Managing national parks in the era of rapid global changes

The rules have changed, and we must deal with it.

Main points:

I. *The rules have changed*. In the face of rapid, pervasive global changes, our current approach to natural resources management (post-Leopold) is inadequate and can even get us in trouble.

II. The future will be characterized by massive yet largely unpredictable changes, and some unpleasant surprises.

III. Even in the face of massive, unpredictable changes, we can do some useful things.

I. *The rules have changed*. In the face of rapid, pervasive global changes, our current approach to natural resources management (post-Leopold) is inadequate and can even get us in trouble.

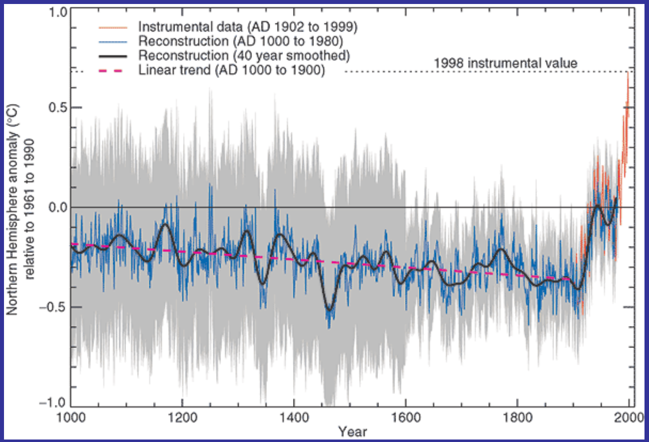
A. Climatic change and its effects are here, now.

B. We have entered an era of unprecedented environmental conditions.

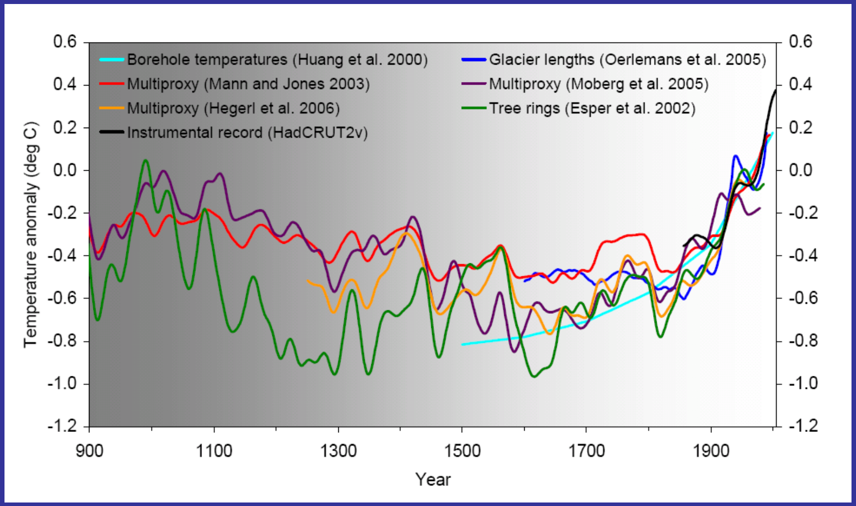
C. We can no longer use the past as a target for restoration or management, nor depend on natural processes alone.

A. CLIMATIC CHANGE AND ITS EFFECTS ARE HERE, NOW

(1) The world is warmer now than at any time in the last 400 years, and probably much longer.



IPCC 2001 / Mann, Bradley, & Hughes



NRC 2006

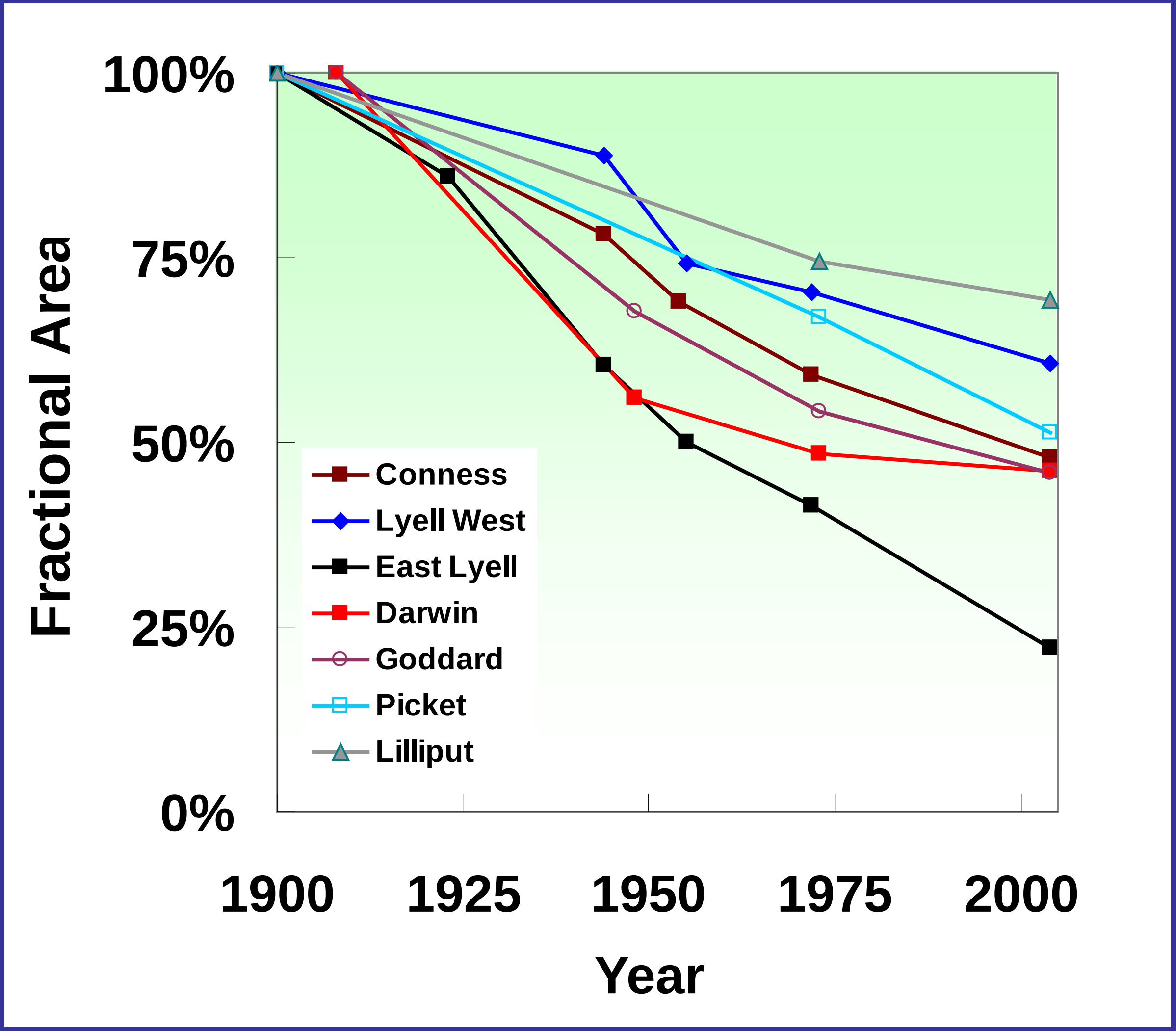
(2) Glaciers are melting

Photo by G. K. Gilbert

Photo by H. Basagic

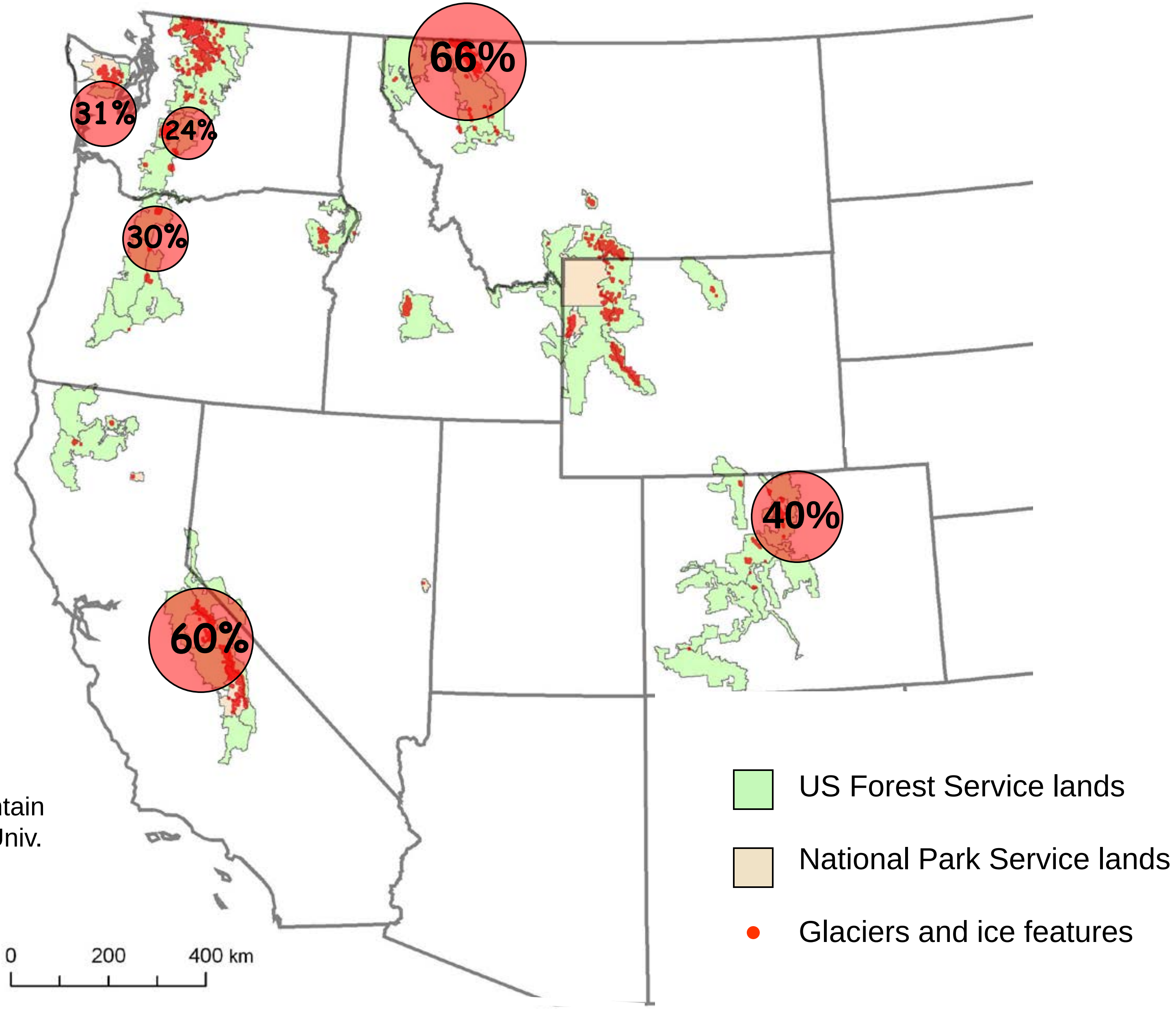
Darwin glacier,
Kings Canyon
National Park,
Sierra Nevada

Sierra Nevada



H. Basagic and A. Fountain, Portland State Univ.

Fraction of Glacial Area Lost Since 1900



Andrew G. Fountain
Portland State Univ.

Arctic ice extent and thickness is decreasing.

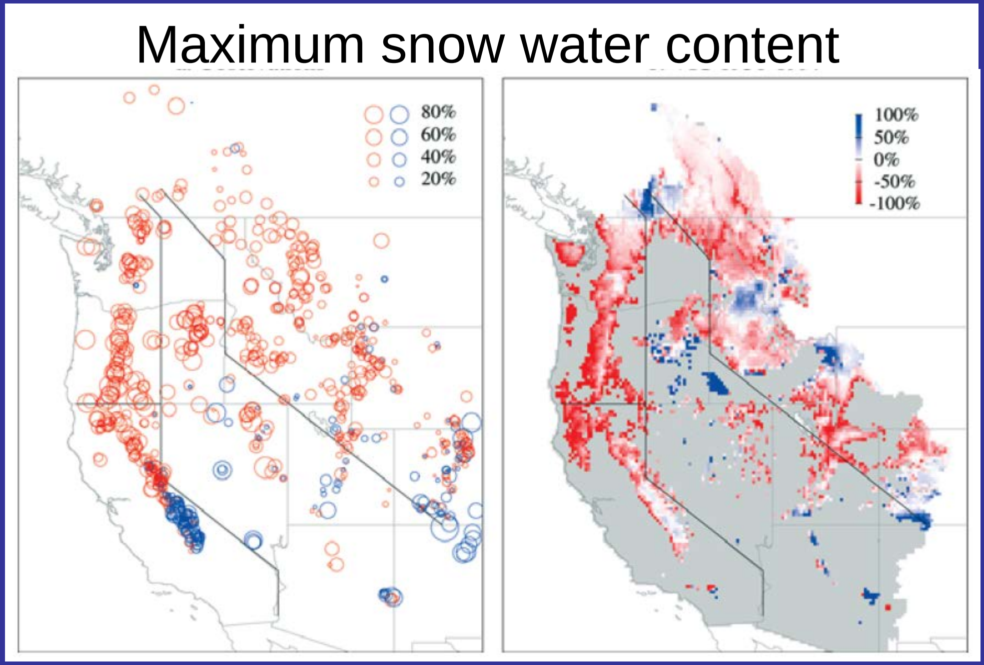
1979

2003

Source: Our Changing Planet

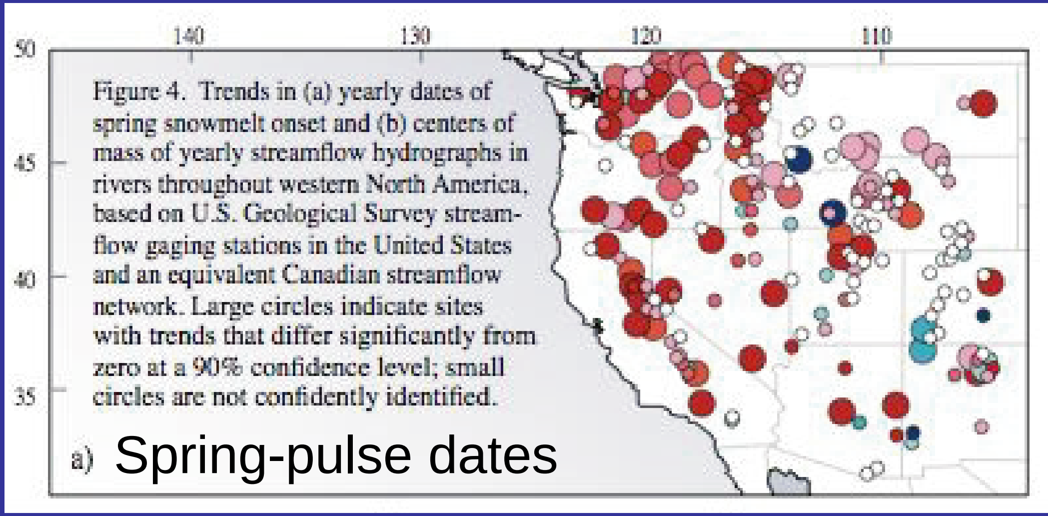
(3) Summers are getting longer and drier

Snowpack has been decreasing over most of the West in recent decades …



Mote et al., *BAMS*, 2005

… and spring streamflow has been arriving earlier.



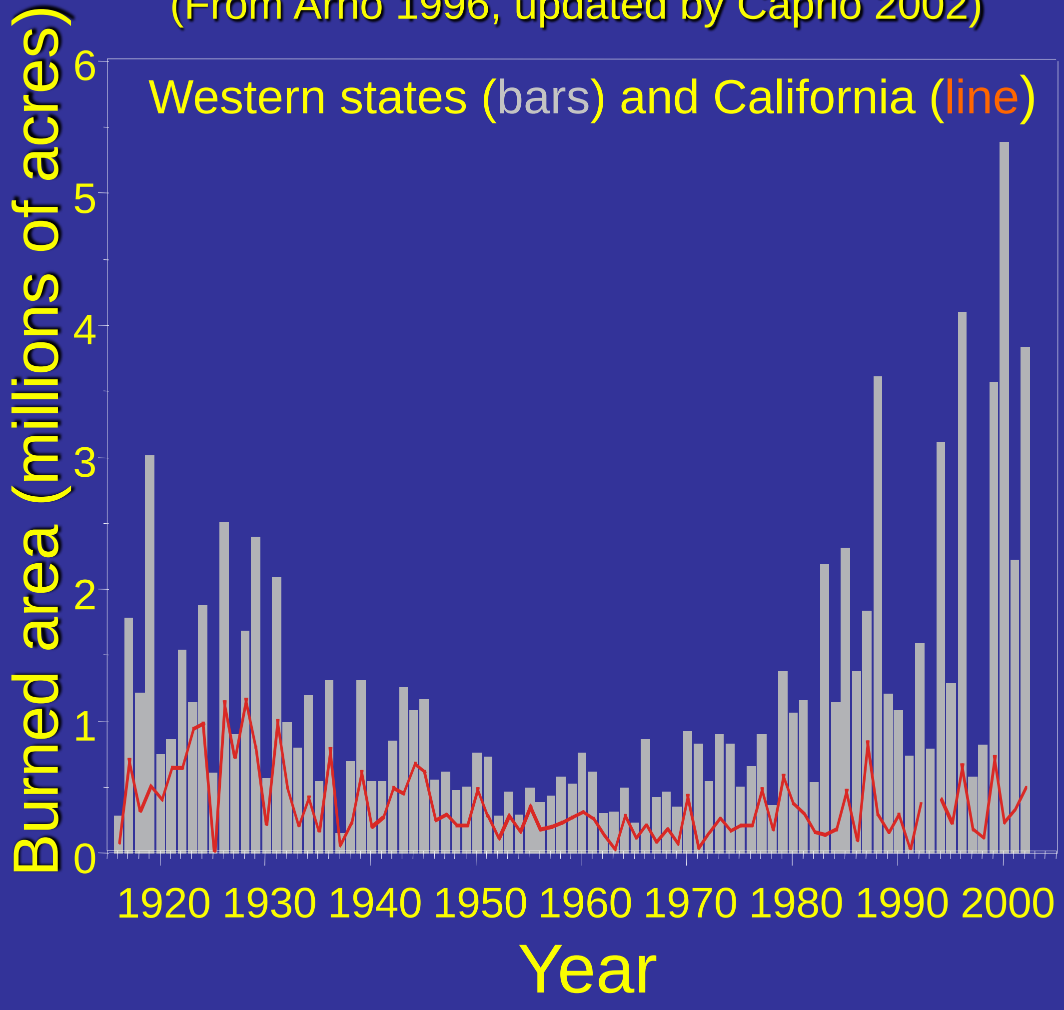
Stewart et al., 2004

(4) Area burned is increasing, fire season is lengthening, and fires are harder to control ...

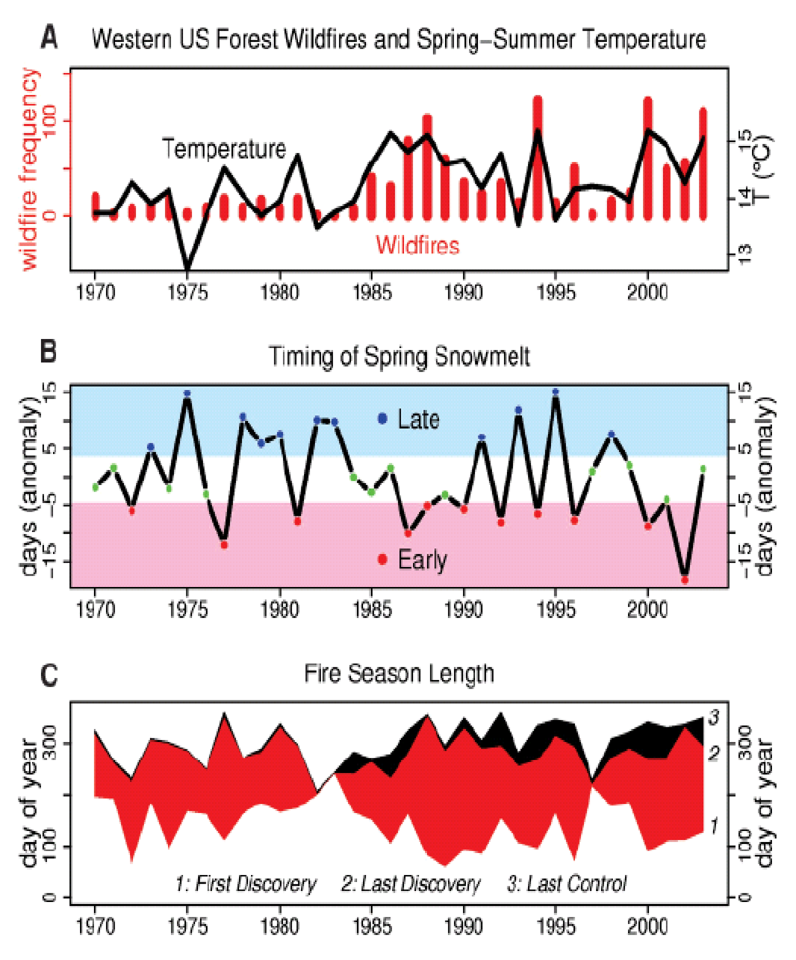
Photo: N. Stephenson

Acres Burned - 1916 to 2002

(From Arno 1996, updated by Caprio 2002)



... at least partly due to warming.

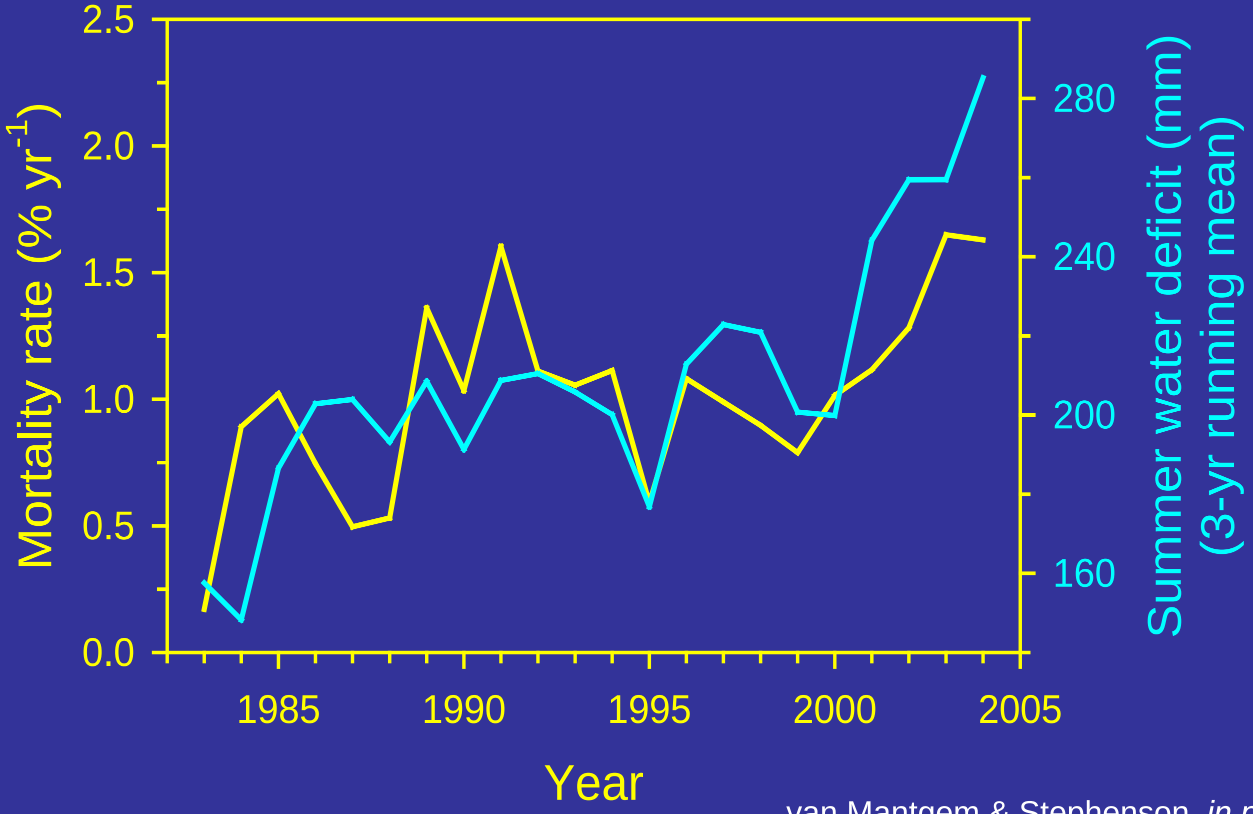


Westerling et al., *Science*, 2006

(5) Tree mortality rate is increasing in the Sierra Nevada

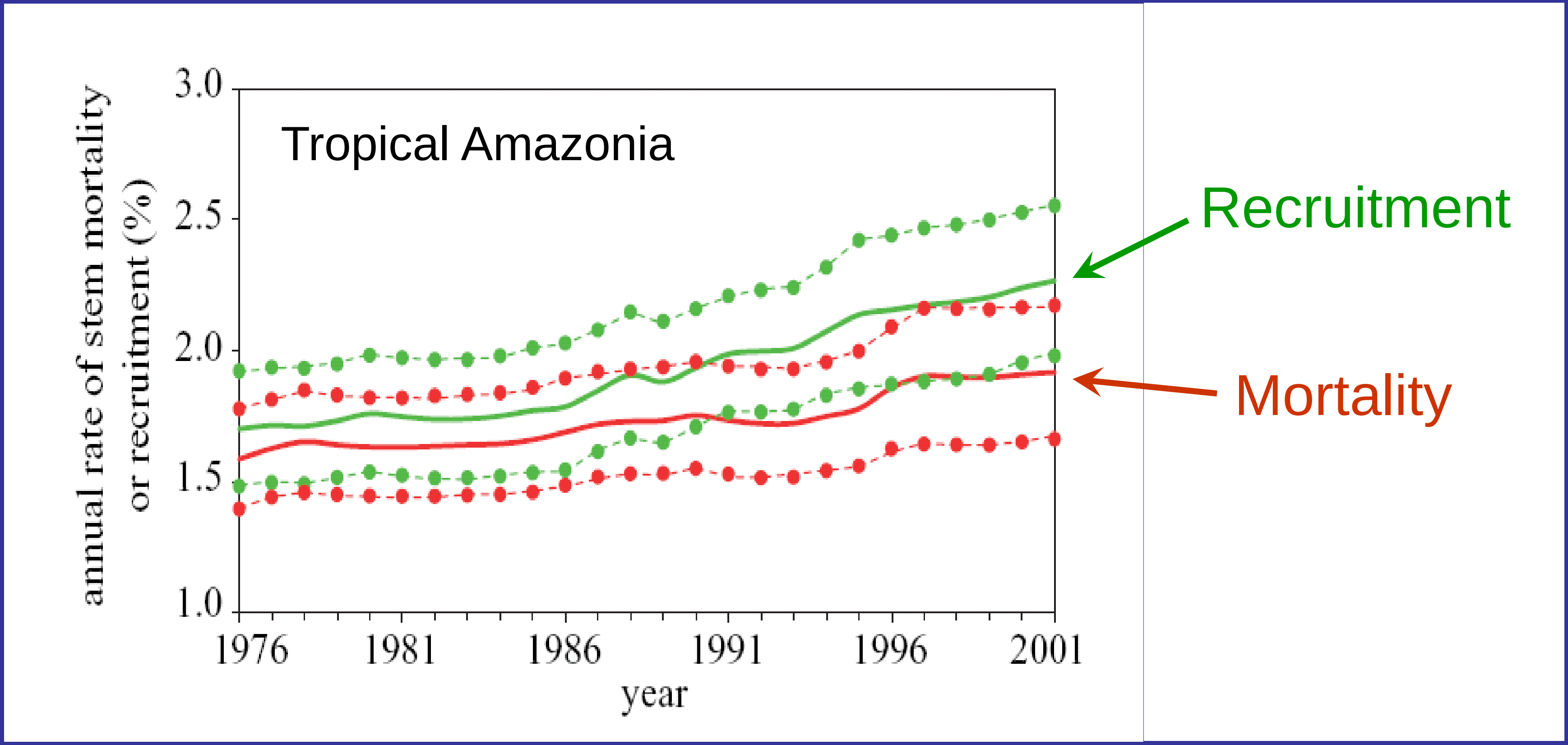
Photo: N. Stephenson

- Summer drought (water deficit) is increasing, due to increasing temperature (*not* decreasing precipitation).
- Increasing tree mortality rates are being driven by increasing deaths due to insects, pathogens, and stress.



van Mantgem & Stephenson, *in prep.*

Similar forest changes are in progress in at least Oregon and Washington, and also the New World tropics:

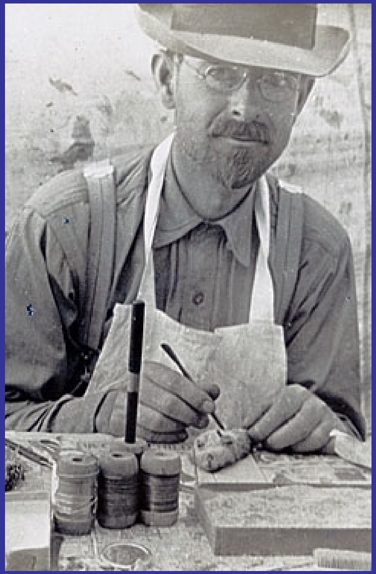


Phillips et al., *Phil. Trans. B*, 2004

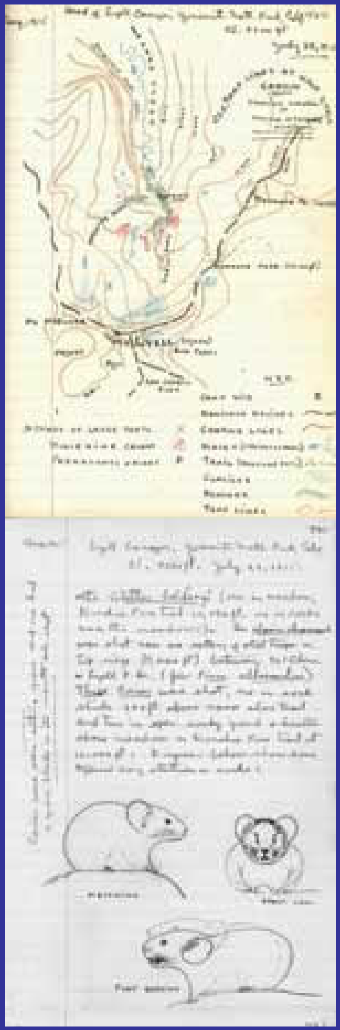
(6) Vertebrates are moving up slope in the Sierra

The Grinnell Resurvey Project

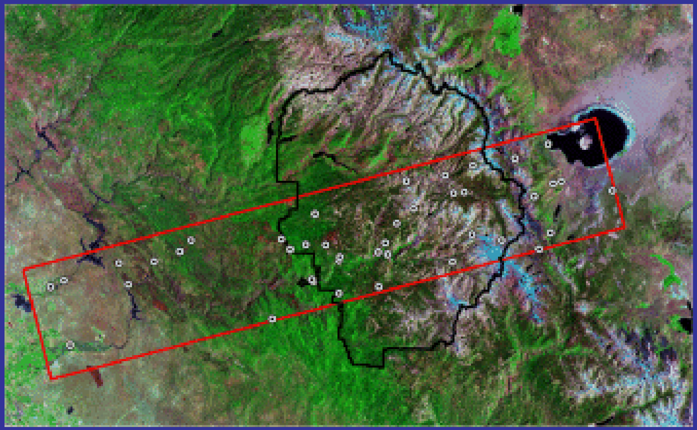
1914 - 1920



Bancroft Library, UC Berkeley



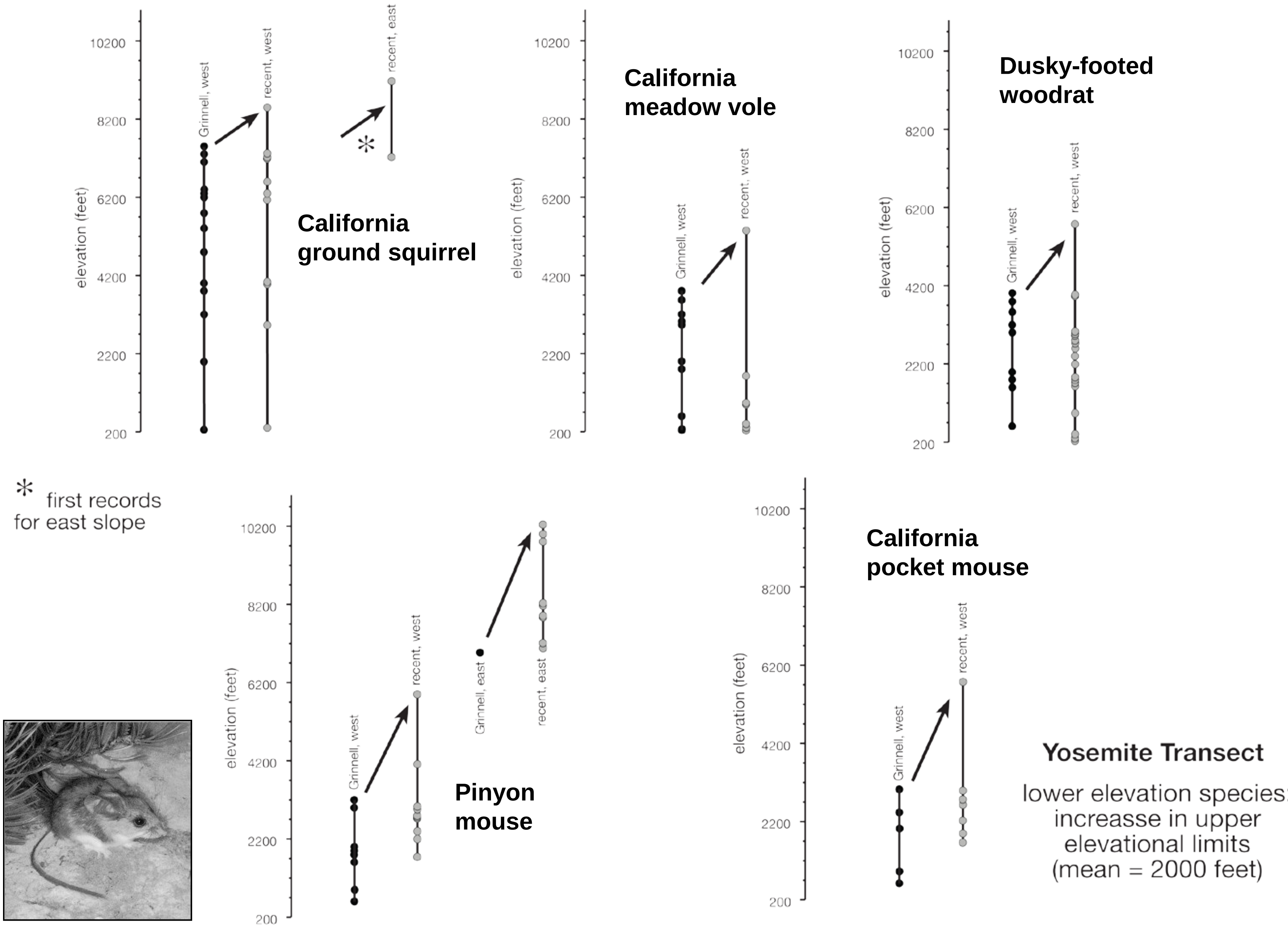
2003 - present



MVZ, UC Berkeley

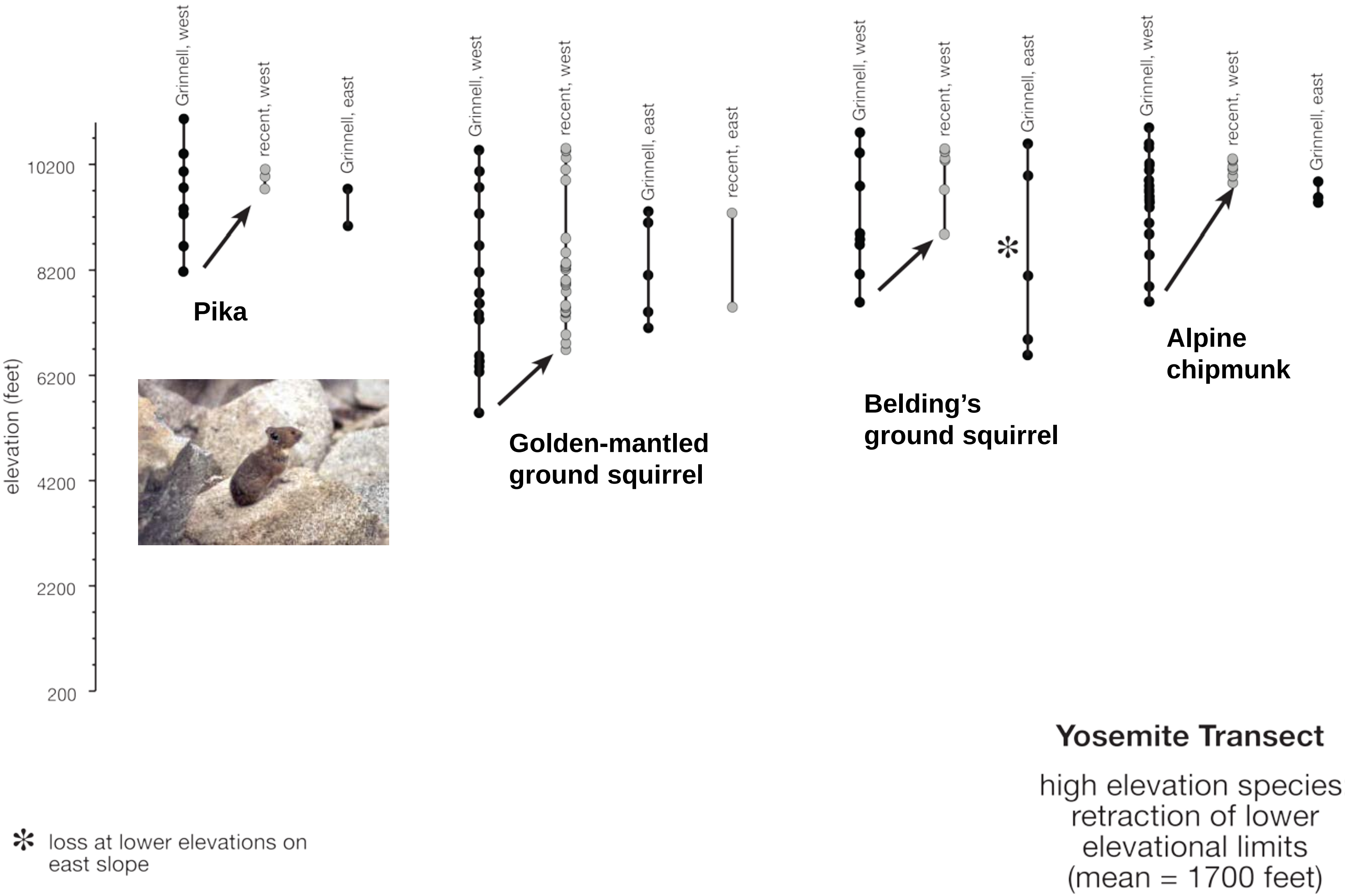
© Les Chow

Low-elevation species: increase in upper elevational limits (ave. 2000 ft)



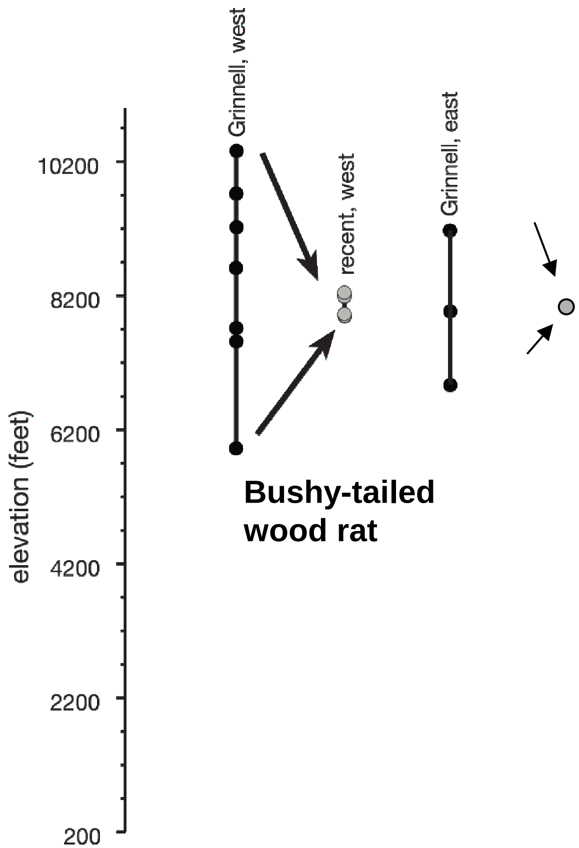
Courtesy of Jim Patton, Chris Conroy, Michelle Koo, and the Grinnell Project

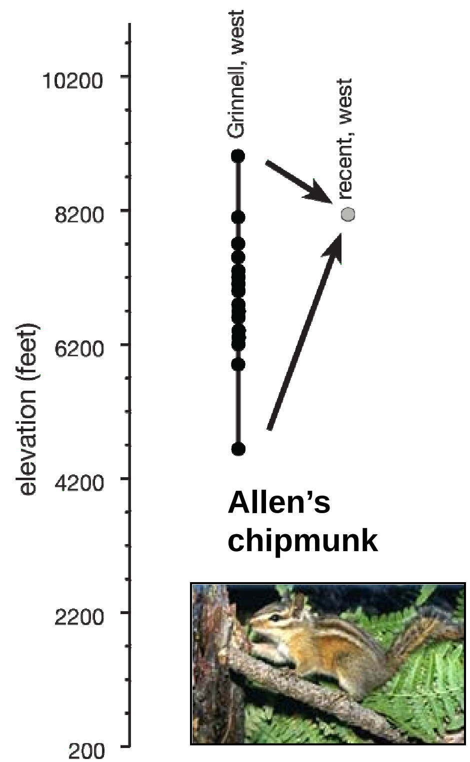
High-elevation species: retraction of lower elevational limits (ave. 1700 ft)



Courtesy of Jim Patton, Chris Conroy, Michelle Koo, and the Grinnell Project

A few species: severe range contraction and rarity





Also:

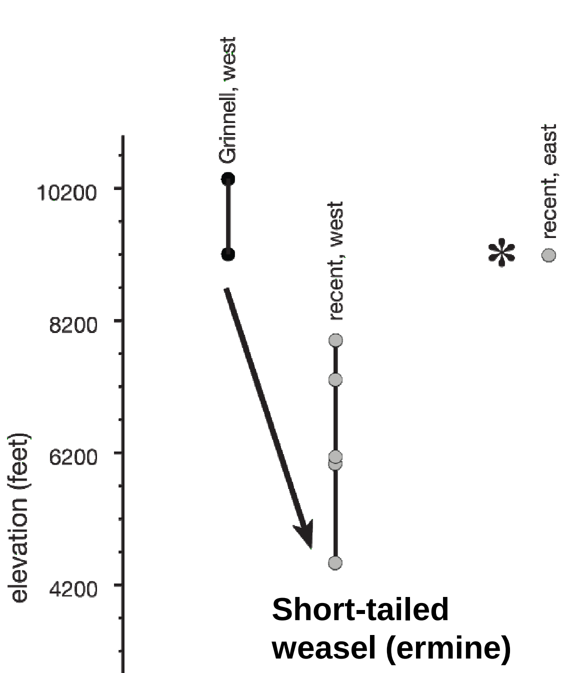
- **White-tailed jackrabbit**
- **Porcupine**
- **Wolverine**

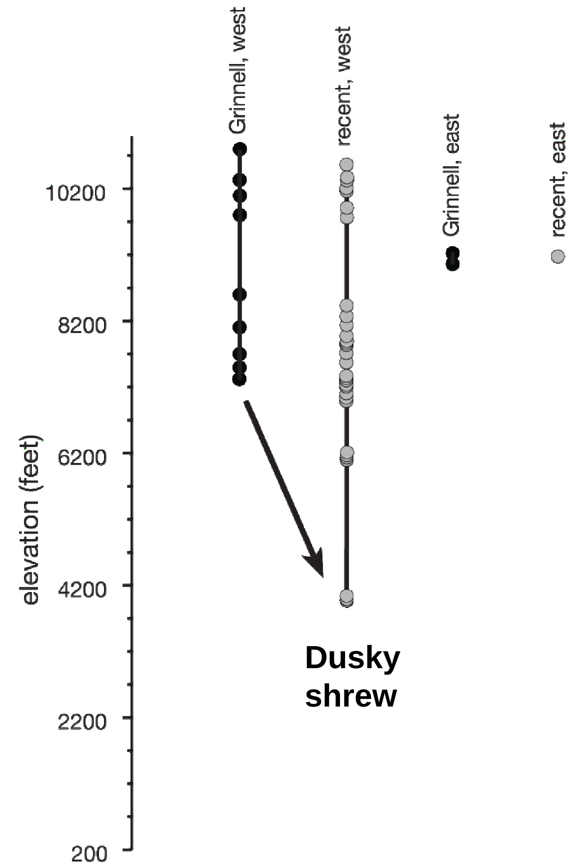
Yosemite Transect

species that have experienced severe range contractionand rarity

Courtesy of Jim Patton, Chris Conroy, Michelle Koo, and the Grinnell Project

A few high-elevation species: expansion of lower limit (ave. 3800 ft)





* only record on east slope

Courtesy of Jim Patton, Chris Conroy, Michelle Koo, and the Grinnell Project

These range changes are similar to global observations for all kinds of organisms (trees, shrubs, herbs, lichens, birds, mammals, insects, reptiles, amphibians, fish, marine invertebrates, and marine zooplankton)
(Parmesan & Yohe, *Nature*, 2003).

460 of 920 species (50%) showed significant changes.

	Distributional changes	
	As predicted	Opposite prediction
At poleward or upper limit	81%	19%
At equatorial or lower limit	75%	25%

	Abundance changes	
	As predicted	Opposite prediction
Cold-adapted species	74%	26%
Warm-adapted species	91%	9%

B. WE HAVE ENTERED AN ERA OF UNPRECEDENTED ENVIRONMENTAL CONDITIONS

Though warmer climates of the future may have some precedent in the past,

-- that past is probably quite distant (meaning extant species didn't evolve in it), and

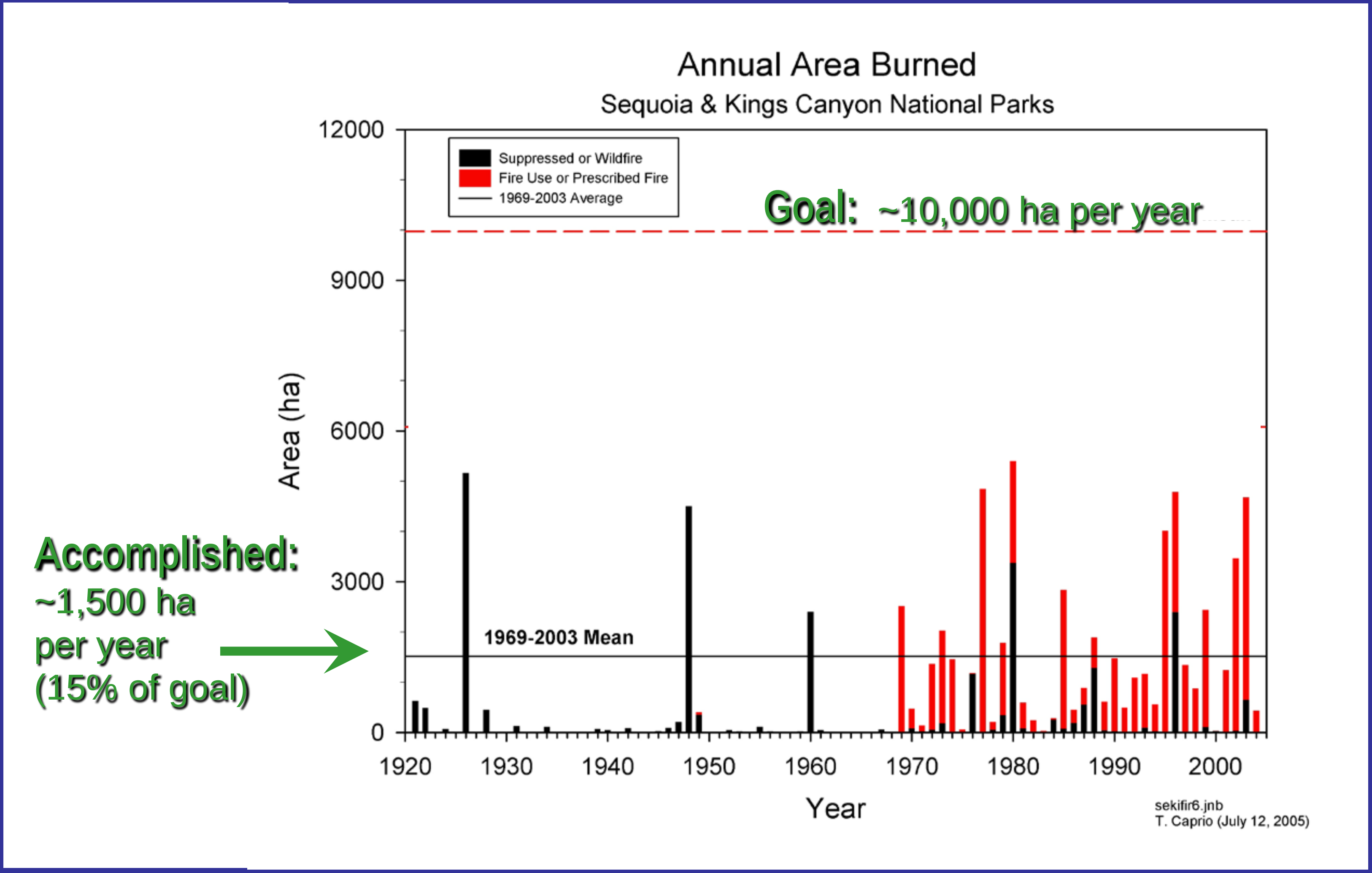
-- did not include a whole suite of novel, interacting stresses.

THE NOVEL, INTERACTING STRESSES

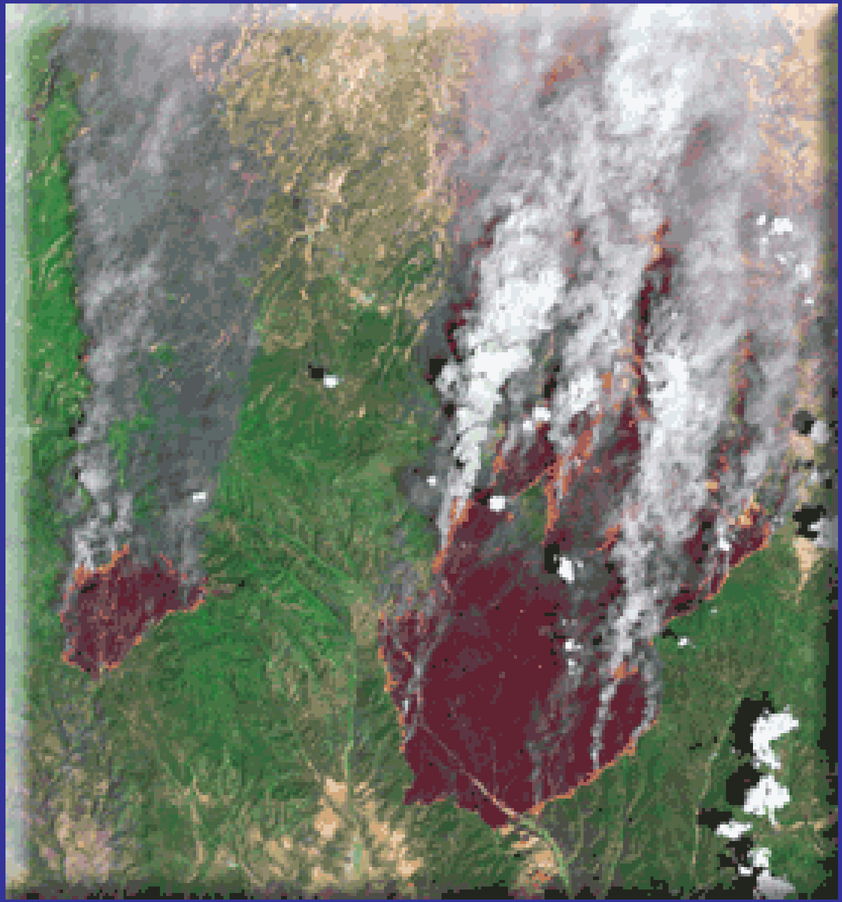
The 800-pound gorillas:

(1) Altered disturbance regimes

After 35 years of prescribed fire, we haven't come close to restoring fire regimes at a landscape scale.



... and wildfires now often burn with a severity rarely encountered in the past



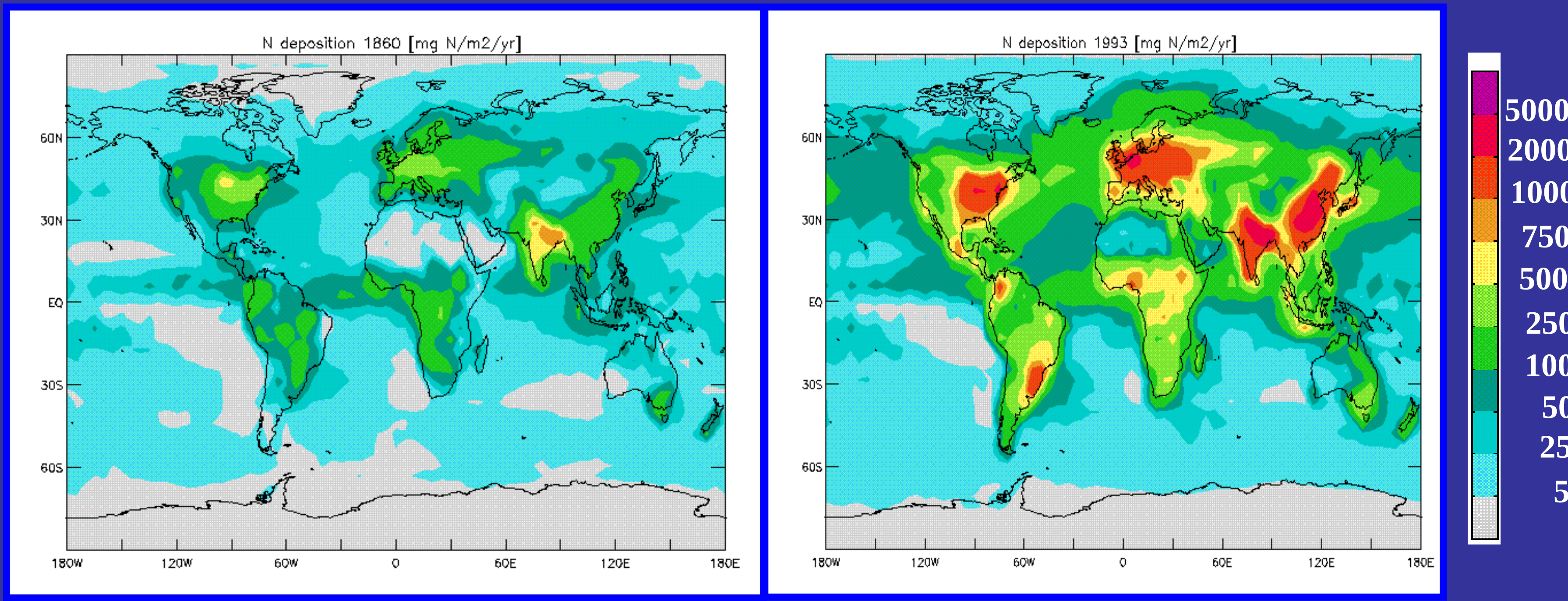
The 800-pound gorillas:

(1) Altered disturbance regimes

(2) Air pollution

Photo credits: NPS

- Acid deposition
- Nitrogen deposition
- Pesticides
- Particulates
- Ozone
- CO_2

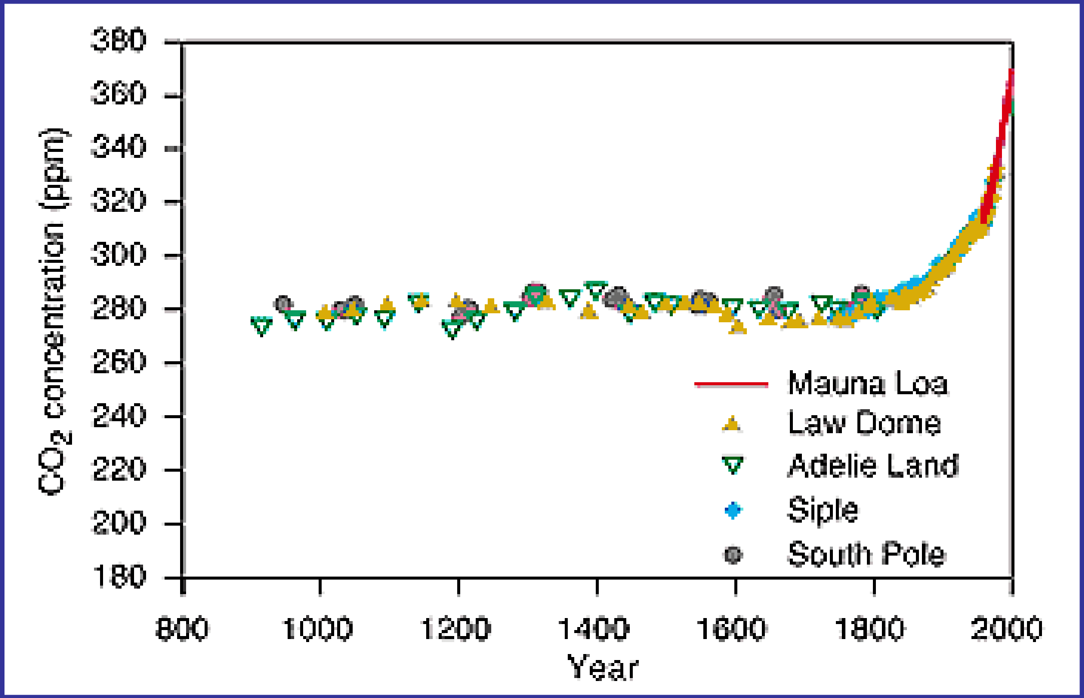


N deposition, 1860

N deposition, 1993

Humans now fix more biologically active nitrogen per year than is fixed by natural processes.

Galloway & Cowling 2002;
Galloway et al., 2002b



Current atmospheric CO_2 concentrations are the highest in at least the last 600,000 years, and probably in the last 20 million years.

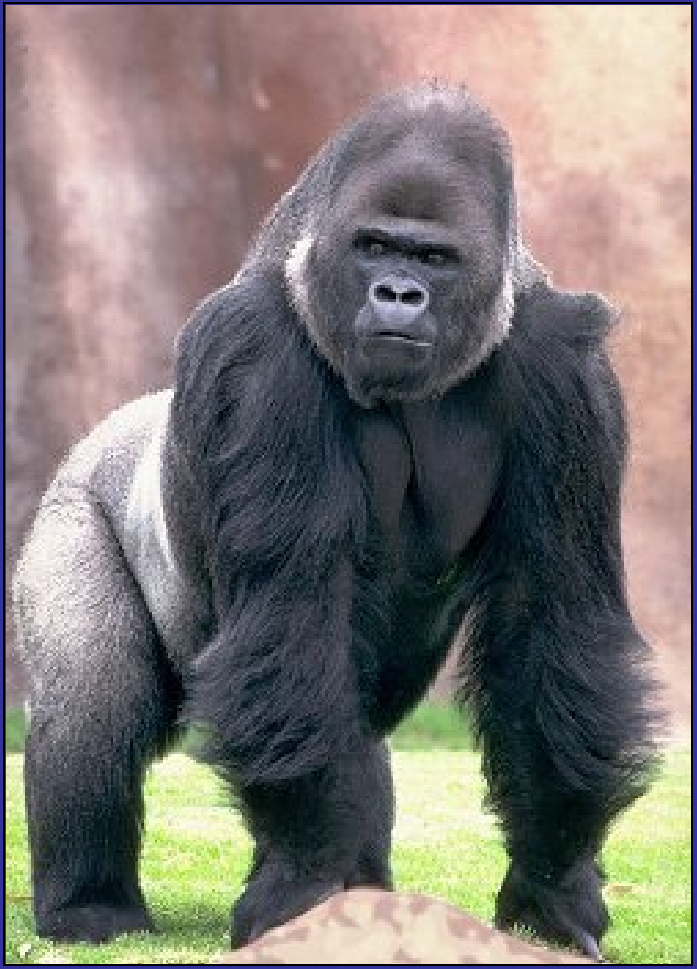
This will affect plant competition,
therefore community structure and composition.

The 800-pound gorillas:

(1) Altered disturbance regimes

(2) Air pollution

(3) Non-native invasive species



- Animals
- Plants
- Pathogens

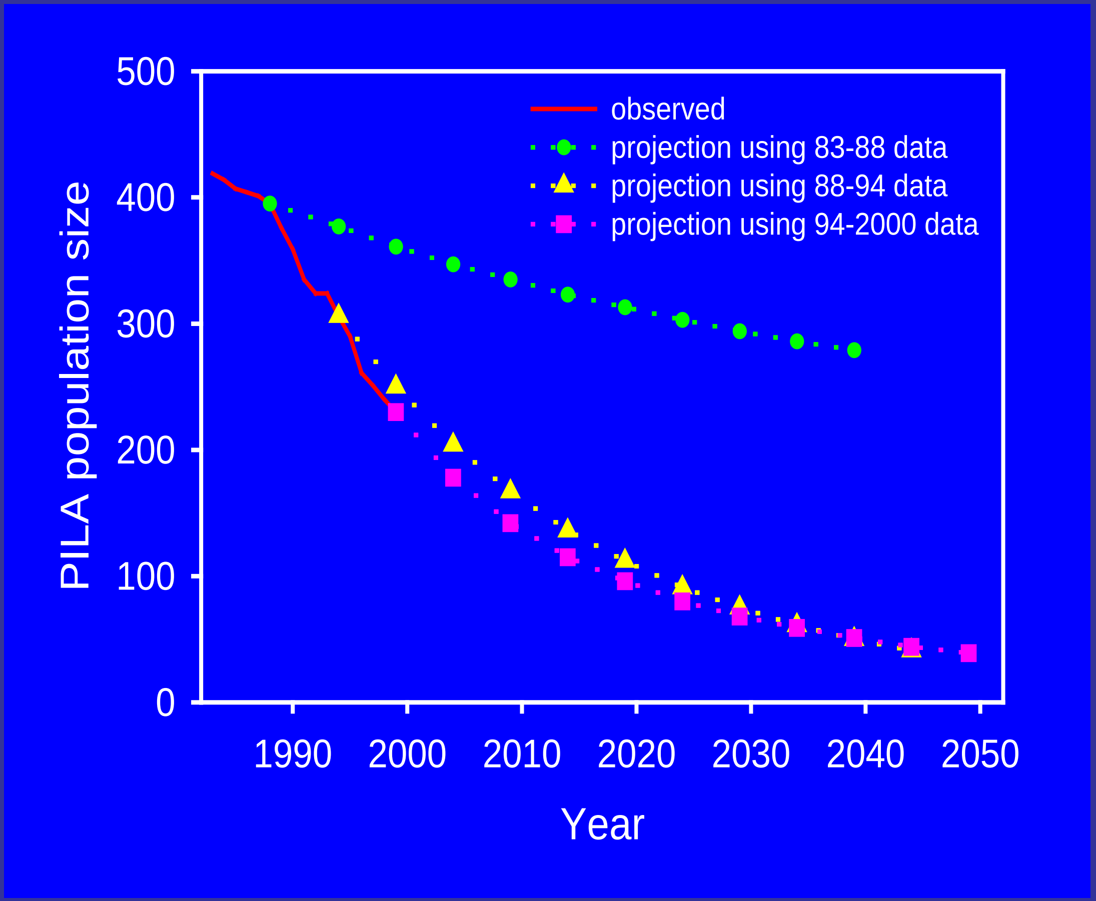
An example from the Mojave desert:

Invasion → altered fire regime → loss of natives

Credit: Todd Esque, USGS

An example from the Sierra Nevada:

White pine blister rust contributes to sugar pine loss



van Mantgem et al. *Ecol. Appl.* 2004

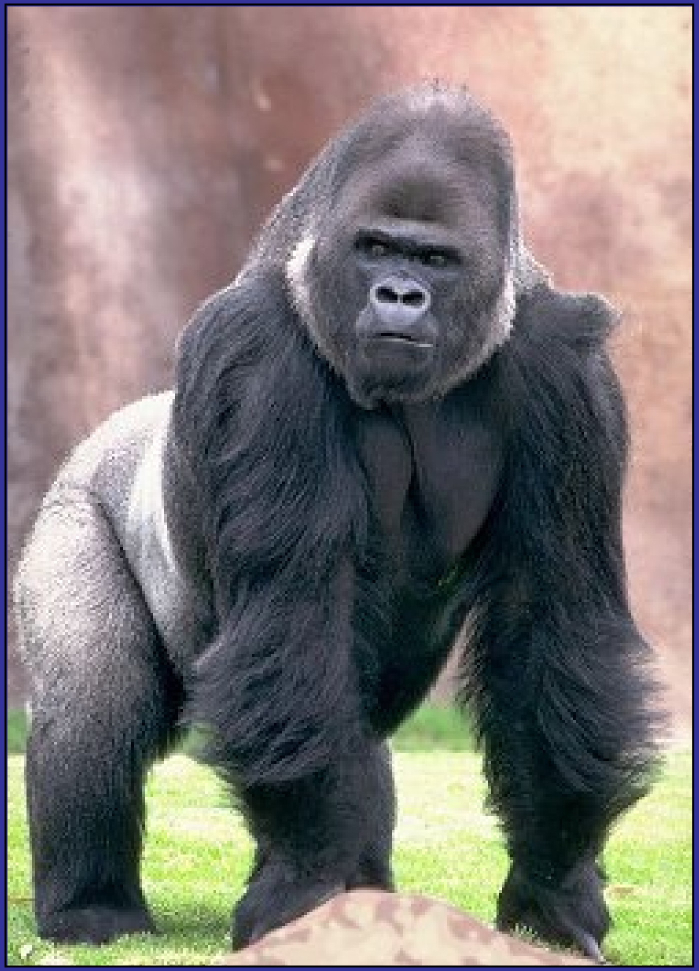
The 800-pound gorillas:

(1) Altered disturbance regimes

(2) Air pollution

(3) Non-native invasive species

(4) Habitat fragmentation



- Reduced gene flow
- Disrupted metapopulation dynamics
- Habitats too small for viable populations
- Barriers to species reintroductions
- Road kill

The 800-ton gorilla:

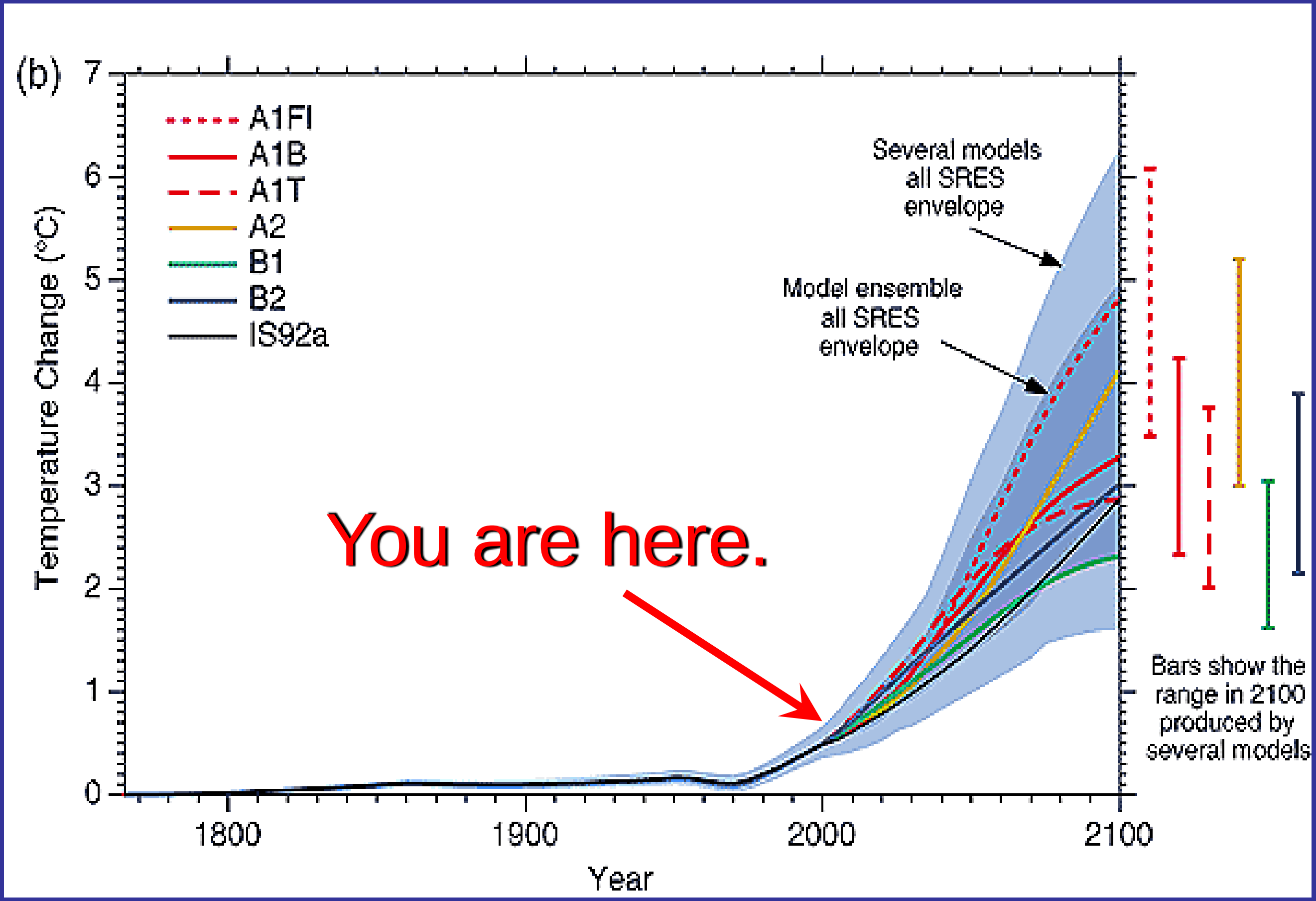
(1) Altered disturbance regimes

(2) Air pollution

(3) Non-native invasive species

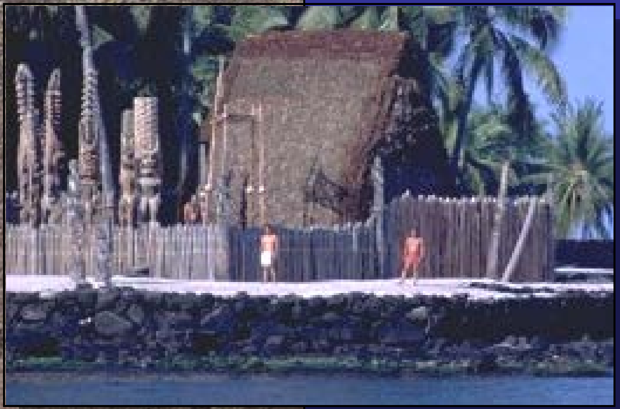
(4) Habitat fragmentation

(5) Rapid climatic change


(b)
A1FI
A1B
A1T
A2
B1
B2
IS92a
Several models all SRES envelope
Model ensemble all SRES envelope
You are here.
Bars show the range in 2100 produced by several models
Temperature Change (°C)
Year
0
1
2
3
4
5
6
7
1800
1900
2000
2100

Source: IPCC

Warming, rising oceans create unprecedented problems.



Source: Australian Inst. Marine Science

Source: NPS / PWRO GIS

Mountain snowpack will diminish significantly, and timing of peak stream flow will advance

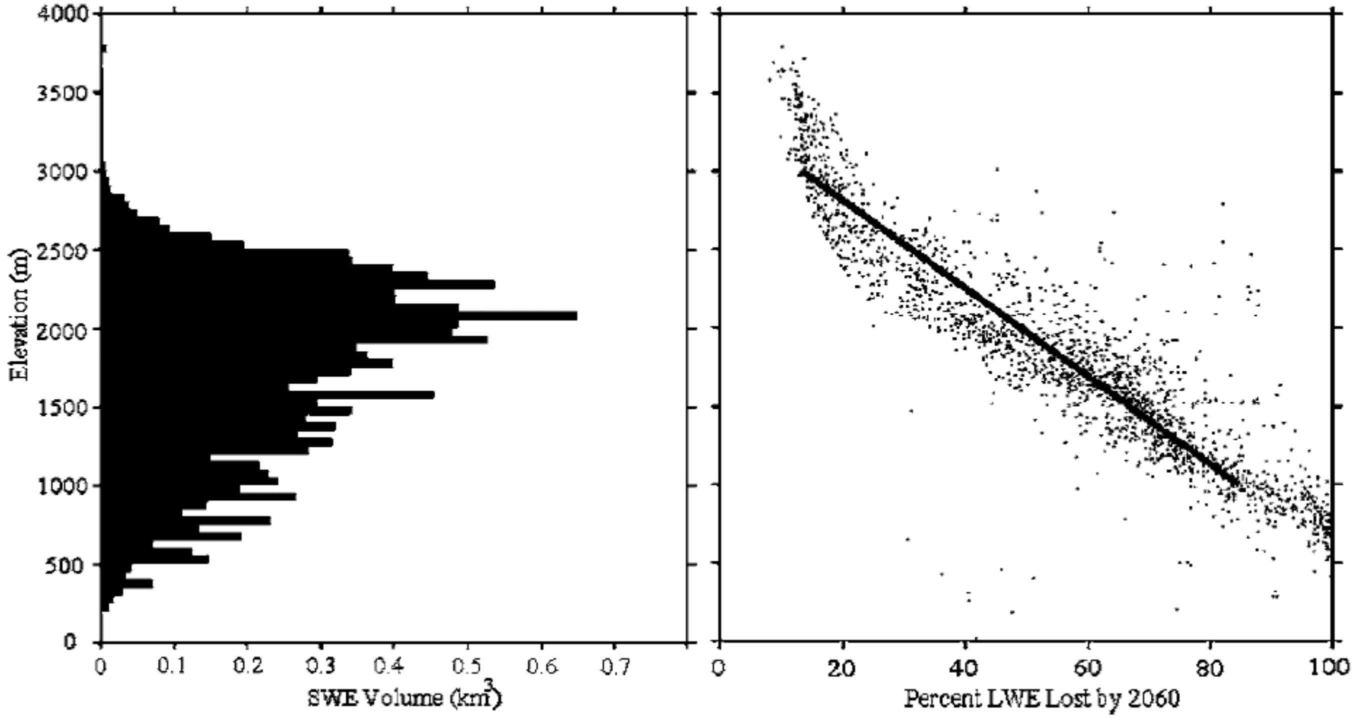


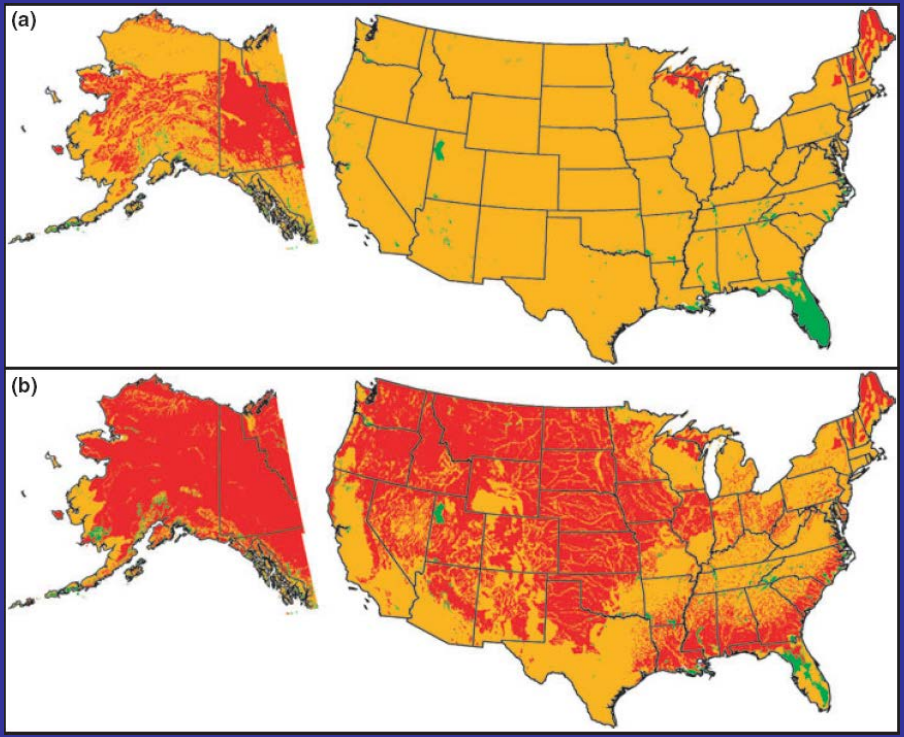
Figure 5. Left: Distribution of present-day April snow water equivalent volume versus elevation, in 50 m bins. Right: Percent of April snowpack lost due to projected global warming by 2060, versus elevation, for the Sierra-Nevada region.

Knowles & Cayan 2004, *Clim. Change*

Many contemporary environments will disappear ...

2100:
Moderate-emissions scenario

2100:
High-emissions scenario



Saxon *et al.* 2005, *Ecol. Lett.*

Red = environments that disappear from U.S.

Orange = environments that decrease in U.S.

Green = environments that increase in U.S.

... and no-analog environments will appear

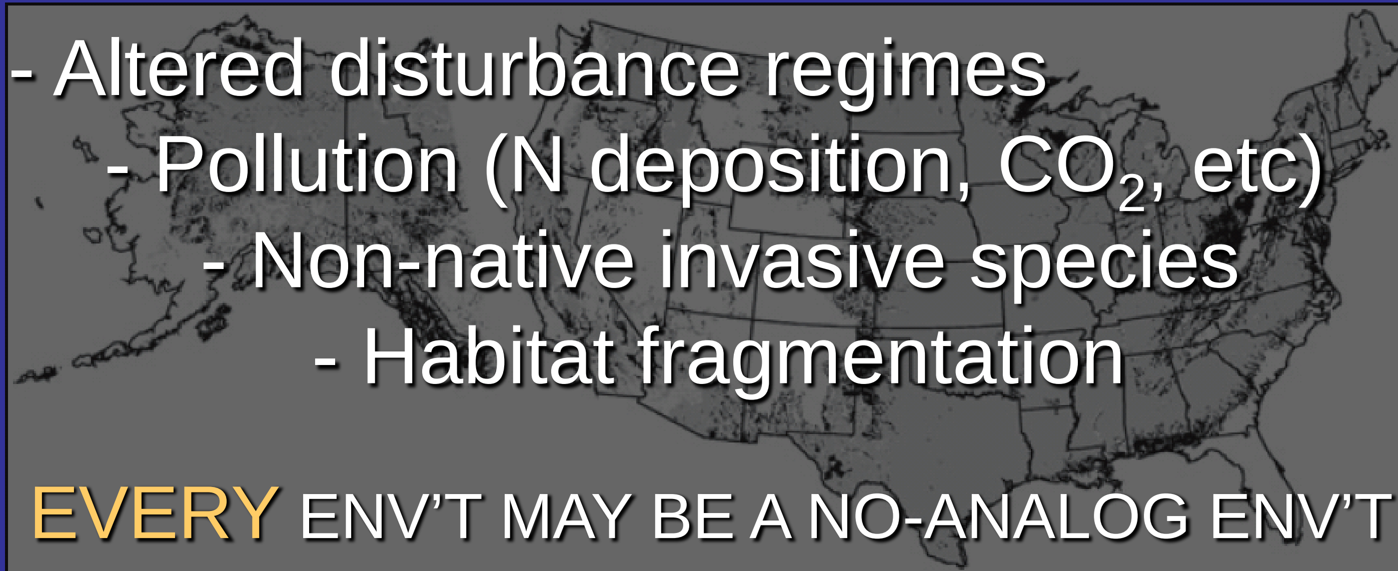
Saxon *et al.* 2005, *Ecol. Lett.*

White = environments with a current analog in U.S.

Gray = environments without current analog in U.S., under both emissions scenarios

Black = environments without current analog in U.S., under high emissions scenario

... and no-analog environments will appear



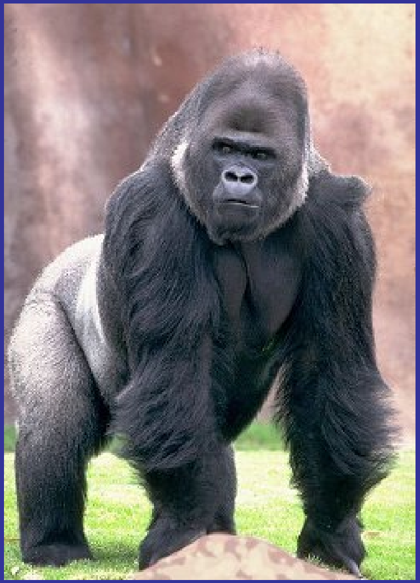
Saxon *et al.* 2005, *Ecol. Lett.*

White = environments with a current analog in U.S.

Gray = environments without current analog in U.S., under both emissions scenarios

Black = environments without current analog in U.S., under high emissions scenario

What does it all mean?



This: Current and future environmental conditions *have no precedent*. It is no longer possible to restore and maintain naturally-functioning ecosystems, nor to conserve them unimpaired.

C. WE CAN NO LONGER USE THE PAST AS A TARGET FOR RESTORATION AND MANAGEMENT, NOR DEPEND ON NATURAL PROCESSES ALONE

In fact, if we try to maintain "natural" ecosystems, we might sometimes unwittingly promote conditions that are inherently unstable in the face of novel stresses, leading to the sudden, catastrophic loss of resources we are trying to preserve.

Key concept: thresholds.


I like managing ecosystems!

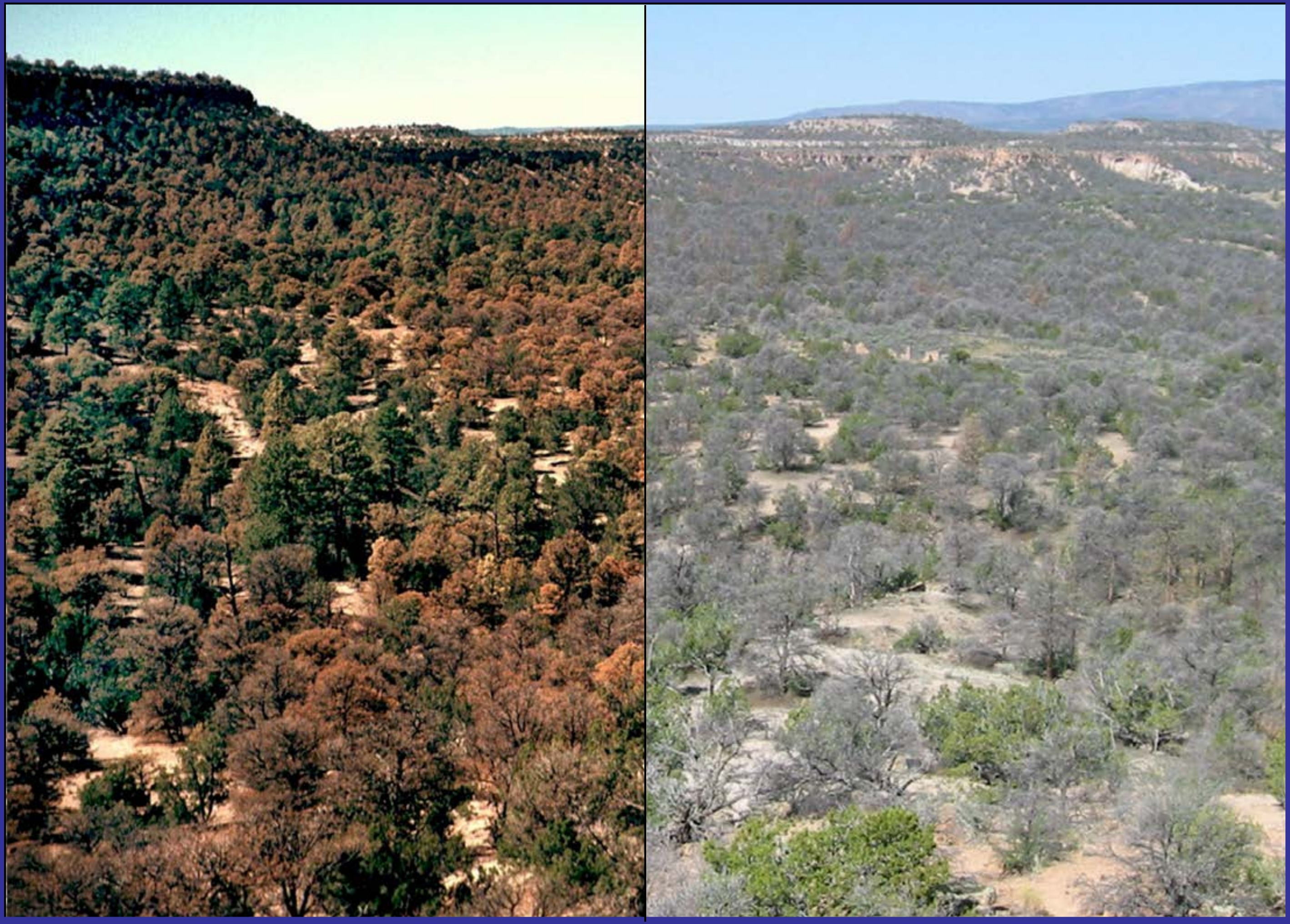

Uh oh! Rough water. … Let me put things back the way they were! *
* … or let me sit back and watch natural processes sort things out on their own!


Honest, I can hold it all together!


There goes my promotion to SES.

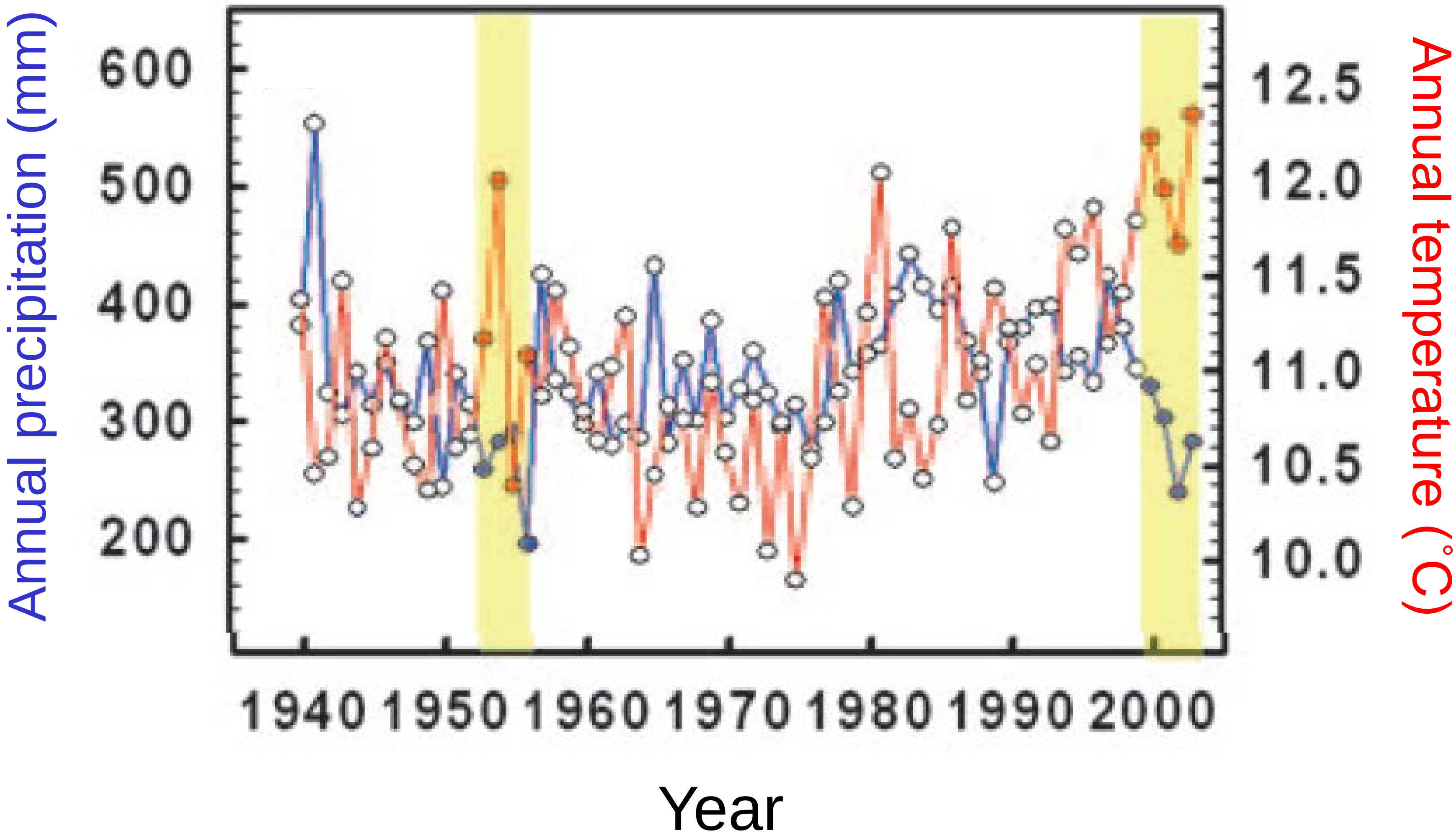
A recent example of a threshold response:

The massive pinyon pine die-off in the Southwest



Credit: Craig Allen & NSF

The drought was not exceptional (it was wetter than the 1950s drought), but the temperature was higher



Breshears *et al.* 2005, *PNAS*

II. The future will be characterized by massive yet largely unpredictable changes, and some unpleasant surprises.

A. We cannot precisely predict the future.

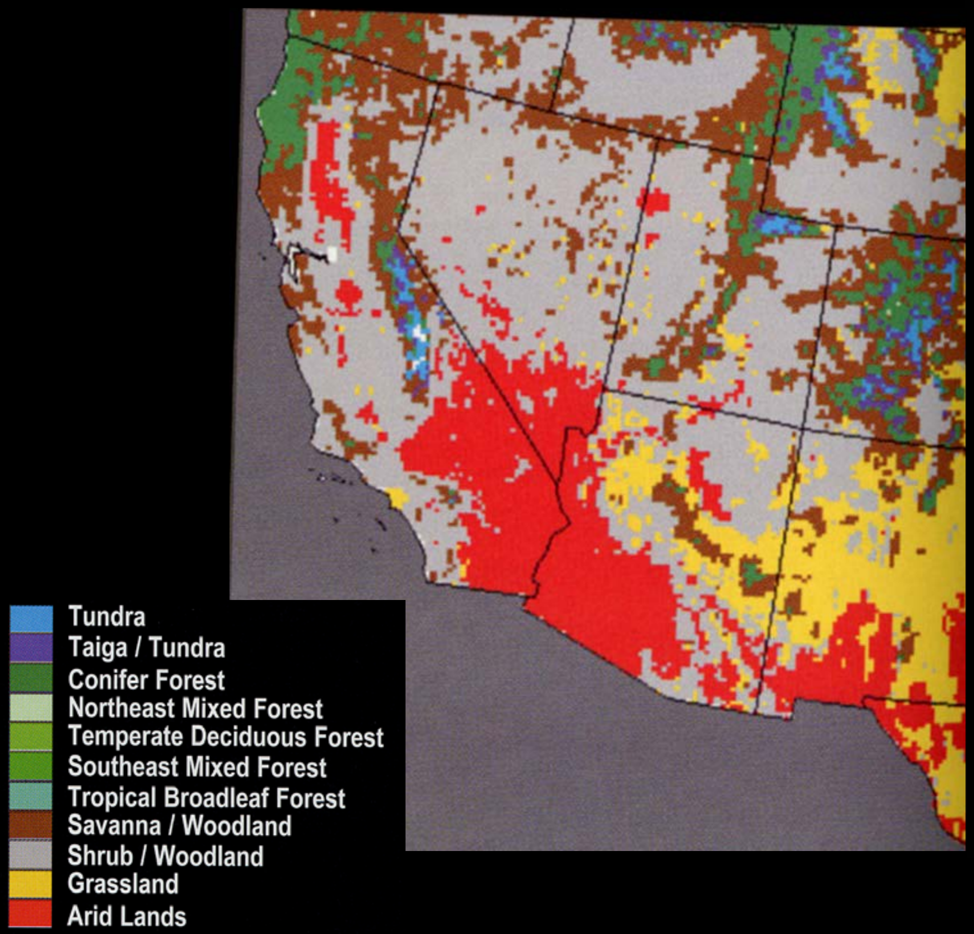
B. Threshold responses will lead to surprises.

C. Species ranges and phenologies will shift, and biotic communities will dissociate in space and time.

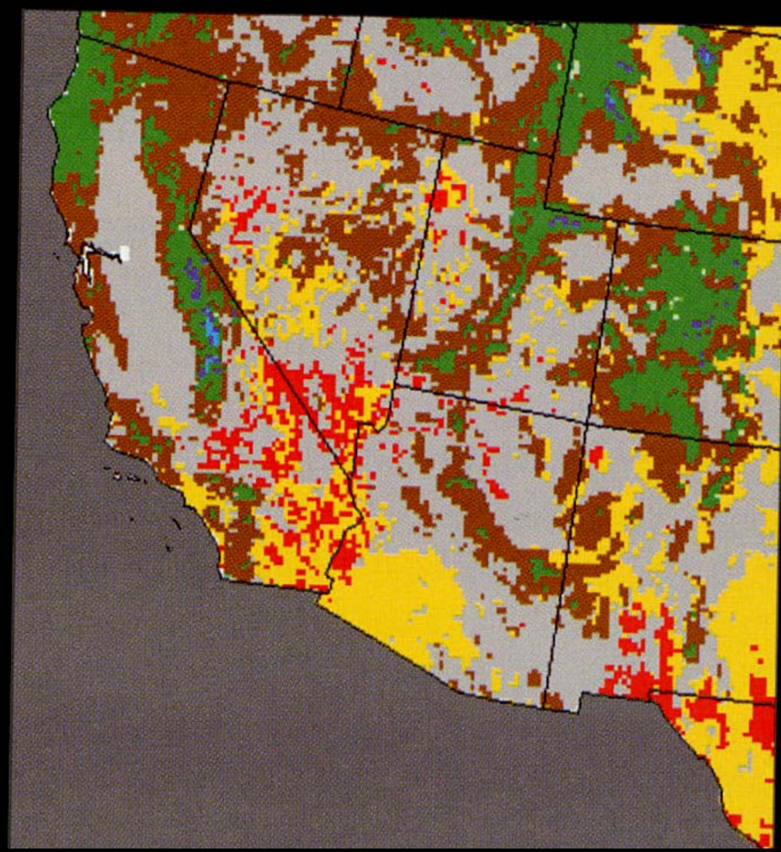
A. WE CANNOT PREDICT THE FUTURE

Can’t we just start managing for projected future conditions?

Current

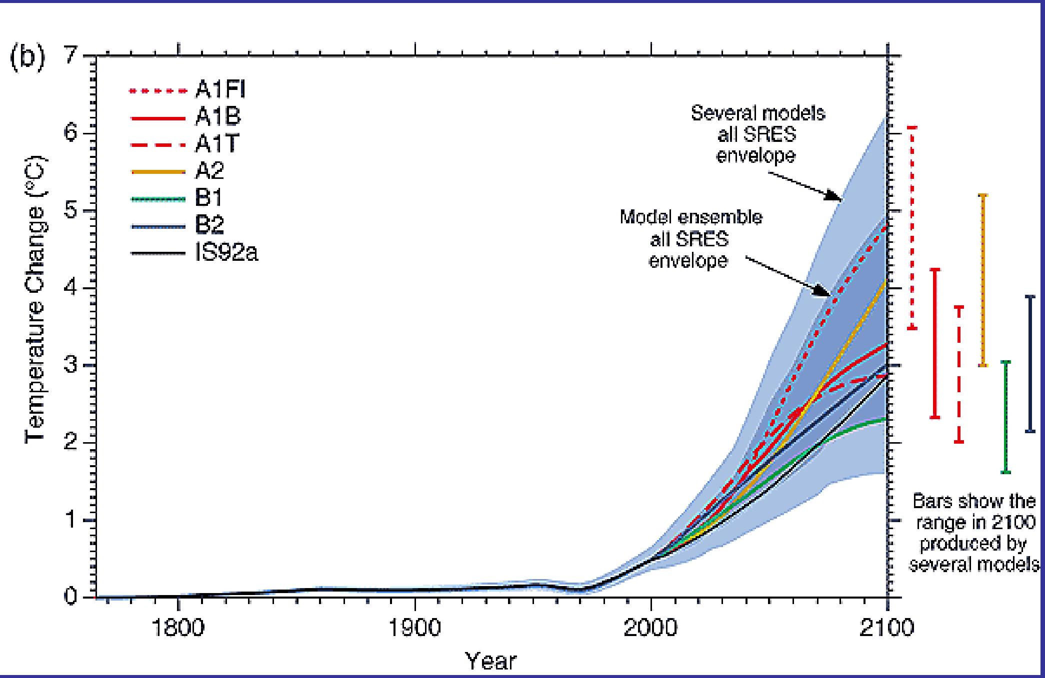


Projected



Source: National Assessment and Synthesis Team

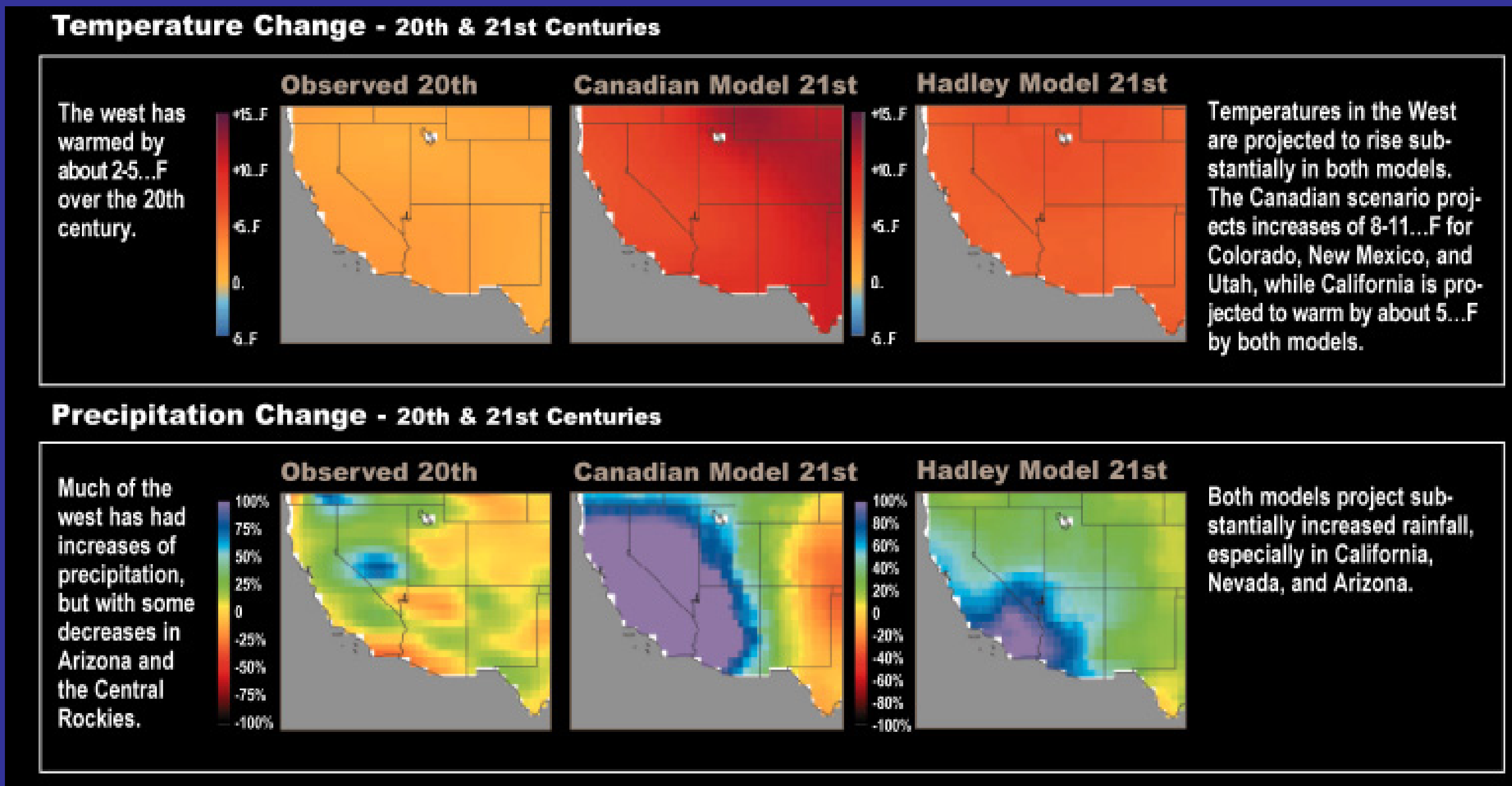
The IPCC used 35 scenarios (combinations of climate models and possible future greenhouse gas emissions) to project possible future *global* temperatures:



Source: IPCC

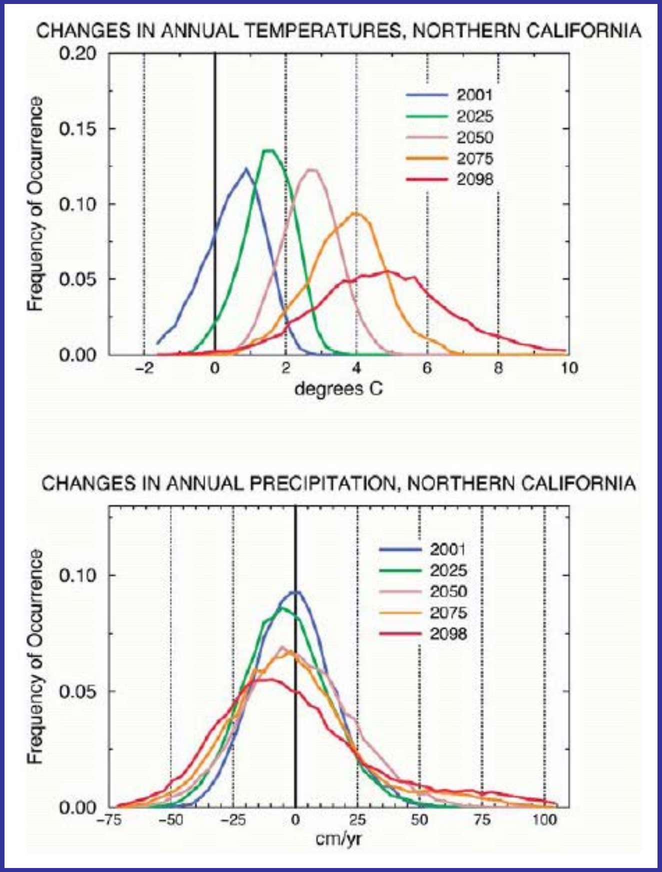
Reality will probably match none of these.

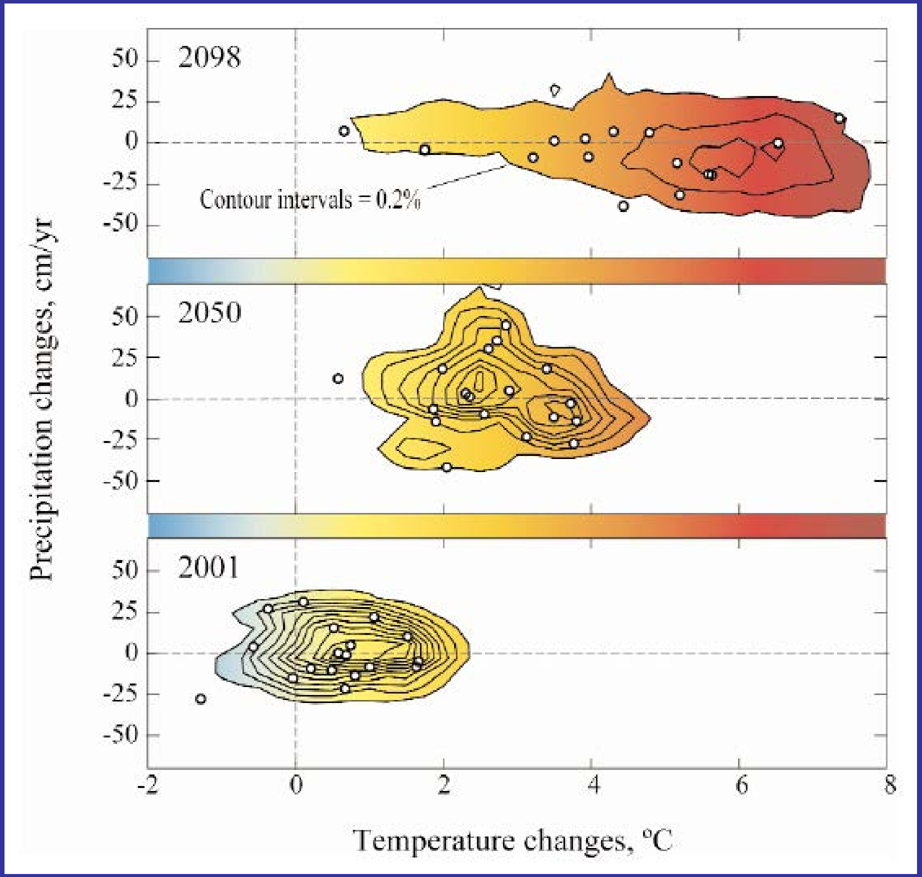
Our ability to project future climates is worse at the regional and local scales important to land managers, and especially for precipitation changes!



Source: National Assessment and Synthesis Team

Results of (only) 18 future scenarios for northern California:



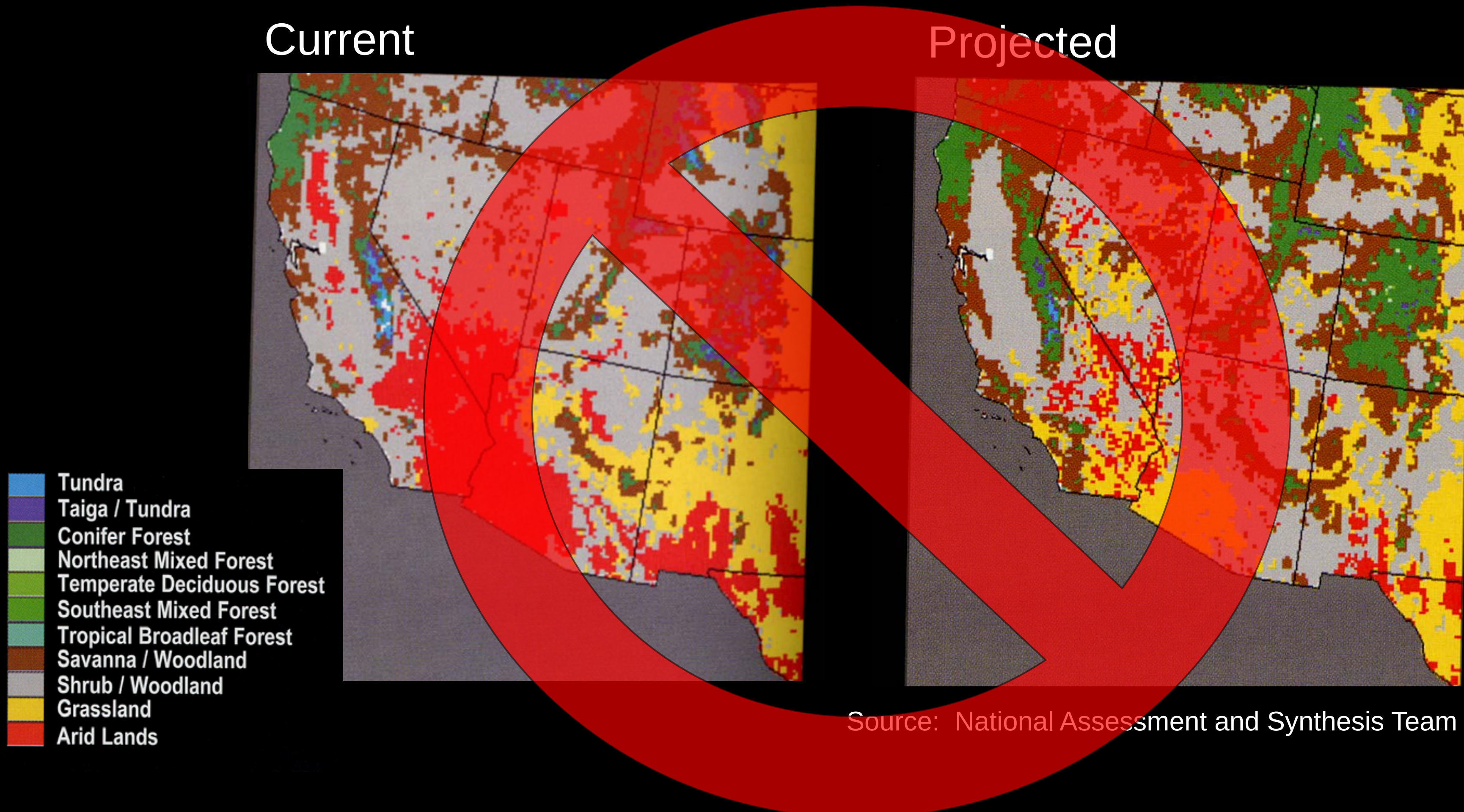


Dettinger 2005

CONCLUDE: The future is *quite likely to be substantially warmer*, but we don't know by how much or how quickly. The future *may be either wetter or drier*, with unknown changes in seasonality.

The really bad news: OUR BIOLOGICAL MODELS ARE **MUCH** LESS CERTAIN THAN OUR CLIMATE MODELS!

(Not to mention that the number of possible climate-vegetation scenarios balloons out of control: e.g., 35 climate x 10 veg. = 350 scenarios)



Source: National Assessment and Synthesis Team

Compound these uncertainties with the largely unknown, interacting effects of novel stresses (the 800-pound gorillas, plus any new gorillas), and we are left to conclude:

Over the next century, climatic and biotic changes are virtually certain to be profound, but in ways we largely can't predict.

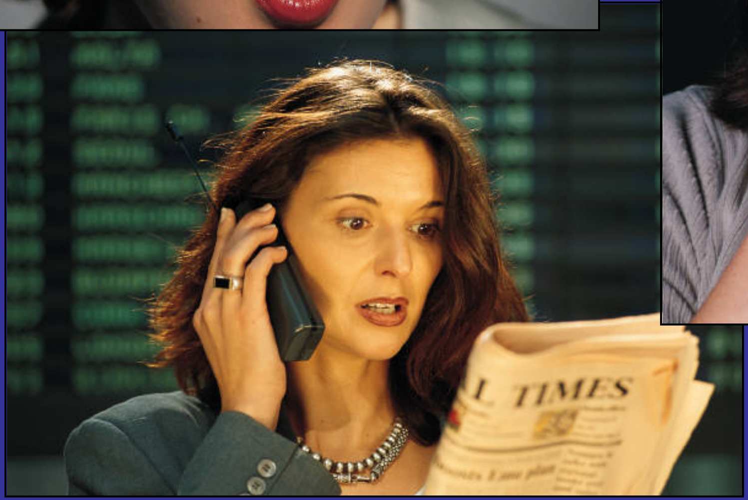
Compound these uncertainties with the largely unknown, interacting effects of novel stresses (the 800-pound gorillas, plus any new gorillas), and we are left to conclude:

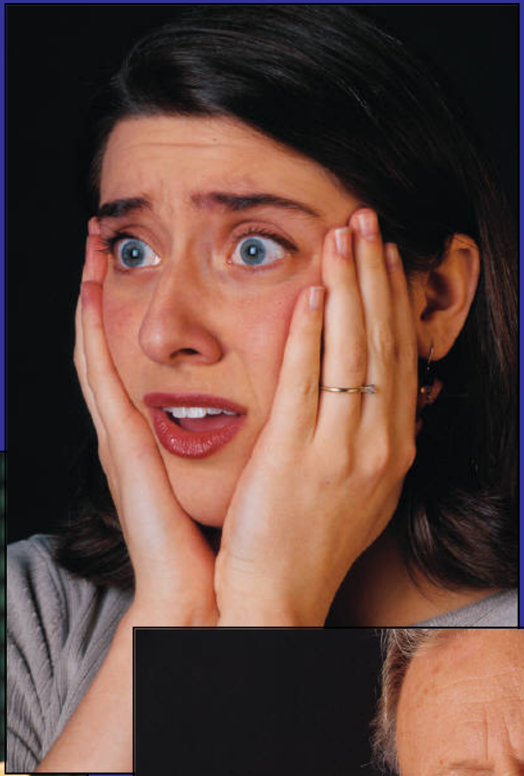
Over the next century, climatic and biotic changes are virtually certain to be profound, but in ways we largely can't predict.

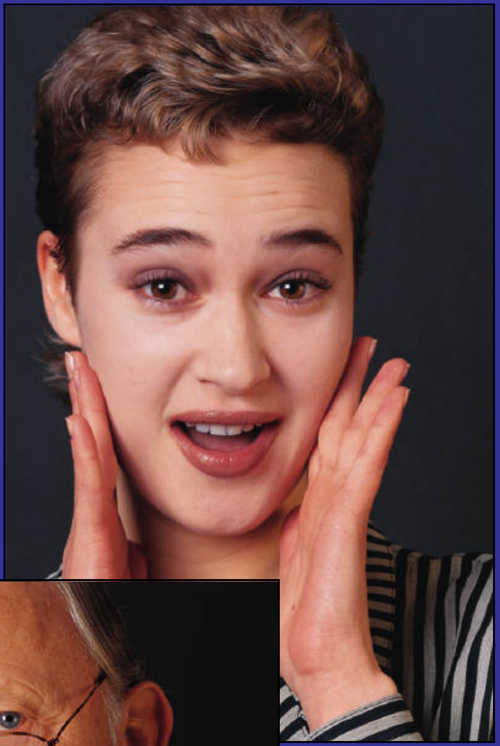
... But we must not forget some qualitative predictions that are highly likely to be correct, such as:

- -- Most places will get warmer.
- -- Snow pack will diminish in most (all?) places.
- -- Fire season will become longer and more severe in some (most?) places.
- -- Sea level will rise.

B. THRESHOLD RESPONSES WILL LEAD TO SURPRISES







Catastrophes are notoriously difficult to predict.

Humans designed every square inch of the space shuttle, which is VASTLY simpler than planet Earth.

Source: NASA

Catastrophes are notoriously difficult to predict.

Humans designed every square inch of the space shuttle, which is VASTLY simpler than planet Earth.

Pre-Challenger, engineers calculated the chance of a catastrophic failure as 1 in 10,000.

Source: NASA

Catastrophes are notoriously difficult to predict.

Humans designed every square inch of the space shuttle, which is VASTLY simpler than planet Earth.

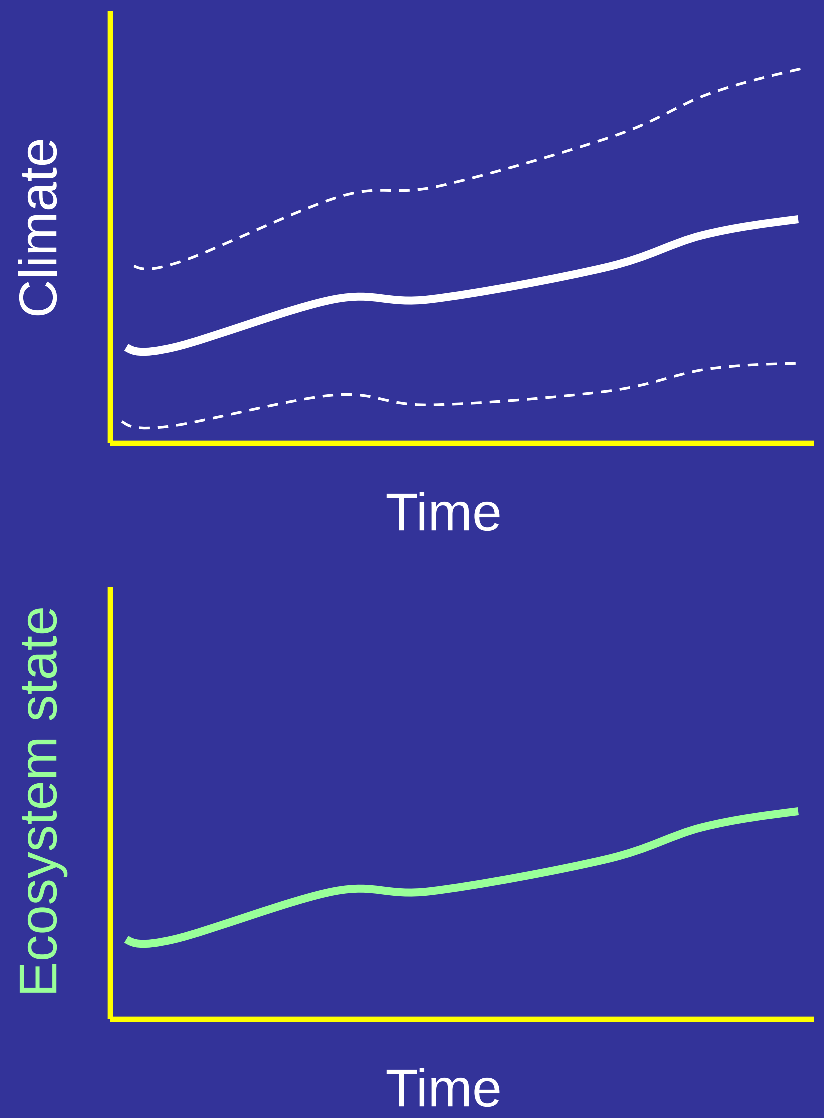
Pre-Challenger, engineers calculated the chance of a catastrophic failure as 1 in 10,000.

Source: NASA

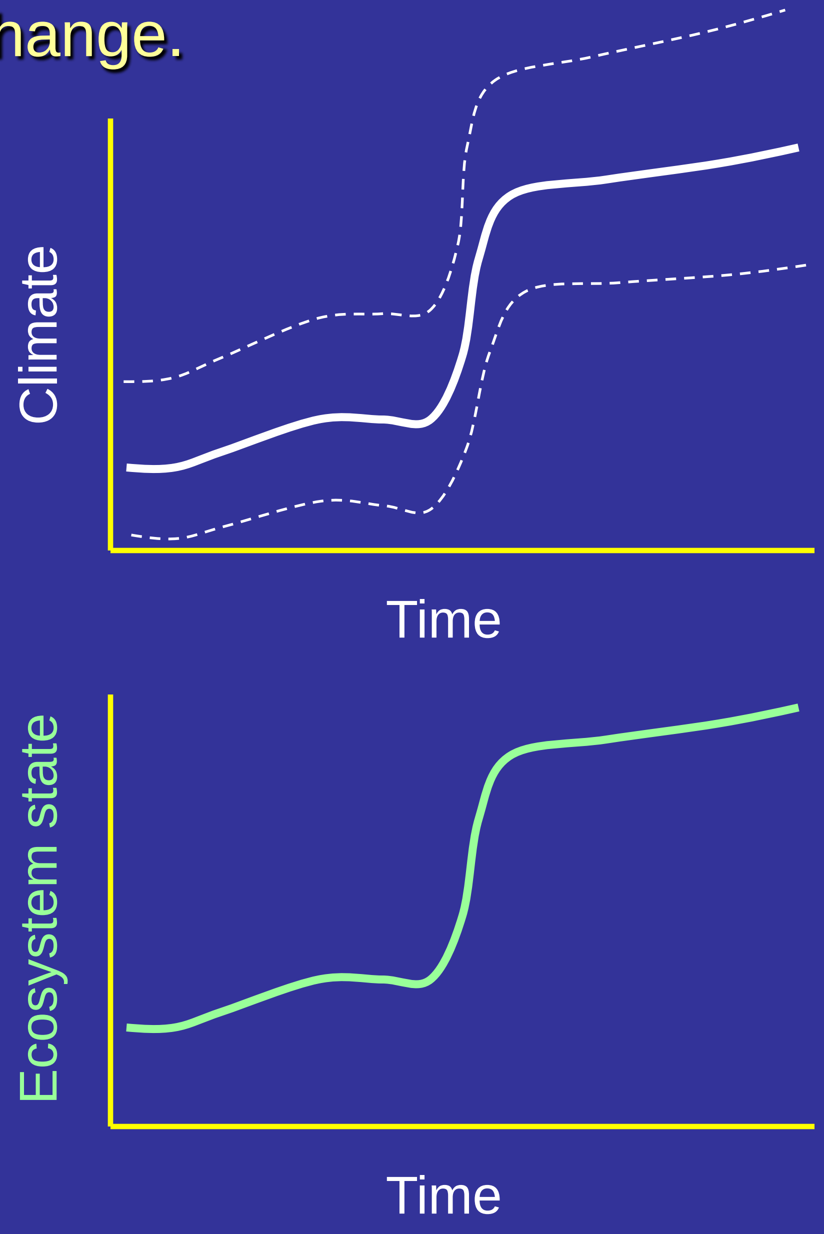
Post-Challenger, with new information, they re-calculated the chance as 1 in 100.

EARTH'S CLIMATE AND BIOTA
ARE VASTLY MORE COMPLEX
AND POORLY UNDERSTOOD

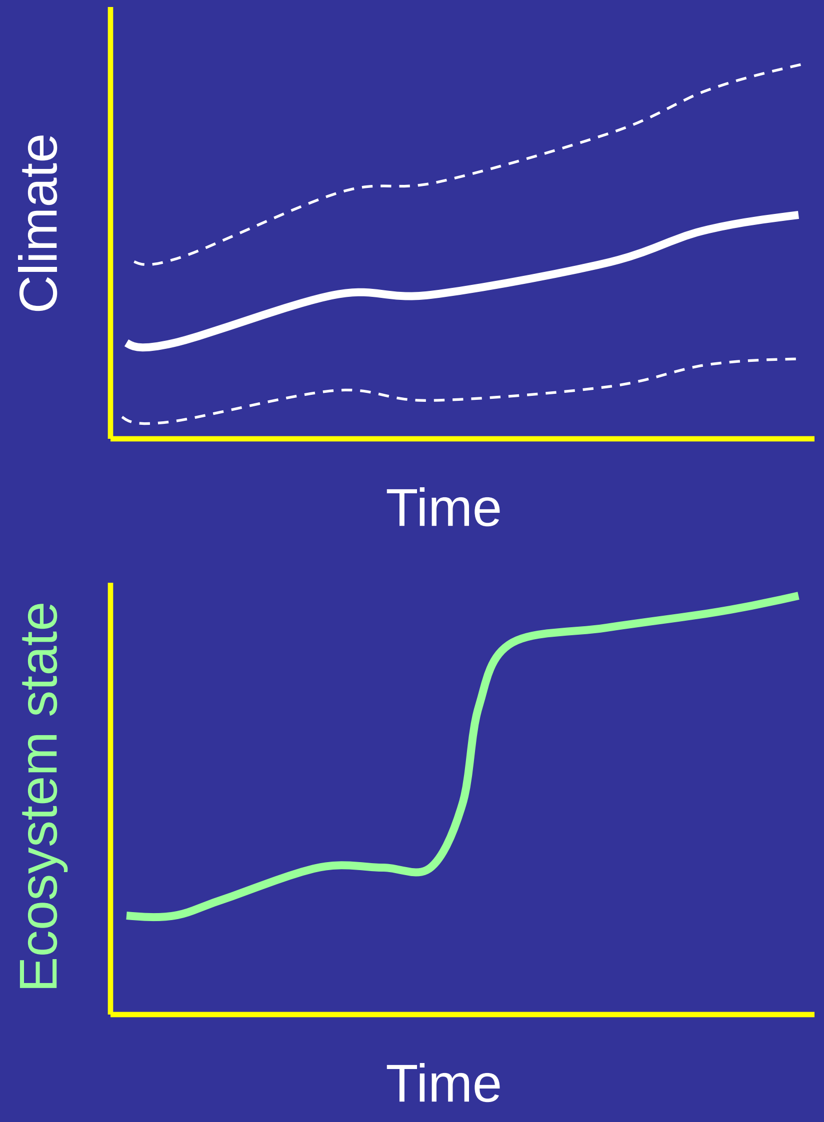
Current thinking often emphasizes gradual changes.



However, abrupt climatic change can lead to abrupt ecosystem change.



Perhaps more surprising, gradual climatic change may trigger abrupt ecosystem change (threshold response).



Already, climate has been linked to episodes of sudden, broad-scale forest die-back in the West

Warming + drought
(e.g., southern Calif.)

Credit: USFS

Warming
(e.g., British Columbia)

Credit: BC Ministry of Forests and Range

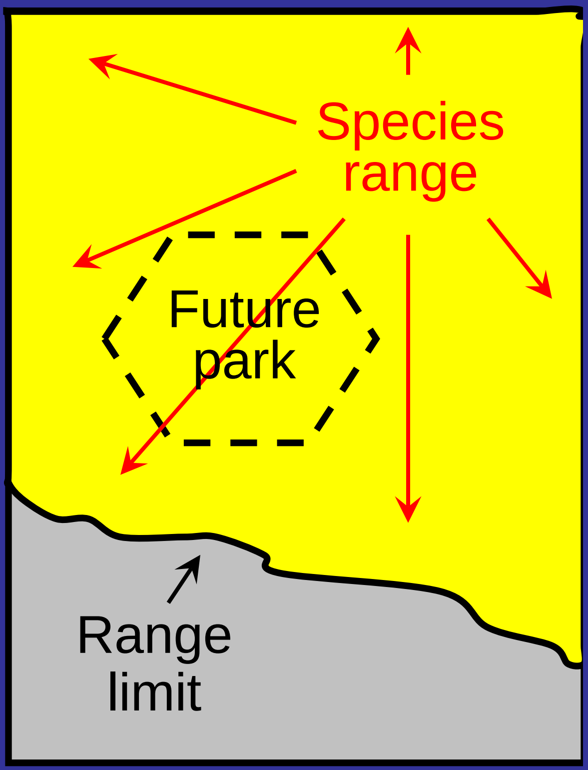
This could lead to cascading threshold events, such as
(2) bigger and more severe wildfires,
(3) subsequent soil loss, and
(4) irreversible conversion of ecosystems.

And in general, climatic extremes are expected to increase in magnitude and frequency

C. SPECIES WILL SHIFT, AND BIOTIC COMMUNITIES WILL DISSOCIATE IN SPACE AND TIME

Some consequences of range shifts

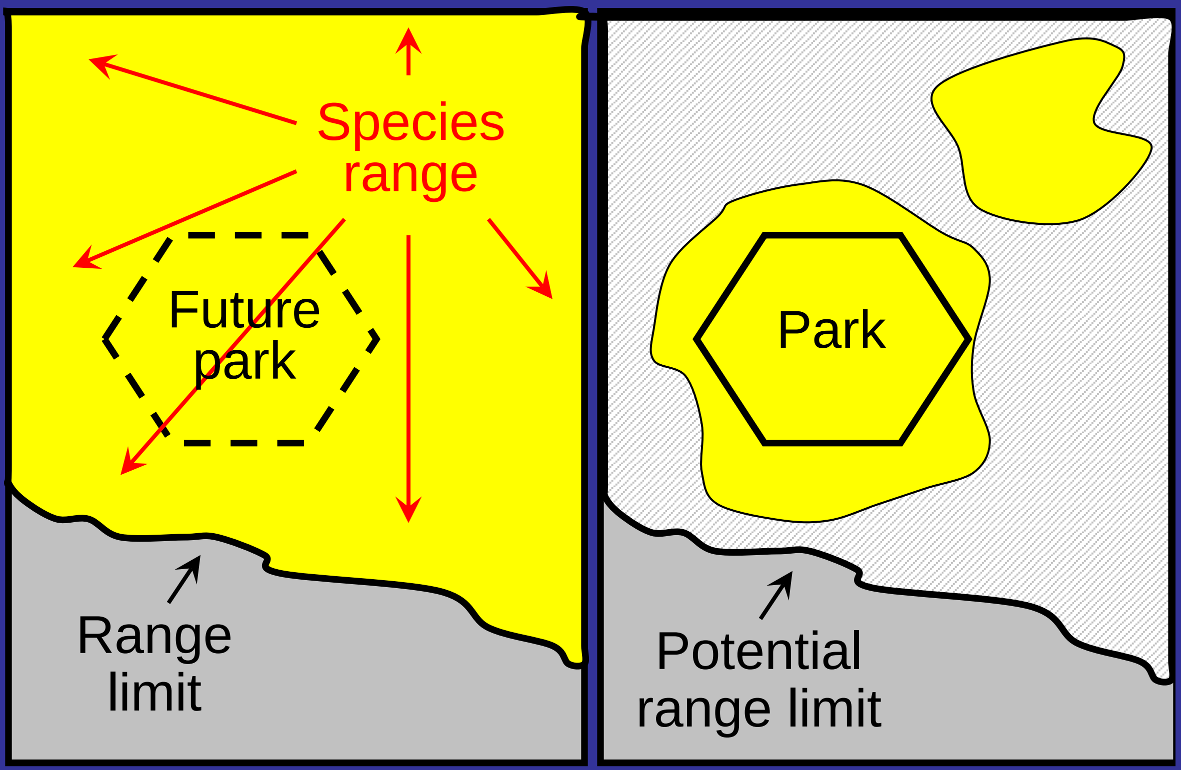
(1) Many current parks will become unsuitable



After Peters (1992)

Some consequences of range shifts

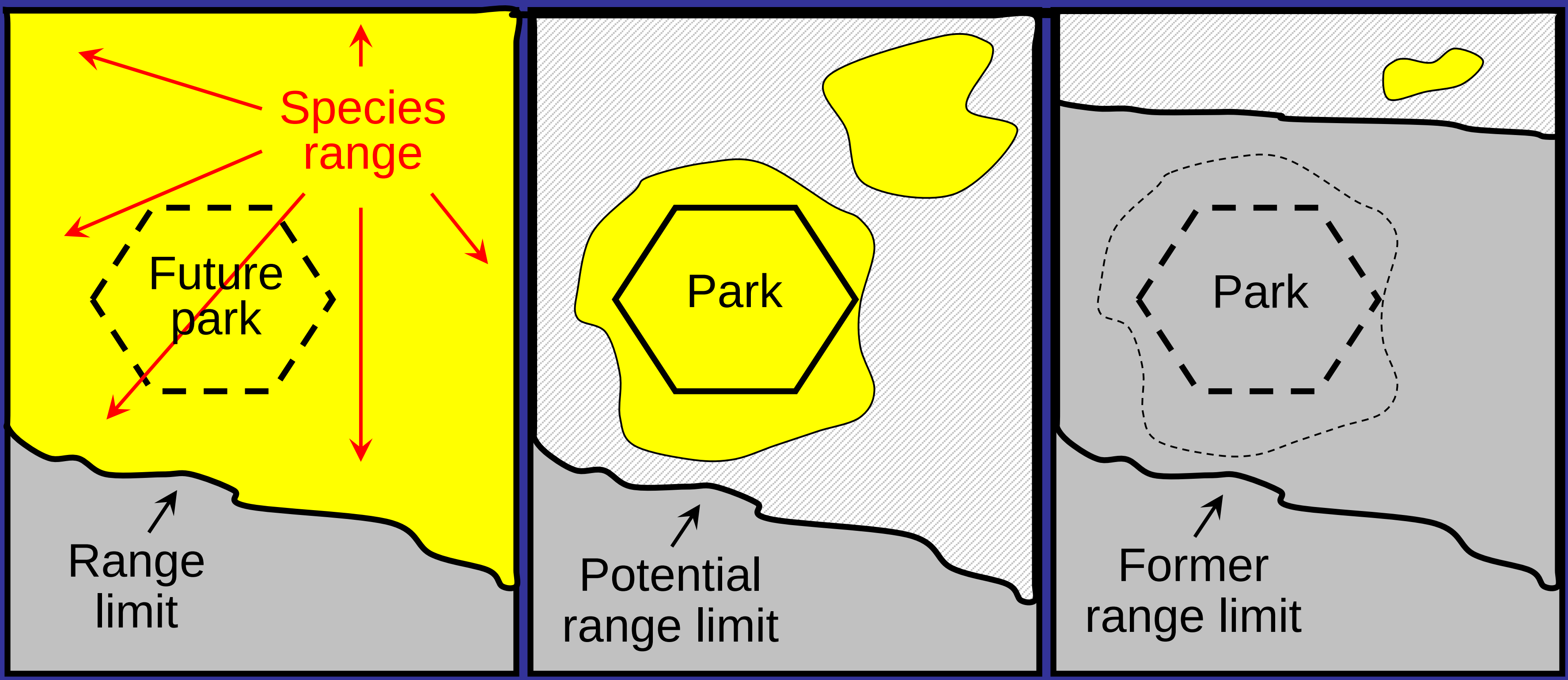
(1) Many current parks will become unsuitable



After Peters (1992)

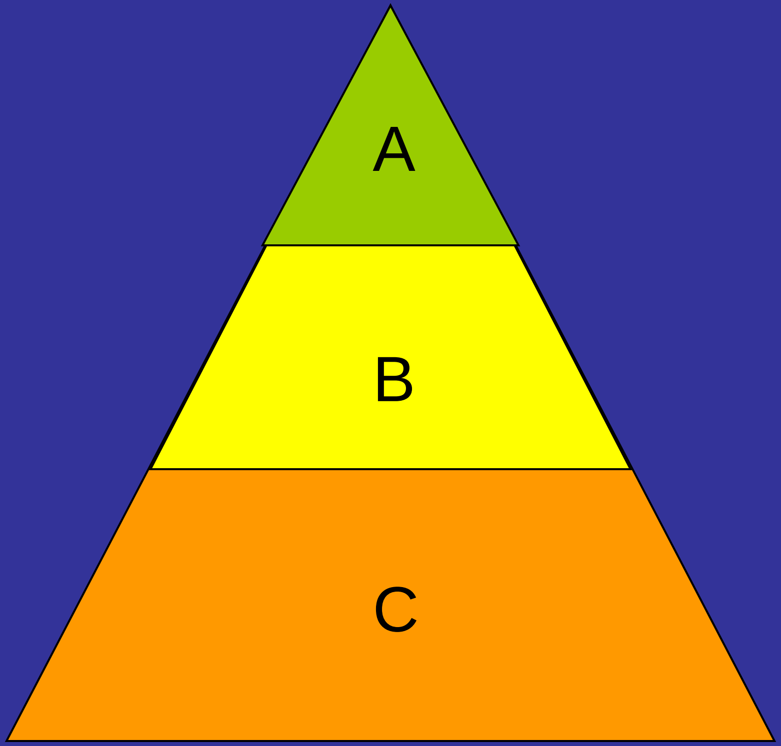
Some consequences of range shifts

(1) Many current parks will become unsuitable



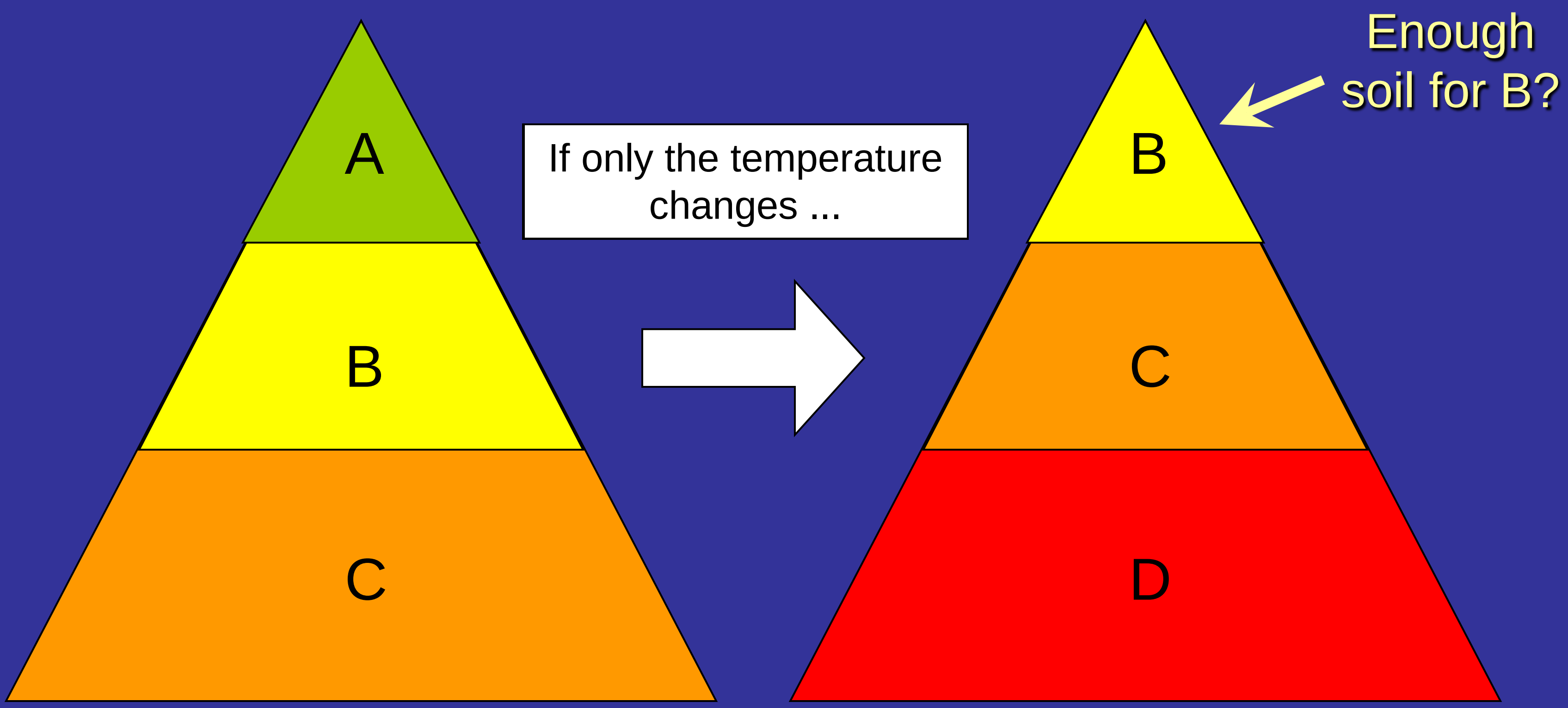
After Peters (1992)

Can mountain parks save the day?



After Peters (1992)

Only when mountains and the organisms of interest coincide, and even then only sometimes.



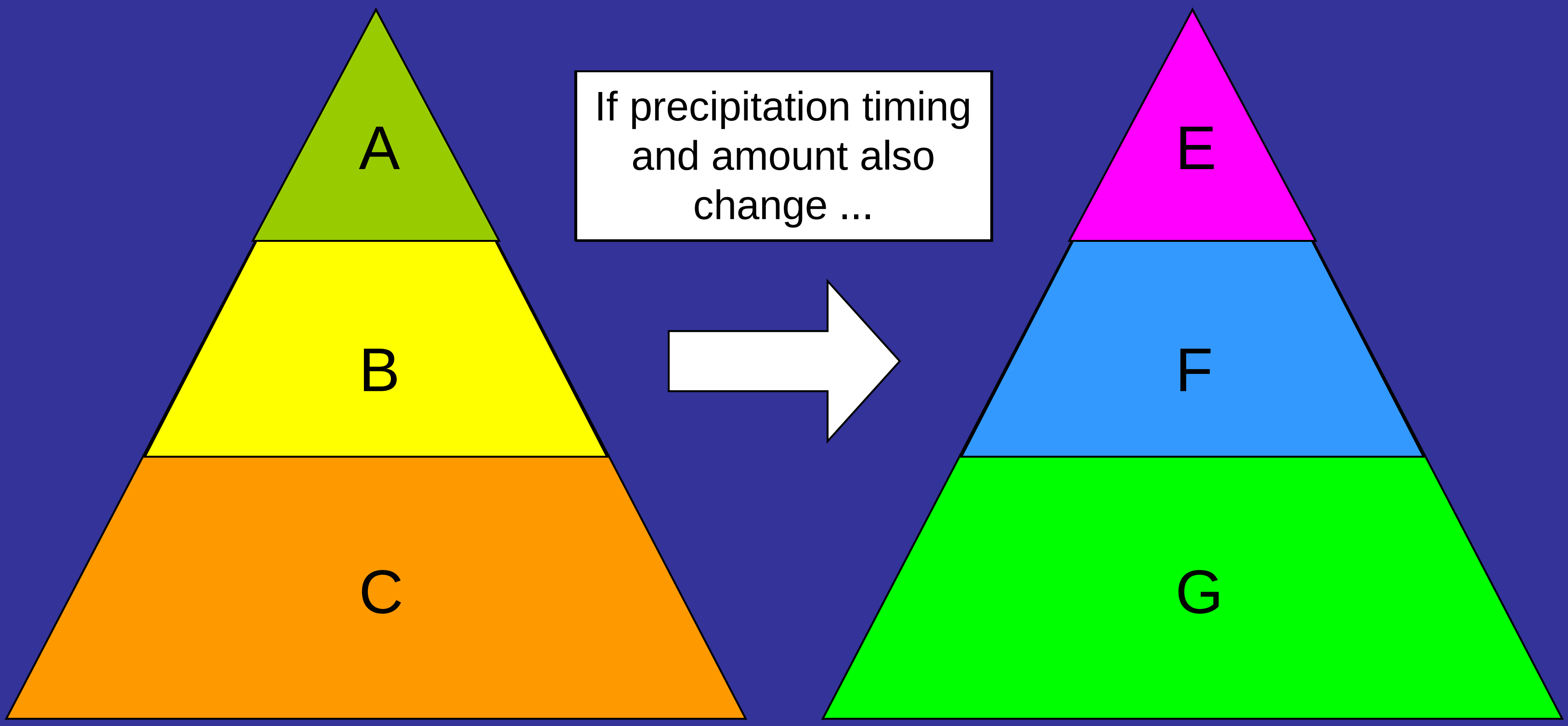
After Peters (1992)

Making it real for the Sierra, ~100 to 150 years from now:

Can this ...

... become established and thrive here?

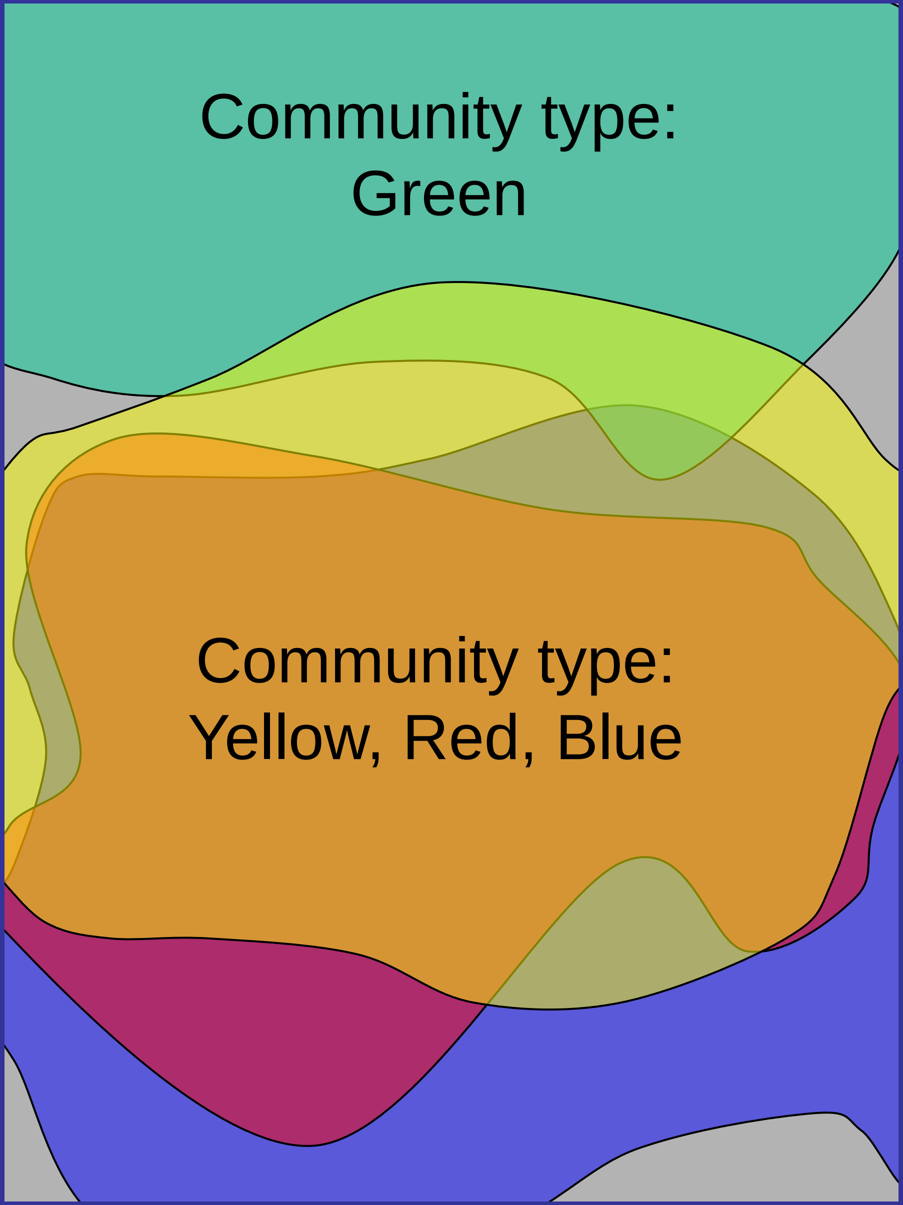
A more likely scenario ...

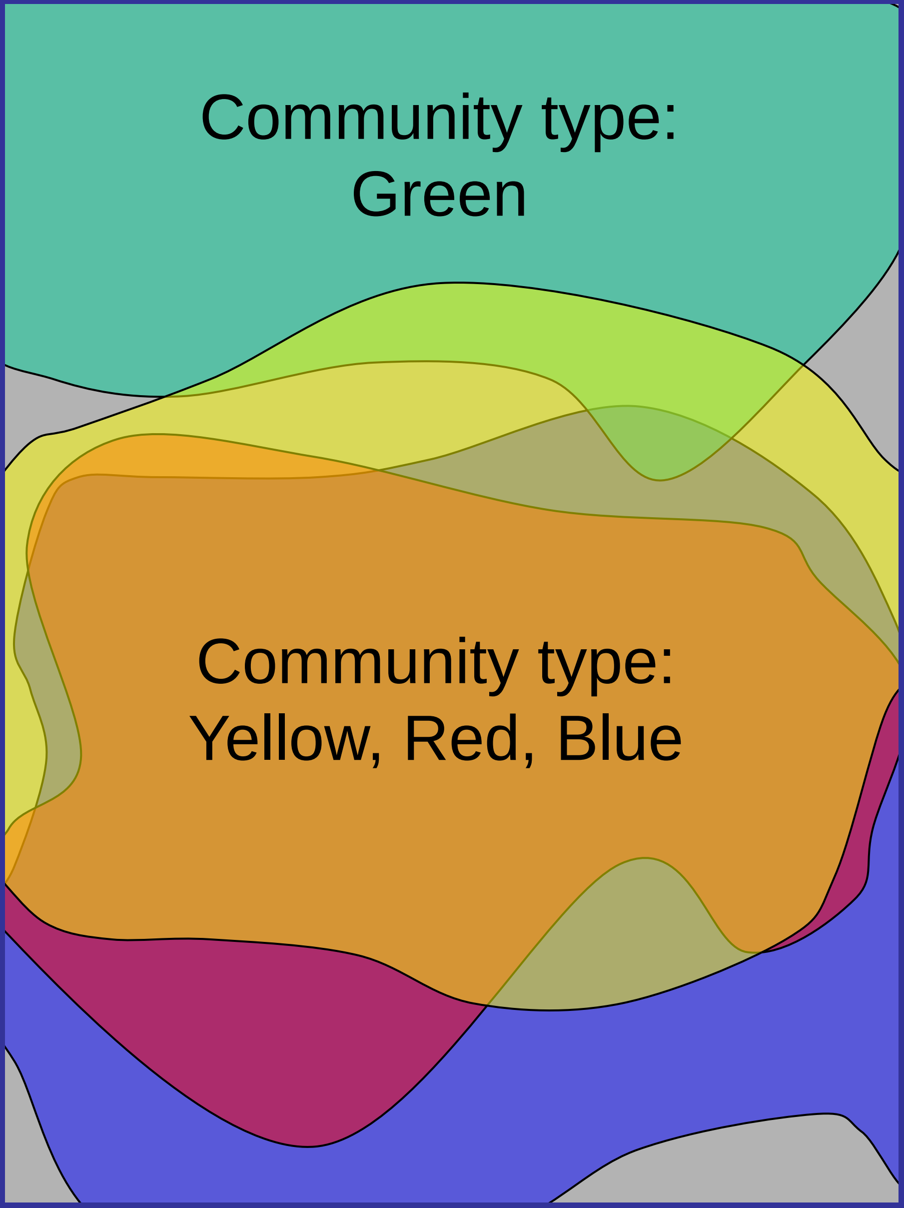


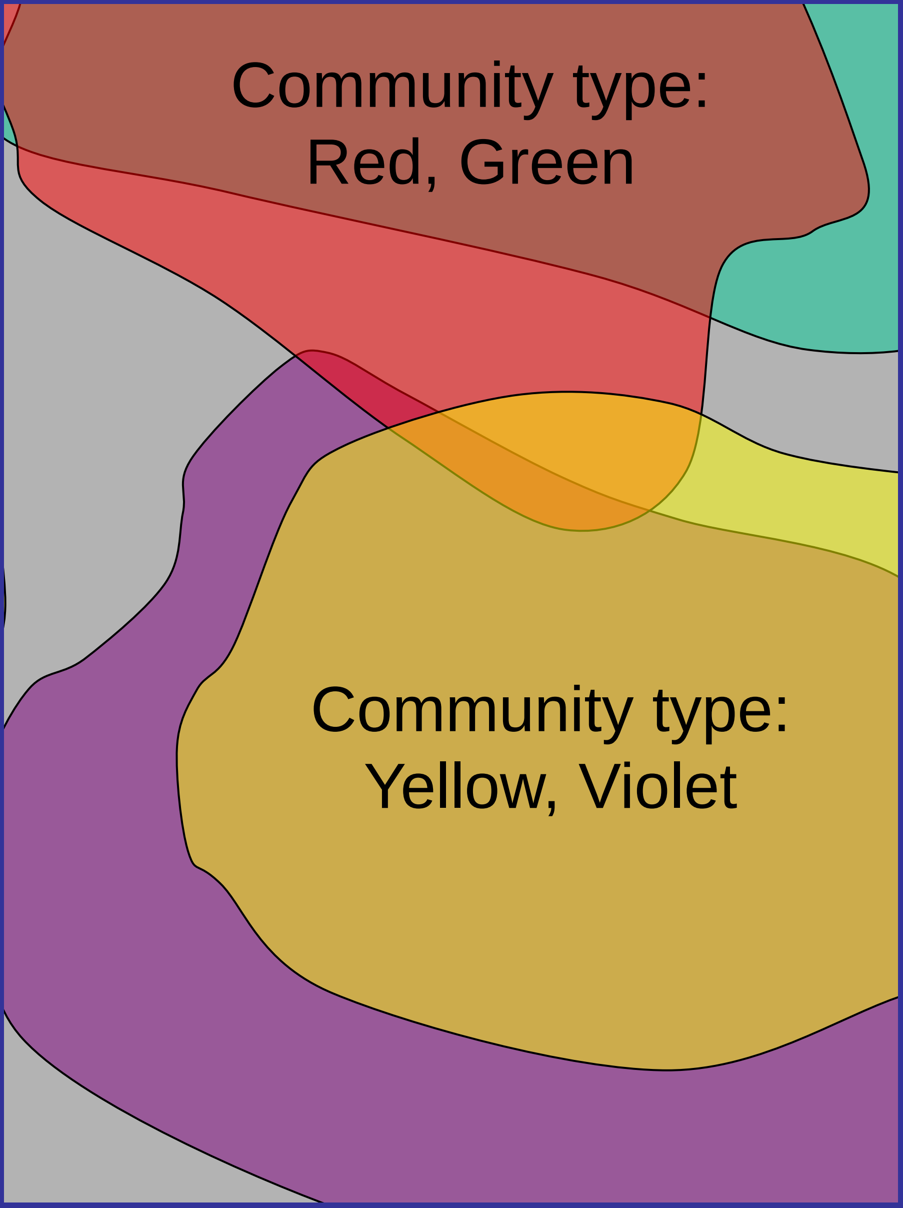
After Peters (1992)

Some consequences of range shifts

(2) Species will behave individualistically, meaning it will be impossible to maintain biotic communities in their current state.


Community type:
Green
Community type:
Yellow, Red, Blue


Community type:
Green
Community type:
Yellow, Red, Blue


Community type:
Red, Green
Community type:
Yellow, Violet

Some consequences of range shifts

(3) Weedy species will migrate fastest, capturing vacated territory. … Welcome to WeedWorld.

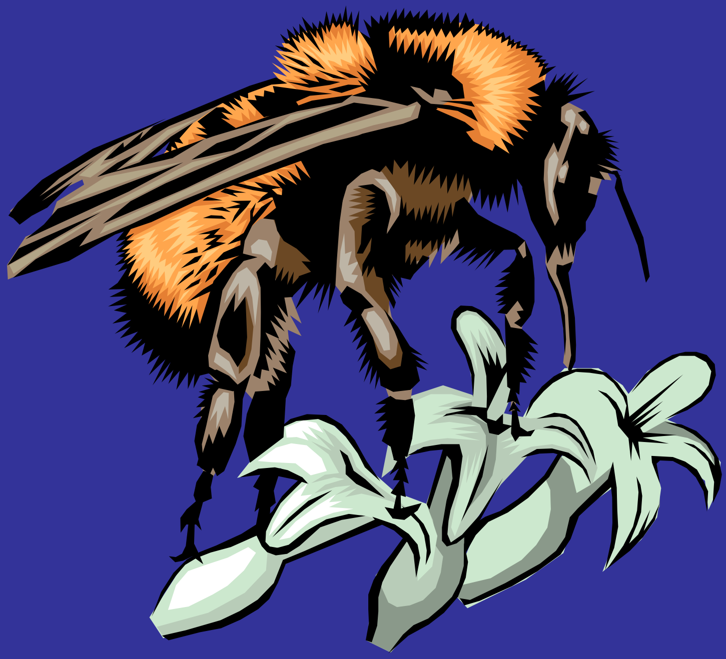
Some consequences of range shifts

(4) Native species can become invasive pests (example: mountain pine beetle).

Logan et al., 2004

Some consequences of phenological shifts

Some organisms will become phenologically decoupled from critical resources.



Plants and their pollinators

Migratory animals

(e.g. Pied flycatcher; Both & Visser, 2001)

SUMMARY, PARTS I AND II

I. *<u>The rules have changed</u>*. In the face of rapid, pervasive global changes, our current approach to natural resources management (post-Leopold) is inadequate and can even get us in trouble.

A. Climatic change and its effects are here, <u>now</u>.

B. We have entered an era of unprecedented environmental conditions.

C. We can no longer use the past as a target for restoration or management, nor depend on natural processes alone.

II. The future will be characterized by massive yet largely unpredictable changes, and some unpleasant surprises.

A. We cannot precisely predict the future.

B. Threshold responses will lead to surprises.

C. Species ranges and phenologies will shift, and *biotic communities will dissociate in space and time*.

III. Even in the face of massive, unpredictable changes, we can do some useful things.

A. Educate.
B. Lead by example.
C. Monitor!
D. Redefine goals.
E. Reduce current stresses.
F. Buy time.
G. Hedge your bets.
H. Practice triage.
I. Actively adapt.
J. But what if we’re wrong?

A couple of limited sources of ideas ...

Welch, D. 2005. *George Wright Forum* **22**:75-93. (http://www.georgewright.org/221welch.pdf)

What Should Protected Areas Managers Do in the Face of Climate Change?

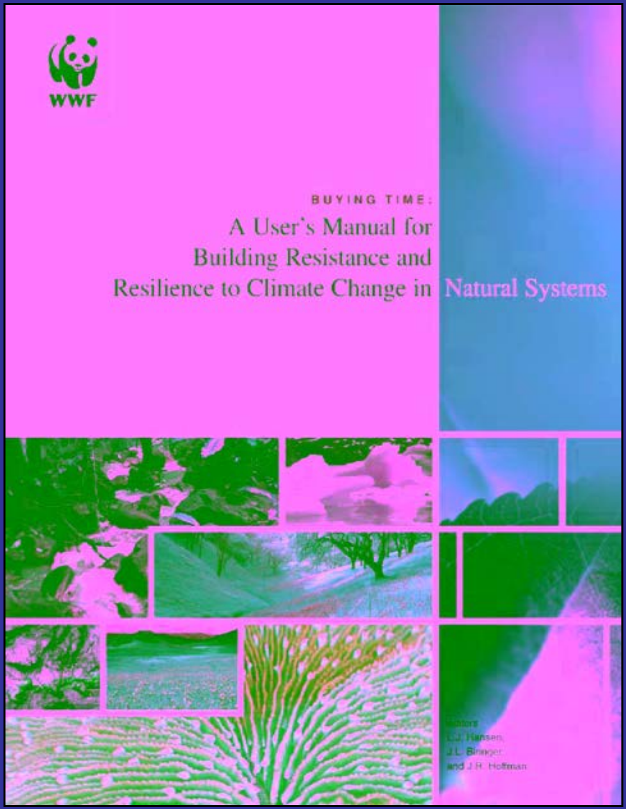
David Welch

The face and pace of change, past and future

Climate change across geological time. Climate has always been changing, is changing, and will continue to change. Throughout geological deep time the Earth witnessed long warm phases interspersed with ice ages, with perhaps even a "snowball Earth" occurring as many as four times between 750 million and 580 million years ago (Hoffman and Schrag 2000). Surface temperatures across all latitudes rose by 6°C to 8°C at the start of the Eocene epoch 55 million years ago, corresponding to massive increases in atmospheric carbon triggered by large-scale igneous activity and hydrate melting under what is now the Norwegian Sea (Svensen et al. 2004). Over the past 4 million years, the Earth has gone from global surface temperatures about 3°C warmer than today, with smaller ice sheets and higher sea levels, to the current cooler conditions (Ravelo et al. 2004). The 1.8 million years of the Pleistocene and Holocene epochs were characterized by roller-coaster swings of many degrees Celsius, corresponding to glacial intervals and abrupt warming at the onset of interglacials (Folland et al. 2001; Figure 1). While driven by 100,000-year cycles in the shape of Earth's elliptical orbit and 40,000-year cycles in its rotational tilt, there has also been a close association between climate and greenhouse gases, such as carbon dioxide and methane, over as much as the last 740,000 years (EPICA 2004). Within historical times, our planet experienced several temperature shifts, such as the Medieval Warm Period and the late 19th century Little Ice Age (Figure 2). During the last century, average annual precipitation changed up to 50% in some regions (Figure 3).

Recent climate change. While rapid in terms of geological time scales, these changes were, well, geological in pace. Over the past 100 years, however, global average temperature has risen approximately 0.6°C, and the rate of warming has greatly accelerated since the 1970s (Figure 2). This change is ascribed mainly to rapid and large releases of greenhouse gases from the burning of fossil fuels for power generation and transportation (IPCC 2001a). It is even possible that were it not for increased releases of CO_2 and CH_4 due to the burning of forests to clear land for agriculture, starting around 8,000 years ago, and the invention of rice paddy cultivation about 6,000 years ago, the Earth would have already entered the next glacial interval (Ruddiman 2003).

Impacts of recent climate change. There is ample evidence of the physical and ecological impacts of recent climate change. Walther et al. (2002) summarize many of these observed changes, such as increased



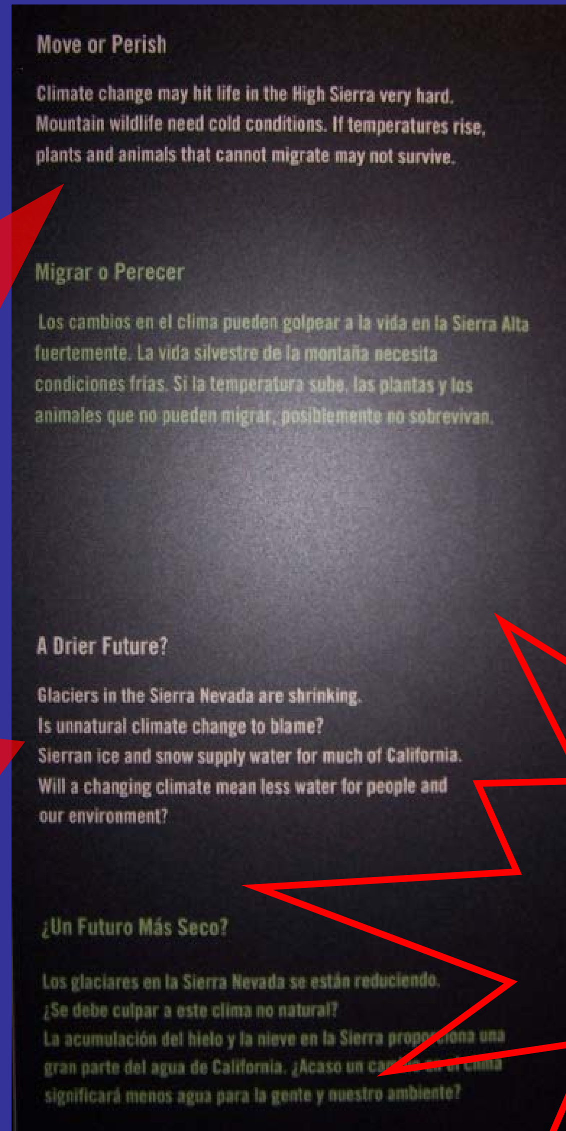
Hansen, L.J., *et al.* (eds). 2003. (http://www.worldwildlife.org/forests/pubs/buyingtime_unfe.pdf)

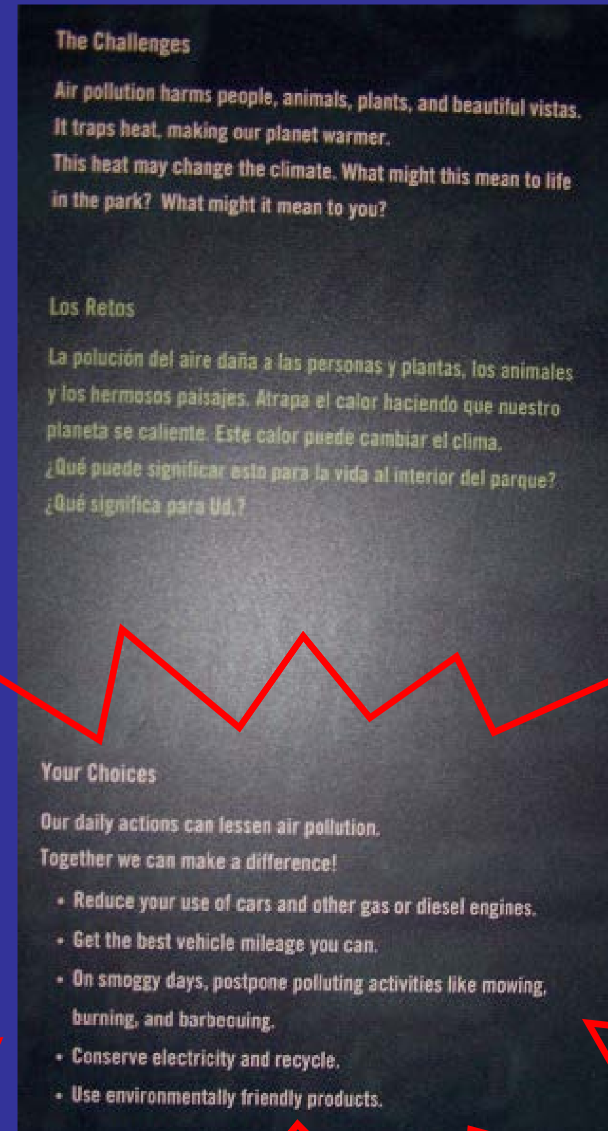
A. EDUCATE:

RAISE AWARENESS IN STAFF, PUBLIC, AND STAKEHOLDERS

Grant Grove visitor center, Kings Canyon NP

Grant Grove visitor center, Kings Canyon NP





B. LEAD BY EXAMPLE:

PUT YOUR OWN GREENHOUSE-GAS HOUSE IN ORDER

The Climate-Friendly Parks Initiative

(http://www2.nature.nps.gov/air/features/climatechangeparks.cfm)

“The Climate Friendly Parks program enhances the greening program by adding a focus on climate change mitigation and energy efficiency and providing park visitors examples of environmental excellence and leadership that can be emulated in communities, organizations, and corporations across the country.”

Glacier National Park, Montana:

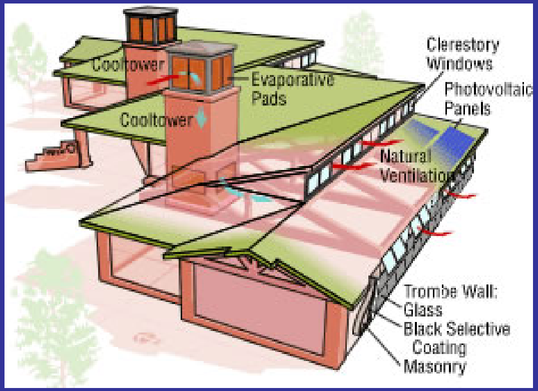
- Conducted, and will periodically reconduct, an inventory of greenhouse gas emissions.
- Bought bicycles for employees to commute between out buildings.
- Expanded the public shuttle bus system, and switched the buses to natural gas or propane.

- Switched some snow plows to biodiesel.
- Ongoing efforts aim to improve energy efficiency in the park's many historical buildings.
- Made it a social sin to leave park vehicles idling for more than one minute.

Zion National Park, Utah

Earlier accomplishments:

- Established shuttle system.
- Constructed two LEED-certifiable buildings.



Zion visitor center

Chief strategies in their action plan include:

- Conducted, and will periodically reconduct, an inventory of greenhouse gas emissions.
- Water conservation through xeriscape landscaping.
- Alternative transportation for park employees through a partnership with the Utah Transportation Authority.
- Use renewable biodiesel fuel.
- Spread the word about “green issues.”

C. MONITOR!

Monitoring is fundamental to:

(1) Education.

(2) Early warning.

(3) Defining and redefining goals.

(4) Determining outcomes of management actions.

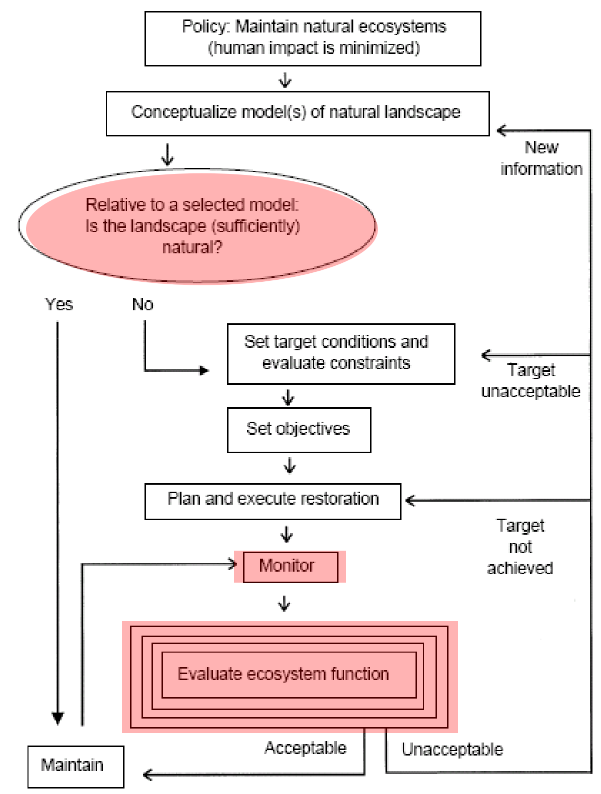
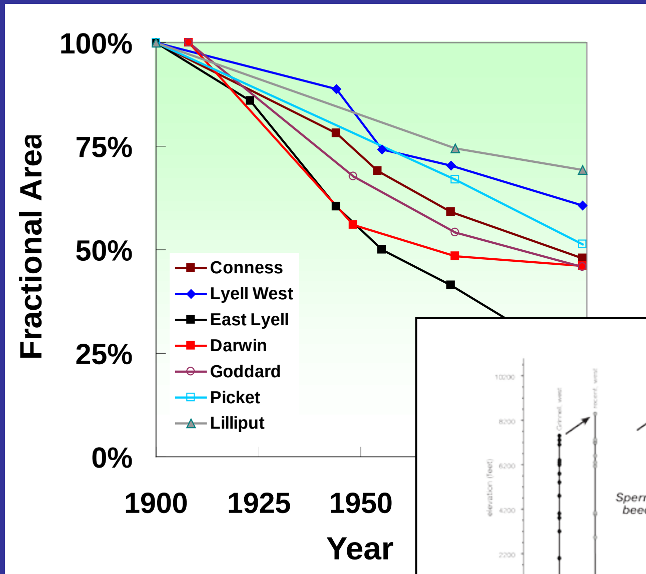


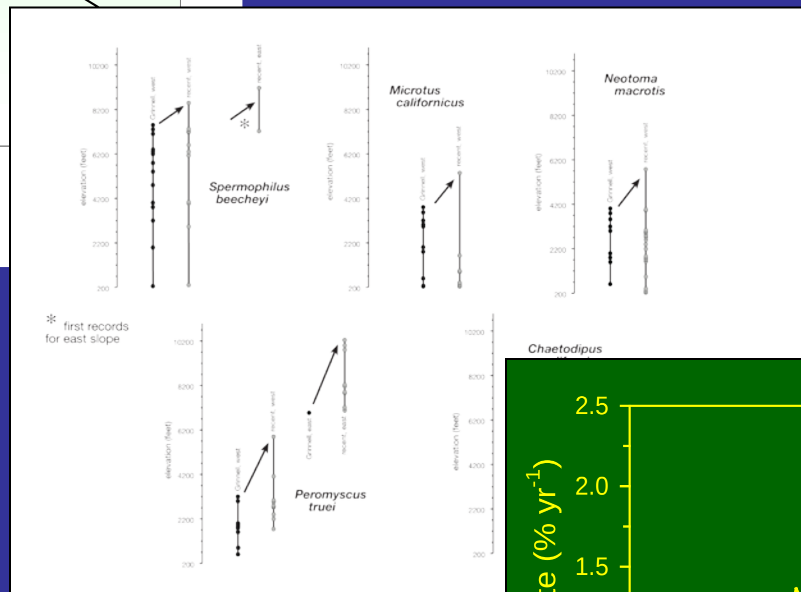
Figure 2—Decision tree diagram for implementing restoration and maintenance of fire in National Park ecosystems, based on collective efforts of the "Fire Management Objectives Workshop," Rancho Cordova, CA; 3-6 November 1998.

Keeley & Stephenson 2000

Some examples of what we've learned from monitoring:

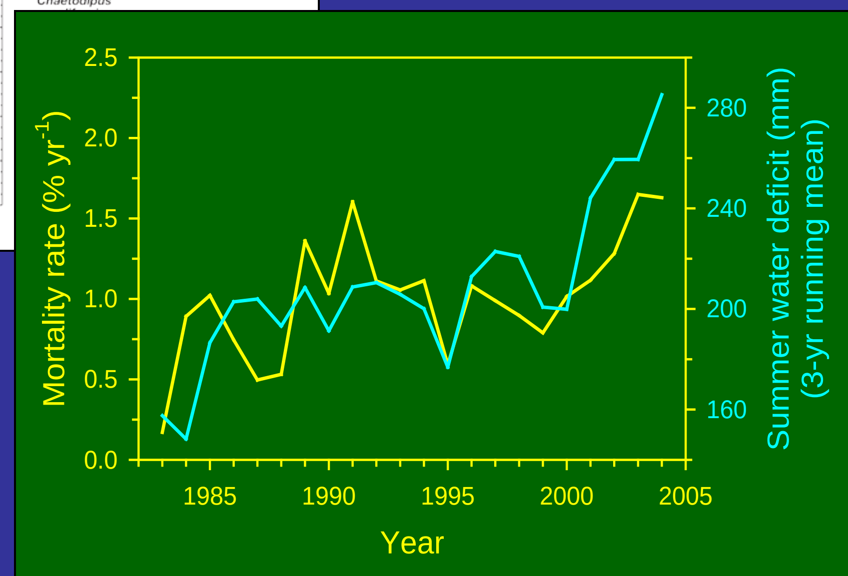


Glaciers



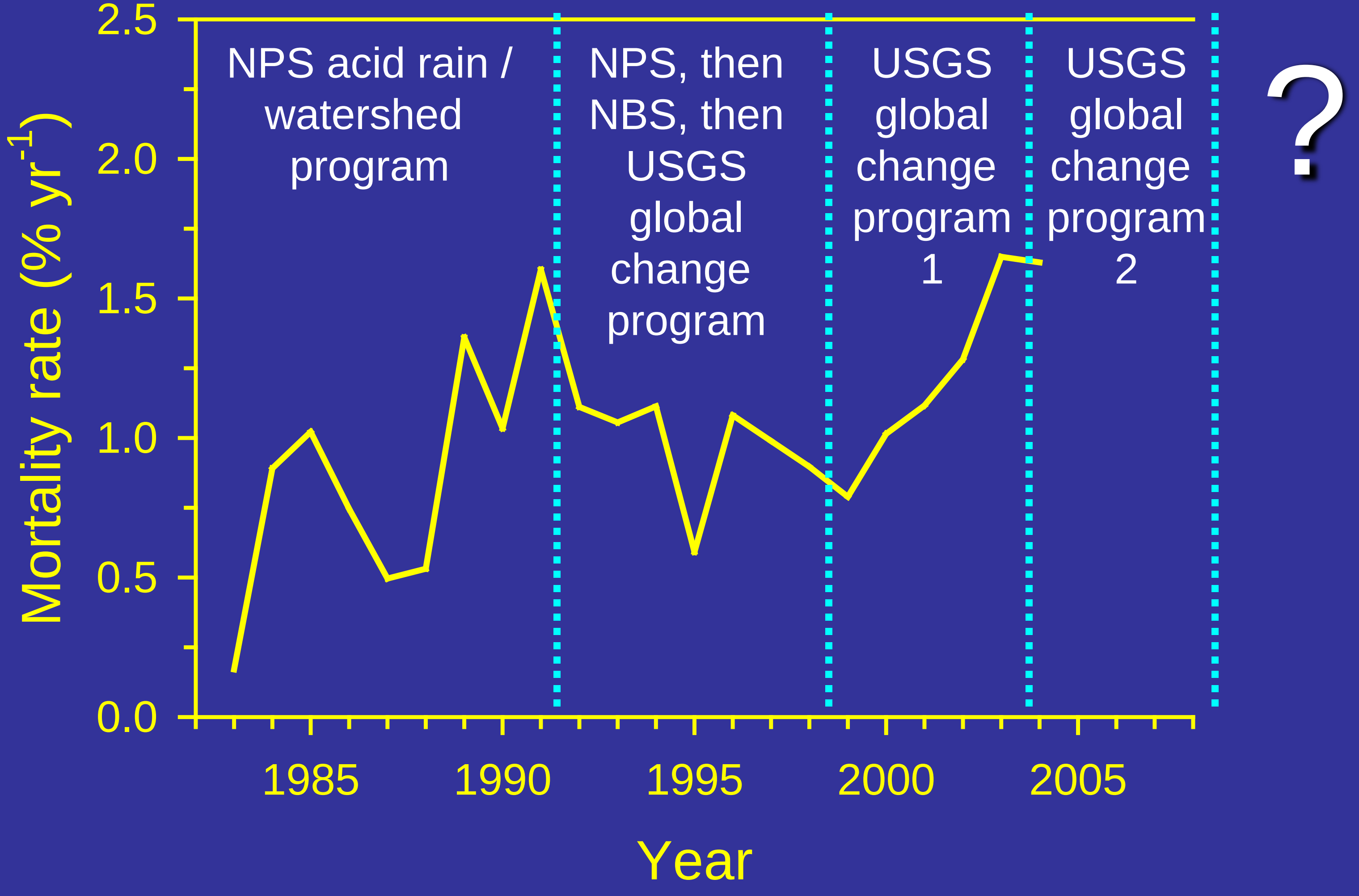
Vertebrates

Trees & climate



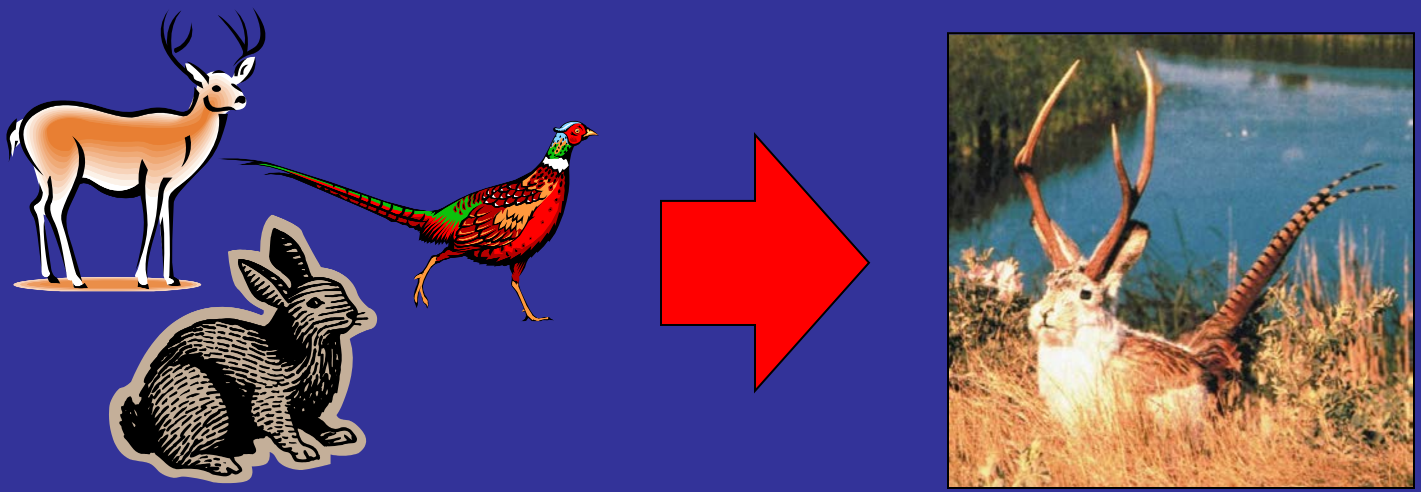
Monitoring can be hard to maintain. Do it anyway!

20,000 trees, visited every year for 24 years
(each year now requires 3 to 4 GS-5s for 4 to 5 months,
or about $40,000 [could be made cheaper])



D. REDEFINE GOALS

E.g., we can no longer count on maintaining natural <ins>*communities*</ins> (“correct” combinations of species).



But we can redirect our focus toward <ins>***maintaining native biodiversity and ecosystem function***</ins>

(e.g., maintain forest cover, which in turn sequesters carbon, provides wildlife habitat, and regulates hydrology).

E. REDUCE CURRENT STRESSES

But beware:

Don’t win the battle while losing the war

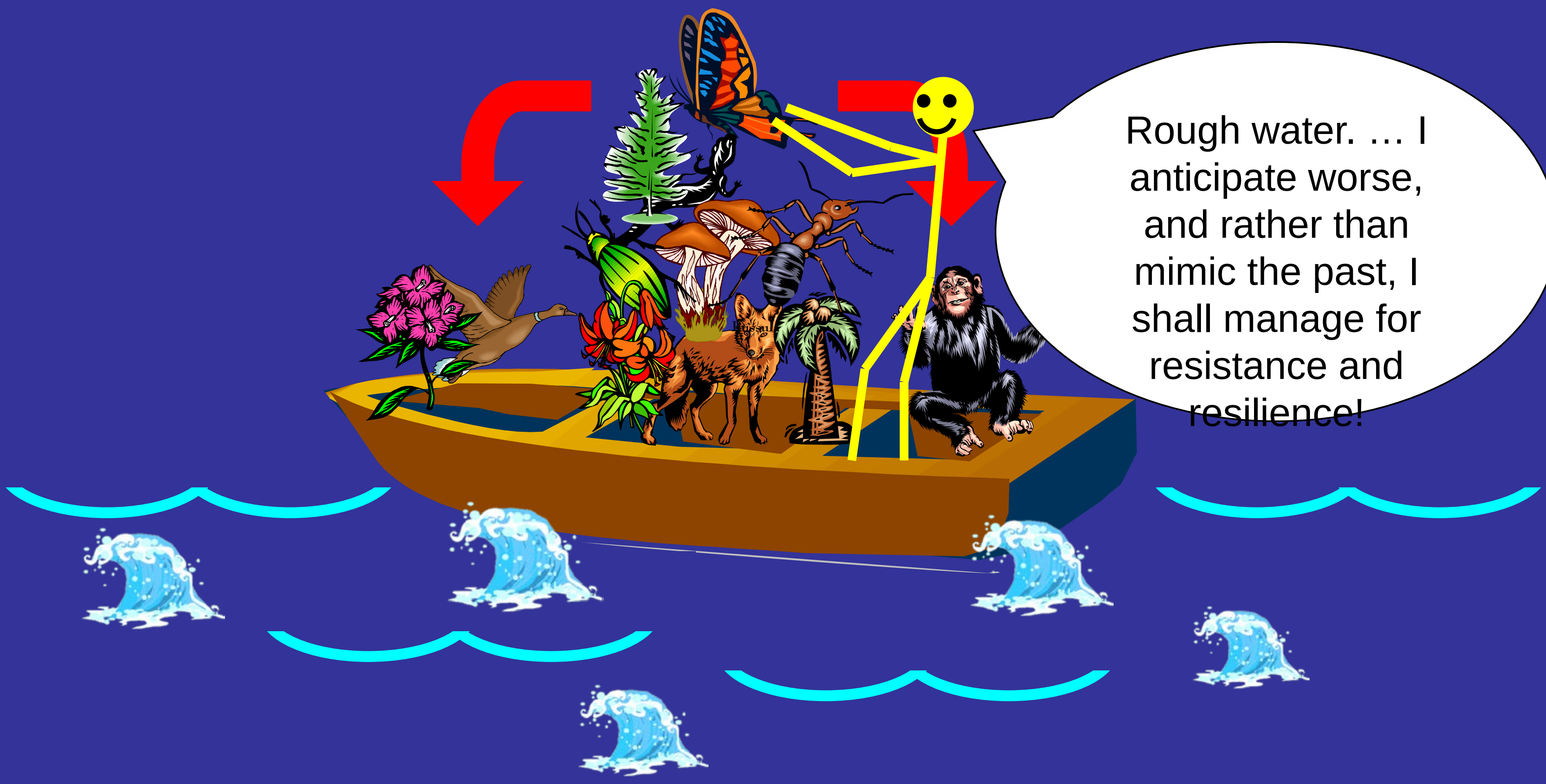
(e.g., don’t just focus on controlling invasives, because they’re relatively tractable, while everything else goes to hell in a handbasket).

F. BUY TIME

... SO THAT THINGS HAVE MORE TIME TO SORT THEMSELVES OUT, WITH OR WITHOUT MANAGEMENT INTERVENTION

Buying time will entail, at least in part, managing for ecosystem resistance and resilience (especially to sudden, undesirable changes).

Resistance: ability to resist stresses.
Resilience: ability to recover from stresses.

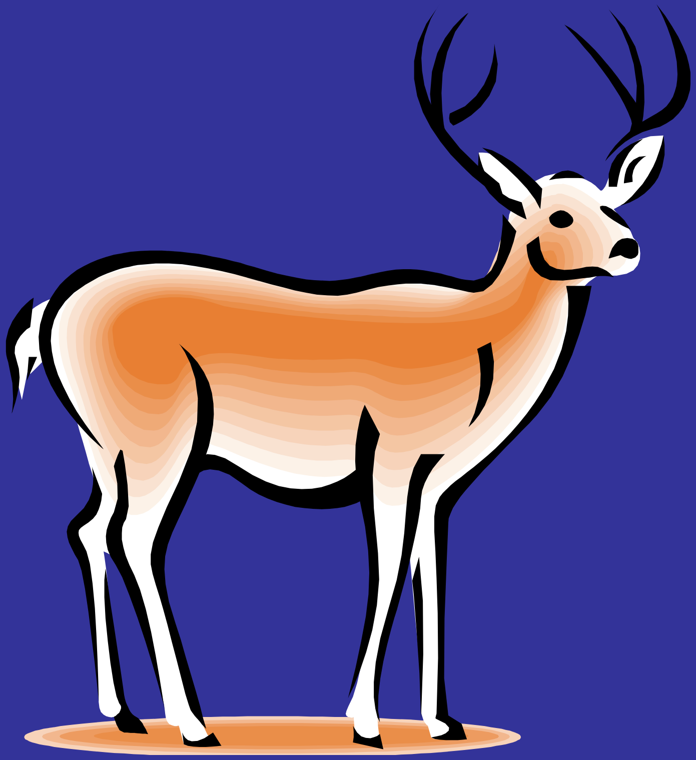

Rough water. … I anticipate worse, and rather than mimic the past, I shall manage for resistance and resilience!


Now I’m sure
to be
promoted!
Russula

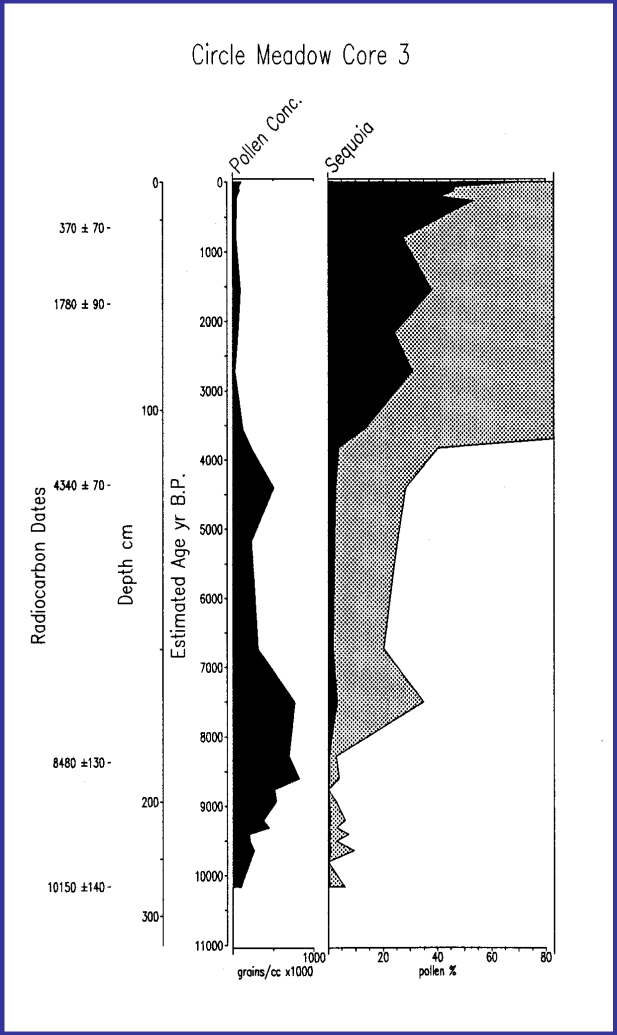
G. HEDGE YOUR BETS

Try different management approaches in different areas (management as experiments). Don’t put all of your eggs in one basket.

H. PRACTICE TRIAGE



☺ Probably can cope without our help.



- 😐 May be in big trouble without our help.

(Pretend this is sky pilot)

☹ Doomed,
at least within
a park or region.

I. ACTIVELY ADAPT

Think the unthinkable, and gore sacred cows:

(1) Instead of jealously protecting local gene pools, purposely mix gene pools to increase adaptive potential to novel (but unknown) future conditions.

(2) Purposely over-thin forests to increase their resistance and resilience.

(3) Assist species migrations (e.g., wildly spread seeds of everything everywhere).

(4) Foster out species that will completely lose their habitat within a park.

(5) Accept foster species from other areas.

J. BUT WHAT IF WE'RE WRONG?

THAT IS, WHAT IF WE PREPARE FOR THE WORST, BUT THE WORST NEVER ARRIVES?