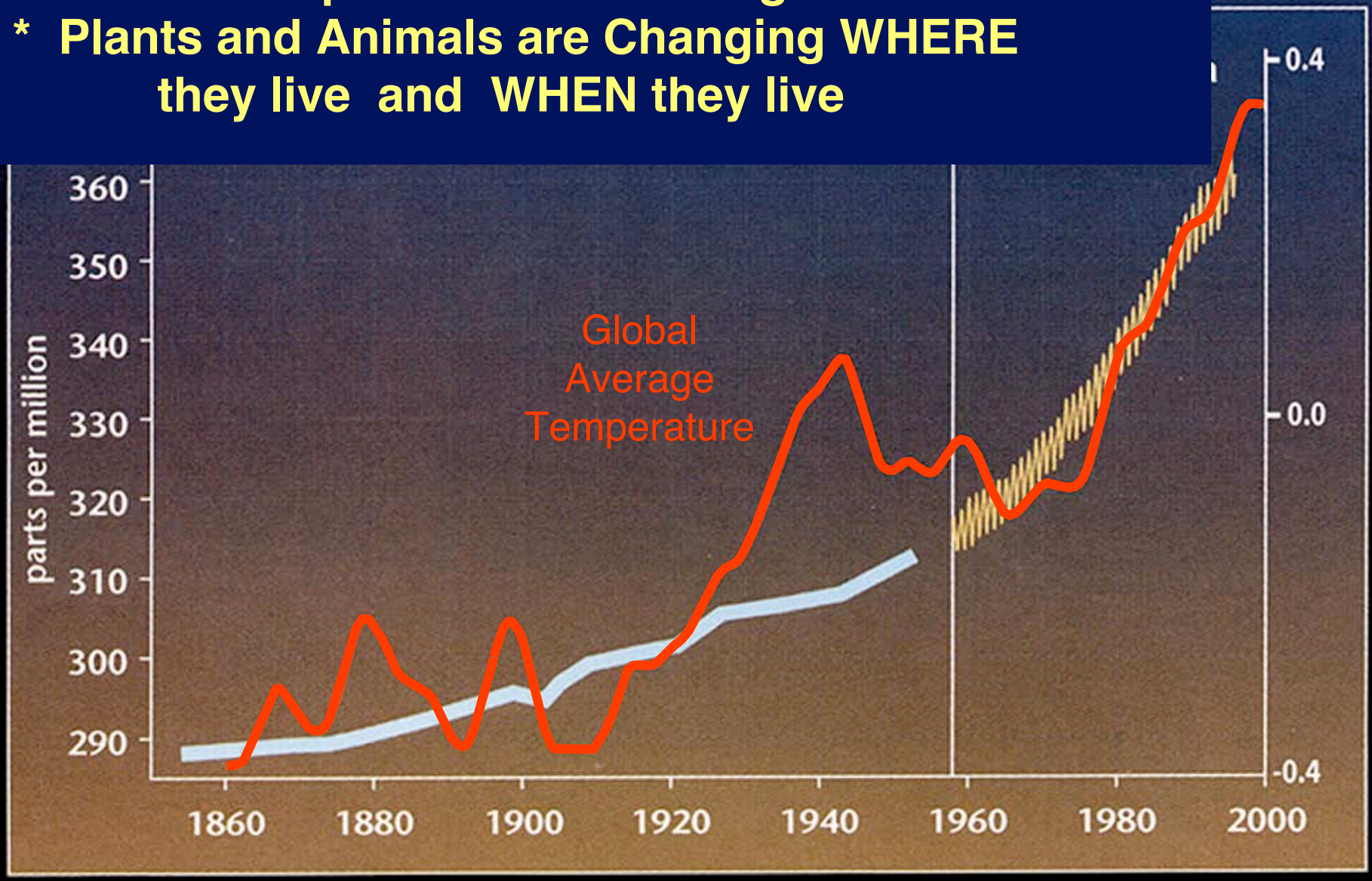
Global Warming and Wild Life

Camille Parmesan
Integrative Biology, University of Texas at Austin

* Global Temperatures are Rising
* Plants and Animals are Changing WHERE they live and WHEN they live



How do we know a biological change is caused by climate?

Correlational Patterns

- Long-term patterns --- Does biological change match climate trends in direction and magnitude?
- “natural experiments” --- does population respond to extreme weather events and climate years?

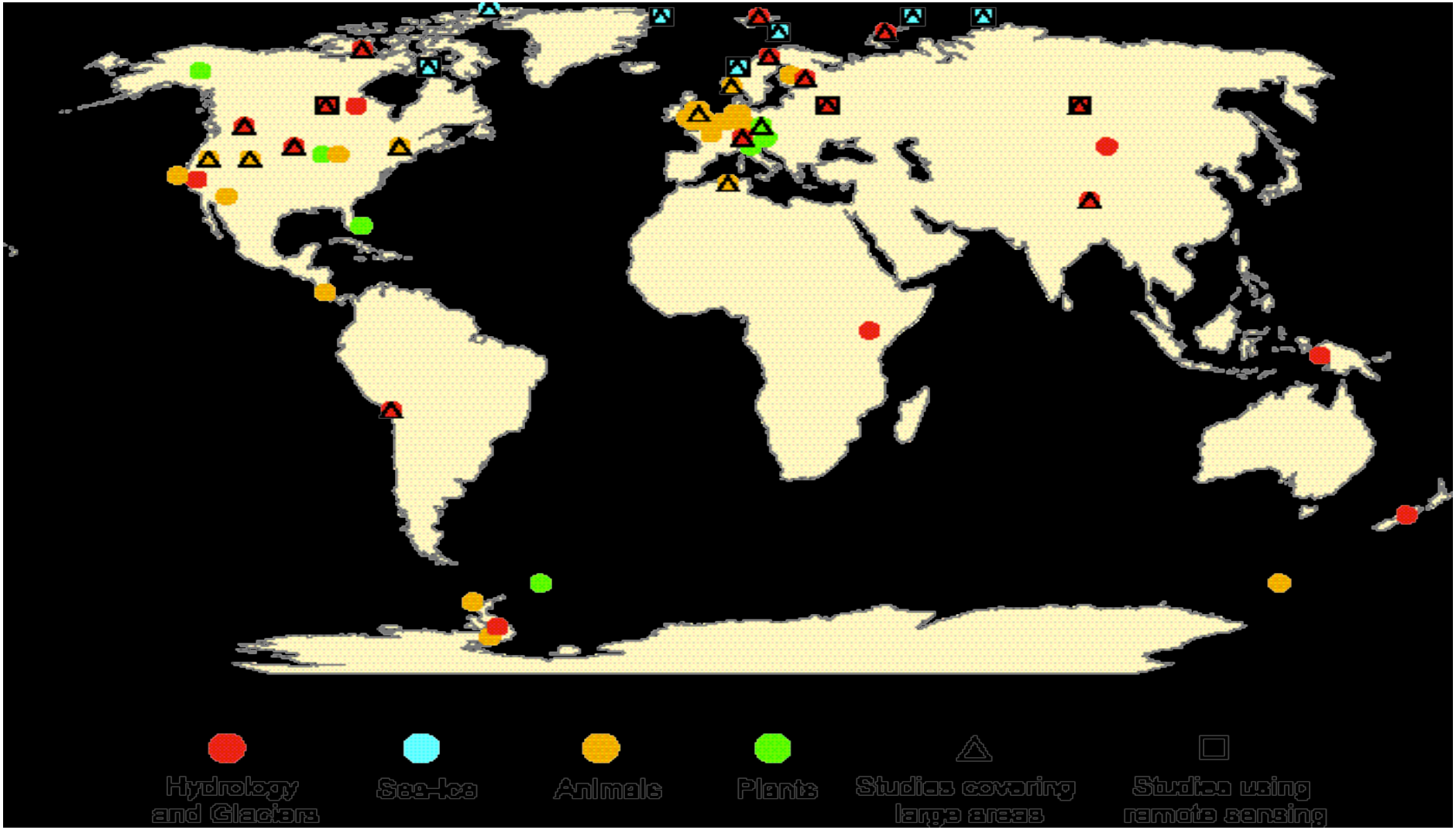
Field Manipulations of temperature and fitness

- impacts on behavior (foraging, mating)
- impacts on growth and fecundity

Laboratory Experiments

- temperature survival thresholds

IPCC 2001: 8 Biological studies in USA



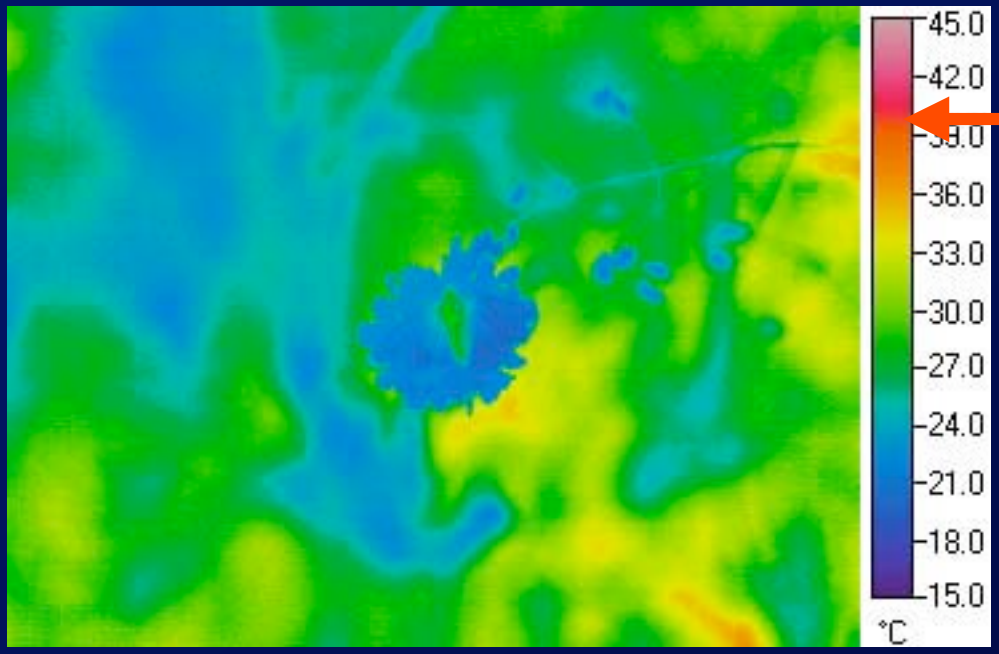
Pew report - USA only

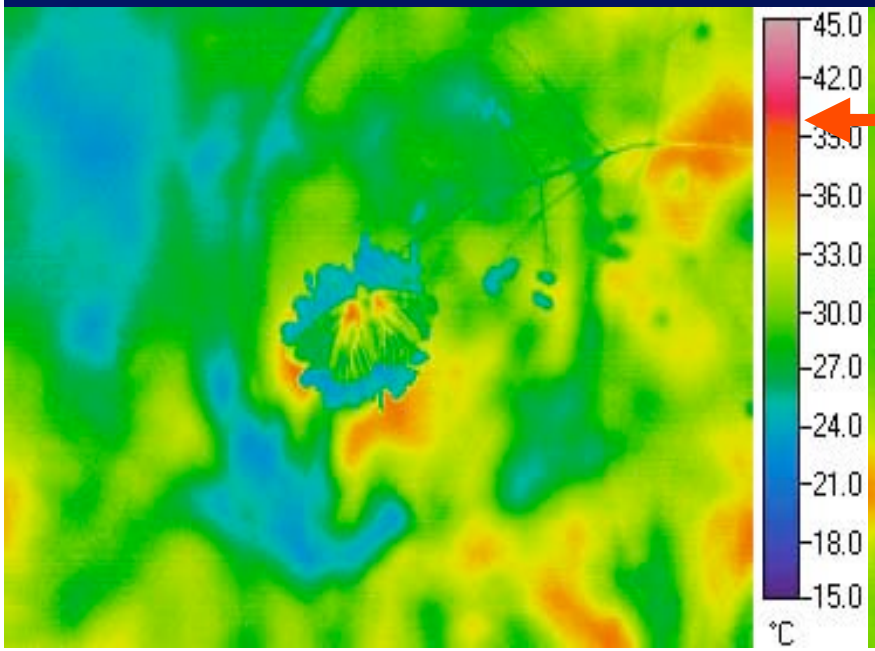
- 40 studies total
  - all would have qualified under IPCC criteria

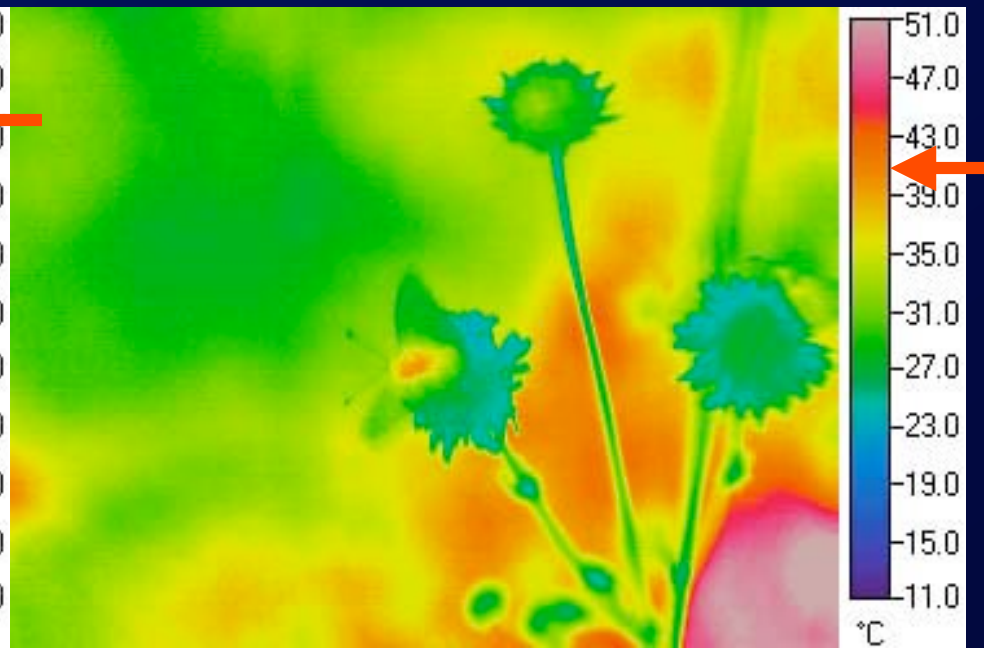
- "Strong evidence" = 21 studies > 237 species / functional groups

Parmesan & Galbraith 2004

Butterflies want their body temperature to be ~ 100° F

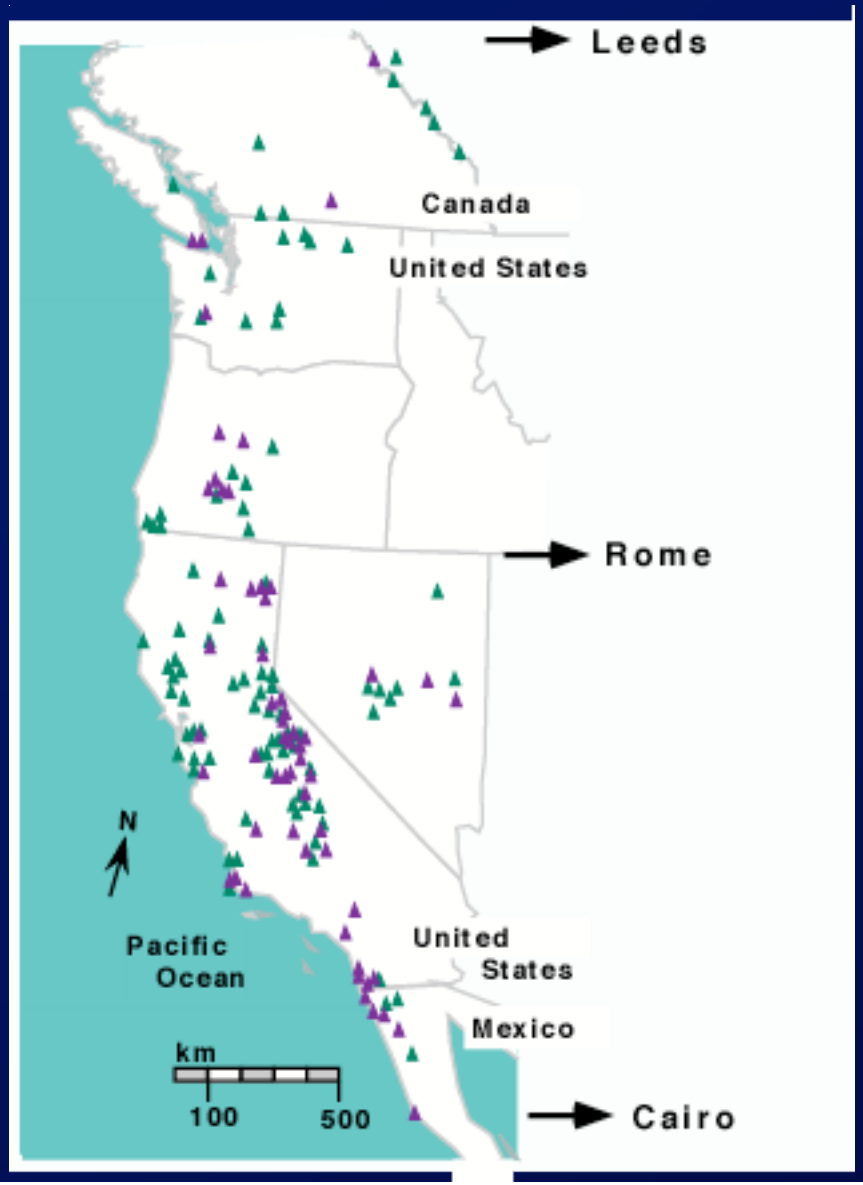






Edith's Checkerspot butterfly experiences frequent population extinctions in undisturbed habitats

Species' range has shifted northward and upward during the 20th c.



Most extinctions in south and at low elevations

green = present

purple = extinct

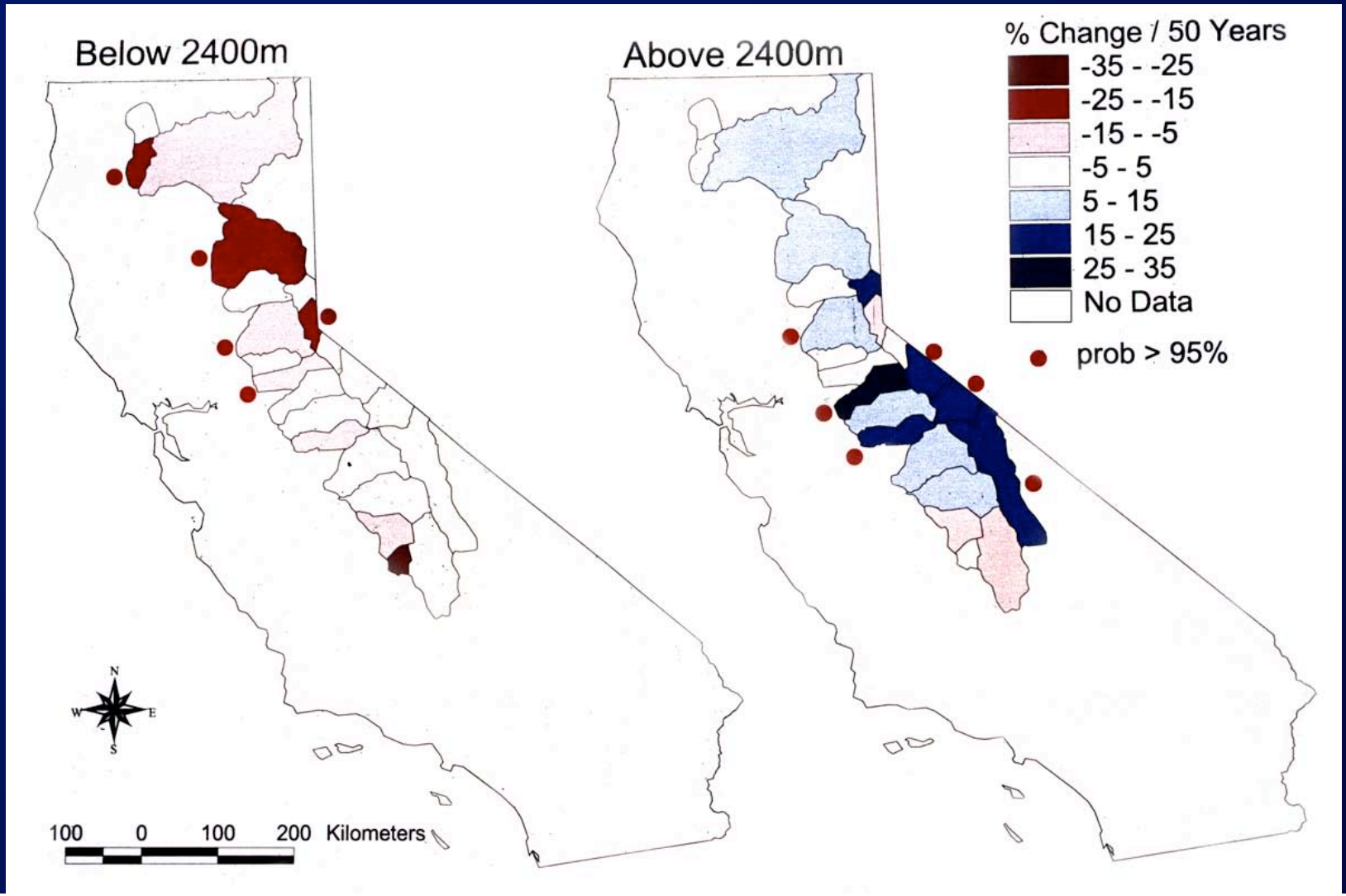
Parmesan 1996

Warming Causes Asynchrony --- Extinctions

- 2° C warming causes timing mis-match
- Host plants dry up 3-7 days earlier,
- caterpillars starve

False Springs Cause Extinctions

Heavy snowpack at high elevations benefits populations by delaying flight season to peak summer heat



Shift in status - at diversity of latitudes

Vagrants from Africa establish residency in Spain

1) Plain tiger (*Danaus chrysippus)*

1980 - 1st resident populations

1990s - evidence of many breeding populations

Haeger, *Shilap* 1999

2) Desert orange tip *(Colotis evagore)*

Specialist of hot micro-climates

lab - needs 164 °d > 60° F

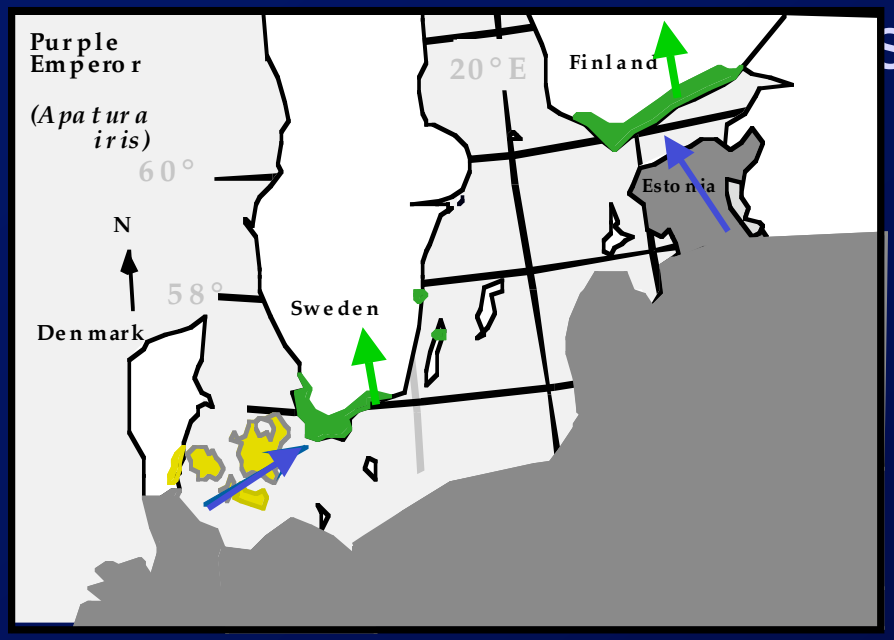
lab - no evolution of hibernation

field & lab - no switch of food

Jordano *et al. J. Biogeog.* 1991

Shifts in Nationality: Multiple invasions

Purple emperor *(Apatura iris)*



1) 1900 - rare Denmark

1940s - common Denmark

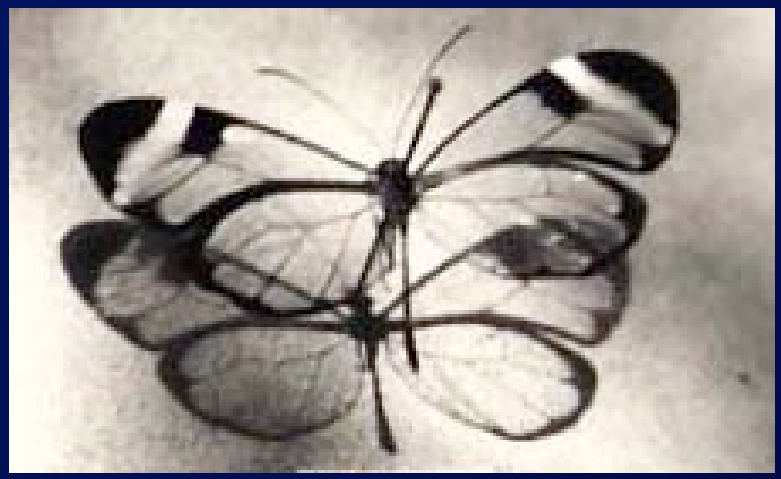
1983 - Sweden (1st record)

2) 1991 - Finland from Baltics (1st in 50 years)

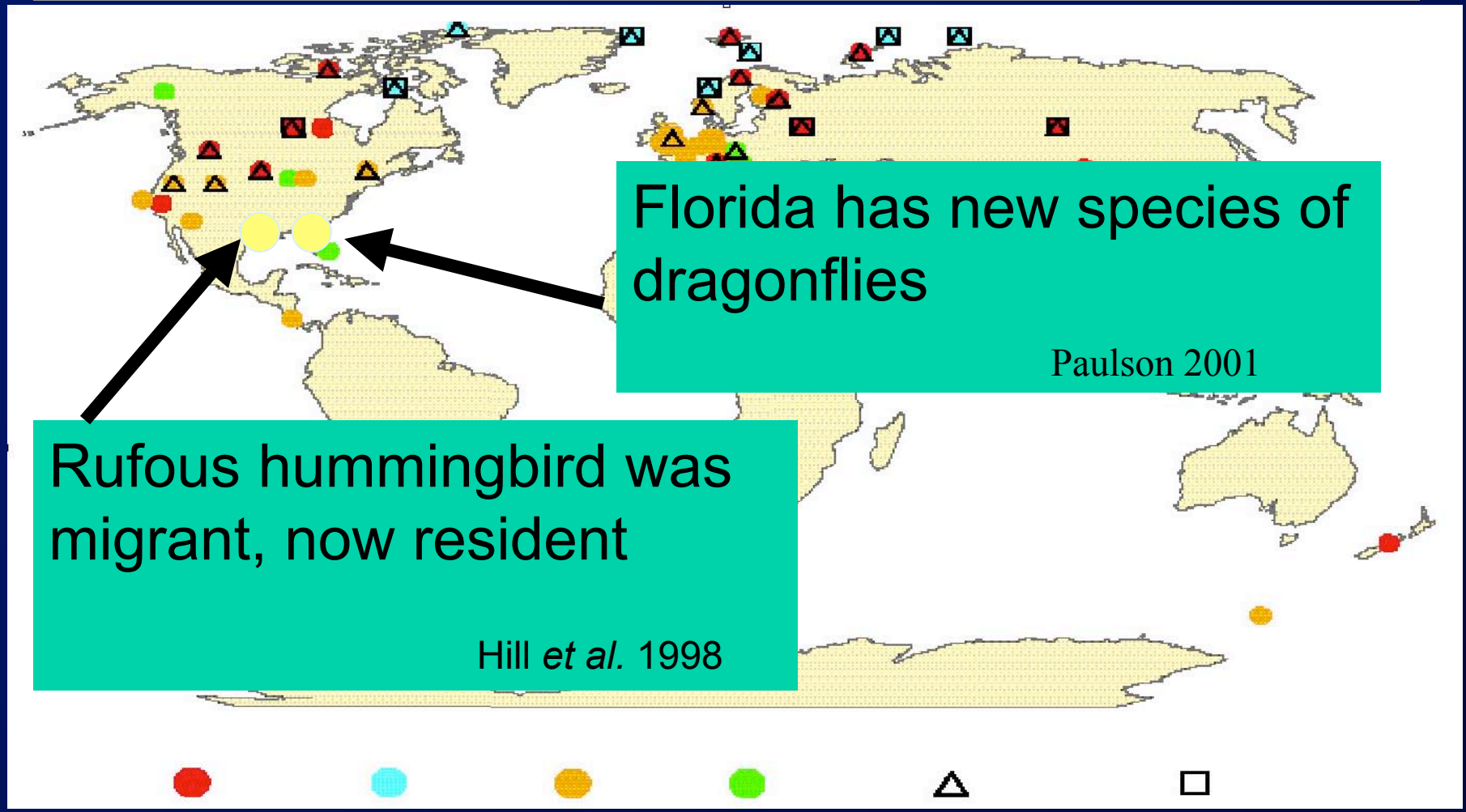
Ryrholm unpub.; Kaila & Kullberg pers. Comm.; Henriksen & Kreutzer 1982

Texas Has 5 New Species of Tropical Butterflies

- Tropical species are active year-around
- No winter hibernation
- Killed by freeze



Species have moved into USA from Central America & Caribbean



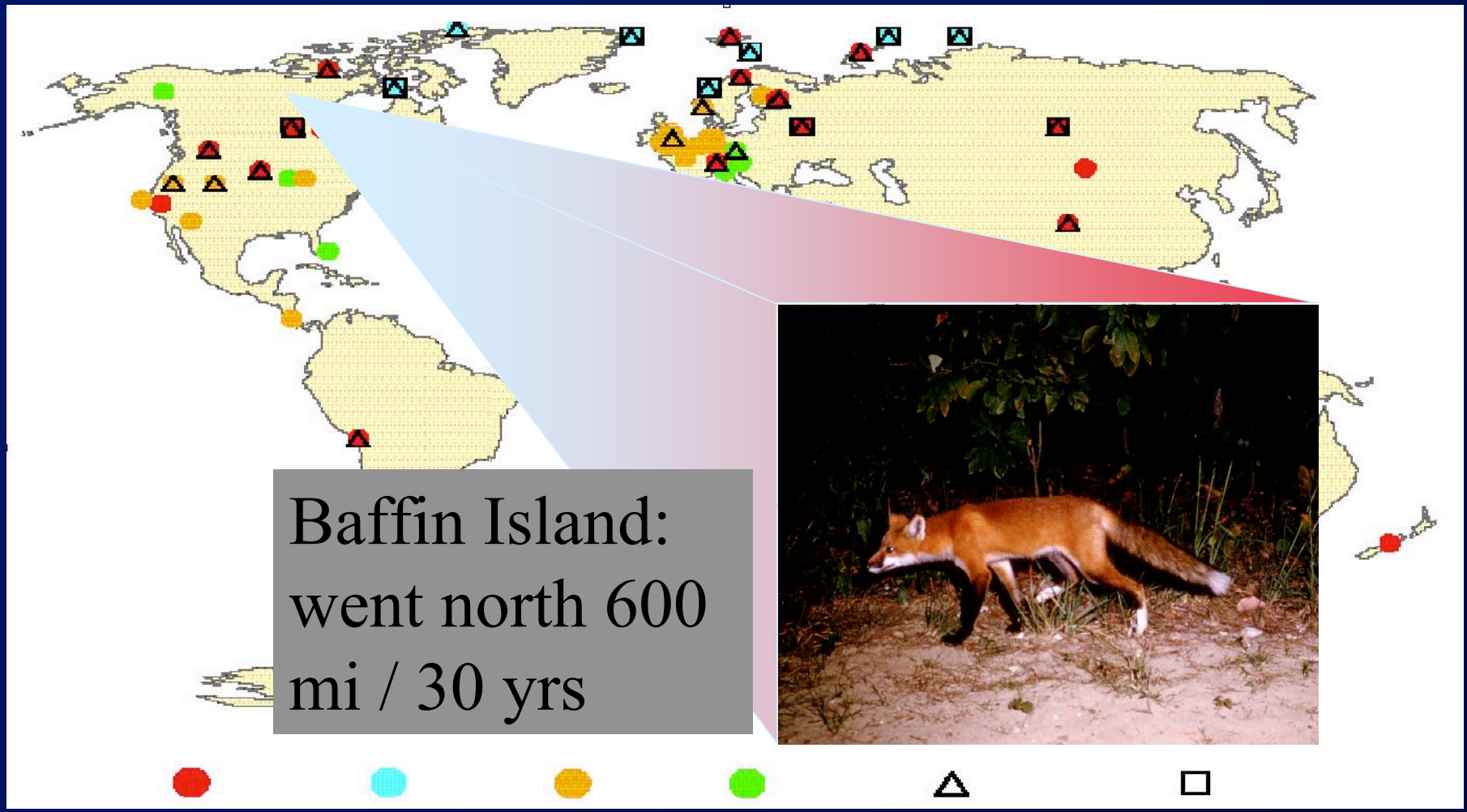
Florida has new species of dragonflies

Paulson 2001

Rufous hummingbird was migrant, now resident

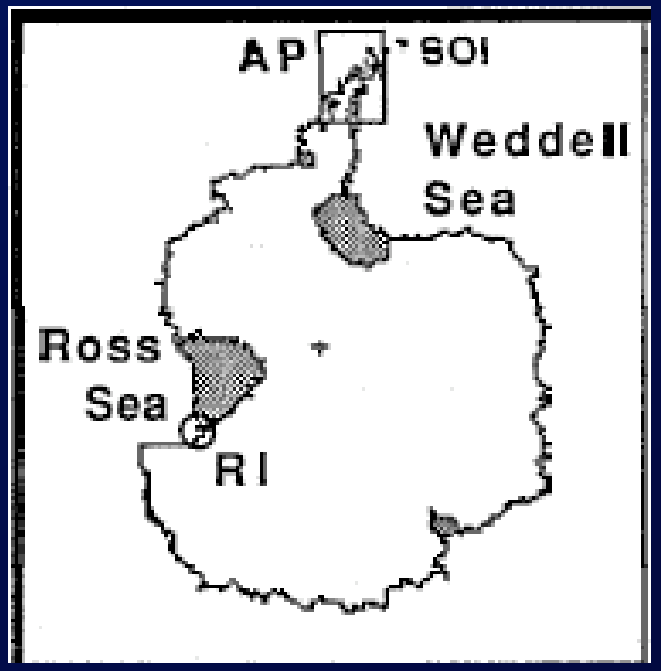
Hill *et al.* 1998

The Red fox has shifted its range north, threatening the Arctic fox



Hersteinsson & Macdonald 1992

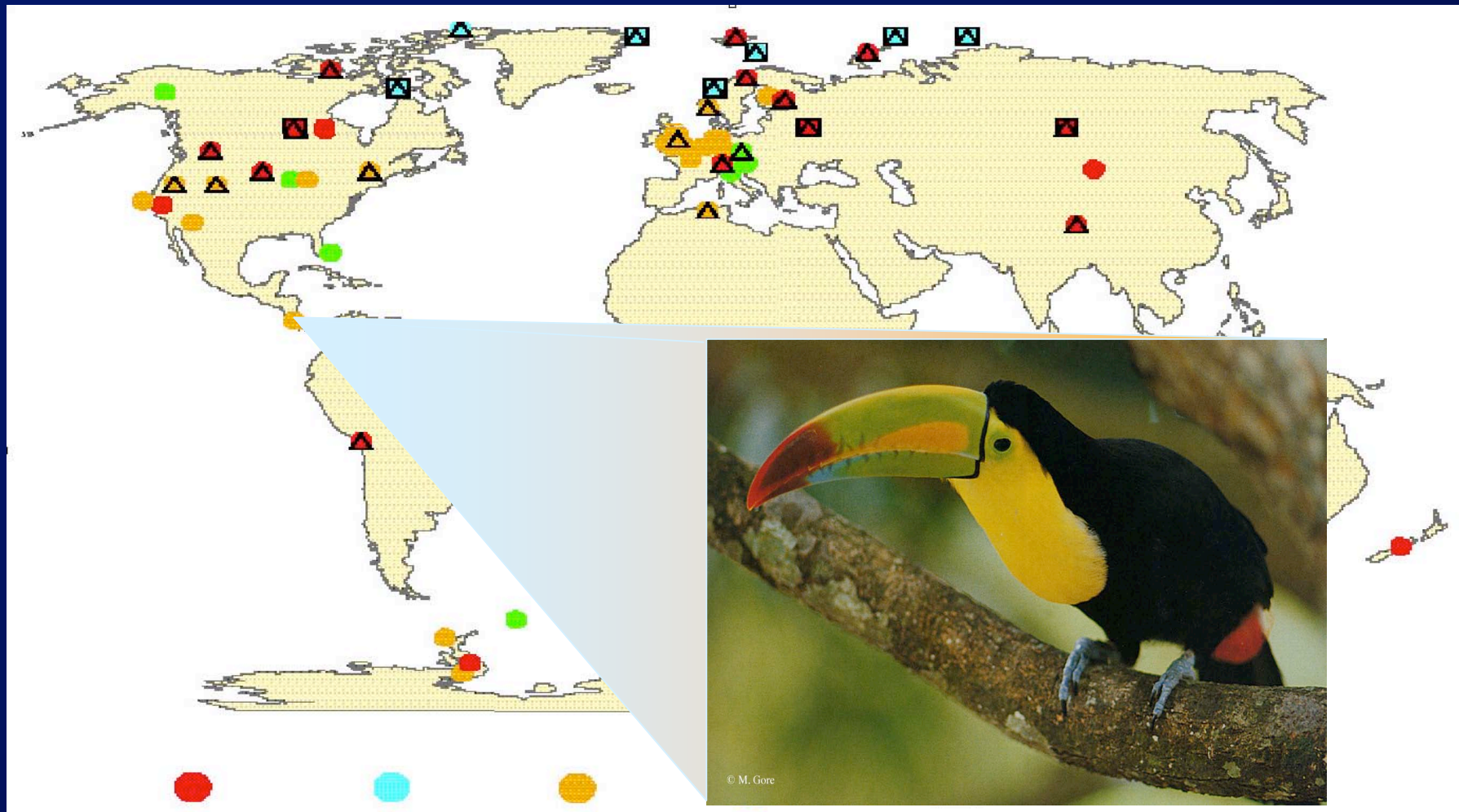
Species Replacement: Antarctic Penguins



- Ice-adapted Adelie
  - moving poleward
- Warm-adapted Chinstrap & Gentoo
  - Arrived 20-50 years ago

Smith *et al. Bioscience* 1999; Fraser *et al.* Polar Biol. 1992; Emslie *et al.* Ant. Science 1998

The toucan and other lowland tropical birds have moved uphill, threatening high elevation birds.



Pikas are Sensitive to Heat

- live > 7,500 feet
- Must forage

  > 9 x / day

Smith 1974

Low Elevation Populations Don't Forage Mid day

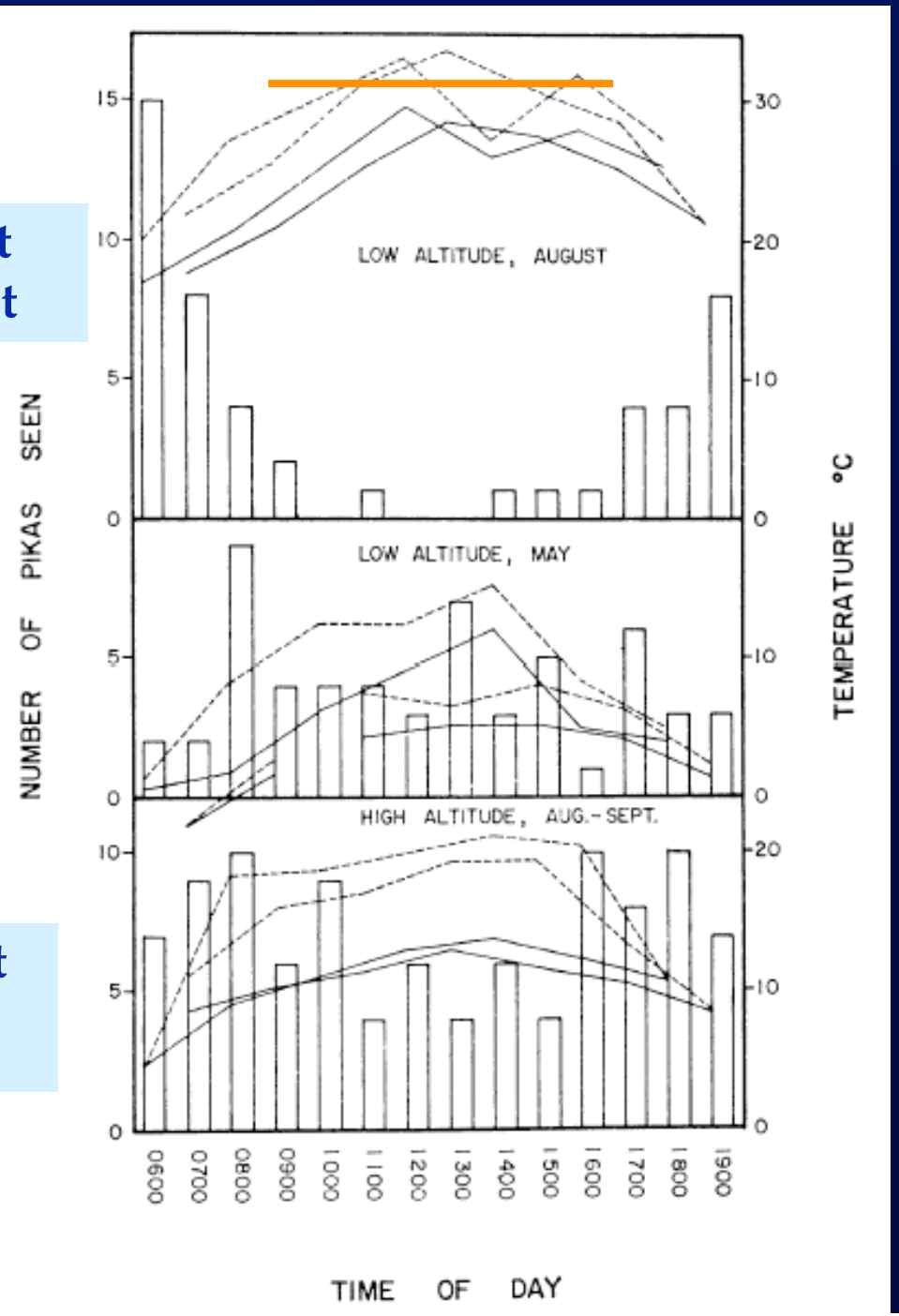
- Adults killed by heat stress (> 31° C in sun)
- Foraging time limited by temperature

Smith 1974

9,000 ft August

9,000 ft May

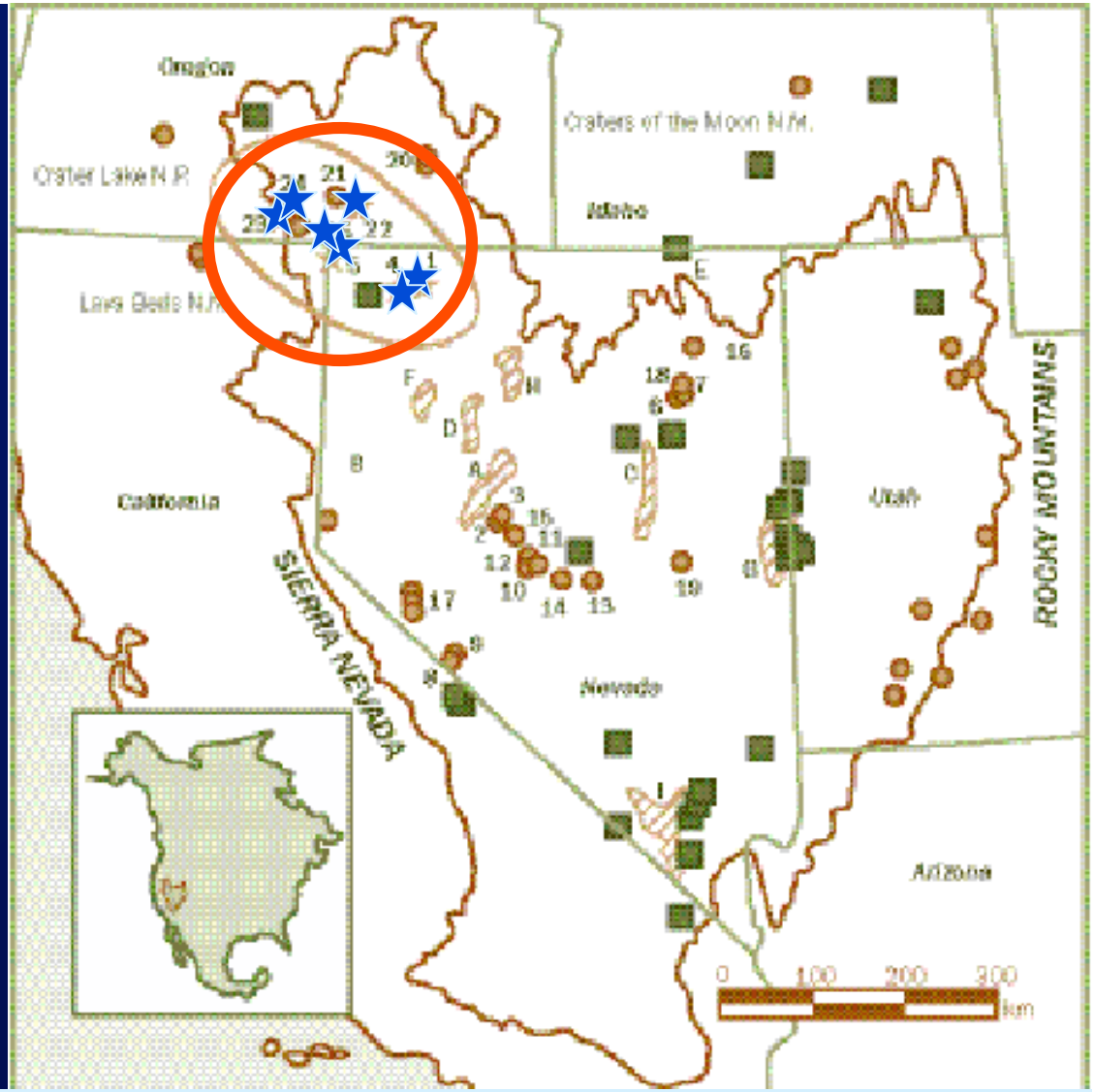
12,500 ft August



Upward shift of the pika

- 7 / 25 populations have gone extinct since 1930s
- Extinct populations were at lowest elevations

Beever et al. 2003



Ice Age

Still present

★ extinct

-- Spring is 2 weeks earlier and Fall is 2 weeks later
-- Growing season extended by 3 weeks at high latitudes (where moisture available)

(Northern Hemisphere temperate zone)

Estimated: More than Half of Wild Species have Responded to 20th c. Climate Change

(>1500 species / species groups)

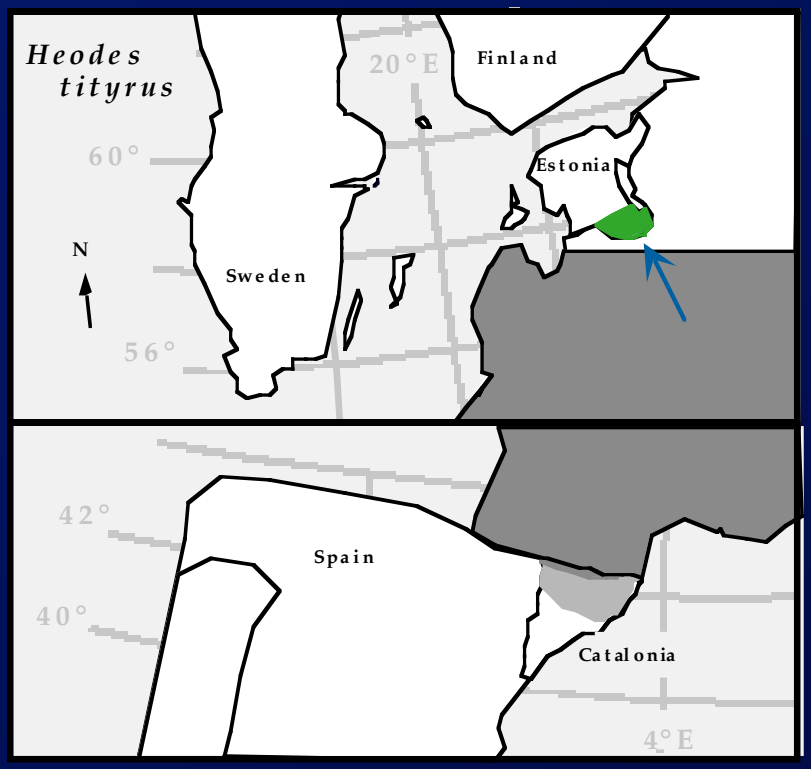
Type of Analysis	Changed as predicted (n)	Changed opposite to prediction (n)	P
Phenological **N = 484 / (678)**	**87 %**	**13 %**	**< .1 x10^{-12}**
Distributional changes: At poleward/upper range boundaries At equatorial/lower range boundaries	81 % 75 %	19 % 25 %	
Community (abundance) changes: Cold-adapted species Warm-adapted species	74 % 91 %	26 % 9%	
N = 460 / (920)	**81 %**	**19 %**	**< .1 x10^{-12}**
Meta-analysis Range-boundaries (n=99) Phenologies (n=172)	**6.1** km-m/decade northward/upward shift **2.3** d/decade advancement		**.013** **< 0.05**

Diverse species of: trees, herbs, shrubs, reptiles, amphibians, fish, marine zooplankton,marine invertebrates, mammals, birds butterflies

(Parmesan & Yohe, *Nature* 2003)

Is this a Problem?

Sooty copper
(Heodes tityrus)



Invasion of Estonia
1998 - 1st record
1999 - breeding populations
2002 - increase #populations
& northward expansion

Parmesan *et al.* 1999

Habitat loss coupled with climate change

Endangered
Quino checkerspot
(E. editha quino)

extinctions due to habitat loss

healthy populations

extinctions due to climate change

Extinction of the Golden toad in Monteverde Costa Rica

- Cloud forest species require mist
- Population crashes followed years with unusually high #dry days, especially > 5 dry (mist free) days in a row

Whole Ecosystems can collapse with single extreme temperature event

Coral Reefs and extreme Sea Surface Temperatures (SST)

Zooxanthellae - single celled solar batteries (dinoflagellates algae)

about 1/100th of a mm

Polyp

Photosynthesis

More than 100% energy needs

Power calcification

Responsible for high productivity of coral reefs

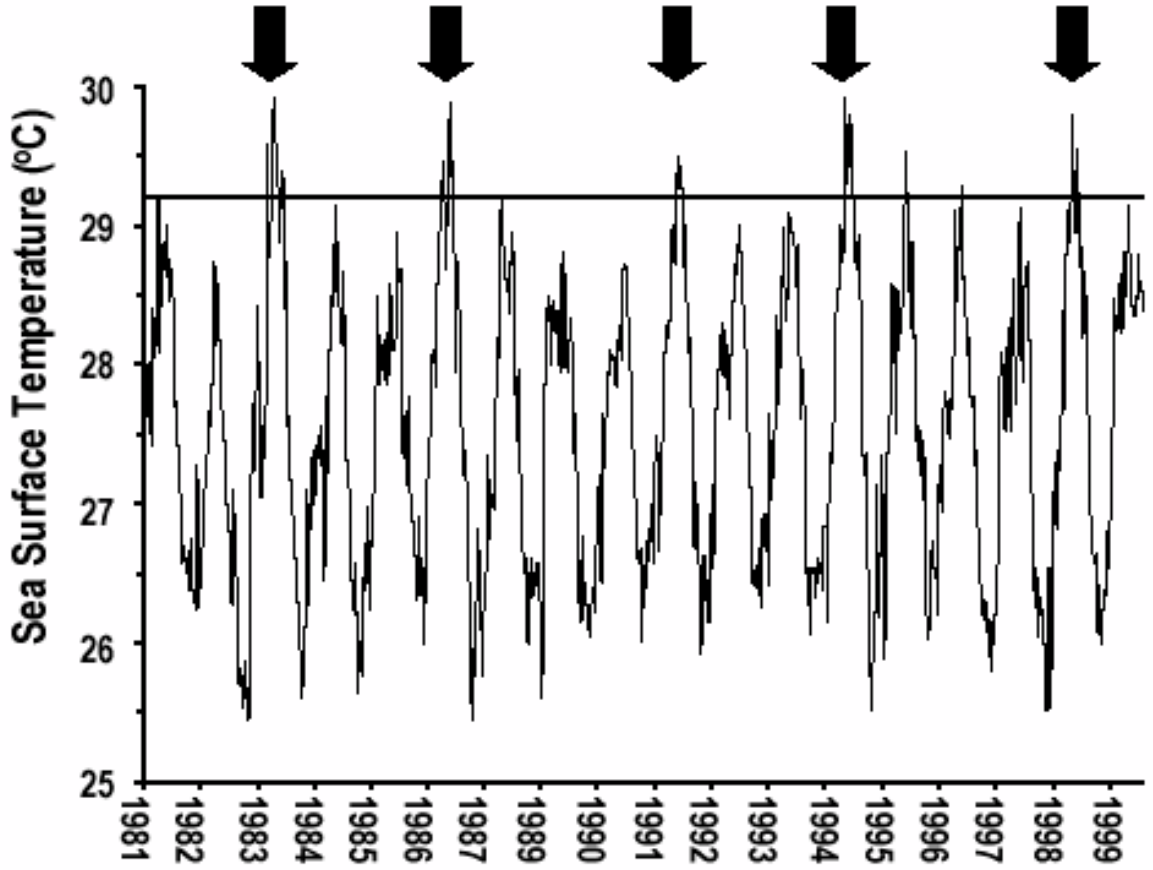
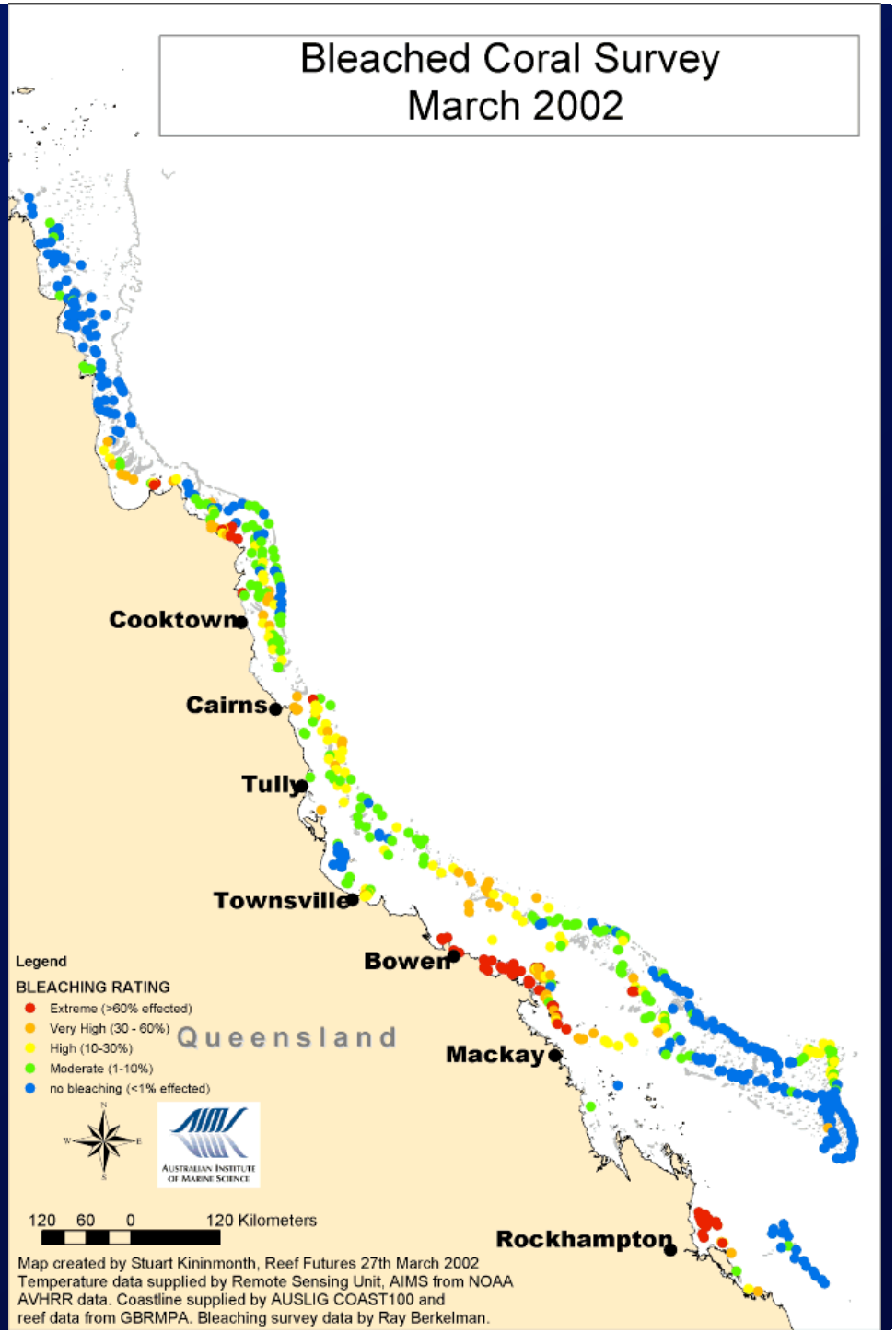


Fig. 7. Weekly sea surface temperature data for Tahiti (17.5°S,149.5°W). Arrows indicate bleaching events reported in the literature. Horizontal line indicates the minimum temperature above which bleaching events occur (threshold temperature). IGOSS-nmc blended data courtesy of the Lamont-Doherty Climate Center at Columbia University.

Stress

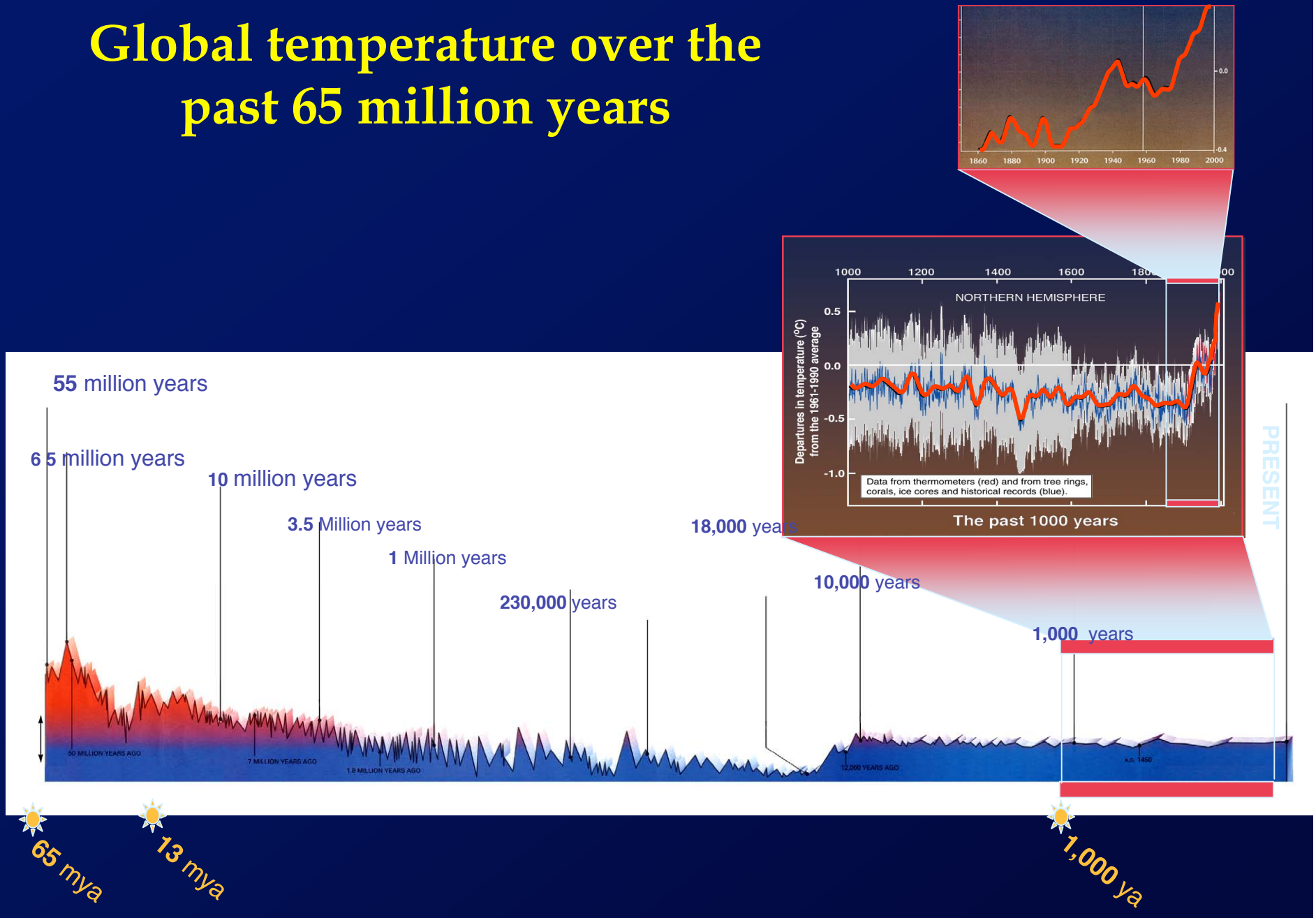

Bleached Coral Survey
March 2002
Cooktown
Cairns
Tully
Townsville
Bowen
Mackay
Rockhampton
Queensland
Legend
BLEACHING RATING
Extreme (>60% effected)
Very High (30 - 60%)
High (10-30%)
Moderate (1-10%)
no bleaching (<1% effected)
AUSTRALIAN INSTITUTE OF MARINE SCIENCE
120 60 0 120 Kilometers
Map created by Stuart Kininmonth, Reef Futures 27th March 2002
Temperature data supplied by Remote Sensing Unit, AIMS from NOAA AVHRR data. Coastline supplied by AUSLIG COAST100 and reef data from GBRMPA. Bleaching survey data by Ray Berkelman.

In 1998, coral bleaching affected every part of the world's oceans – reefs lost 95% of coral in Maldives, Western Australia, Okinawa and Palau.

16% of living corals wiped off reefs in 1998.


Coral reefs are among the most
biologically rich ecosystems on earth.
4,000 species of fish and 800 species of
reef-building corals described

Global temperature over the past 65 million years



Acknowledgements

Raw data:

D. Jordano, L Kaila, J Kullberg, J.J. Lennon, A. Menzel, N. Ryrholm,M.C. Singer, T. Tammaru, J. Tennent, C.D. Thomas, JA Thomas, M Warren

* The Millennium Atlas of Butterflies in Britain and Ireland (Asher *et al. 2001)*
* Field Guide to the Butterflies of Britain & Europe (Higgins & Riley 1970)
* Atlas of Finnish Macrolepidoptera (Hulden *et al.* 2000)
* The Butterflies of Scandinavia in Nature (Henriksen & Kreutzer 1982)
* A World of Butterflies (Schappert 2000)

Material and Images:

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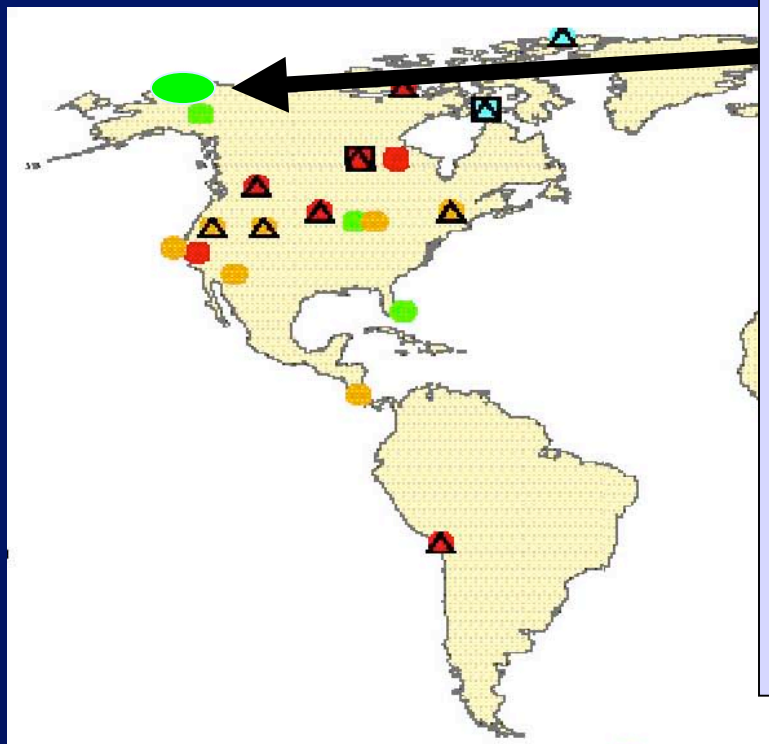
United Nations Intergovernmental Panel on Climate Change
Kristina Schlegel (artist)

First signs of positive feedbacks



Shift in Alaskan tundra carbon balance:

From sink to source

1980s **1990s/2000**

Prudhoe Bay & Toolik Lake, AK

Losing 40 gC/m^2/year

Oechel *et al., Nature* 2000