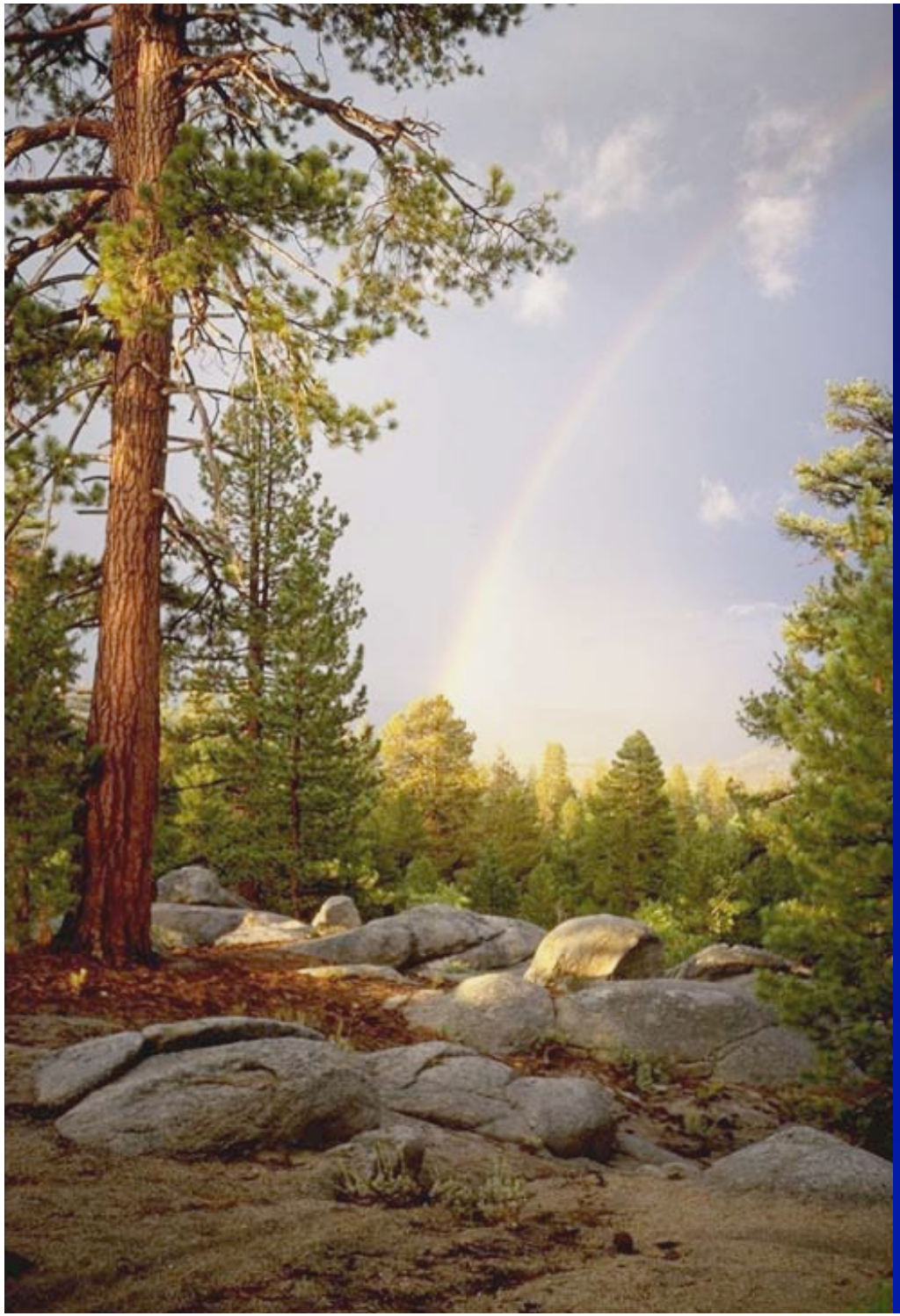


Conserving biodiversity: the role of science

James Kirchner
Swiss Federal Institute for Forest, Snow, and Landscape Research WSL

(Thanks to: Christoph Scheidegger, Kurt Bollmann, Ariel Bergamini & Michael Nobis)

Swiss Federal Institute for Forest, Snow, and Landscape Research "WSL" (www.wsl.ch)

(Birmensdorf)

Forest ecology

Biogeochemistry

Soil science

Mountain hydrology

Ecological genetics

Conservation biology

Land use dynamics

Economics and social sciences

Including: Institute for Snow and Avalanche Research "SLF" (www.slf.ch)

(Davos)

Snow physics

Avalanche dynamics, warning, and prevention

Alpine ecology

Debris flows and rockfalls

Mountain hydrology

And including: Laboratory of Ecological Systems (ECOS)

Community ecology

Management of wooded mountain pastures

Biodiversity in forest ecosystems

Wetland ecology

Climate change dynamics

(EPFL, Lausanne)

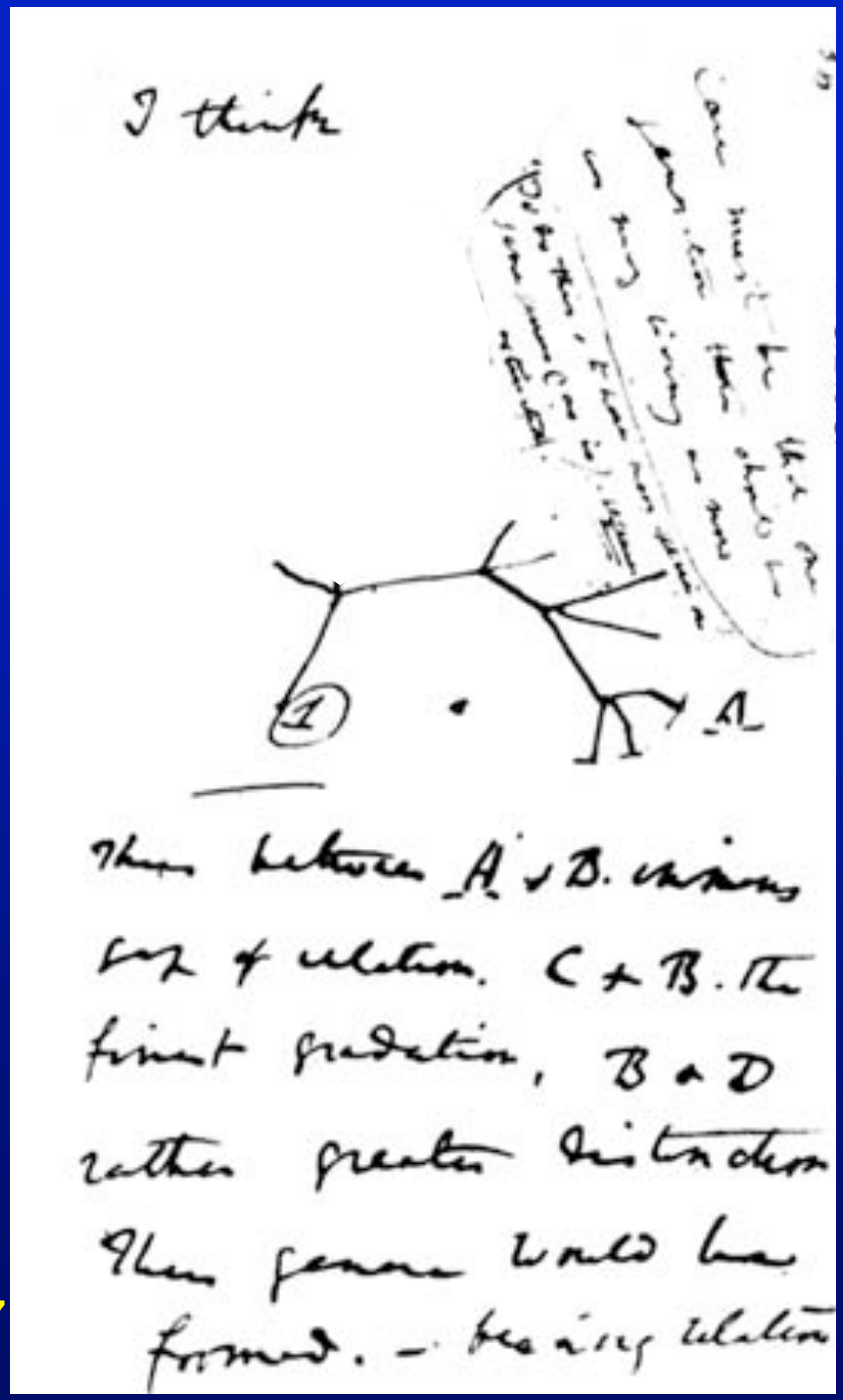
A utilitarian view of biodiversity

Rosy periwinkle
- native only to Madagascar
- source of two important leukemia drugs

Survival rate with these drugs: 95%

Without them: 20%

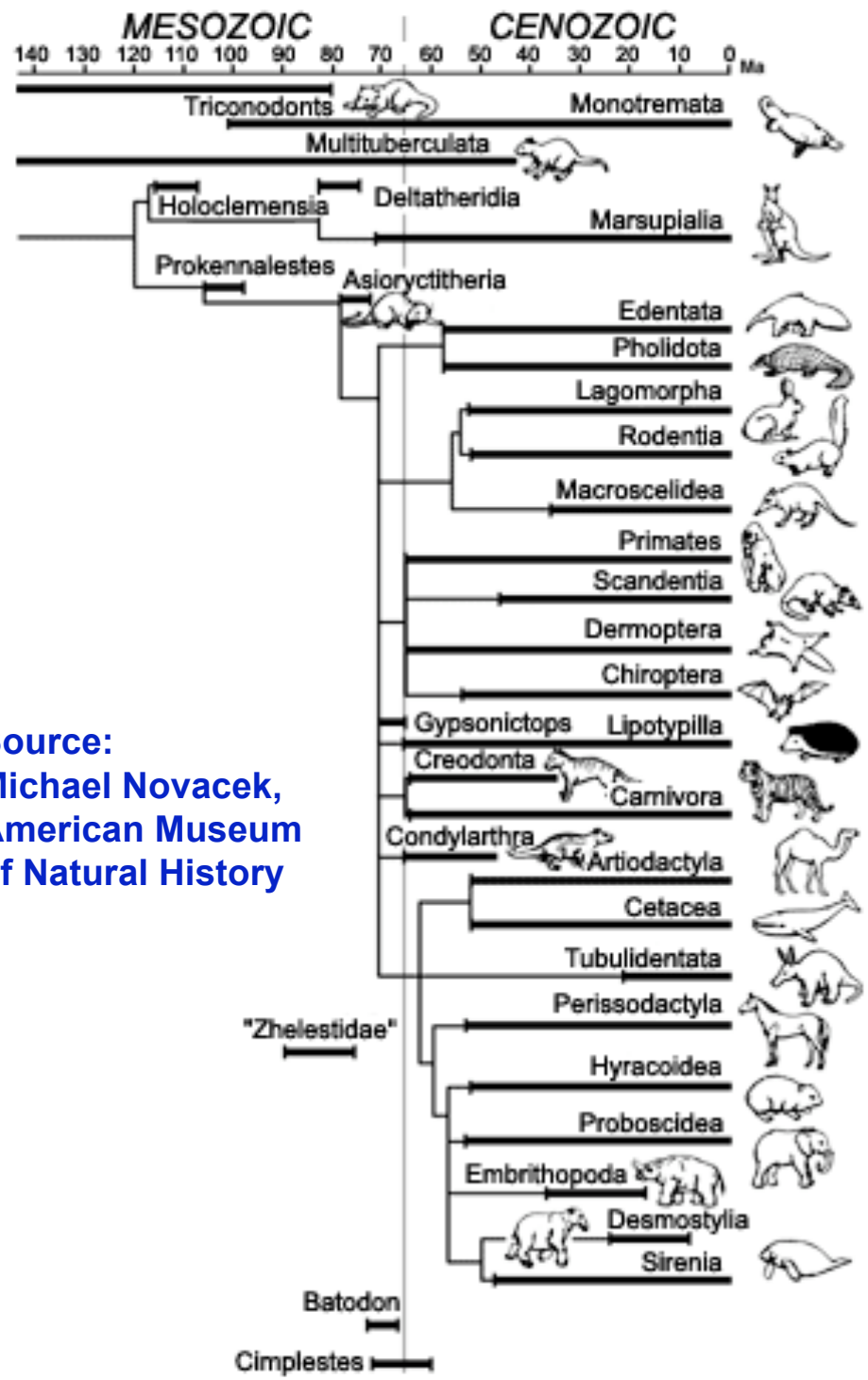
Extinction prunes the branches of the tree of life



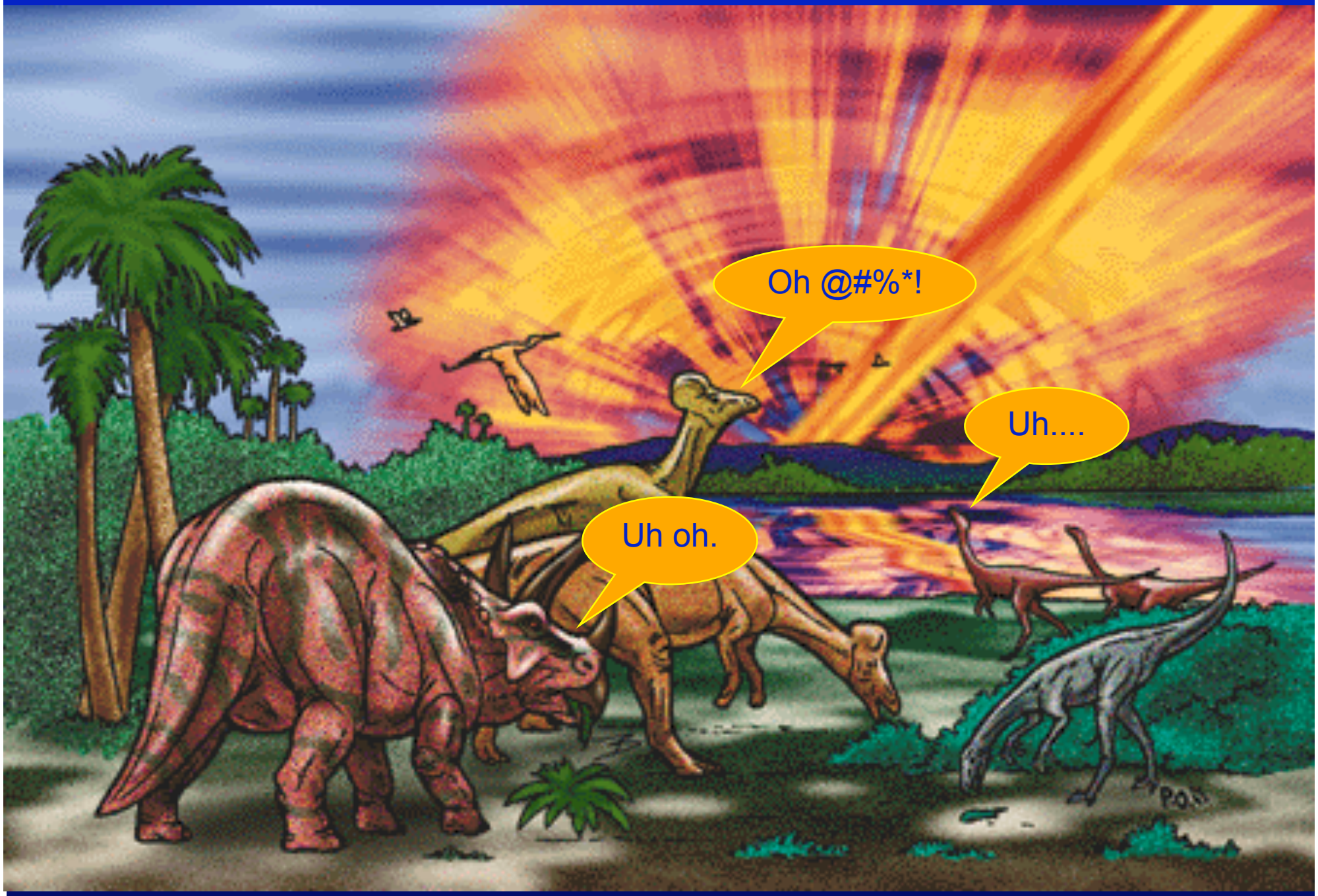
Darwin's notebook, 1837

Origination or diversification: the appearance of new species by branching of existing lineages

Increases biodiversity

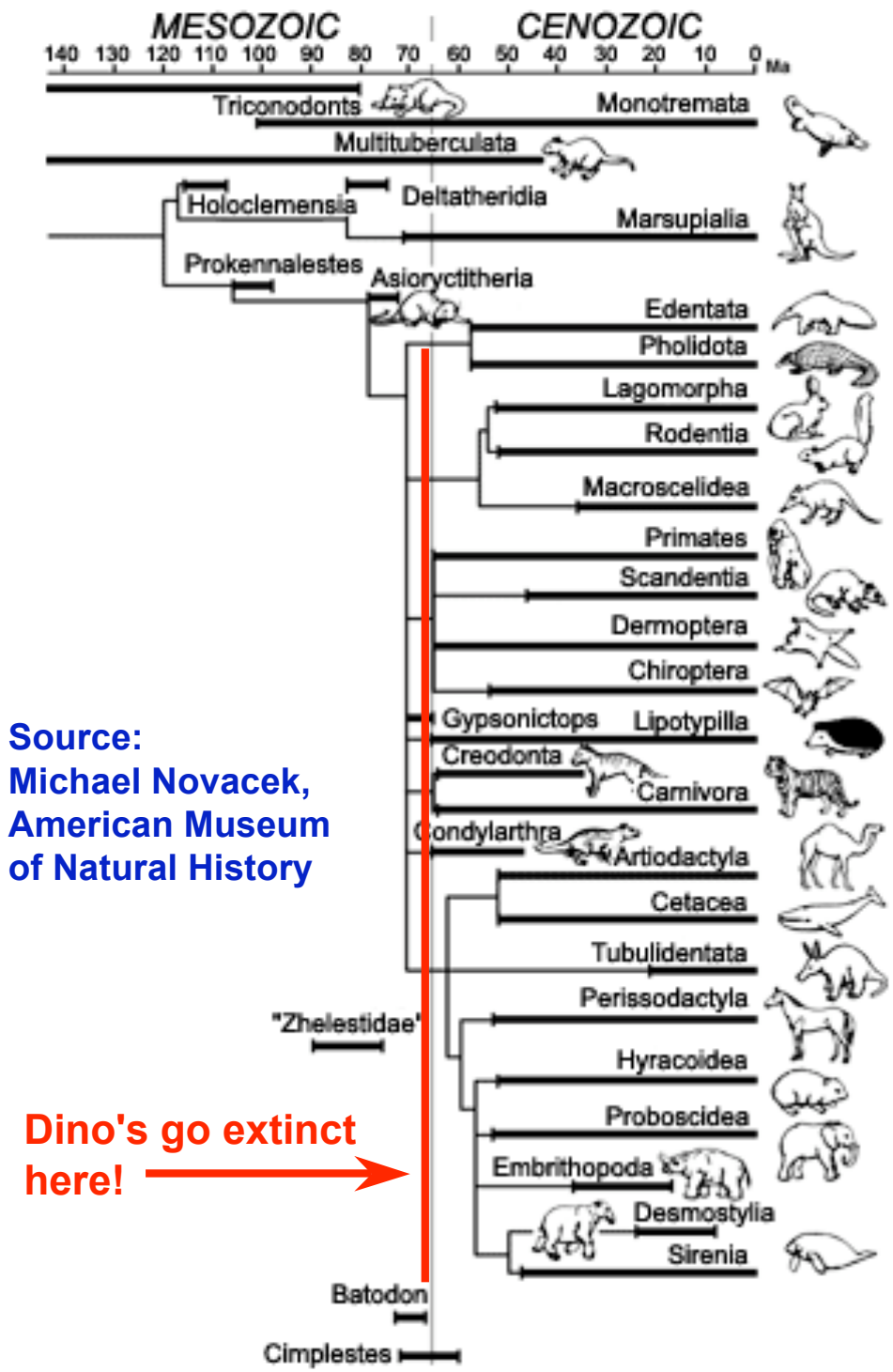


Source: Michael Novacek, American Museum of Natural History


Oh @#%*!
Uh....
Uh oh.

Mind the gap!

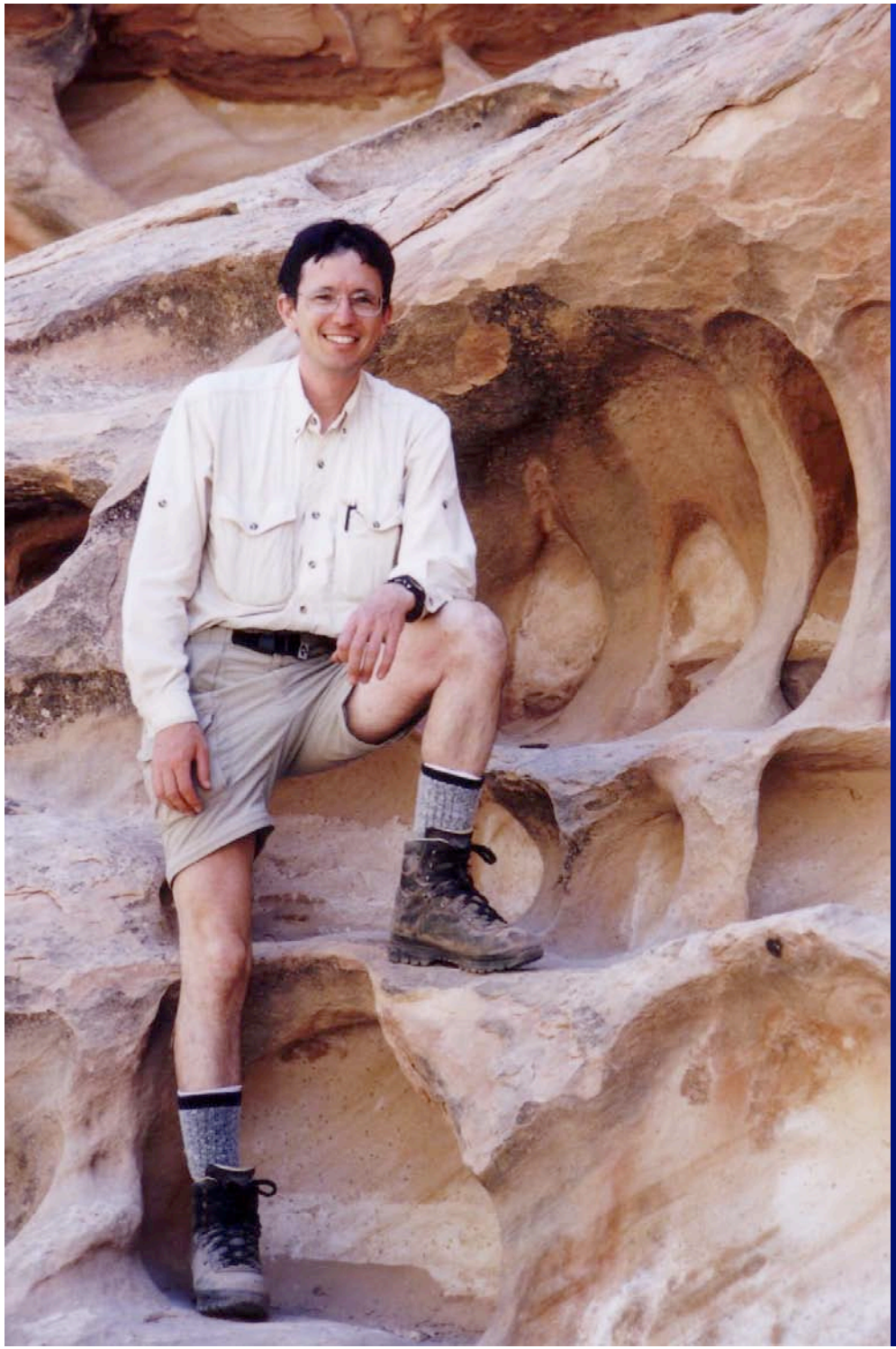
Diversification of the major groups of mammals took ~*10 million years* after the dinosaurs went extinct!



Source:
Michael Novacek,
American Museum
of Natural History

Dino's go extinct here!

The fossil record is our only long-term record of biodiversity through Earth's history



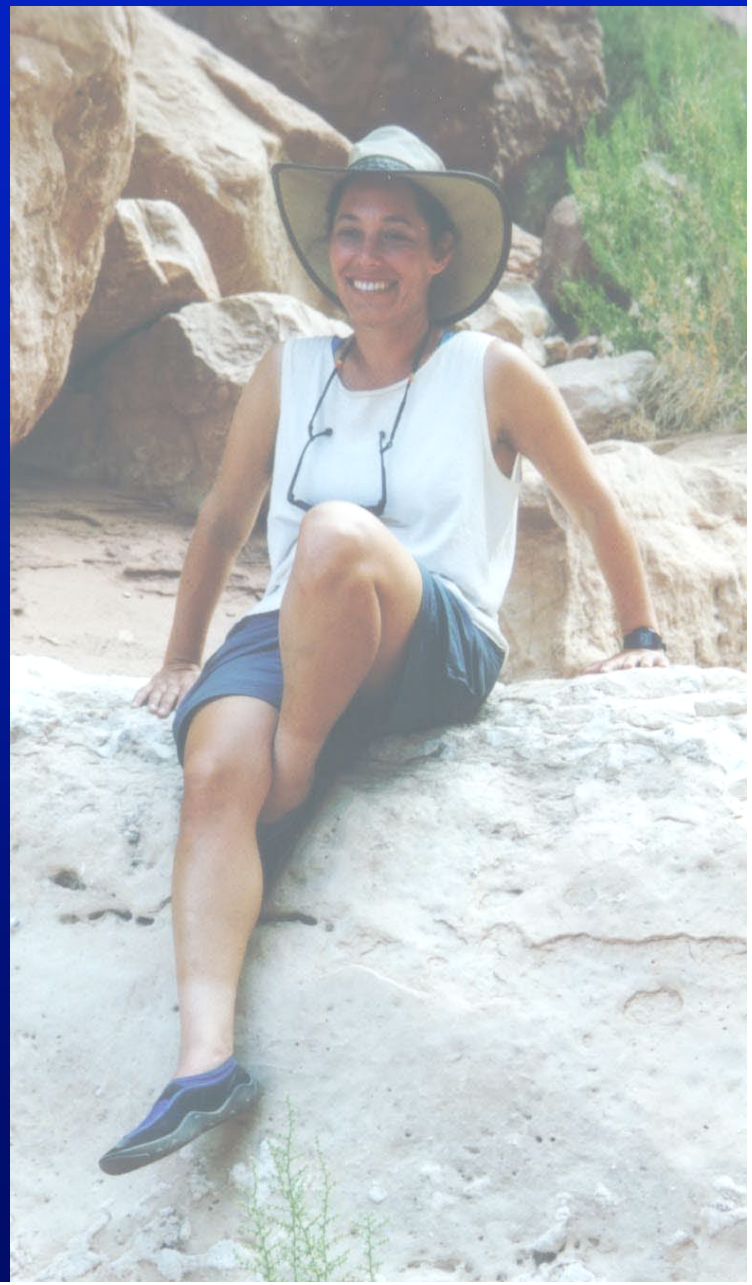
Disclaimer

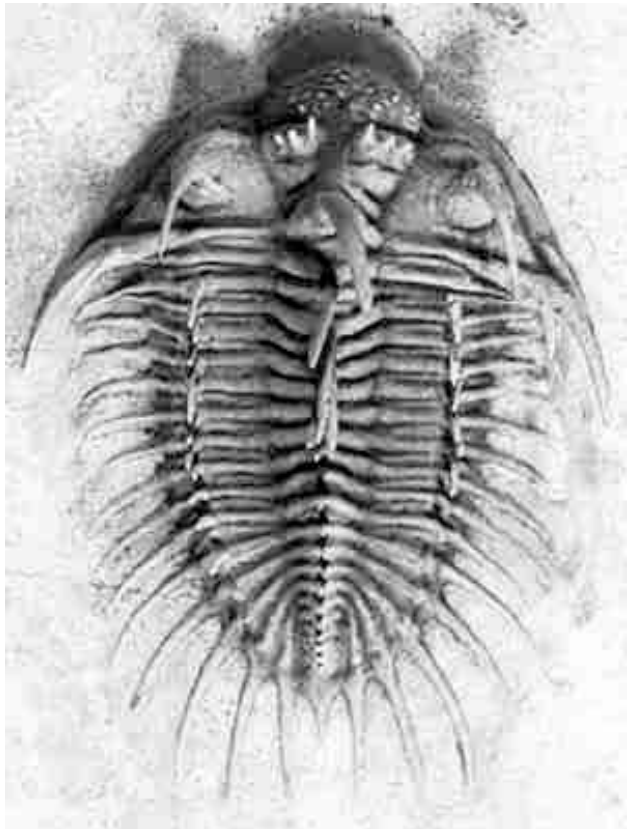
I am not a paleontologist!

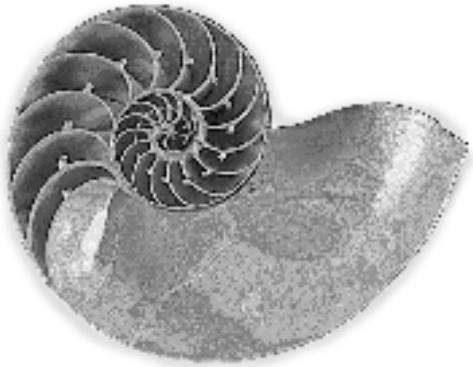
The real paleontologist behind this work is:

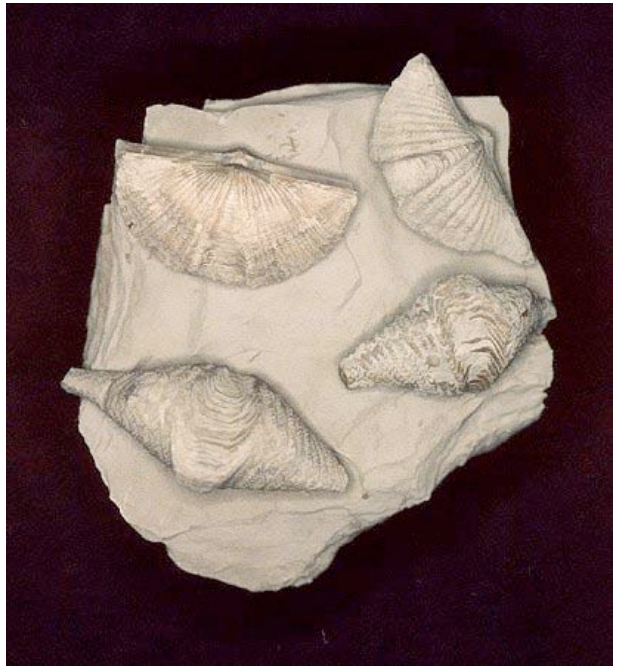
<u>Anne Weil</u>
Duke University

(Ph.D. 1999,
UC Berkeley)

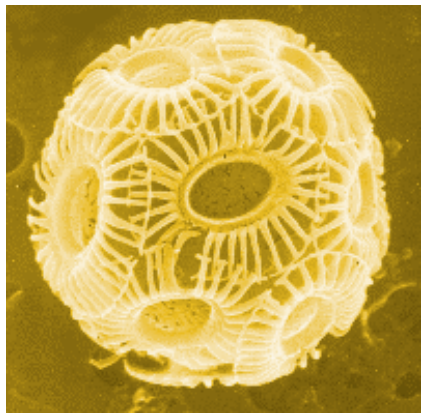


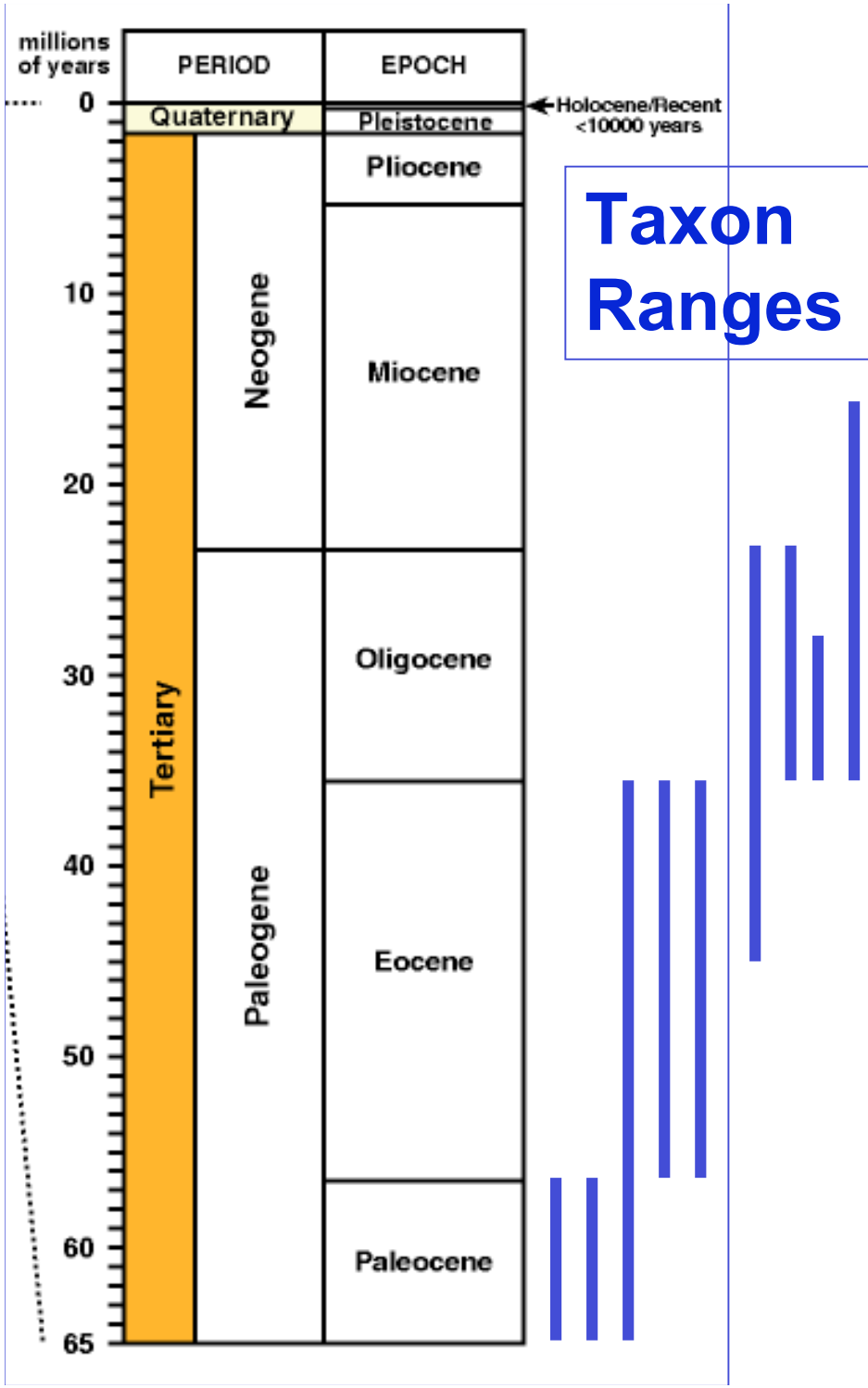






We'll be using marine fossils, mostly invertebrates



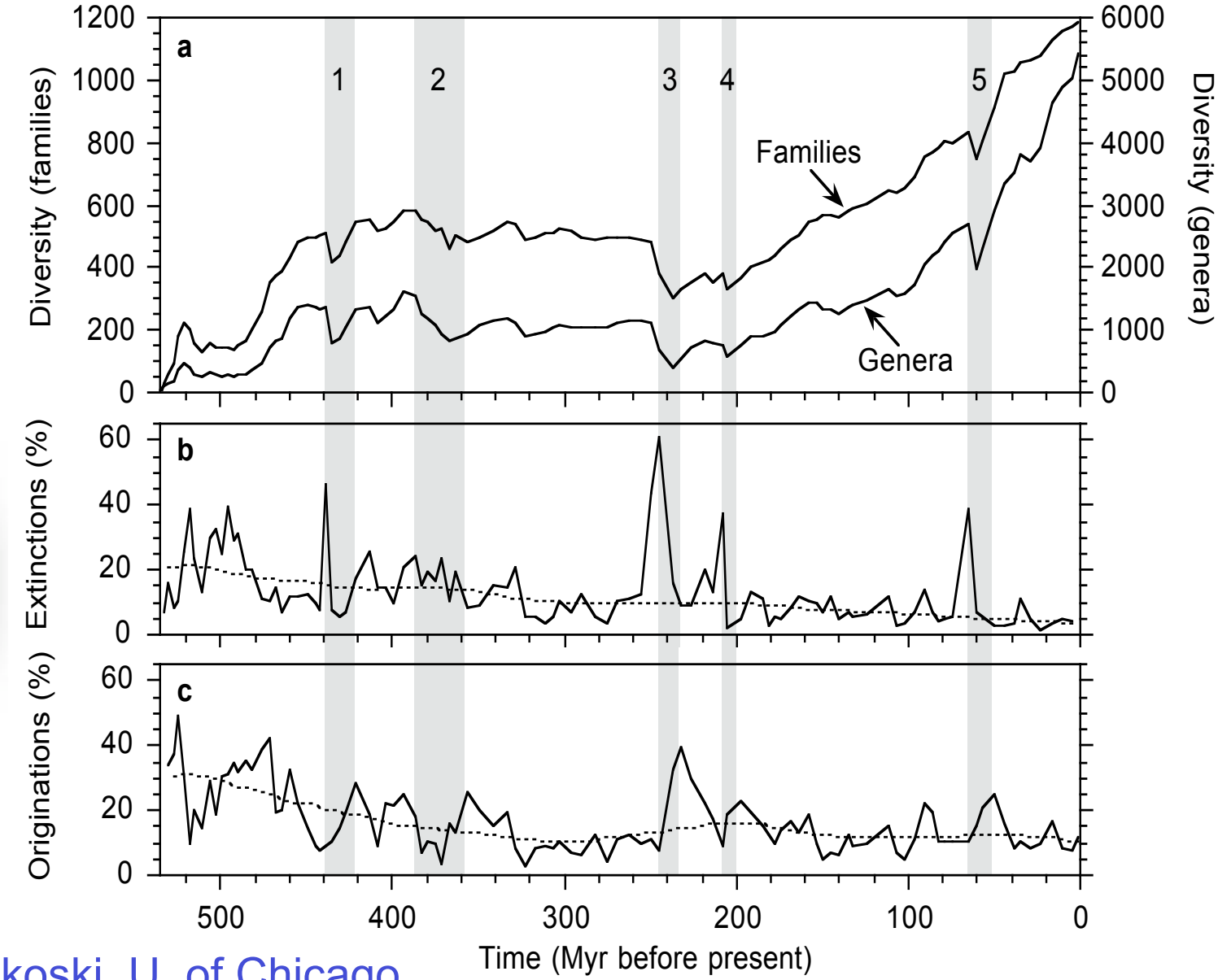


Taxon Ranges

This analysis would not have been possible without:

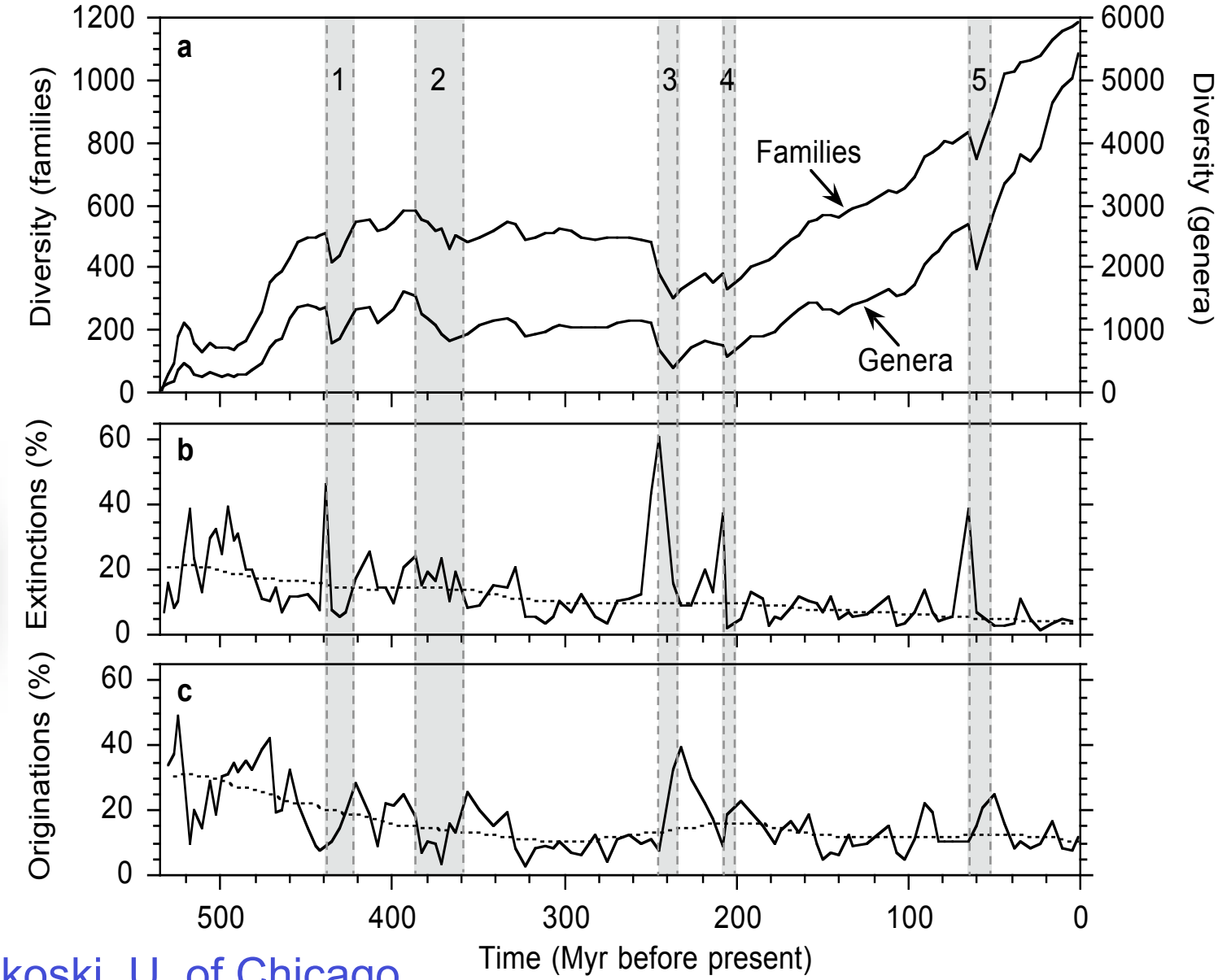
Jack Sepkoski, 1948-1999

What can fossil databases tell us about the dynamics of extinction and diversification?



Data: Jack Sepkoski, U. of Chicago

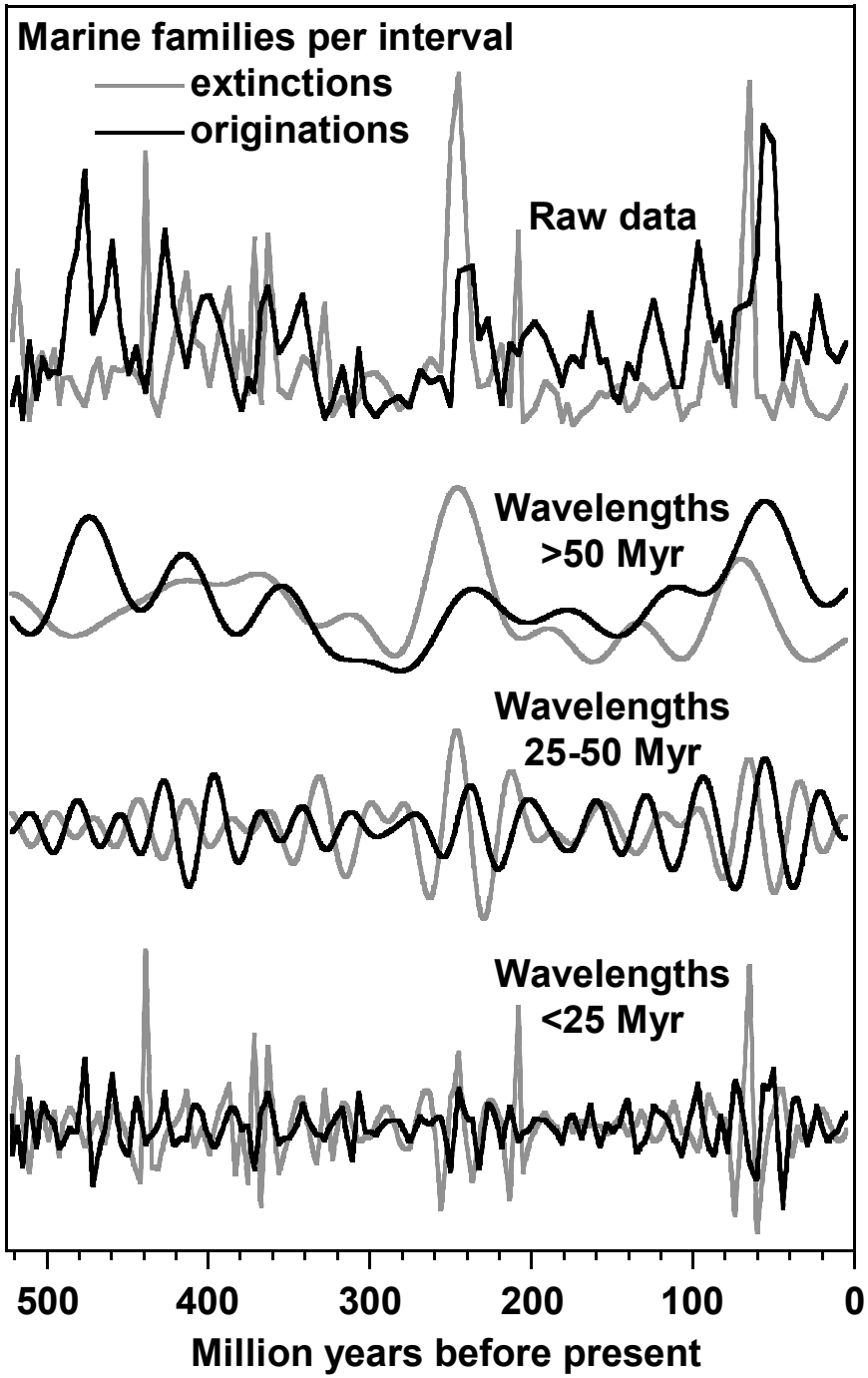
For example, how does the biosphere rebound after extinctions?



Data: Jack Sepkoski, U. of Chicago

Long, medium, and short-wavelength fluctuations separated via *Fourier filtering* (gray=extinction rates, black=origination rates).

Origination & extinction rates are equally variable, <u>except:</u> originations are much less variable than extinctions over the short term (<25 Myr).



Implication: origination rates can't accelerate quickly to offset pulses of extinction

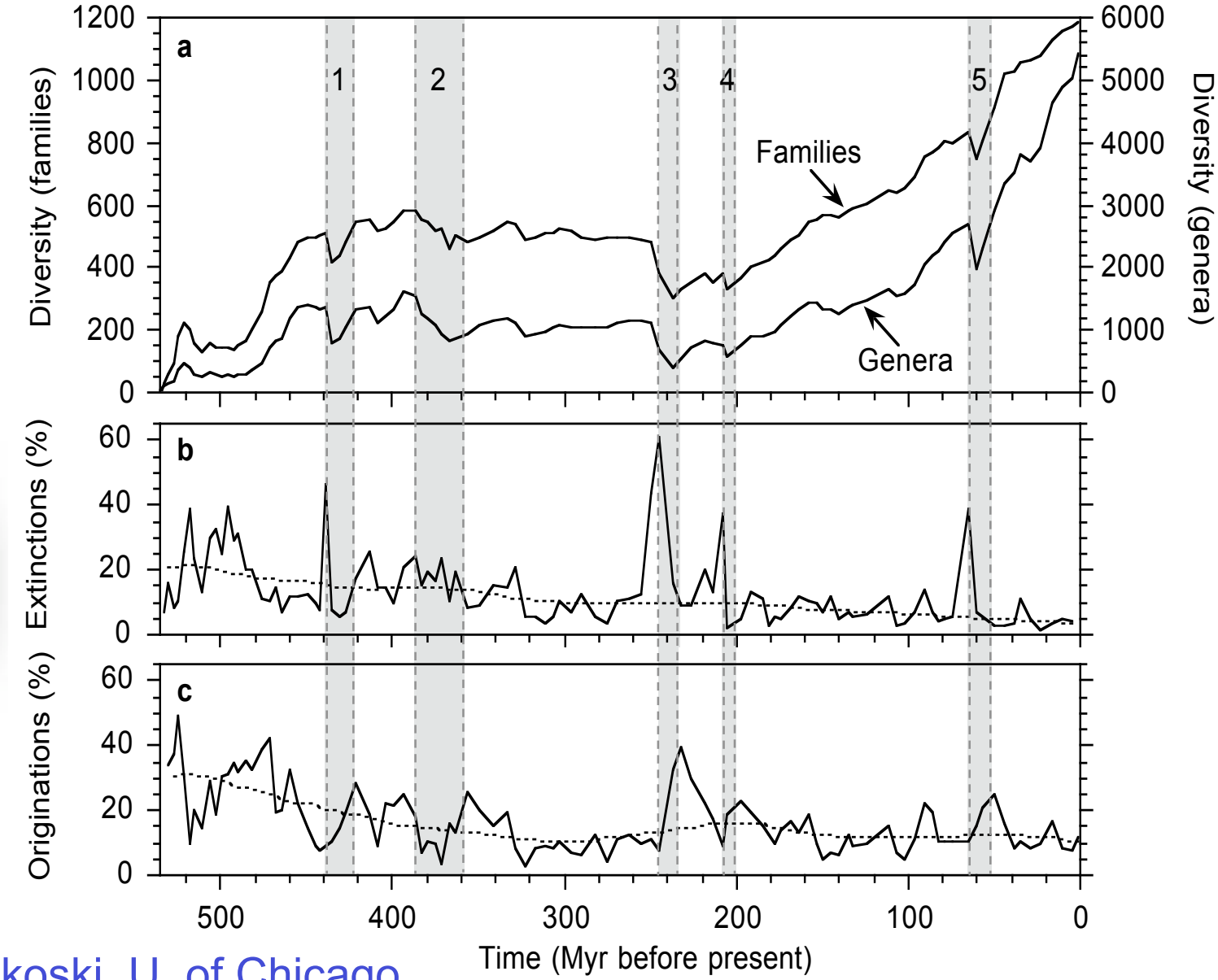
Evolutionary speed limits inferred from the fossil record

James W. Kirchner

Department of Earth and Planetary Science, University of California, Berkeley, California 94720-4767, USA

The dynamics of extinction and diversification determine the long-term effects of extinction episodes[1]. If rapid bursts of extinction are offset by equally rapid bursts of diversification, their biodiversity consequences will be transient. But if diversification rates cannot accelerate rapidly enough, pulses of extinction will lead to long-lasting depletion of biodiversity[2,3]. Here I use spectral analysis of the fossil record to test whether diversification rates can accelerate as much as extinction rates, over both short and long spans of geological time. I show that although the long-wavelength variability of diversification rates equals or exceeds that of extinctions, diversification rates are markedly less variable than extinction rates at wavelengths shorter than roughly 25 million years. This implies that there are intrinsic speed limits that constrain how rapidly diversification rates can accelerate in response to pulses of extinction.

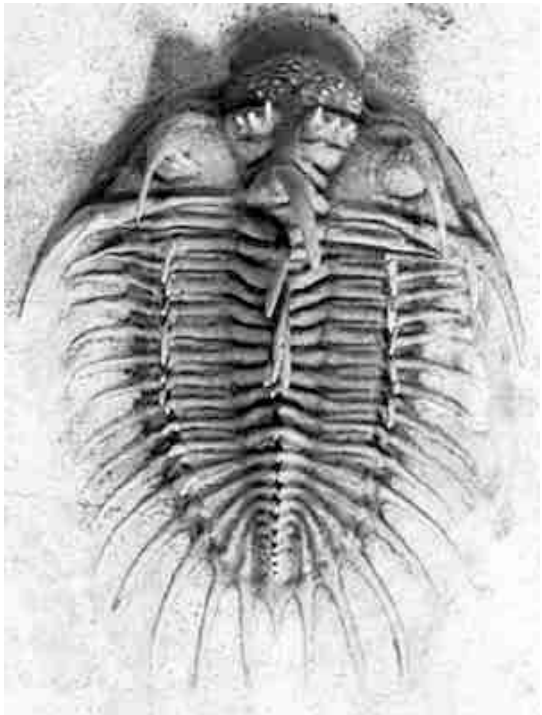
Are pulses of extinction followed by pulses of diversification? If so, what is the recovery time between them?

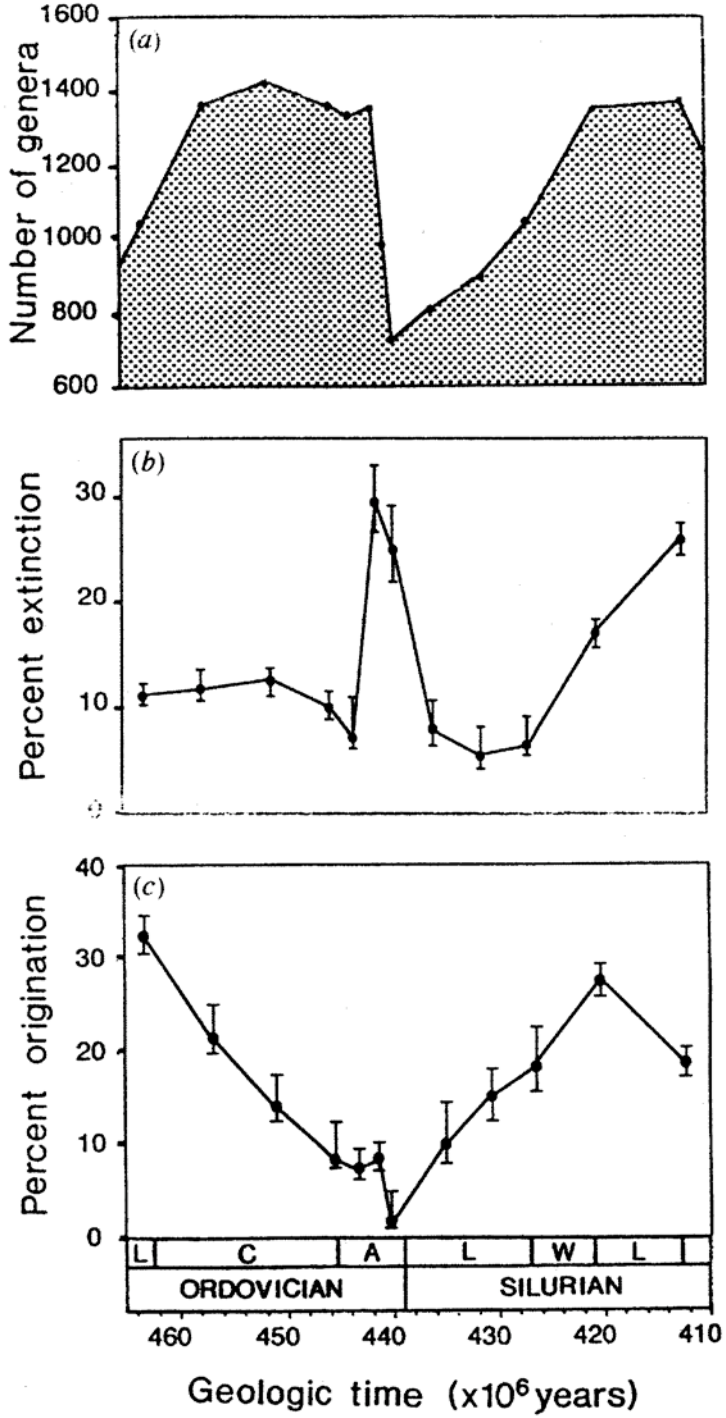


Data: Jack Sepkoski, U. of Chicago

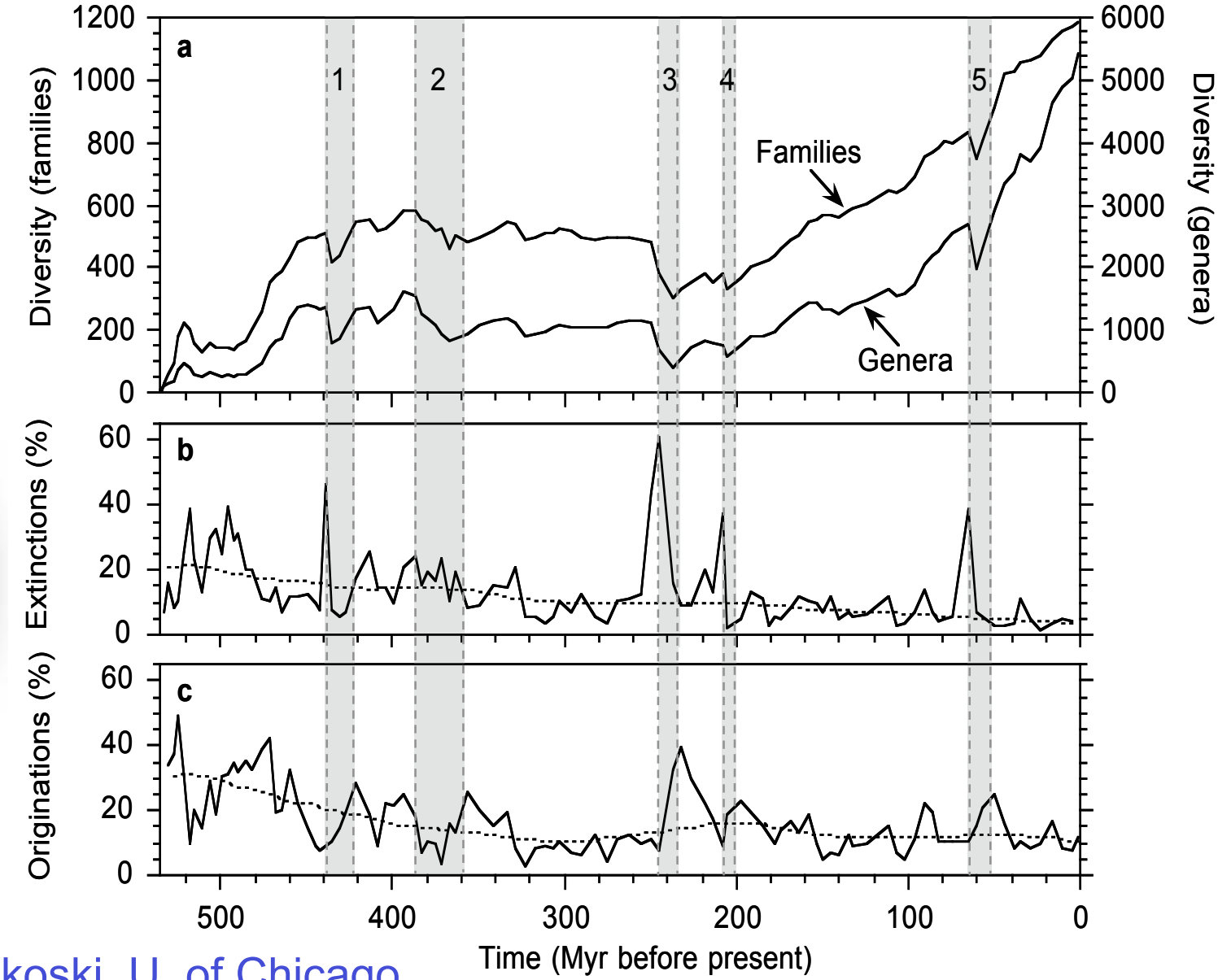
Delayed recovery from one mass extinction

From Sepkoski, 1998



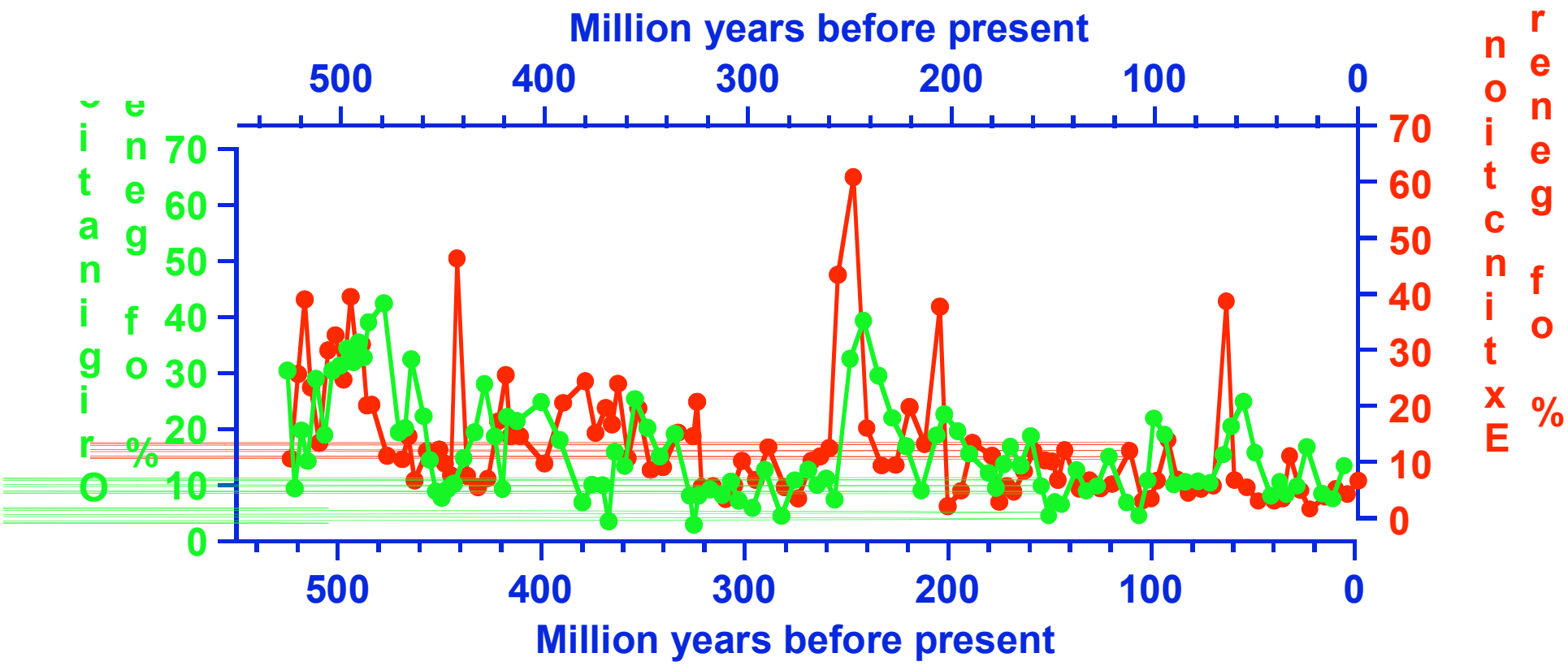


Is there a characteristic lag between pulses of extinction and pulses of diversification?

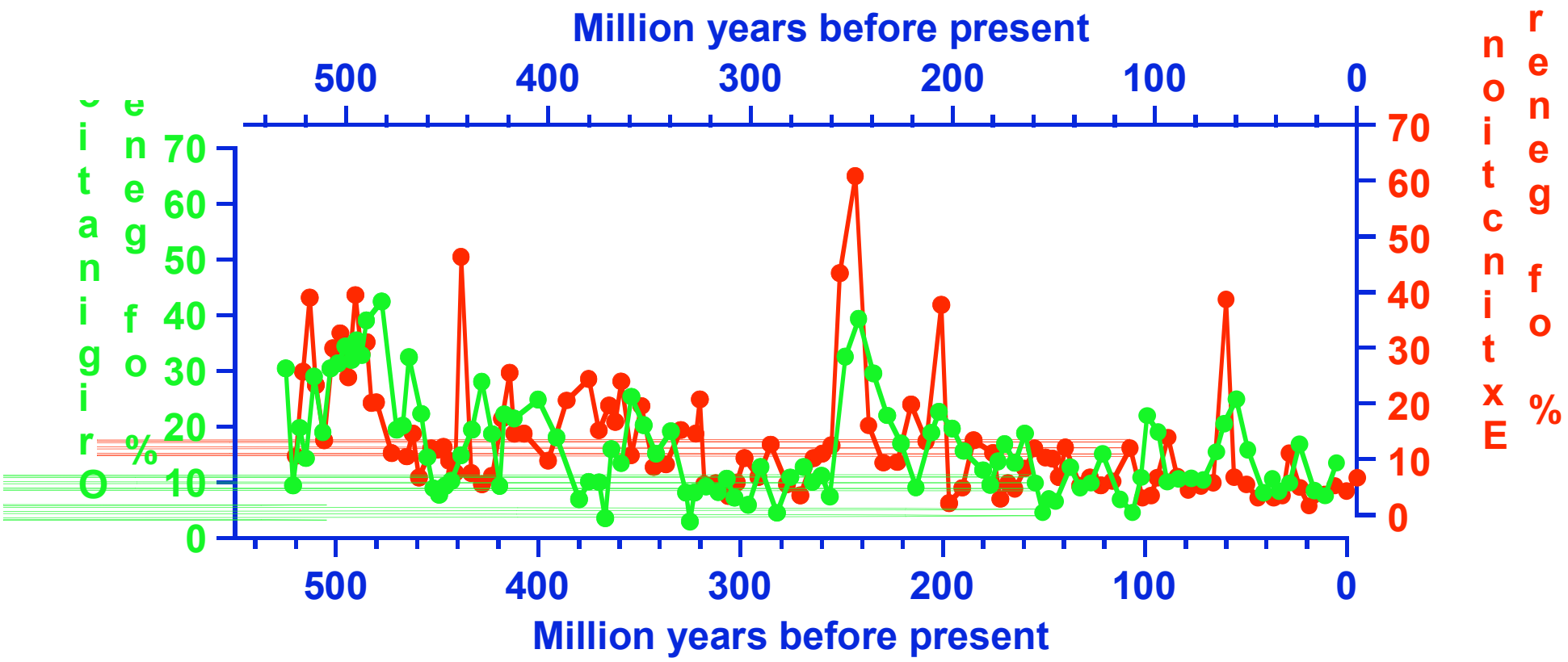


Data: Jack Sepkoski, U. of Chicago

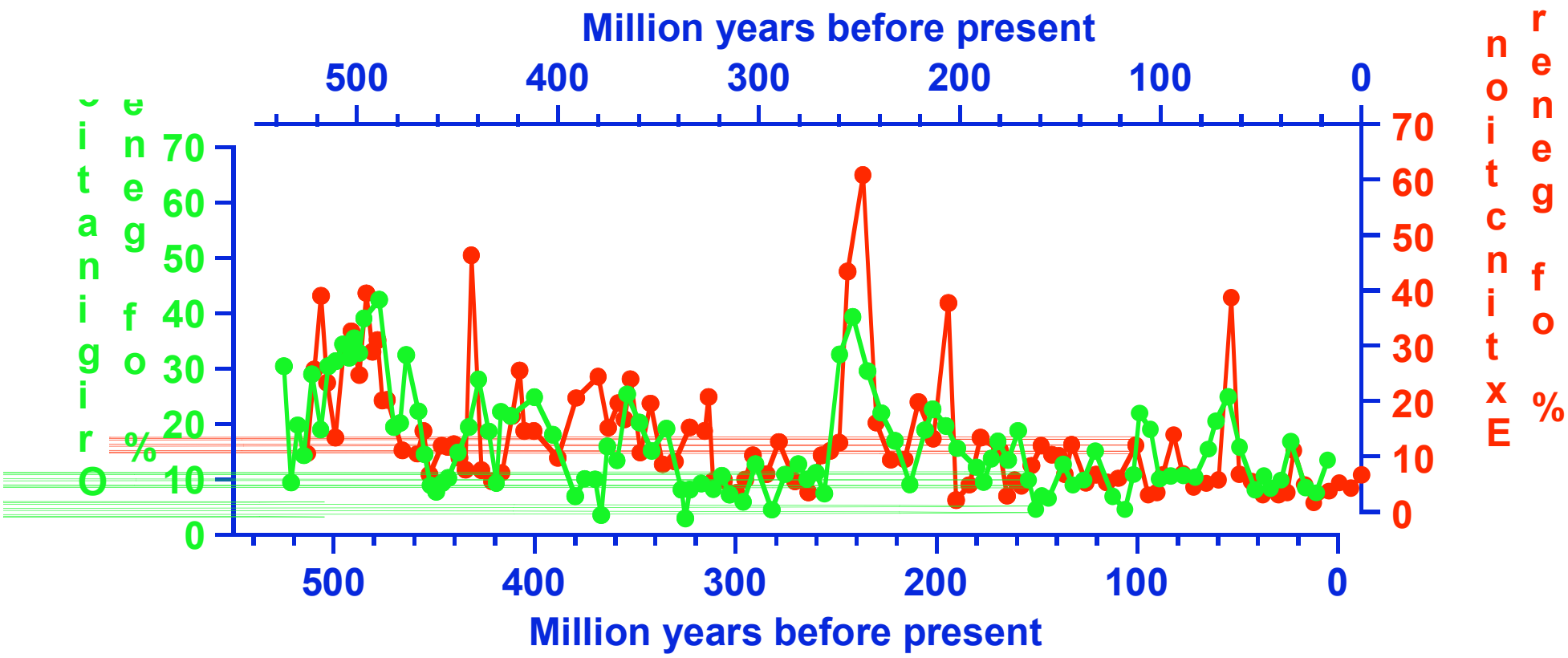
Offset between extinction and diversification time series: 0 Myr



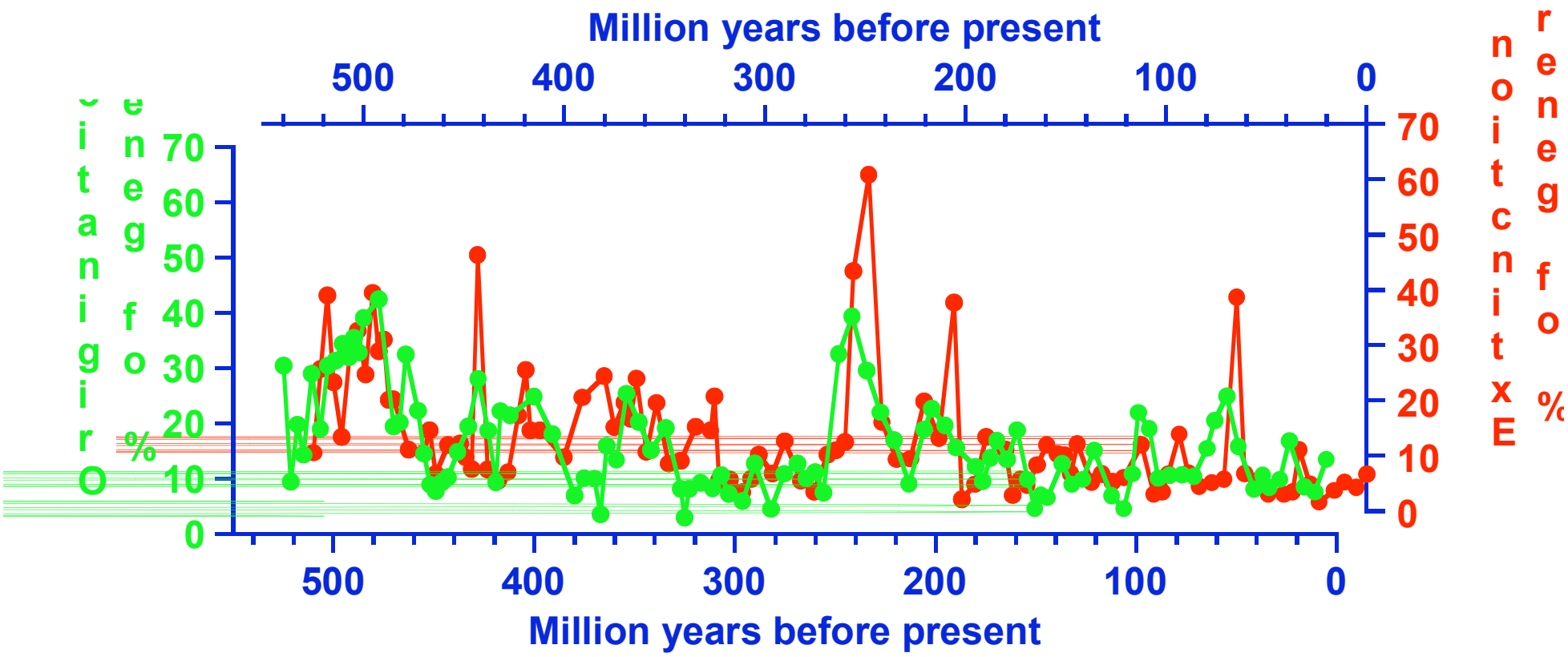
Offset between extinction and diversification time series: 5 Myr



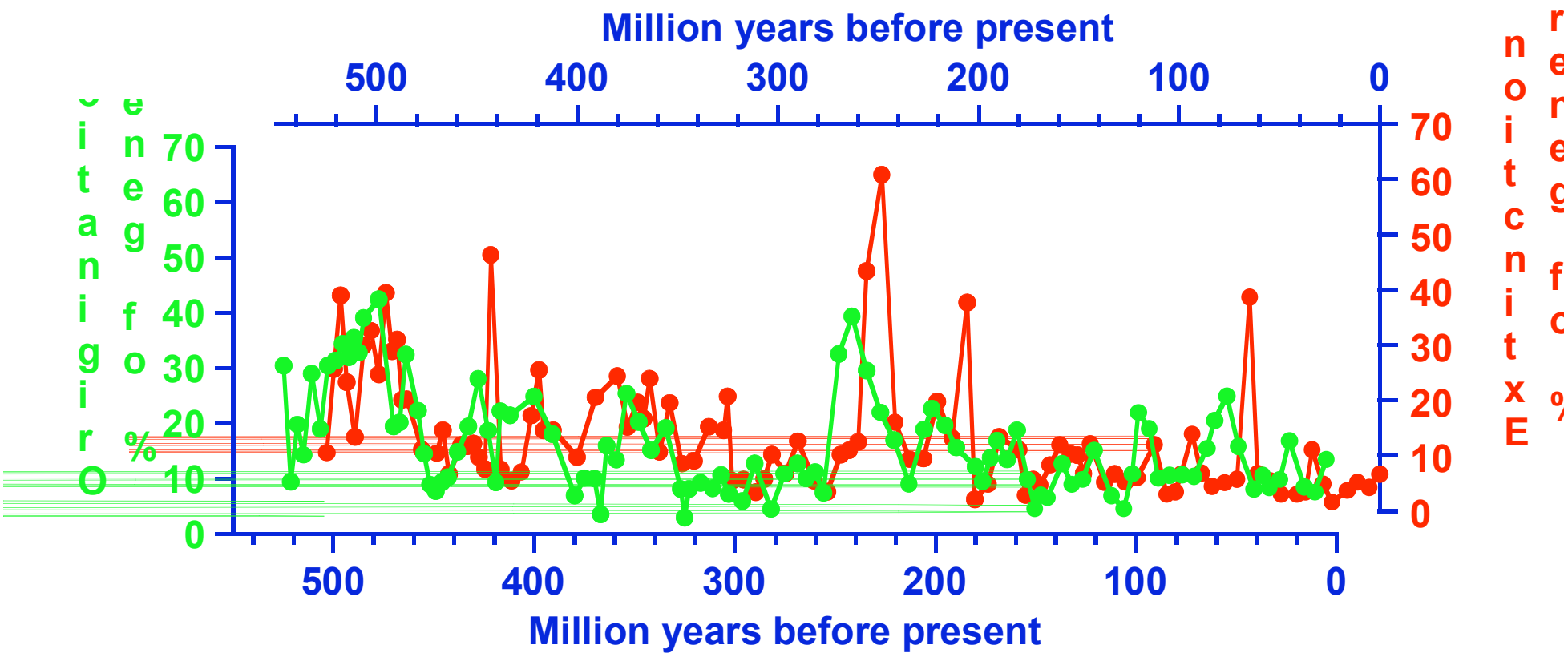
Offset between extinction and diversification time series: 10 Myr



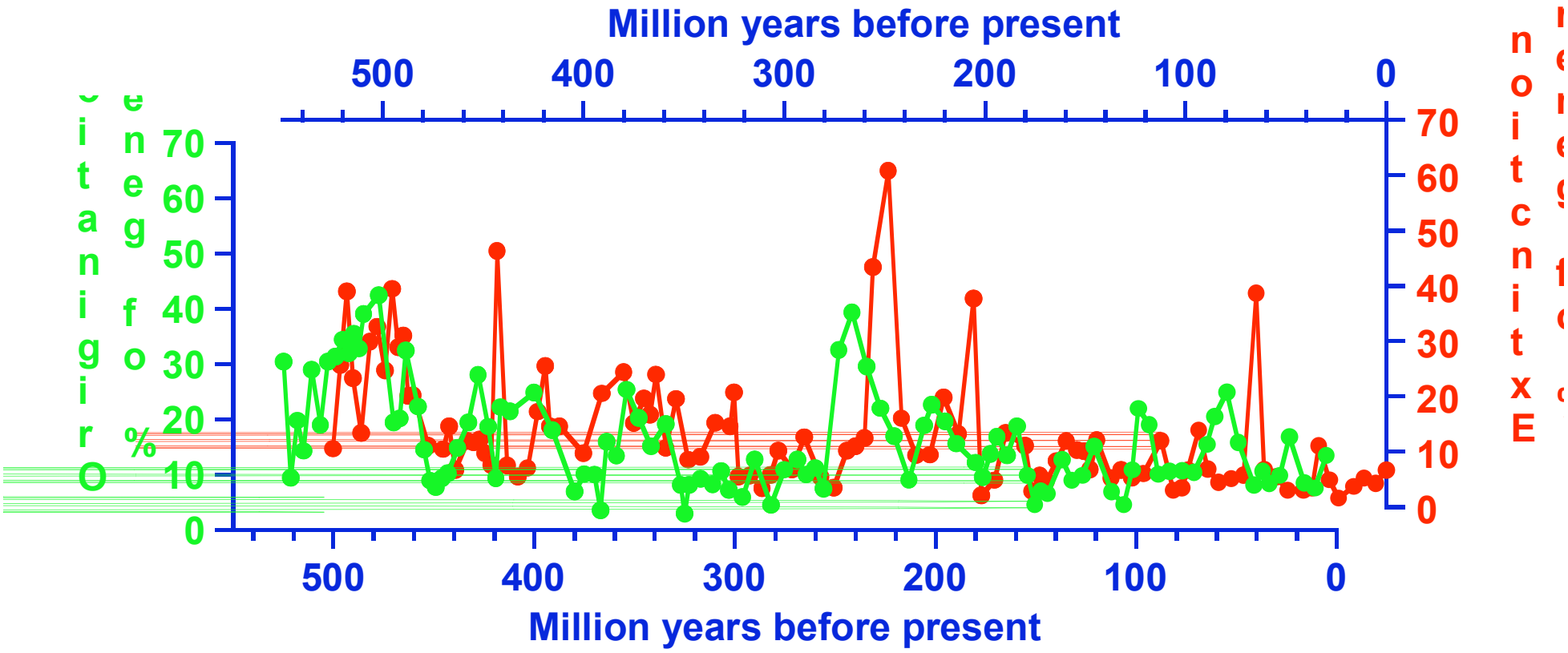
Offset between extinction and diversification time series: 15 Myr



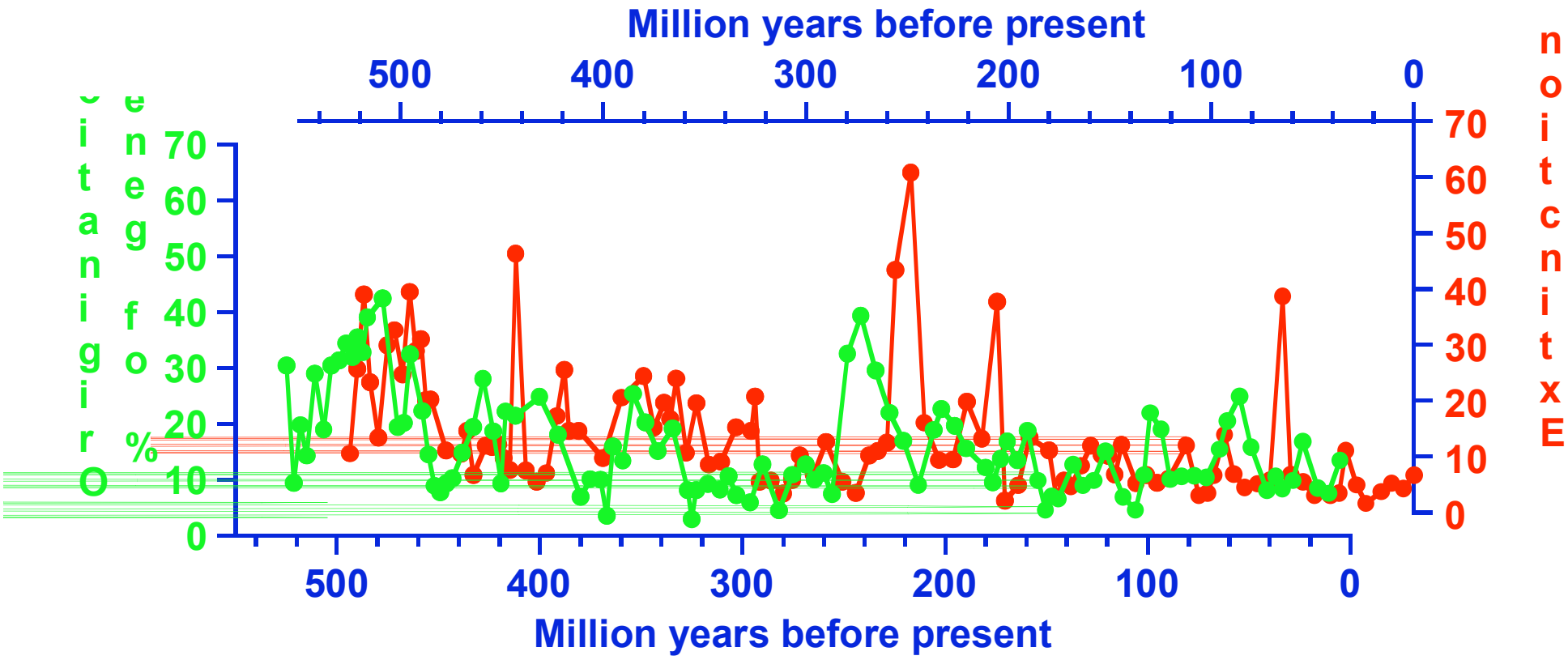
Offset between extinction and diversification time series: 20 Myr



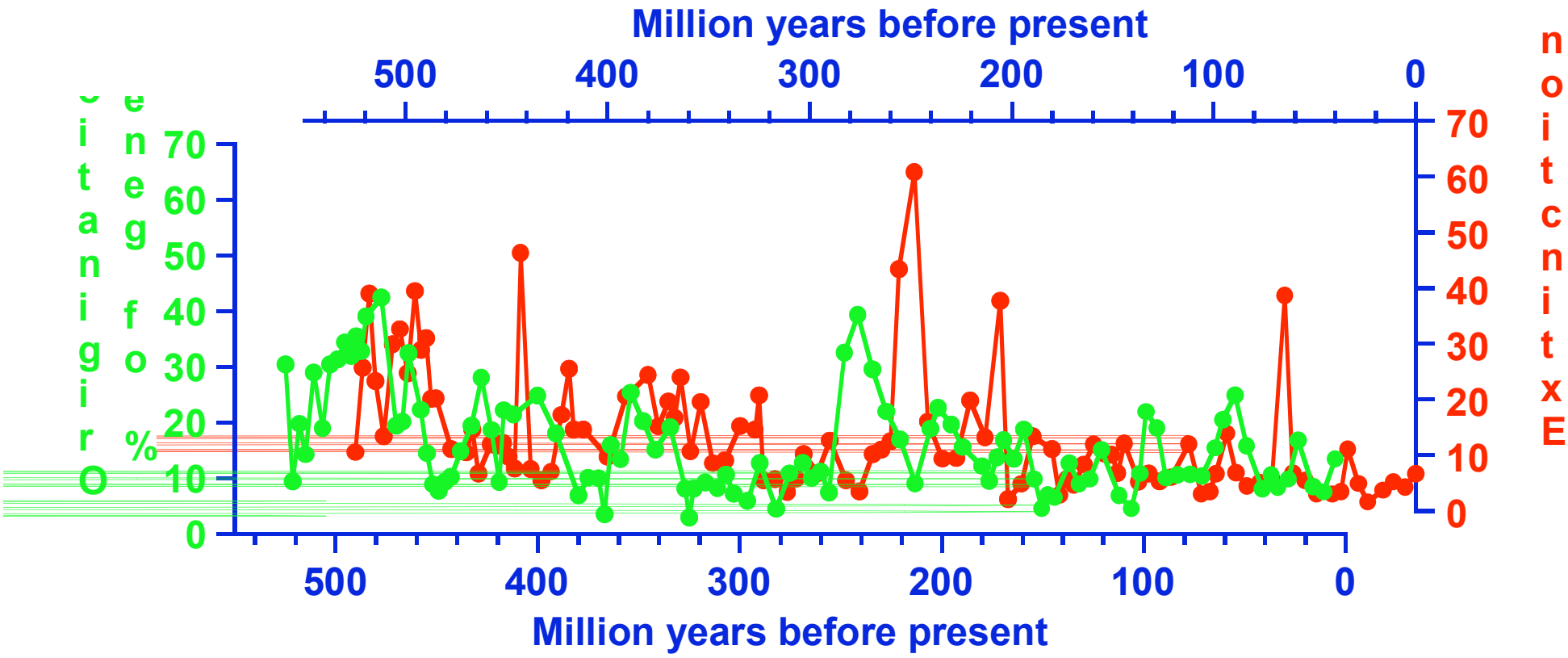
Offset between extinction and diversification time series: 25 Myr



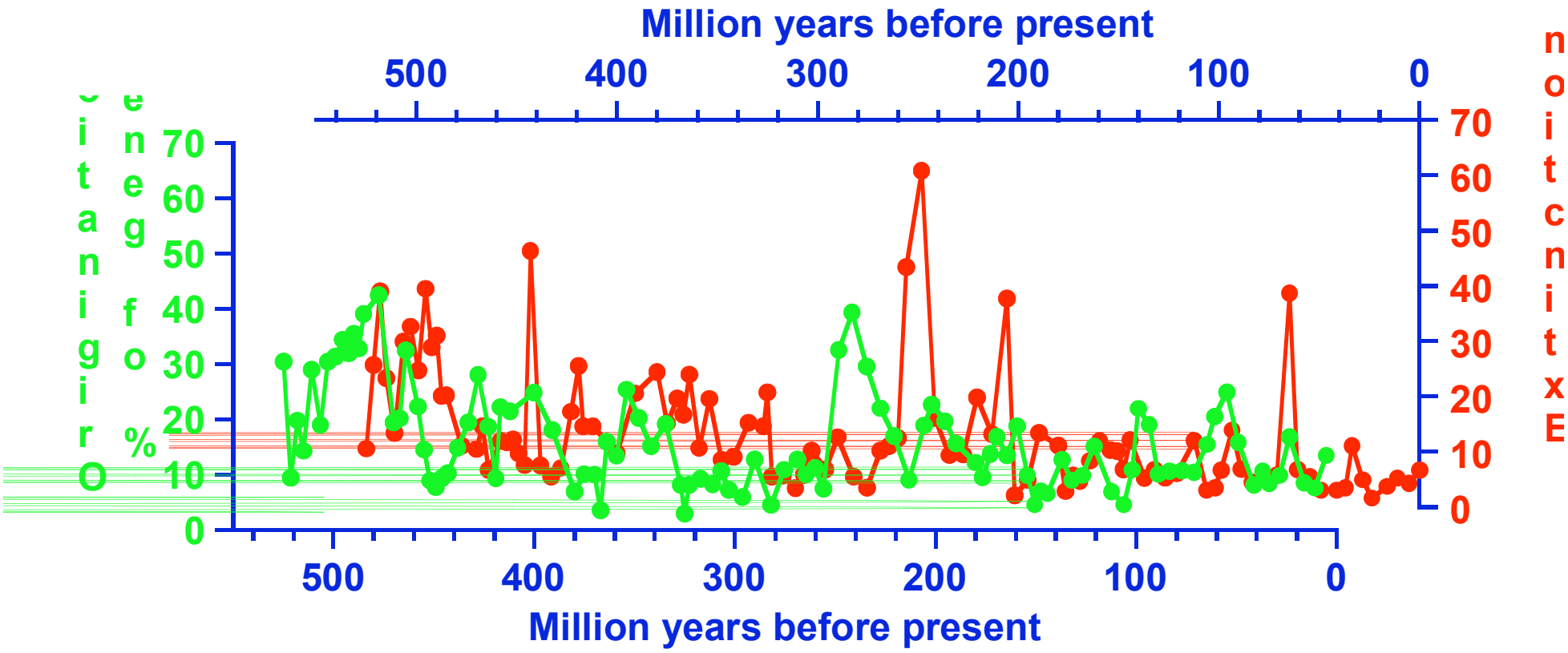
Offset between extinction and diversification time series: 30 Myr



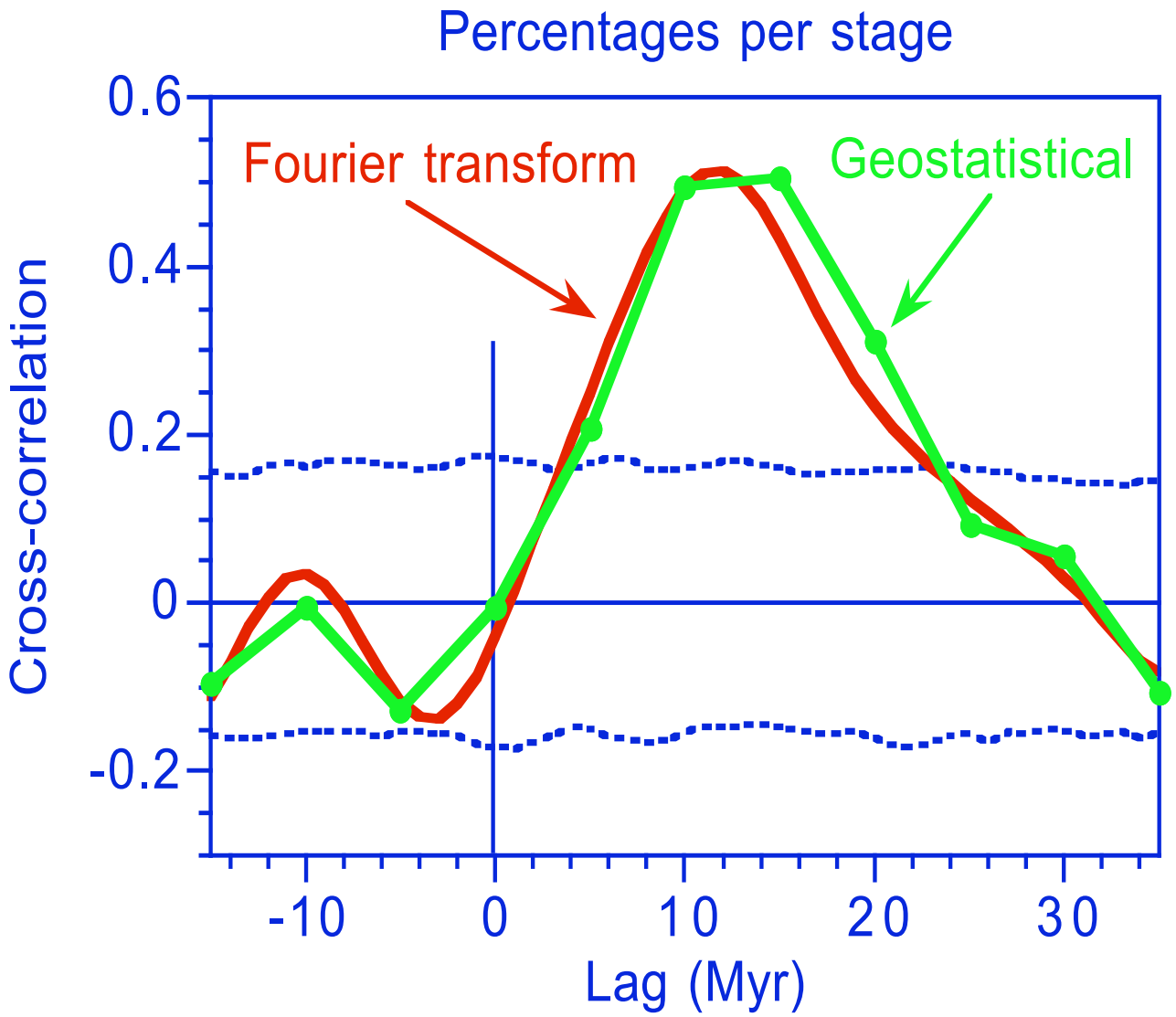
Offset between extinction and diversification time series: 35 Myr



Offset between extinction and diversification time series: 40 Myr



Diversification rates are correlated with extinction rates, but with a 10-million-year lag!



Results:

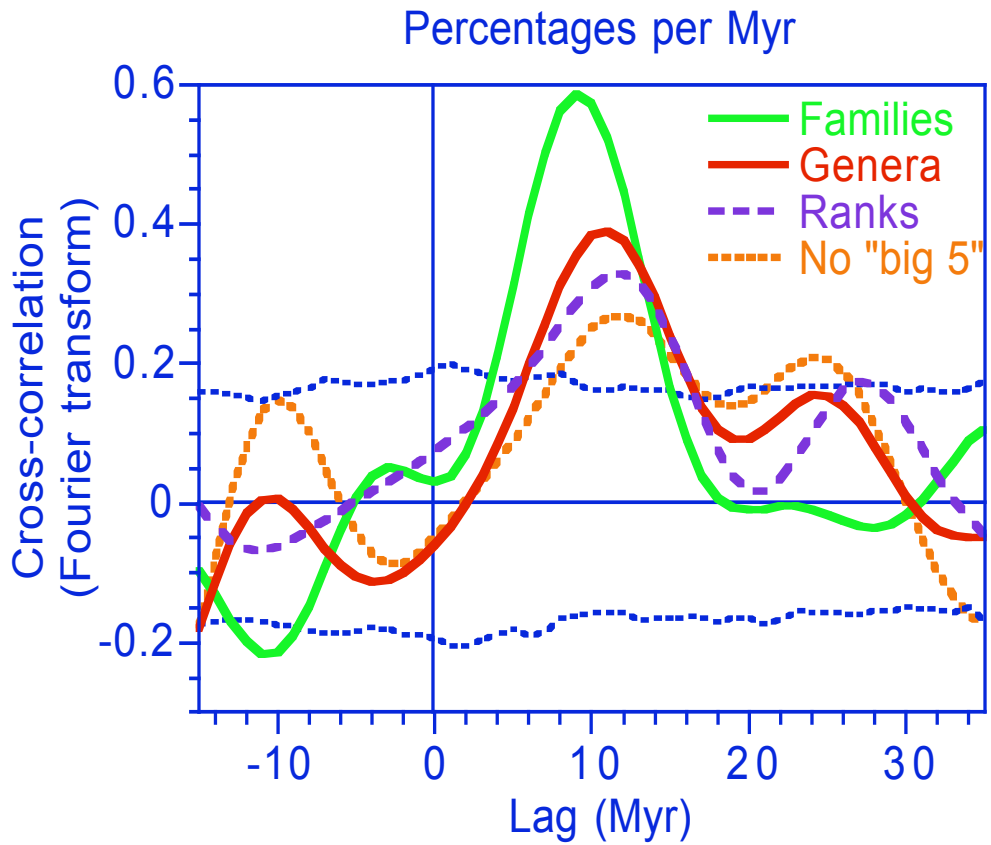
Origination peaks lag extinction peaks by 10Myr...

for both mass extinctions and 'background' extinctions alike

Delayed biological recovery from extinctions throughout the fossil record

James W. Kirchner* & Anne Weil†

* Department of Geology and Geophysics, University of California, Berkeley, California, 94720-4767, USA
† Department of Biological Anthropology and Anatomy, Duke University, Durham, North Carolina 27708-0383, USA



Implications:

Extinction doesn't empty niches, it <u>collapses</u> them.

New taxa create new niches, and new evolutionary starting points for radiation into existing niches.

Delayed biological recovery from extinctions throughout the fossil record

James W. Kirchner* & Anne Weil†

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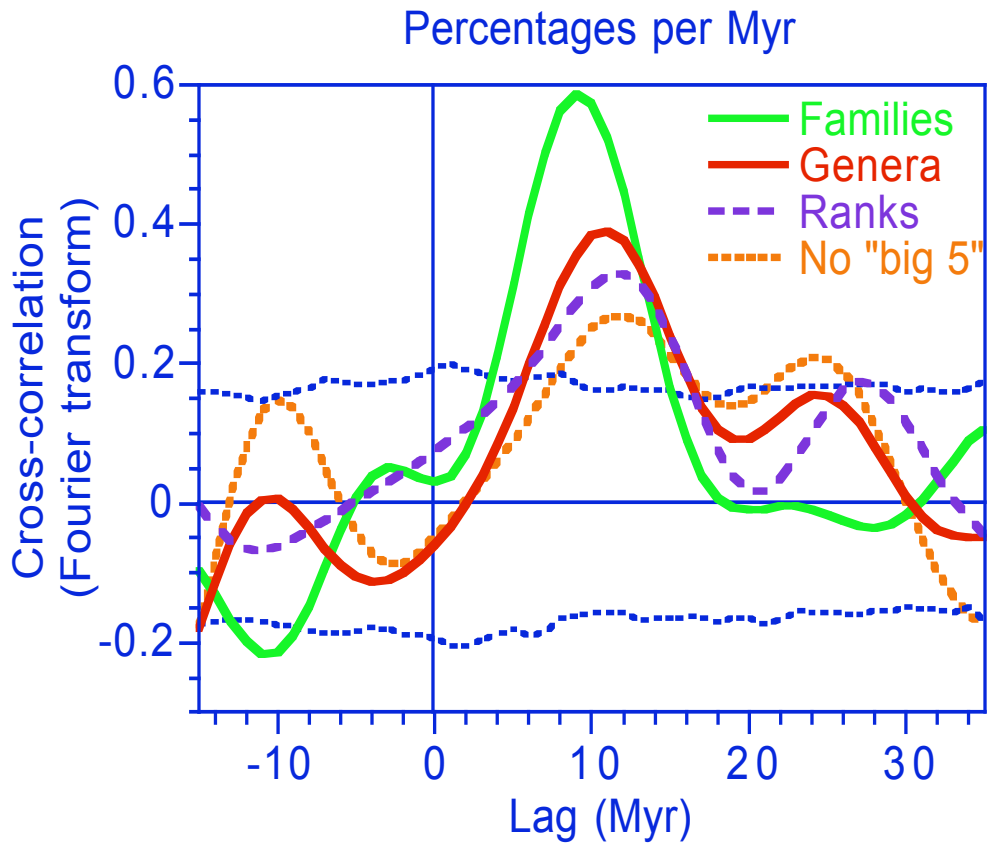

Implications:

Recovery is delayed because it requires not just refilling niches, but creating new niches.

This occurs only as the biosphere diversifies.

Delayed biological recovery from extinctions throughout the fossil record

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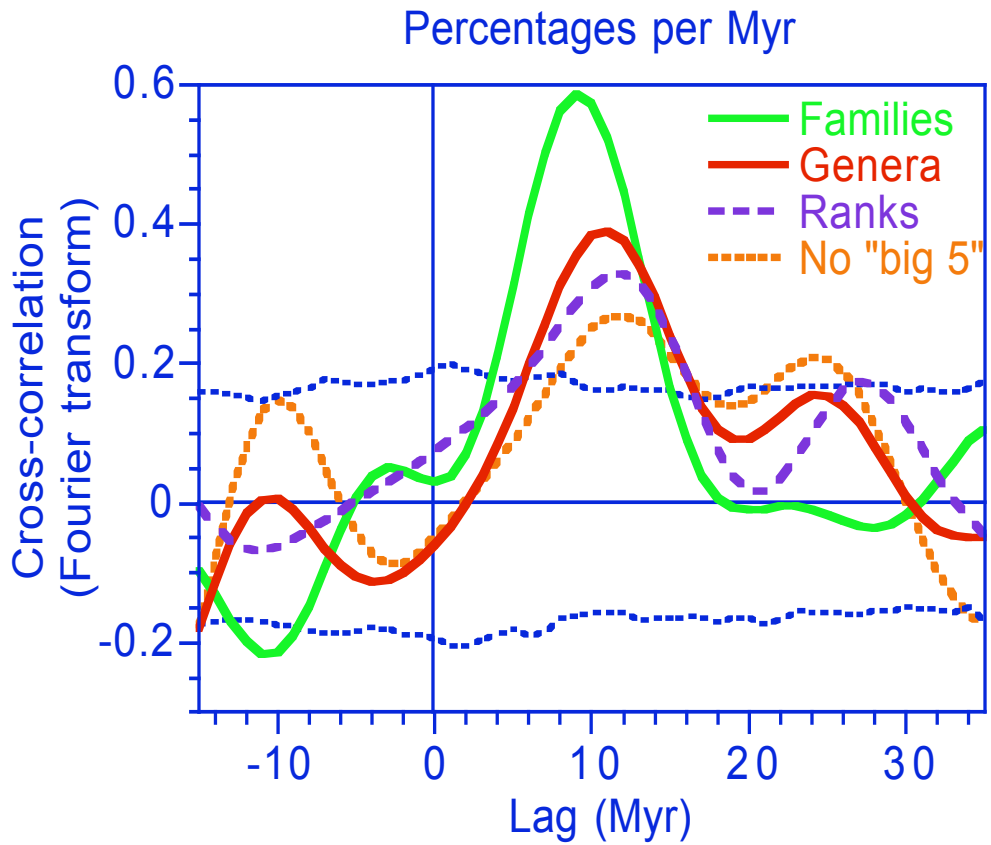
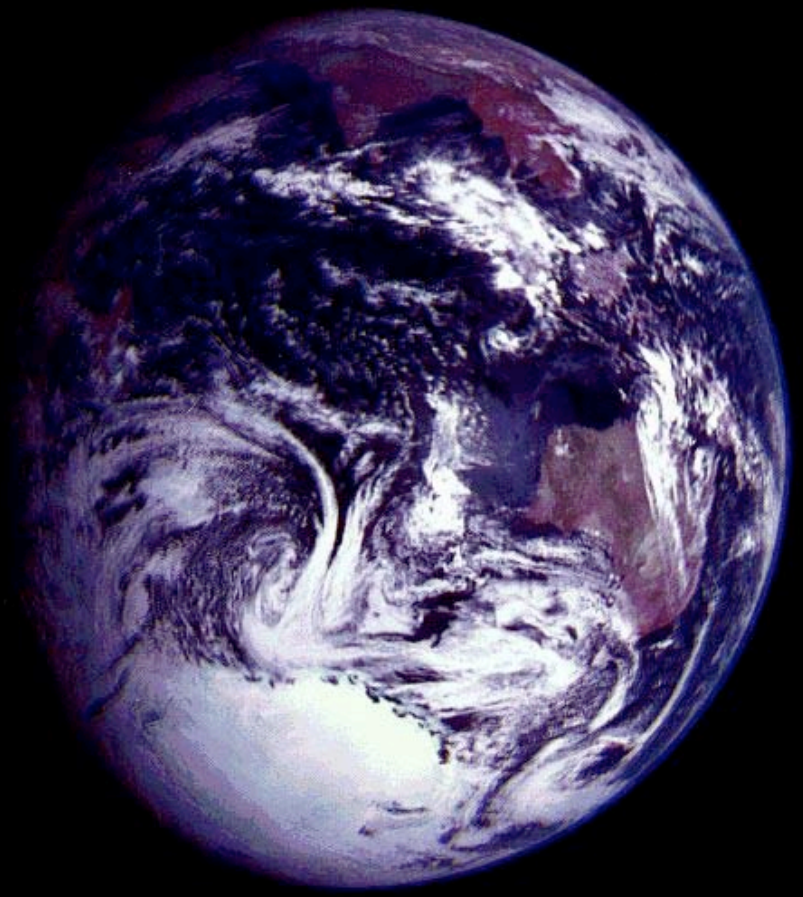


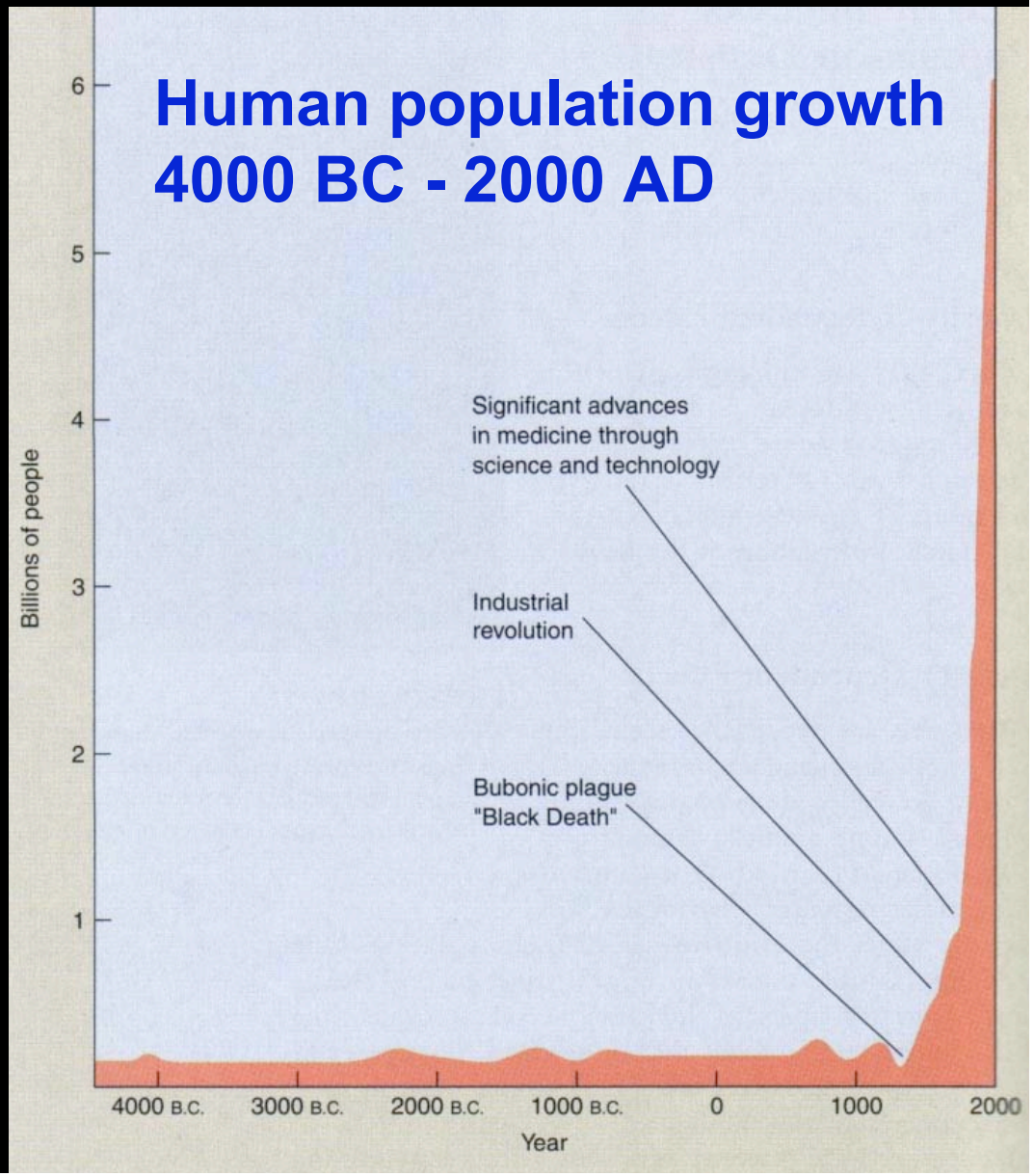


Conclusions:

3. The rate of evolution was much faster during extreme conditions.

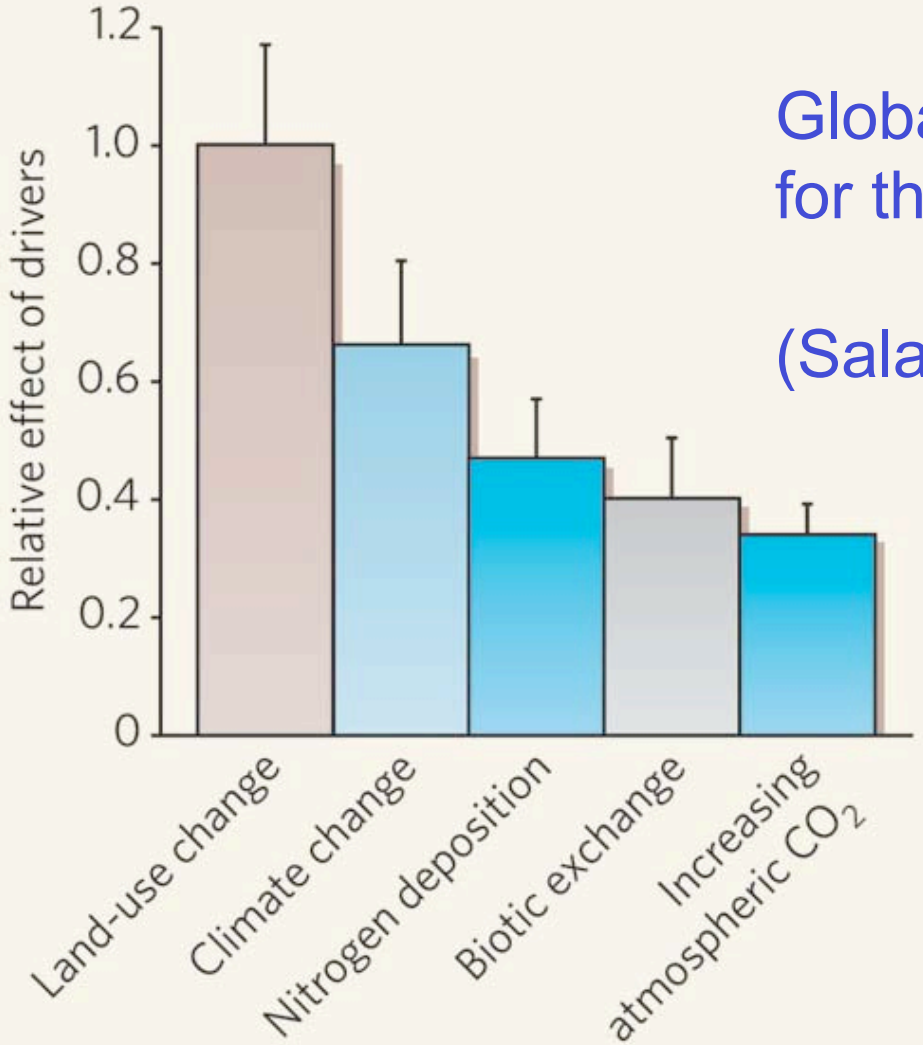
4. There's lots more we need to find out.

What about the present biodiversity crisis?



How can science help?

Science can help by:
Assessing threats to biodiversity

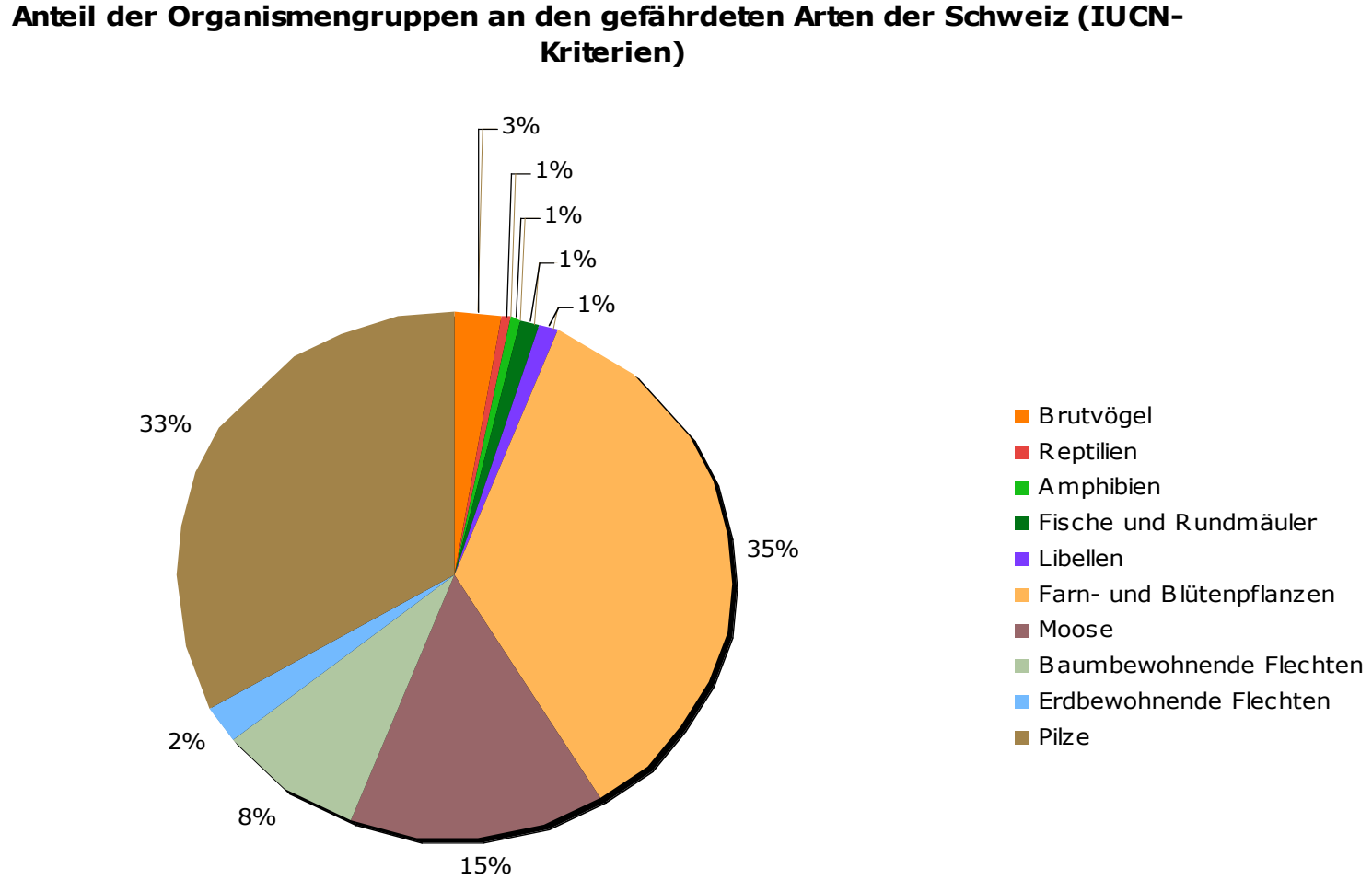


Global biodiversity scenarios for the year 2100

(Sala et al. , Science, 2000)

Extinction of the passenger pigeon: hunting or habitat loss?

Science can help by: identifying species and populations at greatest risk



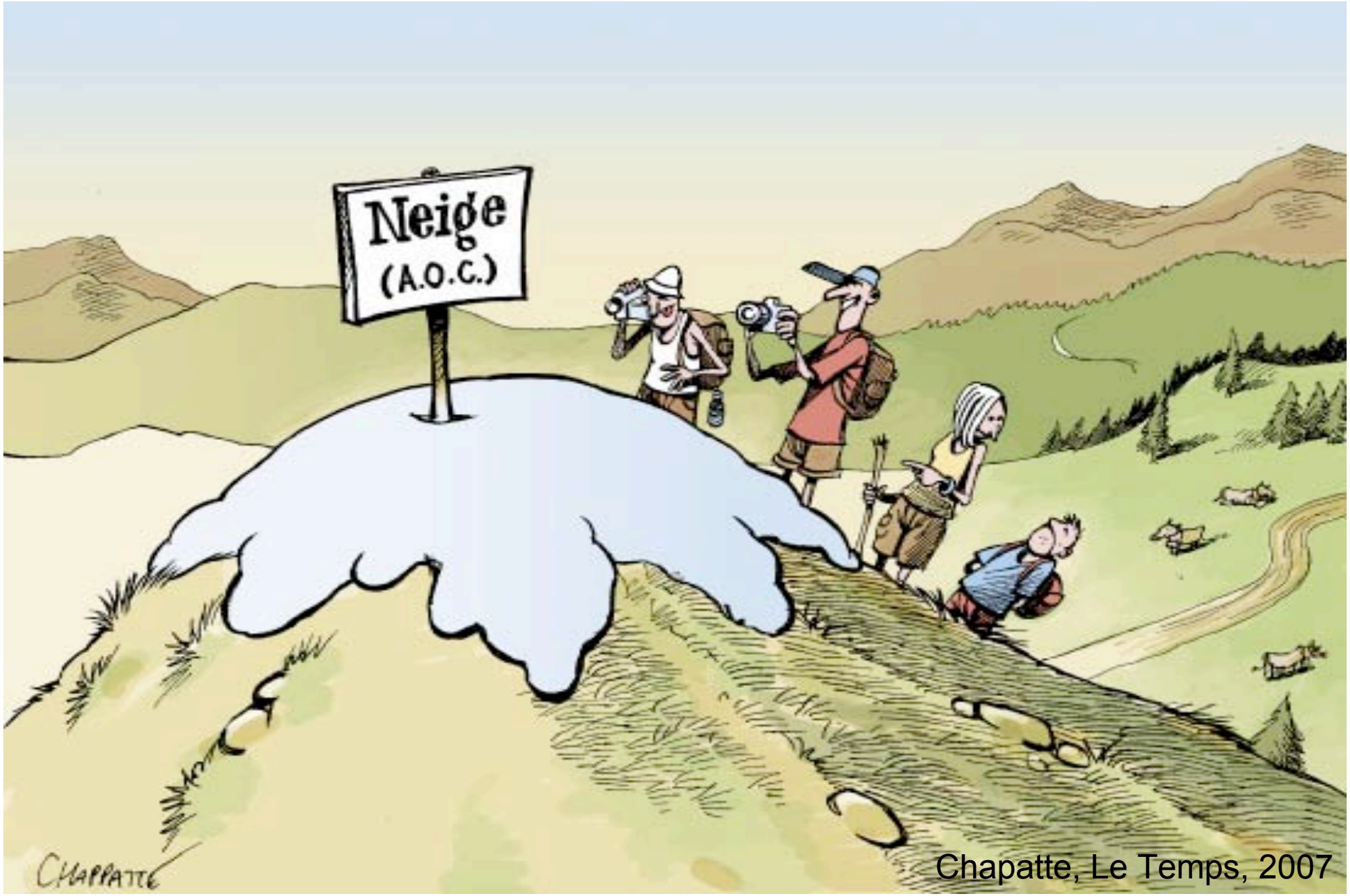
WSL has played key role in developing Red Lists for threatened animals, fungi, lichens, and bryophytes

Unique cultural landscapes -- endangered by changes in climate and society

This bryophyte, *Tayloria rudophiana,* grows mainly on one species of maple tree, and needs horizontal branches (open canopy)

...depends on trees growing outside of forest stands

Direct effects of climate change (warming)



Chapatte, Le Temps, 2007

Artenrückgang: *Umbilicaria virginis*

Einwanderungen

- Expertenmeinungen gehen davon aus, dass in der Schweiz die Zahl der Arten zunehmen wird

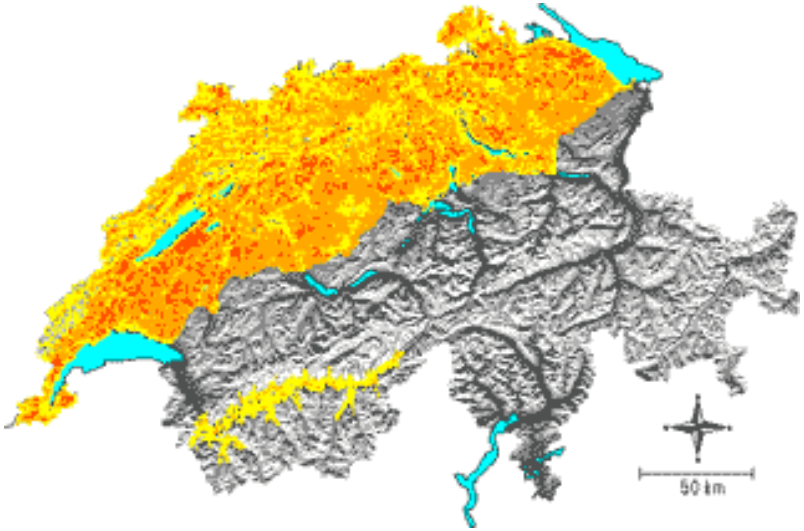
Es wird befürchtet, dass...

- Die Anzahl Antagonisten von Nutzpflanzen und -tieren zunehmen
- invasive Arten zunehmend Probleme verursachen
  - Transformation von naturnahen Lebensräumen
  - Allergene Wirkung
  - Verdrängung von einheimischen Arten

Mehrere seltene Arten werden häufiger werden

Science can help by: mapping potential habitat

Distribution Potential of *Bufo calamita* (Amphibia)



% relative area of suitable habitat

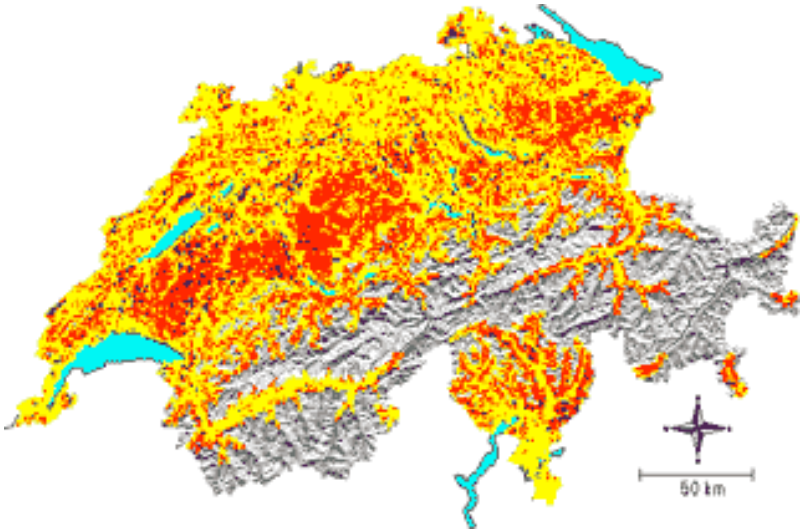
1 - 20 %
21 - 60 %
61 - 100 %

© Professorship for Nature- and Landscape Conservation / Swiss Federal Institute for Forest, Snow and Landscape Research

background: potential solar radiation in march derived from a DTM (50m resolution, TYDAC AG)

Science can help by: mapping potential habitat

Distribution Potential of *Lepus europaeus* (Mammalia)



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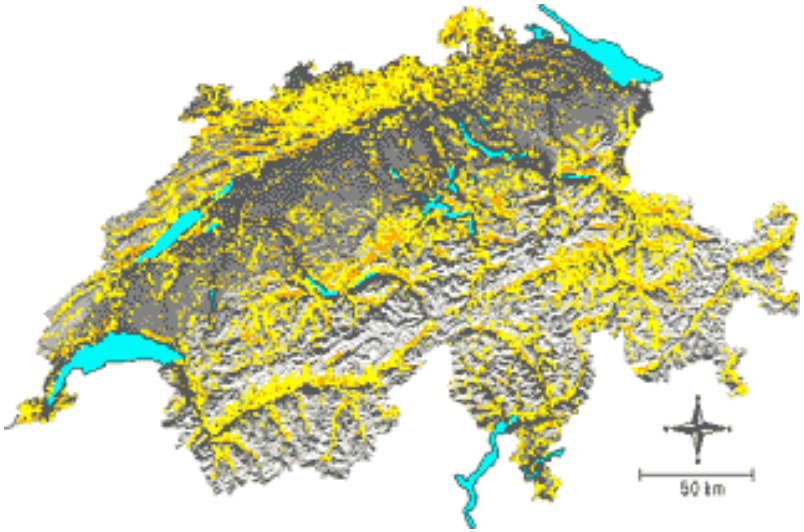
61 - 100 %

© Professorship for Nature- and Landscape Conservation / Swiss Federal Institute for Forest, Snow and Landscape Research

background: potential solar radiation in march derived from a DTM (50m resolution, TYDAC AG)

Science can help by: mapping potential habitat

Distribution Potential of *Melitaea diamina* (Lepidoptera)



% relative area of suitable habitat

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21 - 60 %

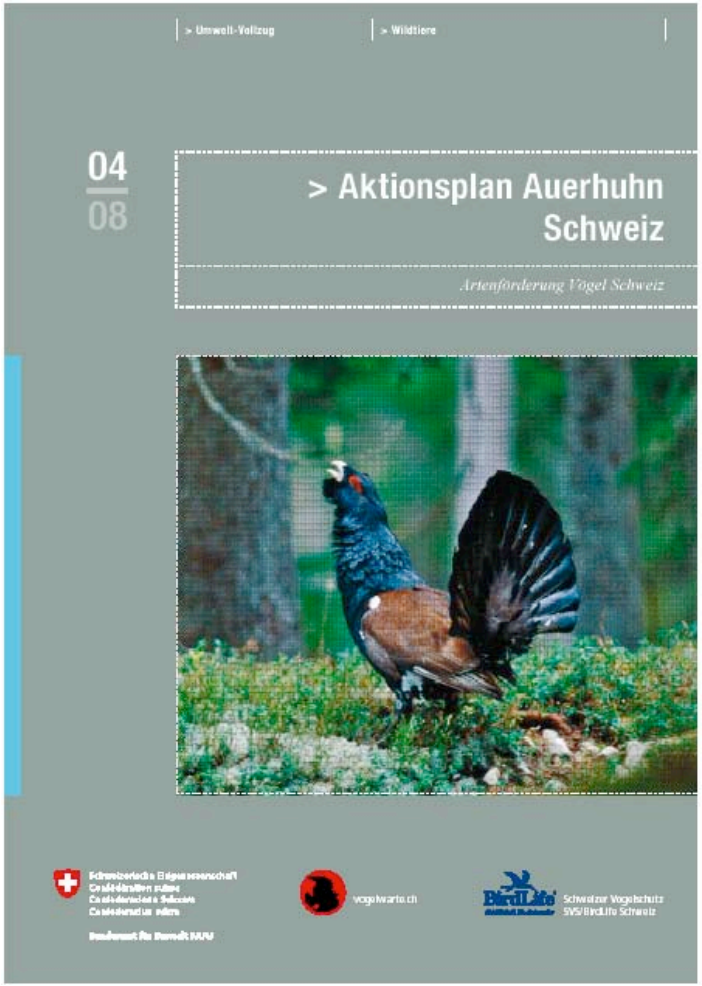
61 - 100 %

© Professorship for Nature- and Landscape Conservation / Swiss Federal Institute for Forest, Snow and Landscape Research

background: potential solar radiation in march derived from a DTM (50m resolution, TYDAC AG)

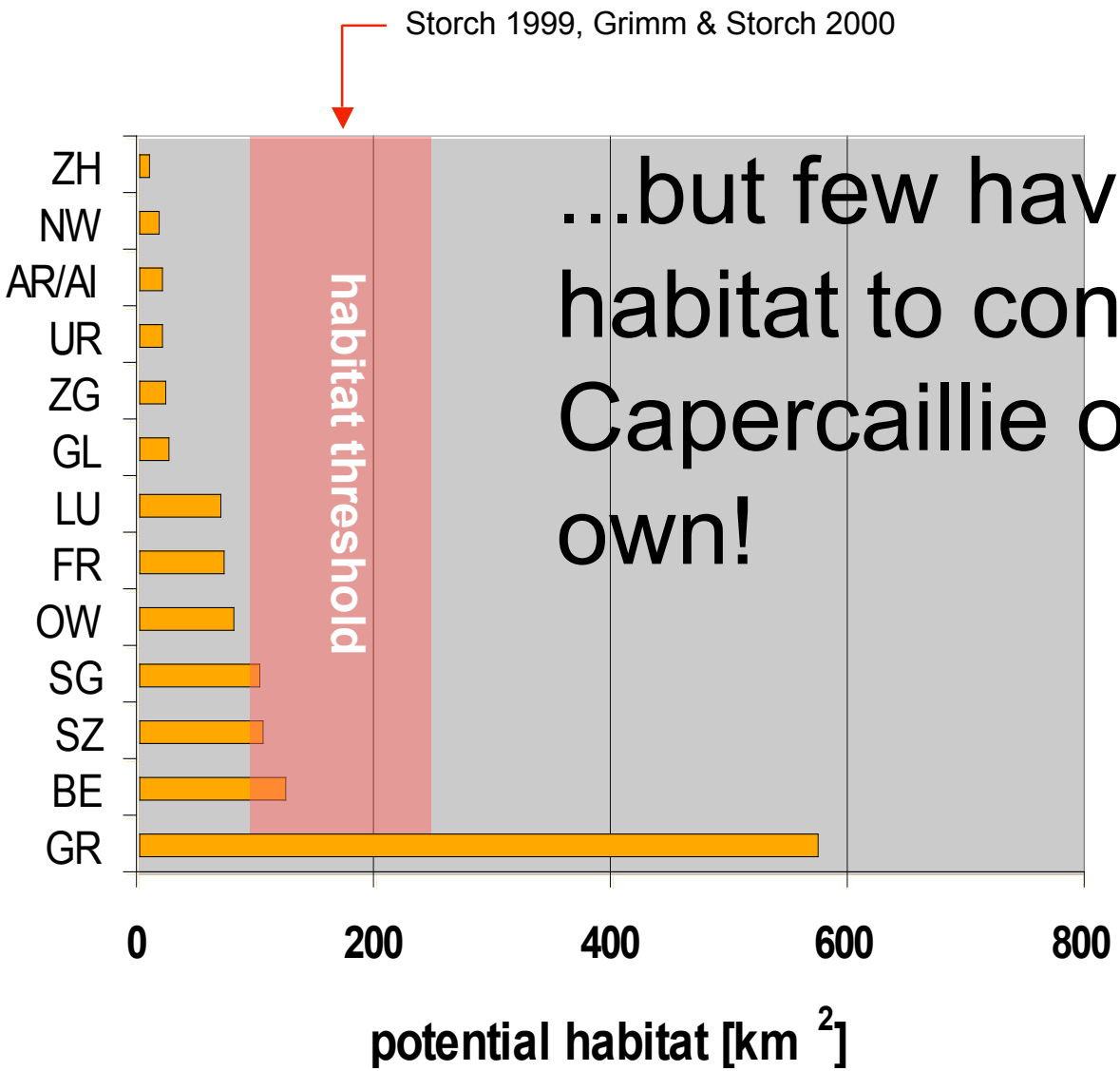
Science can help in: designing strategies to protect species from the 'impact' of climate change and land use intensification

Science can help in: designing strategies to maintain biodiversity



- published April 2008
- objectives, measures and tasks
- priorities and responsibilities
- regional dossiers
- technical and financial
  guidelines for project funding

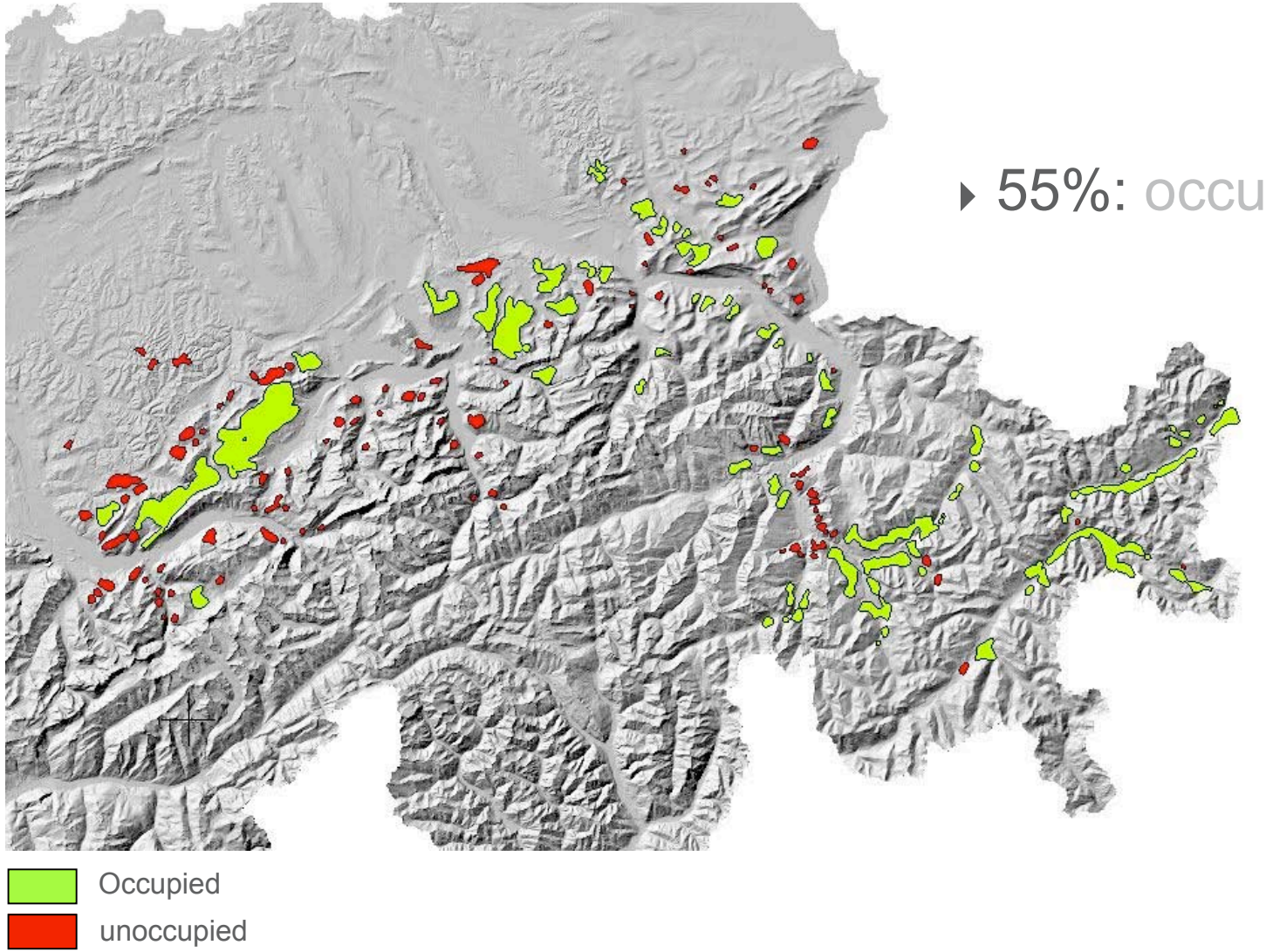
Cantons have primary responsibility for conservation...



...but few have enough habitat to conserve Capercaillie on their own!

(Kurt Bollmann, Pierre Mollet, Bruno Stadler)

Science can help by: documenting population structure

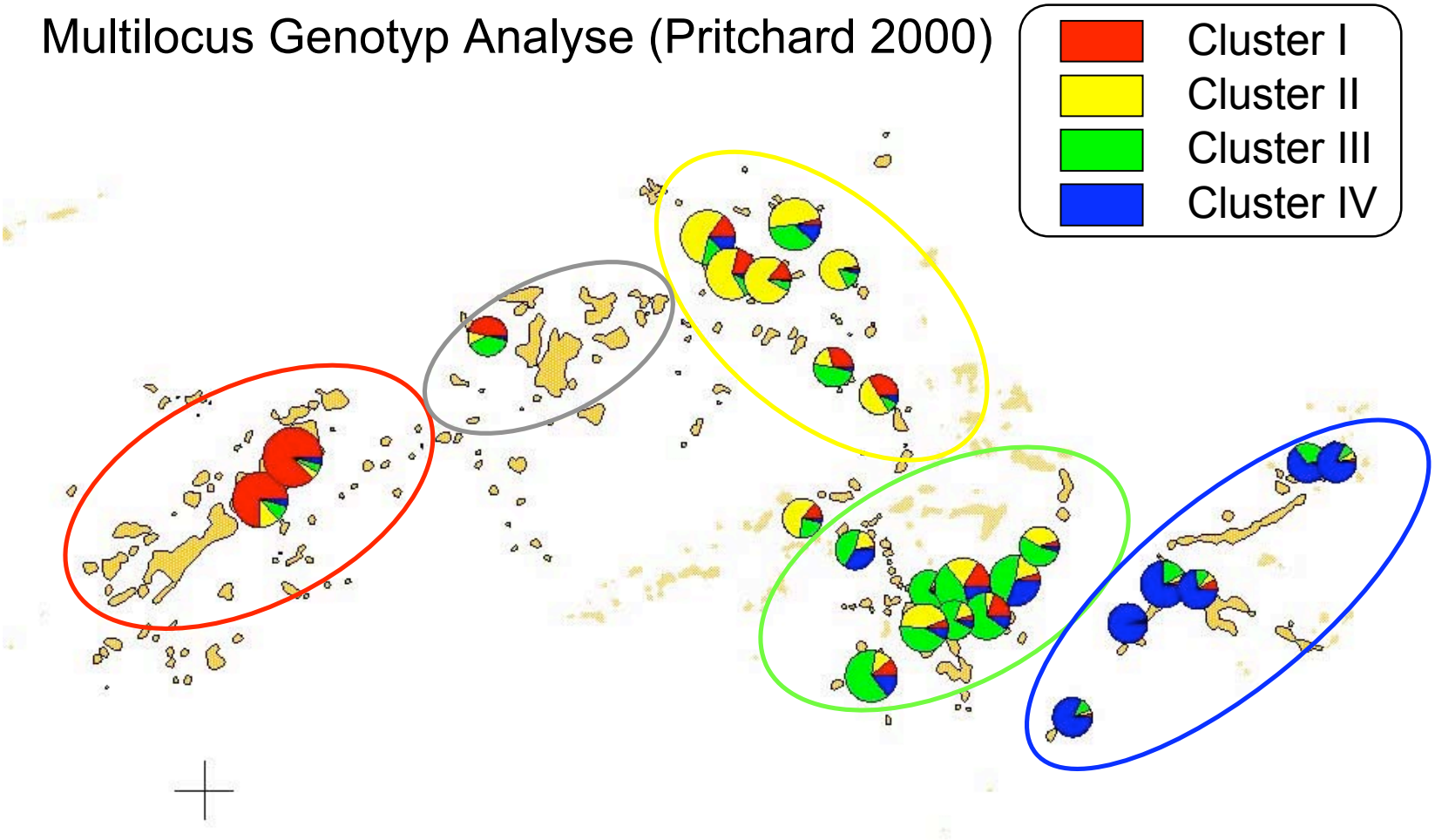


- 55%: occupied

(Kurt Bollmann, Pierre Mollet, Bruno Stadler)

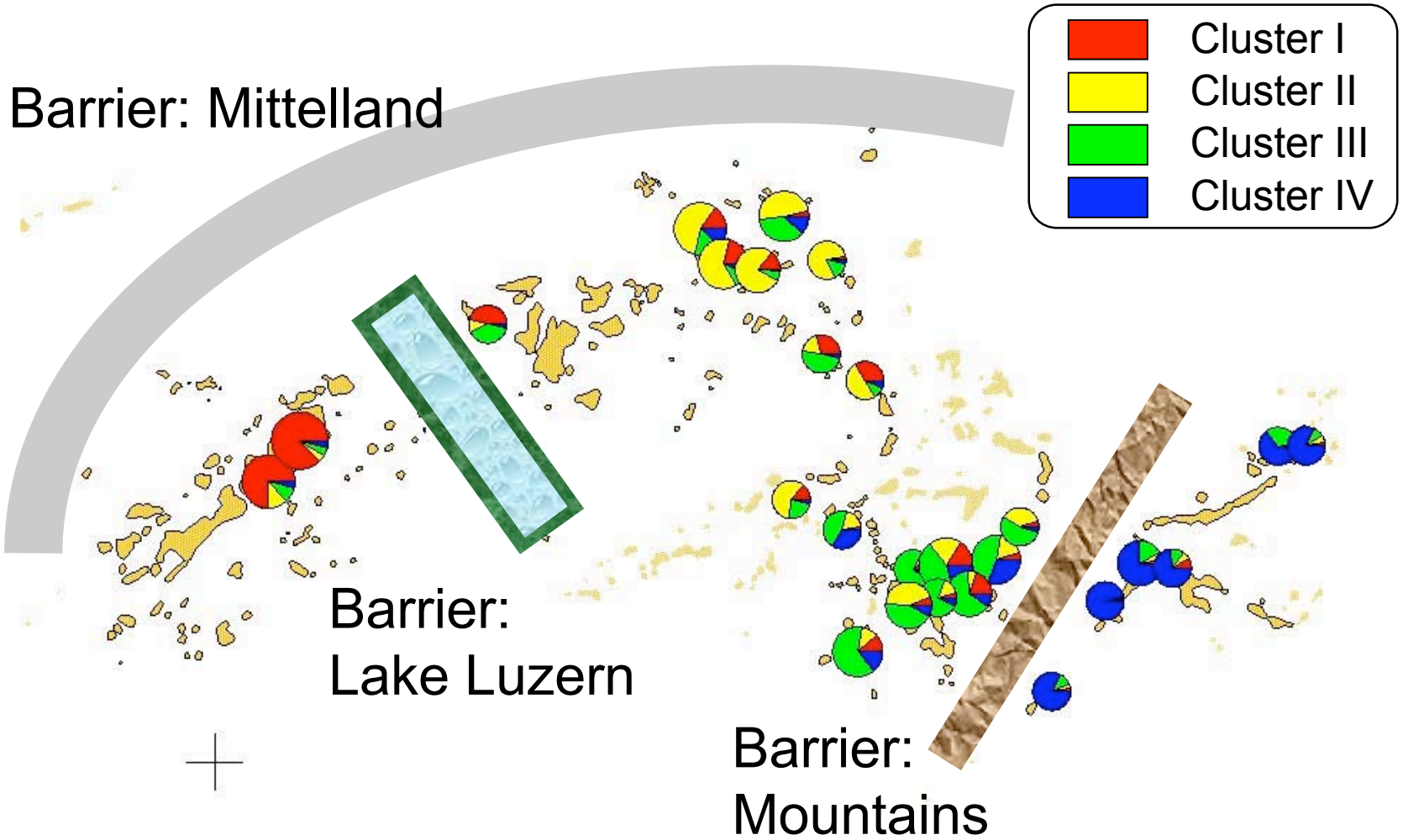
Science can help by: documenting genetic structure

Multilocus Genotyp Analyse (Pritchard 2000)



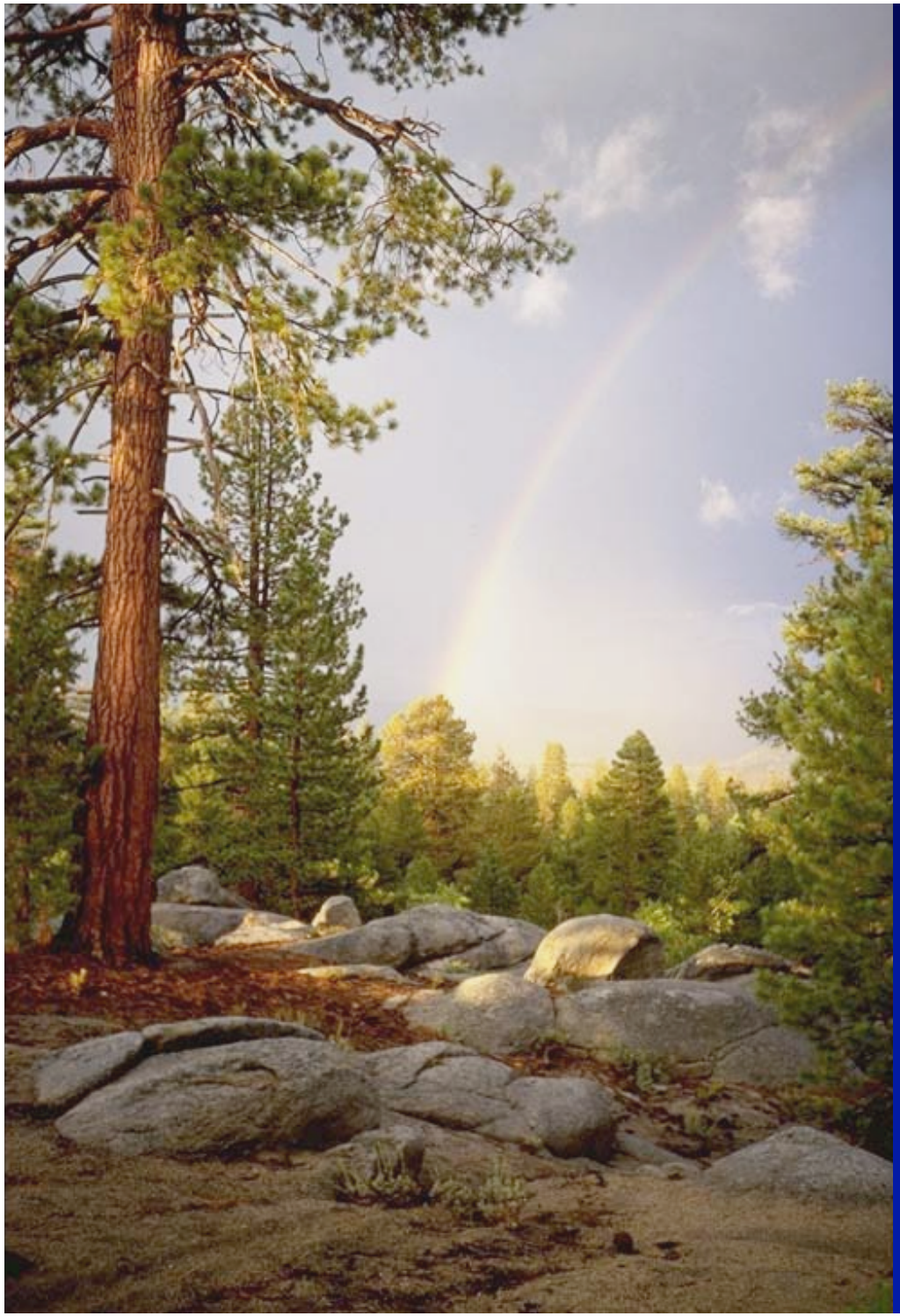
Jacob et al. submitted

Science can help by: documenting barriers to migration and gene flow



Designing conservation strategies requires fundamental research

"trial and error" is not good enough!



Conserving biodiversity: the role of science

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