Paths Toward Maintaining Biodiversity in a Changing Climate

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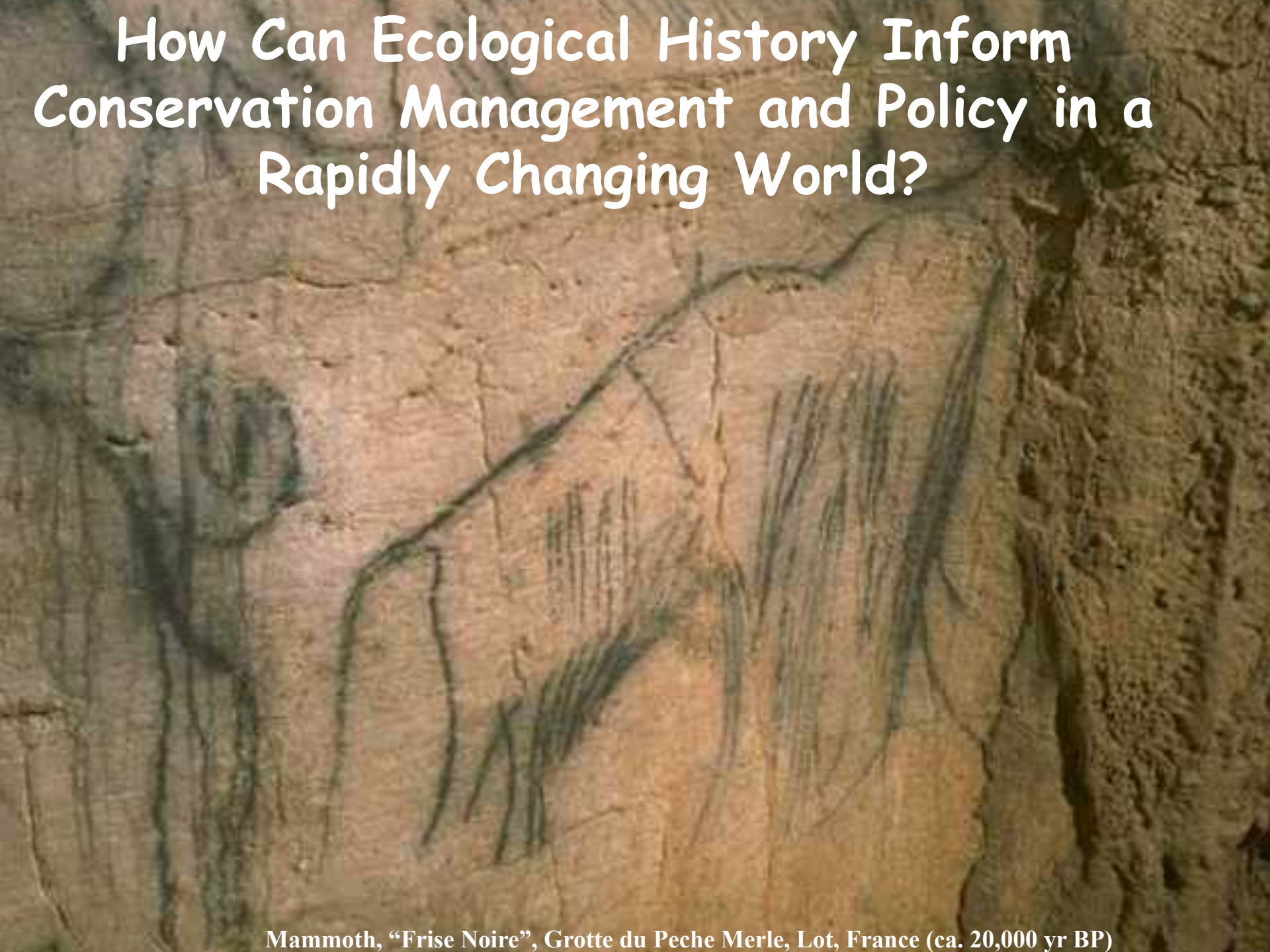
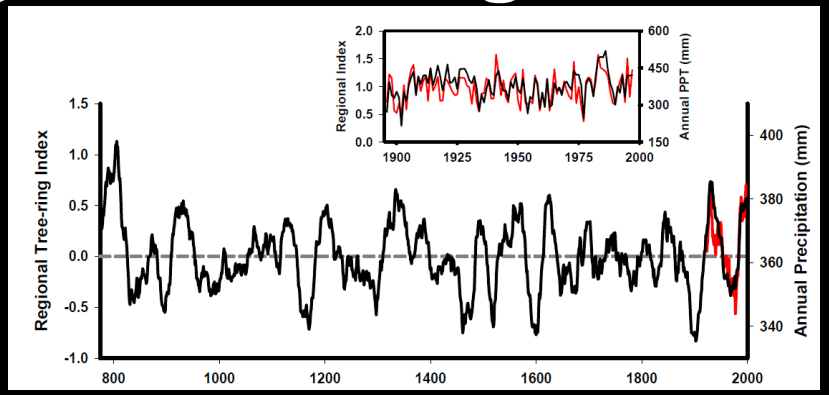
UNIVERSITY OF WYOMING

How Can Ecological History Inform Conservation Management and Policy in a Rapidly Changing World?

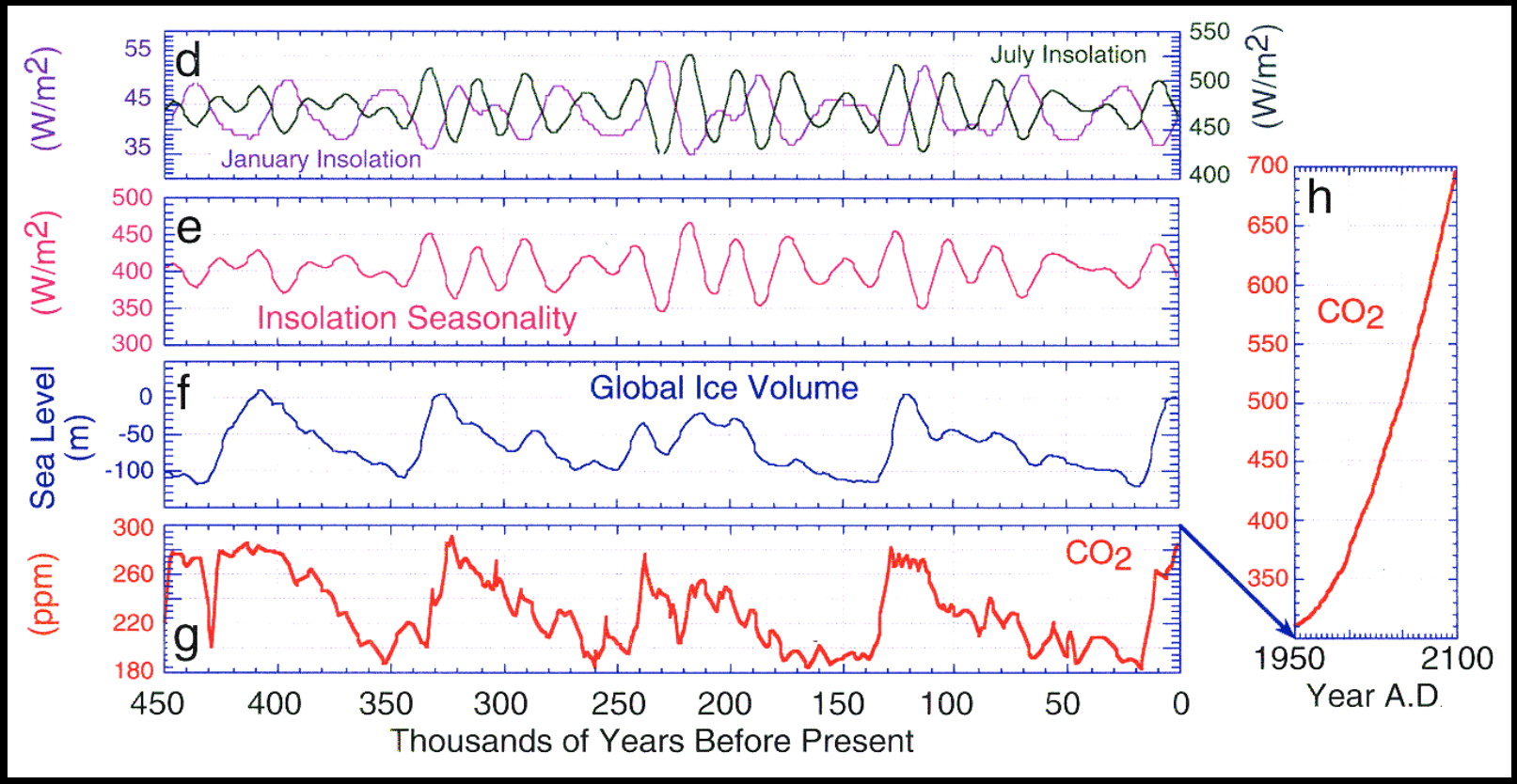


Mammoth, "Frise Noire", Grotte du Peche Merle, Lot, France (ca. 20,000 yr BP)

Climate change is nothing new.

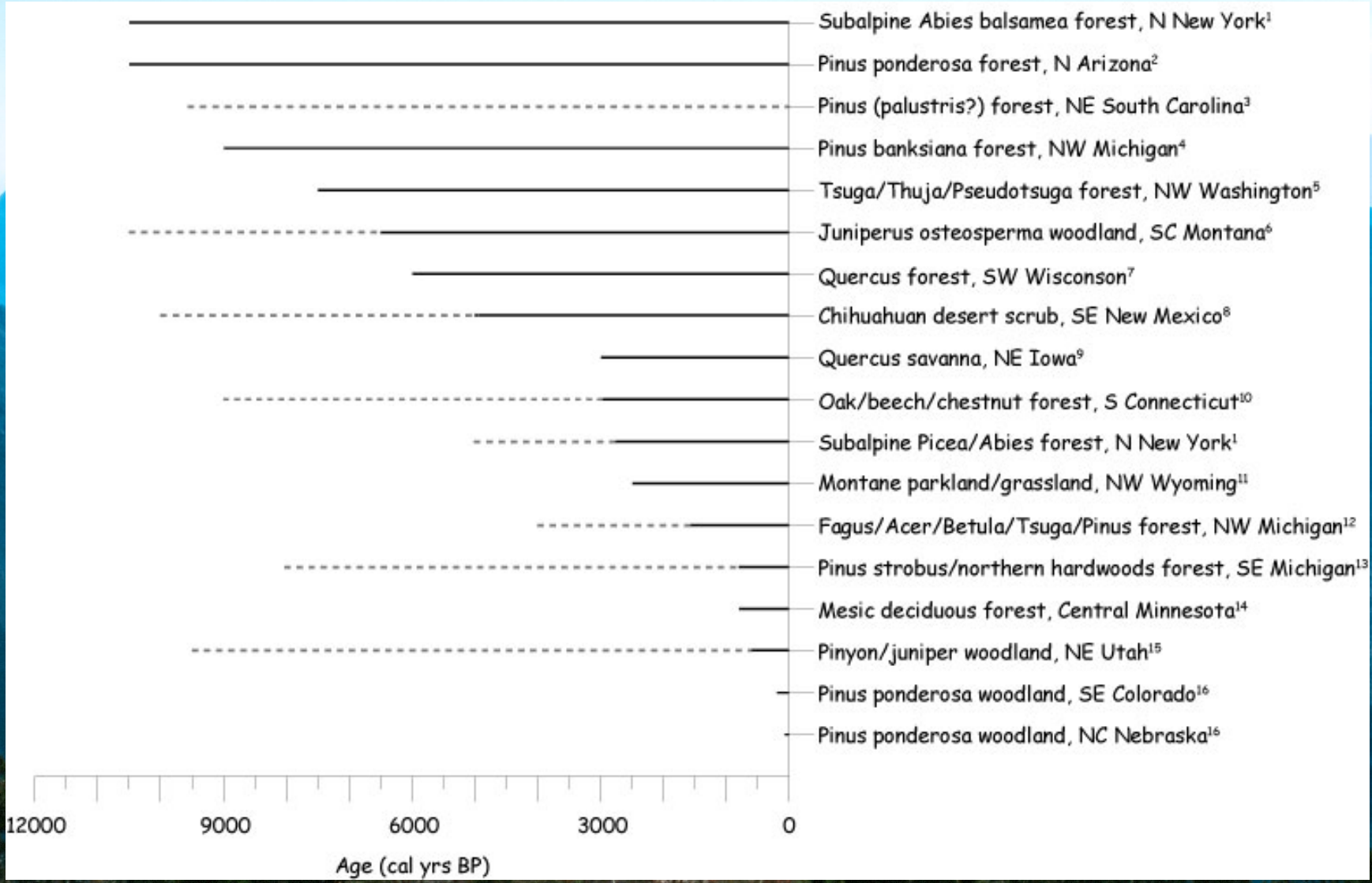


Past 1200 years: Upper Colorado River Basin (after Meko *et al.* 2007)



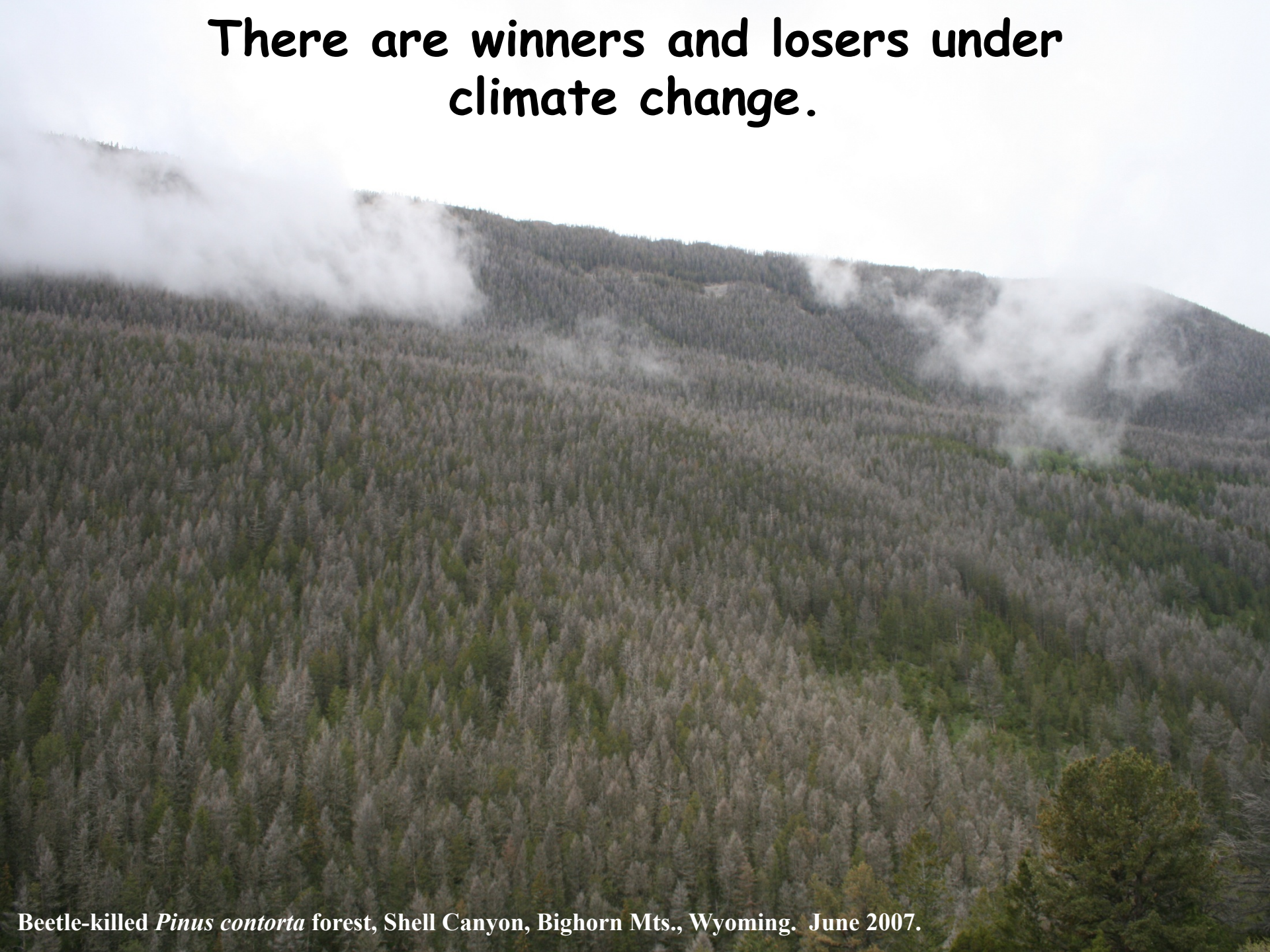
Past 450,000 years: Global (S.T Jackson & J.T. Overpeck. 2000. *Paleobiology (Suppl.)*

All terrestrial ecosystems are young.



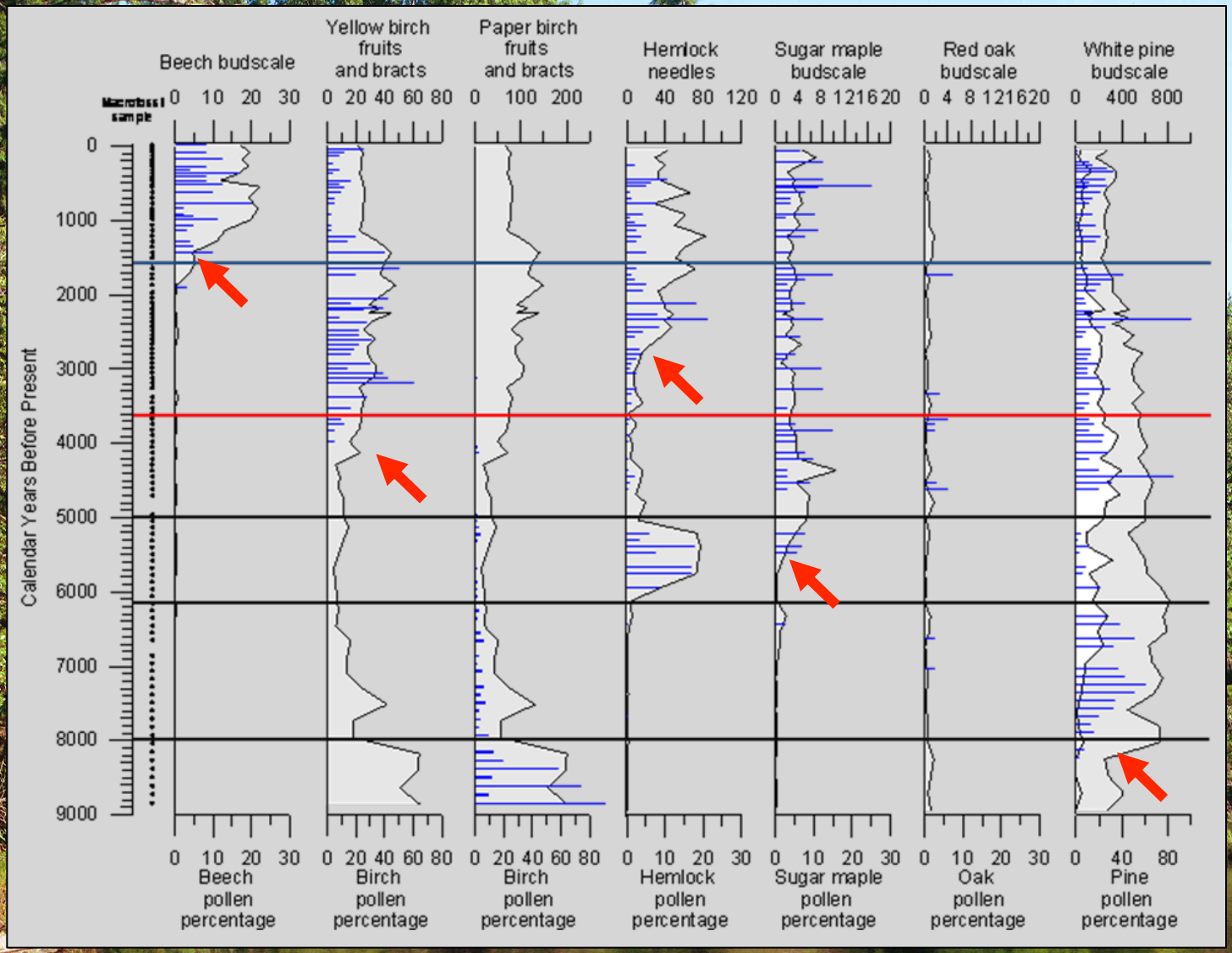
S.T Jackson. 2012. in J. Wiens *et al.* (eds.) *Historical Environmental Variation in Conservation and Natural Resource Management.*

There are winners and losers under climate change.



Beetle-killed *Pinus contorta* forest, Shell Canyon, Bighorn Mts., Wyoming. June 2007.

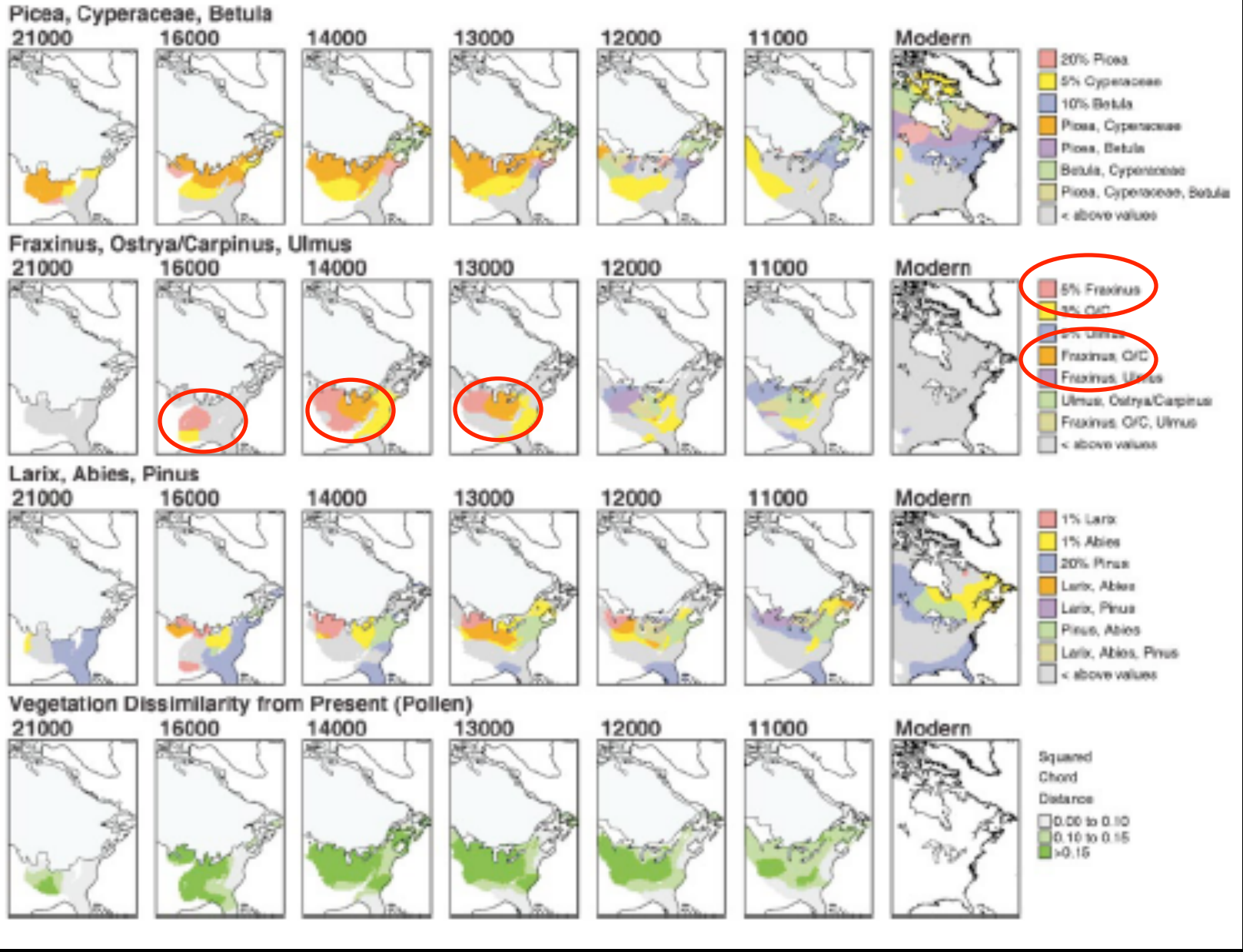
Locally and regionally...



Tower Lake, Upper Michigan

K. Reeves, R.K. Booth, J.J. Andersen, R.A. Jones, T.A. Minckley & S.T Jackson *(in prep.)*

...and globally



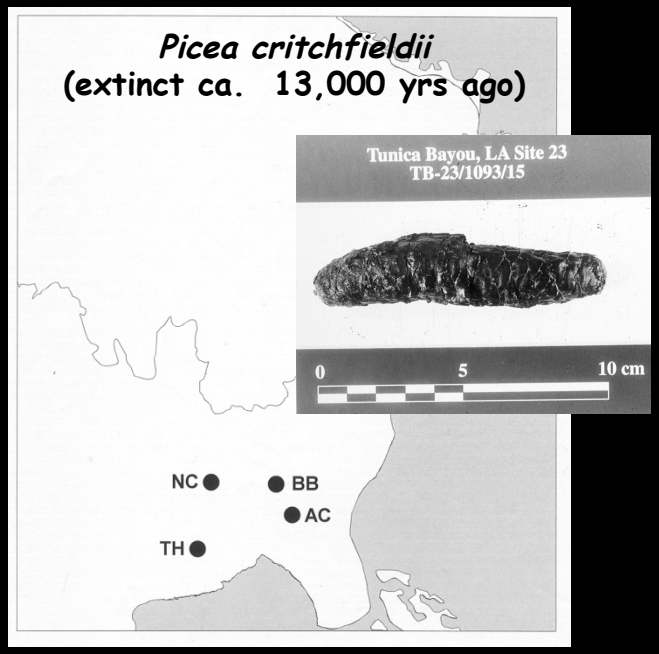
S.T. Jackson & J.W. Williams. 2004. *Ann. Rev. Earth & Planet. Sci.*

Sometimes there are big losers…

S.J. O'Brien & W.E Johnson. 2005.
Ann. Rev. Genomics & Hum. Gen.

A.D. Barnosky. 1986. *Quat. Res.*

F.T. Ledig & M.T. Conkle. 1983. *Evolution*

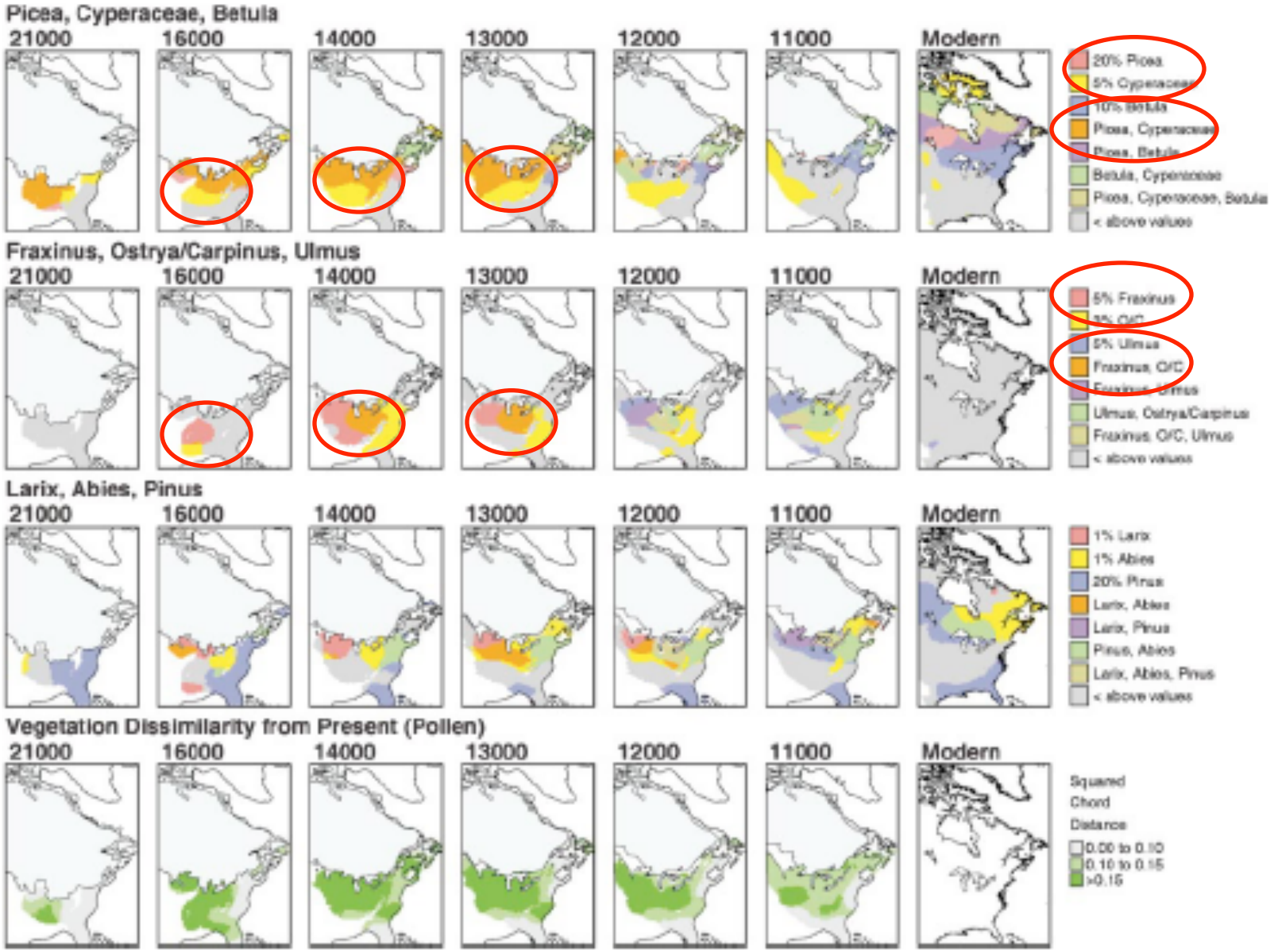


S.T. Jackson & C. Weng, 1999. *PNAS*

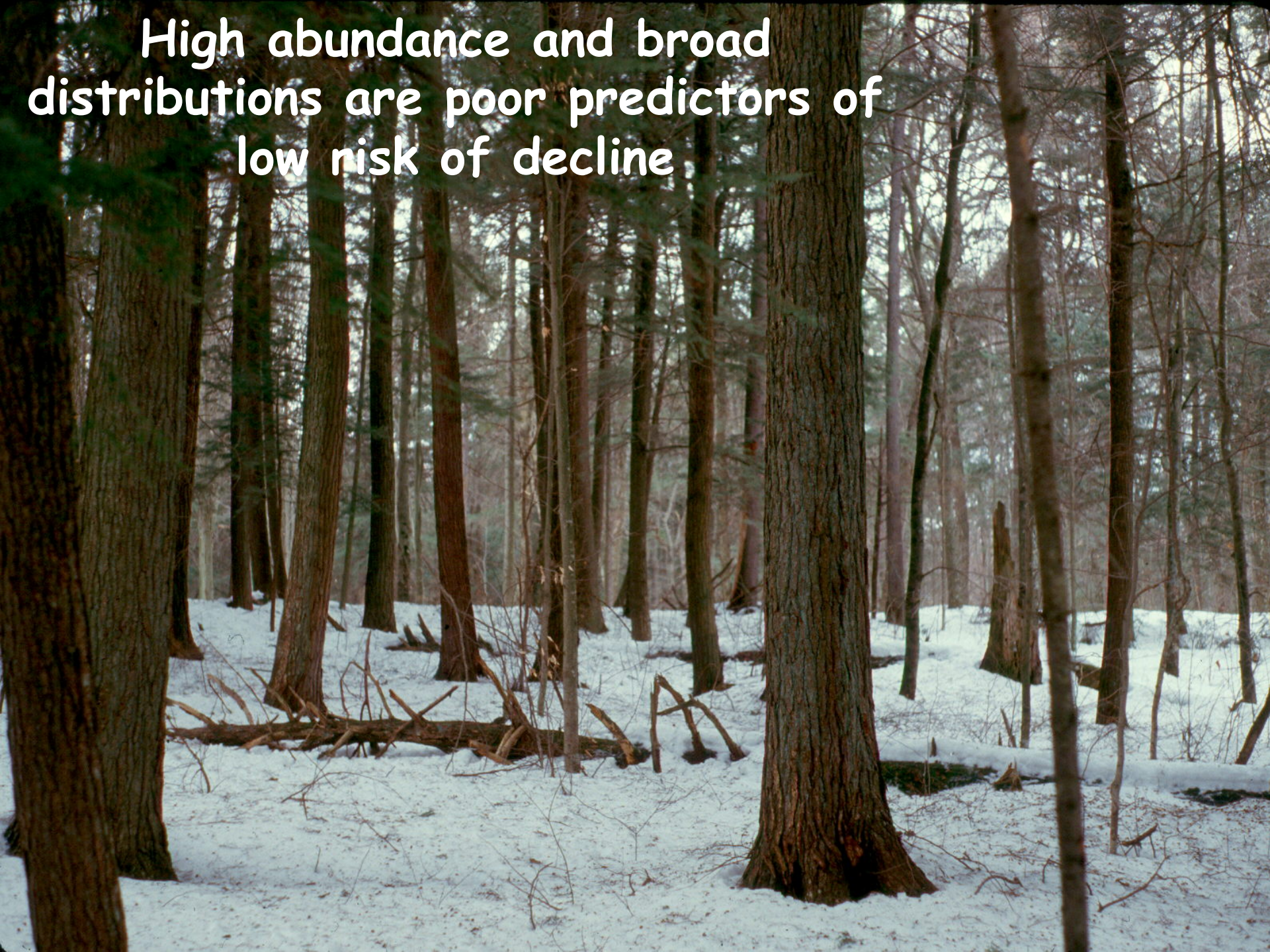
J. Boys *et al.* 2005. *Amer. J. Bot.*

K.J. Hundtermark *et al.* 2002.
Mol. Phylogen. Evol.

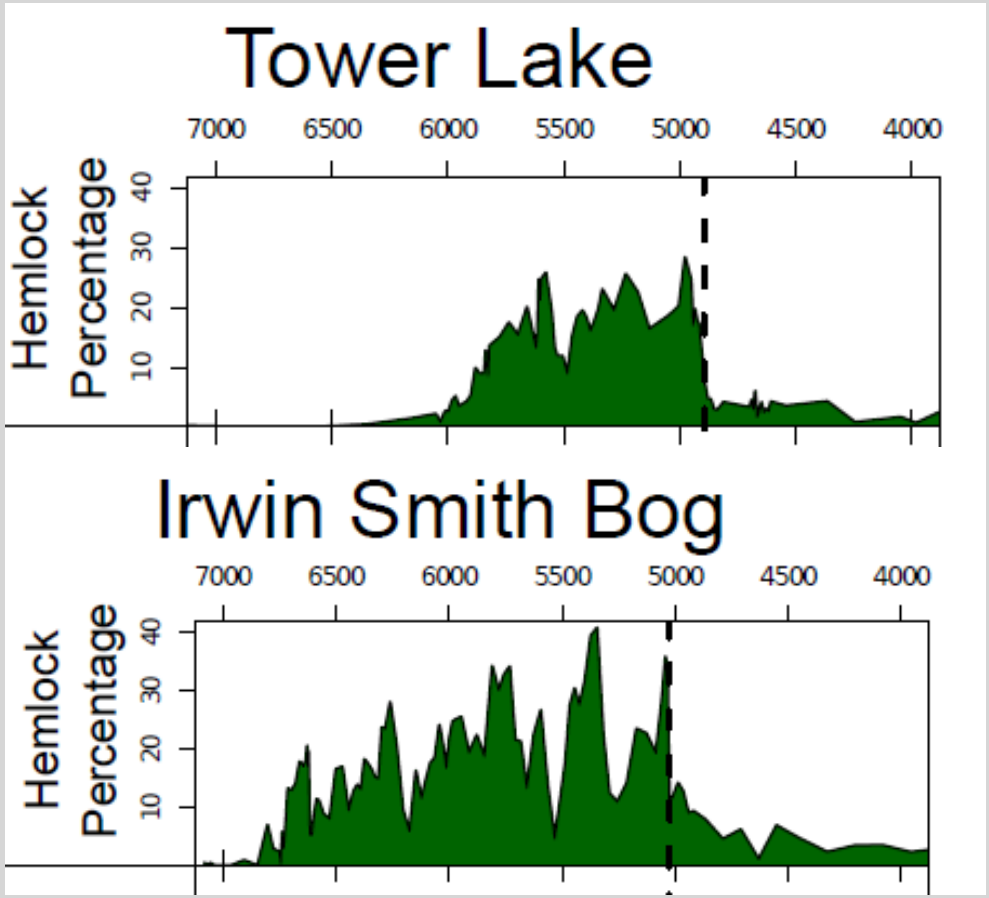
Community composition isn't conserved.

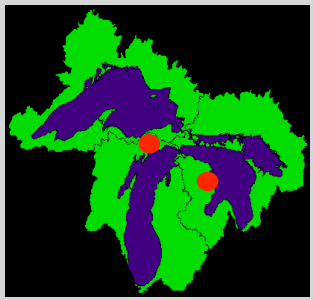


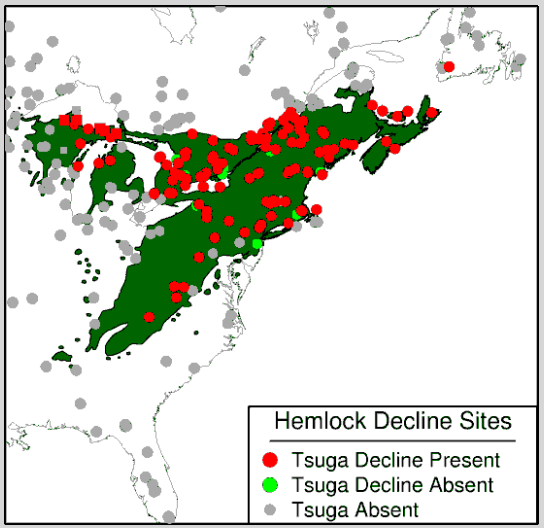
S.T. Jackson & J.W. Williams. 2004. *Ann. Rev. Earth & Planet. Sci.*


High abundance and broad distributions are poor predictors of low risk of decline

Example 1: Mid-Holocene *Tsuga* decline

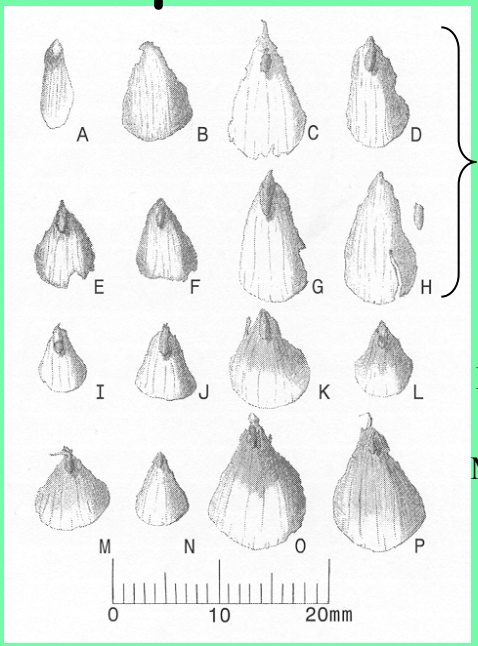






R.K. Booth *et* al. 2012. *Ecology (in press).*

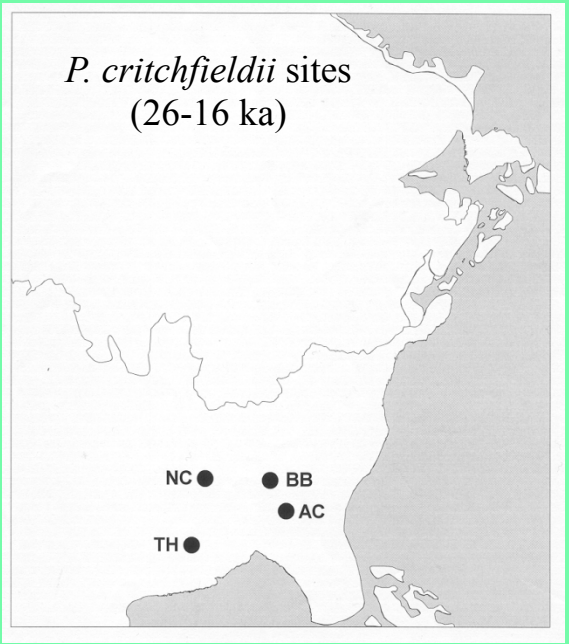
Example 2: The extinction of *Picea critchfieldii*

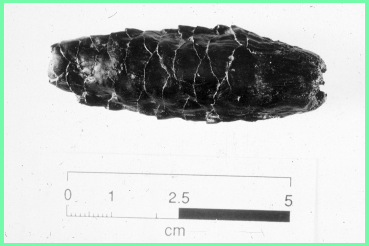


Picea critchfieldii

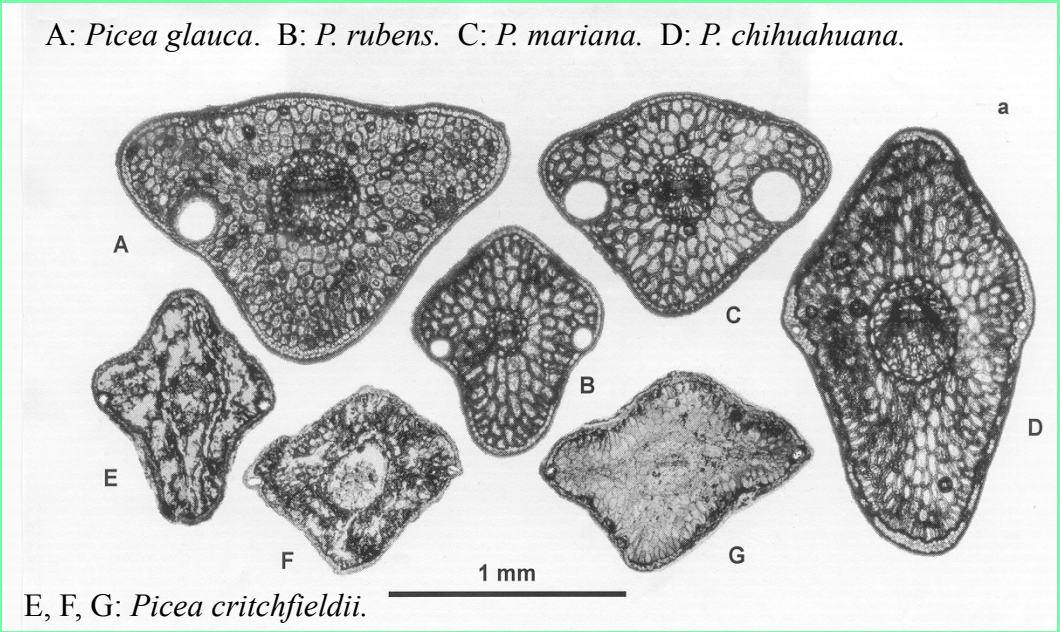
I, J: *P. glauca*
K, L: *P. chihuahuana*

M, N: *P. breweriana*
O, P: *P. martinezii*





A: *Picea glauca*. B: *P. rubens*. C: *P. mariana*. D: *P. chihuahuana*.



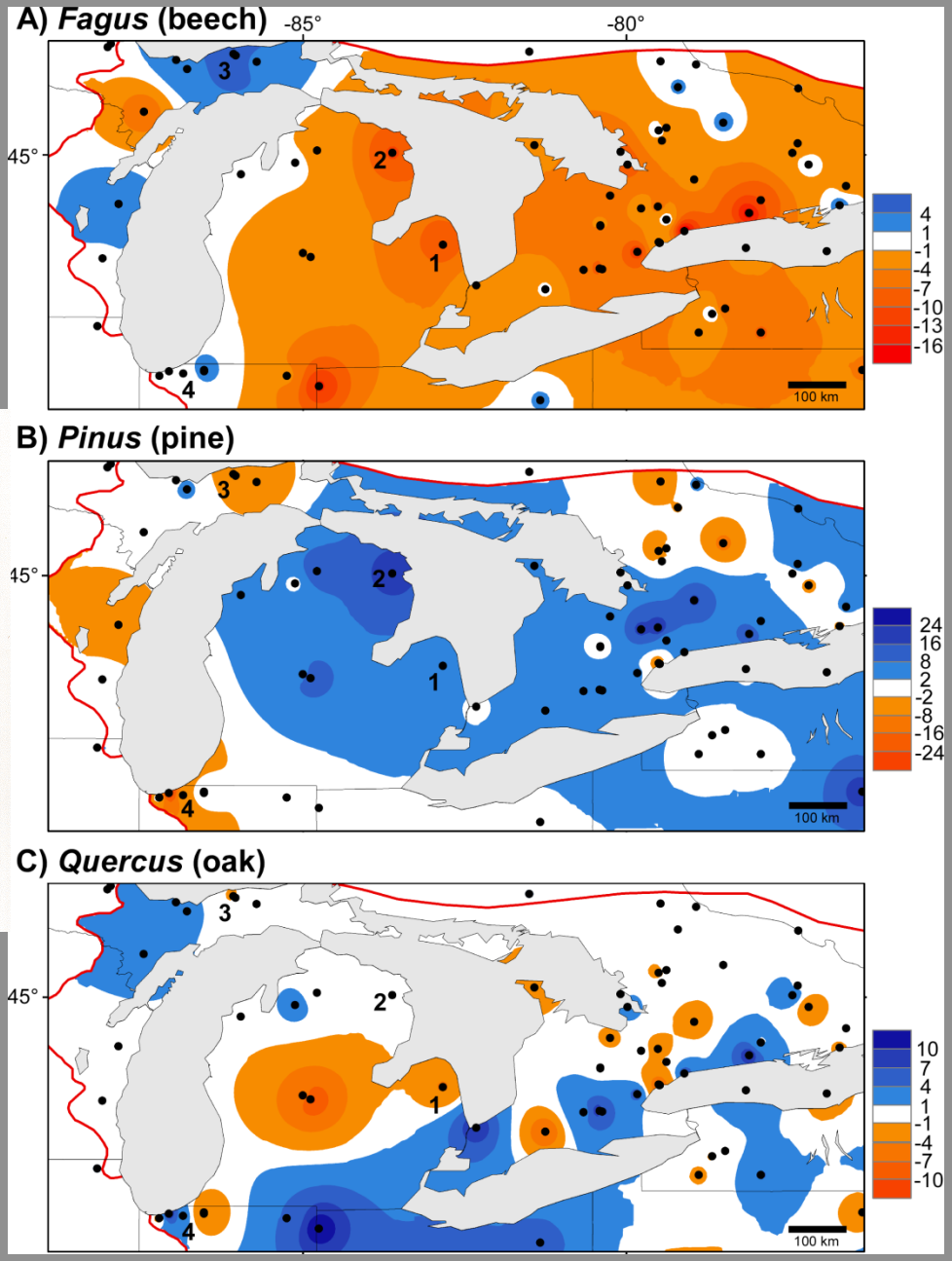
E, F, G: *Picea critchfieldii*.

S.T. Jackson & C. Weng, 1999. *PNAS*

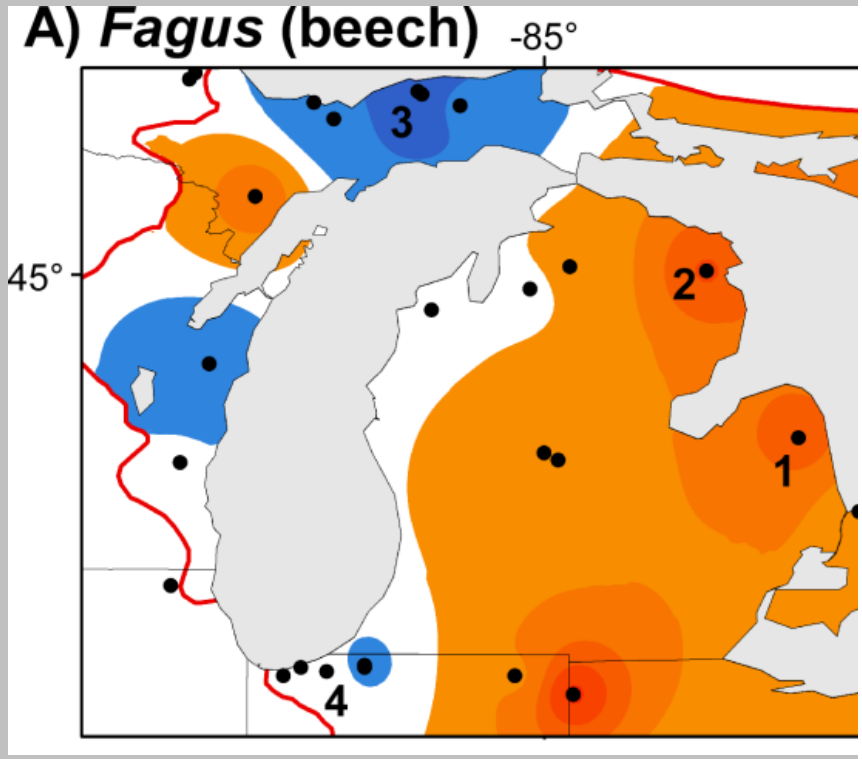

Climate change and its ecological consequences
are often spatially and temporally complex.

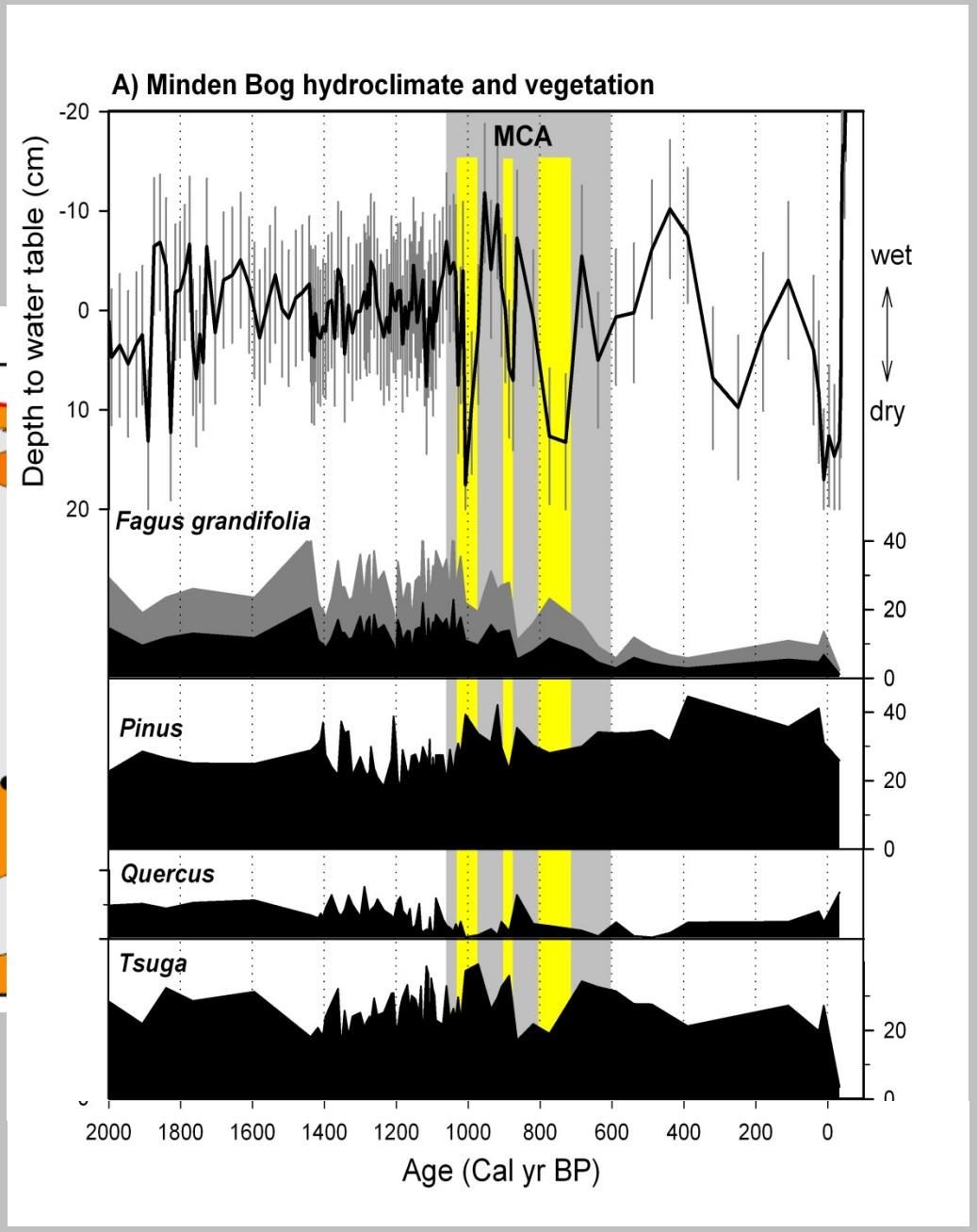
Late Holocene *Fagus* Decline in the Central Great Lakes

Mean pollen difference: Before vs. after Medieval Climate Anomaly (1000-1400 CE)



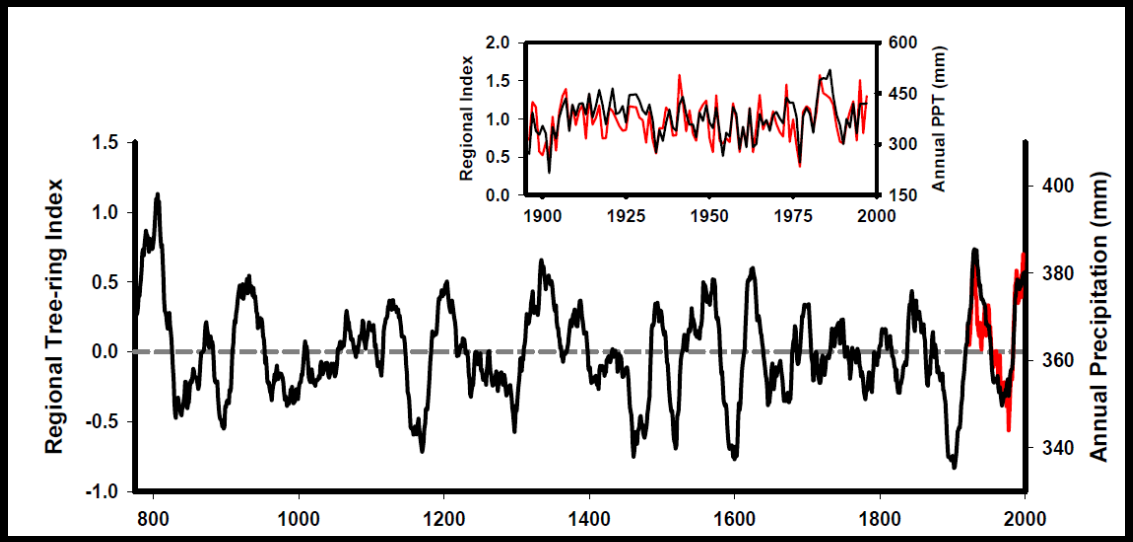
R.K. Booth, S.T. Jackson, V.A. Sousa, M.E. Sullivan, T.A. Minckley & M. Clifford. 2012. *Ecology*.





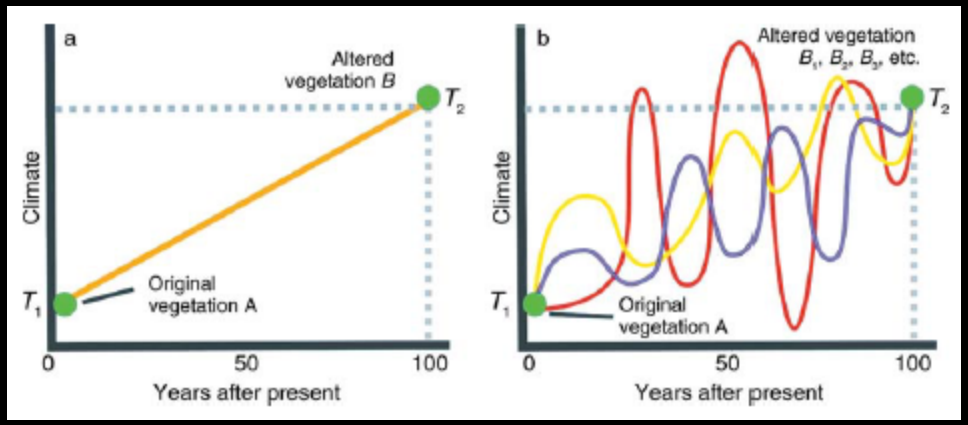
R.K. Booth, S.T. Jackson, V.A. Sousa, M.E. Sullivan, T.A. Minckley & M. Clifford. 2012. *Ecology*.

From any point in time, the path to the future has always been twisted and tortured.



(Jackson *et al.* 2009. *PNAS* (after Meko *et al.* 2007))

(S.T. Gray *et al.* 2006. *Ecology)*

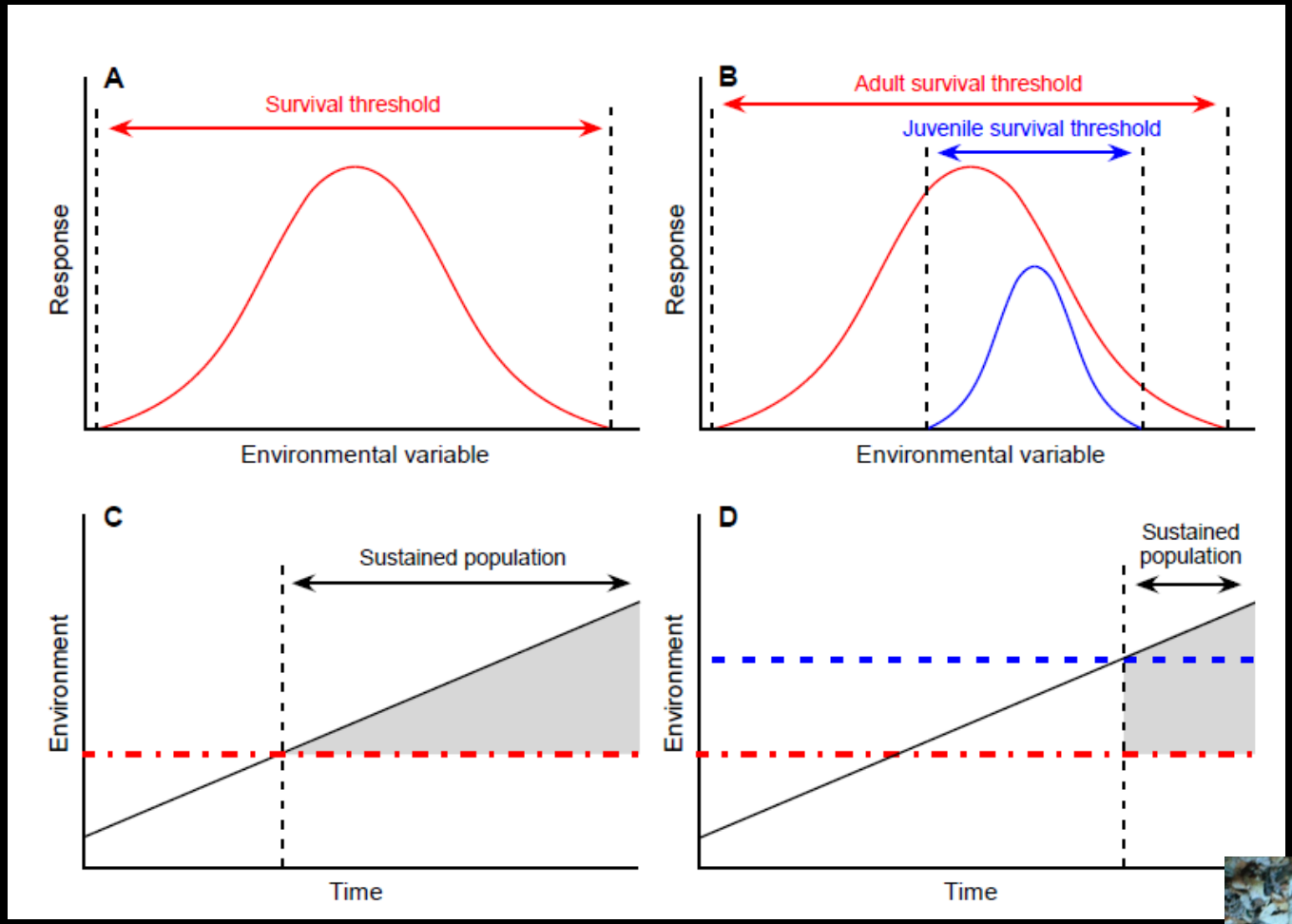


Corollary: The path from 2012 to 2025, 2050, 2100, etc. will NOT be a straight one.

Disturbances will interact with climate variation.

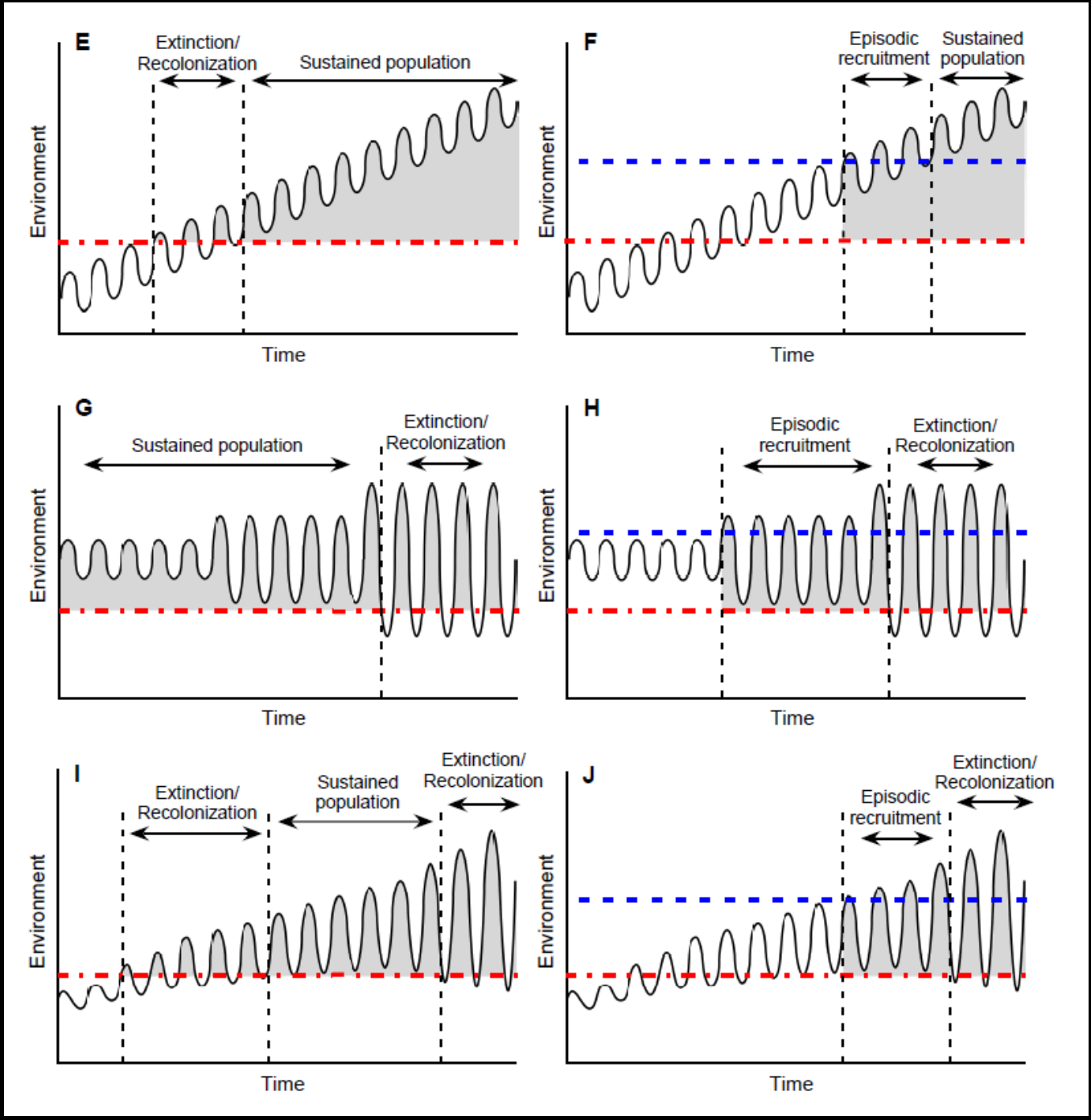
Photo courtesy of Sherrill Goodrich, USFS

Regeneration niches will interact with climate variation…



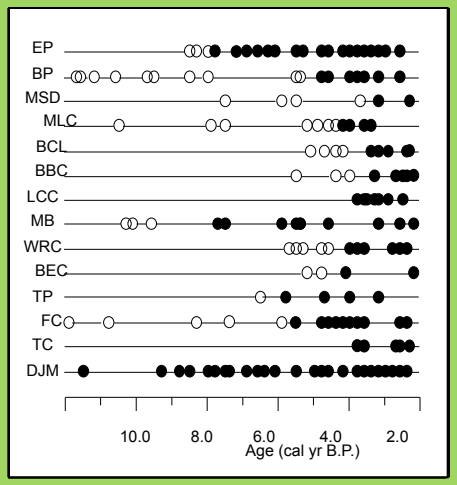
S.T. Jackson *et al.* 2009. *PNAS.*

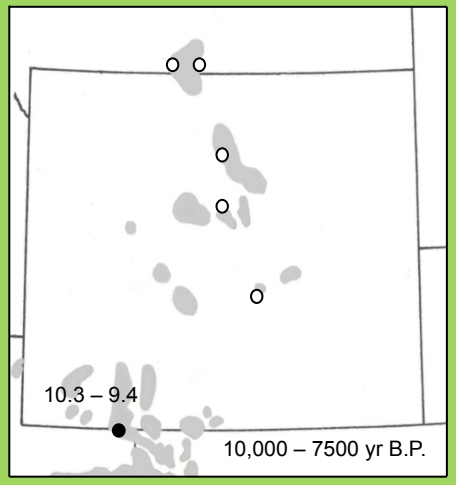
…leading to episodic recruitment and colonization

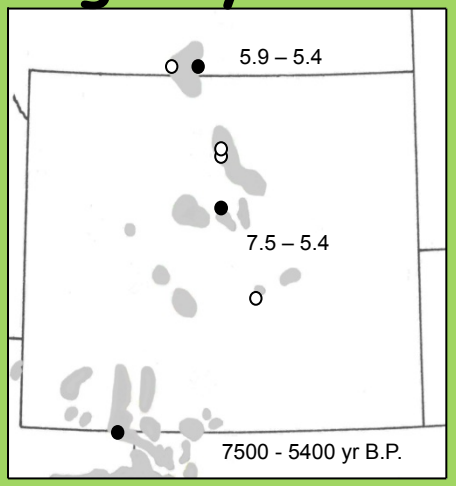


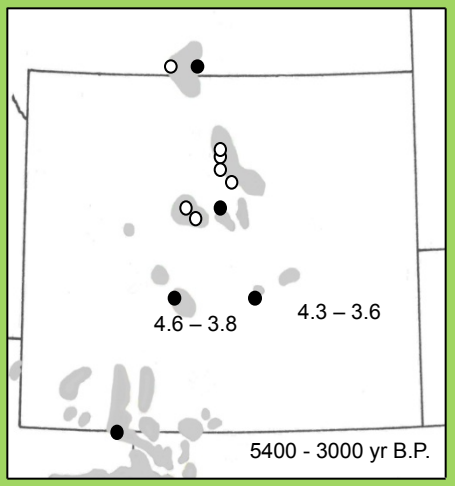
S.T. Jackson *et al.* 2009. *PNAS* .

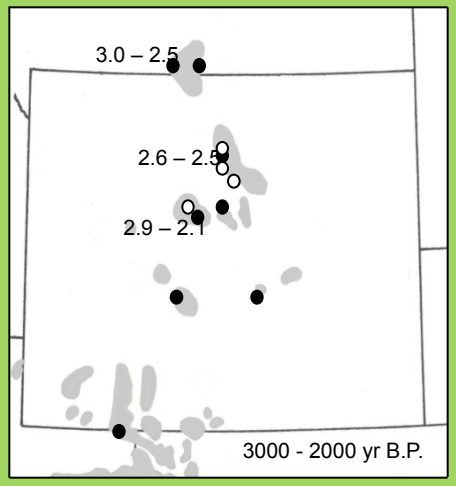
Corollary: Ecological states, including species distribution and abundance, are (and will be) laden with historical contingency

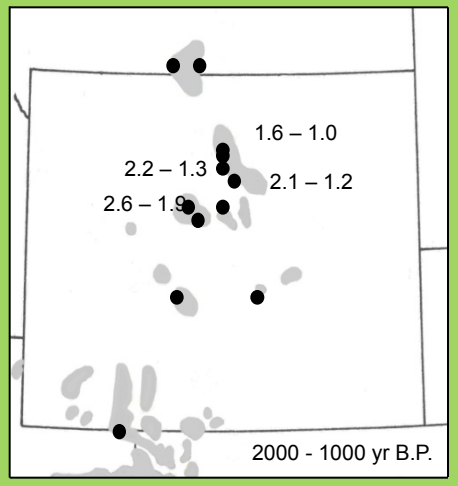






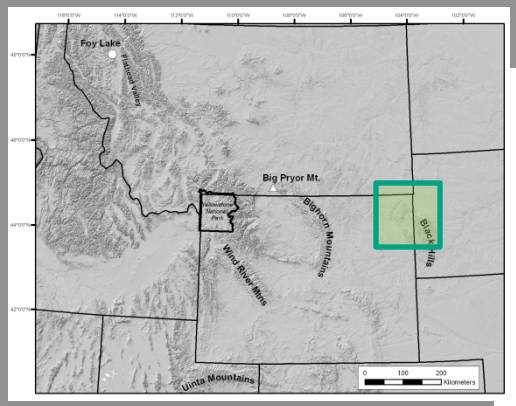






Episodic invasion of *Juniperus osteosperma* in Wyoming and Montana

M.E. Lyford, S.T. Jackson, J.L. Betancourt, S.T. Gray. 2003. *Ecological Monographs*



Widespread fires occur during droughts

Recruitment pulses occur during pluvials, especially after droughts

Precipitation

Recruitment

Fire scars

a.

1564 1576 1580 1591 1637 1664 1668 1684 1697 1706 1743 1753 1757 1785 1807 1822 1823 1845 1859 1863 1864 1870 1890

b.

No. of stems

0 10 20 30 40

1750s drought

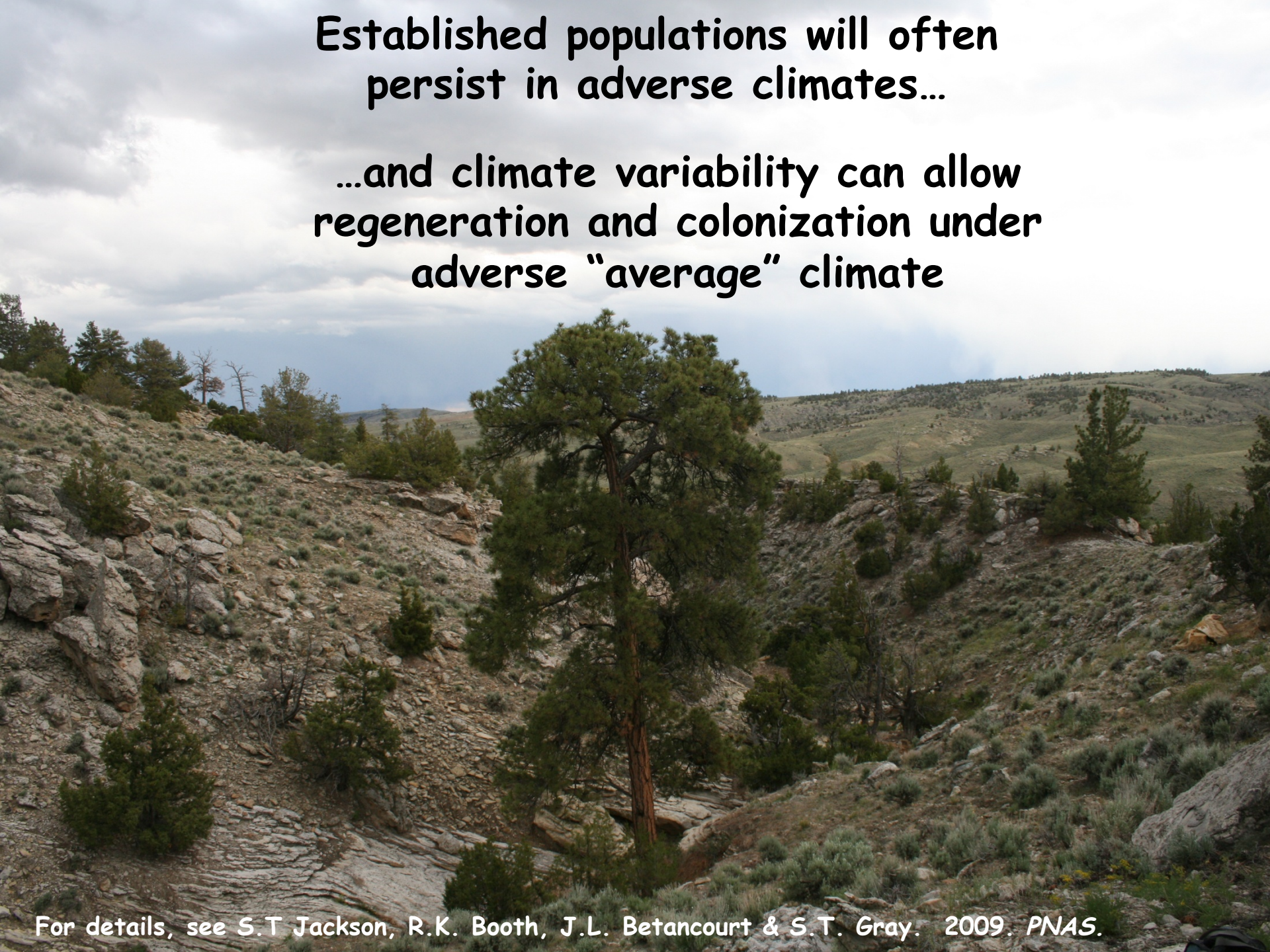
Distribution Uncertain

Precip. anomaly Wet Dry

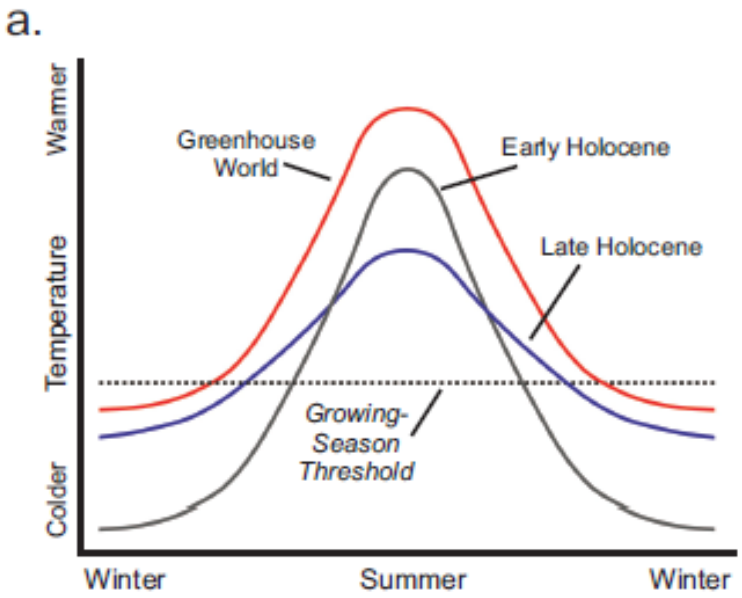
1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000

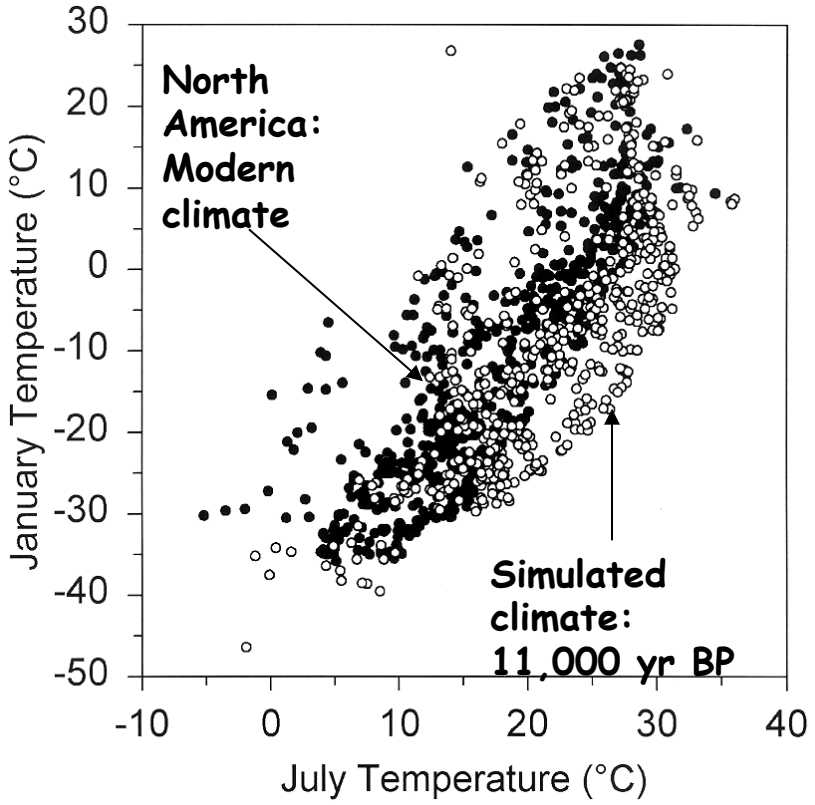
Year

P.M. Brown. 2006. *Ecology.*


Established populations will often persist in adverse climates…
…and climate variability can allow regeneration and colonization under adverse "average" climate
For details, see S.T Jackson, R.K. Booth, J.L. Betancourt & S.T. Gray. 2009. PNAS.

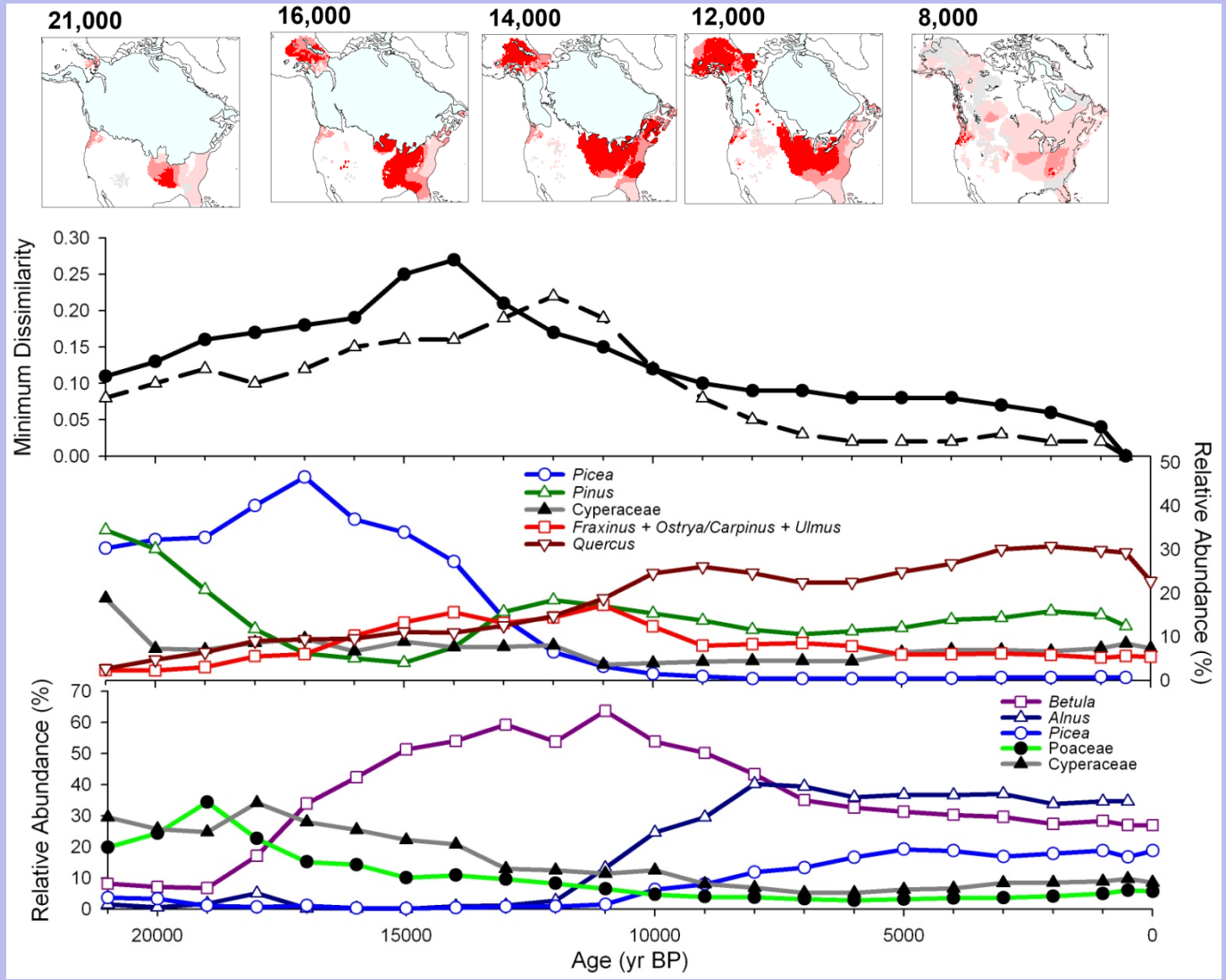
Correlations among climate variables may be conserved along spatial gradients, but not through time.





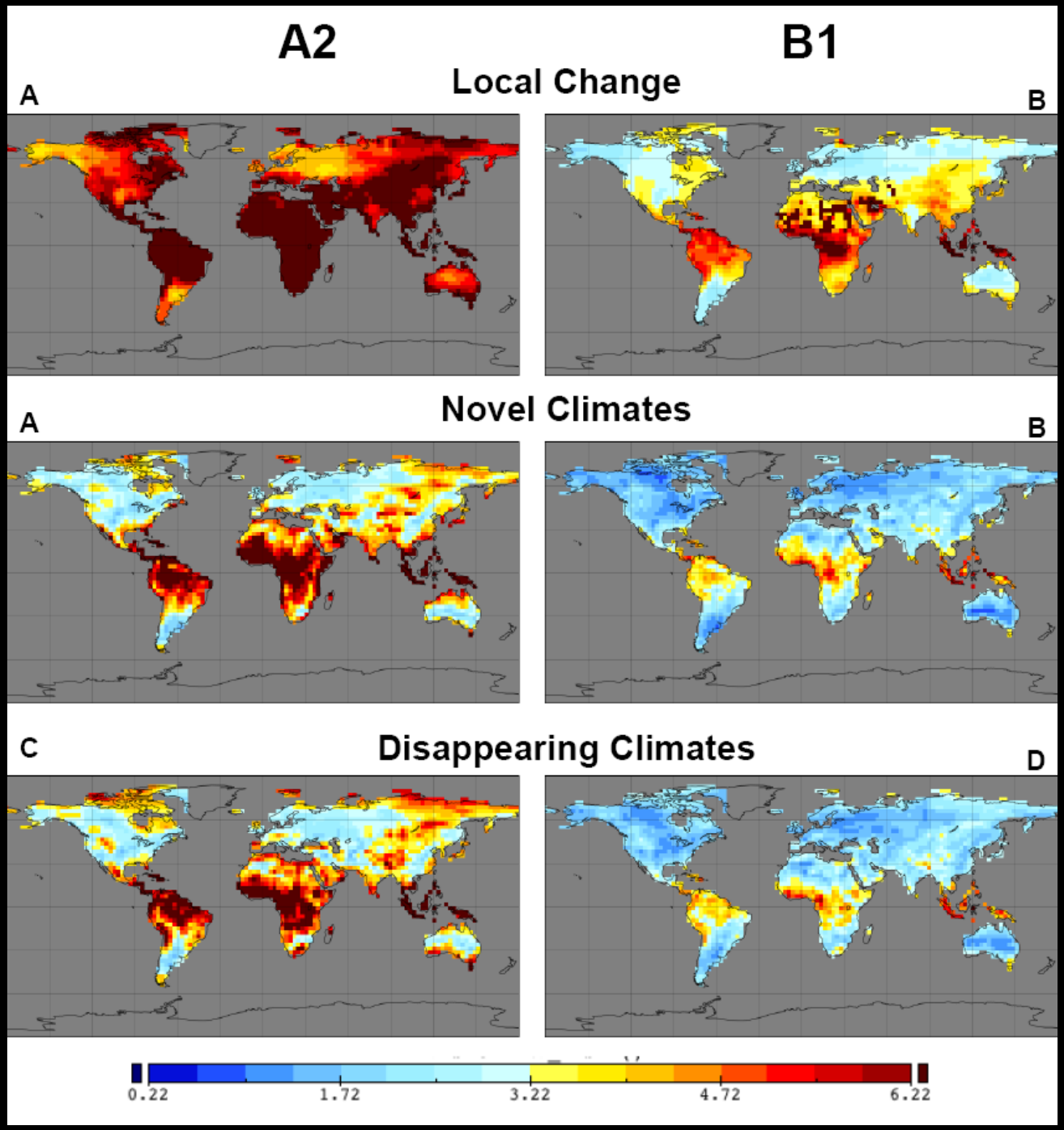
S.T. Jackson *et al*. 2009. *PNAS*.

S.T. Jackson & J.T. Overpeck. 2000. *Paleobiology* (Suppl.).



J.W. Williams & S.T. Jackson. 2007. *Frontiers in Ecology and the Environment.*

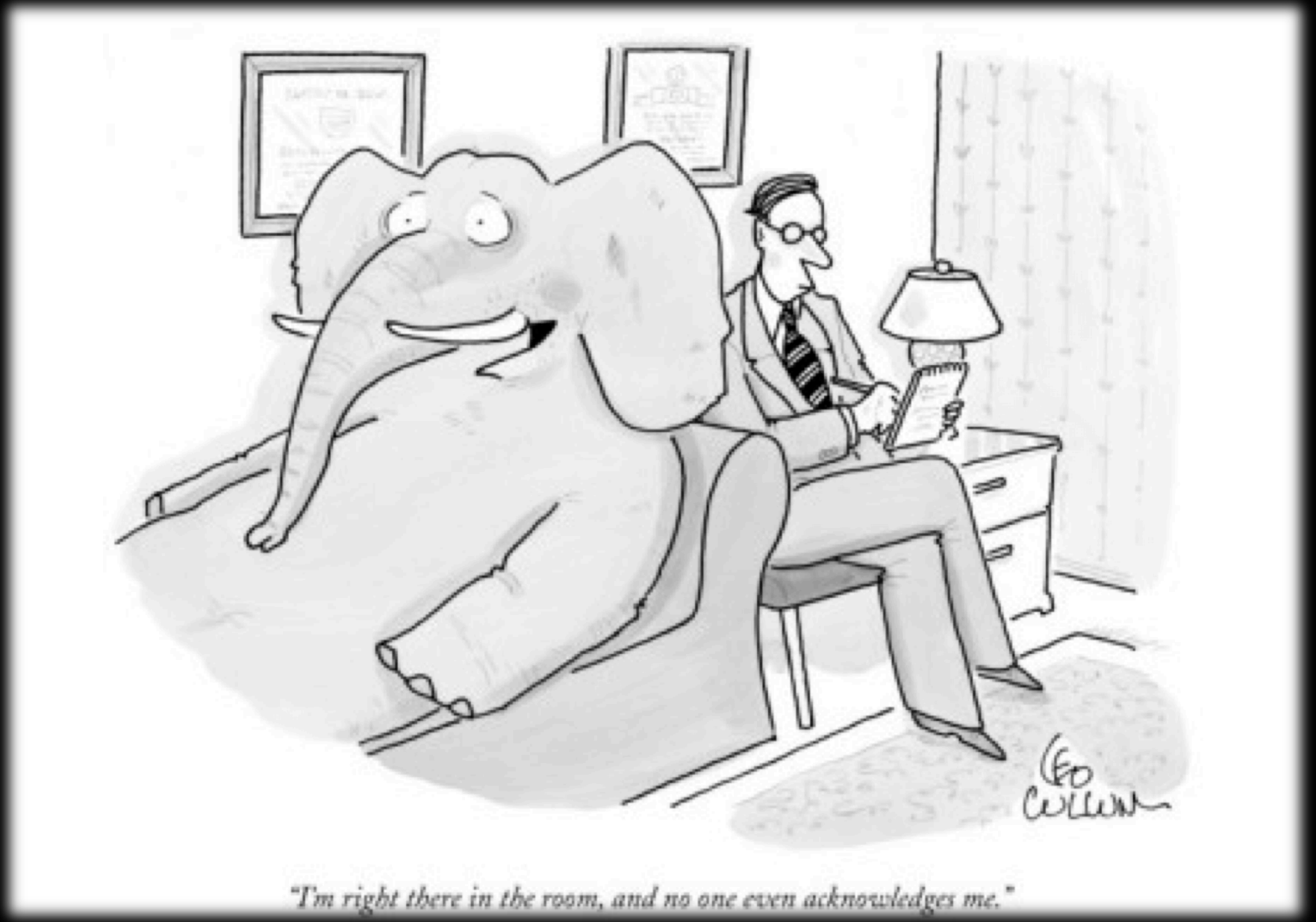
No-analog climates have prevailed in the past, and will in the future.



J.W. Williams, S.T. Jackson & J.E. Kutzbach. 2007. *PNAS.*

- Multiple futures
- All look bad
- Can't predict…

The Good News



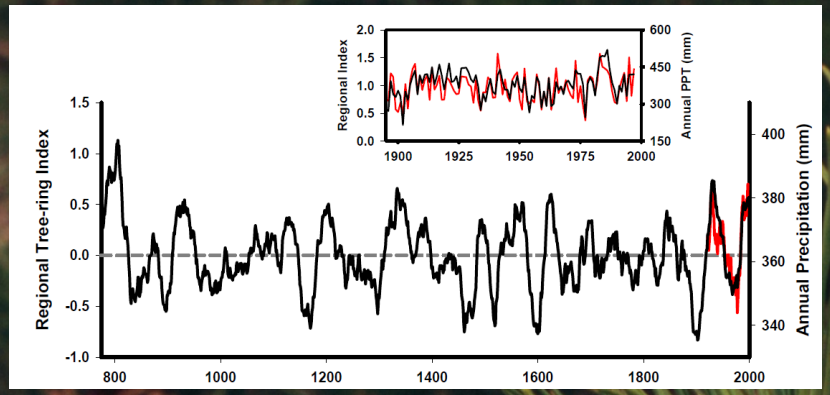
"I'm right there in the room, and no one even acknowledges me."

And yet, biodiversity abides.

Many (most? all?) species have capacity for adapting to climate change via:

- Phenotypic adjustment
- Habitat shift
- Migration
- Evolutionary adaptation

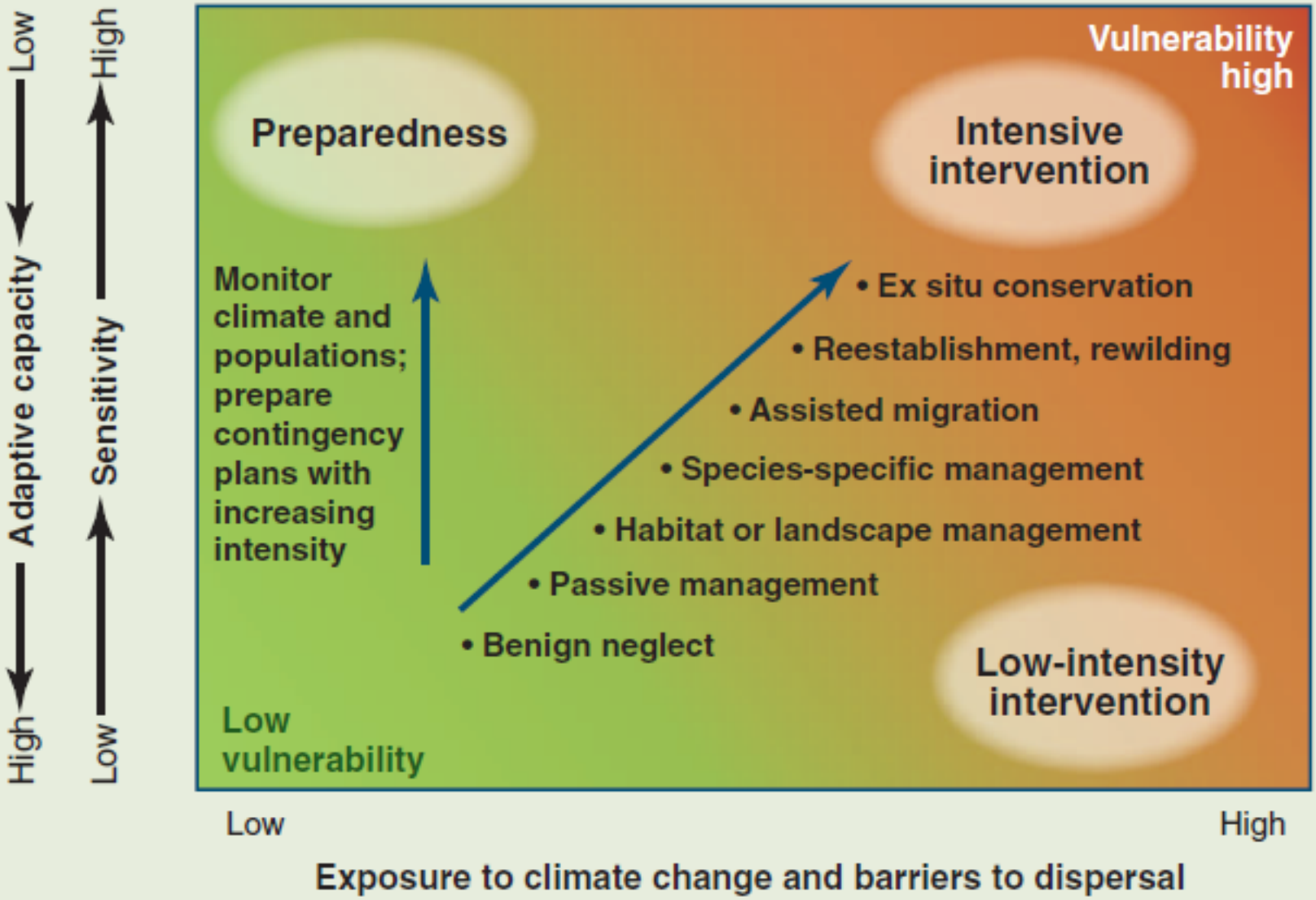
Opportunities



Leverage Natural Climate Variability

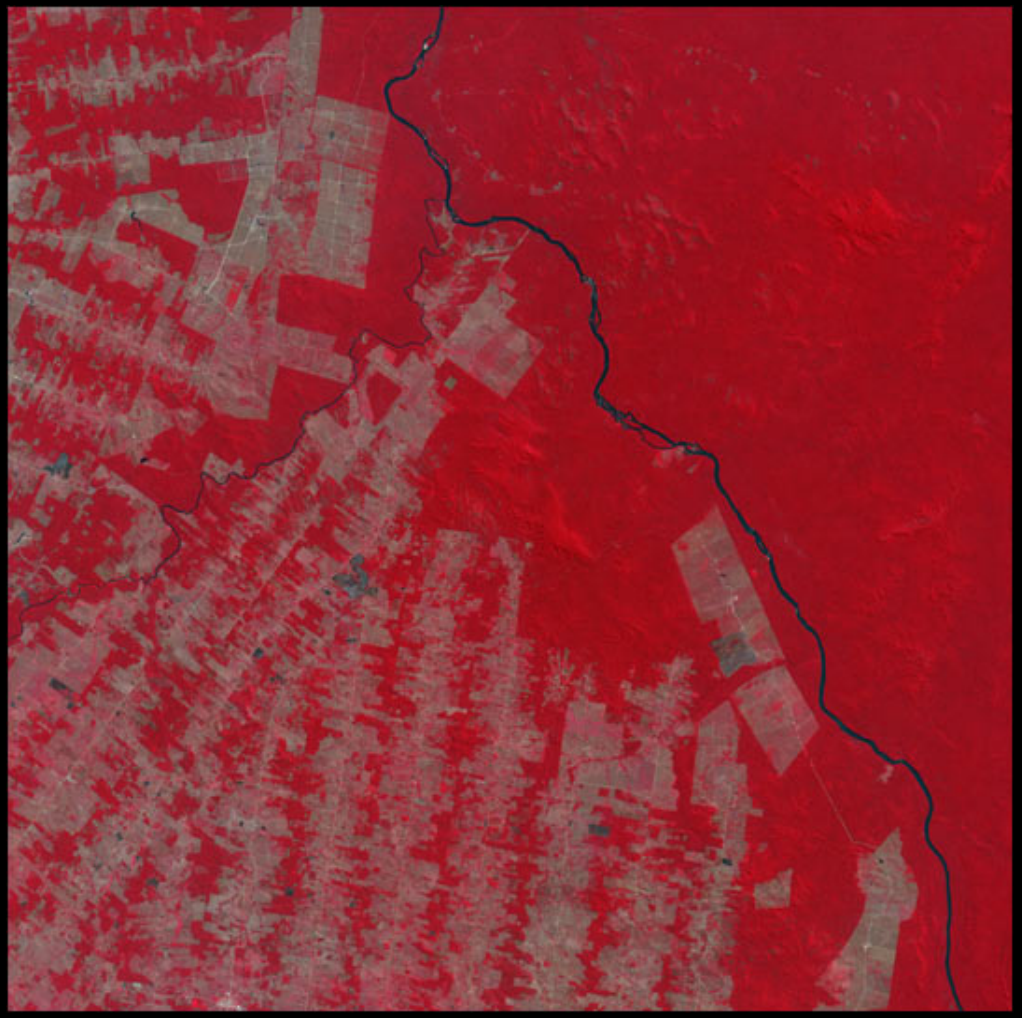
Leverage Natural Adaptive Capacity

Assess and Reduce Direct Vulnerabilities

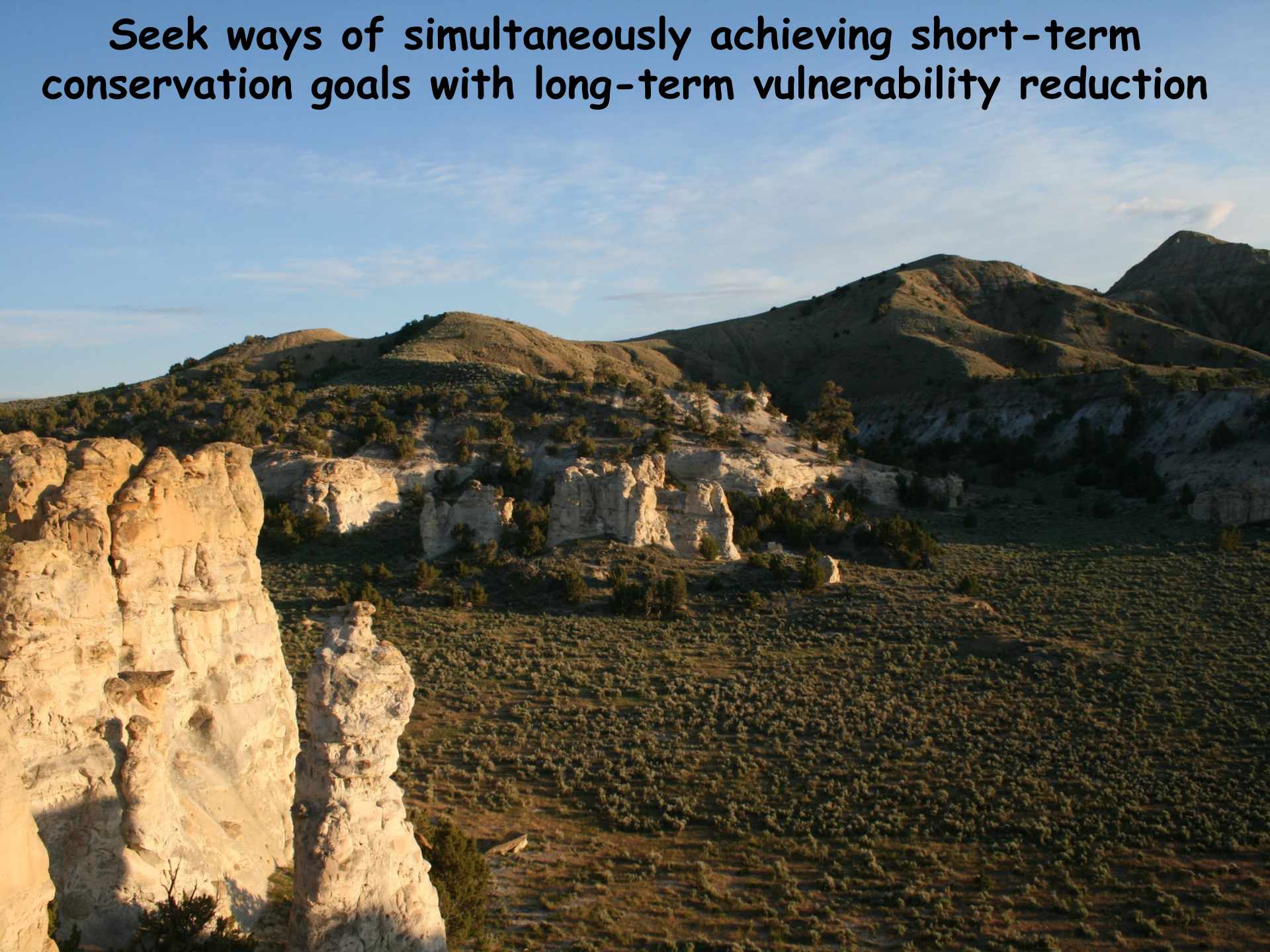


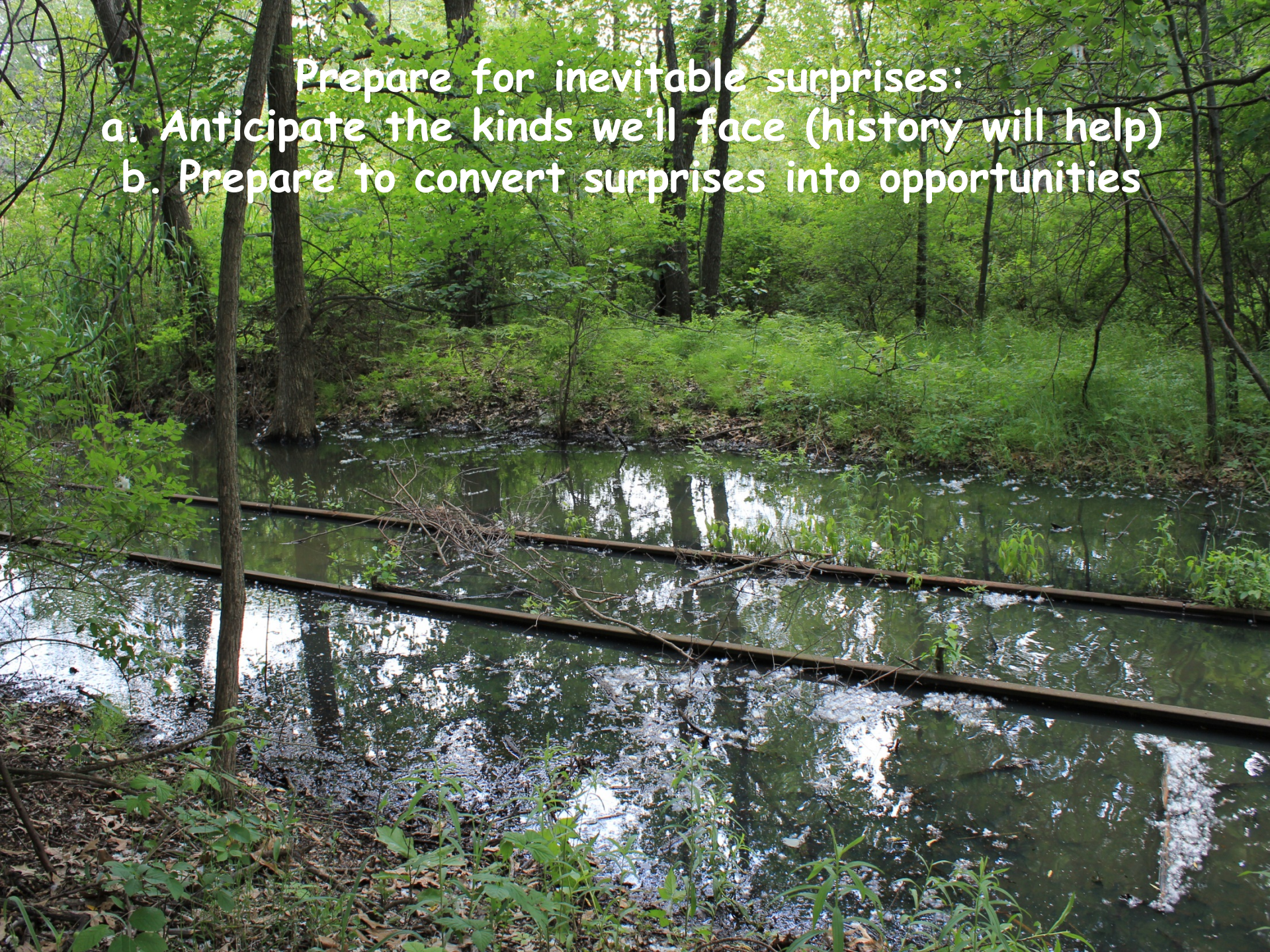
T.P. Dawson, S.T. Jackson, J.I. House, I.C. Prentice & G.M. Mace. 2011. *Science* 332:53-58.

Reduce threats and stresses arising from sources other than climate change (Benefits: increases adaptive capacity, may decrease sensitivity and exposure)



Seek ways of simultaneously achieving short-term conservation goals with long-term vulnerability reduction




Prepare for inevitable surprises:
a. Anticipate the kinds we'll face (history will help)
b. Prepare to convert surprises into opportunities

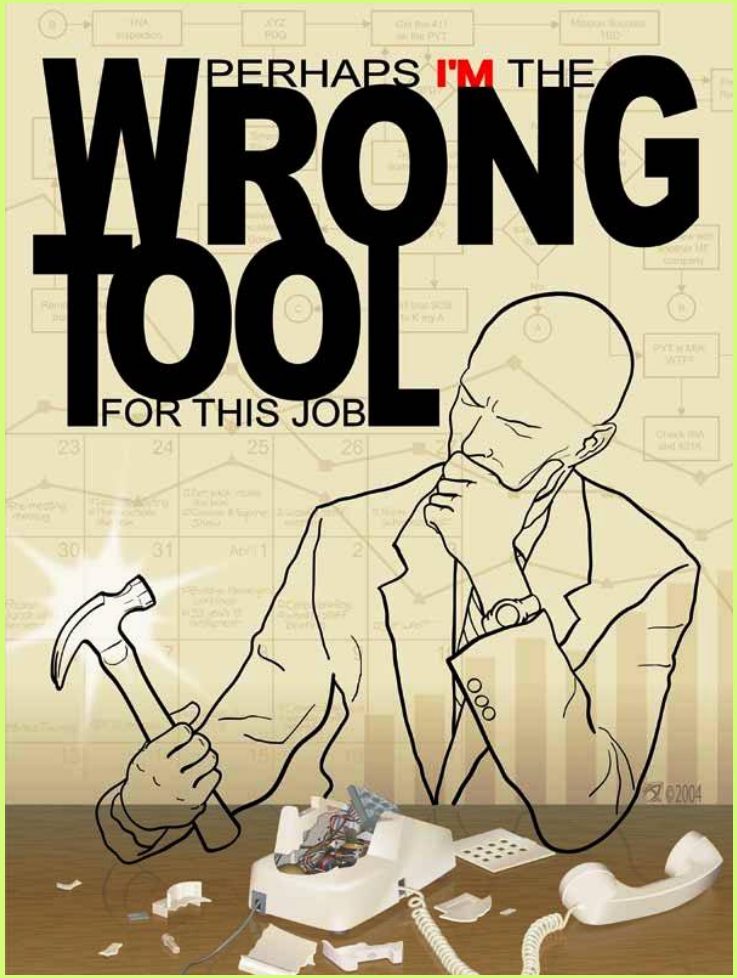

History no longer provides an objective "natural" standard.
Historical states will continue to be relevant, but decisions
about the future will inevitably involve *values*
(economic, utilitarian, ethical, aesthetic)

Role of Science in a Weird New World?

- **Post-stationary world**
  - -"stationarity is dead" (Milly *et al.* 2008. *Science.*)
- **Post-normal world**
  - -high stakes, high uncertainty (Funtowicz & Ravetz 1993. *Futures.*)
- **Post-predictive world**
  - -indeterminacies and uncertainties; prediction elusive
- **Post-global world**
  - -climate-change adaptation will necessarily play out at local to regional scales
- **Post-natural world**
  - -"Garden management" (Marris; Kareiva & Marvier)

Kaplan's Law of the Instrument:

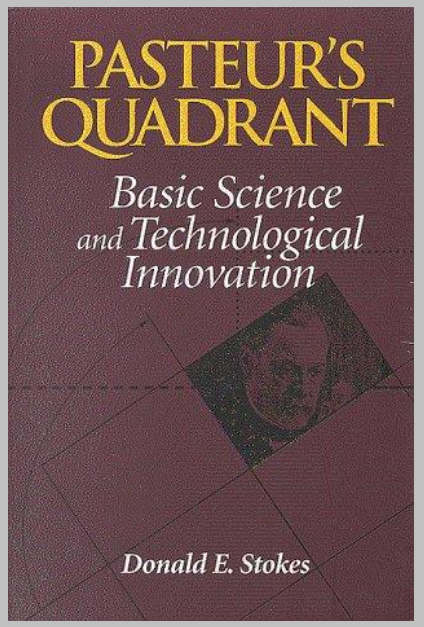
"…a scientist formulates problems in a way which requires for the solution just those techniques in which he himself is particularly skilled."



A. Kaplan. 1964. *The Conduct of Inquiry.*

Problem: insufficient science is directed toward critical needs of climate-change adaptation.

Research is inspired by	Considerations of Use?	
	No	Yes
Quest for fundamental understanding? Yes	Pure basic Research (Bohr)	Use-inspired basic research (Pasteur)
Quest for fundamental understanding? No		Pure applied research (Edison)



"Leopold's Quadrant"

(…and Elton's, and Clements', and Ricker's, and Odum's, and…)

Universal

Broad; General

Scope

Local; Particular

Robert May's "Perfect crystals"

NSF core programs

Humboldtian synthesis & induction

Natural history

Monitoring & inventory

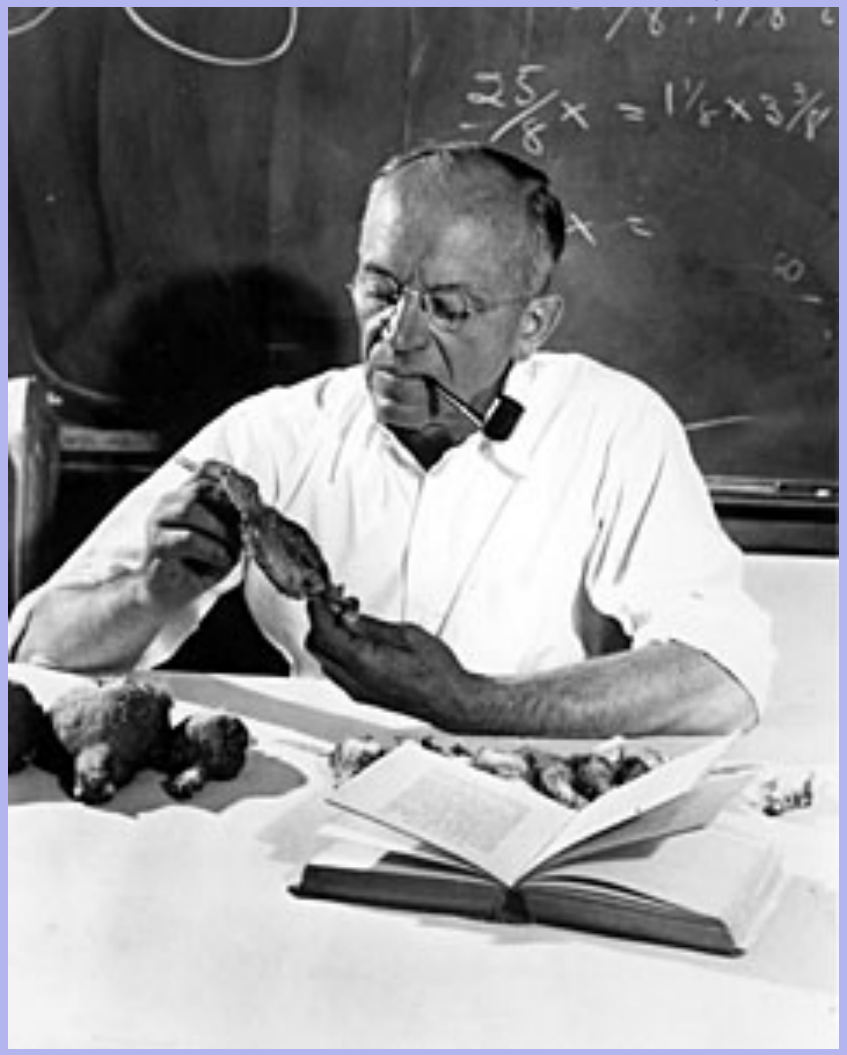
Local problem-solving

Curiosity-driven

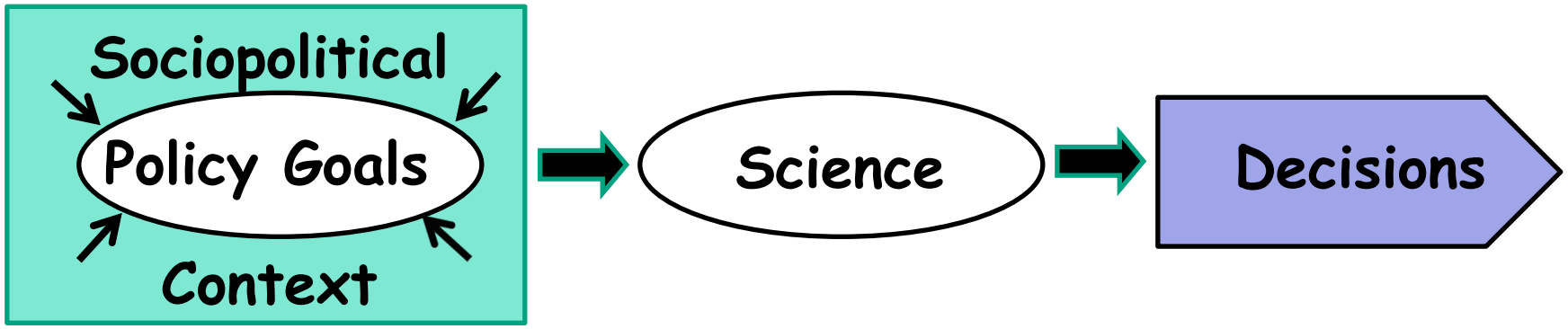
Motivation

Utility-driven

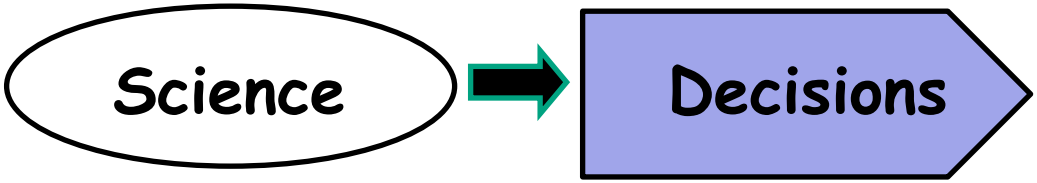
A missing third axis:
How do we ensure that scientifically justified decisions are made where they're needed?



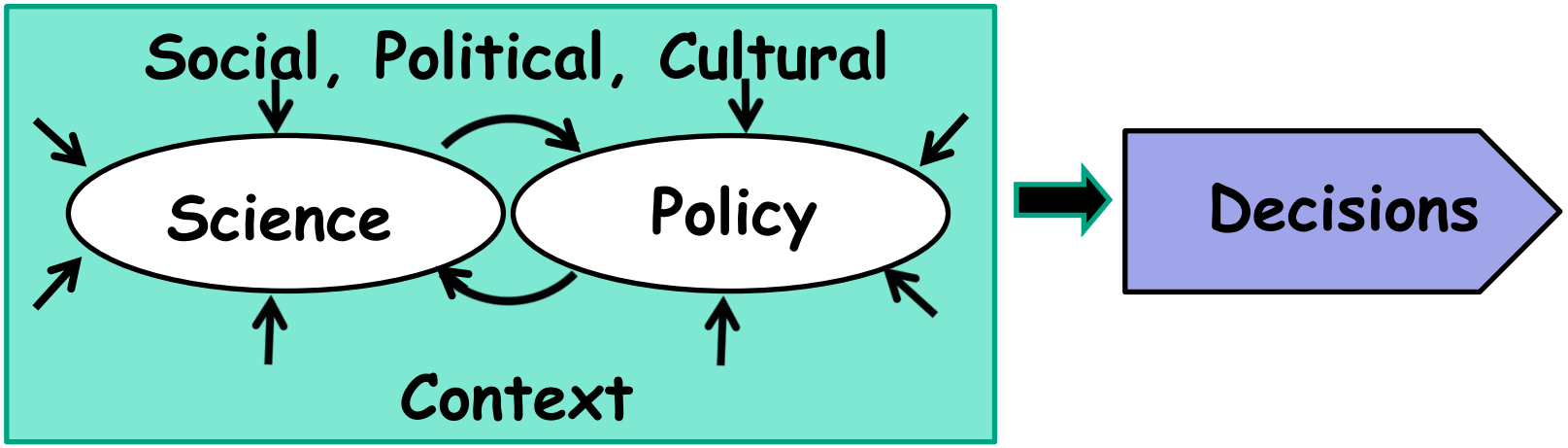
a) The Decisionist Model



b) The Technocratic Model



c) The Co-Production Model



Adapted from P. van Zwanenberg & E. Millstone. 2005. *BSE: Risk, Science, and Governance.*

Cultures and Subcultures

Academic

- Disciplines & subdiscipline
- Institutions

Agencies

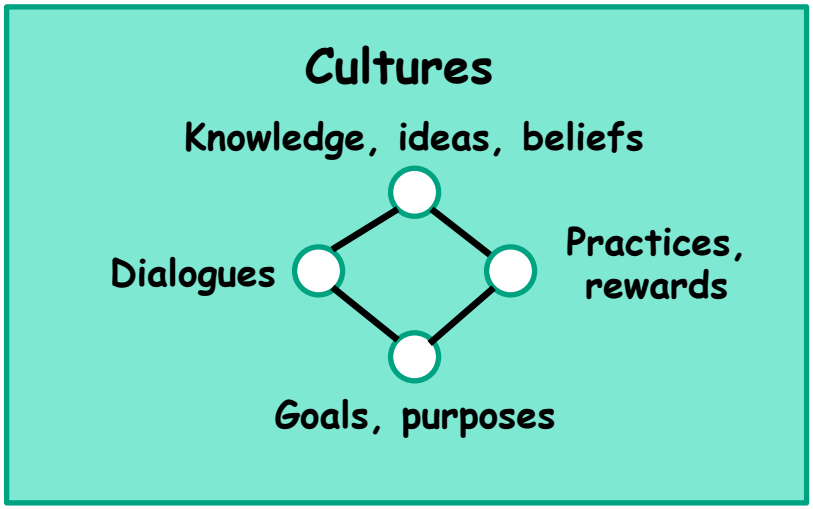
- Federal
- Tribal
- State

Civic

- NGOs
- Policymakers
- Educators
- User groups
- Lay public (multiple…)

Economic

- Energy & mining
- Grazing
- Tourism
- Timber
- Etc.



Adapted from S. Jasanoff & B. Wynne. 1998. Science and decisionmaking. In Rayner & Malone (eds.), *Human Choice & Climate Change. Vol. I. The Societal Framework.*

WANTED

Scientists with skills (latent or realized) at working across cultural borders (disciplinary, professional, political, linguistic, philosophical)

REWARD