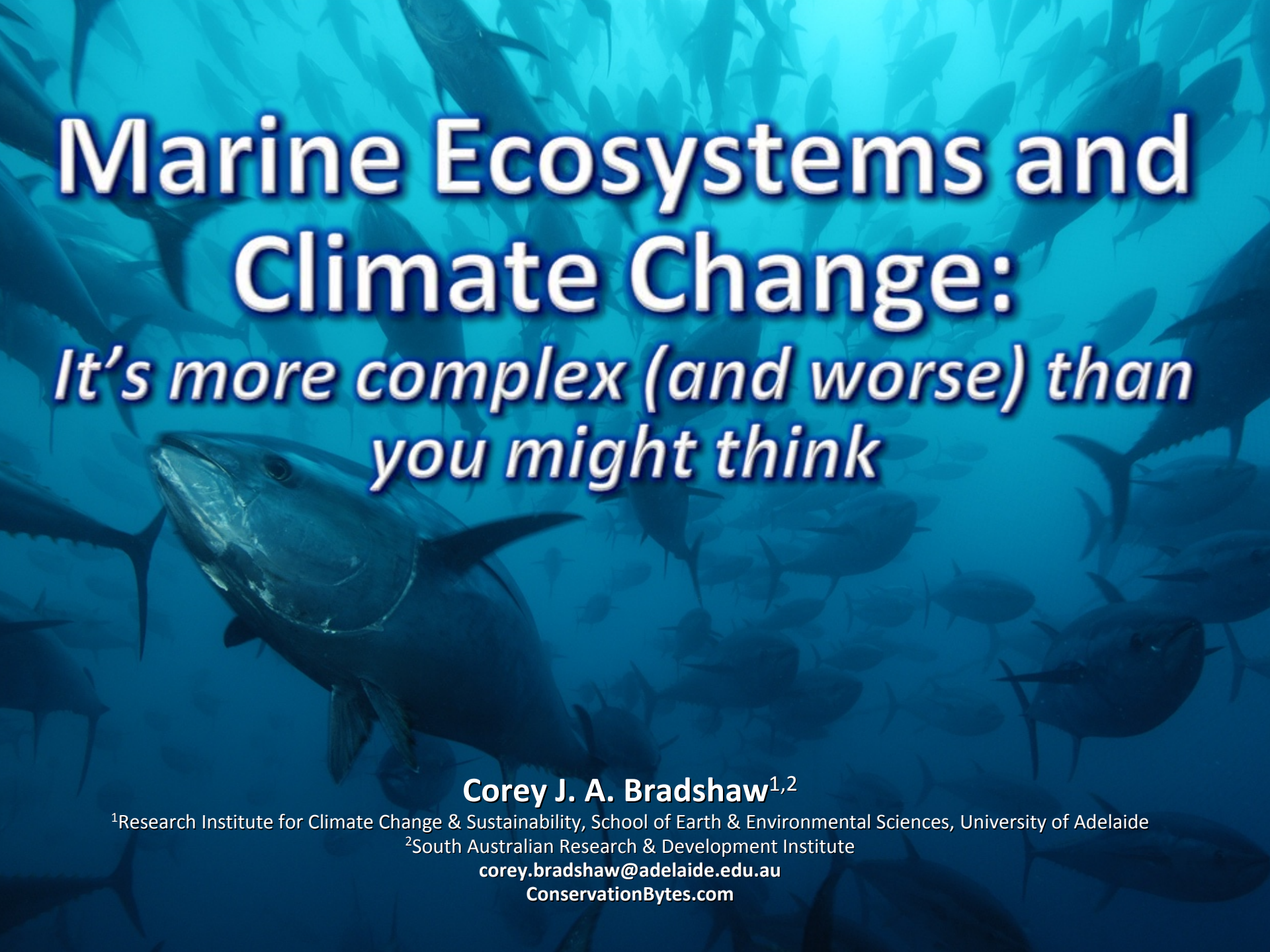

Marine Ecosystems and Climate Change:

It's more complex (and worse) than you might think

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- Ecosystem services
- Damaged oceans
- Marine climate change in Australia
- It’s the pace, not magnitude
- It’s the tail, not the peak
- Synergies
- Emergent properties

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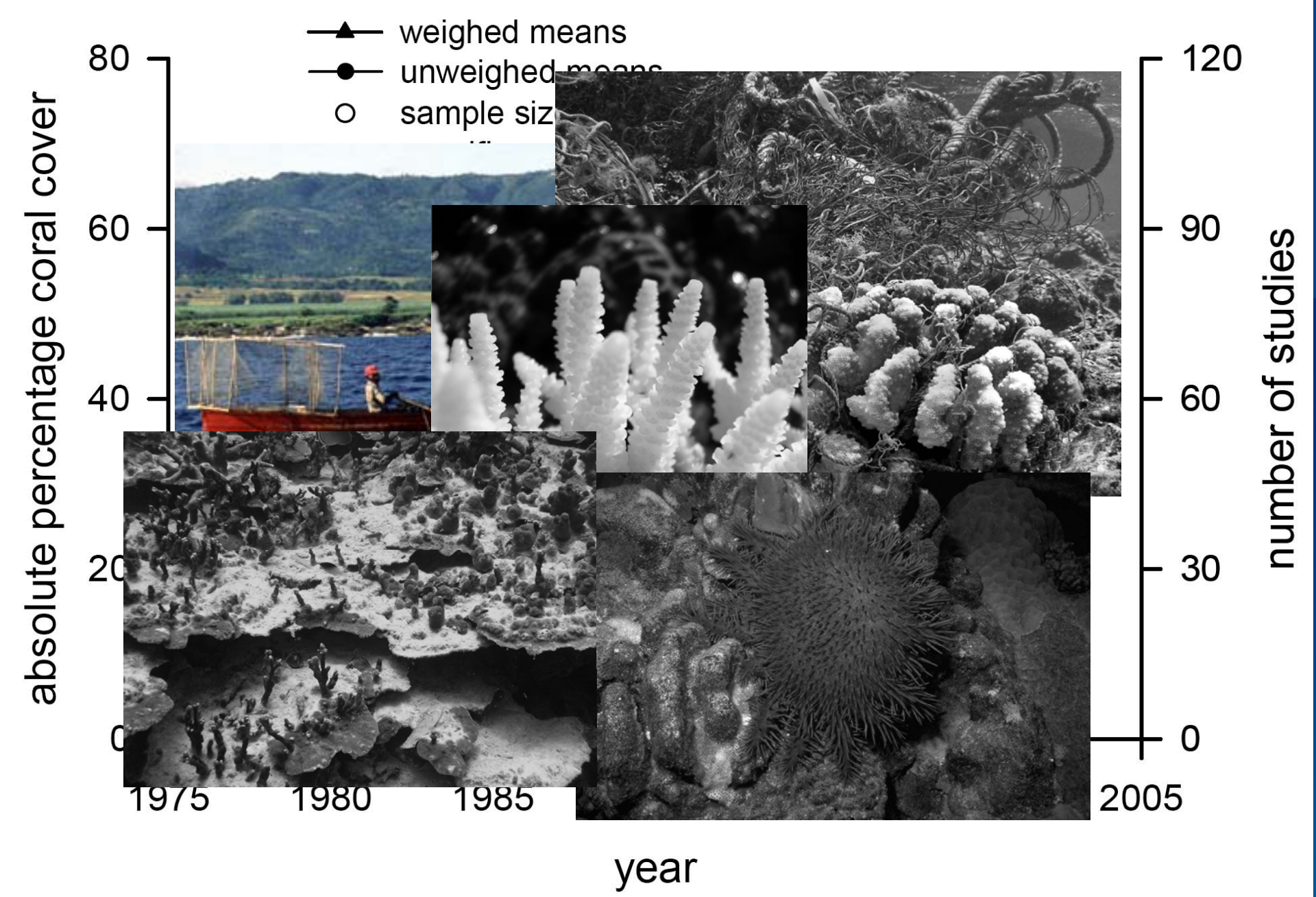
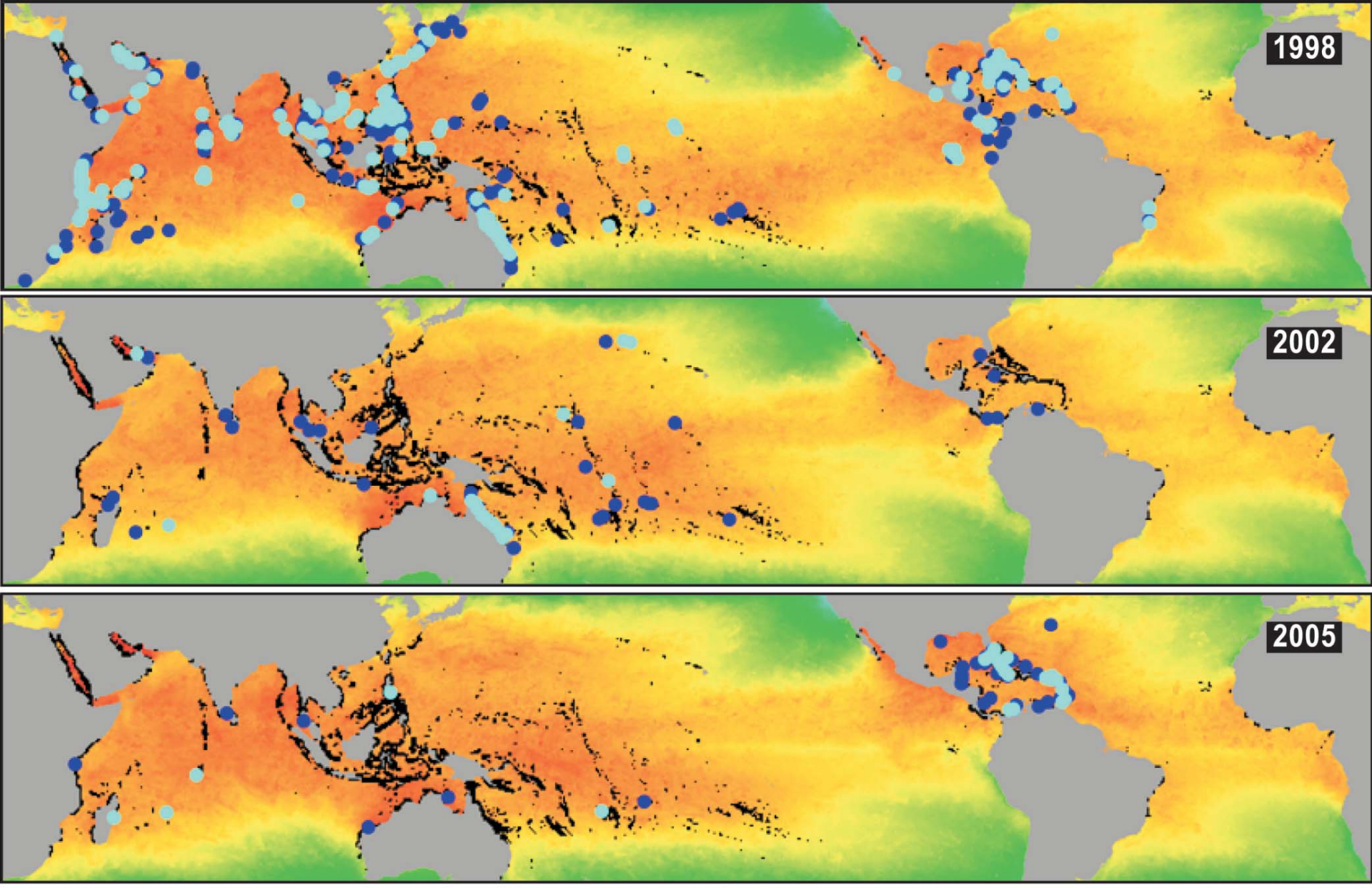
- Reduce desertification
- Maintain soils
- Crop pollination → €153 billion/year
- Seed dispersal
- Food provision → fisheries: €50 billion/year
- Water purification
- Fuel provision
- Fibre provision
- Climate regulation
- Flood regulation
- Disease regulation
- Waste decomposition/detoxification
- Nutrient cycling
- Soil formation
- Primary production
- Pharmaceutical sources
- Cultural appreciation (aesthetic, spiritual, educational, recreational…)

- €50 billion lost/year
- Land-based ecosystem loss €545 billion by 2010
- > €14 trillion/year lost by 2050

Cost of Policy Inaction (COPI):
The case of not meeting the 2010 biodiversity target.
European Commission



Gardner et al. (2003) *Science* 301:958-960


1998
2002
2005
18°
20°
22°
24°
26°
28°
30°
32°
34°C
Severe bleaching
Low to medium bleaching

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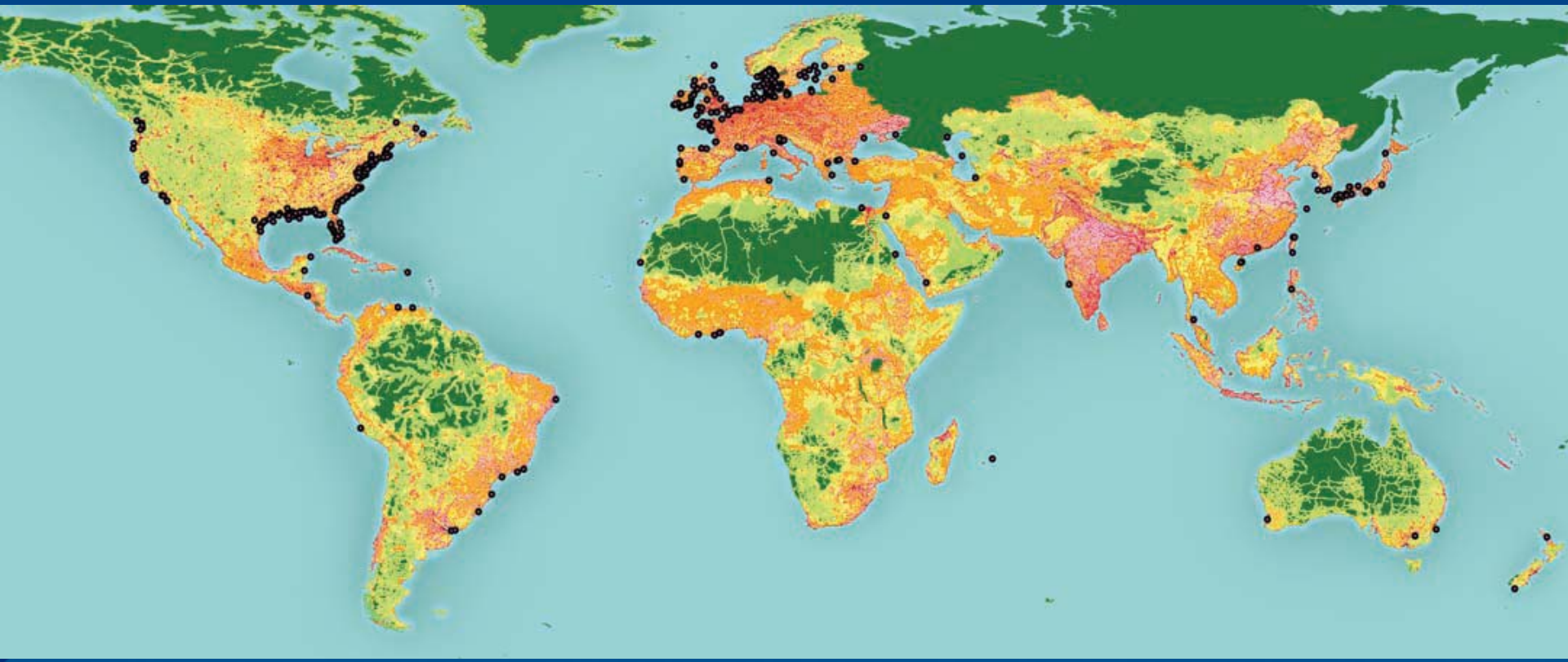
Marine Dead Zones



Diaz & Rosenberg (2008) *Science* 321:926-929

Connell et al. (2008) *Mar Ecol Prog Ser* 360:60-72

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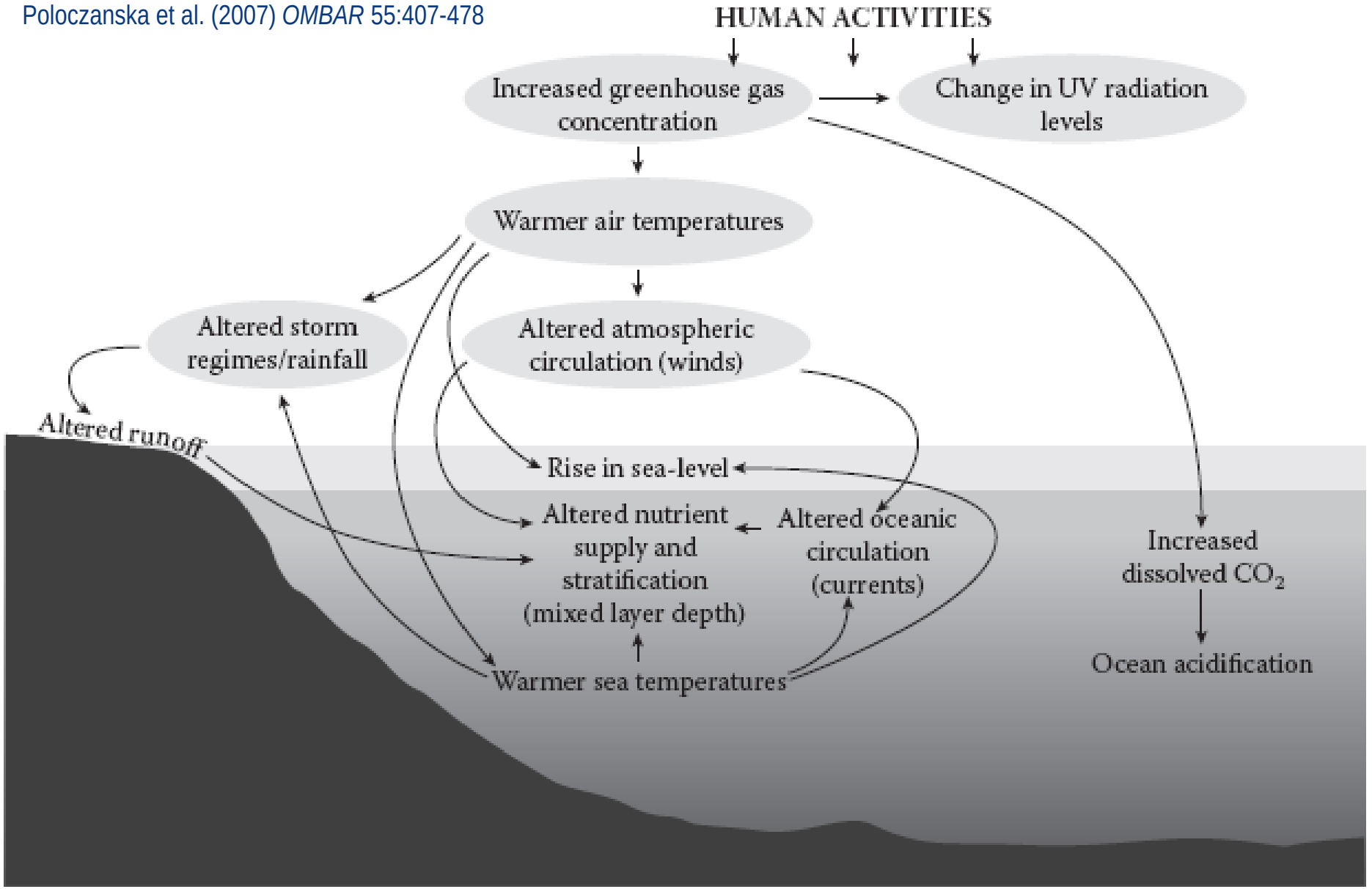
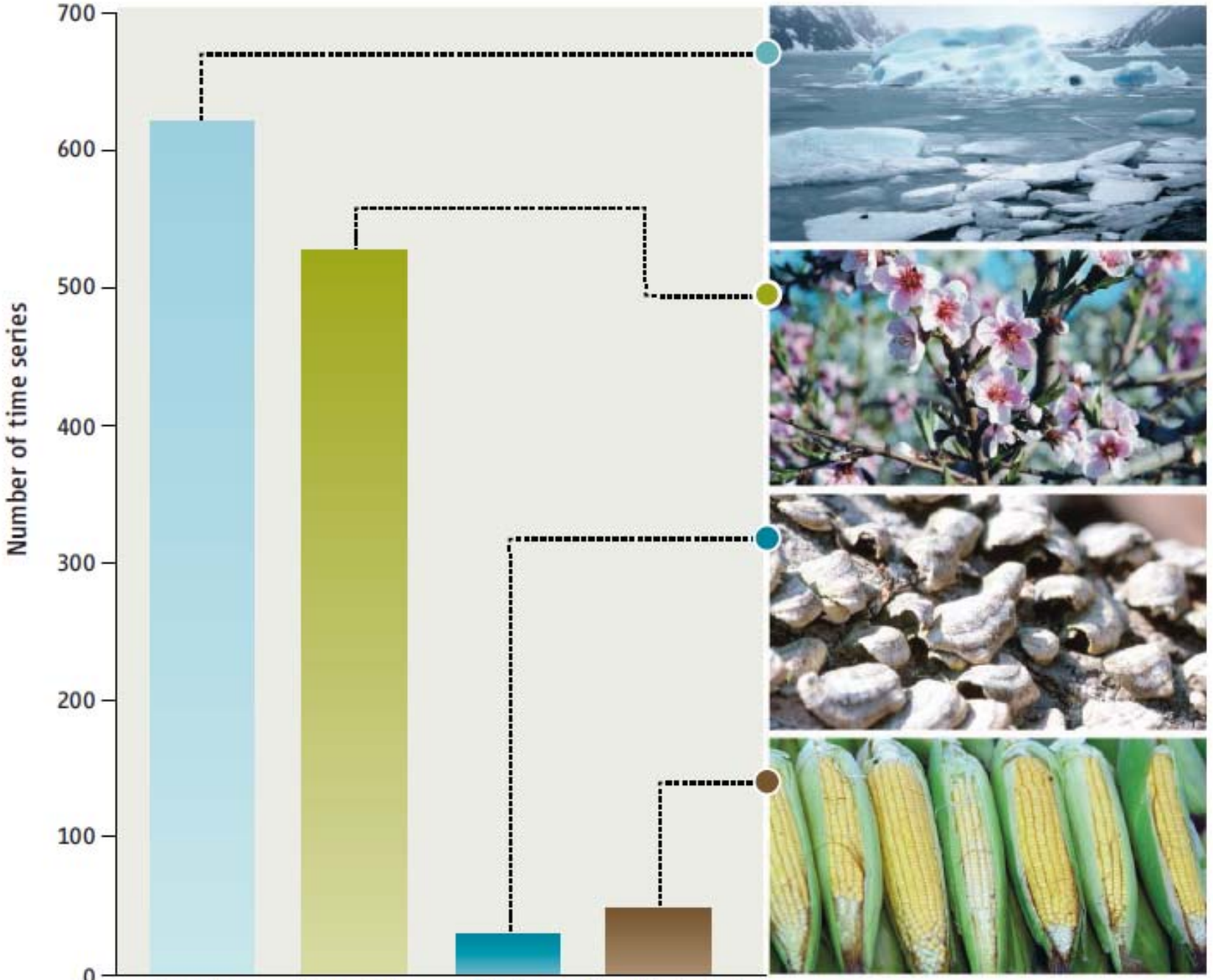
Ocean Damage Tour

Poloczanska et al. (2007) *OMBAR* 55:407-478

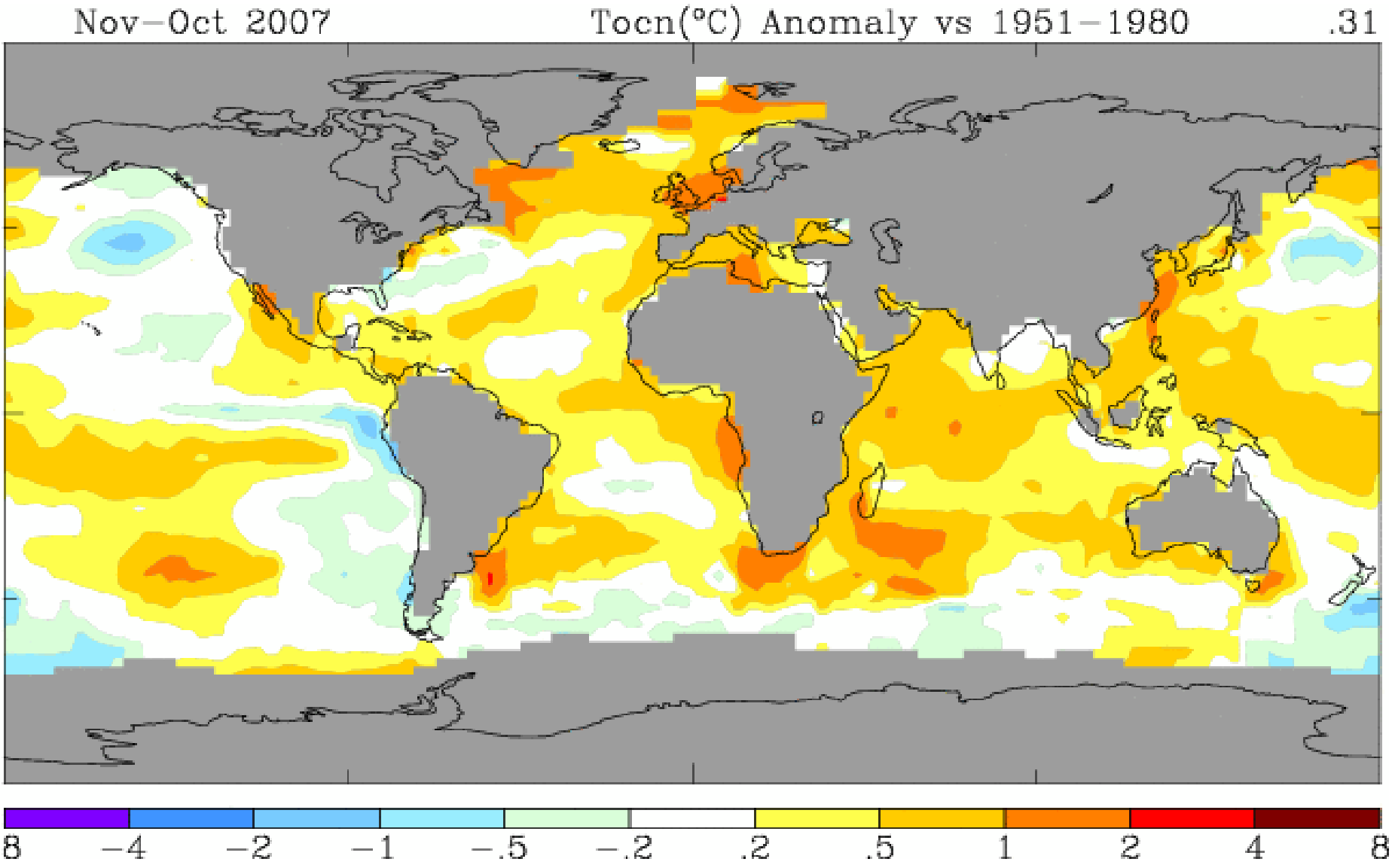




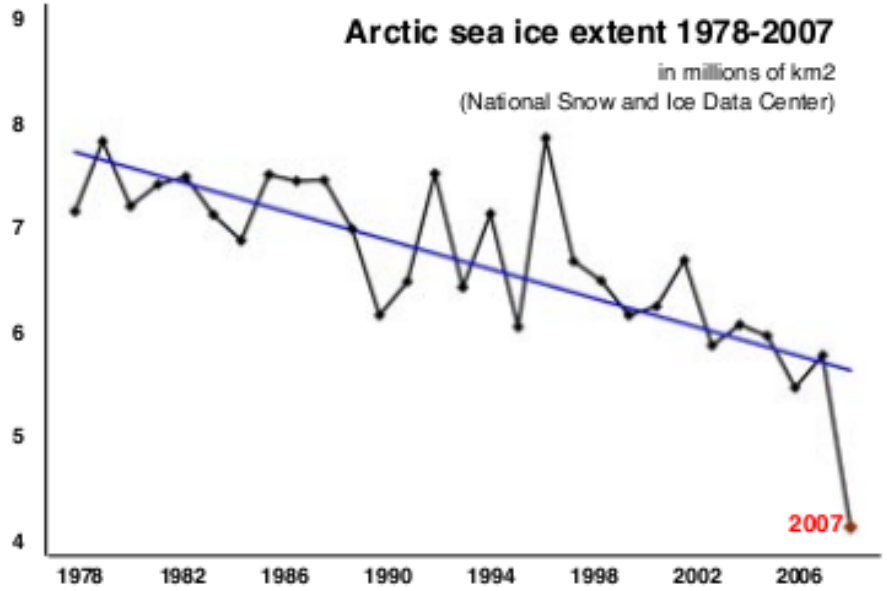
Richardson & Poloczanska (2008)
Science 320:1294-1295

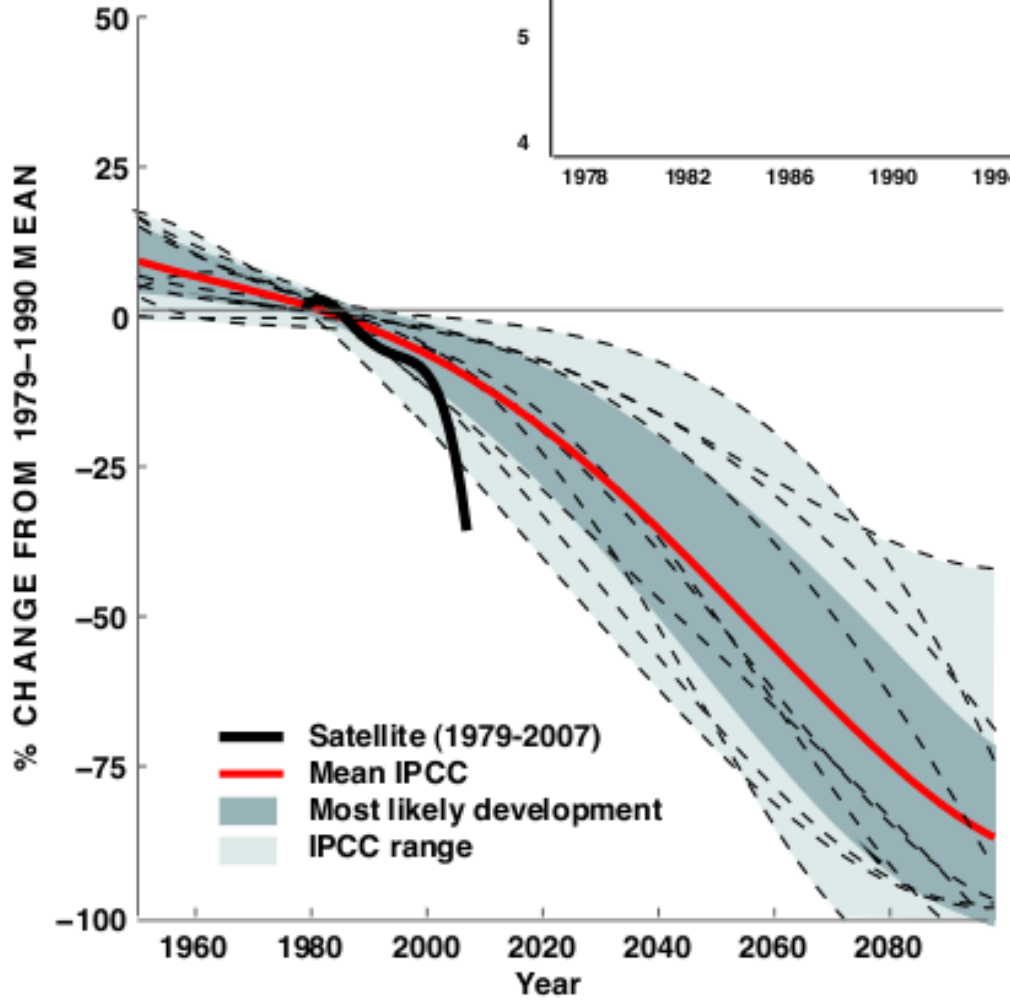
Sources and parameters: HR2SST_1200km_Anom1112_2007_2007_1951_1980

Note: Gray areas signify missing data.



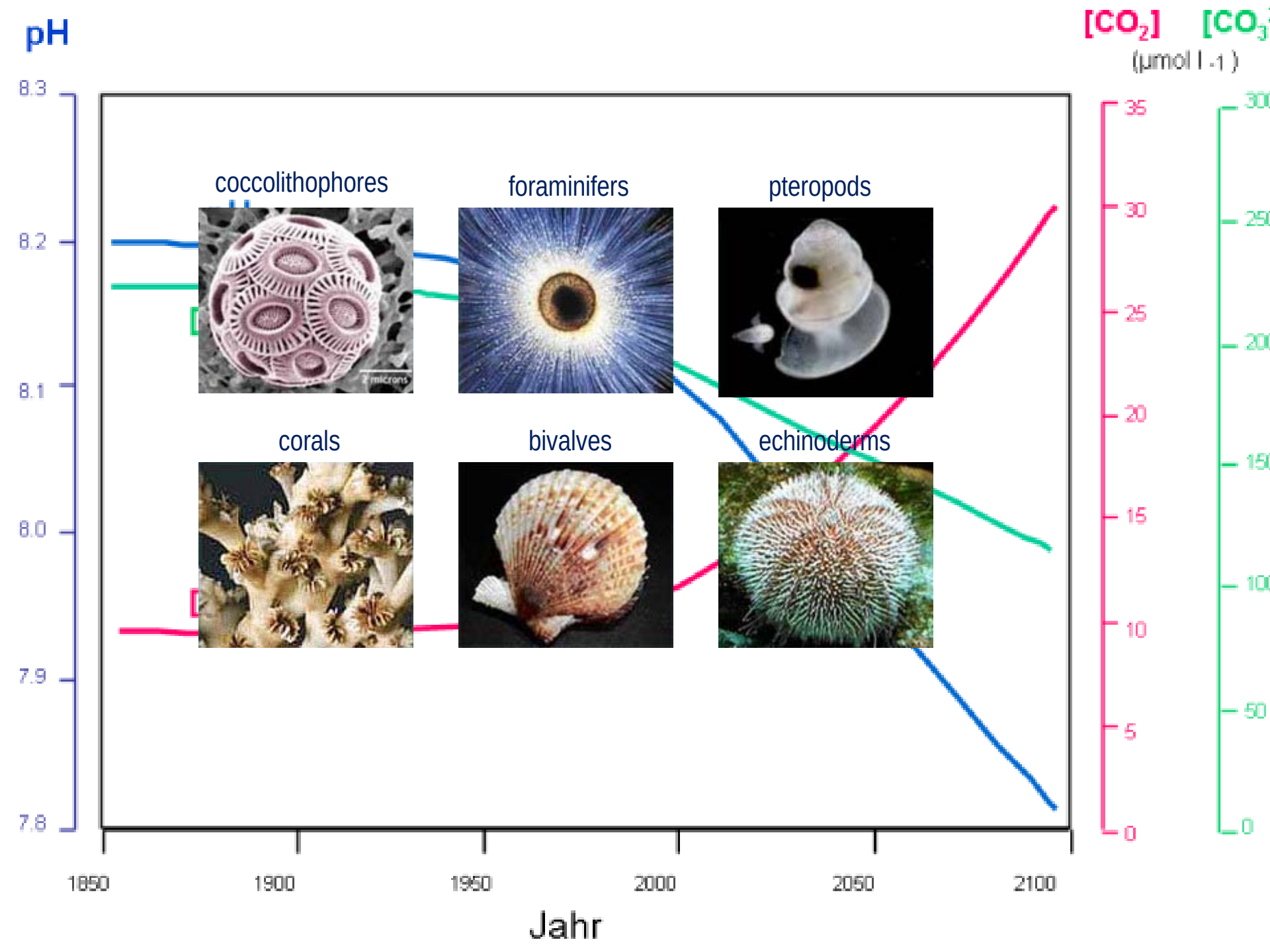
www.carbonequity.info/PDFs/arctic.pdf



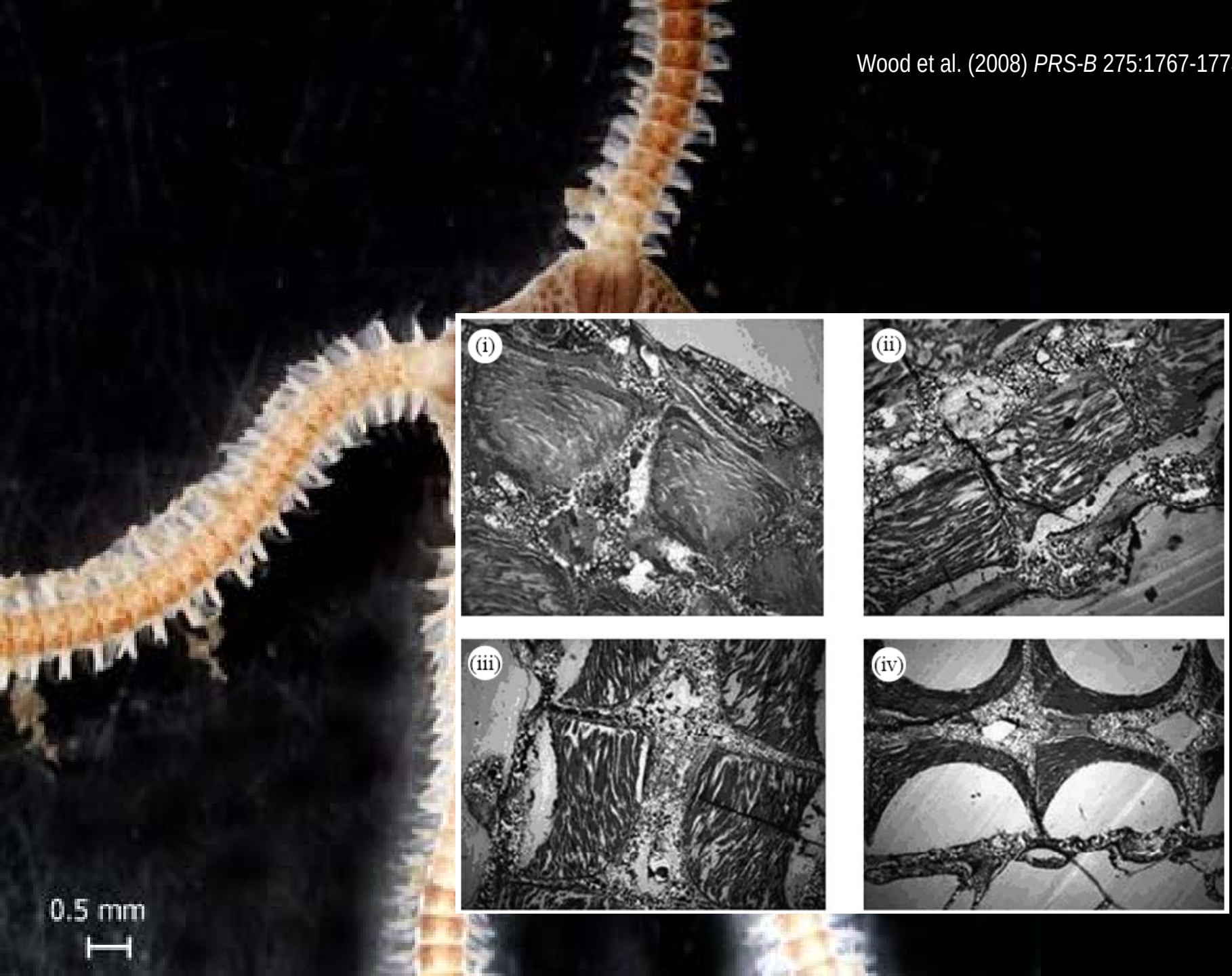


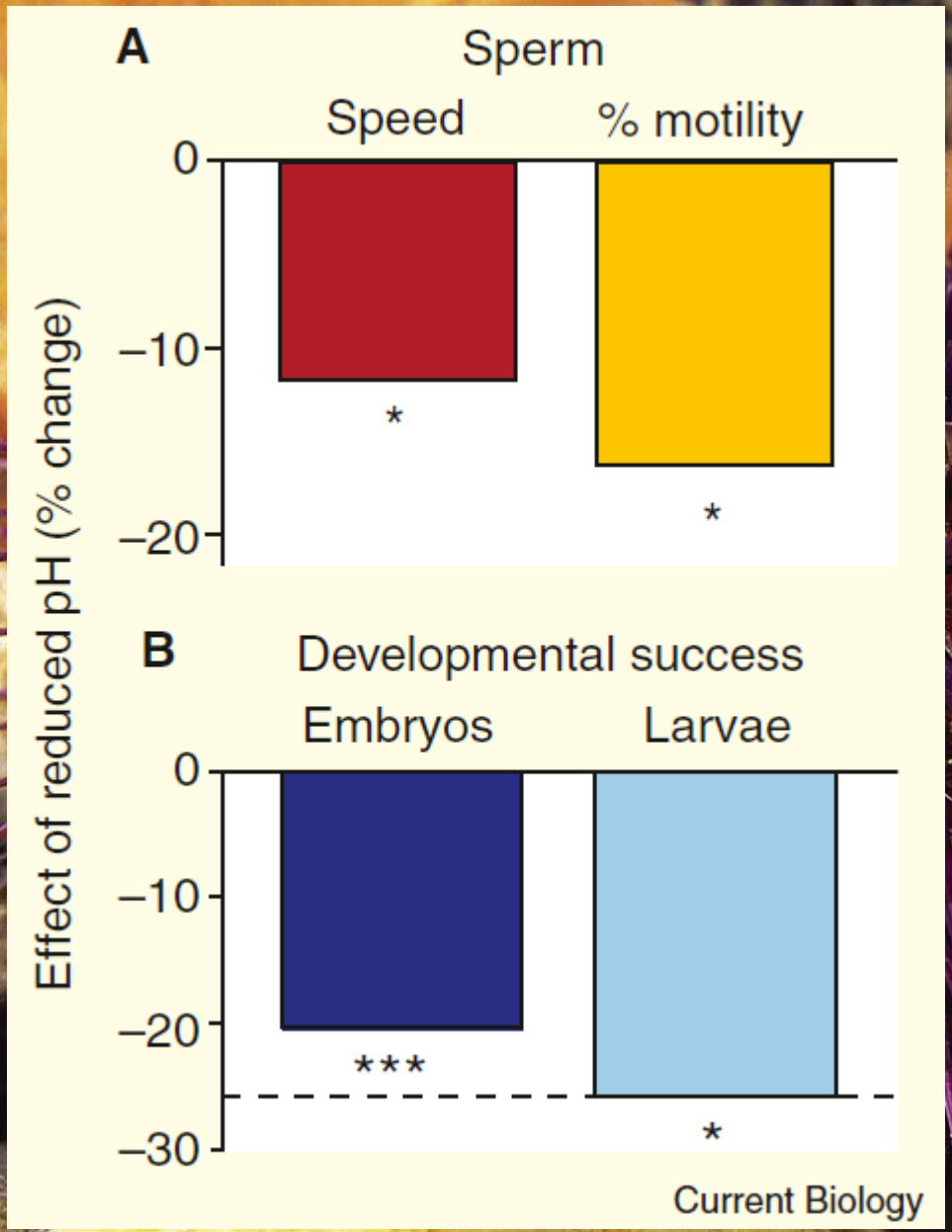
Arctic sea ice summer extent loss compared to IPCC projections

Arctic ice extent loss to September 2007 compared to IPCC modelled changes using the SRES A2 CO2 scenario (IPCC high CO2 scenario). September loss data from satellite observations. Data smoothed with a 4th order polynomial to smooth out the year-to-year variability. Chart courtesy Dr Asgeir Sorteberg, Bjeknes Centre for Climate Research and University Center at Svalbard, Norway.


pH
8.3
8.2
8.1
8.0
7.9
7.8
[CO2]
[CO3]
(µmol l -1)
35
30
25
20
15
10
5
0
300
250
200
150
100
50
0
coccolithophores
foraminifers
pteropods
corals
bivalves
echinoderms
2 microns
1850
1900
1950
2000
2050
2100
Jahr

Wood et al. (2008) *PRS-B* 275:1767-1773

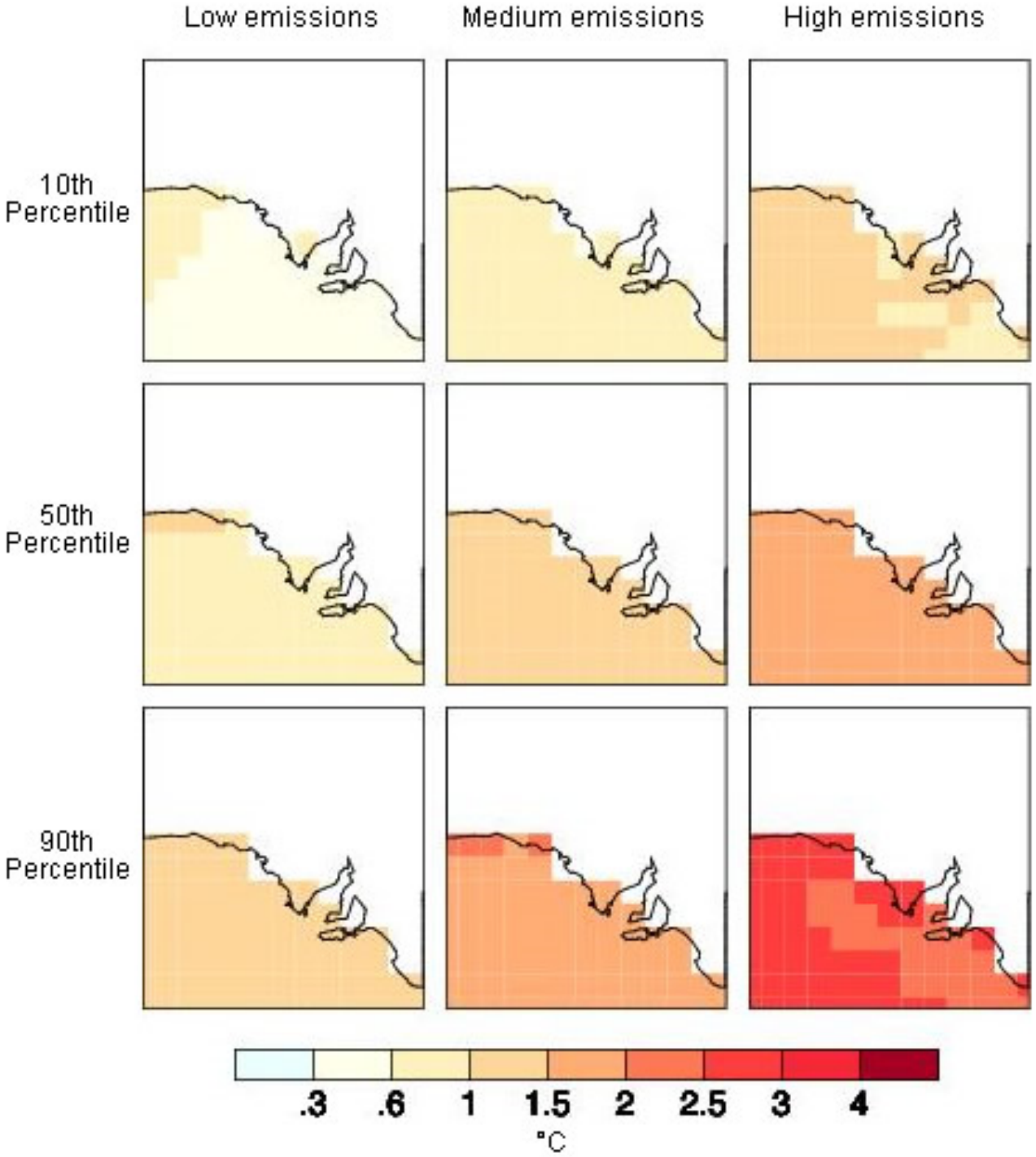


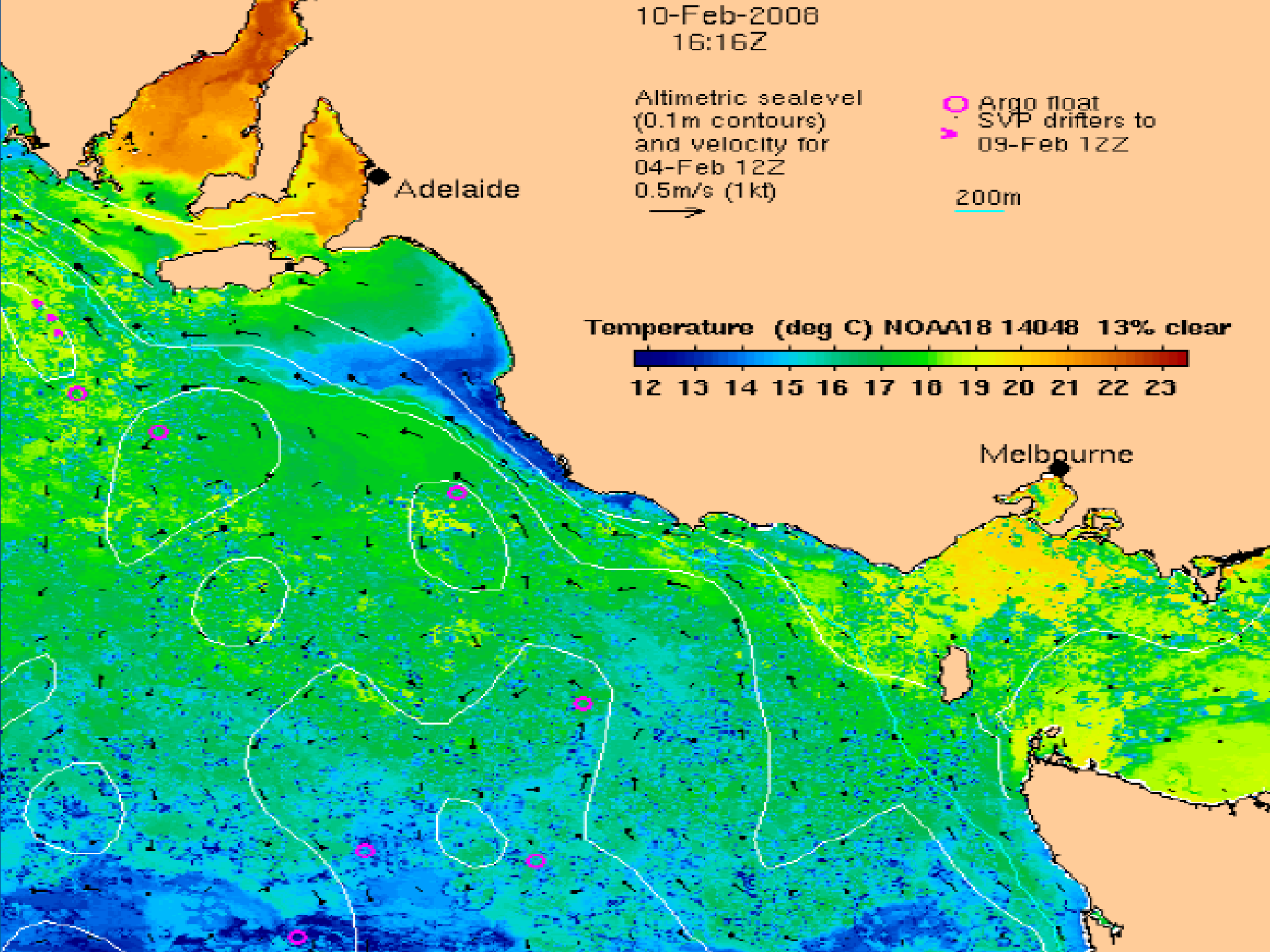


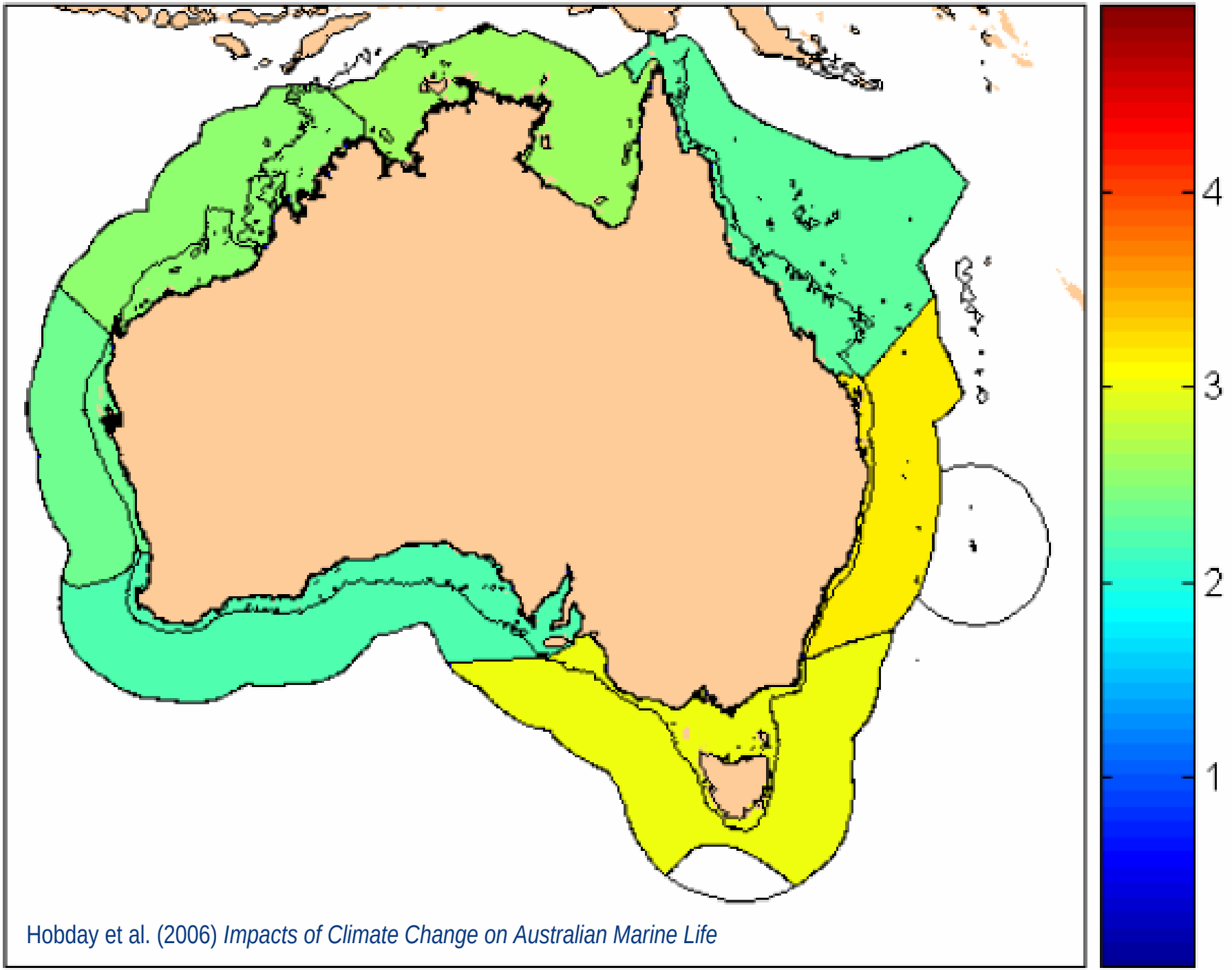
Heliocidaris erythrogramma

Havenhand et al. (2008) *Curr Biol* 275:R651-R652

- warming by 1–2 °C by 2030s; 2–3 °C by 2070s
- CSIRO climate model projects greatest warming off southeast Australia
- area of greatest warming this century in Southern Hemisphere
- strengthening of EAC; increased southward flow
- greater upwelling (e.g., Bonney Coast)
- decreasing pH by 0.2
- mass coral bleaching events
- seagrass die-offs/contraction of kelp ranges
- poleward shift in phytoplankton/zooplankton/fish (e.g., long-spined sea urchin, 36 spp Tasmanian marine fish)


Low emissions
Medium emissions
High emissions
10th Percentile
50th Percentile
90th Percentile
.3
.6
1
1.5
2
2.5
3
4
°C

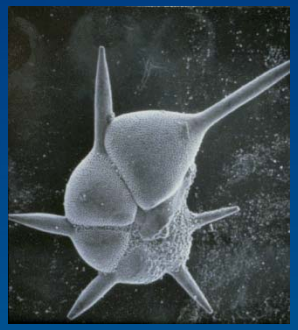

10-Feb-2008
16:16Z
Altimetric sealevel
(0.1m contours)
and velocity for
04-Feb 12Z
0.5m/s (1kt)
Argo float
SVP drifters to
09-Feb 1ZZ
200m
Adelaide
Melbourne
Temperature (deg C) NOAA18 14048 13% clear
12 13 14 15 16 17 18 19 20 21 22 23



Hobday et al. (2006) *Impacts of Climate Change on Australian Marine Life*

Phytoplankton & Zooplankton

- ↑ SST & EAC flow → southward movement
- ↑ abundance already, including toxic blooms
- ↓ abundance of calcareous species (e.g., coccolithophores)
- earlier phenology
- likely community changes through mixing
- ↑ jelly swarms



Hobday et al. (2006) *Impacts of Climate Change on Australian Marine Life*

Seagrasses & Kelp

- ↑ biomass through ↑ CO_2
- shifts distribution southward
- Δ timing reproduction
- ↑ destruction from ↑ storms
- ↓ UV-intolerant species
- Δ rainfall → species Δ

Hobday et al. (2006) *Impacts of Climate Change on Australian Marine Life*

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Benthic & Demersal Fishes

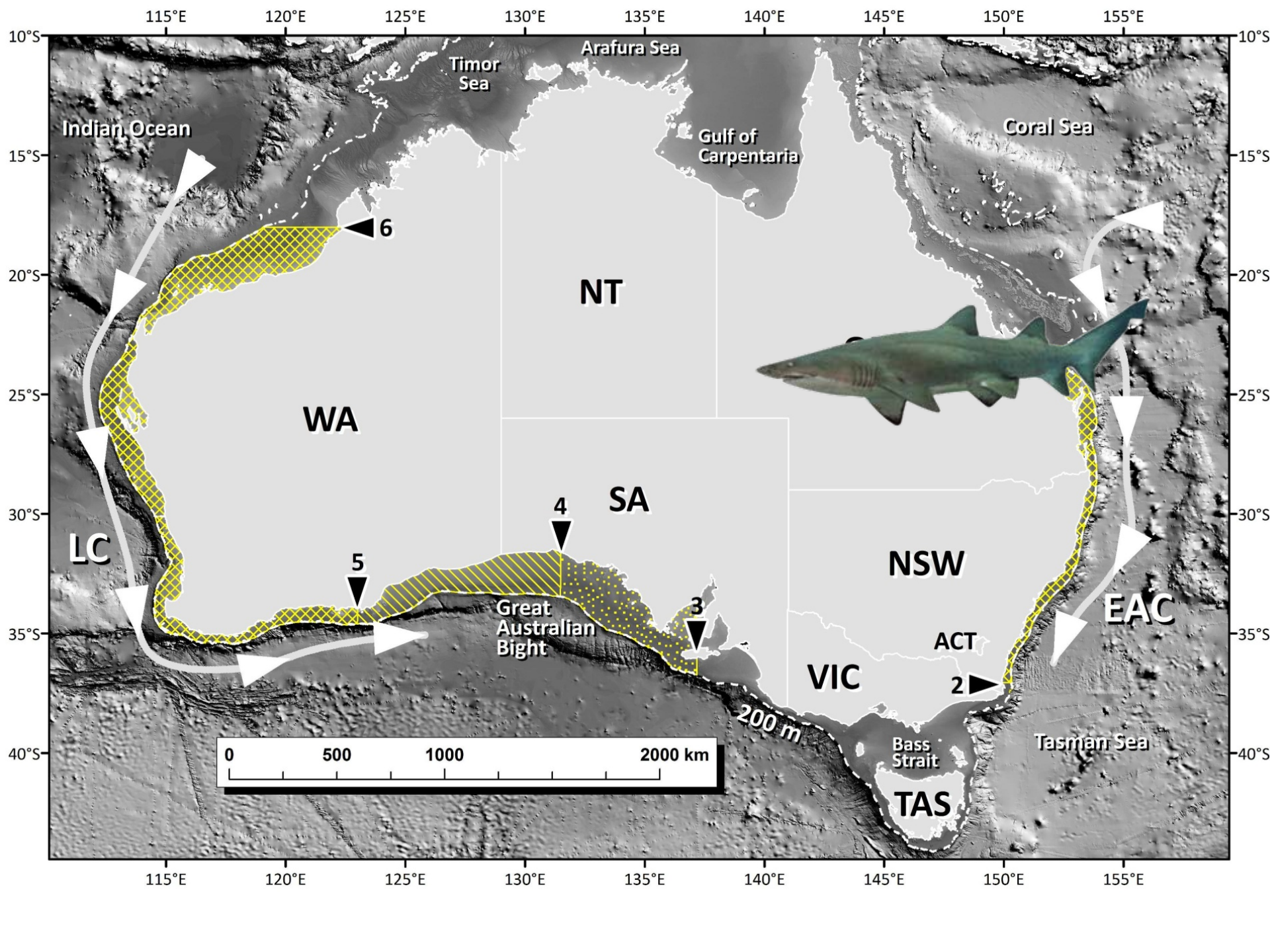
- ↑ southward shifts (already)
- ↑ temperature will change abundance & distribution
- ↓ ranges where bounded in south
- synergies with fishing

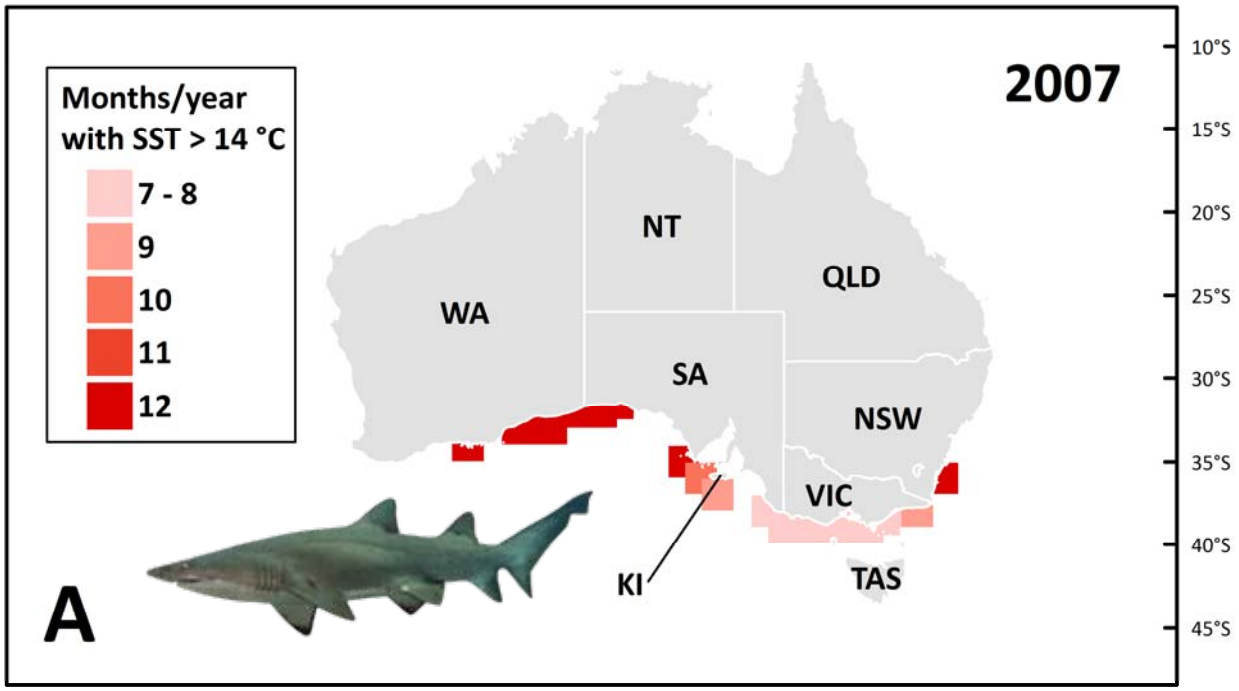
Hobday et al. (2006) *Impacts of Climate Change on Australian Marine Life*

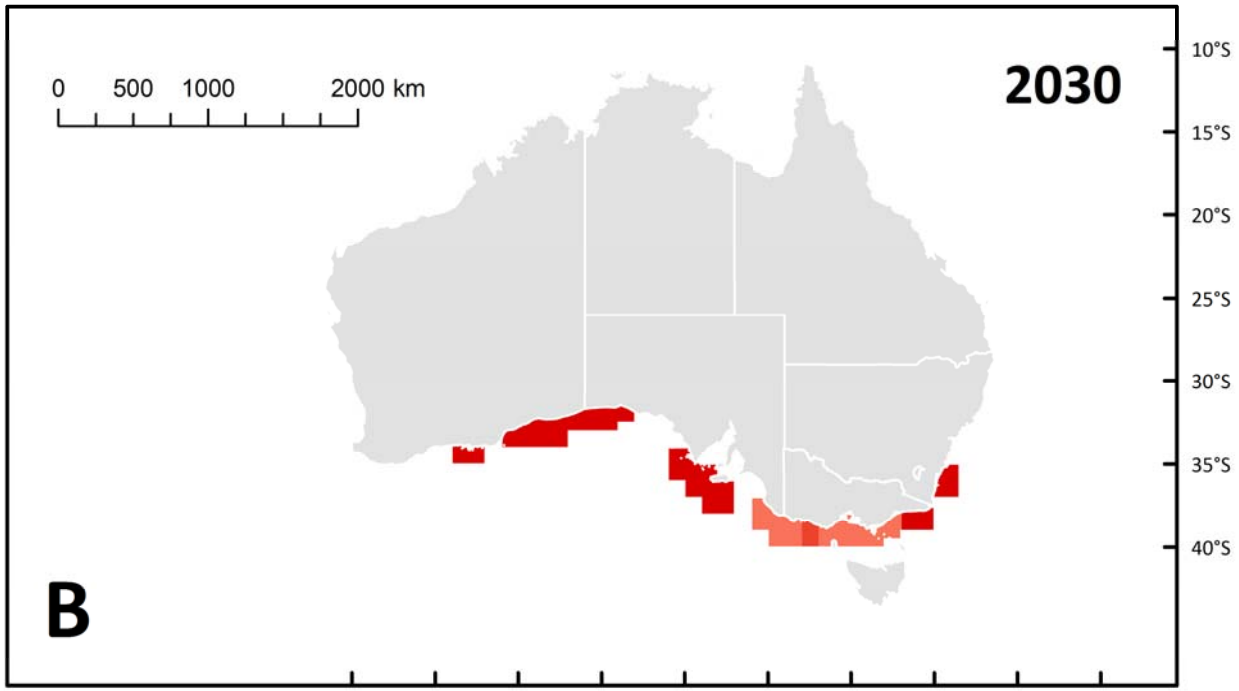
Pelagic Fishes

- ↑ southward movement
- Δ upwelling intensity affect mid-trophic pelagics (e.g., anchovy)
- larval transport

Hobday et al. (2006) *Impacts of Climate Change on Australian Marine Life*


115°E
120°E
125°E
130°E
135°E
140°E
145°E
150°E
155°E
10°S
15°S
20°S
25°S
30°S
35°S
40°S
Indian Ocean
Timor Sea
Arafura Sea
Gulf of Carpentaria
Coral Sea
NT
WA
SA
NSW
VIC
ACT
TAS
LC
EAC
6
5
4
3
2
Great Australian Bight
200 m
Bass Strait
Tasman Sea
0
500
1000
2000 km


Months/year
with SST > 14 °C
7 - 8
9
10
11
12
2007
NT
QLD
WA
SA
NSW
VIC
TAS
KI
A
10°S
15°S
20°S
25°S
30°S
35°S
40°S
45°S


0 500 1000 2000 km
2030
B
10°S
15°S
20°S
25°S
30°S
35°S
40°S
115°E
120°E
125°E
130°E
135°E
140°E
145°E
150°E
155°E
160°E

$\bar{r} < 0$

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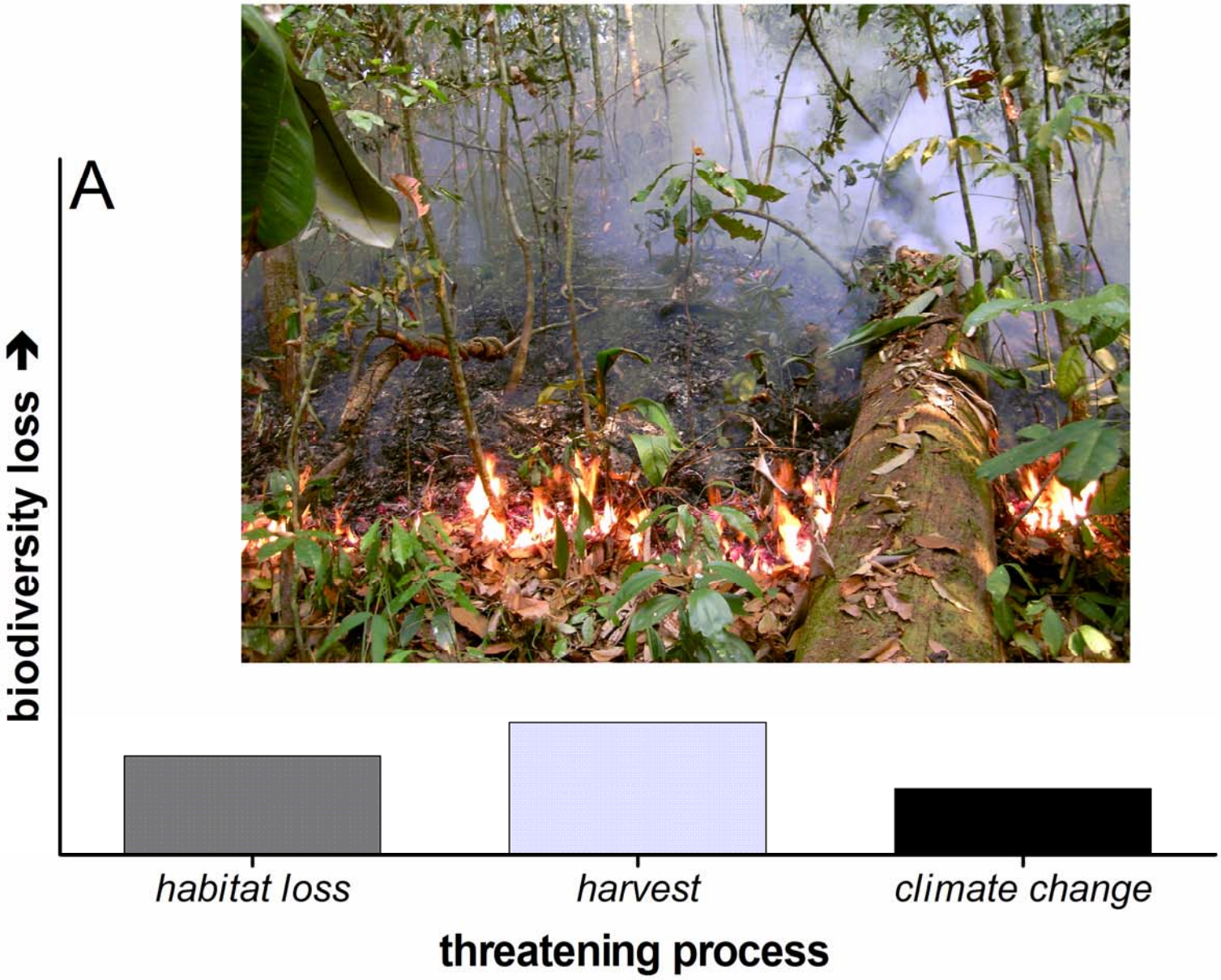
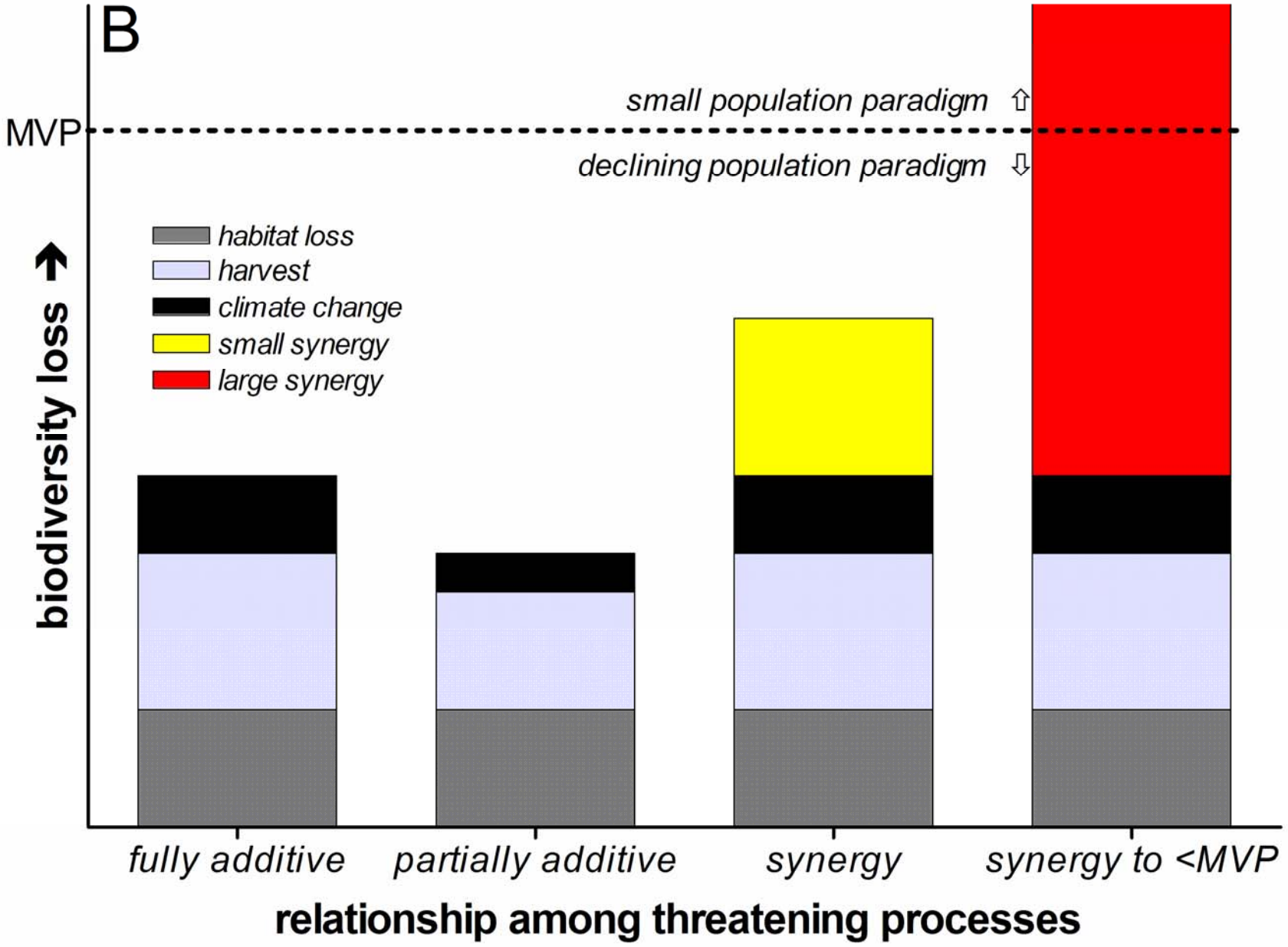
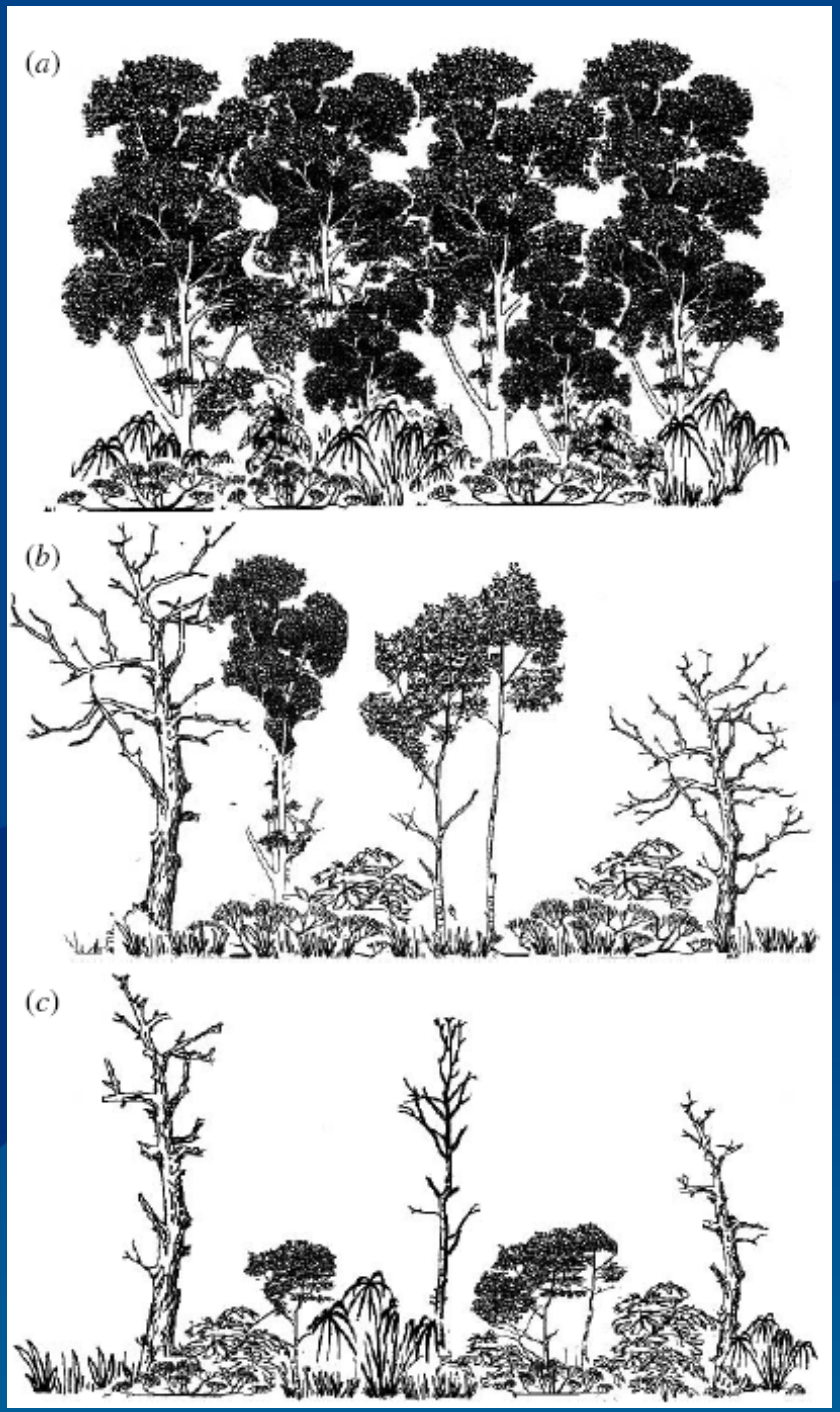
Inflation of current reported fishing rates	No connectivity MVP_{40G99}	No connectivity $Pr(r < 0)_{40G}$	Connectivity MVP_{40G99}	Connectivity $Pr(r > 0)_{40G}$
R1 ×	4250	0.014	3750	0.015
R2 ×	6000	0.030	5350	0.054
R4 ×	7550	0.185	7200	0.227



Brook et al. (2008) *Trends Ecol Evol* 23:453-460



Brook et al. (2008) *Trends Ecol Evol* 23:453-460



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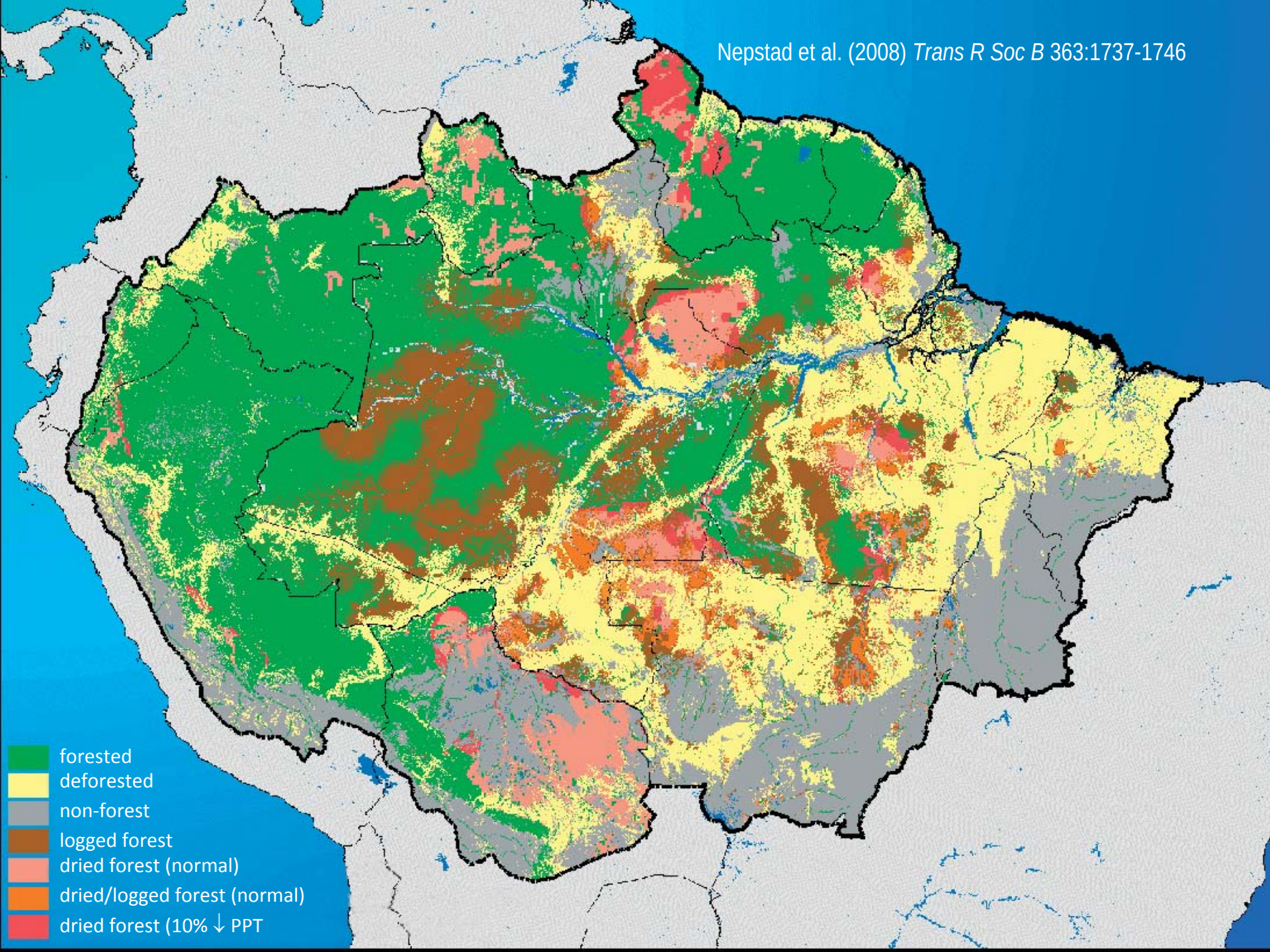
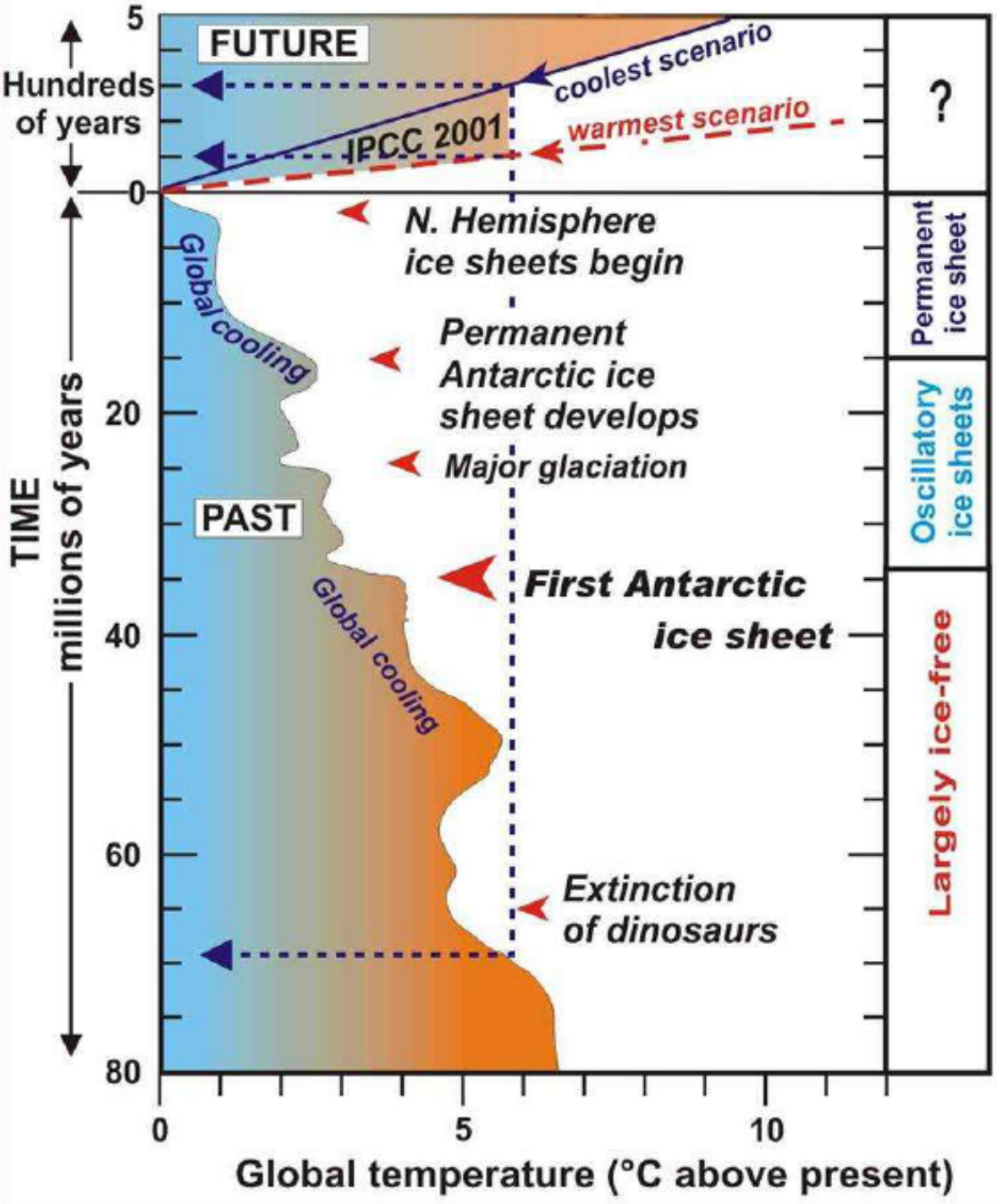
no fire

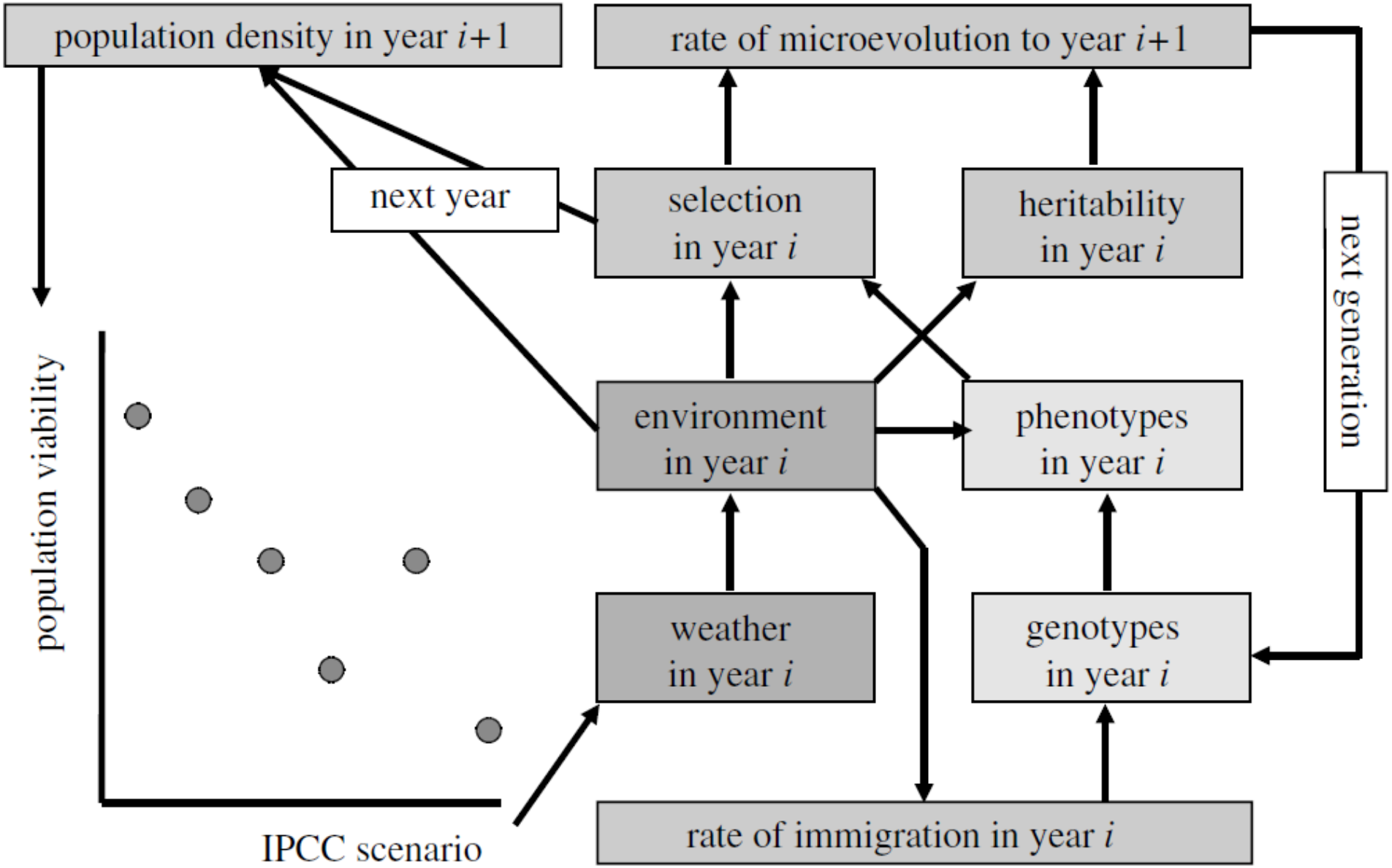
1 fire

≥ 3 fires

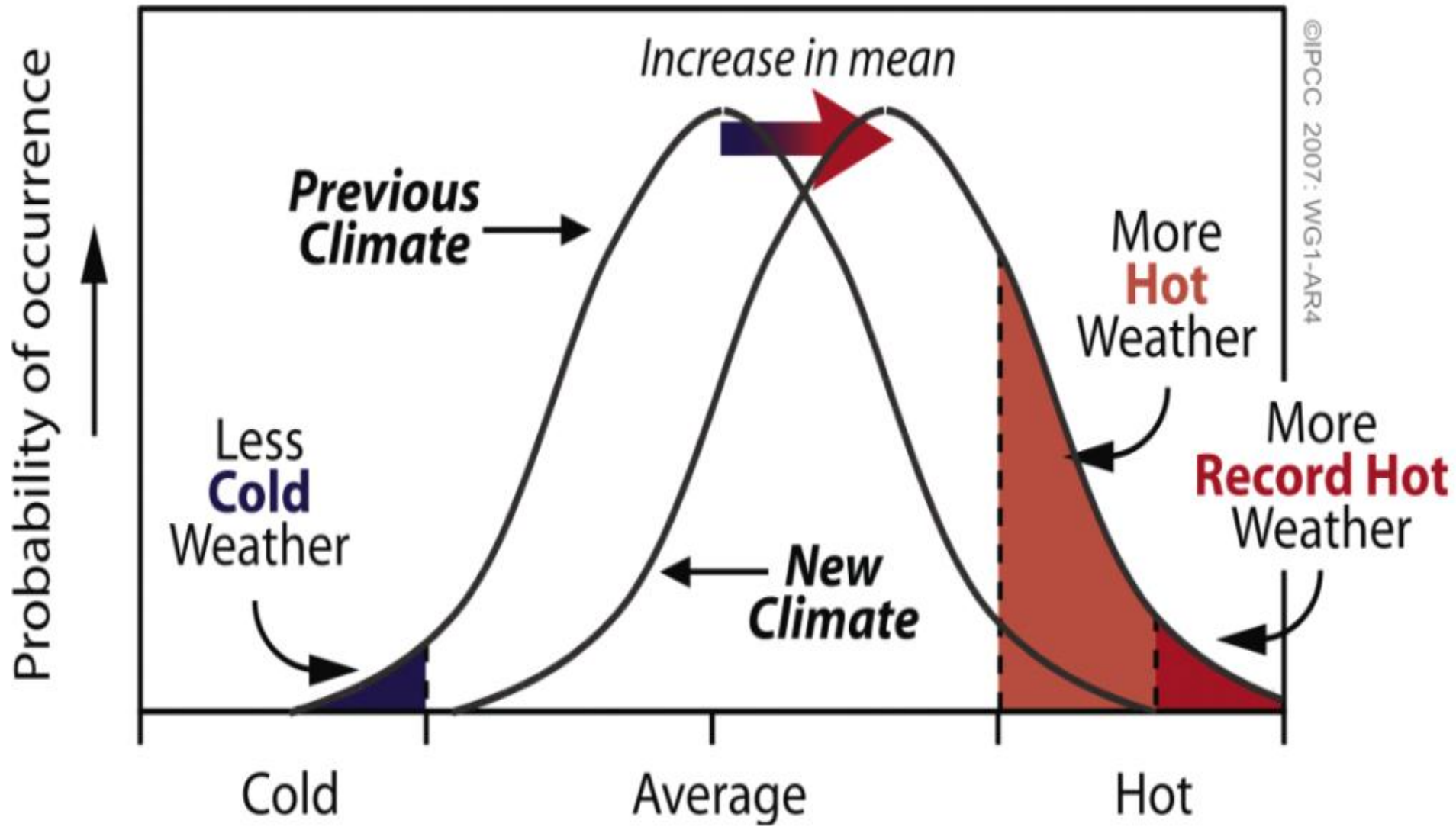
Barlow & Peres (2008) *Trans R Soc B* 363:1787-1794

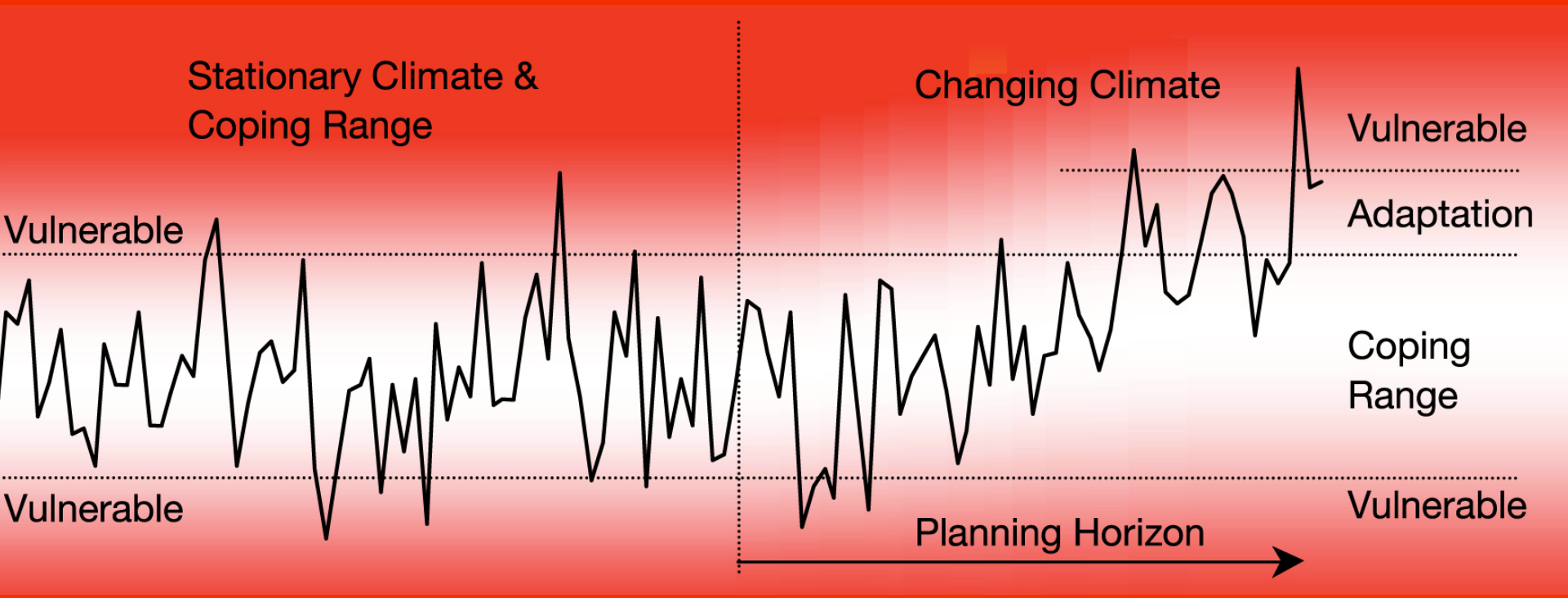

Nepstad et al. (2008) *Trans R Soc B* 363:1737-1746
forested
deforested
non-forest
logged forest
dried forest (normal)
dried/logged forest (normal)
dried forest (10% ↓ PPT

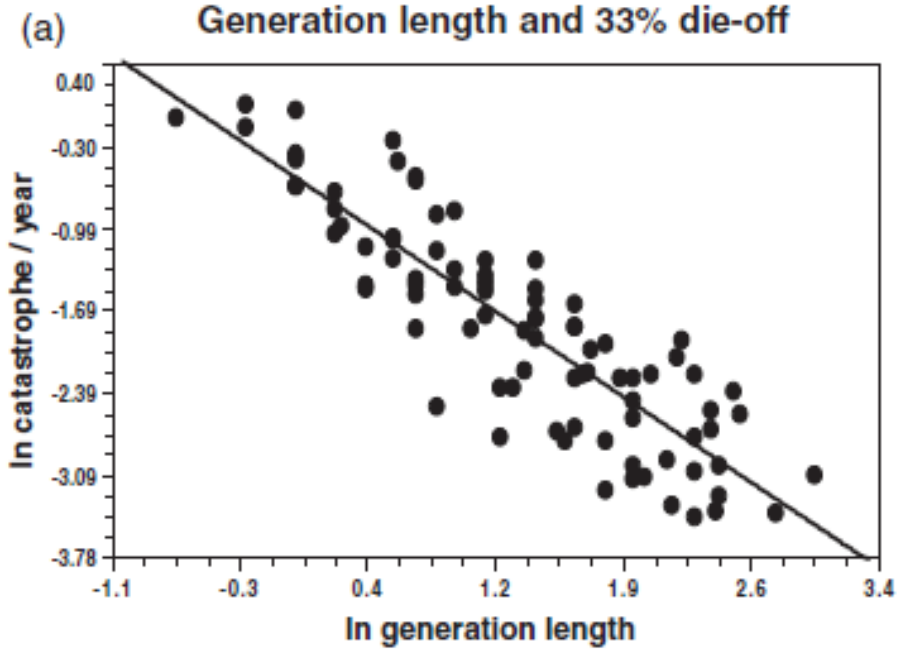

FUTURE
Hundreds of years
5
0
coolest scenario
IPCC 2001
warmest scenario
?
N. Hemisphere ice sheets begin
Permanent ice sheet
Global cooling
Permanent Antarctic ice sheet develops
Major glaciation
Oscillatory ice sheets
TIME millions of years
20
PAST
First Antarctic ice sheet
Global cooling
40
Largely ice-free
60
Extinction of dinosaurs
80
0
5
10
Global temperature (°C above present)

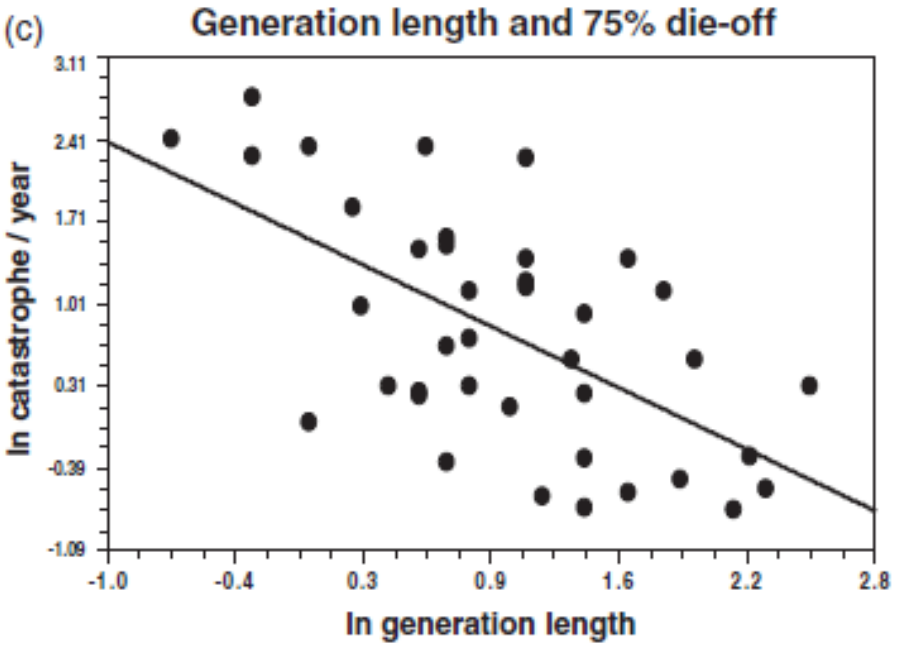


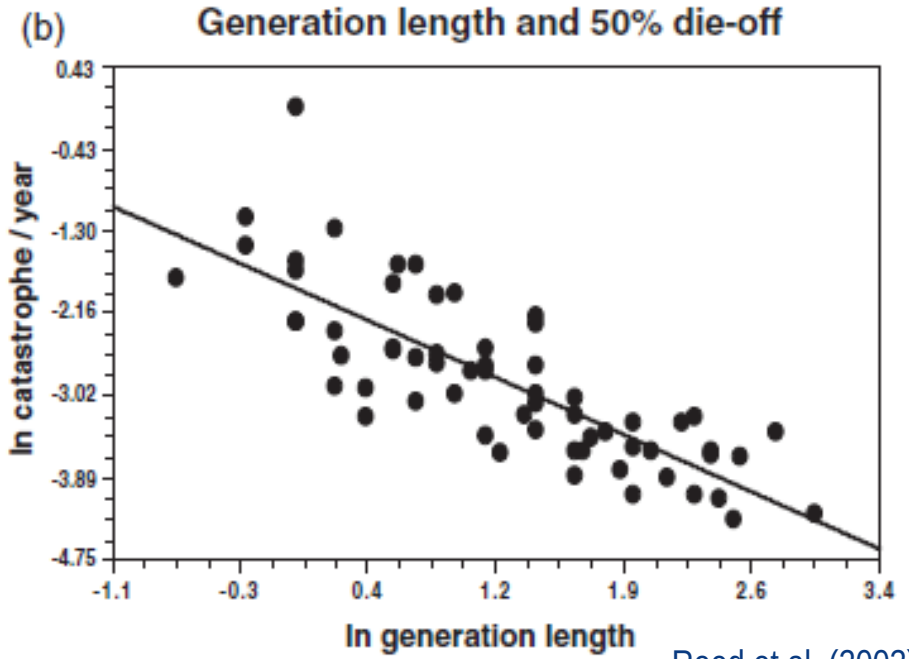
Visser (2008) *PRS-B* 275:649-659

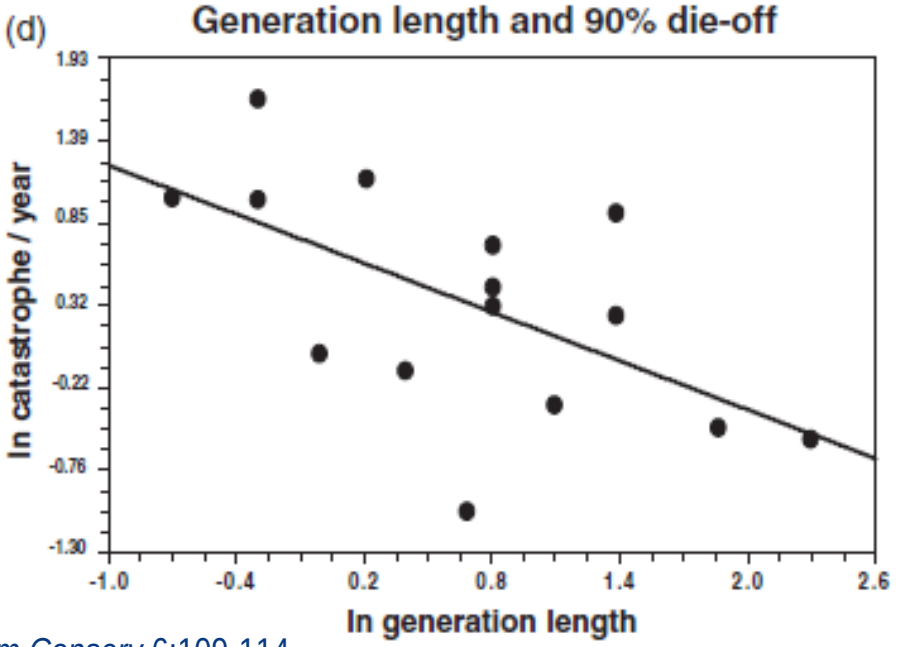

Probability of occurrence
Increase in mean
Previous Climate
New Climate
Less Cold Weather
More Hot Weather
More Record Hot Weather
Cold
Average
Hot
©IPCC 2007: WG1-AR4


Stationary Climate &
Coping Range
Changing Climate
Vulnerable
Adaptation
Vulnerable
Coping
Range
Vulnerable
Vulnerable
Planning Horizon

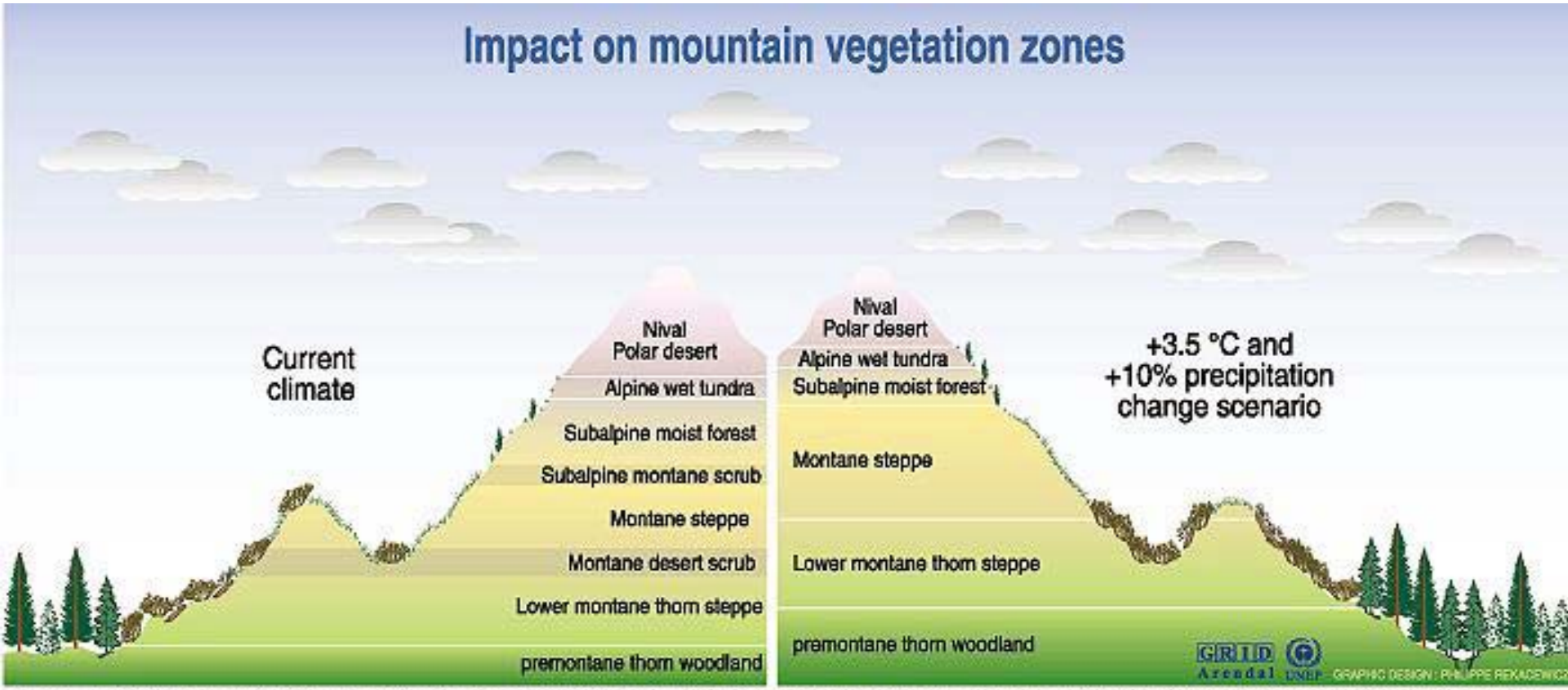




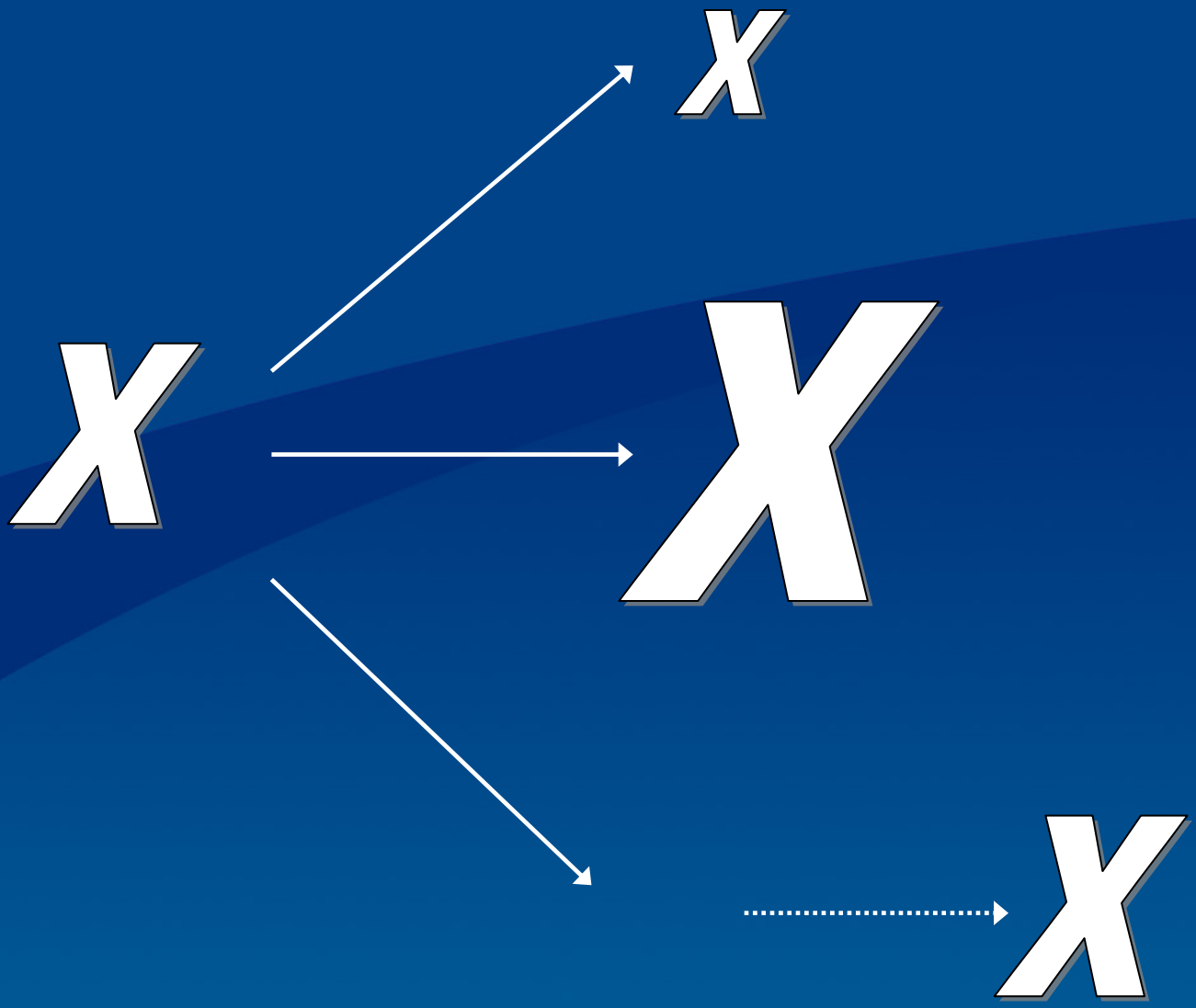


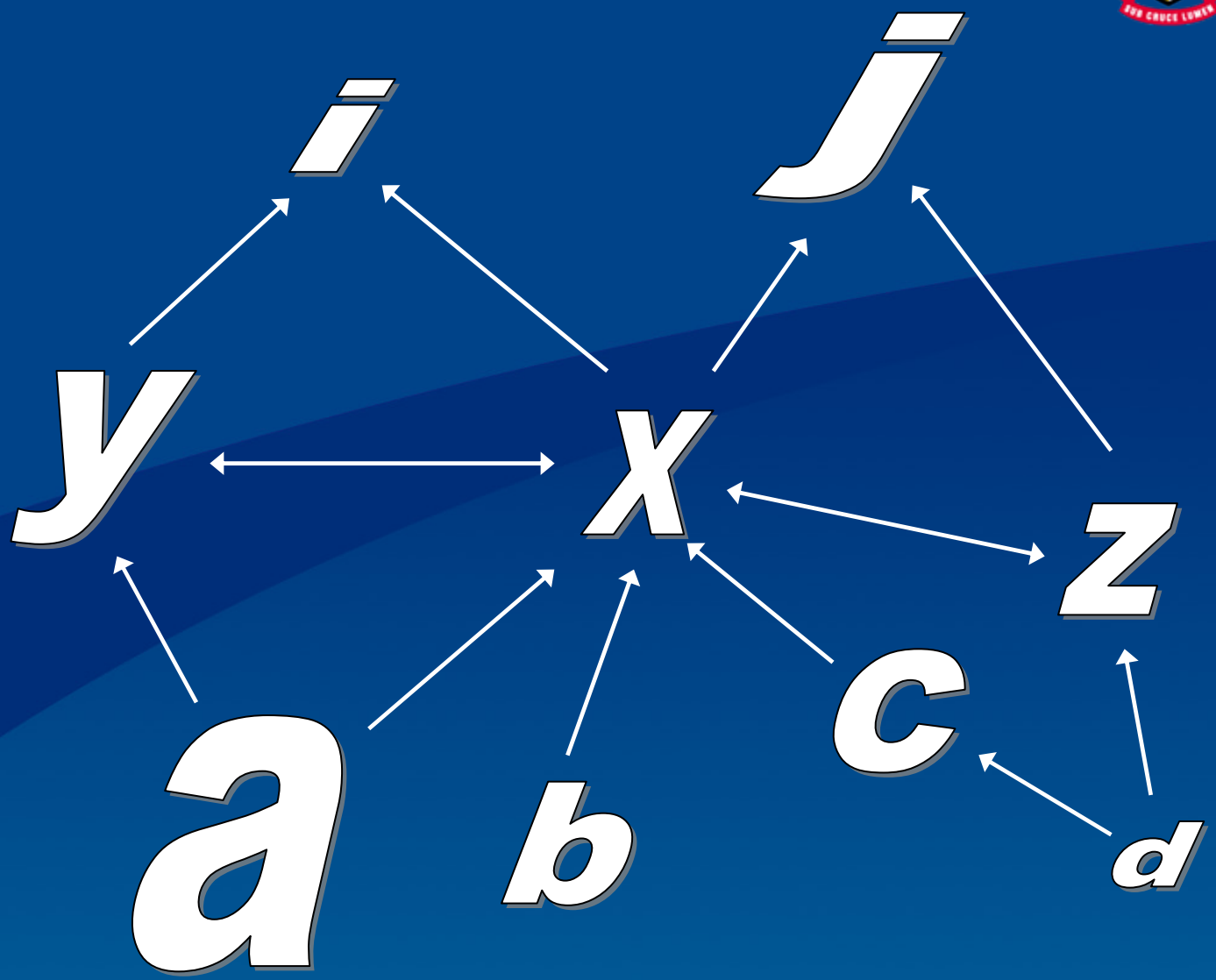


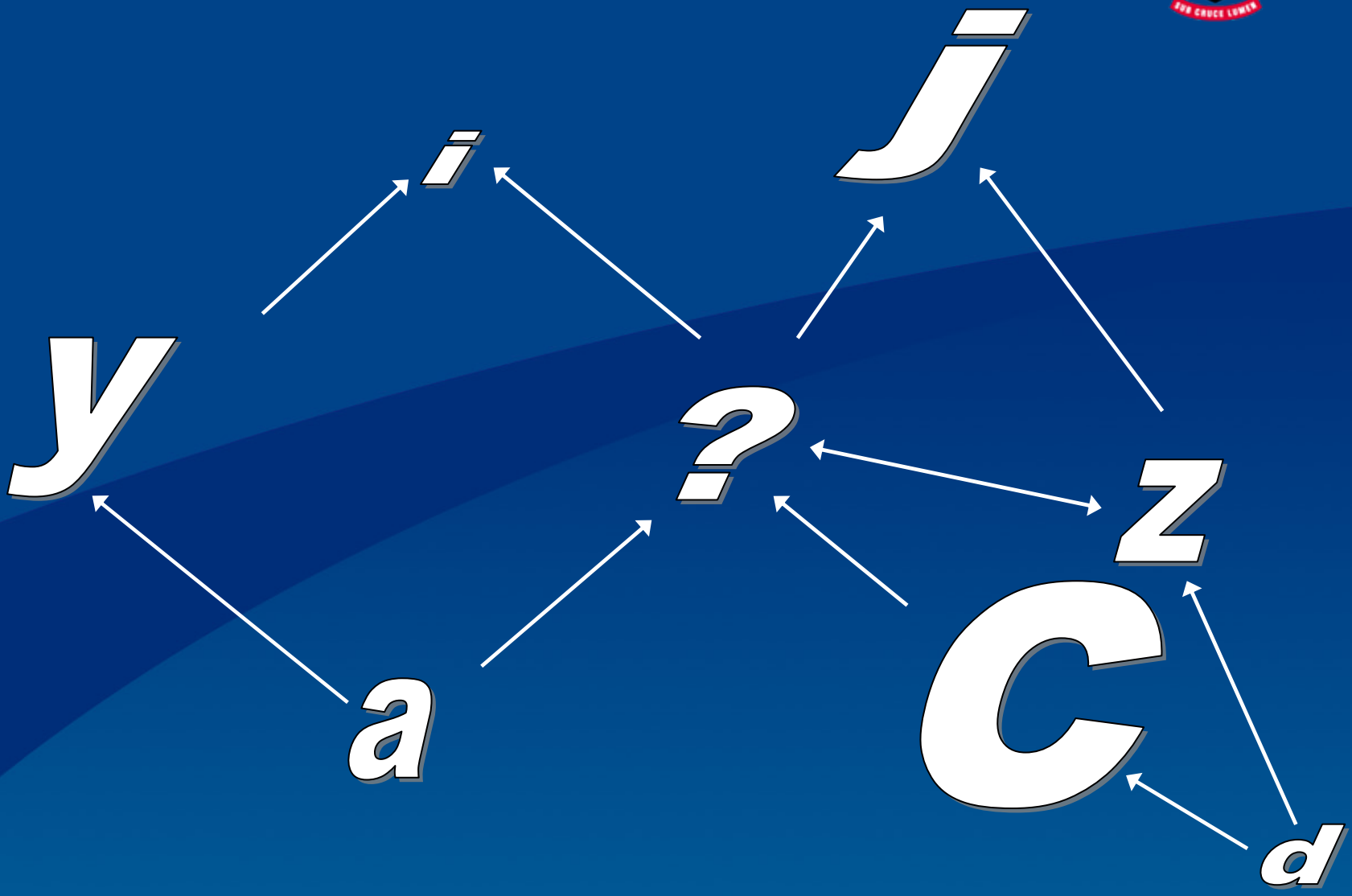
Reed et al. (2003) *Anim Conserv* 6:109-114

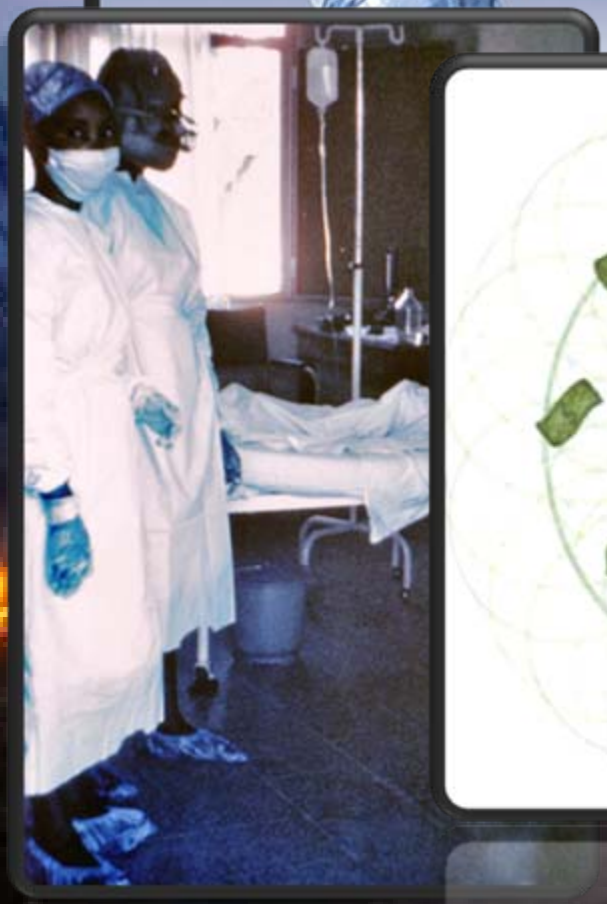


Sources: Martin Benitson, Mountain environments in changing climates, Routledge, London, 1994; Climate change 1995, Impacts, adaptations and migration of climate change, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change (IPCC), UNEP and WMO, Cambridge press university, 1996.









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