Impacts of Changes in Extreme Weather and Climate on Wild Plants and Animals

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- **Species' Level:** **Climate extremes determine species' distributions**
- **Community Level:** **Climate extremes alter species' interactions**
- **Ecosystem Level:** **Single extreme weather/climate events can affect whole ecosystems (*i.e.* all plants and animals that make up an ecological system)**

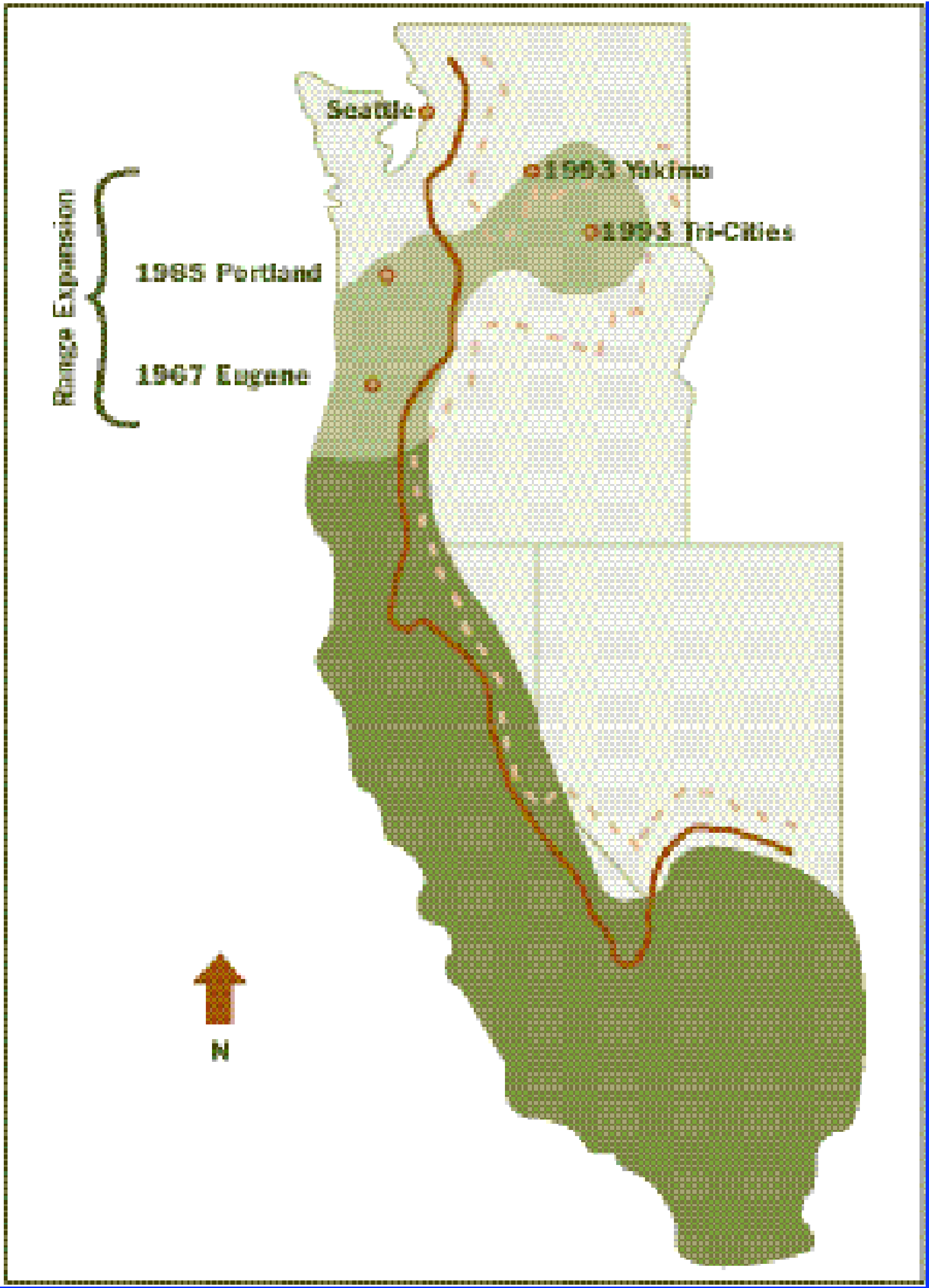
Northward shift of the winter range of the Sachem Skipper butterfly

Caterpillars killed by

• Single event
1/2 hr < -10° C

• Several hours
< -4° C

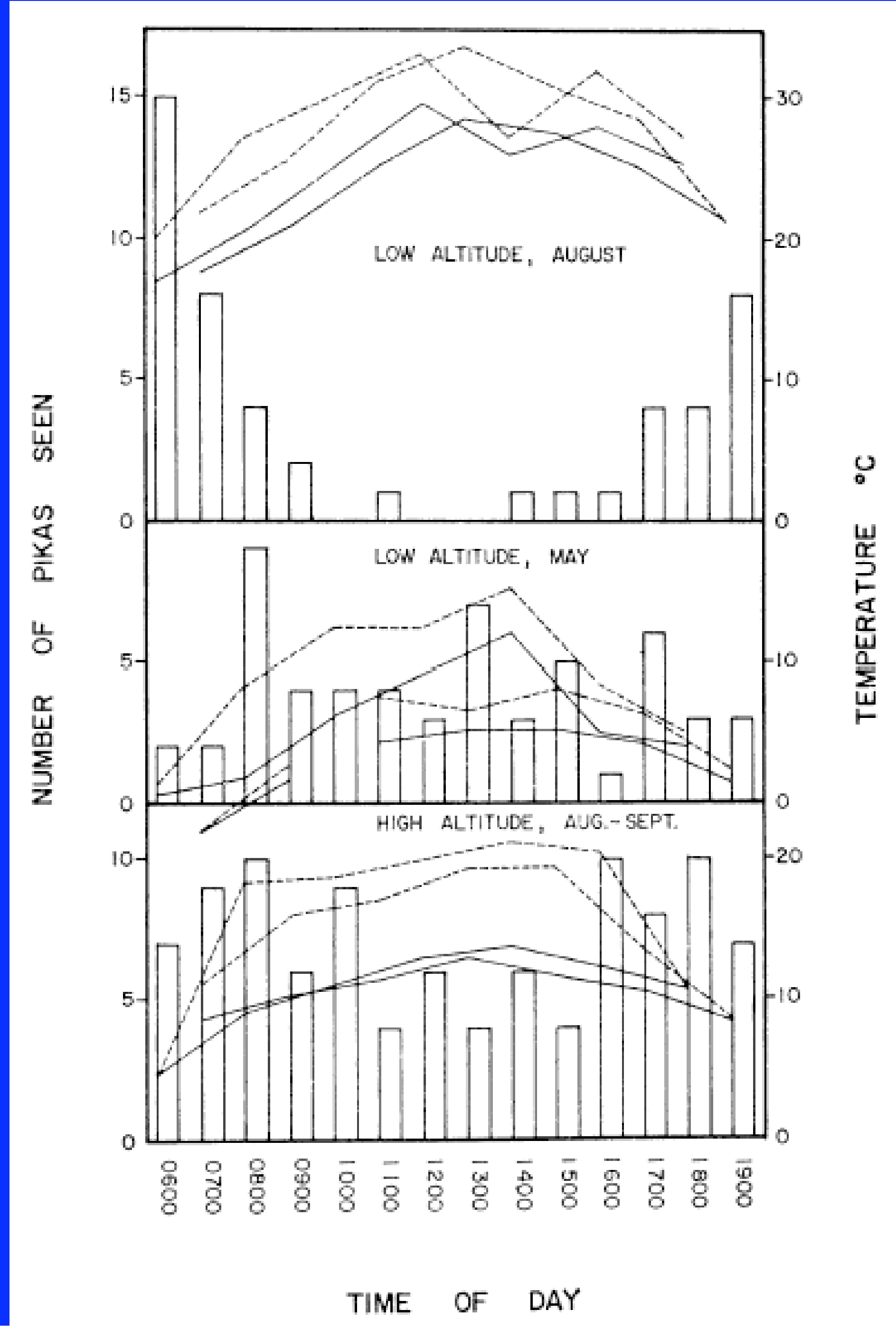
Crozier 2003a,b



Pika is sensitive to heat

- live > 2,300 m
- Must forage > 9x/day
- low elev. pops. don't forage mid-day
- Adults killed by heat stress (>31° C in sun)
- Foraging time limited by temperature

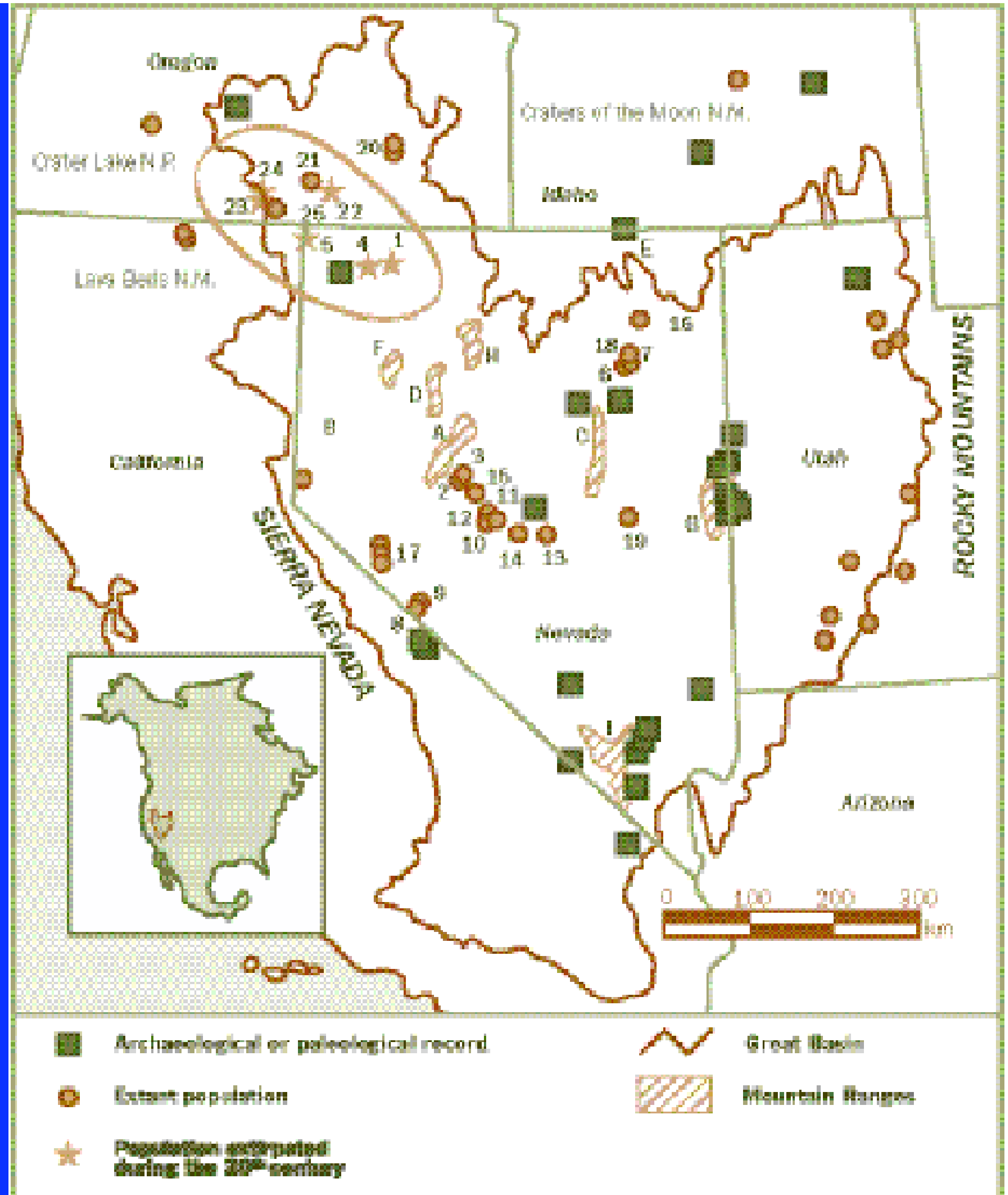
Smith 1974



Upward shift of the pika

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

Beever et al. 2003



Extinction of the Golden toad in Monteverde, Costa Rica

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

RE: Extreme indices

-- -- Strong local and species-level adaptation

-- Biological definition of “extreme” differs by locality

- Tropical butterflies killed by single night freeze (> .5-1 hr at <0° or -2° C). 5 new species just reported in Texas - breeding as far north as Austin (>200 mile northward shift)
- Sub-tropical butterflies killed by several hours <-4°C
- northern temperate species can withstand well below freezing, but still have limits. One species now moving into Fairbanks because of winters not reaching -40° C.
- Boreal species appear to have no cold limit, but many walk rather than fly (takes less energy)

False Springs Cause High Mortality

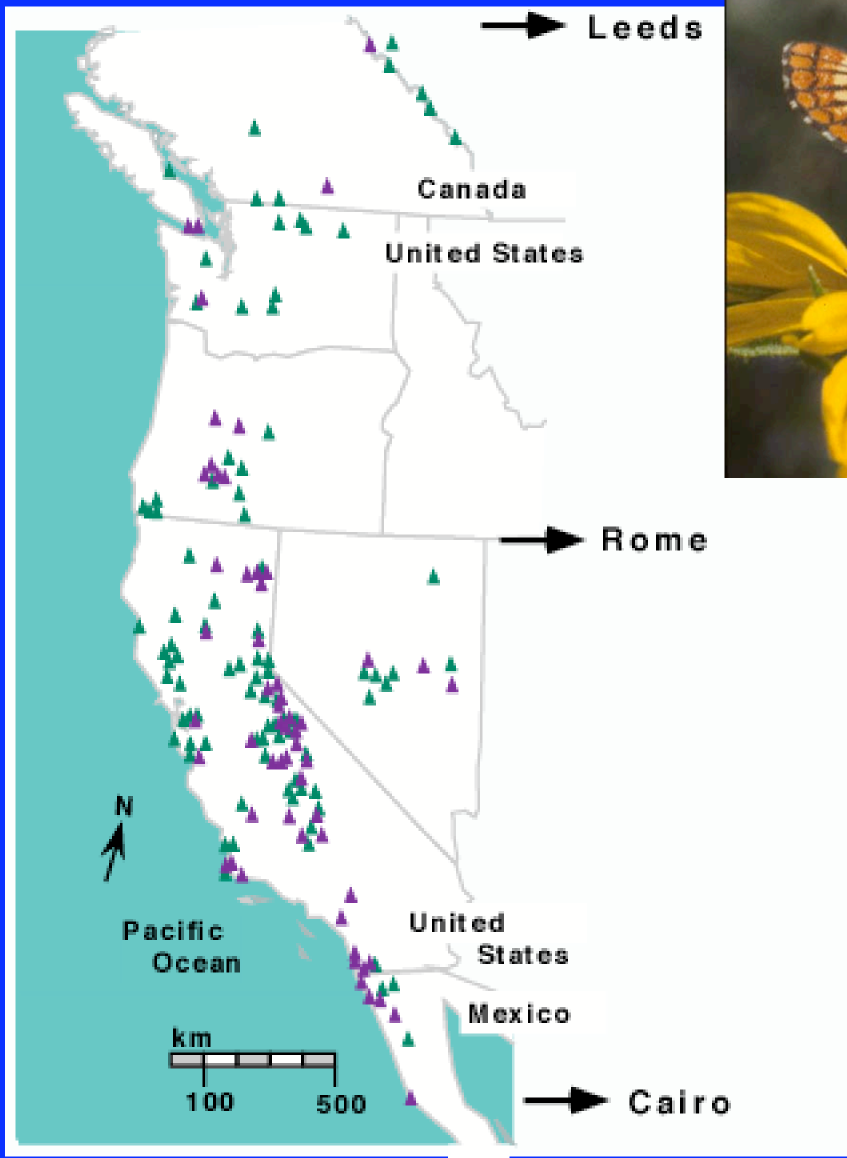
- Hibernation in animals and dormancy in plants is an adaptation to allow survival during extreme temperatures in winter
- In many species, metabolic shift is driven by temperature and not photoperiod
- Warmth in early January breaks hibernation in animals and dormancy in plants
- Active animal/plant vulnerable to "Normal" freeze in late Jan./early Feb.

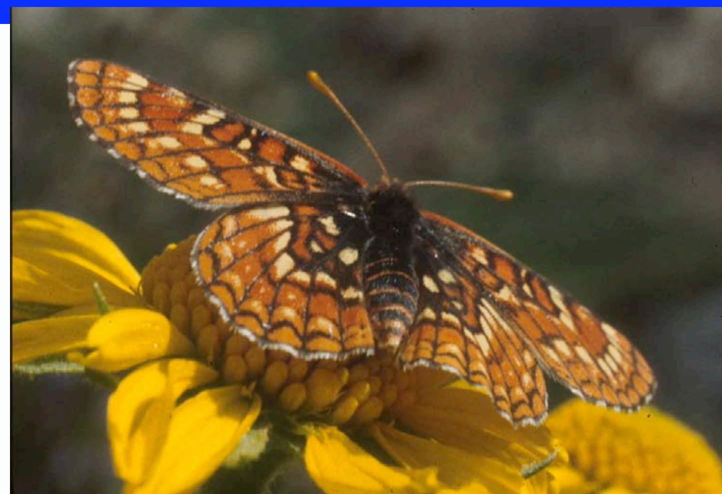
False Springs correlated with:

- Large tree die-offs in southern France
- Extinctions of low elevation populations (< 900 m) of the Apollo butterfly. The range across southern France has contracted upward by about 300 m.

Descimon et al 2005

Northward & Upward Range Shift from 1860 - 1996
Edith's Checkerspot *(Euphydryas editha)*





census 1993-1996
green = present
purple = extinct

Population extinctions followed false springs:

- April flight at 8,000 ft (normal June) - Adults killed by snow/cold temps (12° F)
- December flight near San Diego in 2005 (normal March) - no offspring recorded

Parmesan, C, *Nature* 1996

Climate Extremes affect Species' Interactions

Drought

stresses plants

lowers production of defenses

herbivores do better

Absence of hard winter freezes

pest species tend to build up bigger populations

Drought + mild winters

probable cause of recent large outbreaks of forest pests (moths & beetles) in western USA, Canada, & southern France

Many Communities Maintained by Fire
Intensity (heat & height) & Frequency

Southeastern long-leaf pine forest:

- low heat / underbrush fire
- 10 yr cycle

Giant Redwood forests

- moderate heat / all but canopy
- 15- 20 yr cycle

South Africa Fynbos

- high heat / canopy fire
- 3-5 yr cycle


Whole Ecosystems can collapse with single extreme temperature event
Coral Reefs and extreme SST

Zooxanthellae - single celled solar batteries (dinoflagellates algae)

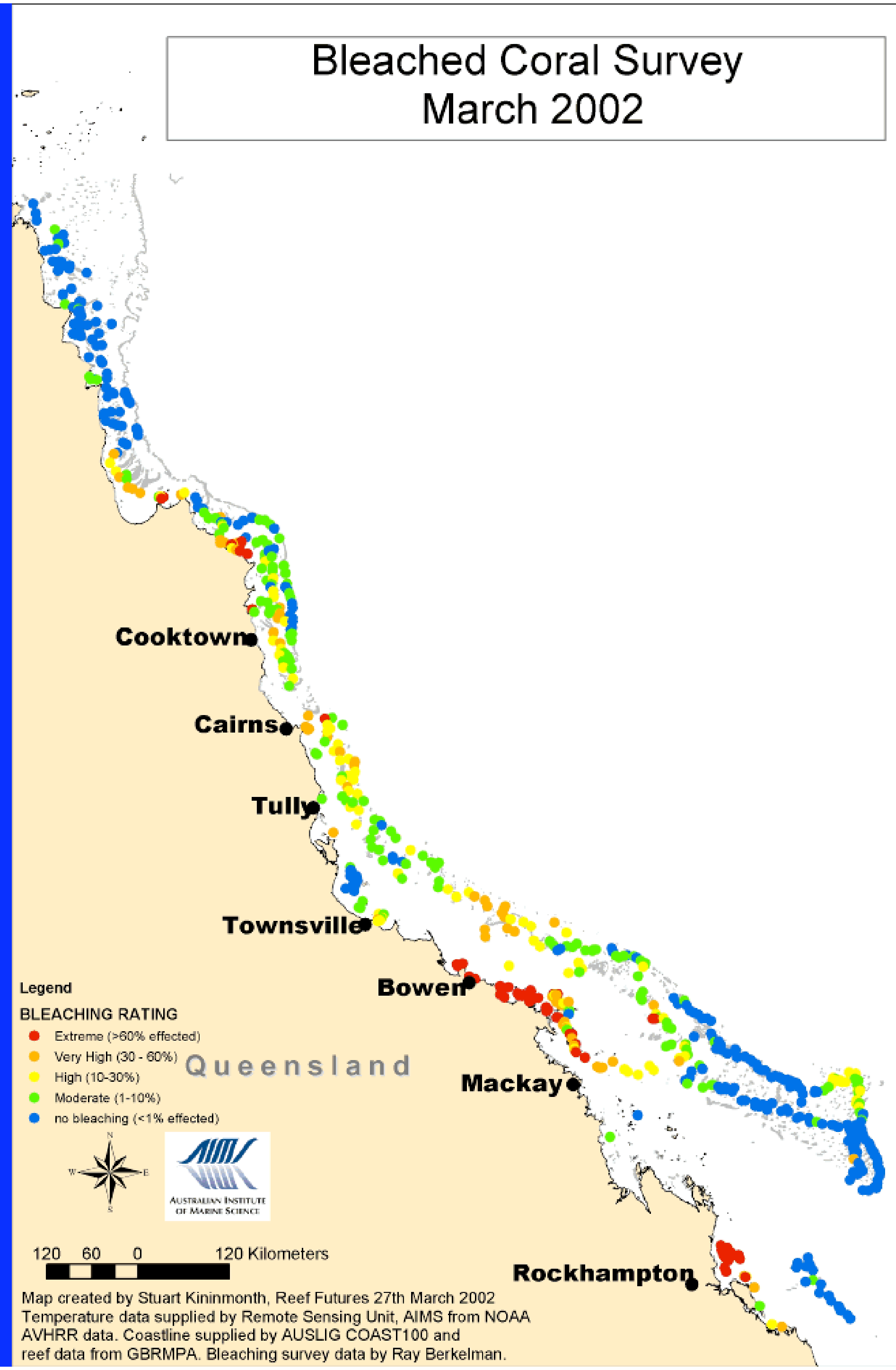
<u>Photosynthesis</u>

More than 100% energy needs

Power calcification

Responsible for high productivity of coral reefs


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.

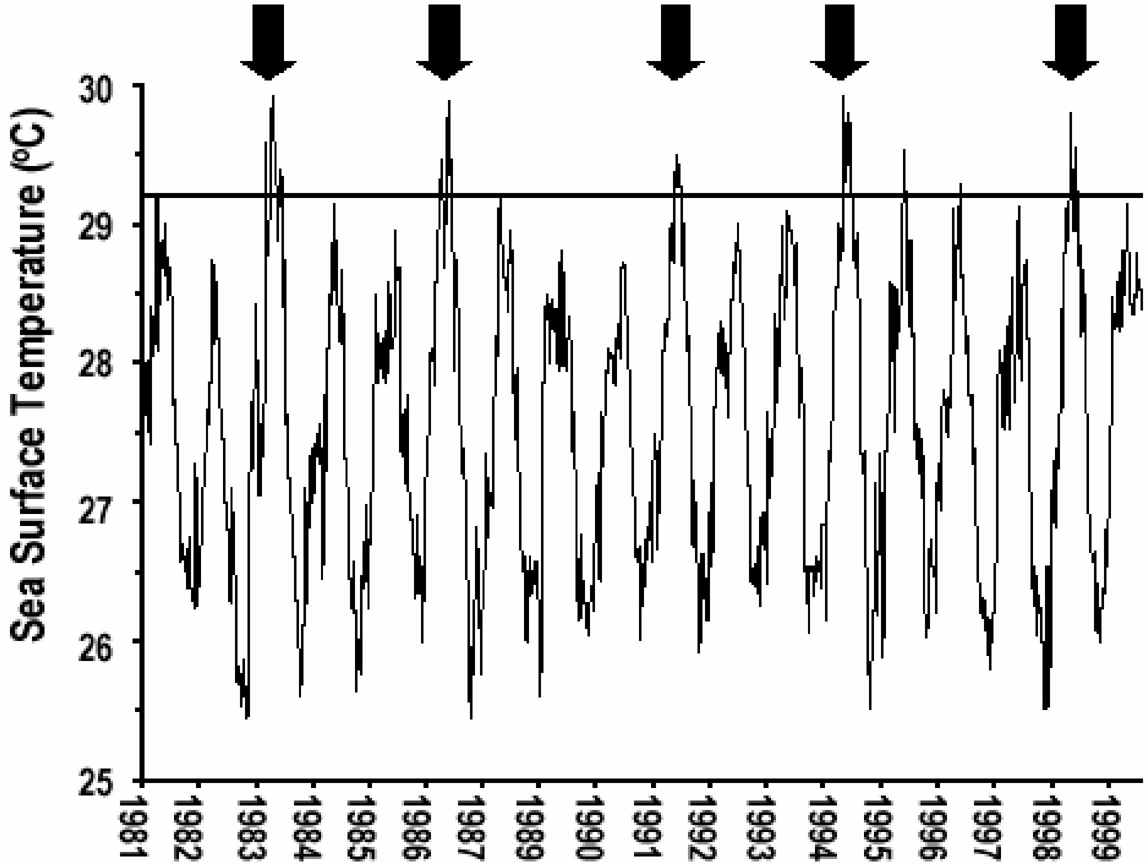
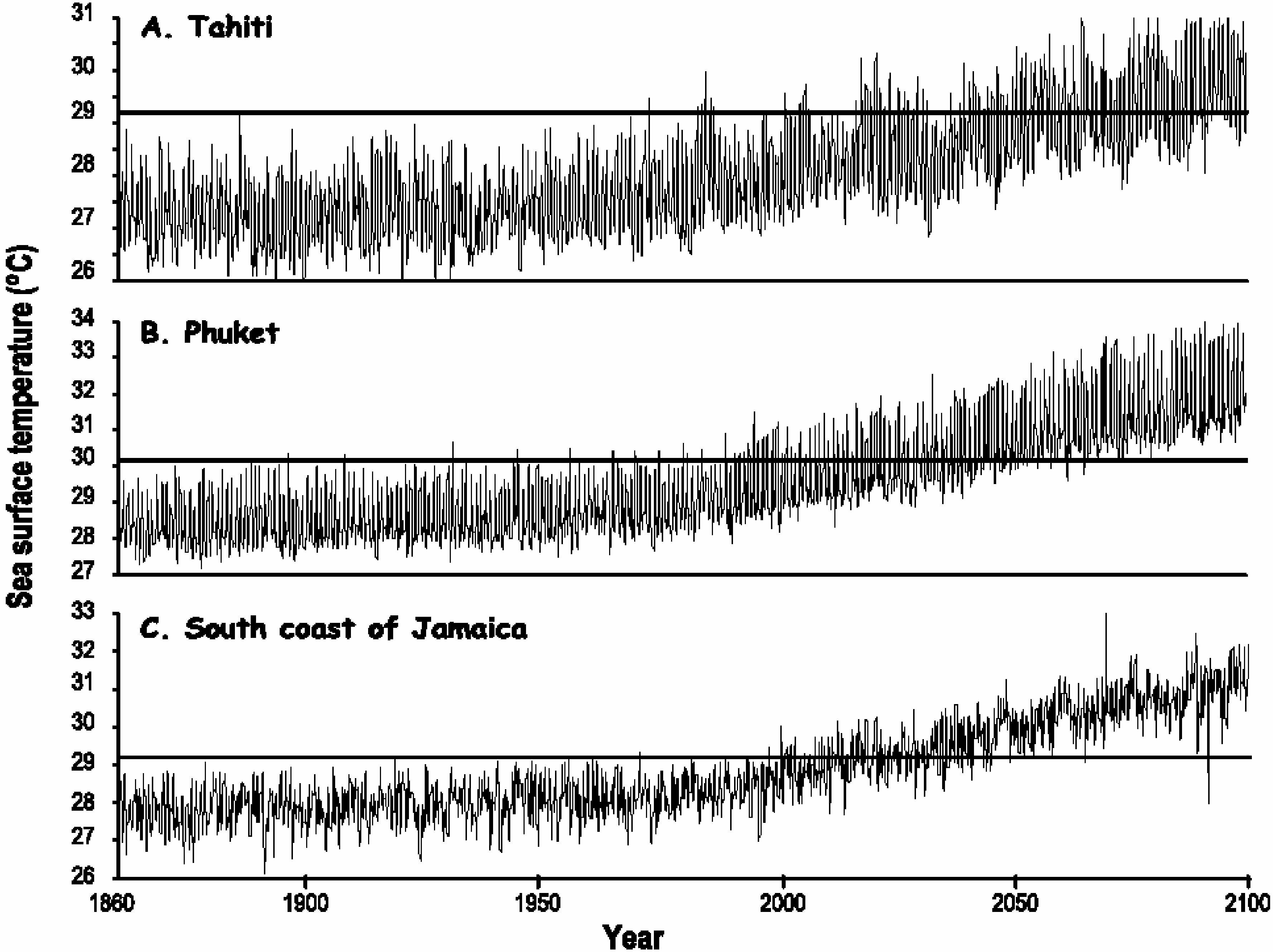


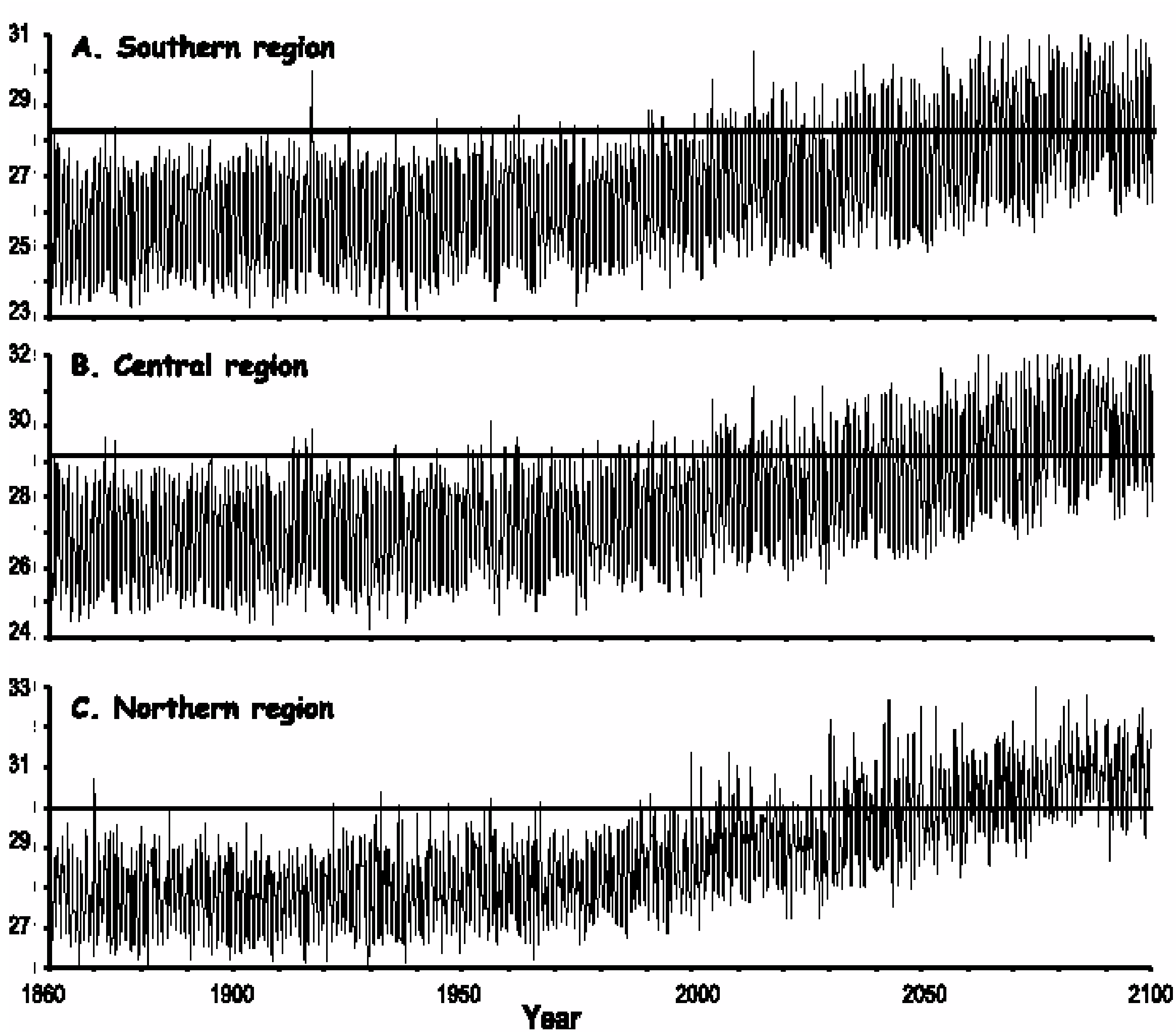
Fig. 7. Weekly sea surface temperature data for Tahiti (17.5°S,149.5°W). Arrows indicate bleaching events reported in the literature. Horizontal line indicates the minimum temperature above which bleaching events occur (threshold temperature). IGOSS-nmc blended data courtesy of the Lamont-Doherty Climate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

Hoegh-Guldberg *Mar. Freshwater Res.*, 1999, **50**, 839–66

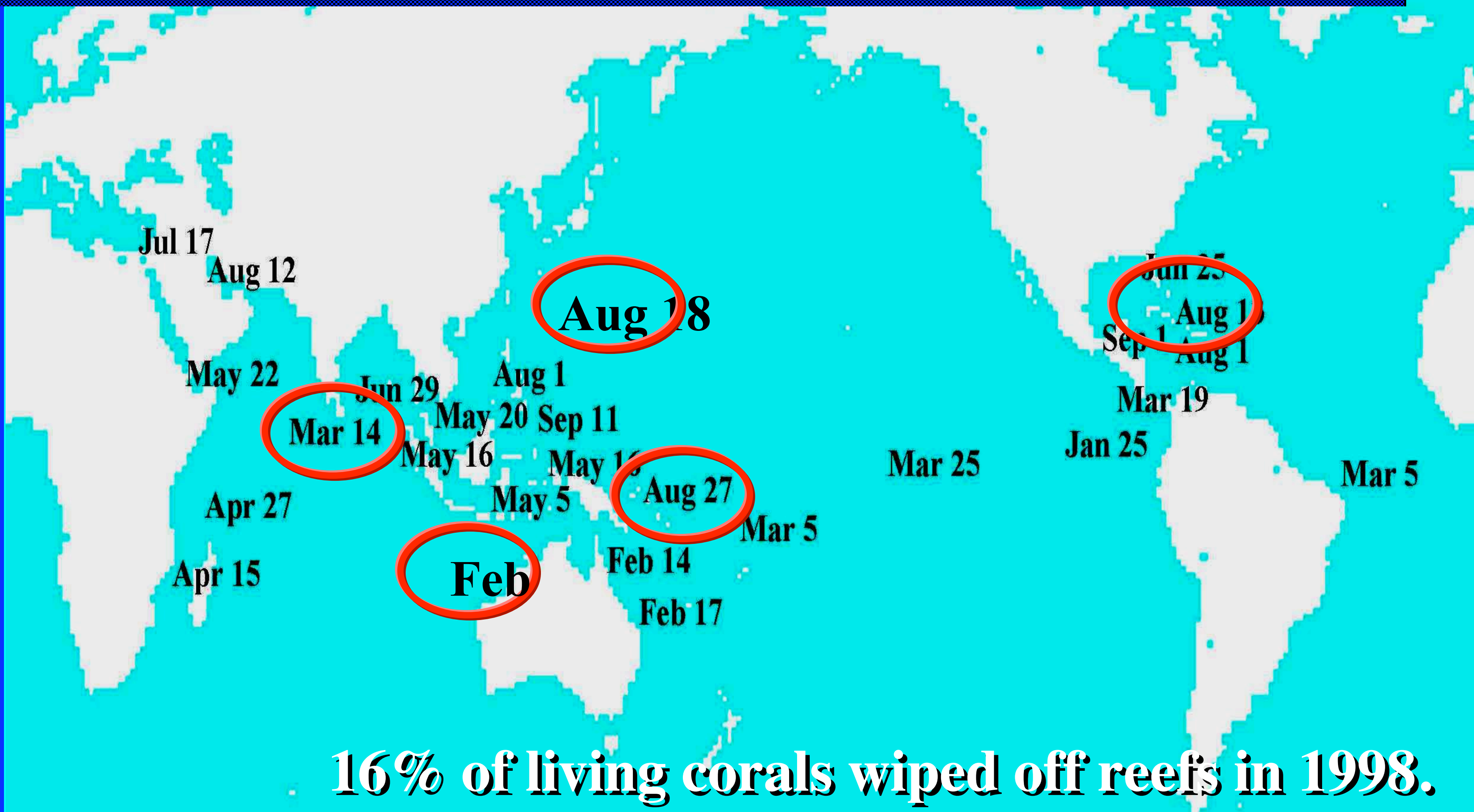


A. Tahiti
B. Phuket
C. South coast of Jamaica
Sea surface temperature (°C)
Year
1860
1900
1950
2000
2050
2100
26
27
28
29
30
31
32
33
34

Great Barrier Reef



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



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

Physically based indices
(not necessarily extremes)

- Frost days (Tmin $\leq 0^{o}$)
- Summer days (Tmax $\geq 25^{o}$)
- Ice days (Tmax $\leq 0^{o}$)
- Tropical nights (Tmin $\geq 20^{o}$)
- Growing season length
- Diurnal temperature range

Percentile temperature indices

- Cool nights (Tmin < 10th %)
- Cool days (Tmax < 10th %)
- Warm nights (Tmin > 90th %)
- Warm days (Tmax > 90th %)
- Warm spell duration indicator
  - Annual count of ≥ 6 days in row Tmax > 90th)
- Cold spell duration indicator
  - Annual count of ≥ 6 days in row Tmin < 10th)

Extreme temperature values for the year

- Max Tmax
- Max Tmin
- Min Tmax
- Min Tmin

Extreme temperature values for the year

- Max Tmax
- Max Tmin
- Min Tmax
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NCDC extremes monitoring

- Just being developed
- Uses a subset of the ET's indices
- Starting focus is on North America
  - Plan for close collaboration with Canada and Mexico

Data for extremes monitoring

- U.S. data from those stations that the Menne-Williams homogeneity test could not find a discontinuity in
  - ~ 1,000 stations
  - Different station list for Tmax and Tmin
- Canadian data are the homogeneity adjusted daily temperature data provided by Lucie Vincent
- Mexican data from Art Douglas
  - Homogeneity assessments not yet made
- Will require regular updates of the daily data for the homogeneous stations from the U.S., Canada and Mexico

Physically based indices
(not necessarily extremes)

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- Summer days (Tmax ≥ 25^o)
- Ice days (Tmax ≤ 0^o)
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- Diurnal temperature range

Precipitation indices

- Max 1-day precipitation amount
- Max 5-day precipitation amount
- Simple daily intensity index
- Number of heavy precipitation days – 10 mm
- Number of very heavy precipitation days – 20 mm
- Number of days above nn mm
- Consecutive dry days
- Consecutive wet days
- Very wet days – 95^{th} percentile
- Extremely wet days – 99^{th} percentile
- Annual total wet-day precipitation

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