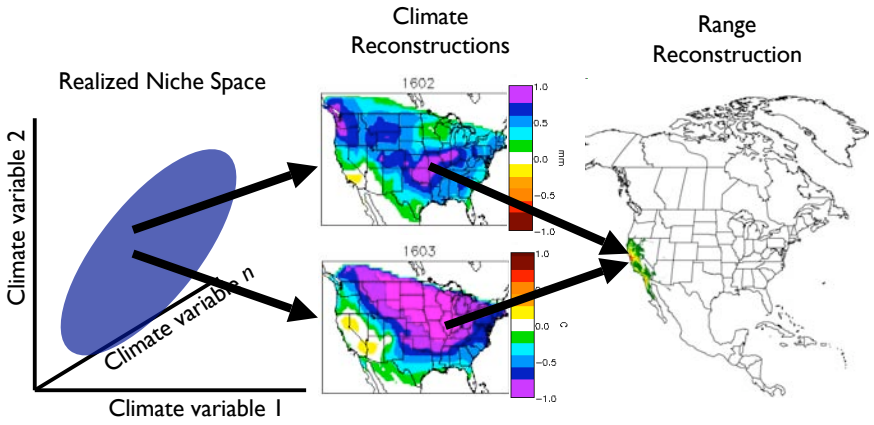
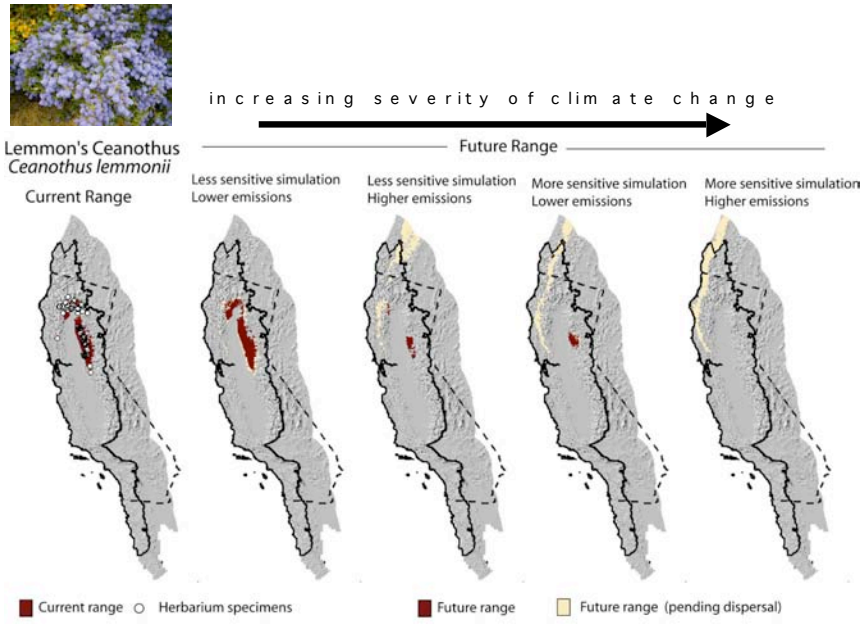
Inferring future geographic ranges: Ecological Niche Modeling

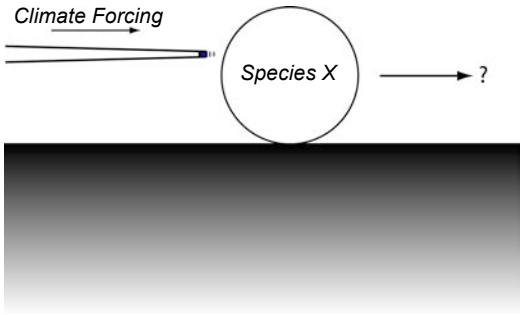


Credit: Jenny McGuire

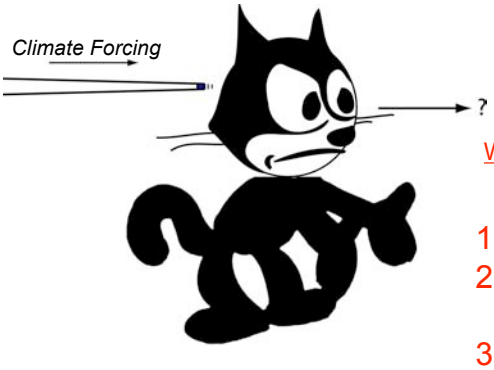


Credit: David Ackerly (UC Berkeley)

How does climate forcing effect biology?
(first generation models, incl. ENM)



How does climate forcing effect biology?
(second generation models – feedbacks; adding in the biology)



What is hidden from view?

1) Biotic interactions
2) Biotic-climate feedbacks
3) Evolutionary and genomic potential
4) Evolutionary history

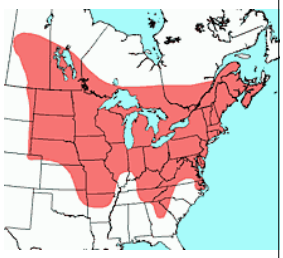
How *test* predictions of Ecological Niche Modeling (ENM)?

1)Use climate models to retrodict past climate.
2)Use ENM to retrodict past distribution.
3)Test with the fossil record.

(This work has only just begun)

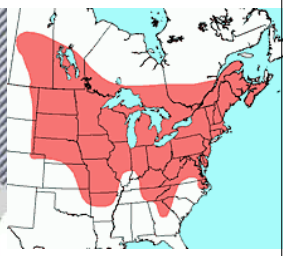
Using the fossil record to test range shifts: ranges inferred Ecological Niche Modeling

Northern short-tailed shrew



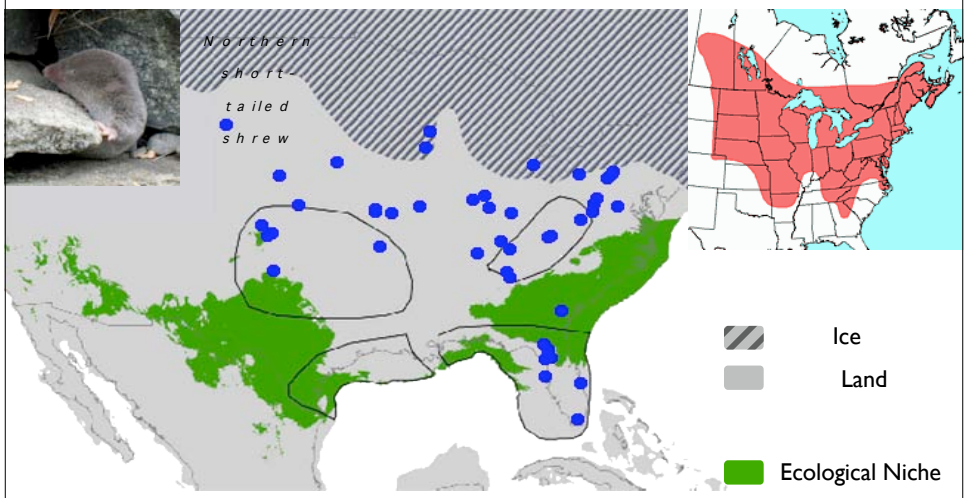
Geographic distributions during the last glacial maximum (~21,000 years ago) inferred with Ecological Niche Modeling

Northern short-tailed shrew



E. Waltari, R. Hijmans, A. T. Peterson, Á. Nyári, S. Perkins, R. Guralnick, 200

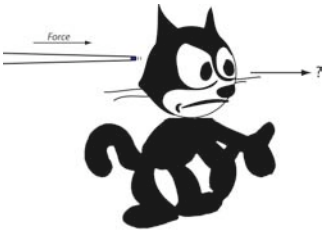
Fossil geographic range during the last glacial maximum does not match the Ecological Niche Modeling!



Davis, McGuire & Orcutt, In preparation

How do organisms respond to climate forcing?

Can't treat species as individualistic particles: a major challenge is determining how species interactions affect the responses of individual species.

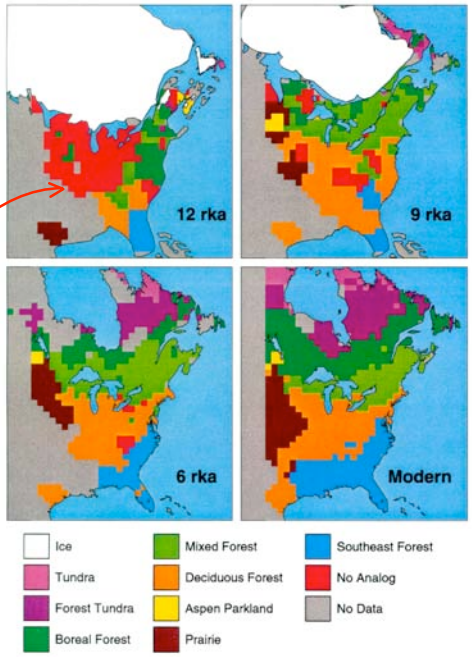


How do ecosystems respond to climate forcing?

To what extent are communities locked together?

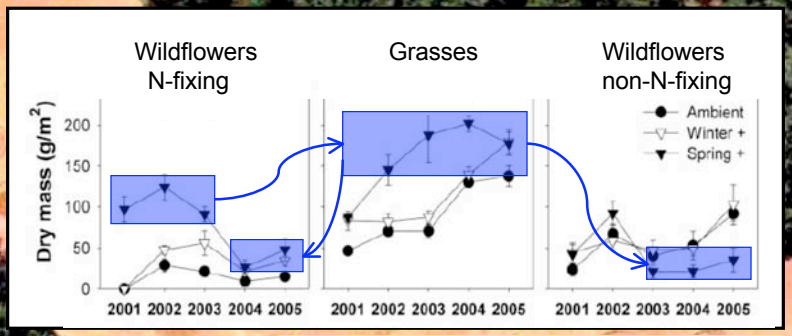
Test with the fossil record: ~14,000 years ago there was an extensive forest type not seen today

Ecosystems can be ephemeral



Jackson, S.T. and J.T. Overpeck 2000.

Experimental Manipulation – Effects of 20% increase in Spring rainfall

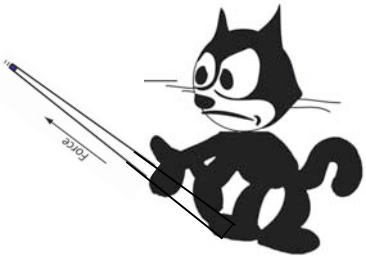


Nitrogen-fed grasses choke out the wildflowers: species interactions can be dominant!

Suttle et al. 2007 *Science*

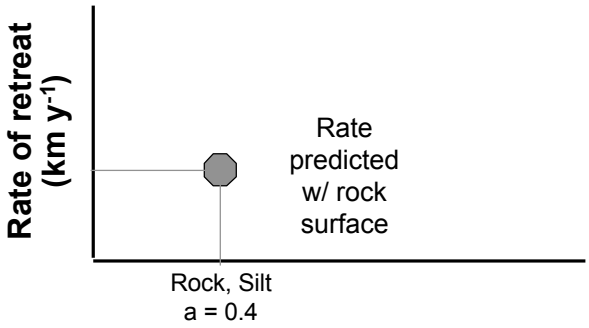
How did the California condor survive the end ice-age megafaunal extinction?

Ecosystem–Climate Feedbacks



Retreat of N. American Ice Sheet

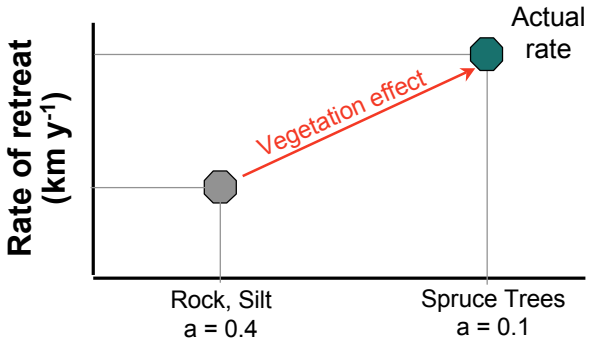
Models with rock and silt surface predict too slow a retreat



Credit: John Harte (UC Berkeley)

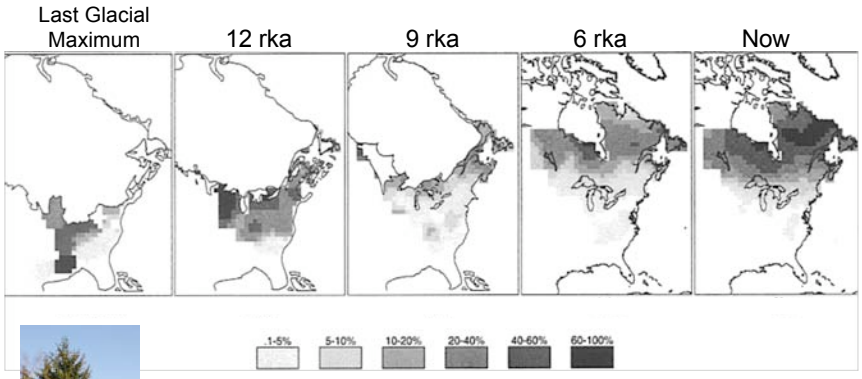
Retreat of N. American Ice Sheet

Models with Spruce trees predict correct retreat rate



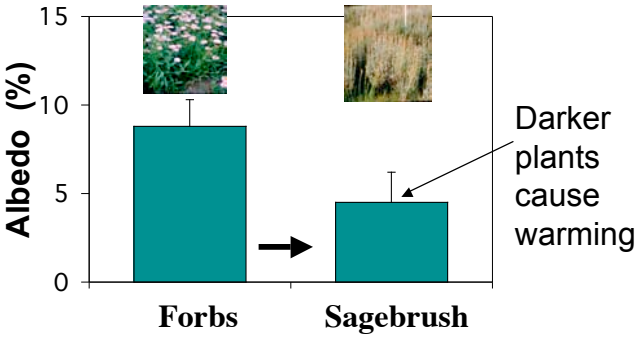
Credit: John Harte (UC Berkeley)

Fossil pollen: show spruce trees lived up against the ice until at least 9 rka.



Jackson, S.T. and J.T. Overpeck 2000. *Paleobiology*

Within-biome Albedo Feedback: climate-induced change in species composition can alter summer surface albedo



A 20% change in regional plant cover will have an effect on local summertime climate that is comparable to 2 x CO_2 forcing

Credit: John Harte (UC Berkeley)

Take Home Messages

1) We are in the discovery phase of determining the factors and feedbacks that will determine the fate of species and ecosystems due to climate forcing.

2) Feedbacks operate over many temporal scales and between the phenotype, the genotype, evolutionary history, geography, and the climate itself.

Berkeley Initiative
IN GLOBAL CHANGE BIOLOGY

UNIVERSITY OF CALIFORNIA BERKELEY

INNOVATIVE SCIENCE,
THREADED BY INFORMATICS

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John Harte
Env. Sci., Policy Management


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Biology
UCLA


David Lindberg
Integrative Biology, UCMP


Jenny McGuire
Integrative Biology, UCMP


Craig Moritz
Integrative Biology, MVZ


Mary Power
Integrative Biology

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EDUCATION, OUTREACH & POLICY