USGS
science for a changing world

DRI

Natural Resource Needs Related to Climate Change in the Great Basin & Mojave Desert: Research, Adaptation, Mitigation

April 20-22, 2010
Las Vegas, NV

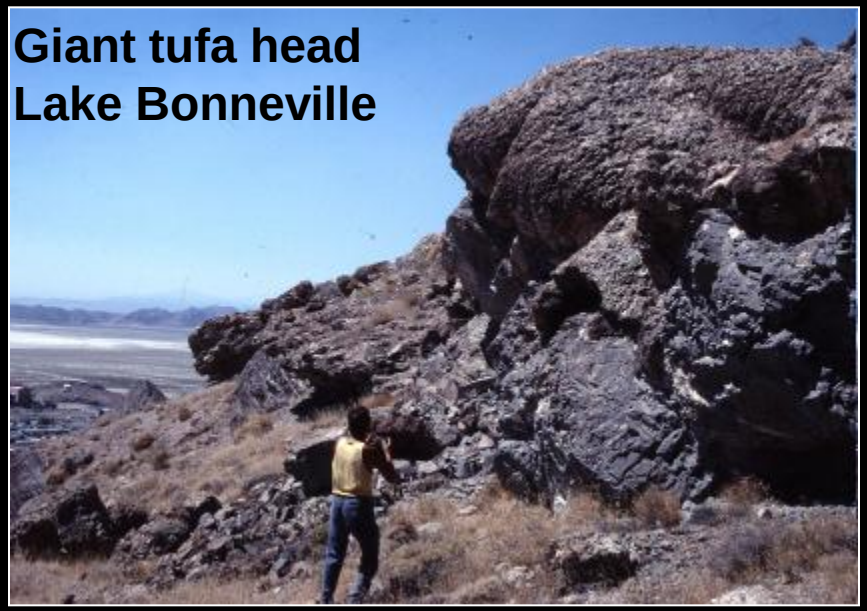
Workshop Synthesis

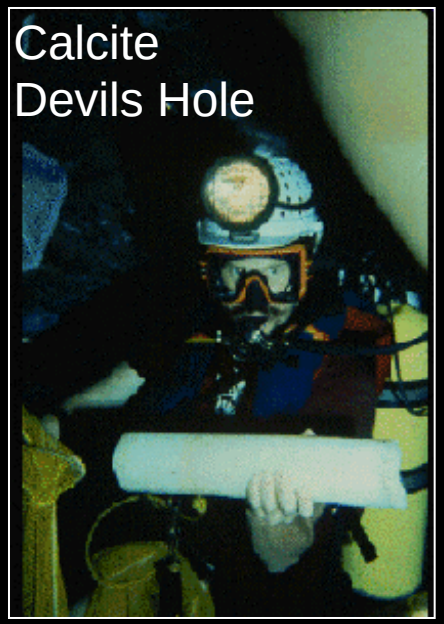
Great Basin Research & Management Partnership

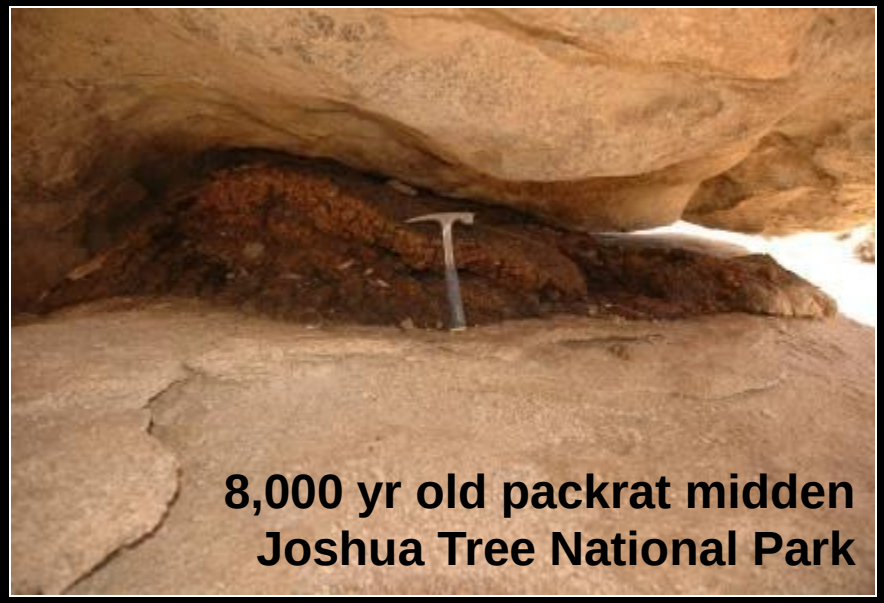
DESERT MANAGERS GROUP

Southern Nevada Agency Partnership

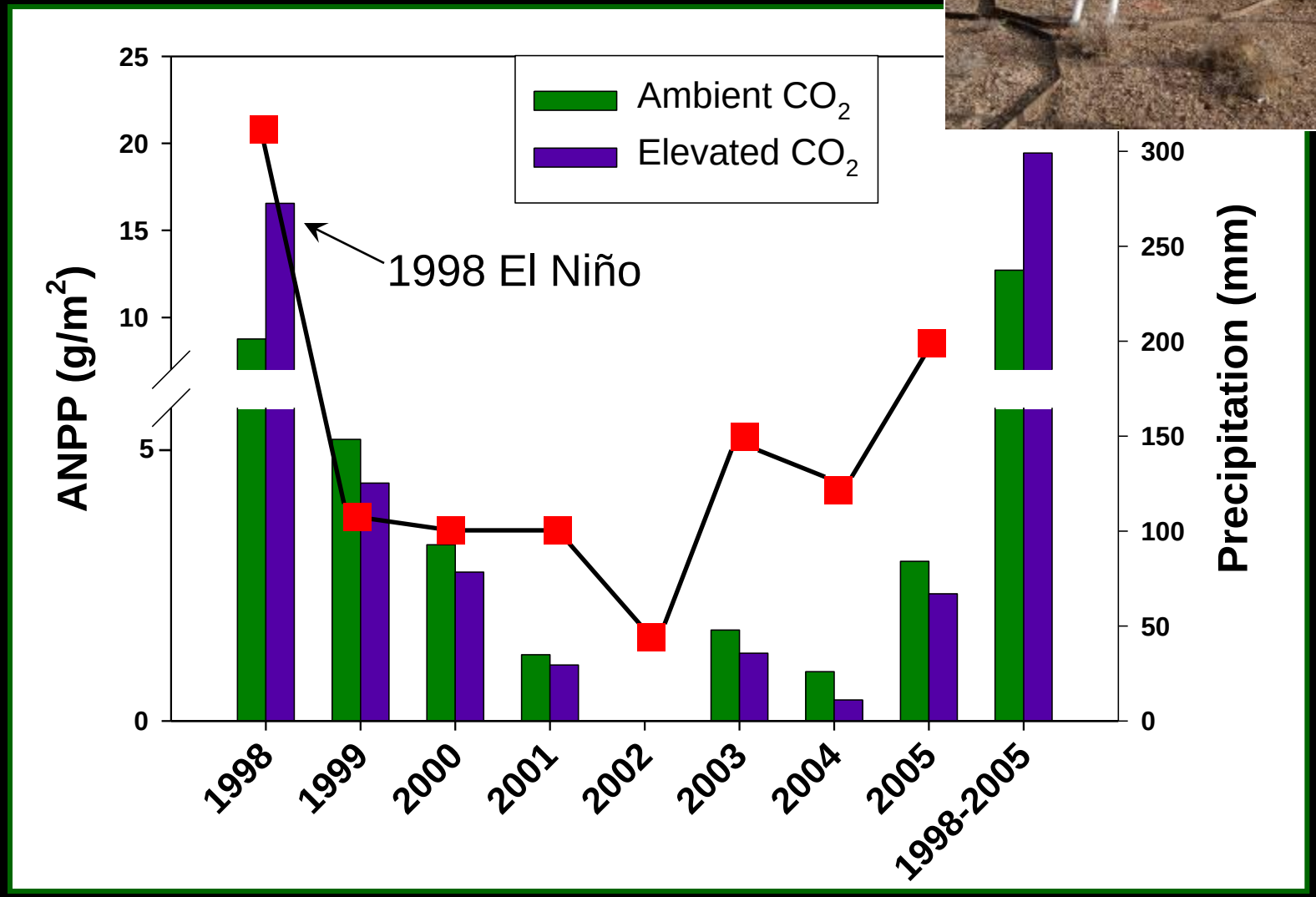
Great Basin & Mojave have a rich historical record: History Still Matters!





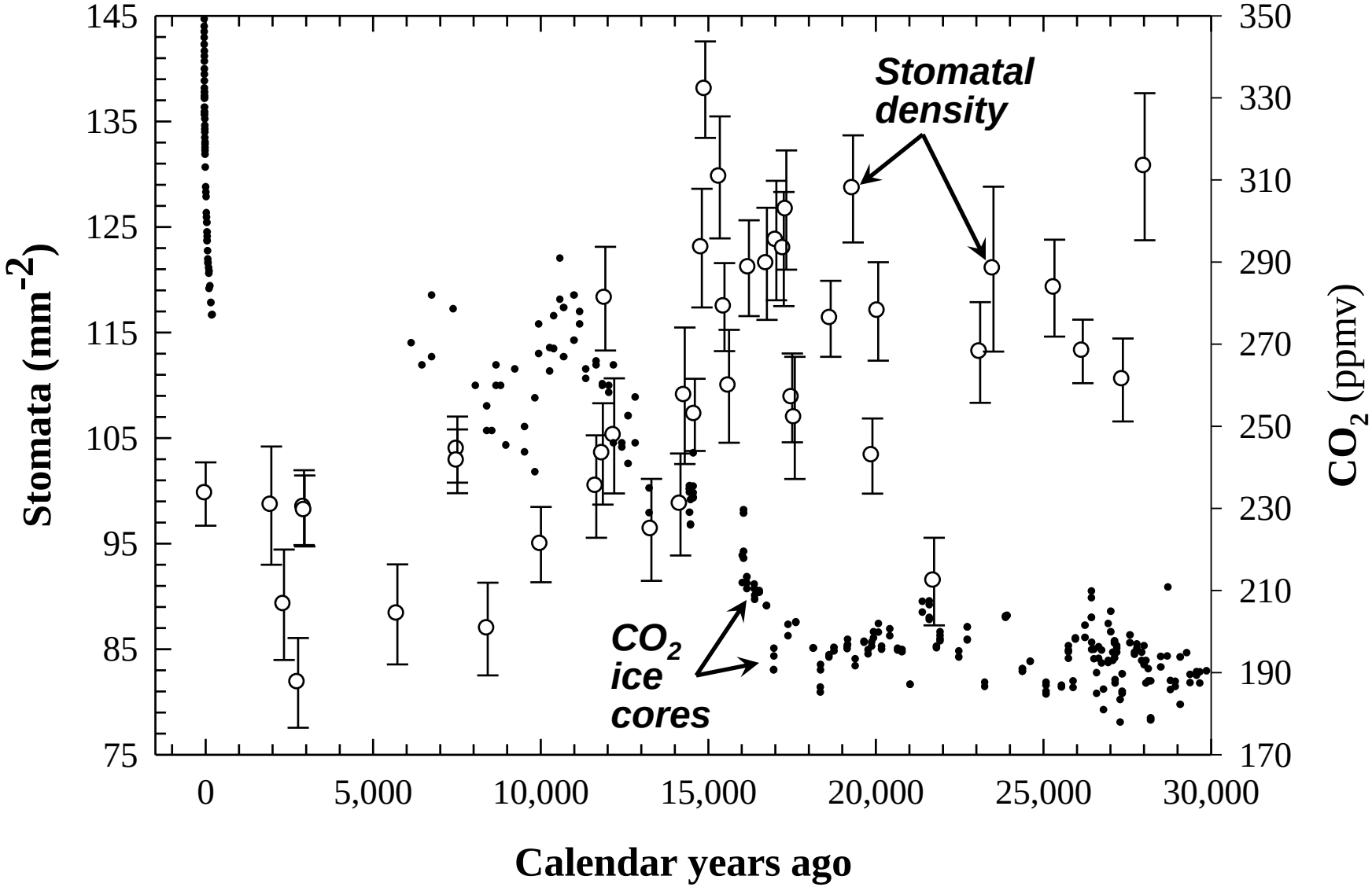


Estimated aboveground ANPP at Nevada FACE Site: In desert CO_2 (550 ppb) matters little if you don't add water (Courtesy Stan Smith)



ANPP for *Larrea* & *Ambrosia*

Stomatal density response to atmospheric CO_2 variations for limber pine leaves in fossil packrat middens



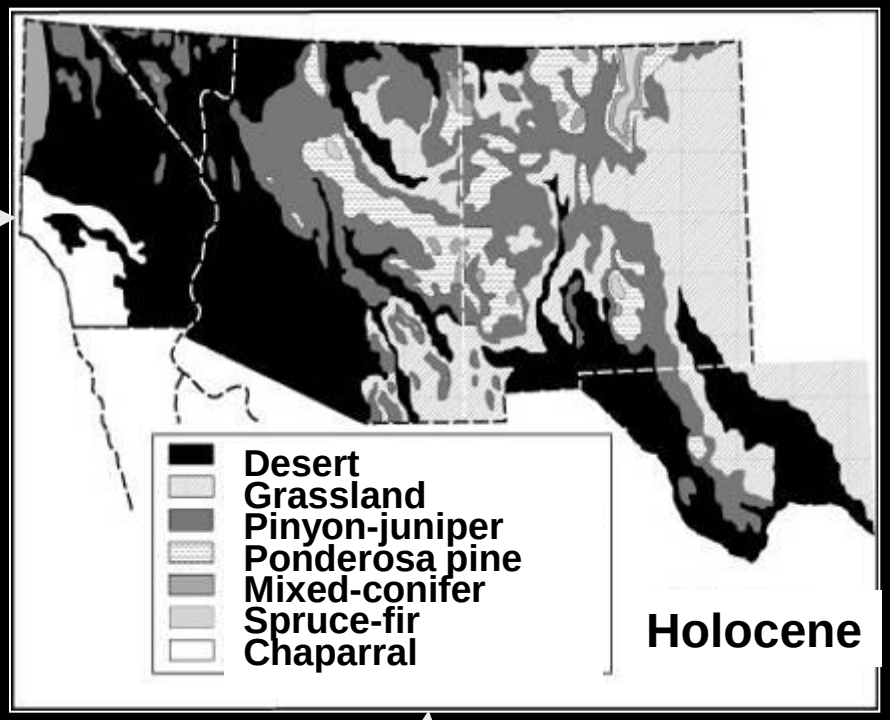
Van de Water, Leavitt, & Betancourt (1994) *Science*

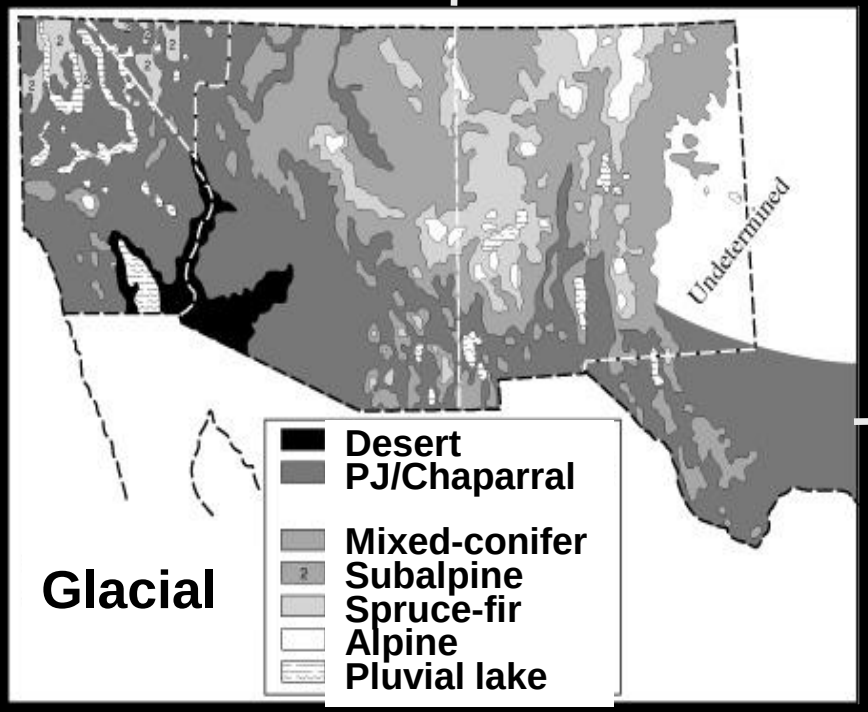
Glacial-Interglacial Changes in the Southwest

Atmospheric CO_2 level ~180 ppmv

P-J woodlands (dark gray) from 1700-400 m elevation

"Desert" (black) limited to Colo. R. Valley & Death Valley





Atmospheric CO_2 level ~280 ppmv

Summers warmed by ~5 C

Winters got drier and more variable

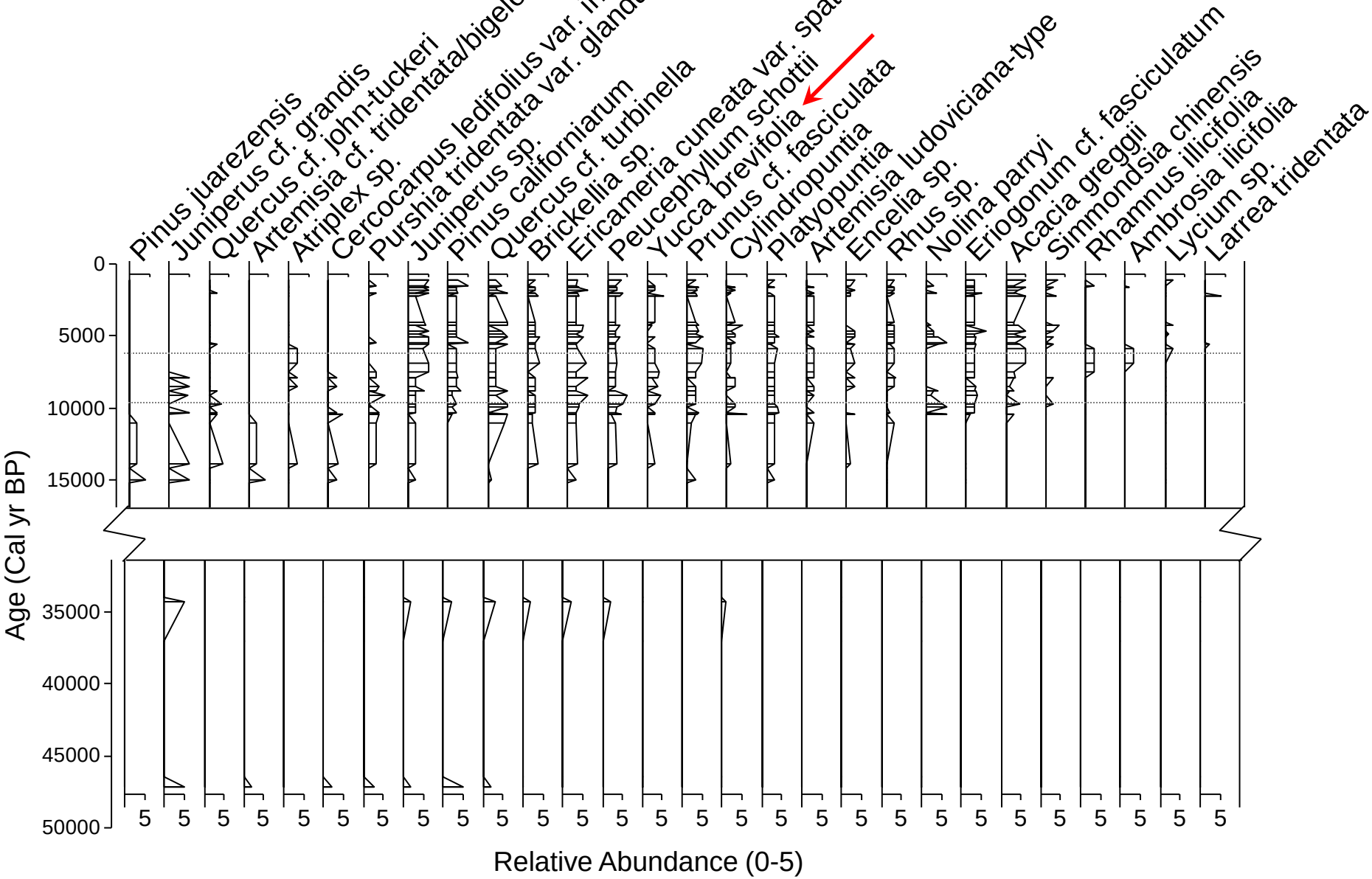
Warm/dry trumped higher CO2 & WUE

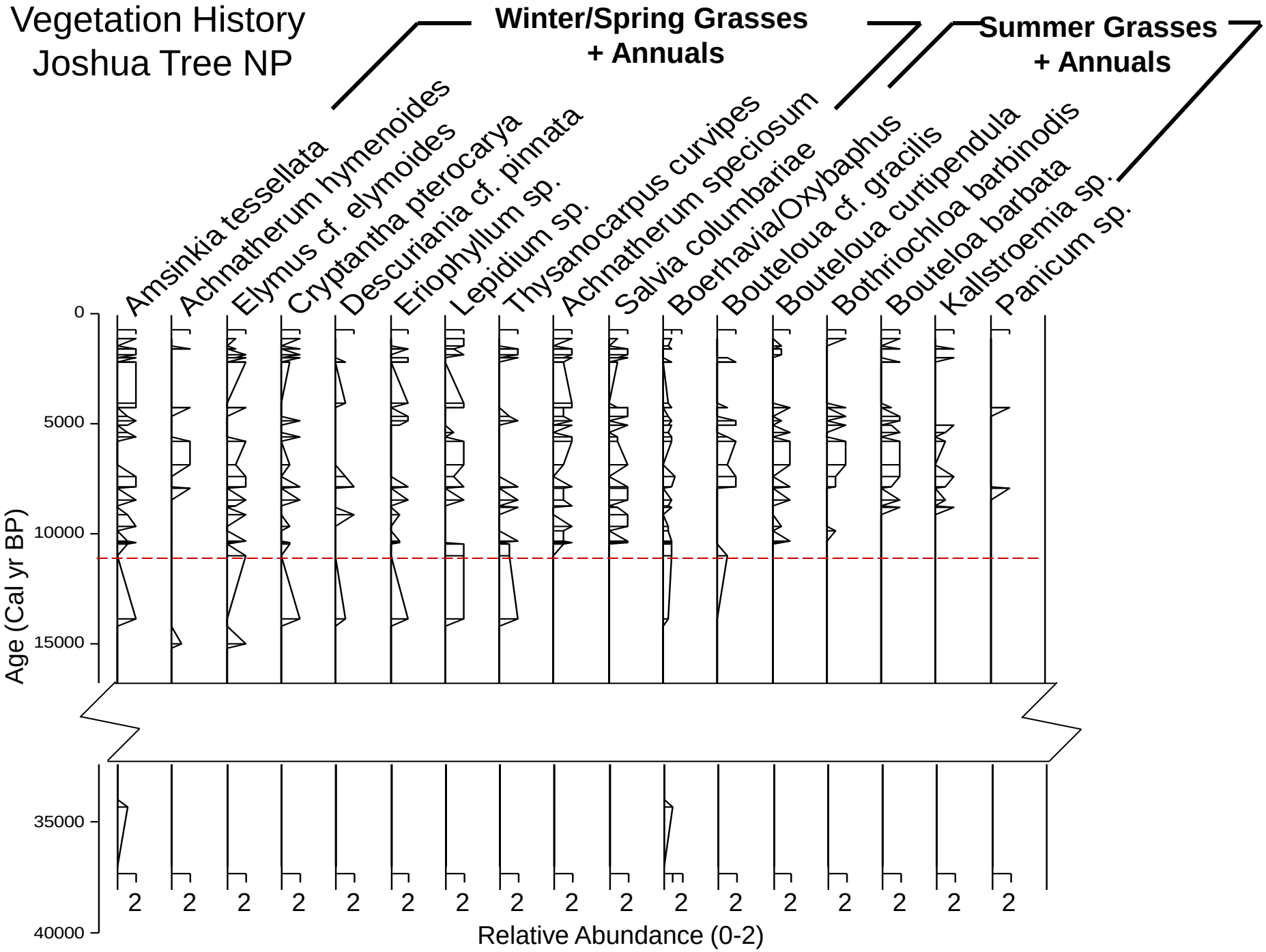
Deserts replaced p-j woodlands

Vegetation History of Joshua Tree NP

Trees, Shrubs & Cacti

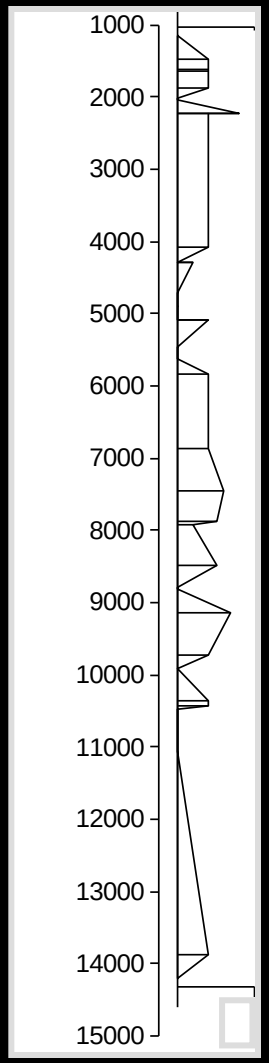
Holmgren & Betancourt 2009
J. Quat. Sciences

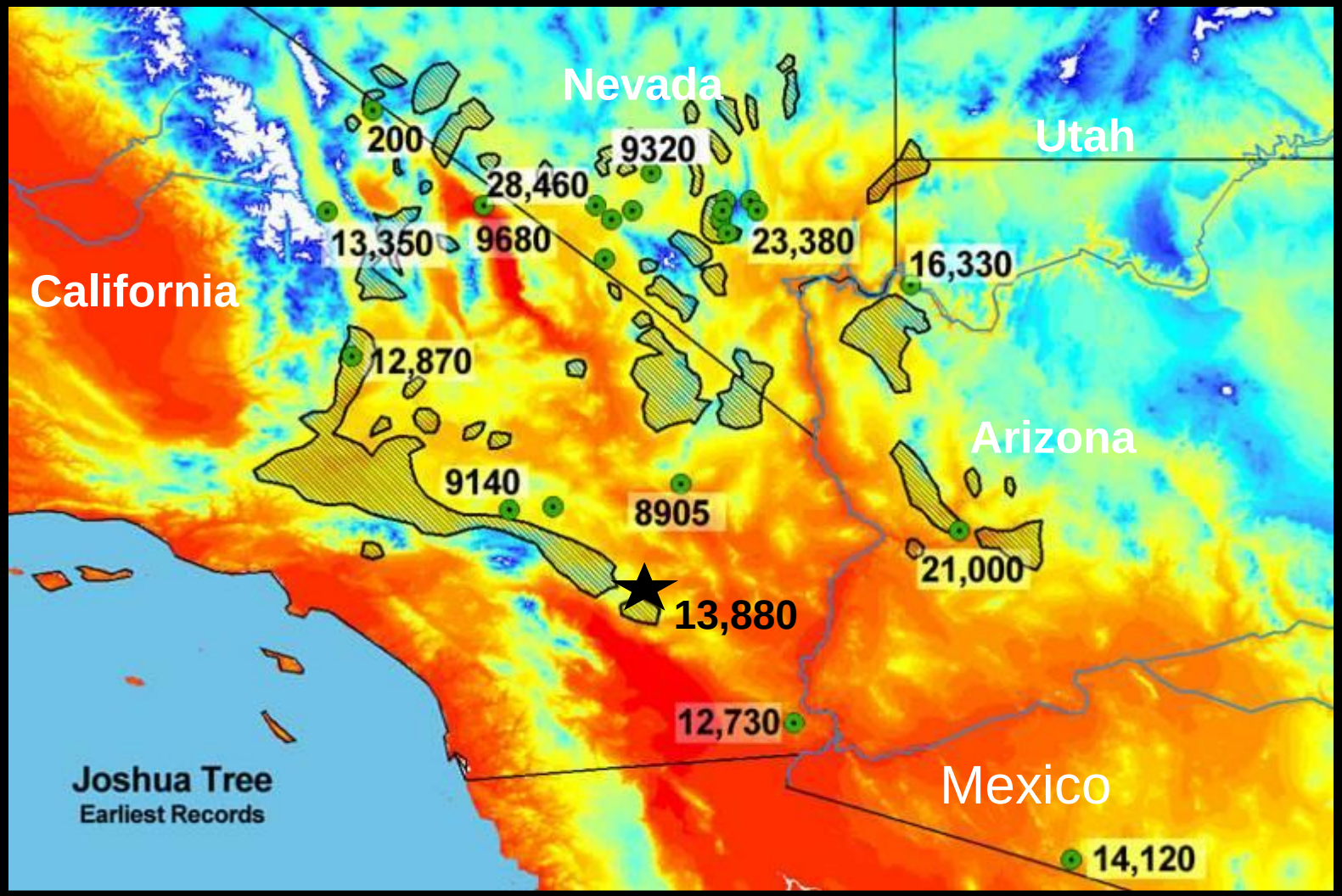



Vegetation History
Joshua Tree NP
Winter/Spring Grasses
+ Annuals
Summer Grasses
+ Annuals
Amsinkia tessellata
Achnatherum hymenoides
Elymus cf. elymoides
Cryptantha pterocarya
Descuriania cf. pinnata
Eriophyllum sp.
Lepidium sp.
Thysanocarpus curvipes
Achnatherum speciosum
Salvia columbariae
Boerhavia/Oxybaphus
Bouteloua cf. gracilis
Bouteloua curtipendula
Bothriochloa barbinodis
Bouteloa barbata
Kallstroemia sp.
Panicum sp.
Age (Cal yr BP)
0
5000
10000
15000
35000
40000
2
Relative Abundance (0-2)

Yucca Brevifolia Plant Remains at JTNP

Earliest Records of Joshua Tree

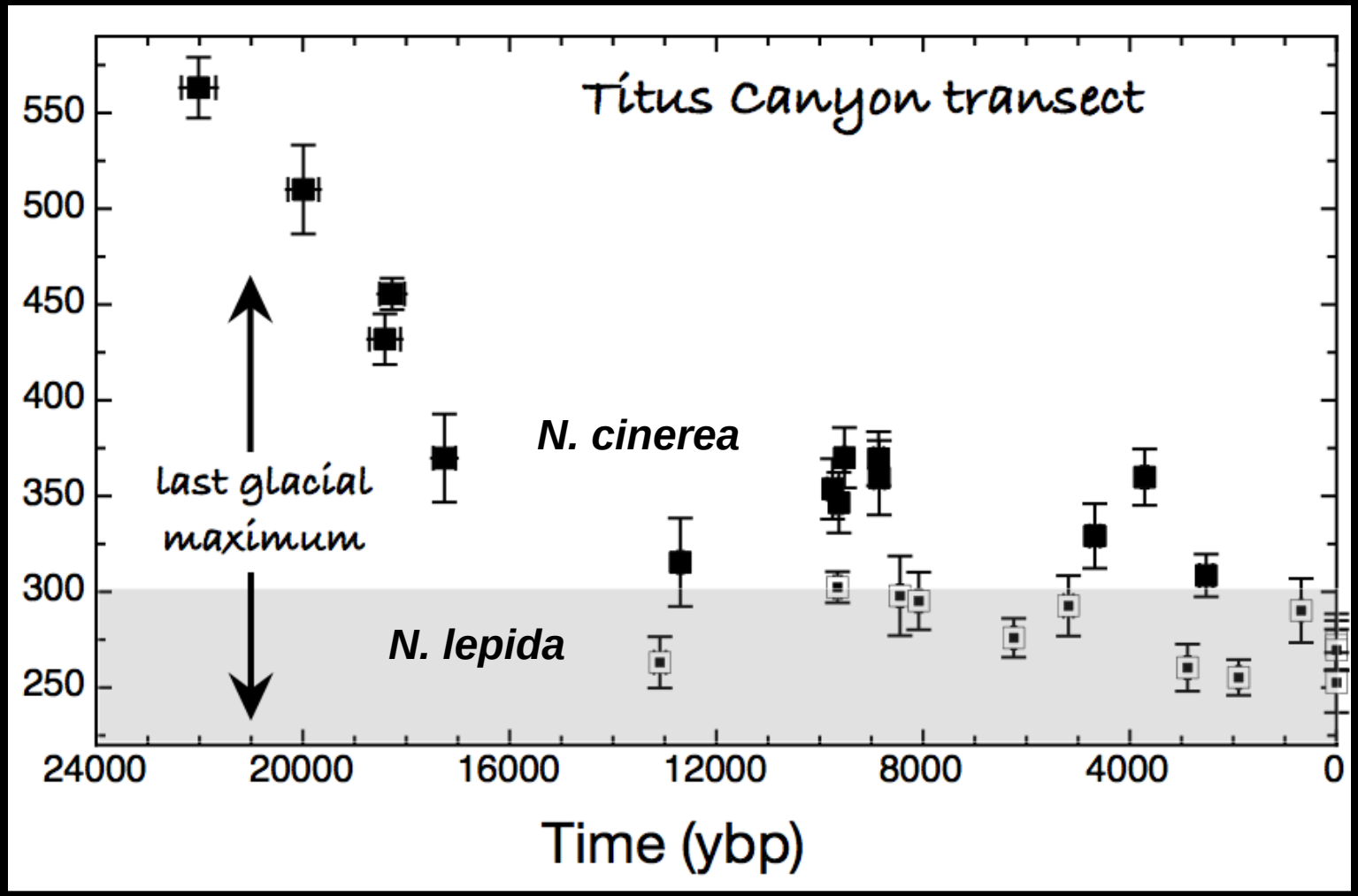




Holmgren & Betancourt 2009

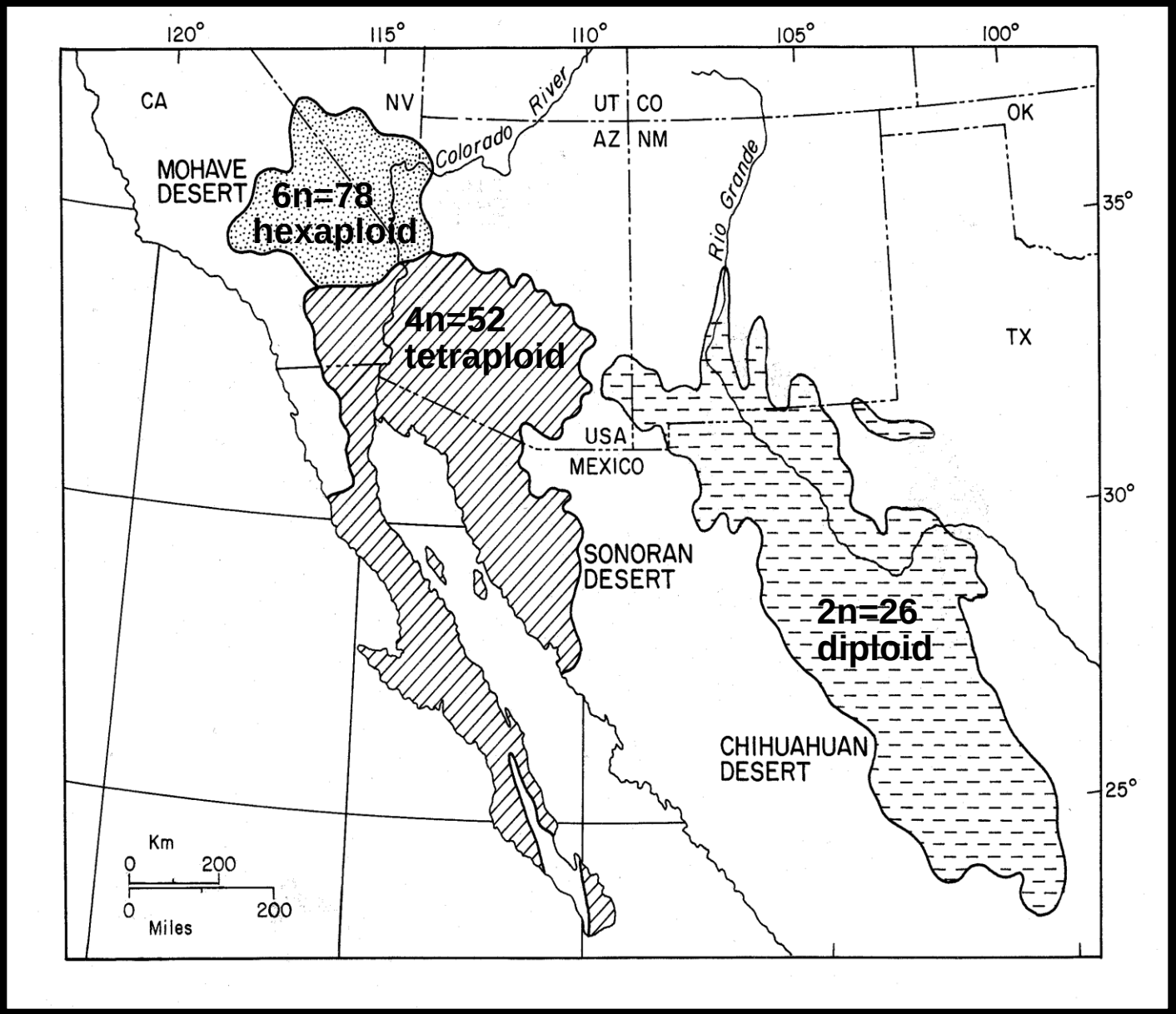
Modified from Cole et al., 2002

Phenotypic plasticity in *Neotoma* body size in response to climate, Death Valley, CA



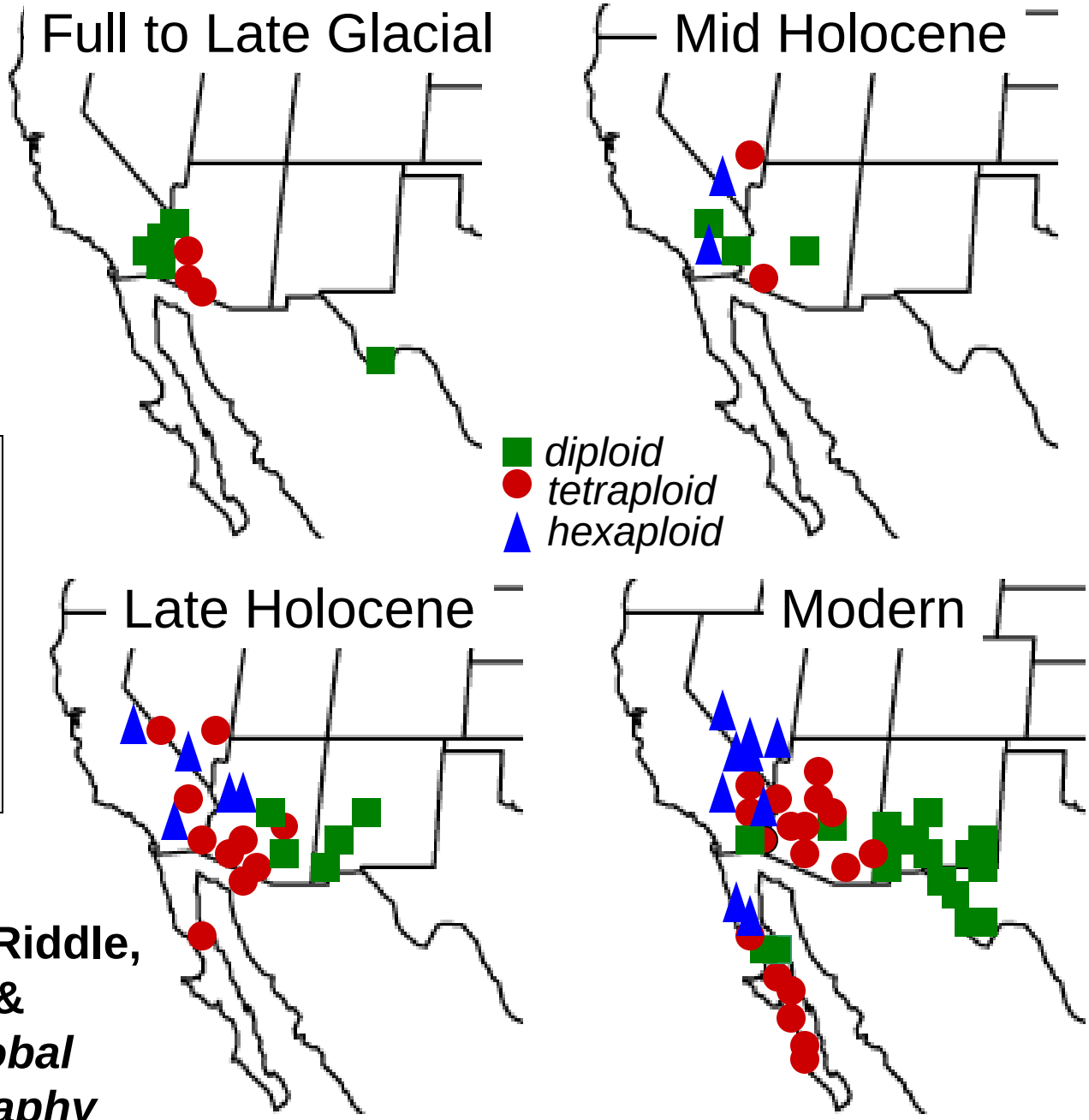
Smith et al. 2009. *Global Ecology & Biogeography*; see also
Smith, Betancourt & Brown. 1995. *Science*; Smith & Betancourt 1998 *QR*;
Smith & Betancourt 2003 *QR*; Smith & Betancourt 2006 *J. Biogeography*

Polyploidy in creosote bush

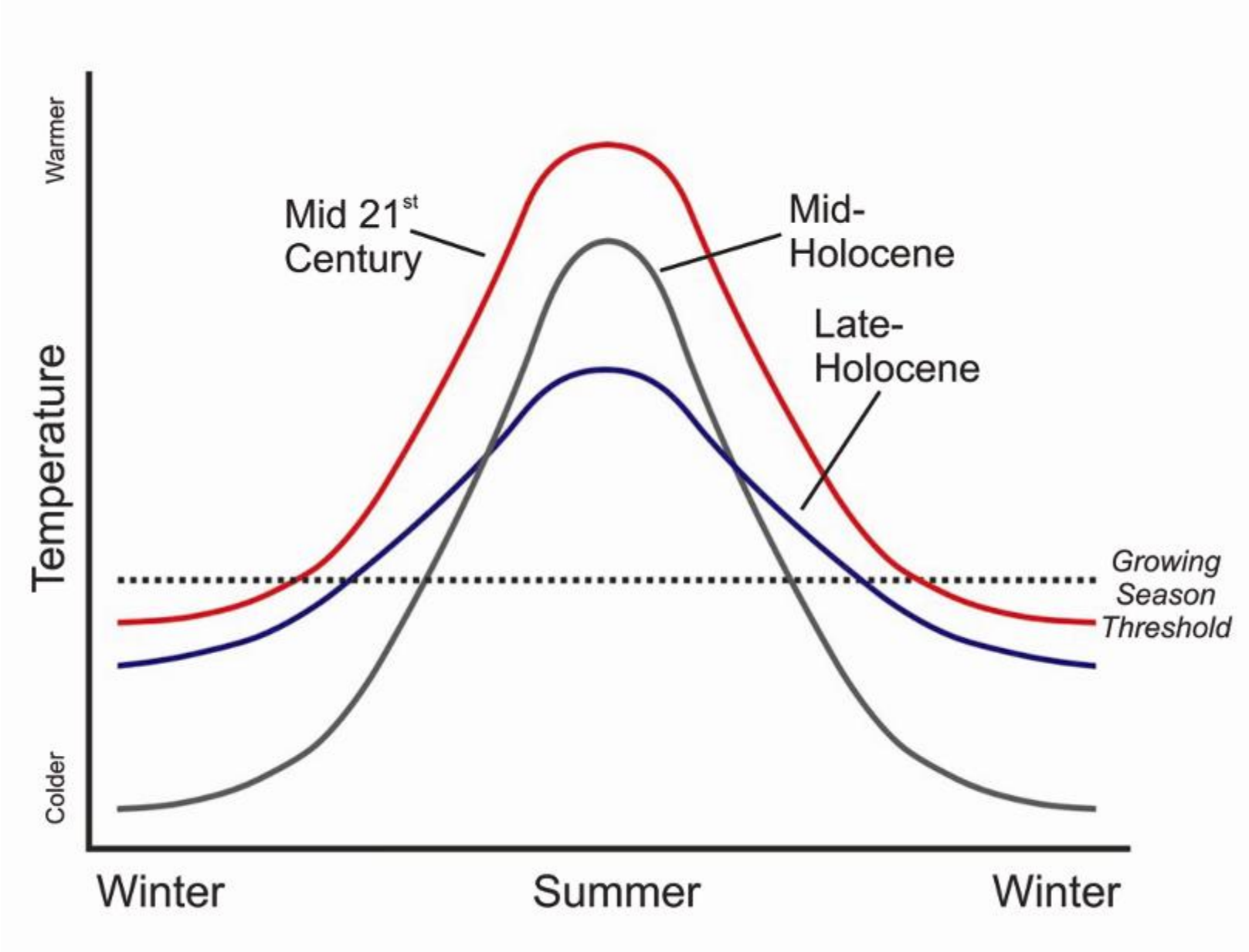


Ploidy race distributions in *Larrea tridentata* since Last Glacial Maximum

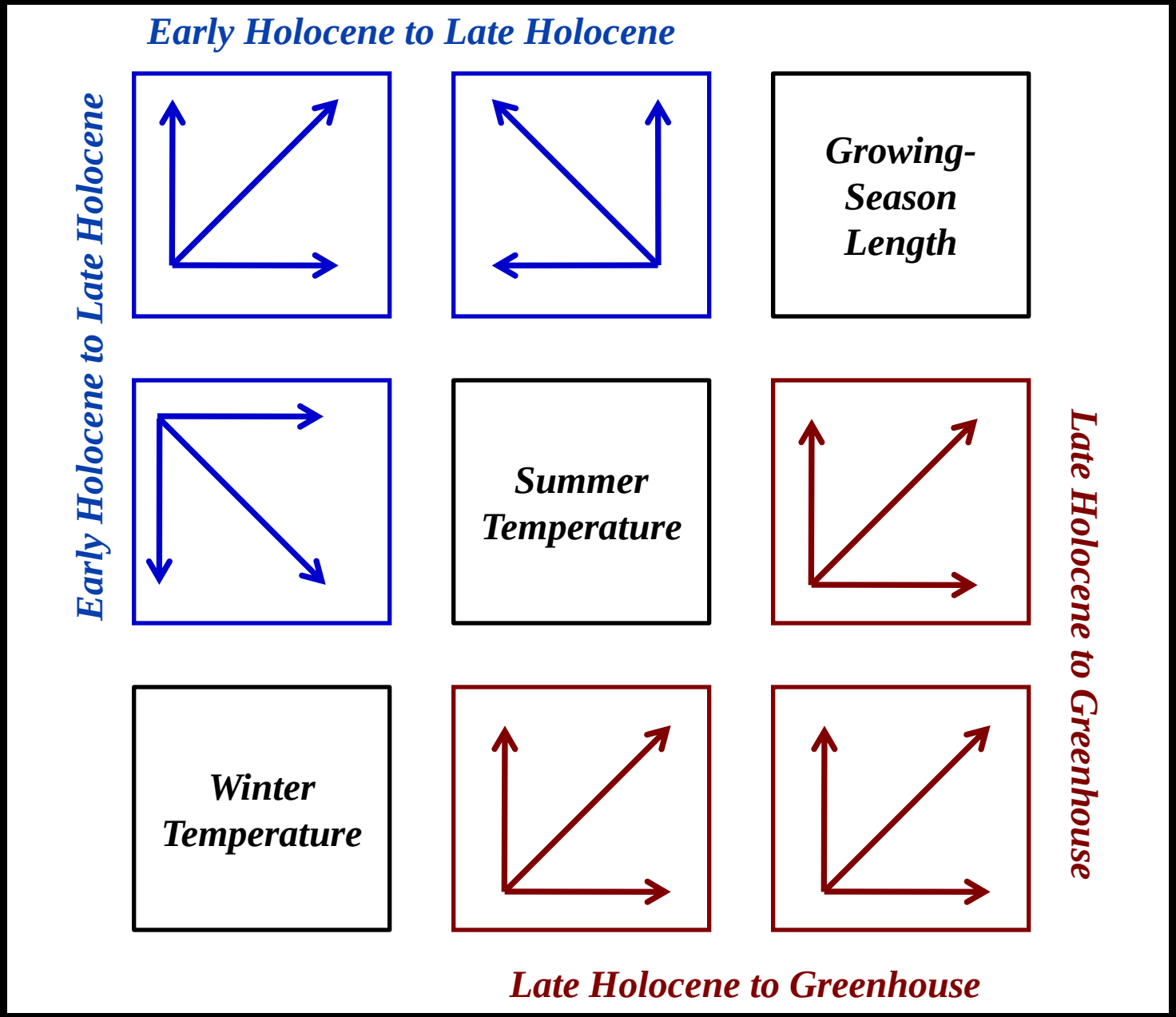
Ploidy Race	Guard cell Area (μm^2)
2X	229.4 ± 8.1
4X	381.7 ± 10.2
6X	482.6 ± 15.5



Hunter, Betancourt, Riddle, Cole, Van Devender & Spaulding (2001) *Global Ecology & Biogeography*



Jackson, Betancourt, Booth & Gray (2009) Ecology & the ratchet of events: climate variability, niche dimensions, & species distributions. *PNAS*

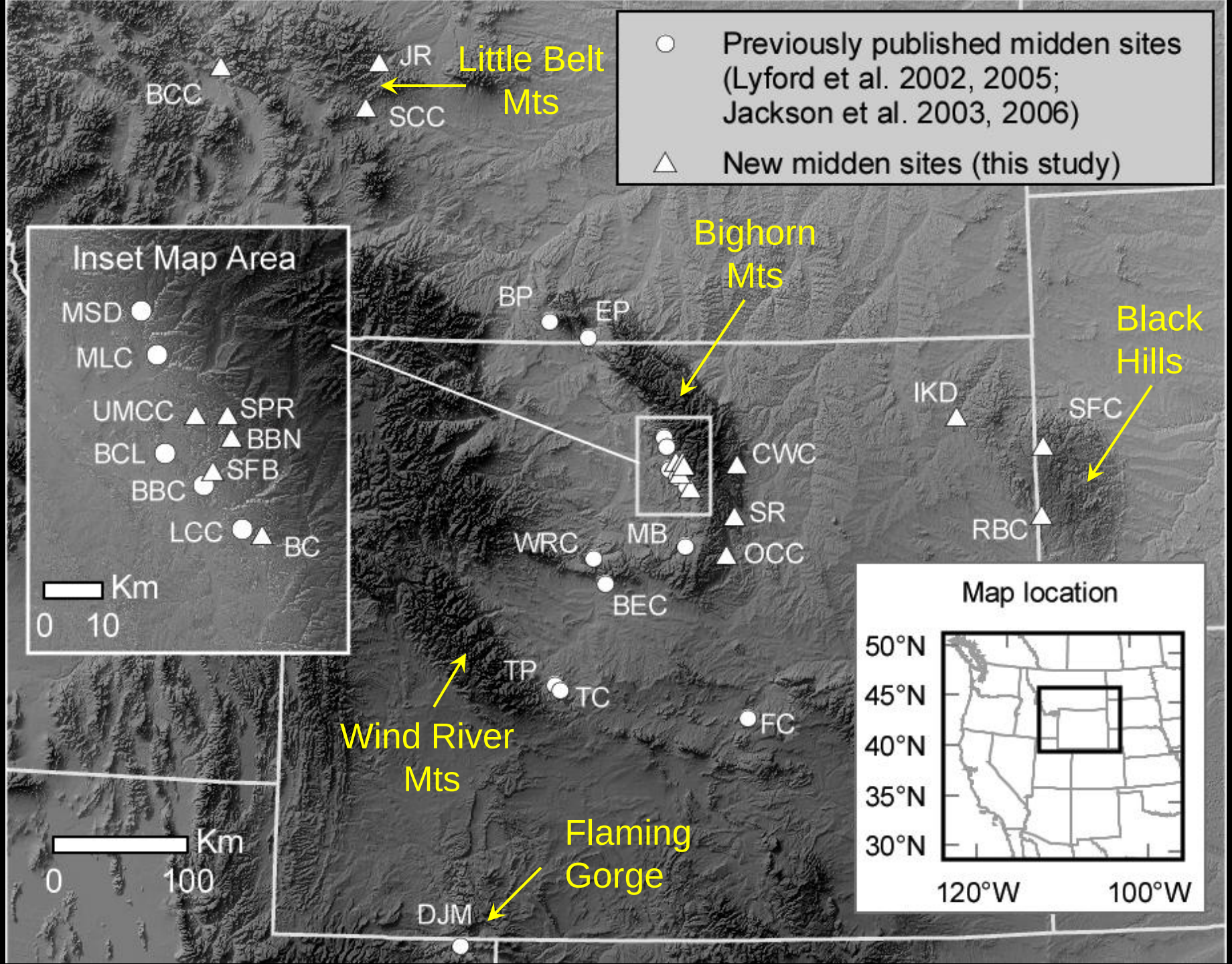


Jackson, Betancourt, Booth & Gray (2009) Ecology and the ratchet of events: climate variability, niche dimensions, and species distributions. *PNAS*

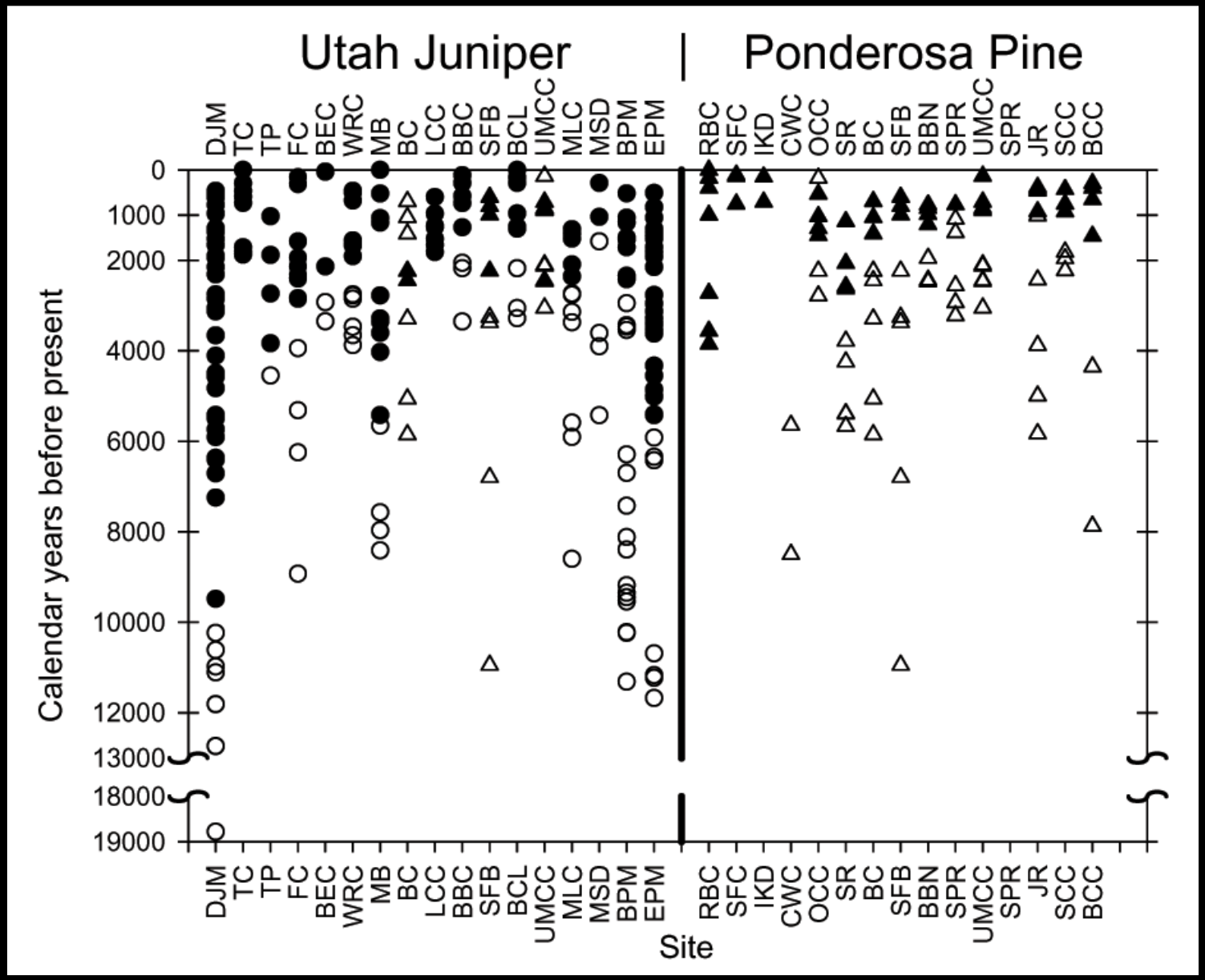
Juniperus osteosperma
Utah juniper

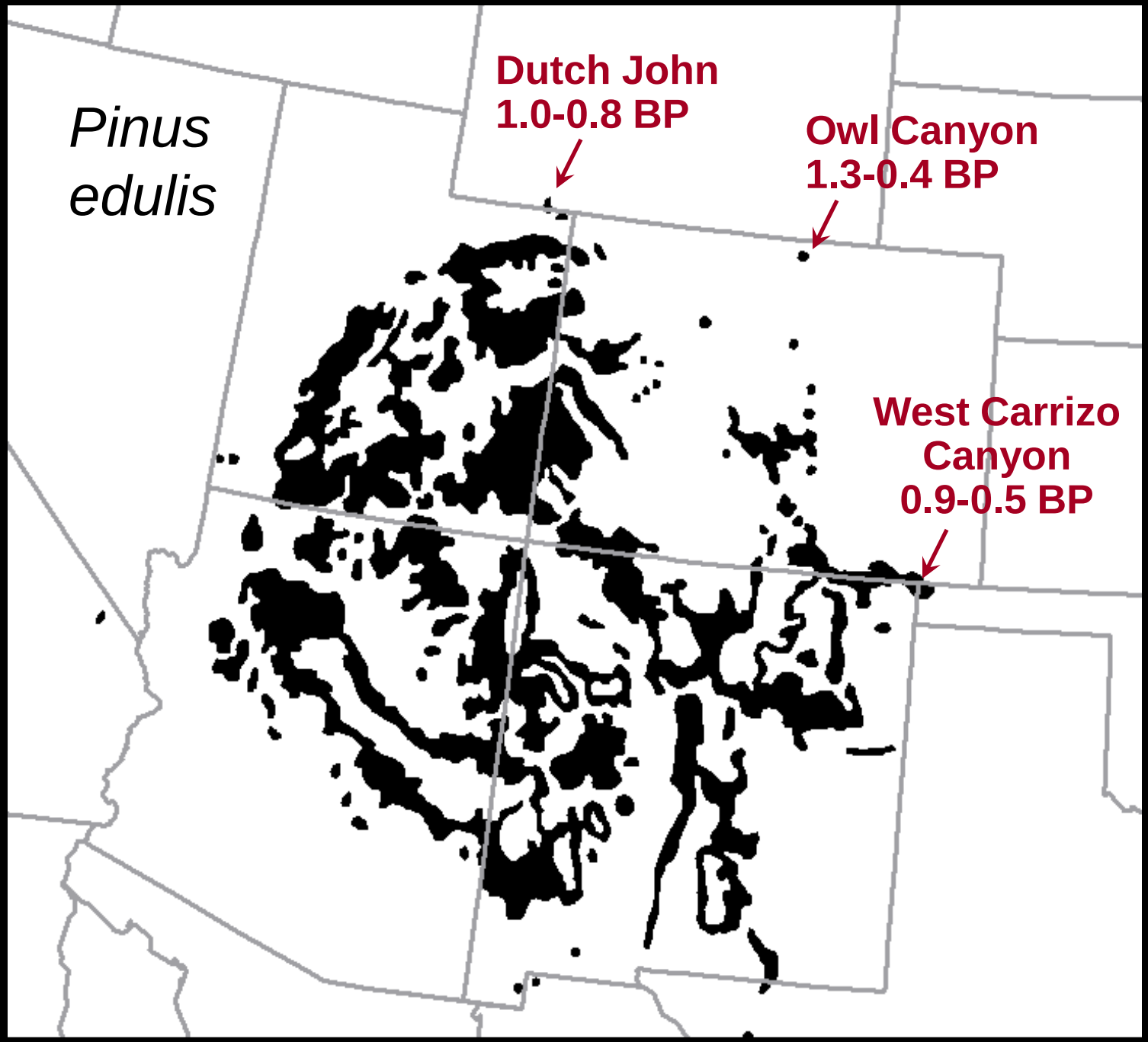
Pinus edulis
Colorado pinyon

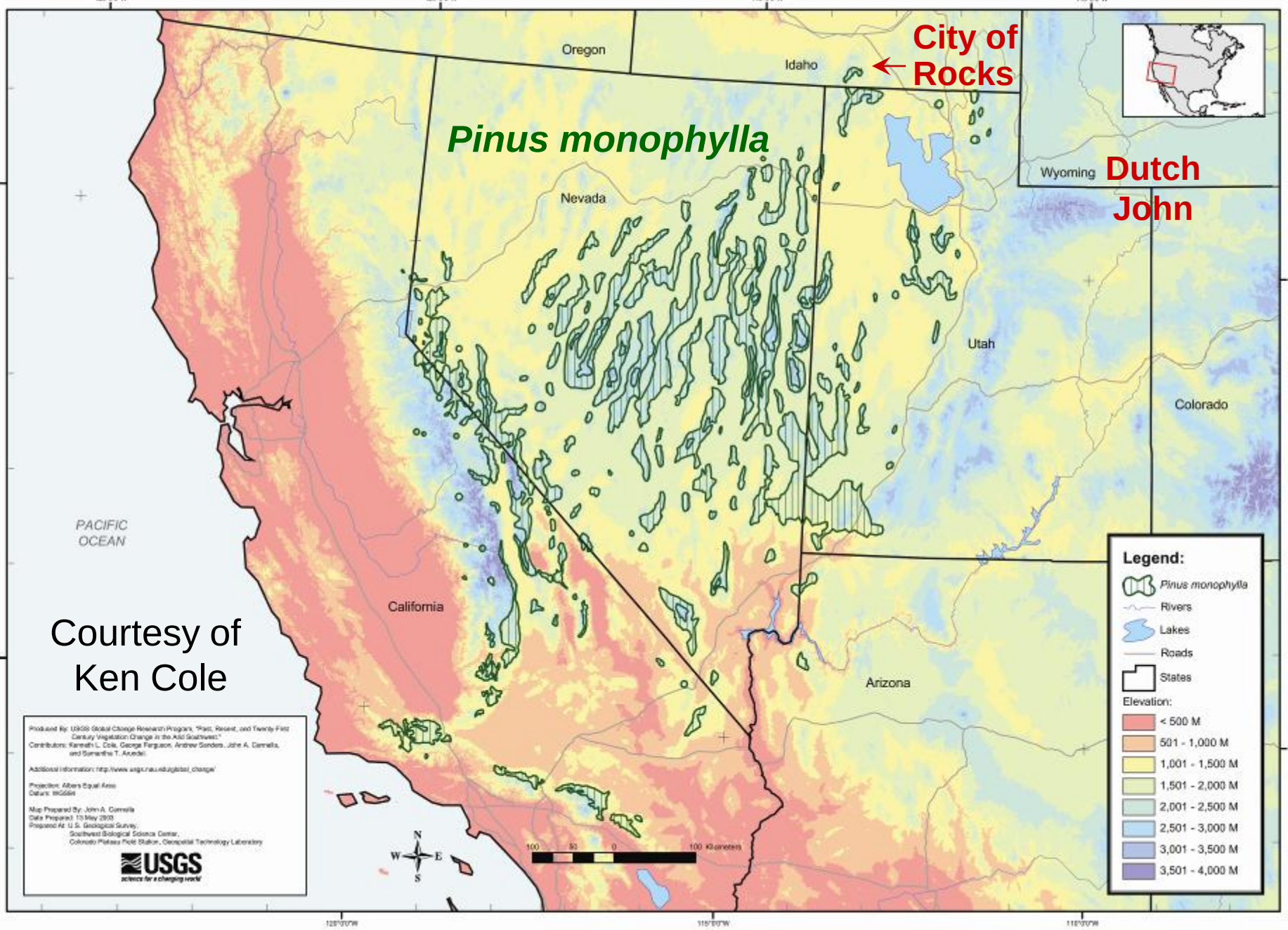
Pinus ponderosa
two main races


Previously published midden sites (Lyford et al. 2002, 2005; Jackson et al. 2003, 2006)
New midden sites (this study)
Little Belt Mts
JR
SCC
BCC
Bighorn Mts
BP
EP
Black Hills
IKD
SFC
CWC
SR
OCC
RBC
MB
WRC
BEC
TP
TC
FC
Wind River Mts
Flaming Gorge
DJM
Inset Map Area
MSD
MLC
UMCC
SPR
BBN
BCL
SFB
BBC
LCC
BC
Km
0 10
Km
0 100
Map location
50°N
45°N
40°N
35°N
30°N
120°W
100°W

Holocene record of Utah juniper & ponderosa pine migration in the Central Rockies

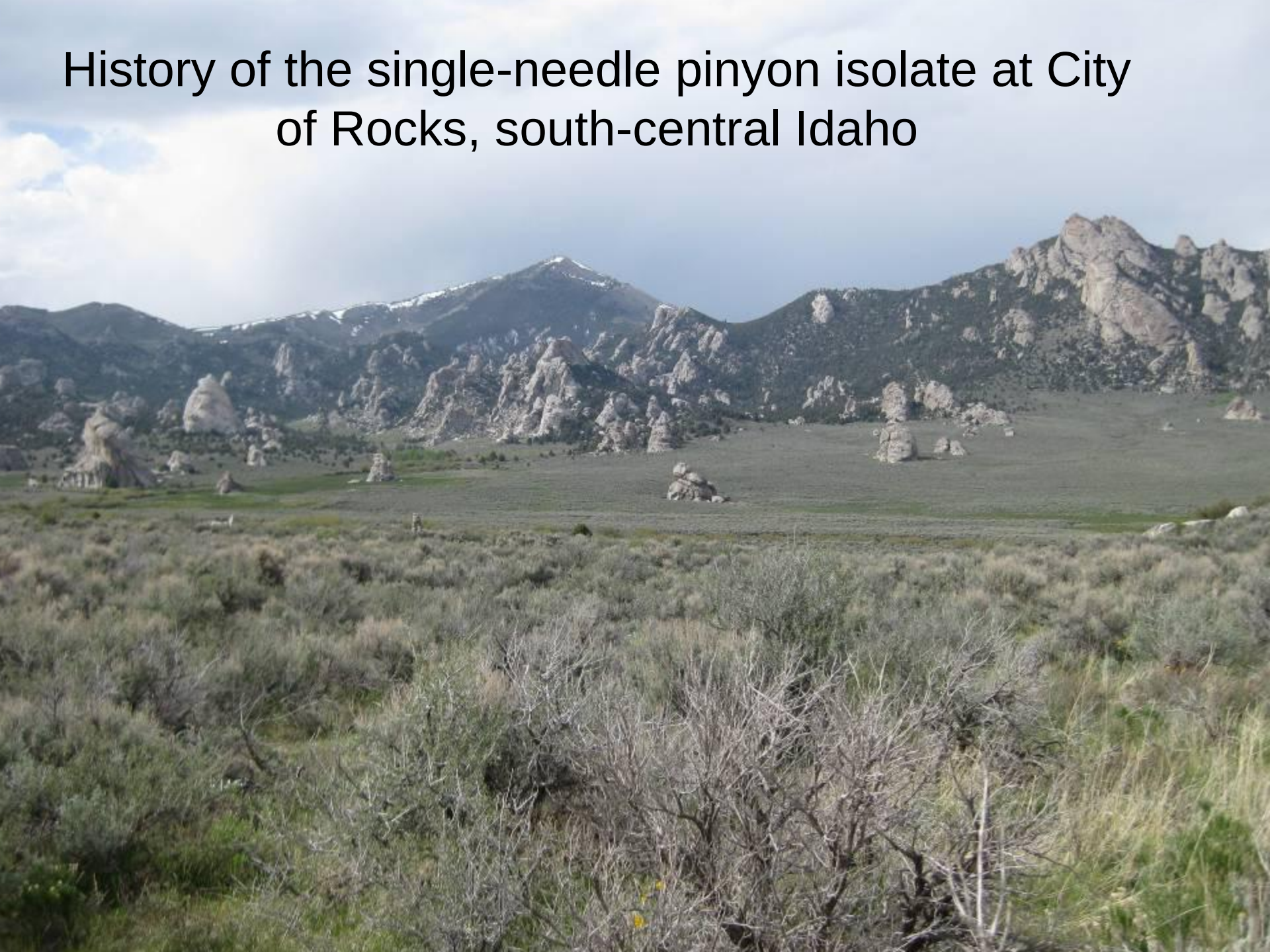



Pinus edulis
Dutch John
1.0-0.8 BP
Owl Canyon
1.3-0.4 BP
West Carrizo Canyon
0.9-0.5 BP



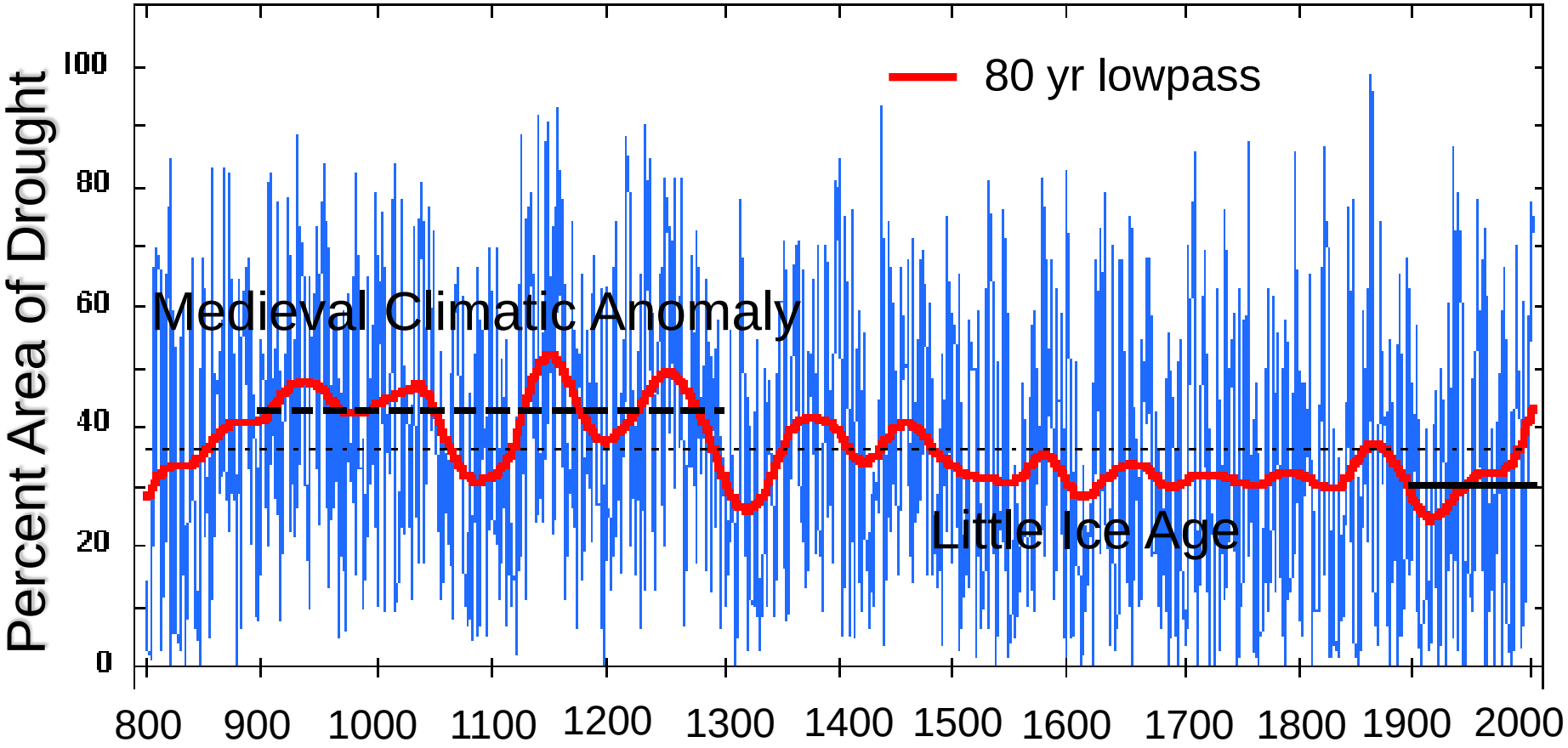
Courtesy of Ken Cole

History of the single-needle pinyon isolate at City of Rocks, south-central Idaho



Western US Drought Area Index (-1 PDSI)

Cook et al (2004) *Science*

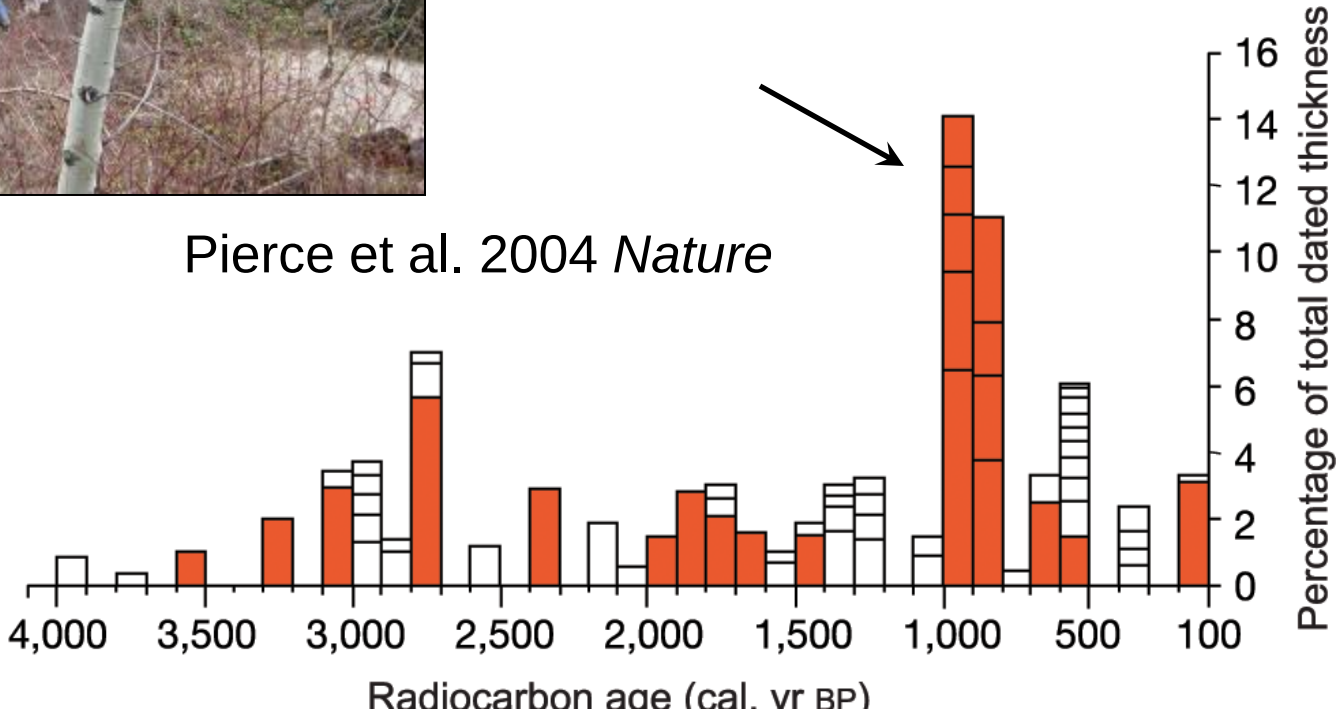


Was the AD 900-1300 dryness unique in the Holocene?

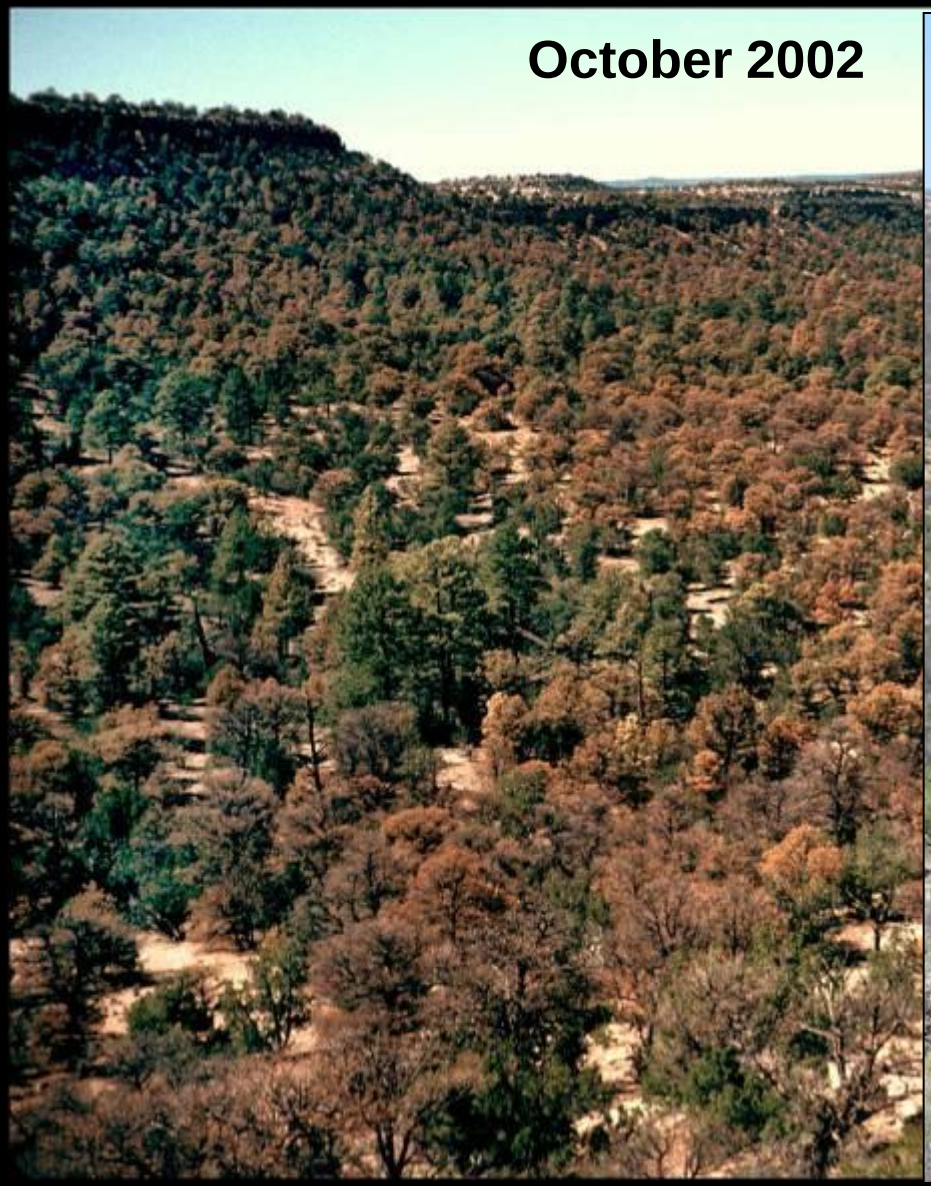
How did it impact western ecosystems?

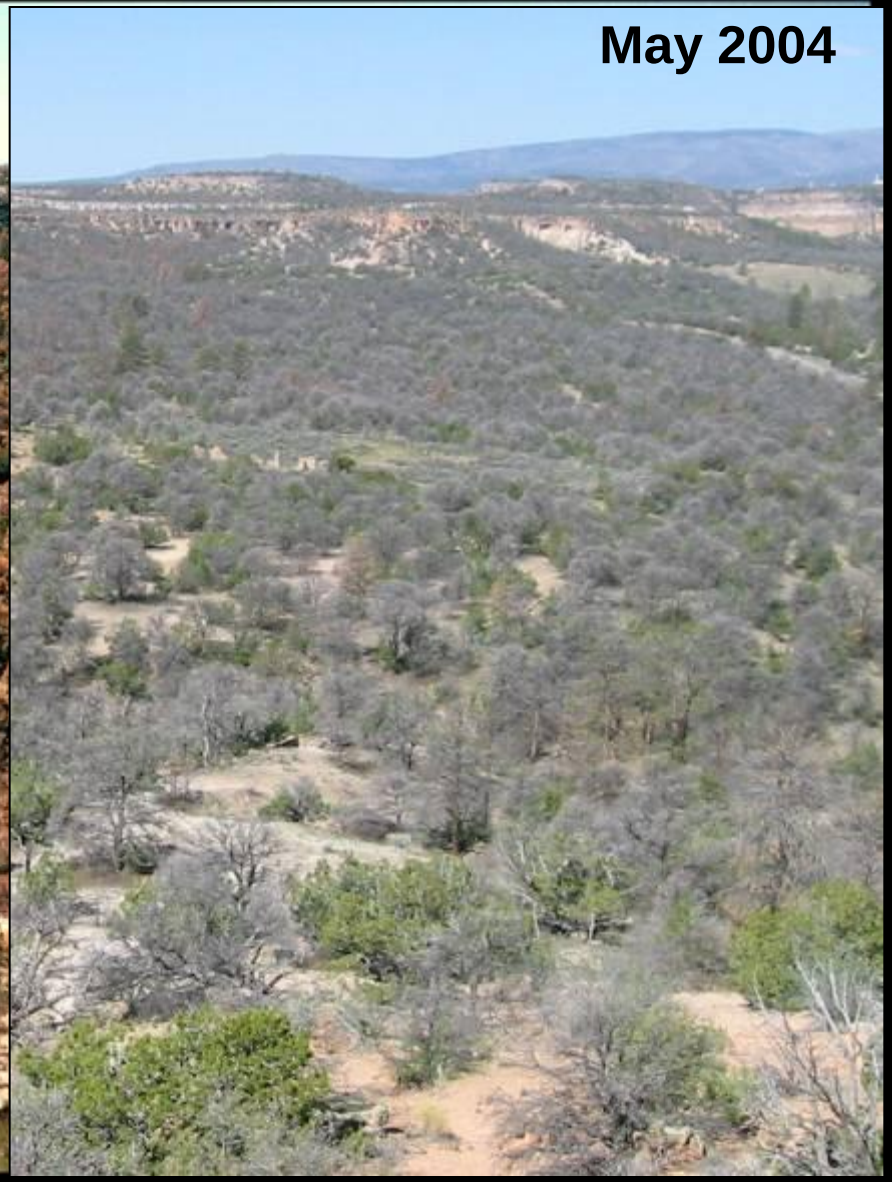
Fire-related deposits on South Fork Payette, ID

Pierce et al. 2004 *Nature*



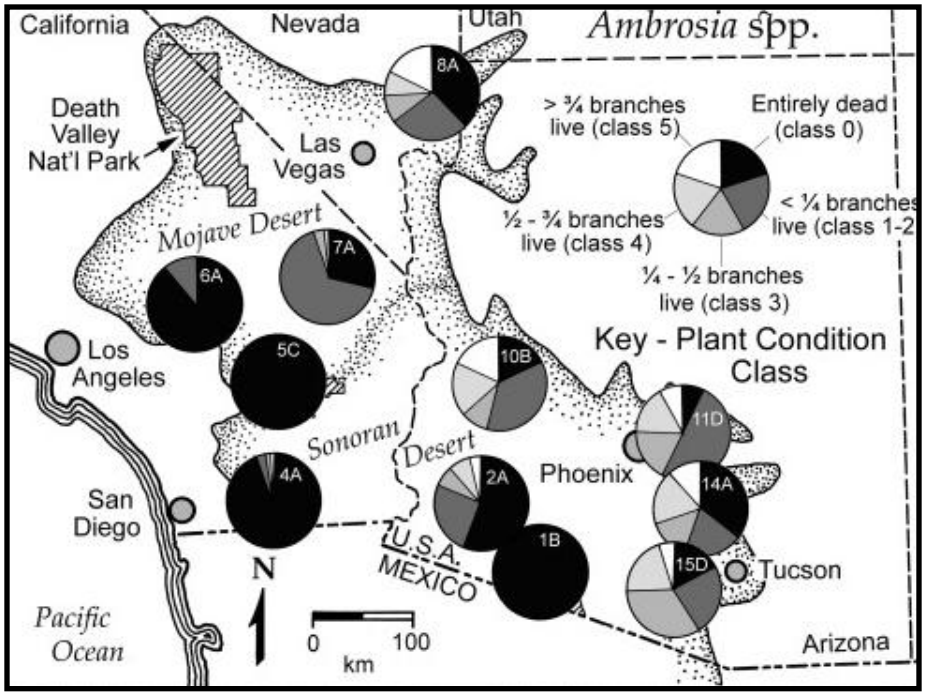
Pinyon Dieoff, Jemez Mts, NM, 1999-2004 drought

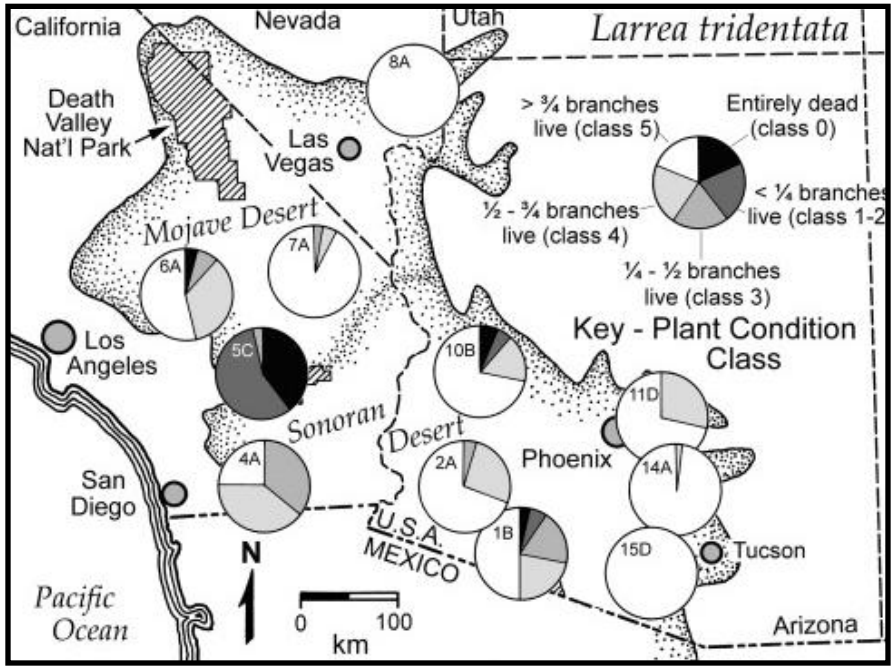




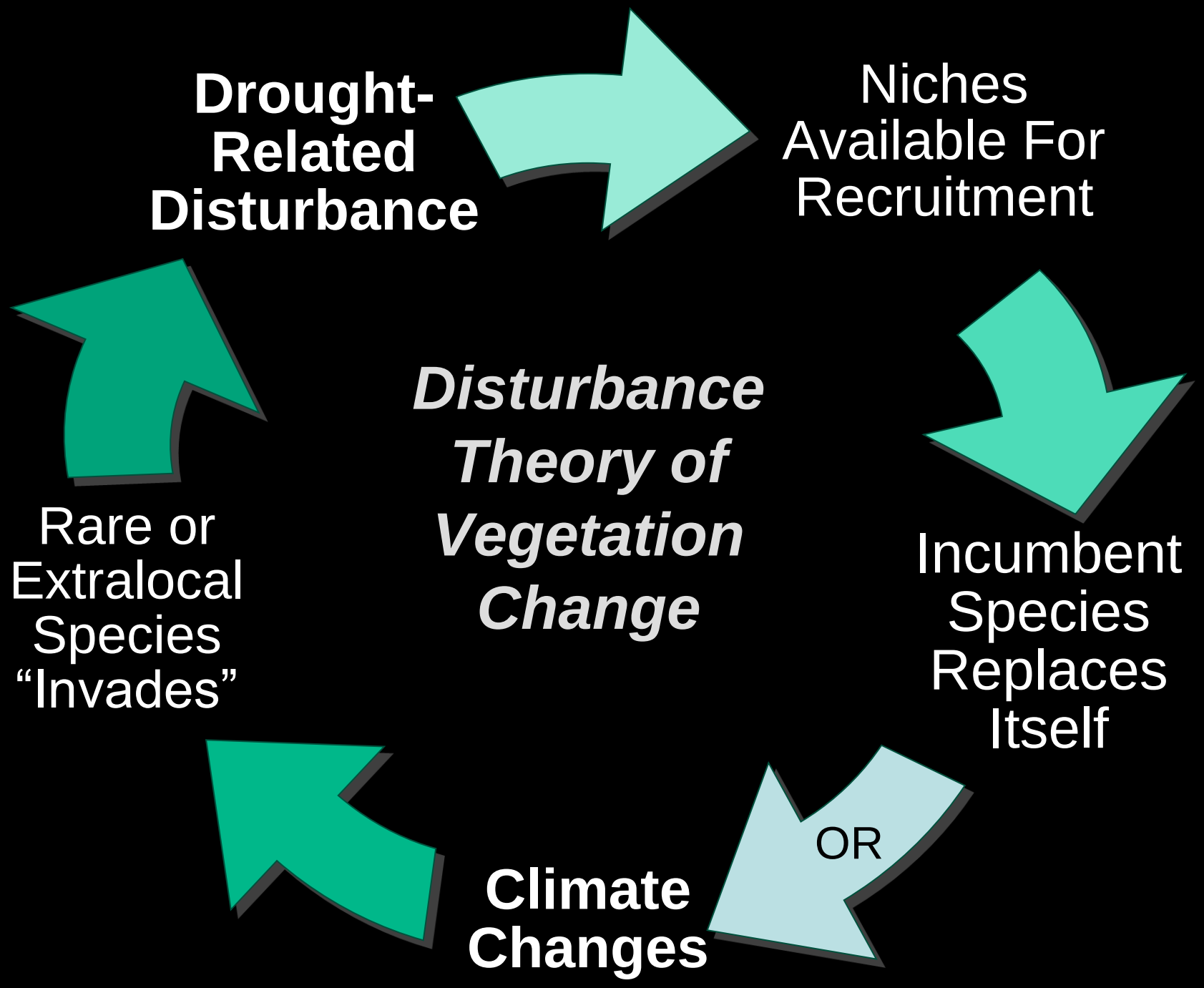
Breshears et al. 2005 PNAS

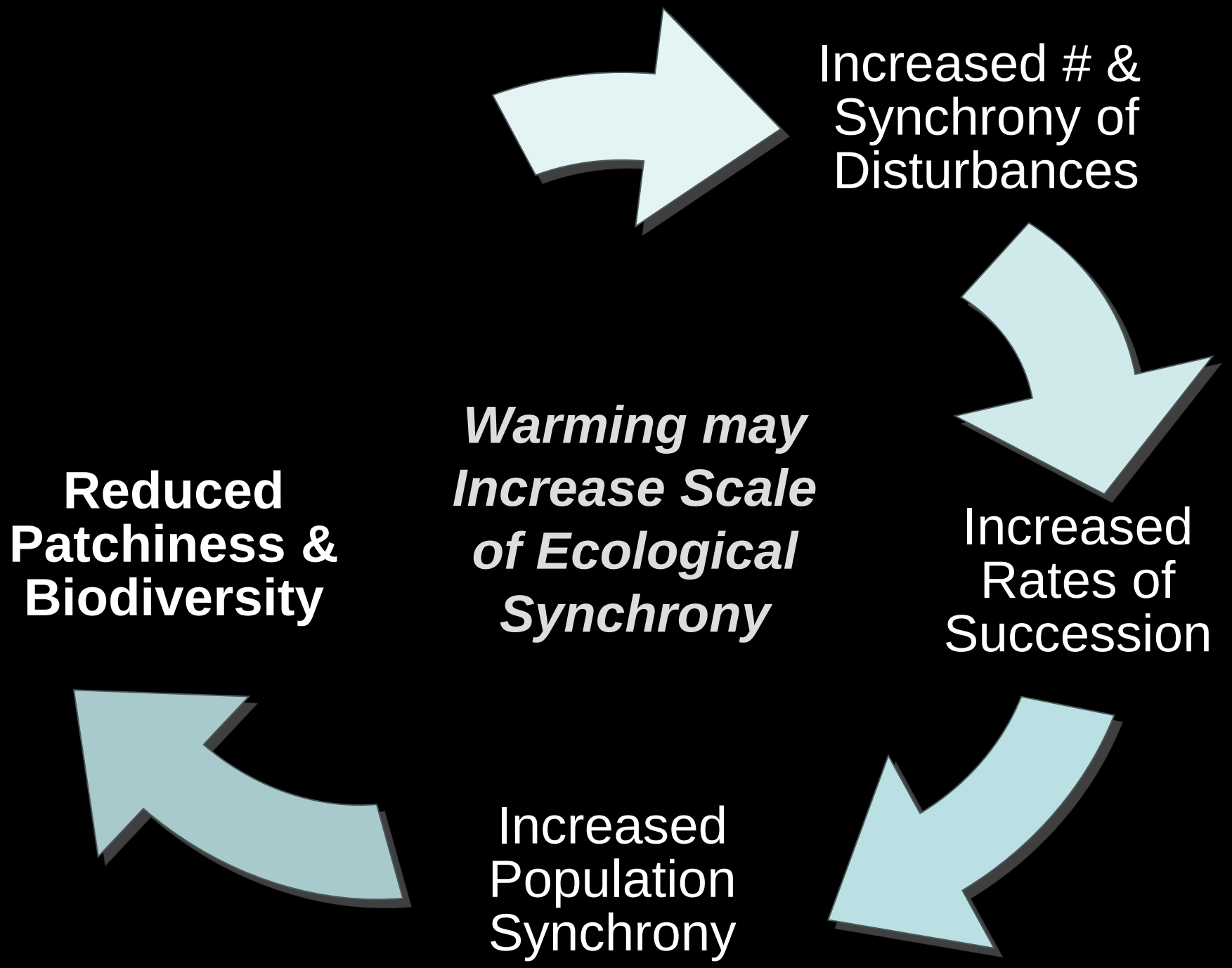
Mcauliffe & Hamerlynck (2010) Perennial plant mortality in the Sonoran & Mojave deserts in response to severe, multi-year drought *J. of Arid Environments*





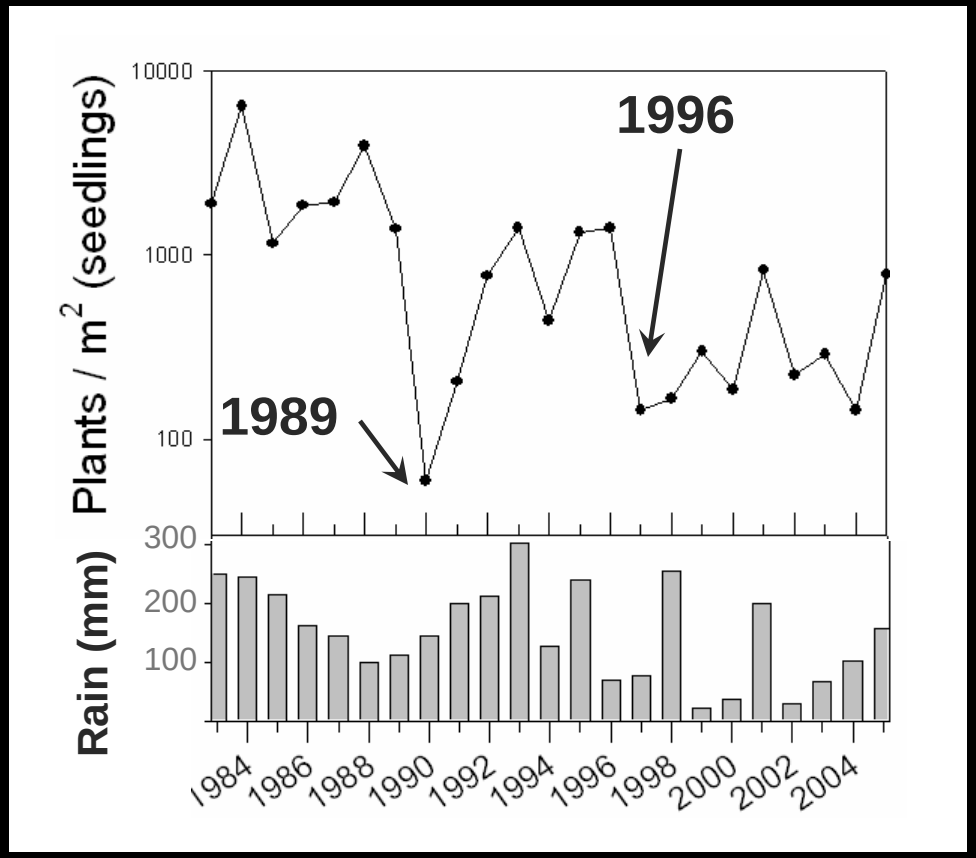
"Models of the population and community dynamics of desert plant communities that implicitly assume constant (but slow) rates of recruitment and mortality do not provide a sound basis for understanding these systems."


Drought-Related Disturbance
Niches Available For Recruitment
Incumbent Species Replaces Itself
OR
Climate Changes
Rare or Extralocal Species "Invades"
Disturbance Theory of Vegetation Change


Increased # & Synchrony of Disturbances
Increased Rates of Succession
Increased Population Synchrony
Reduced Patchiness & Biodiversity
Warming may Increase Scale of Ecological Synchrony

Population Dynamics of Winter Annuals in Permanent Plots on Tumamoc Hill, Tucson

Desert Laboratory on Tumamoc Hill



Courtesy of Larry Venable
University of Arizona

Learn to expect the unexpected: Small shifts in rainfall seasonality can have important consequences

Contemporary climate change in the sonoran desert favors cold-adapted species

SARAH KIMBALL*, AMY L. ANGERT†, TRAVIS E. HUXMAN*‡ and D. LAWRENCE VENABLE*

*Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ 85721, USA, †Department of Biology, Colorado State University, Fort Collins, CO 80523, USA, ‡B2 Earthscience, University of Arizona, Tucson, AZ 85721, USA

Abstract

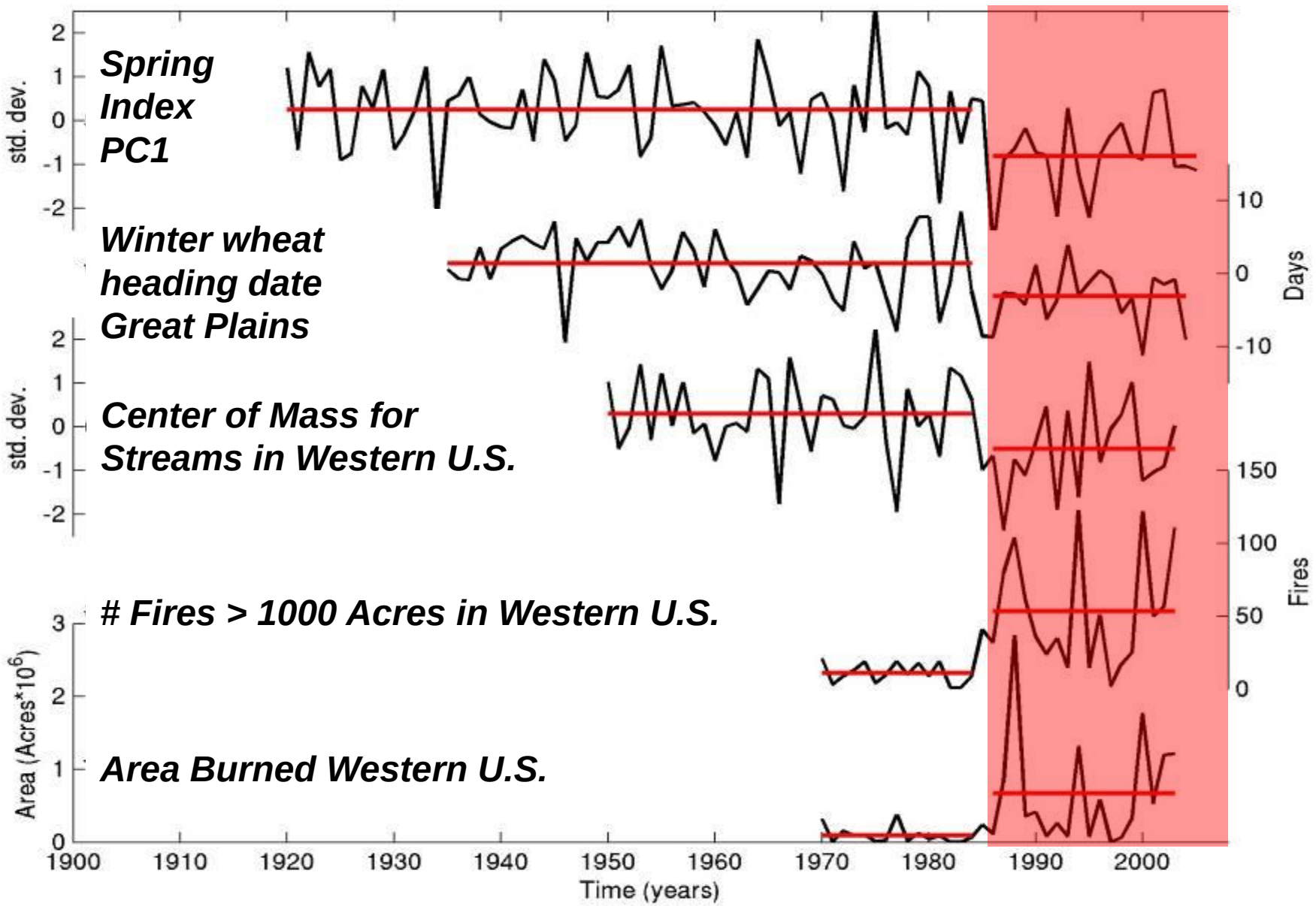
Impacts of long-term climate shifts on the dynamics of intact communities within species ranges are not well understood. Here, we show that warming and drying of the Southwestern United States over the last 25 years has corresponded to a shift in the species composition of Sonoran Desert winter annuals, paradoxically favoring species that germinate and grow best in cold temperatures. Winter rains have been arriving later in the season, during December rather than October, leading to the unexpected result that plants are germinating under colder temperatures, shifting community composition to favor slow growing, water-use efficient, cold-adapted species. Our results demonstrate how detailed ecophysiological knowledge of individual species, combined with long-term demographic data, can reveal complex and sometimes unexpected shifts in community composition in response to climate change. Further, these results highlight the potentially overwhelming impact of changes in phenology on the response of biota to a changing climate.

Global Change Biology 2009

Regional Assessment of the Ecological Responses to the Early Stages of Climate Change

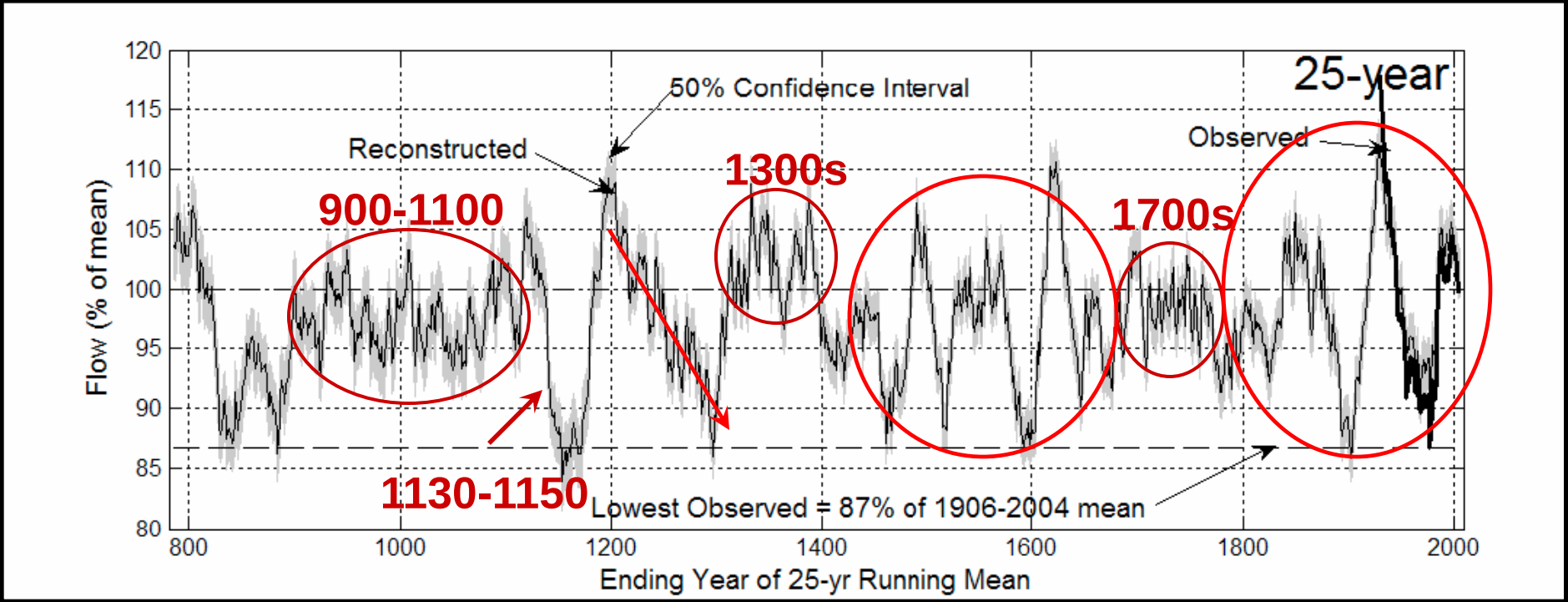
A Guide For Monitoring, Mitigation and Adaptation

Step (?) Change in timing of spring onset, wheat headings, Center of Mass, fire frequency and area burned



Reconstruction of Colorado River at Lees Ferry, AD 762 - 2002

Meko et al. 2007*Geophys. Res. Lett*.



- We have yet to reckon with natural climatic variability that is within realm of expectation
- This will make it that much harder to adapt to climate change

Radiative + D2M SST's: Decadal Predictions?

Science AAAS

Improved Surface Temperature Prediction for the Coming Decade from a Global Climate Model

Doug M. Smith,* Stephen Cusack, Andrew W. Colman, Chris K. Folland, Glen R. Harris, James M. Murphy

DOI: 10.1126/science.1139540
, 796 (2007); **317** *Science*

nature Vol 453 | 1 May 2008 | doi:10.1038/nature06921

LETTERS

Advancing decadal-scale climate prediction in the North Atlantic sector

N. S. Keenlyside[1], M. Latif[1], J. Jungclaus[2], L. Kornblueh[2] & E. Roeckner[2]

Will decadal predictability replace stationarity as the fundamental concept in water & resource planning?

Observations

- Integrating D2M variability will help us adapt to climate change
- Forecasting and adaptation will focus on annual to decadal timescale
- Due to inadequate monitoring, we know very little about ecosystem responses on these timescales?
- Most successful approaches will be the ones that best assimilate short and long-lead climatic and hydroclimatic forecasts

- Climatic change compromises a central tenet in water and ecosystem management that natural systems fluctuate within an unchanging and well-defined envelope of variability.
- This assumption is embodied to varying degrees in the concepts of Hydrologic Stationarity (HS) and Historic Range of Ecological Variation (HRV).
- Adaptation to climate change will require retooling these traditional methods and developing alternative ones that are better suited for managing resources and ecosystems under a nonstationary climate.

Science (Feb. 2008)

POLICYFORUM

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

- Develop nonstationary, probabilistic models of relevant environmental variables, together with cost/benefit analyses, and use them to optimize water systems
- Model nonstationary hydrologic variables stochastically to describe temporal evolution of pdf's
- Develop methods for estimating model parameters that combine historical and paleohydrologic measurements with projections of multiple climate models, driven by multiple climate-forcing scenarios
- Integrate stable institutional platform for downscaled climate predictions & climate information delivery with land and resource use projections
- In a nonstationary world, it is crucial to maintain continuity of observations

Robin Kundis Craig,
Attorneys' Title Professor and Associate Dean for Environmental Programs
Florida State University College of Law

Craig, R.K. in press. "Stationarity Is Dead" -- Long Live Transformation: Five Principles for Climate Change Adaptation Law. *Harvard Law Review*
http://works.bepress.com/robin_craig/4/

Craig 2010, Harvard Law Review

- American law and policy are not keeping up with the need for adaptation, even though adapting law to a world of continuing climate change will be far more complicated than addressing mitigation
- Environmental and natural resources law are currently based on assumptions of ecological stationarity and pursue goals of preservation and restoration
- Those assumptions and goals do not fit a world of continual, unpredictable, and nonlinear transformations of complex ecosystems

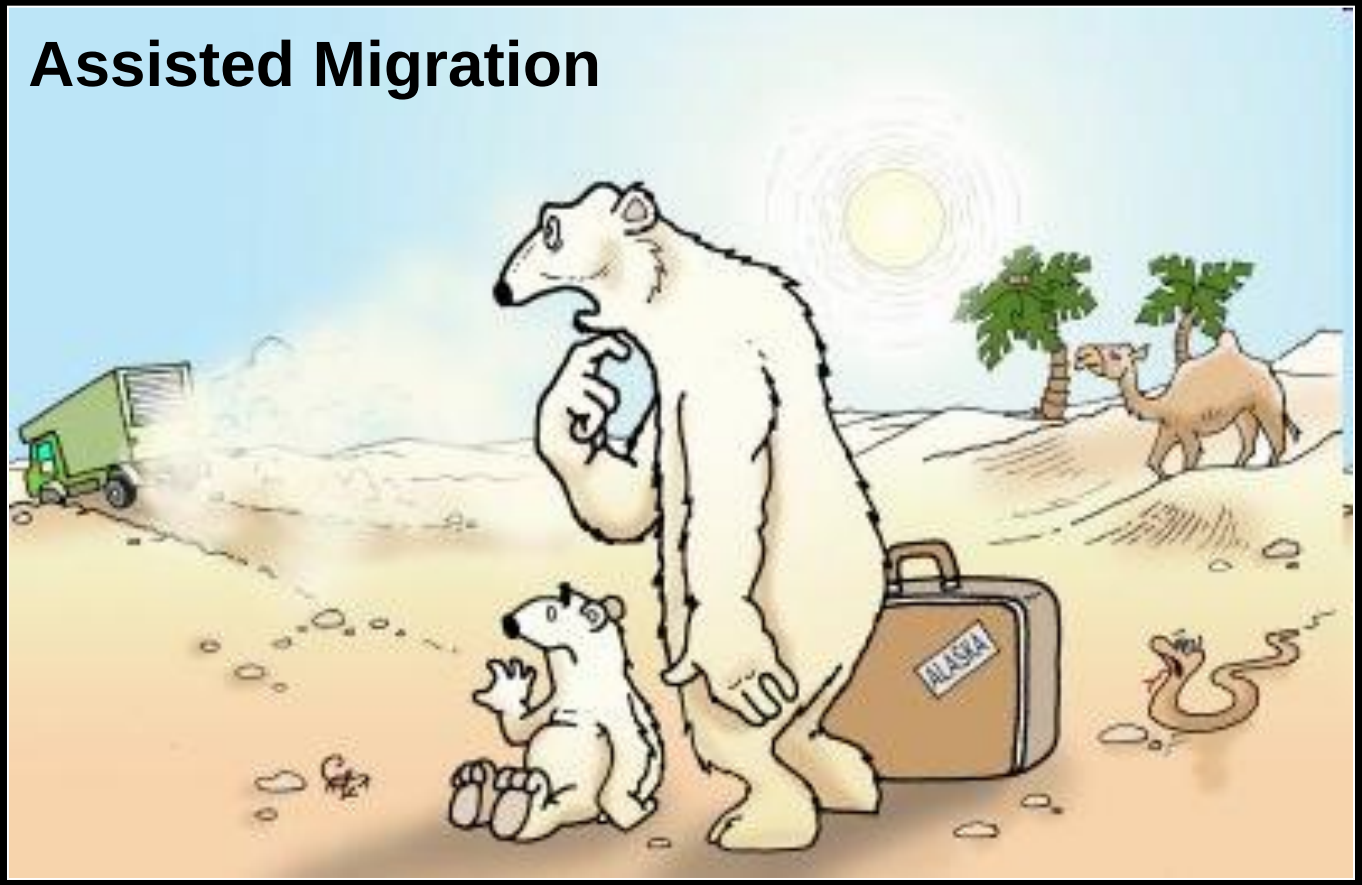
“Altering basic paradigms of environmental and natural resources law from preservation and restoration, based on assumptions of stationarity, to a paradigm of increasing resilience and adaptive capacity, based on assumptions of continuing, unpredictable and nonlinear change, will require different kids of legal amendments, and perhaps even new laws, for different regulatory contexts.”

Robin Craig

Postfire Seeding & Climate Change

What mixes of phenotypes, genotypes and species should we be using to hedge our bets under a changing and uncertain climate?

Assisted Migration



“Although people have been kicking these ideas around for a while, we have reached a critical mass of concern. My suspicion is that in ten years this will be a major subject of research”

-Dov Sax, Brown University-

Shifting of Seed Transfer Zones with Climate Change in W Oregon

Present ***2030*** ***2060*** ***2090***

Douglas-fir
Seed zone #4
0-1000 ft

Seed zone

Courtesy of Lauren Magalska, Glenn Howe and Ron Beloin, OSU & Brad St. Clair, PN Forest Ser.

Present 2030 2060 2090

Douglas-fir
Seed zone #4
0-1000 ft

Seed zone *Climate*

Courtesy of Lauren Magalska, Glenn Howe and Ron Beloin, OSU & Brad St. Clair, PN Forest Ser.

Present **2030** **2060** **2090**

Douglas-fir
Seed zone #4
0-1000 ft

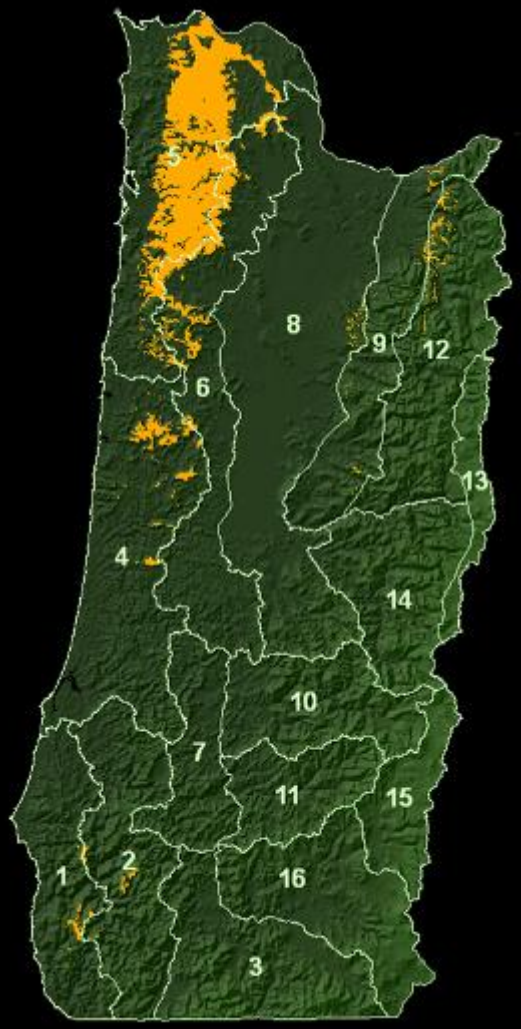
Seed zone *Climate*

Courtesy of Lauren Magalska, Glenn Howe and Ron Beloin, OSU & Brad St. Clair, PN Forest Ser.

Present **2030** **2060** **2090**

Douglas-fir
Seed zone #4
0-1000 ft

Seed zone



Climate

Courtesy of Lauren Magalska, Glenn Howe and Ron Beloin, OSU & Brad St. Clair, PN Forest Ser.

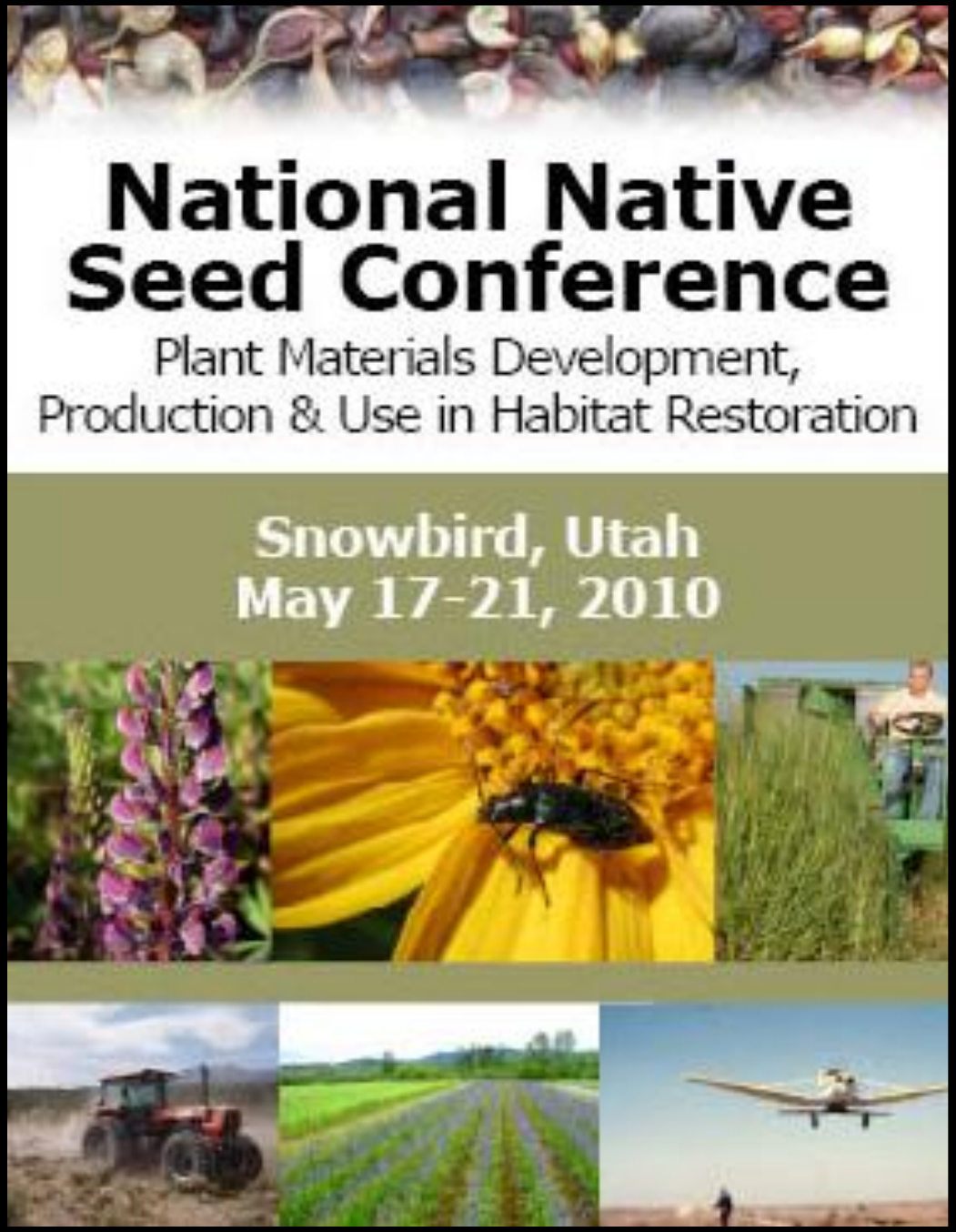
Present **2030** **2060** **2090**

Douglas-fir
Seed zone #4
0-1000 ft

Seed zone

Climate

Courtesy of Lauren Magalska, Glenn Howe and Ron Beloin, OSU & Brad St. Clair, PN Forest Ser.



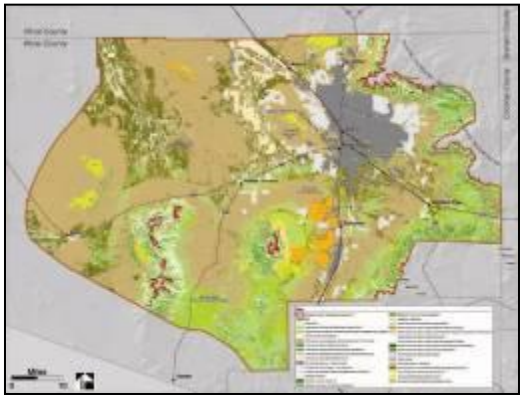
What research and incentives (over what time frame) are needed to justify and mobilize native seed production in service of habitat restoration and adaptation to an uncertain and changing climate?

- Climate variability & climate change will affect opportunities for seeding and its success
- Most successful seed ventures probably will be the ones that best assimilate short and long-lead climatic ecological forecasts and anticipate regional needs
- Long-term success of post-fire seeding in the American deserts will require novel mixes of species, phenotypes, and genotypes adapted to future, not past, climates
- “Assisted migration” may target not just endangered species but also common ones, requiring abundant and well accessioned seed sources
- As large-scale ecological disturbances increase with plant invasions and climate change, there will be an increasing need to manage the products of succession

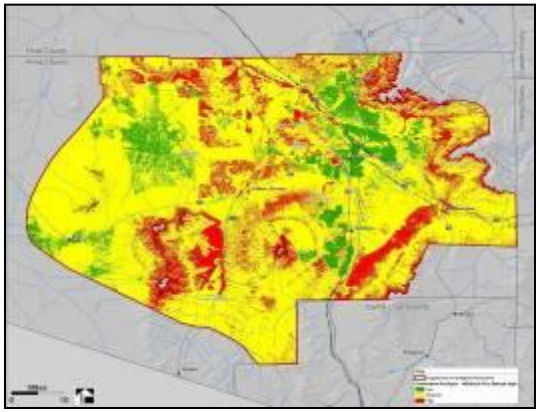
Vulnerability, Risk, & Priority Assessment Associated with Buffelgrass Invasion in the Tucson Basin

Vulnerability, Risk, & Priority Assessment Associated with Buffelgrass Invasion in the Tucson Basin

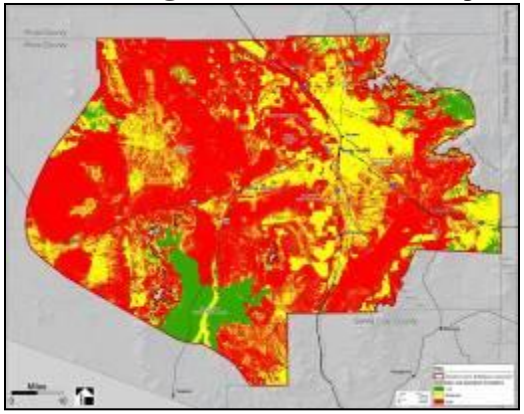
Landcover



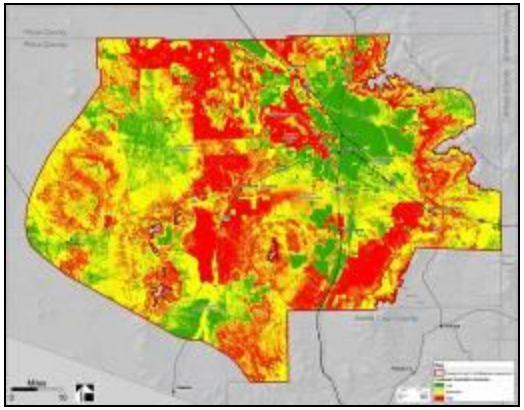
Ecological impacts



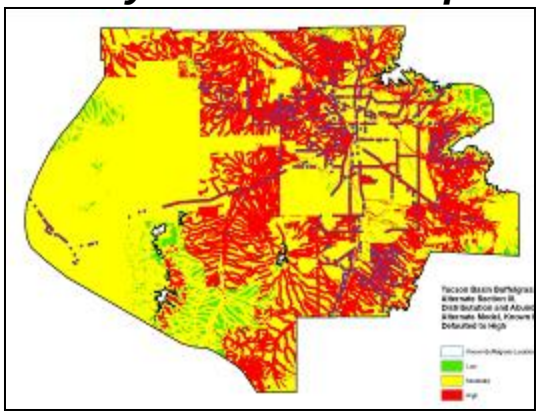
Buffelgrass Suitability



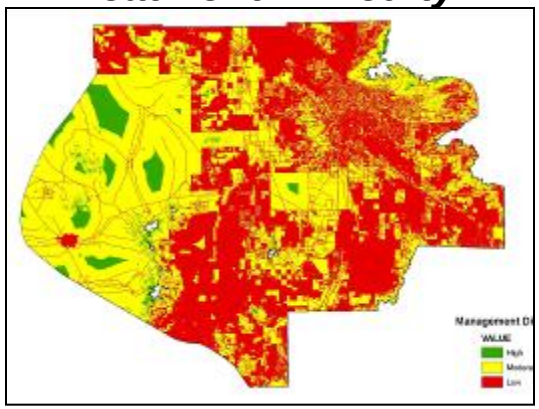
Cumulative Risk



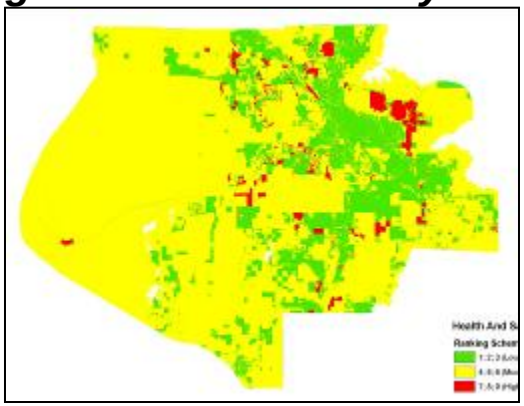
Pathways for Further Spread



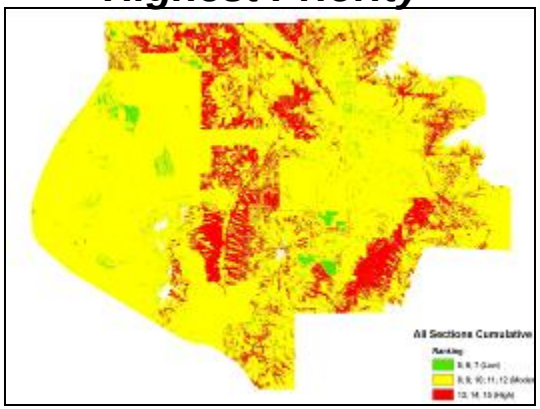
Treatment Difficulty



Highest Health & Safety Risk



Highest Priority



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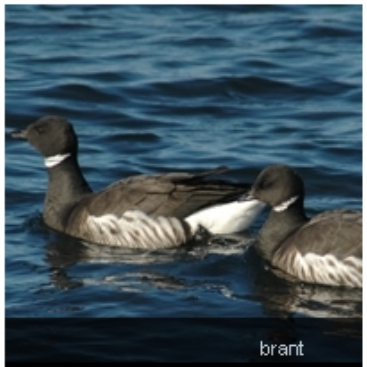

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The USA National Phenology Network brings together citizen scientists, government agencies, non-profit groups, educators and students of all ages to monitor the impacts of climate change on plants and animals in the United States. The network harnesses the power of people and the Internet to collect and share information, providing researchers with far more data than they could collect alone.

Learn more about us

What is phenology?

Phenology is the study of recurring plant and animal life cycle stages, or phenophases, such as leafing and flowering of plants, maturation of agricultural crops, emergence of insects, and migration of birds. Many of these events are sensitive to climatic variation and change, and are simple to observe and record. As an USA-NPN observer, you can help scientists identify and understand environmental trends so we can better adapt to climate change.

Why is phenology important?

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One of our partners?

Interested in creating a partnership?

An educator?