Climate change and the Sonoran Desert

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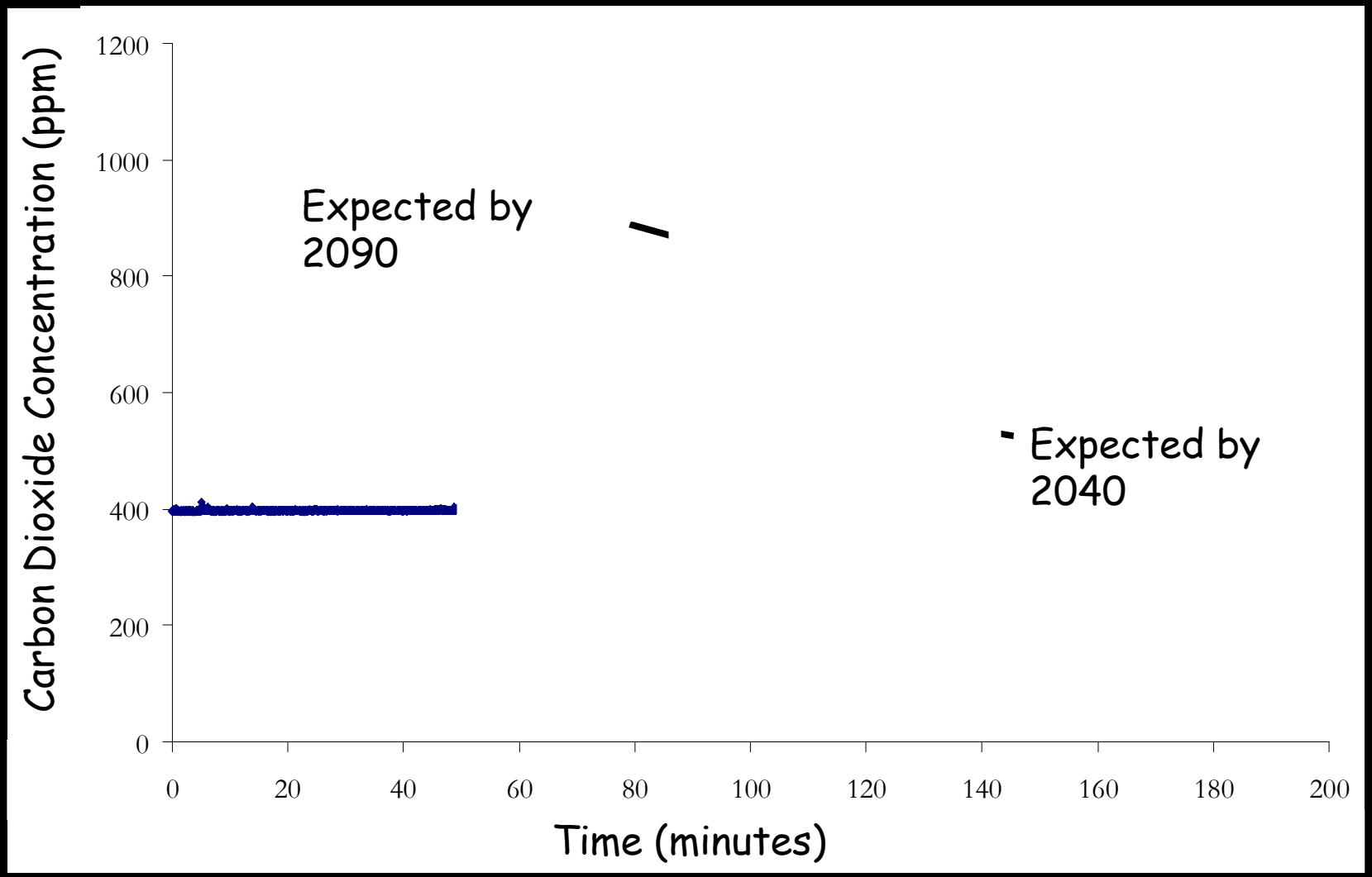
Ecology and Evolutionary Biology

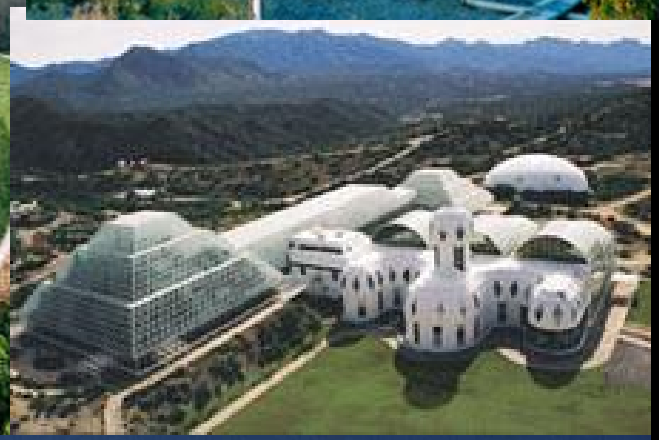
University of Arizona

- Conceptual and experimental examples
- Special case of the Sonoran Desert
- Current patterns and future possibilities

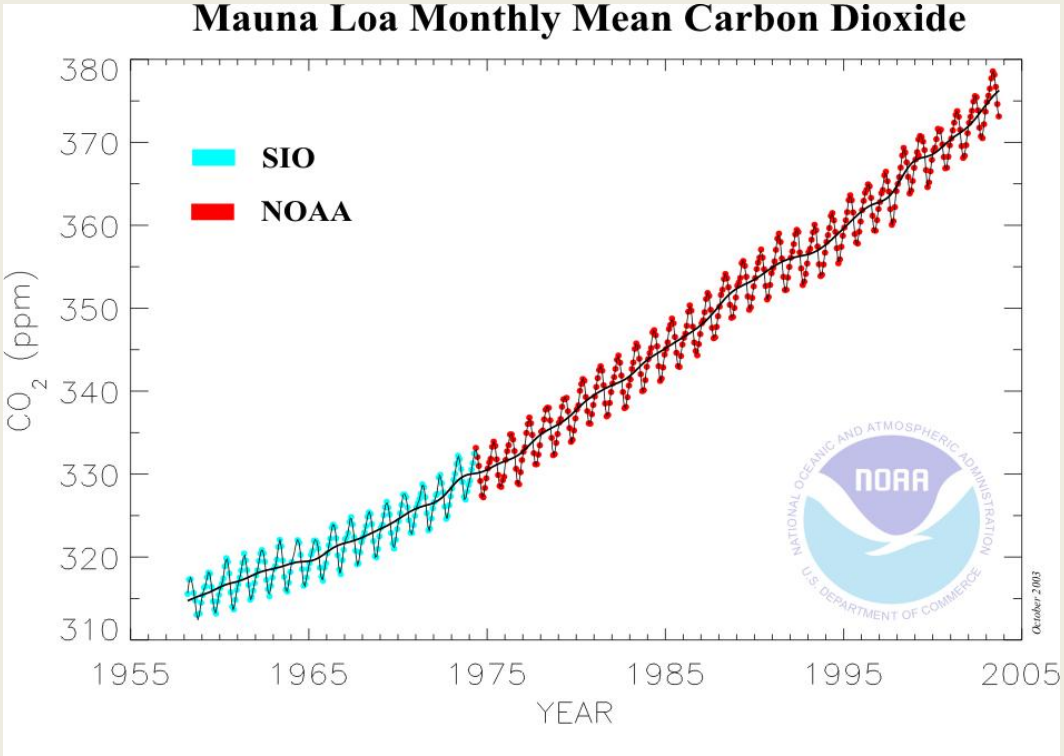
CO_2 production during my last global change seminar

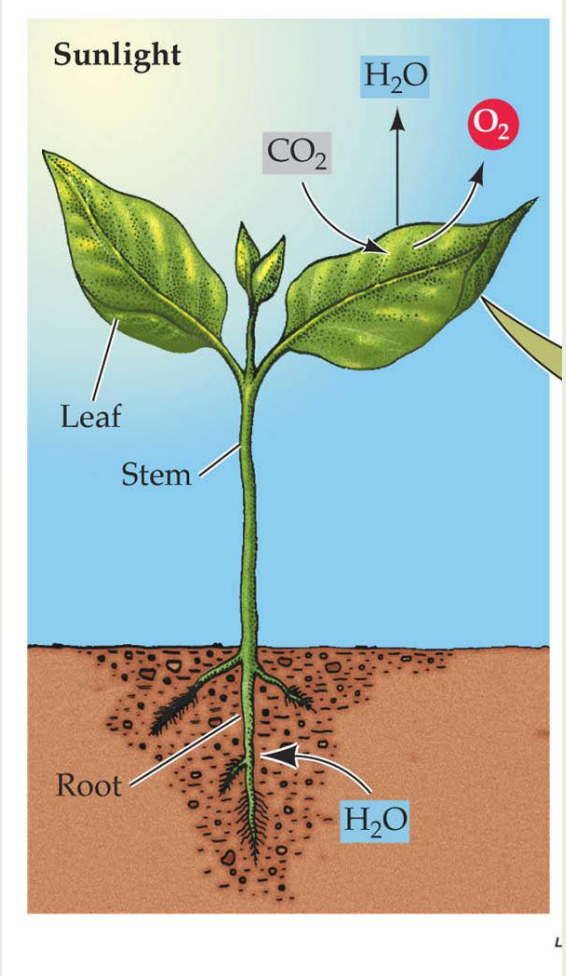


Within minutes we reach the CO_2 values expected globally in 2090 under the 'business as usual scenario'



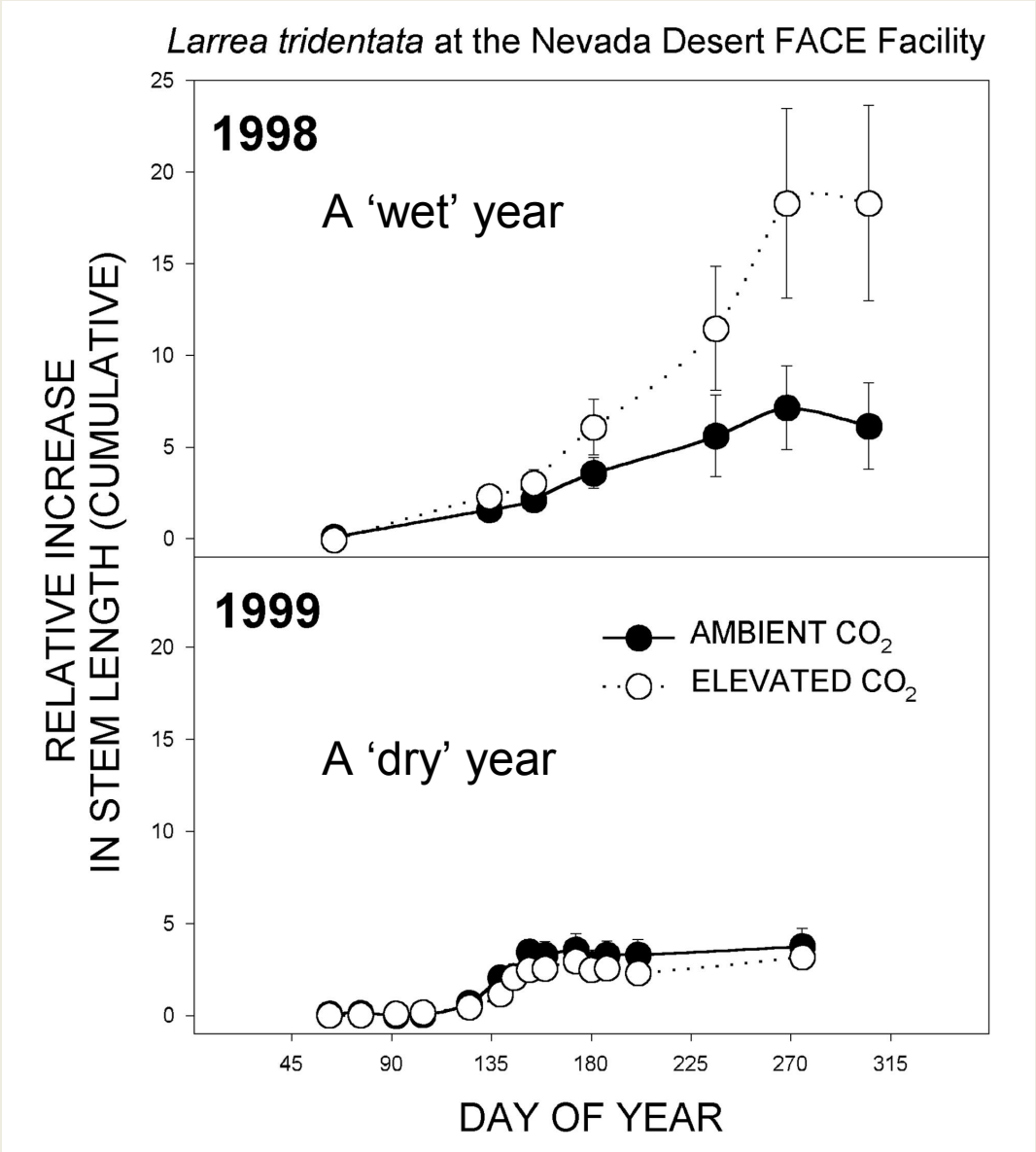
Greater water-use efficiency and growth at high CO_2?





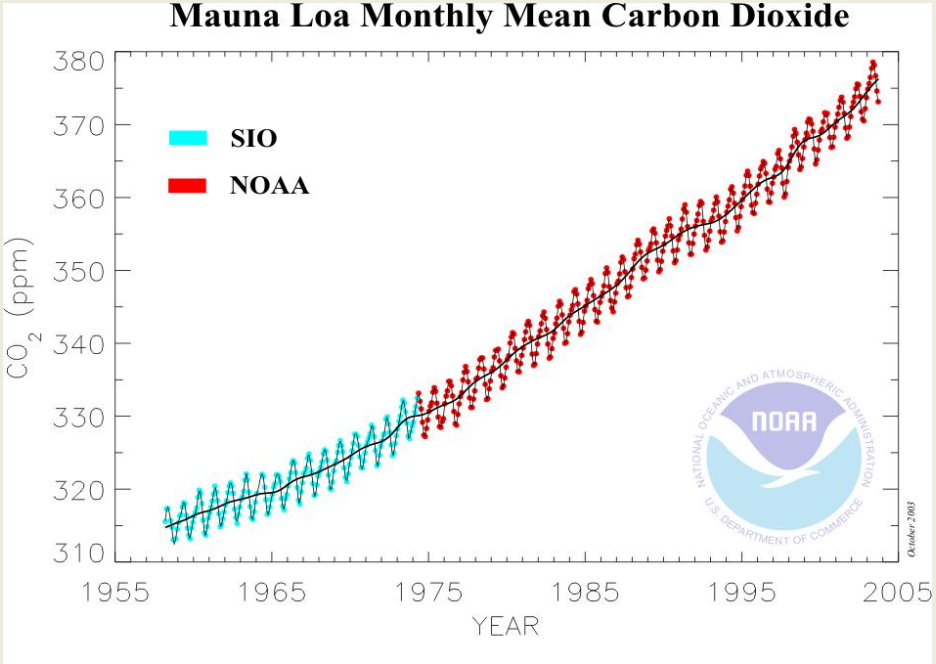
Will deserts become more productive?

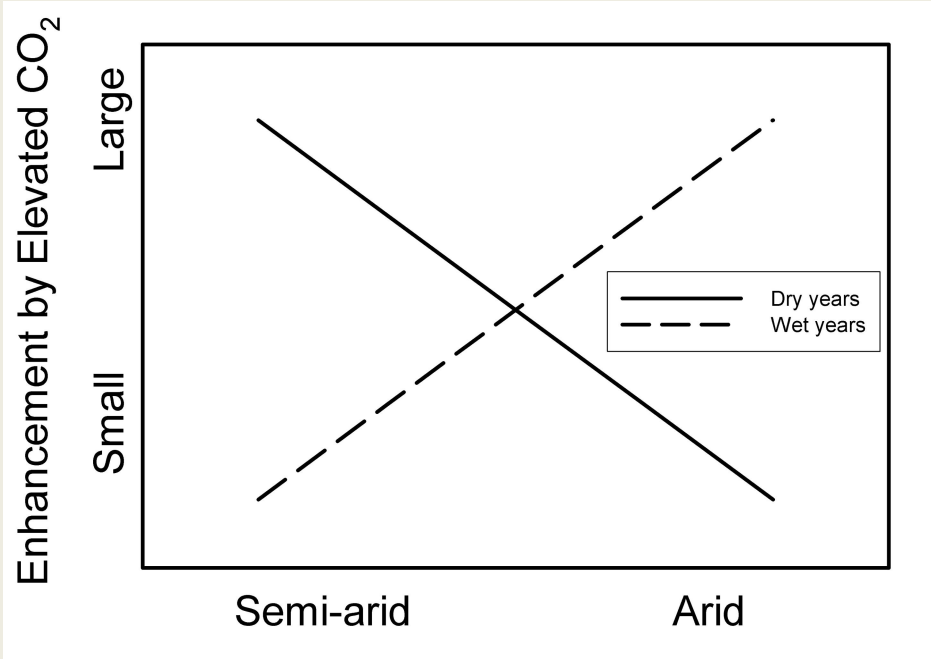
CO_2 response of creosotebush in the Mojave Desert

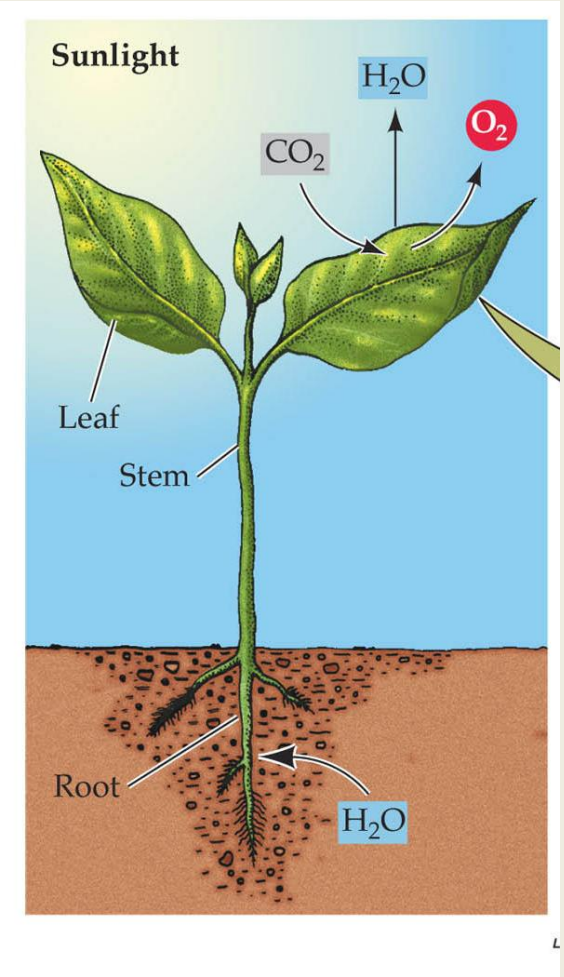


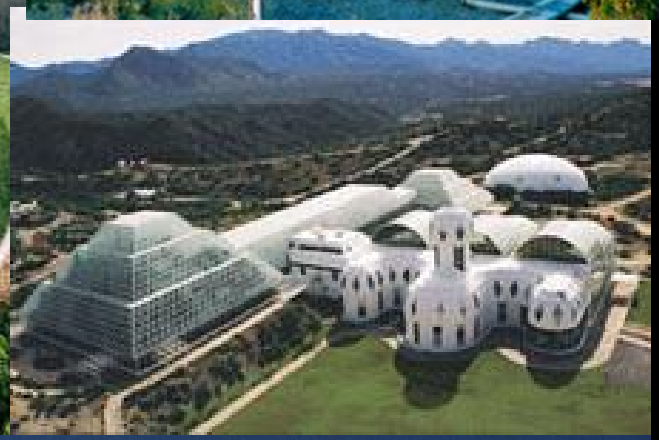
Smith, et al., 2000

Greater interannual variability associated with high CO_2?



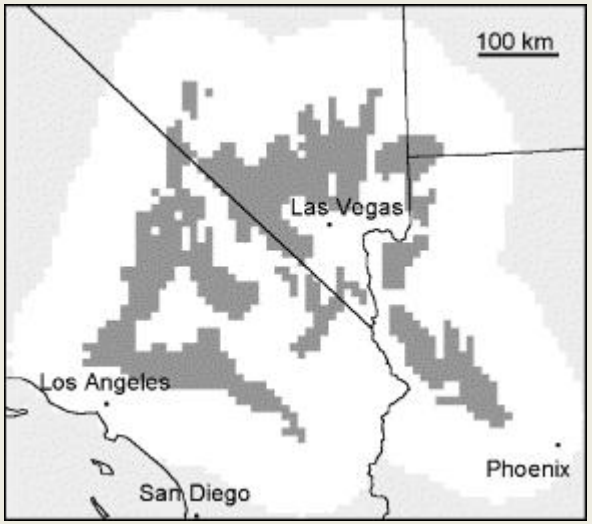




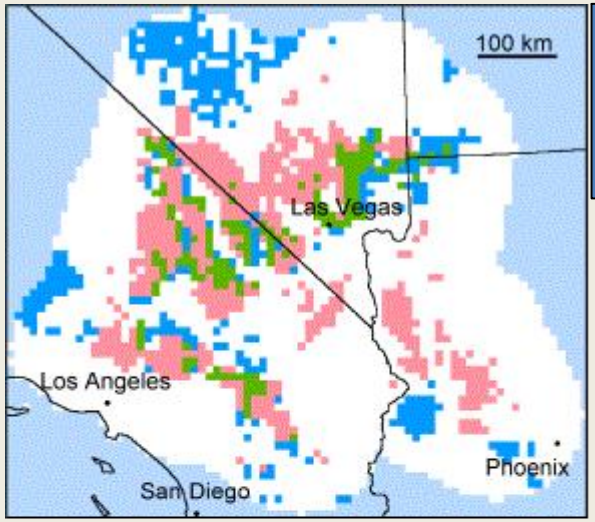


Difficulty of modeling future distribution – physiological tolerances change!

Current Distribution



Future Distribution

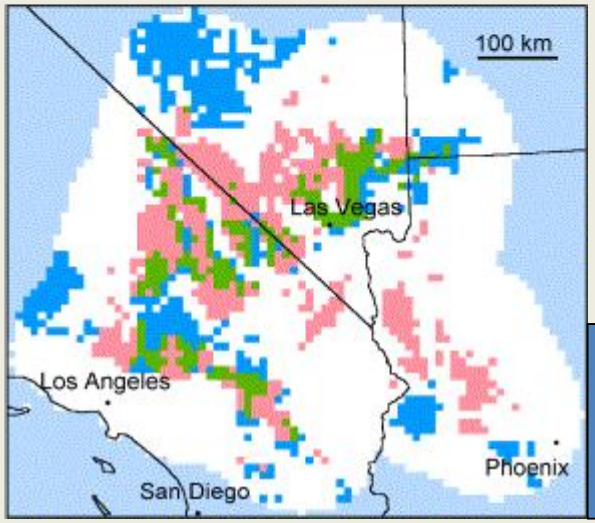


Considering current physiological tolerances

Pink – local extinction

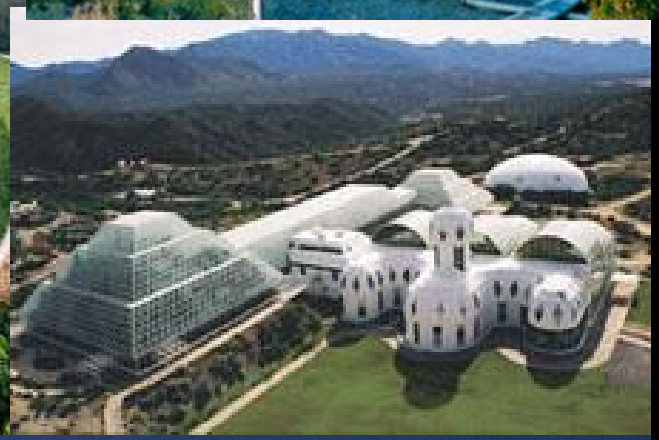
Green – local persistence

Blue – local expansion

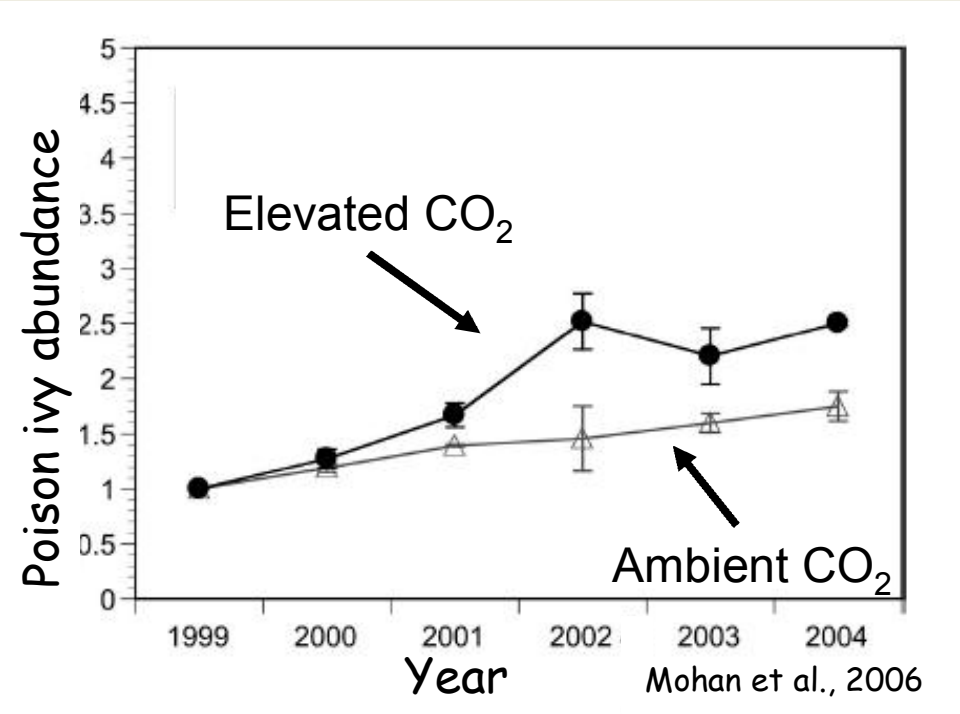


Considering changes in physiological tolerances

[Joshua tree (*Yucca brevifolia*)]

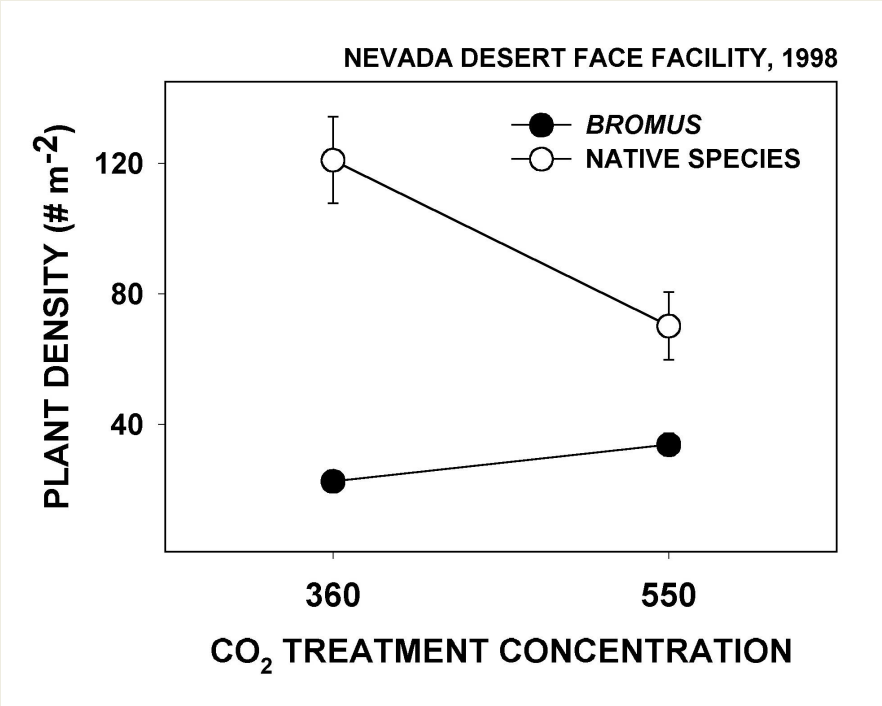


There is always a surprise! - Effects of rising CO_2 on poison ivy abundance & toxicity



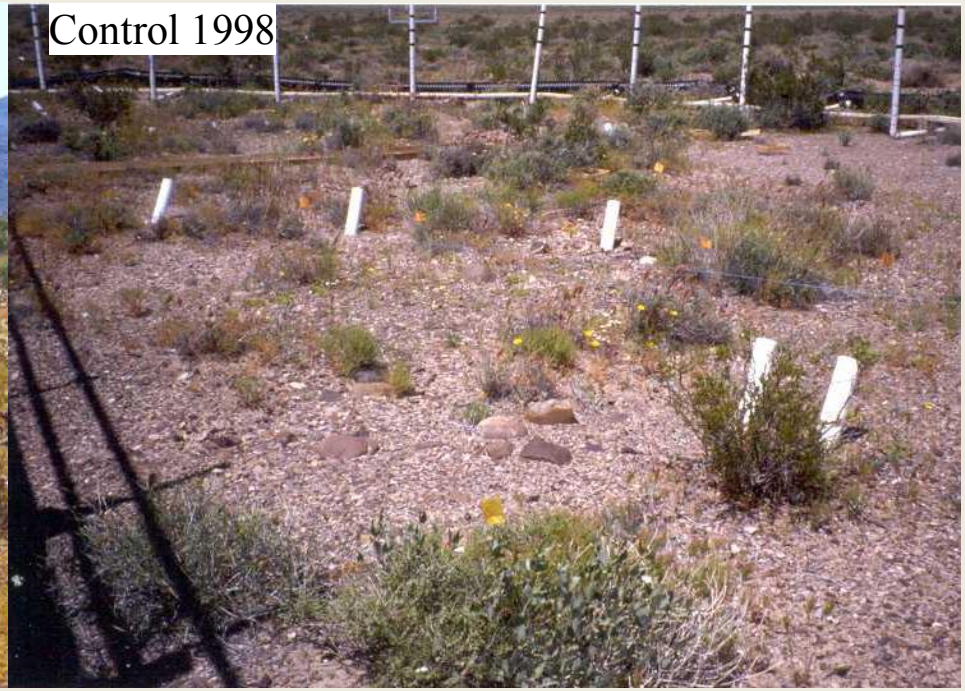
www.poison-ivy.org/rash

www.biology.duke/johnsenlab/nature/images



Red Brome (non-native grass) is the 'surprise' in the western U.S.

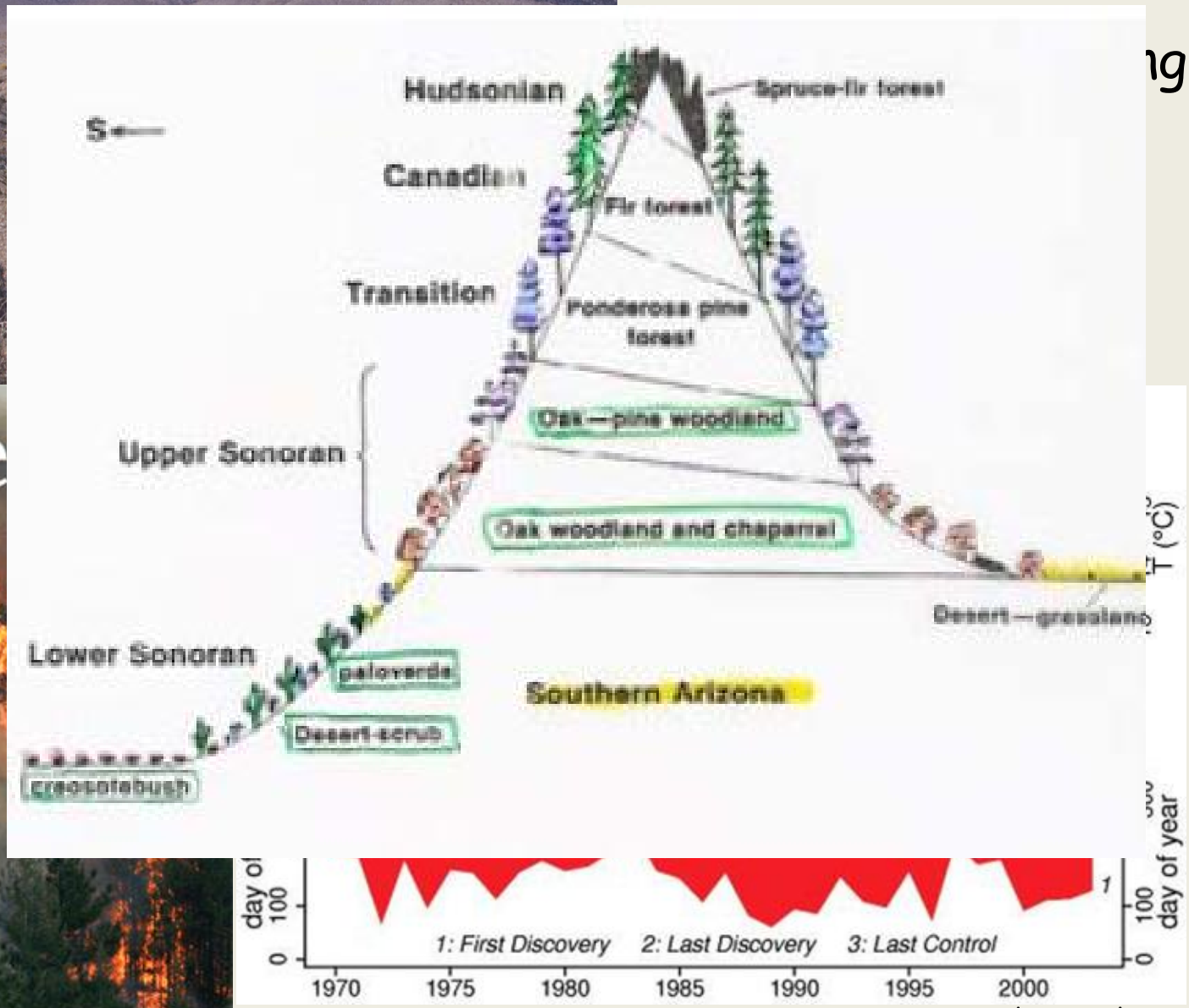
Rising CO_2 dramatically increases it's relative abundance



Consequences of the surprises - Non-native species expansions and disturbance – already a signal from recent CO_2 rise?

•Increase in the frequency of large fires

ngth of



A. L. Westerling et al., 2006 *Science*

- Conceptual and experimental examples
- Special case of the Sonoran Desert
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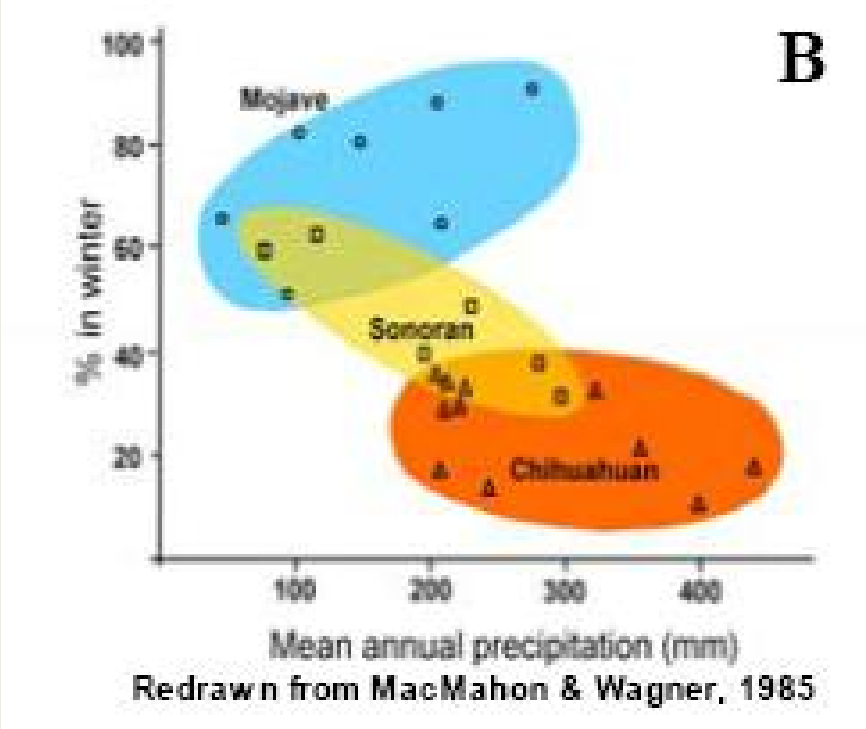
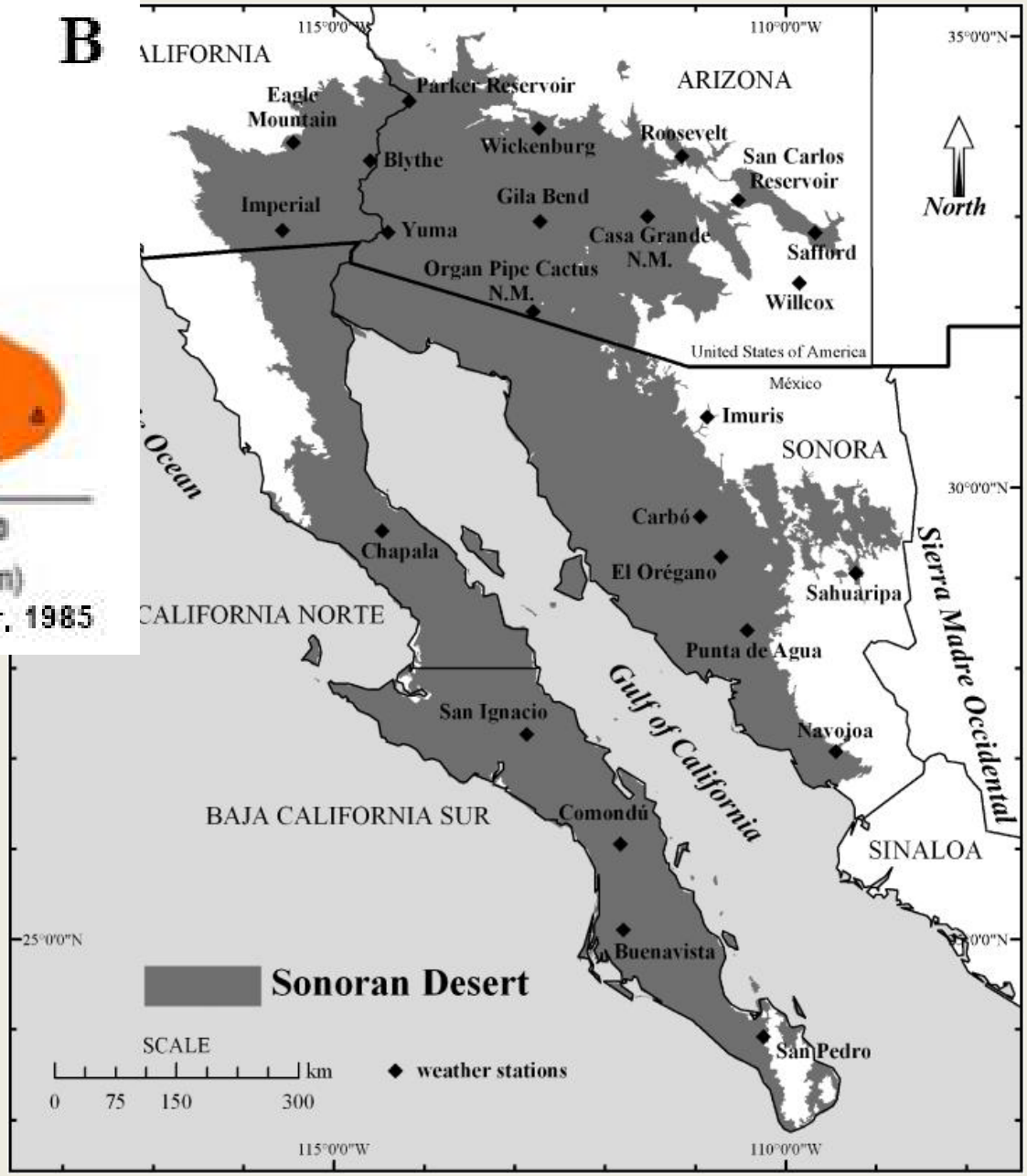




- Bimodal rainfall provides a combination of conditions allowing for fantastic biodiversity
- But, it also puts the system at risk from multiple invaders

Sonoran Desert example – Buffelgrass (*Pennisetum ciliare*)

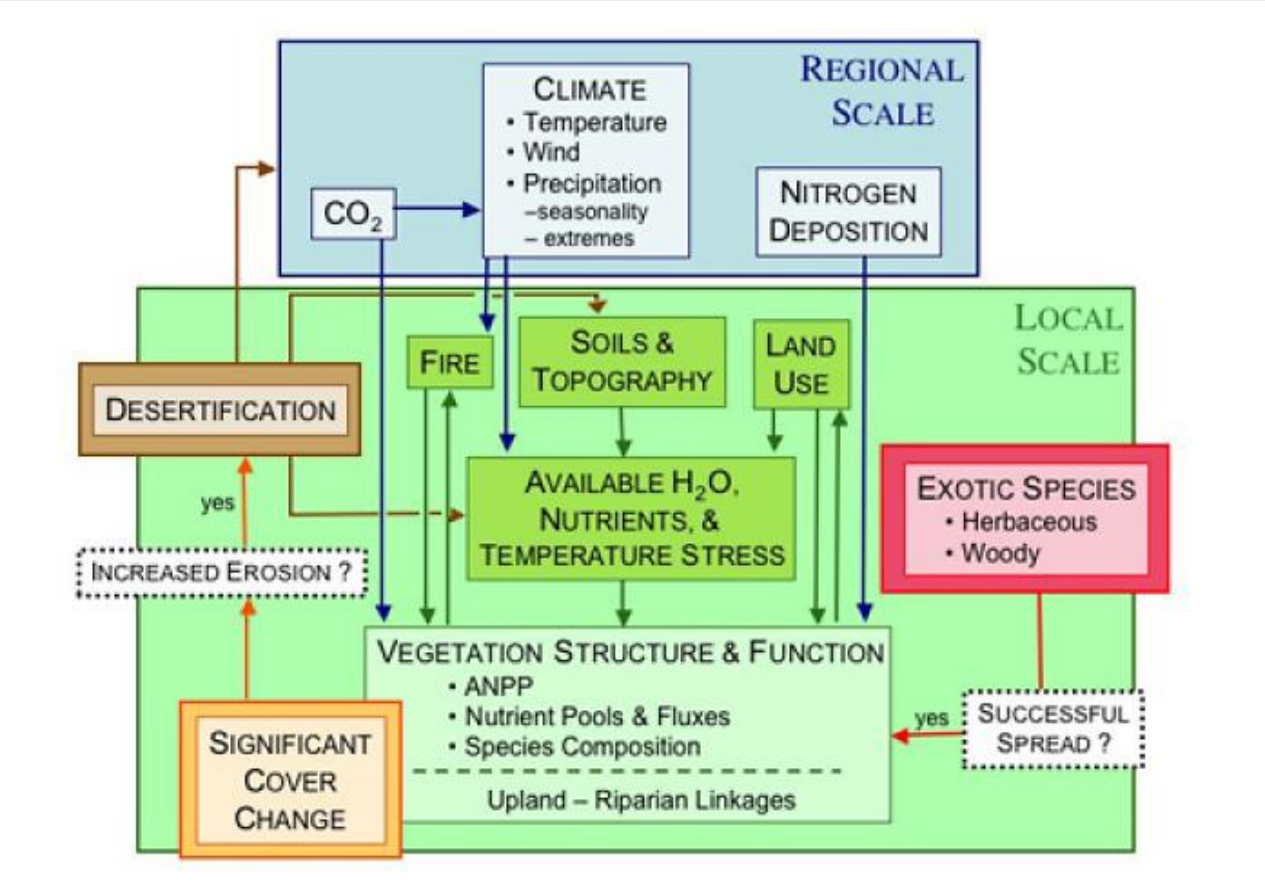
Tumamoc Hill AZ, 1989 – Images courtesy of R. Turner

Tumamoc Hill AZ, 1992 – Images courtesy of R. Turner

Tumamoc Hill AZ, 1998 – Images courtesy of R. Turner

Tumamoc Hill AZ, 2000 – Images courtesy of R. Turner

Figure 3.14 Buffelgrass invasion of saguaro stand in the Tucson Mountains, Arizona (left); fire-damaged saguaro (right). Photos: Ben Wilder.



"Proliferation of non-native annual and perennial grass will predispose sites to fire resulting in a loss of native woody plants and charismatic macroflora. Low elevation arid ecosystems will henceforth experience climate-fire synchronization where none previously existed. The climate-driven dynamics of the fire cycle is likely to become the single most important feature controlling future plant distributions in U.S. arid lands."

US Climate Assessment

- Conceptual and experimental examples
- Special case of the Sonoran Desert
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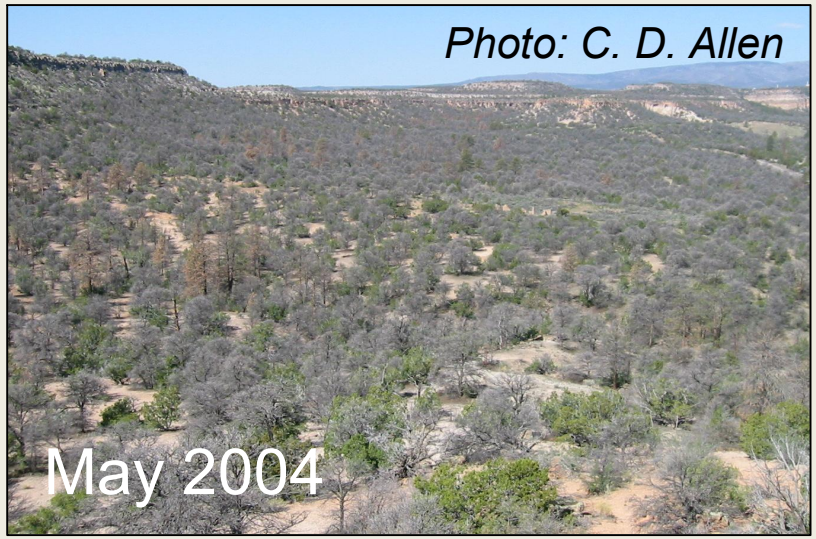
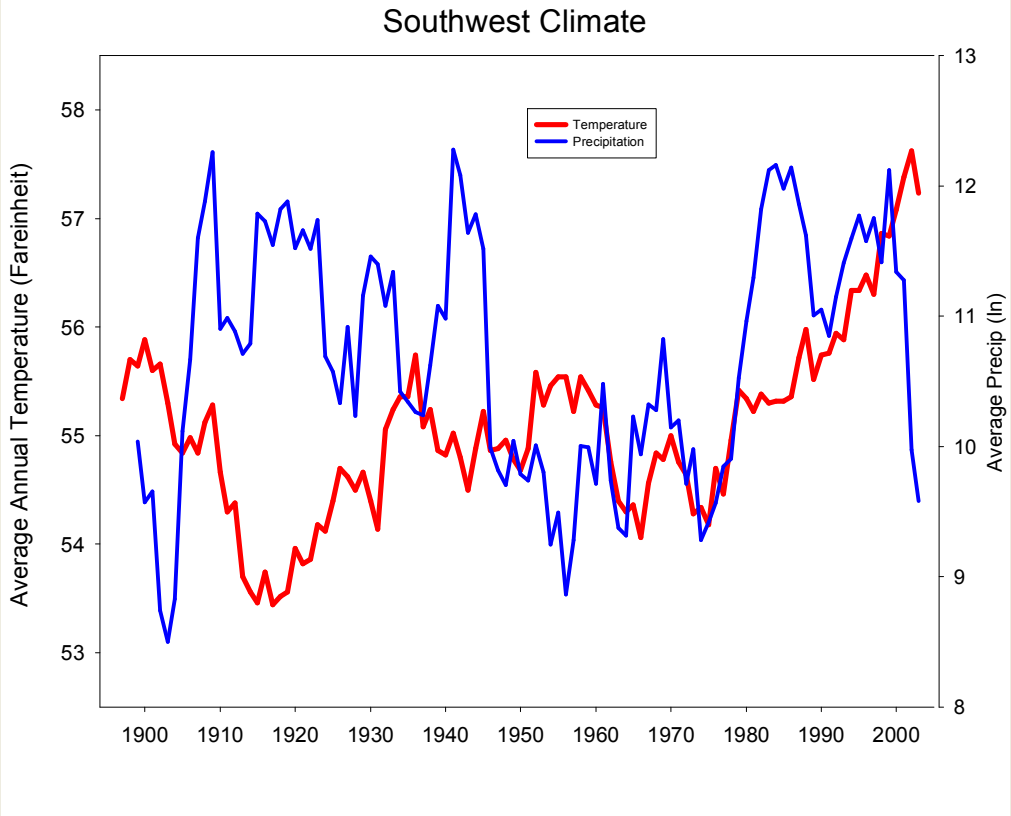
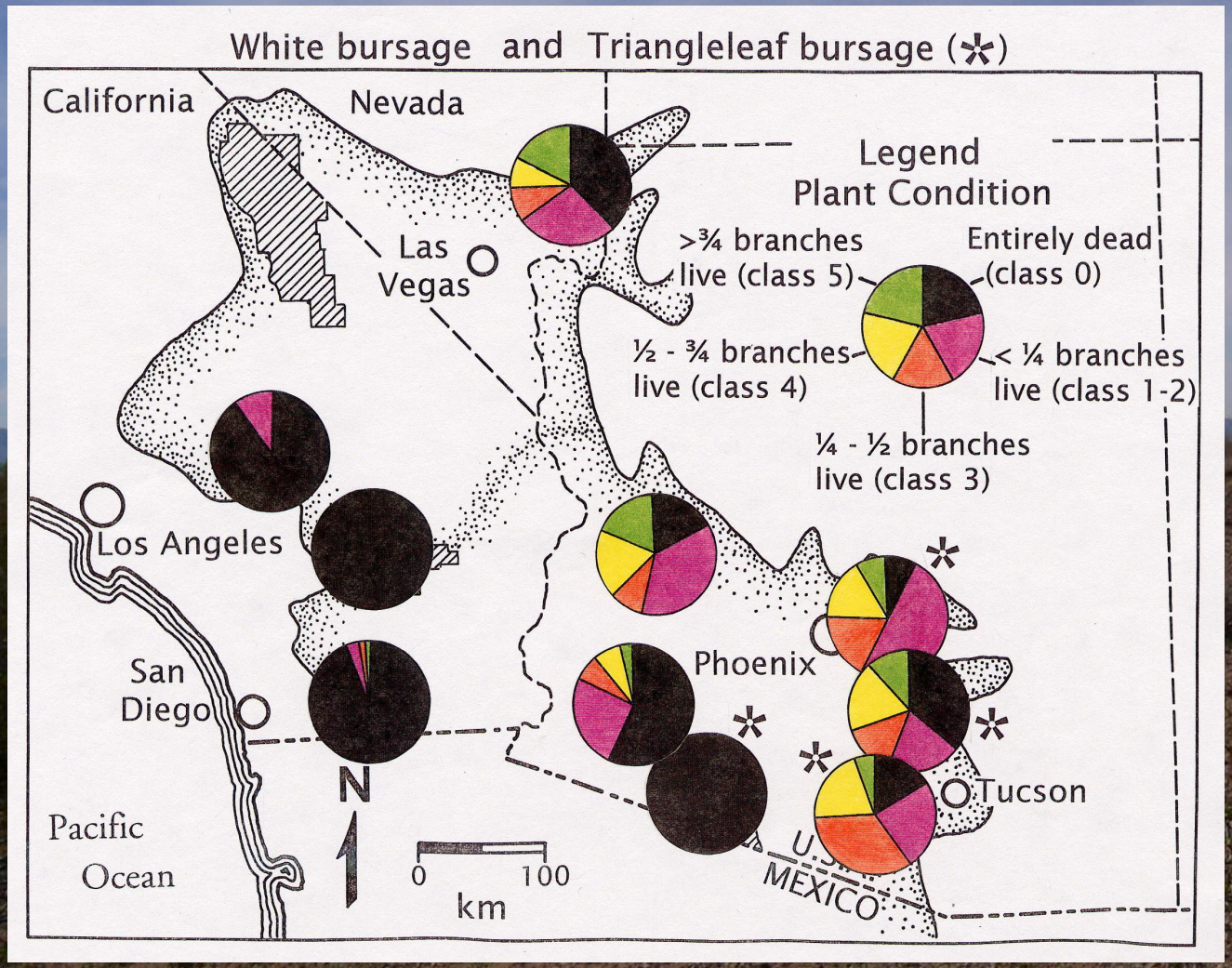




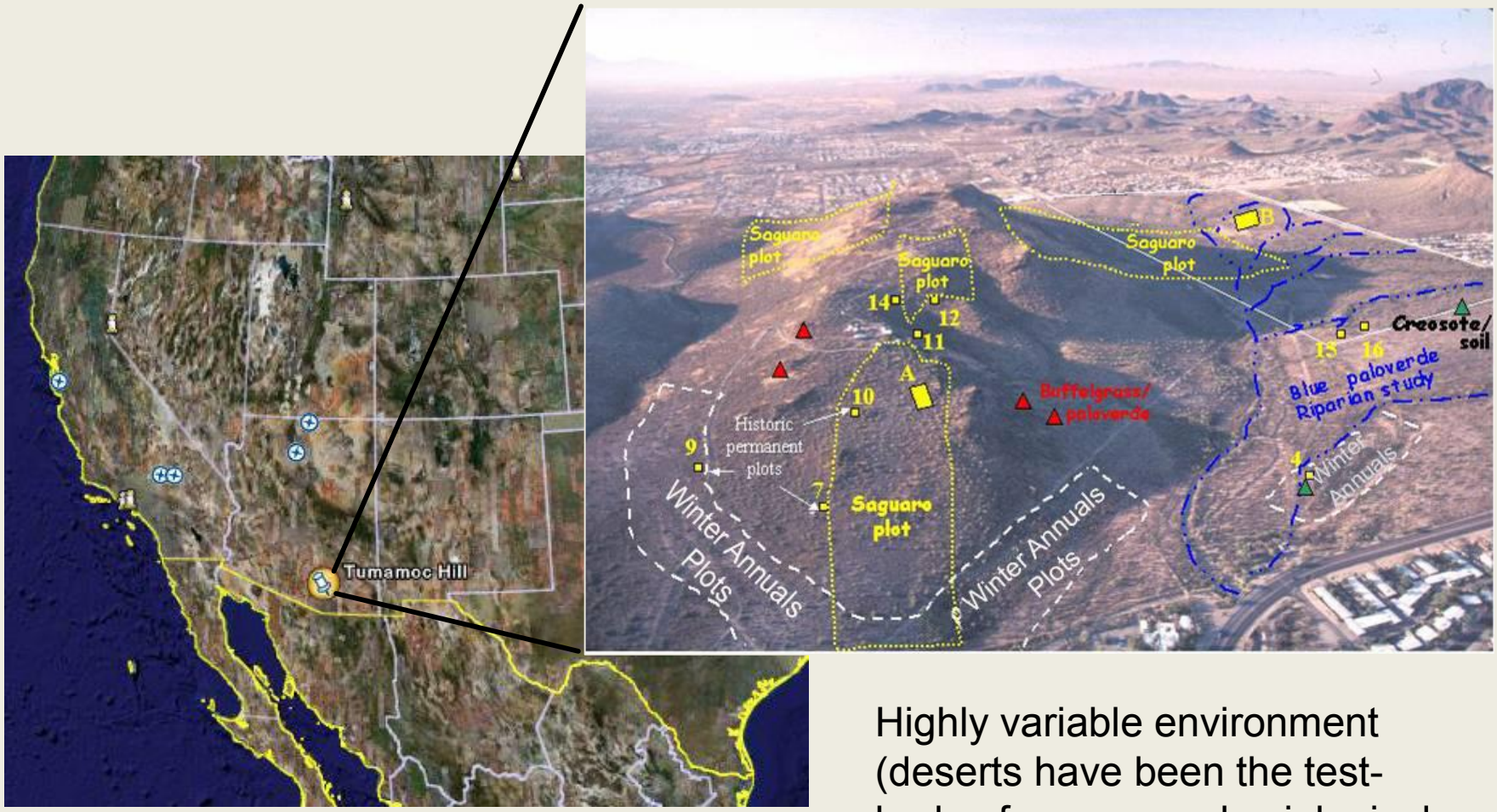
Current drought associated with greater surface temperatures, a 'global warming' type drought (or GC itself….)

Big effects on high elevation systems – what about deserts?


White bursage and Triangleleaf bursage (*)
California
Nevada
Las Vegas
Legend
Plant Condition
>¾ branches live (class 5)
Entirely dead (class 0)
½ - ¾ branches live (class 4)
< ¼ branches live (class 1-2)
¼ - ½ branches live (class 3)
Los Angeles
San Diego
Phoenix
Tucson
Pacific Ocean
N
0
100
km
MEXICO

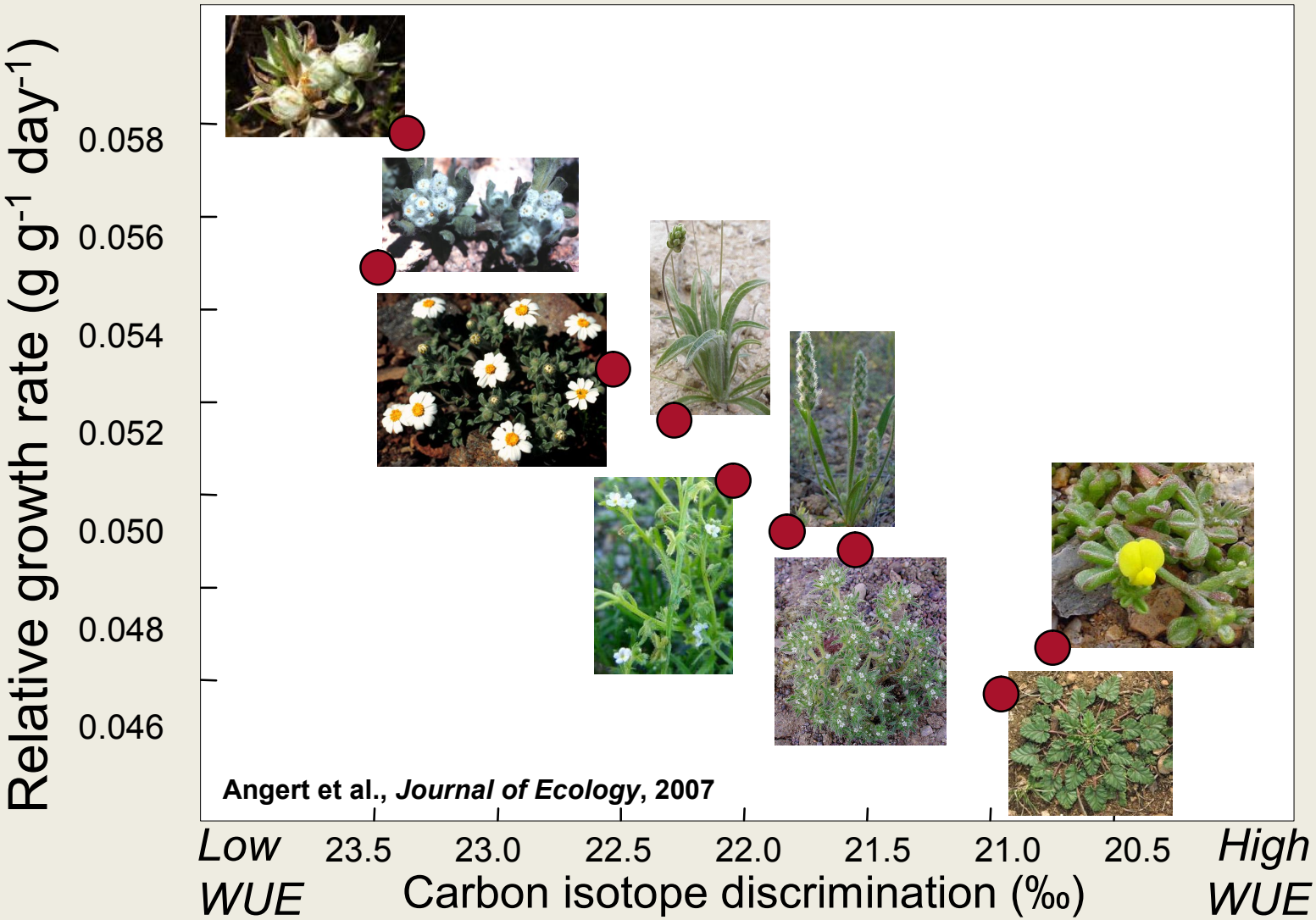
Insights from a fast-responding system that might be ‘seeing’ climate change now….

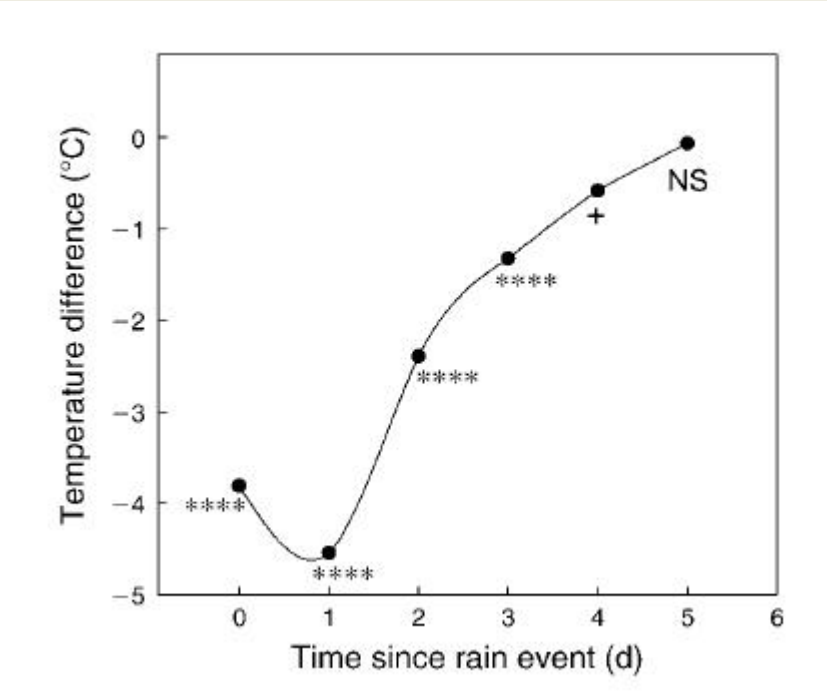
The Desert Lab at Tumamoc Hill Tucson, Arizona

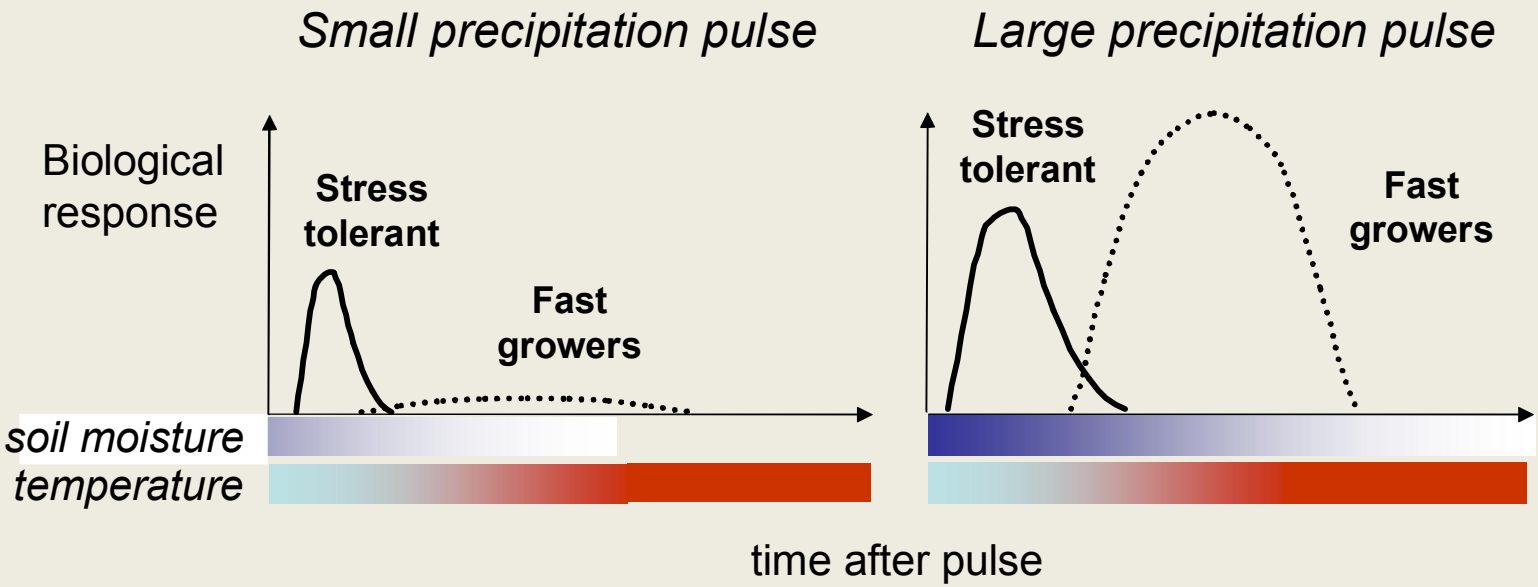


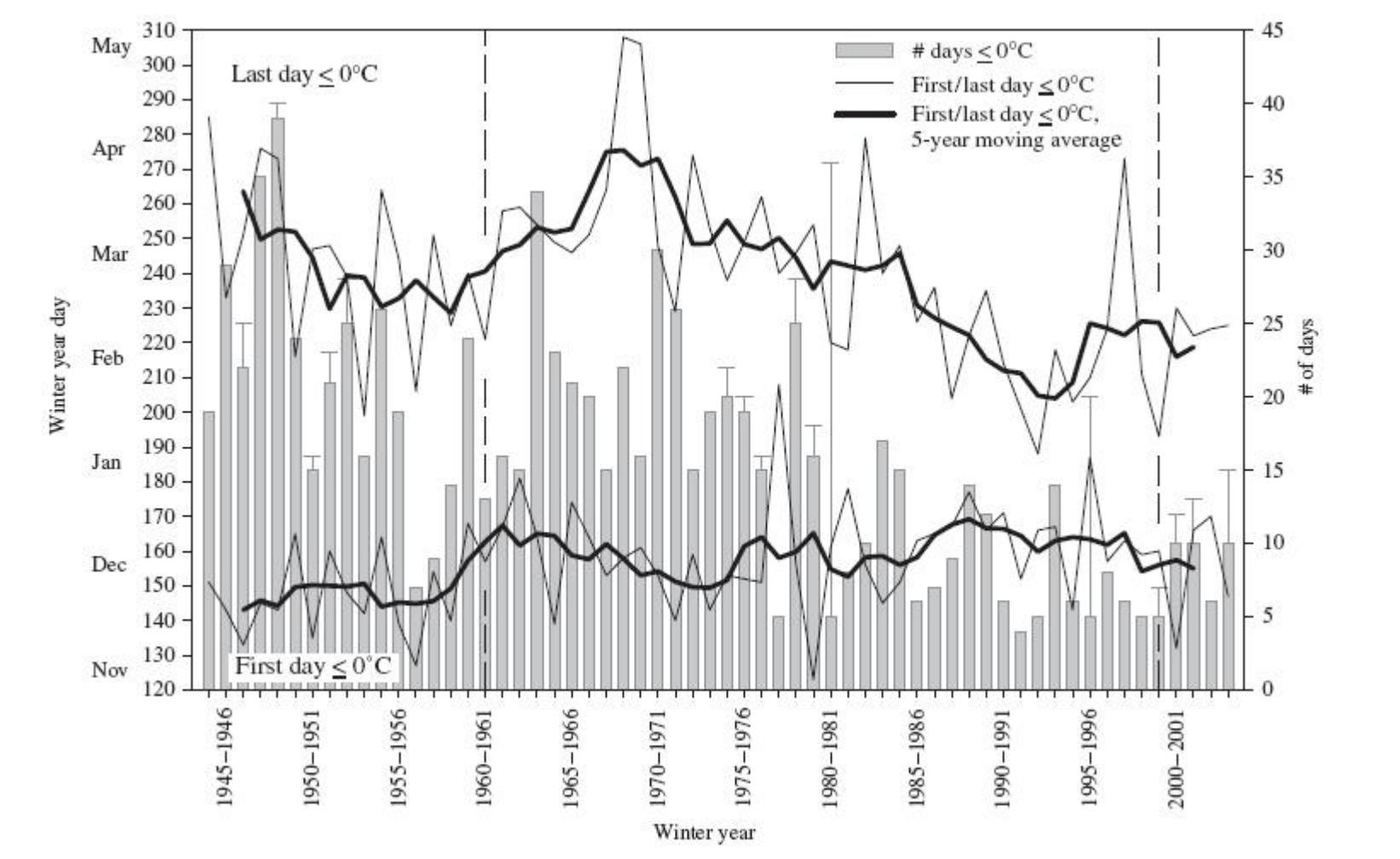
Highly variable environment (deserts have been the test-beds of many ecophysiological investigations)

Stress tolerance – growth rate trade-off




Temperature difference (°C)
0
−1
−2
−3
−4
−5
0
1
2
3
4
5
6
Time since rain event (d)
****
****
****
****
+
NS

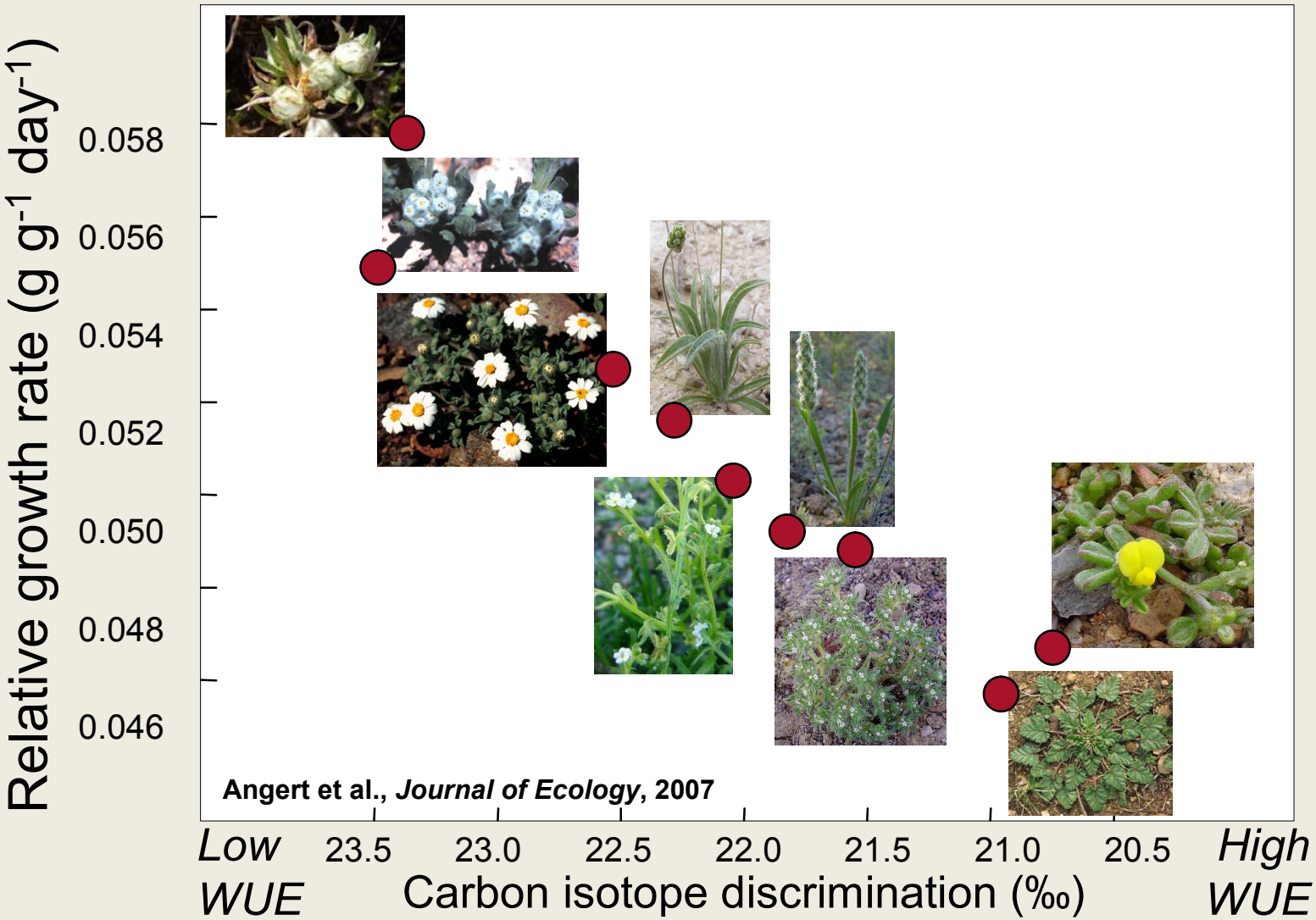

Small precipitation pulse
Large precipitation pulse
Biological response
Stress tolerant
Fast growers
Stress tolerant
Fast growers
soil moisture
temperature
time after pulse

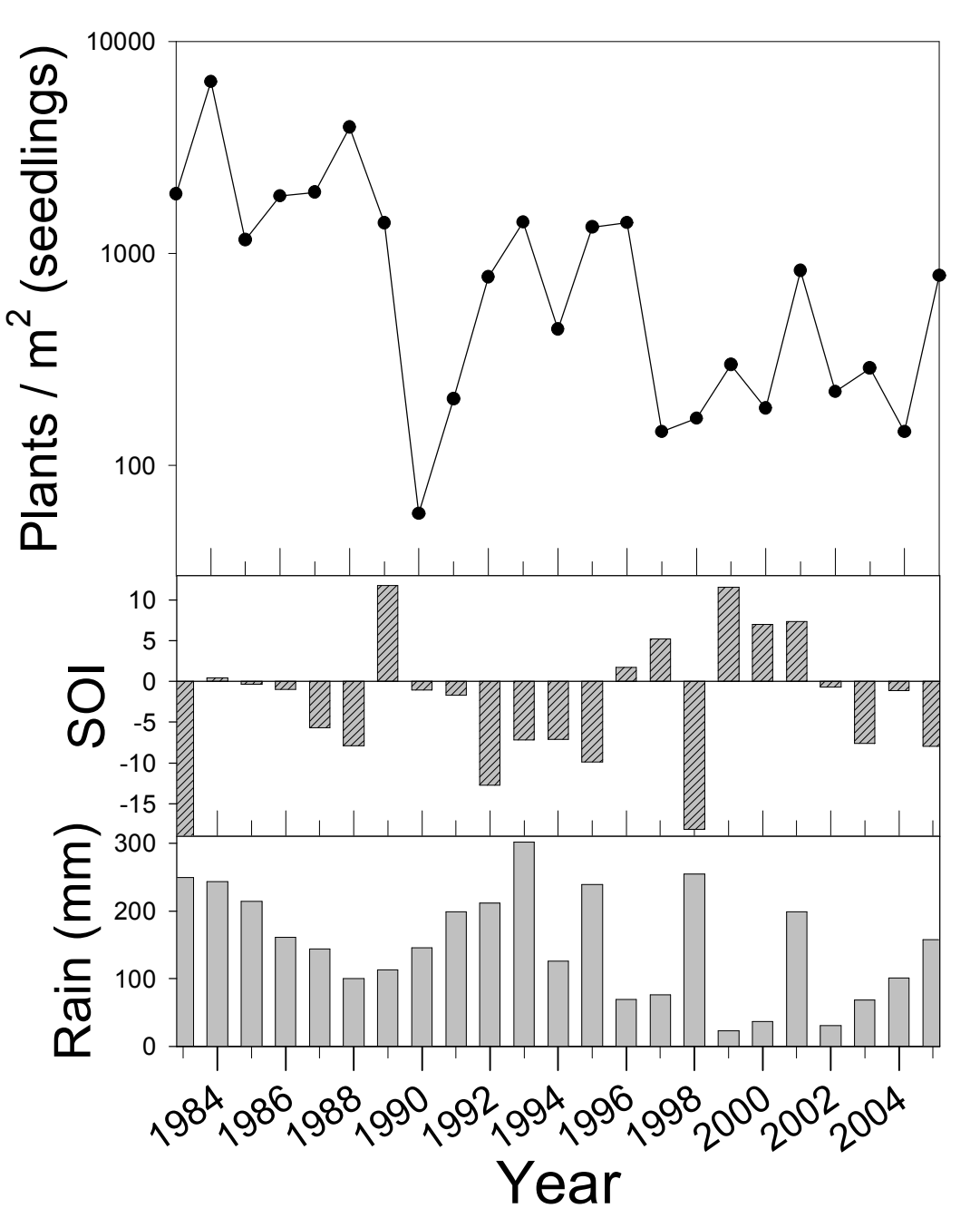


Weiss and Overpeck 2006

Suggests a change in the way that temperature and water co-vary in time – water balance following rainfall should be negatively impacted

Stress tolerance – growth rate trade-off

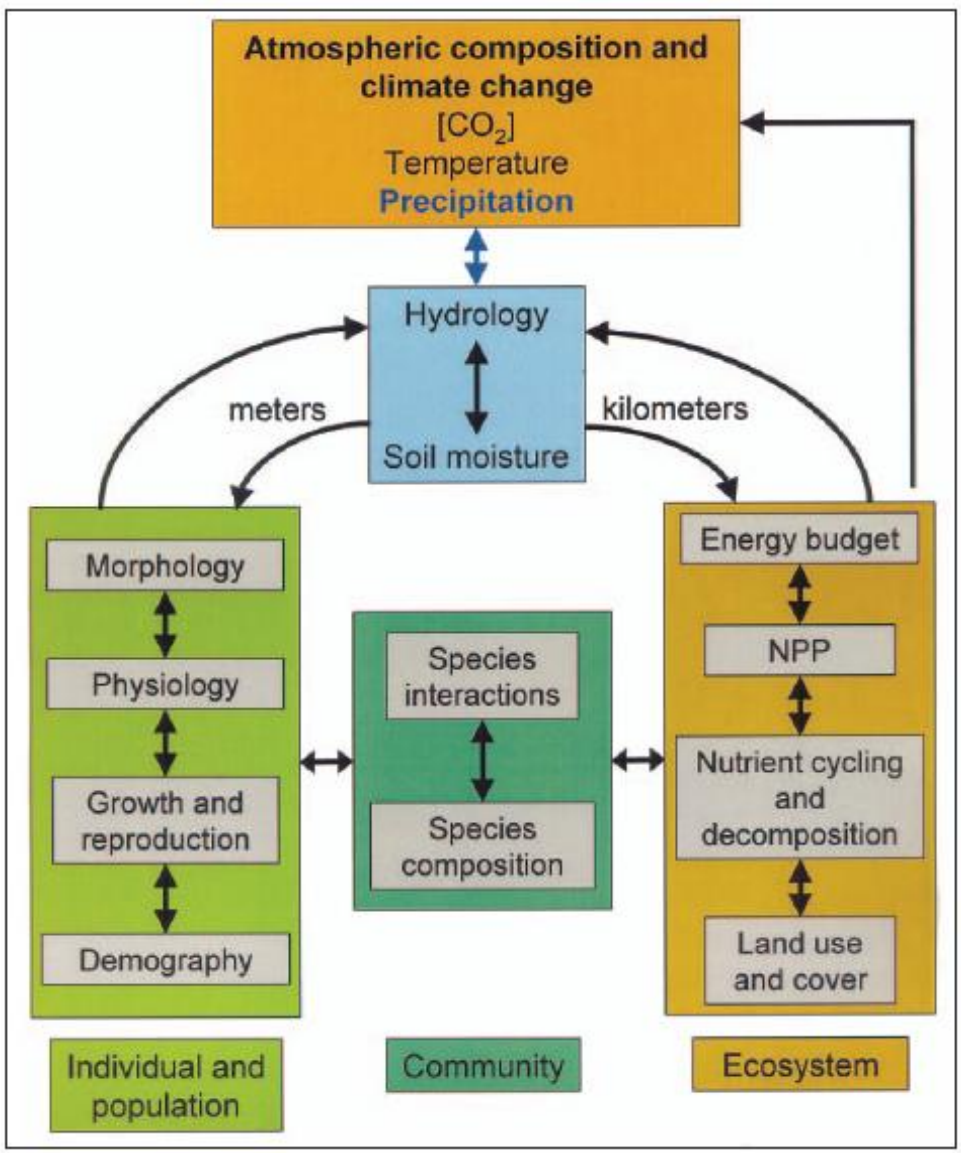




Already a signal of climate change?

A view of the possibilities for ecosystem response in the future?

A focus on water balance and response to water availability



Integrating nature of landscape water balance with respect to shifts in ecology or climate

Weltzin et al., (2001) *BioScience*

US Climate Change Science Program Synthesis and Assessment Product 4.3

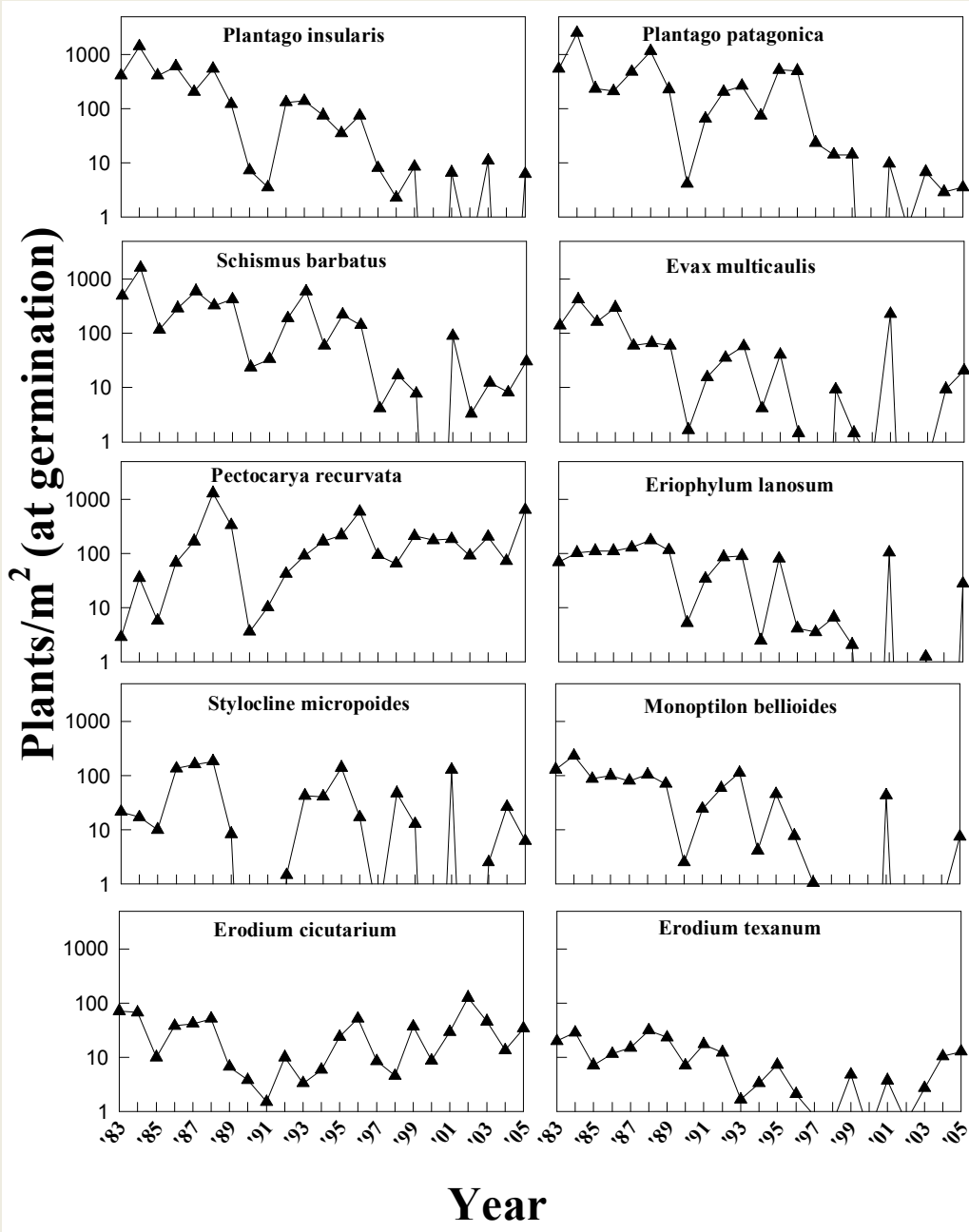
Higher temperatures, increased drought and more intense thunder-storms will very likely increase erosion and promote invasion of exotic grass species.

Arid lands very likely do not offer a large capacity to serve as a "sink" for atmospheric CO2 and will likely lose carbon as climate-induced disturbance increases.

Arid land river and riparian ecosystems will very likely be negatively impacted by decreased streamflow, increased water removal, and greater competition from non-native species.

Changes in temperature and precipitation will very likely decrease the cover of vegetation that protects the ground surface from wind and water erosion.

Current observing systems are very likely inadequate to separate the effects of changes in climate from other effects.

Lots of data that looks like this:

- Plants/m2 counted at germination for 23 years for the whole community