CLIMATE CHANGE

Ecosystem impacts and food security

UNFCCC Art. 2:

......prevent dangerous anthropogenic interference....

...........allow ecosystems to adapt naturally...

...........ensure that food production is not threatened...

...........enable economic development to proceed in a sustainable manner: Petra Tschakert

H.O Pörtner
WGII CH. 6, Ocean Systems,
ocean products in TS and SPM, CC-Boxes, SYR

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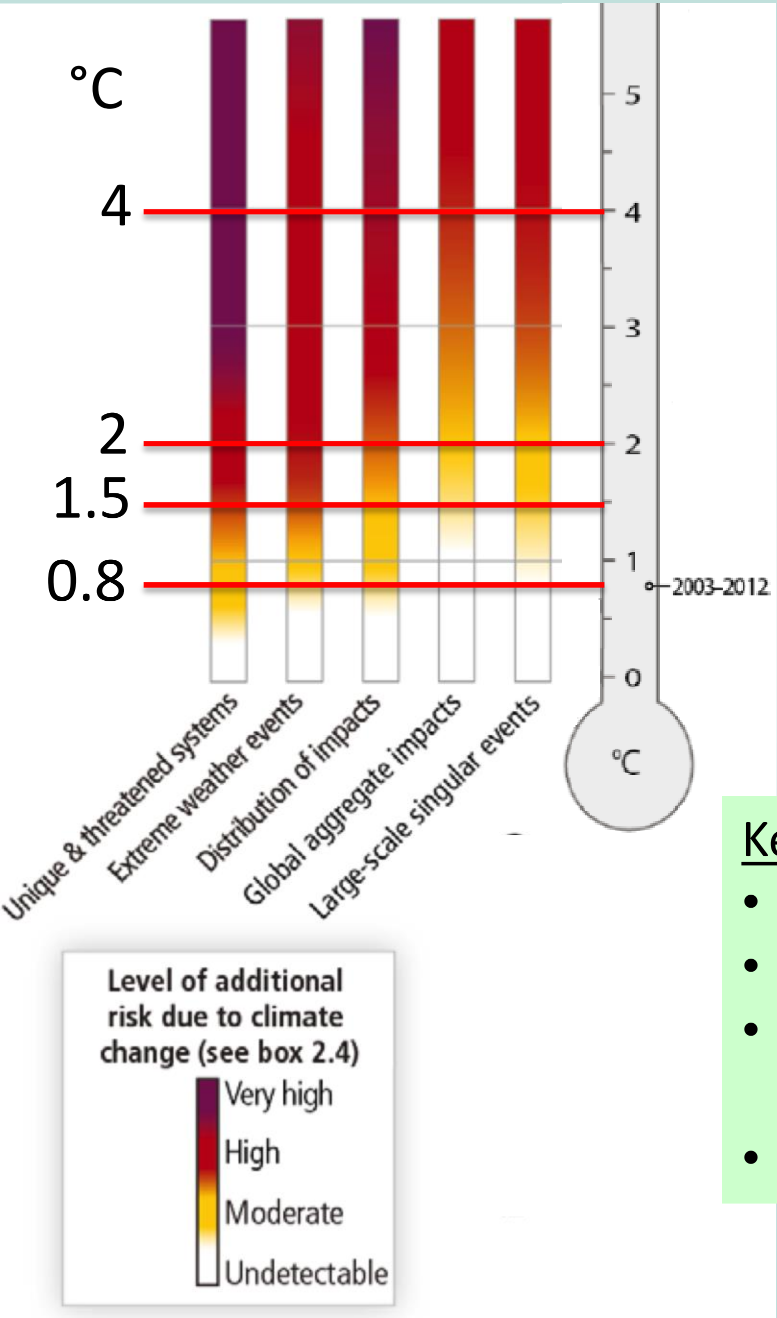
LTGG Reasons for concern



.....allow ecosystems to adapt naturally...

.....ensure that food production is not threatened...

Comparing affected sectors and long-term global goals (LTGG) with respect to:

Key risks of impacts

Avoided impacts

Key climate drivers:

- Temperature
- Precipitation
- Ocean warming, acidification and loss of oxygen
- Extreme events

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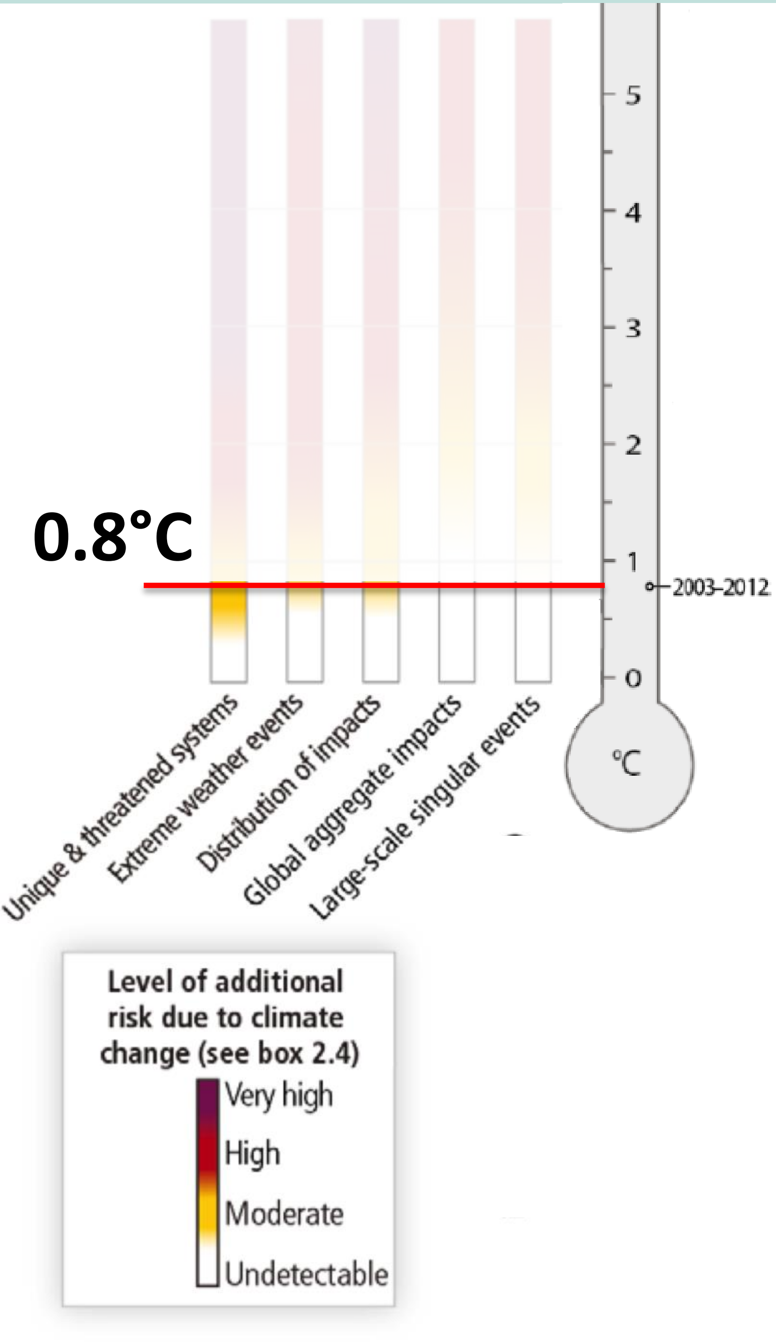
0.8°C



....Climate change: observed impacts on all continents and in all oceans, e.g.

- **Species displacements** (marine, freshwater and terrestrial)
- Increase in **crop production constrained**
- **Forest dieback** due to drought and heat
- Some **unique systems at moderate risk** from climate change (...risk **may rise** if combined with other pressures)

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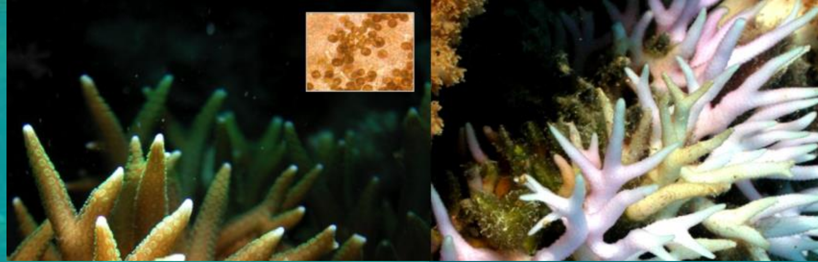
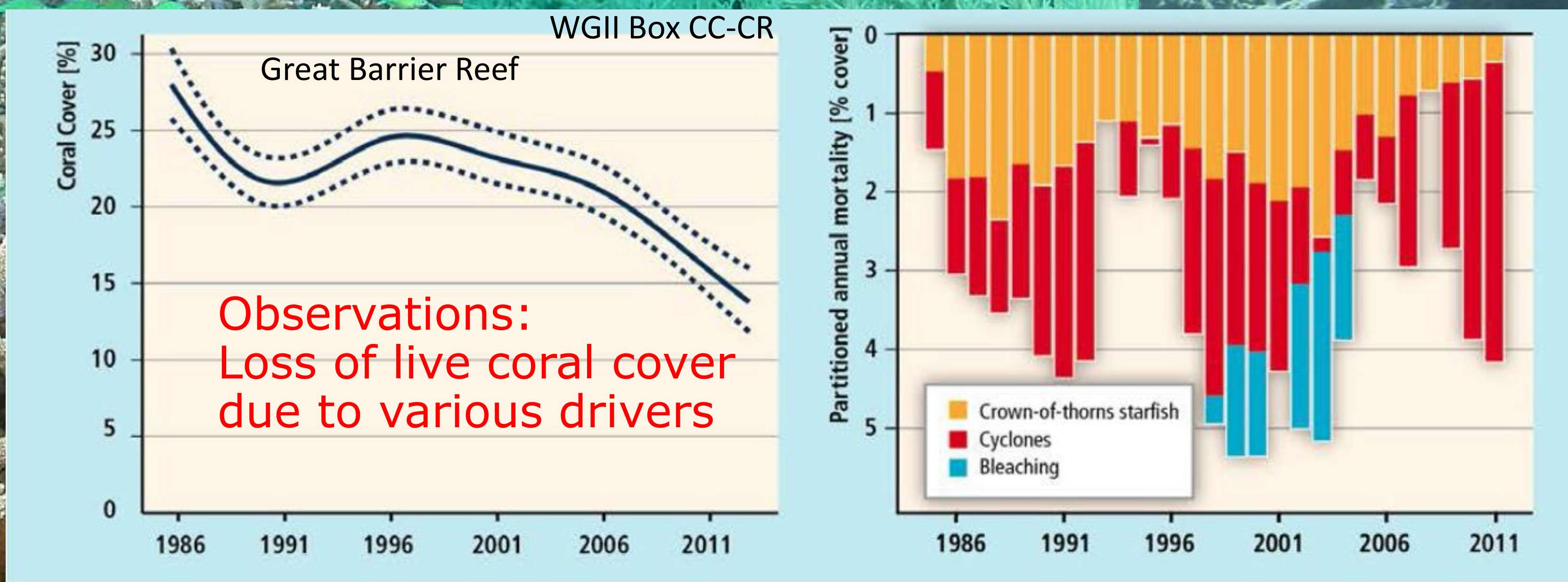


Vulnerable ecosystems

Warm water coral reefs under combined pressures:



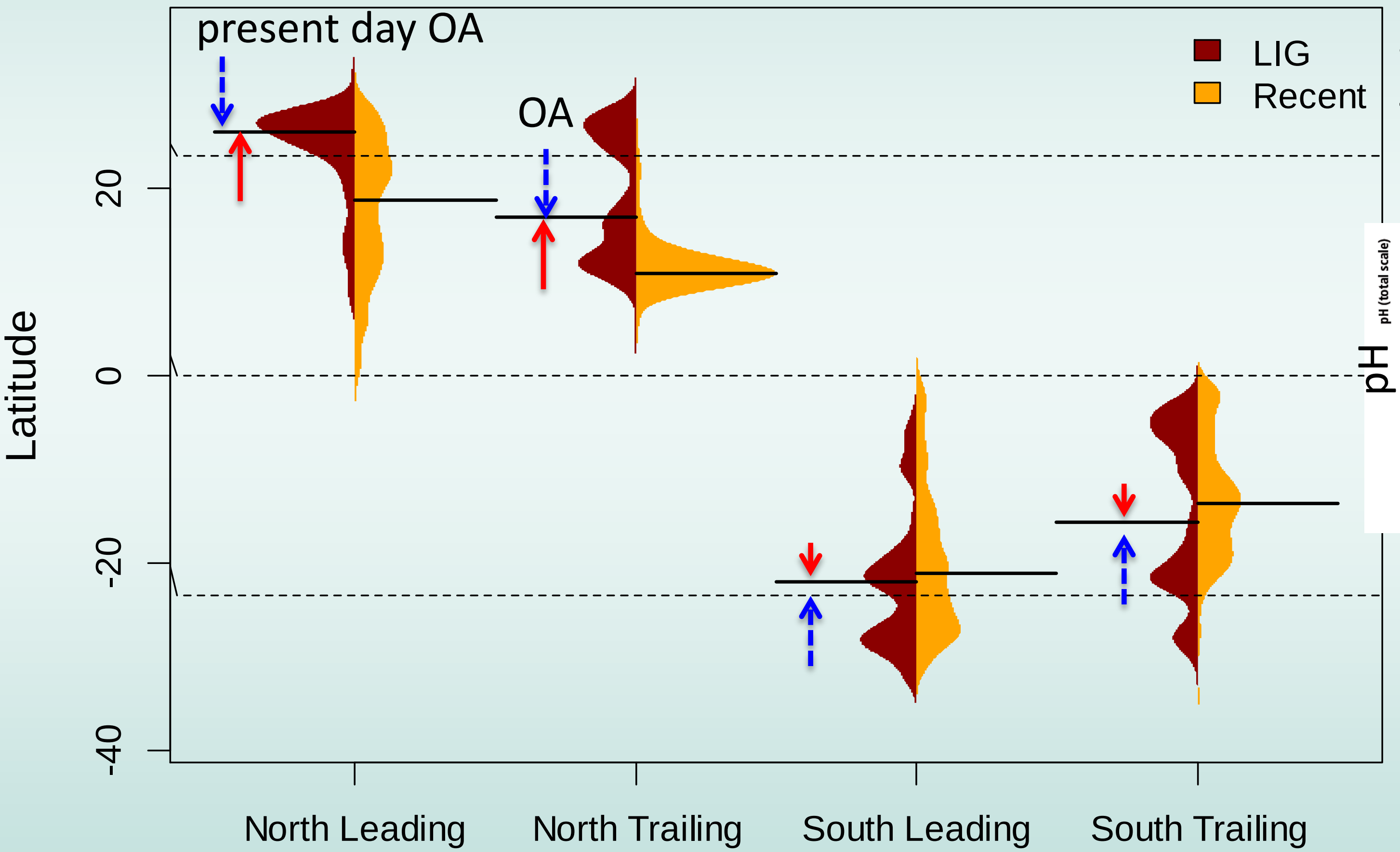
......are reefs on the move?

Verons 2009

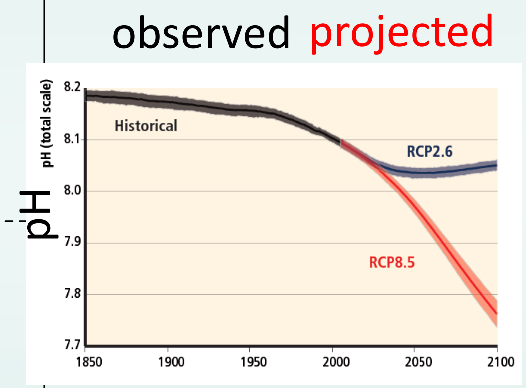
Latitudinal shifts occurred during the Last Interglacial (LIG) compared to today (Δ SST < 1°C)

0.8°C

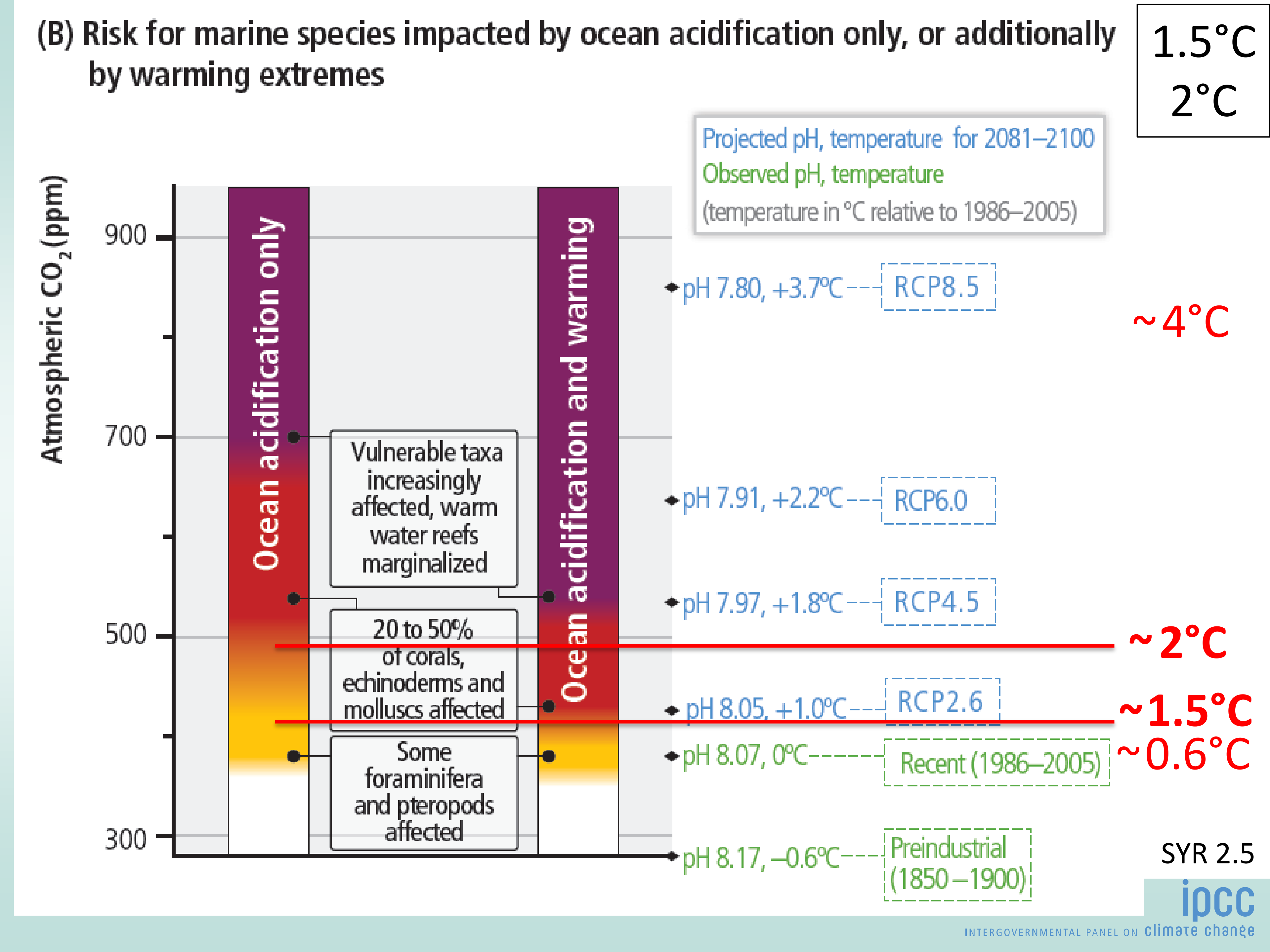
…but today's reefs will be increasingly constrained by ocean acidification (OA) and other pressures



P_{CO_2} (ppm)
280
320 – 380



Kiessling et al. (PNAS 2012)



(B) Risk for marine species impacted by ocean acidification only, or additionally by warming extremes
1.5°C
2°C
Projected pH, temperature for 2081–2100
Observed pH, temperature
(temperature in °C relative to 1986–2005)
Atmospheric CO_2 (ppm)
900
700
500
300
Ocean acidification only
Ocean acidification and warming
Vulnerable taxa increasingly affected, warm water reefs marginalized
20 to 50% of corals, echinoderms and molluscs affected
Some foraminifera and pteropods affected
pH 7.80, +3.7°C
RCP8.5
~4°C
pH 7.91, +2.2°C
RCP6.0
pH 7.97, +1.8°C
RCP4.5
~2°C
pH 8.05, +1.0°C
RCP2.6
~1.5°C
pH 8.07, 0°C
Recent (1986–2005)
~0.6°C
pH 8.17, –0.6°C
Preindustrial (1850–1900)
SYR 2.5
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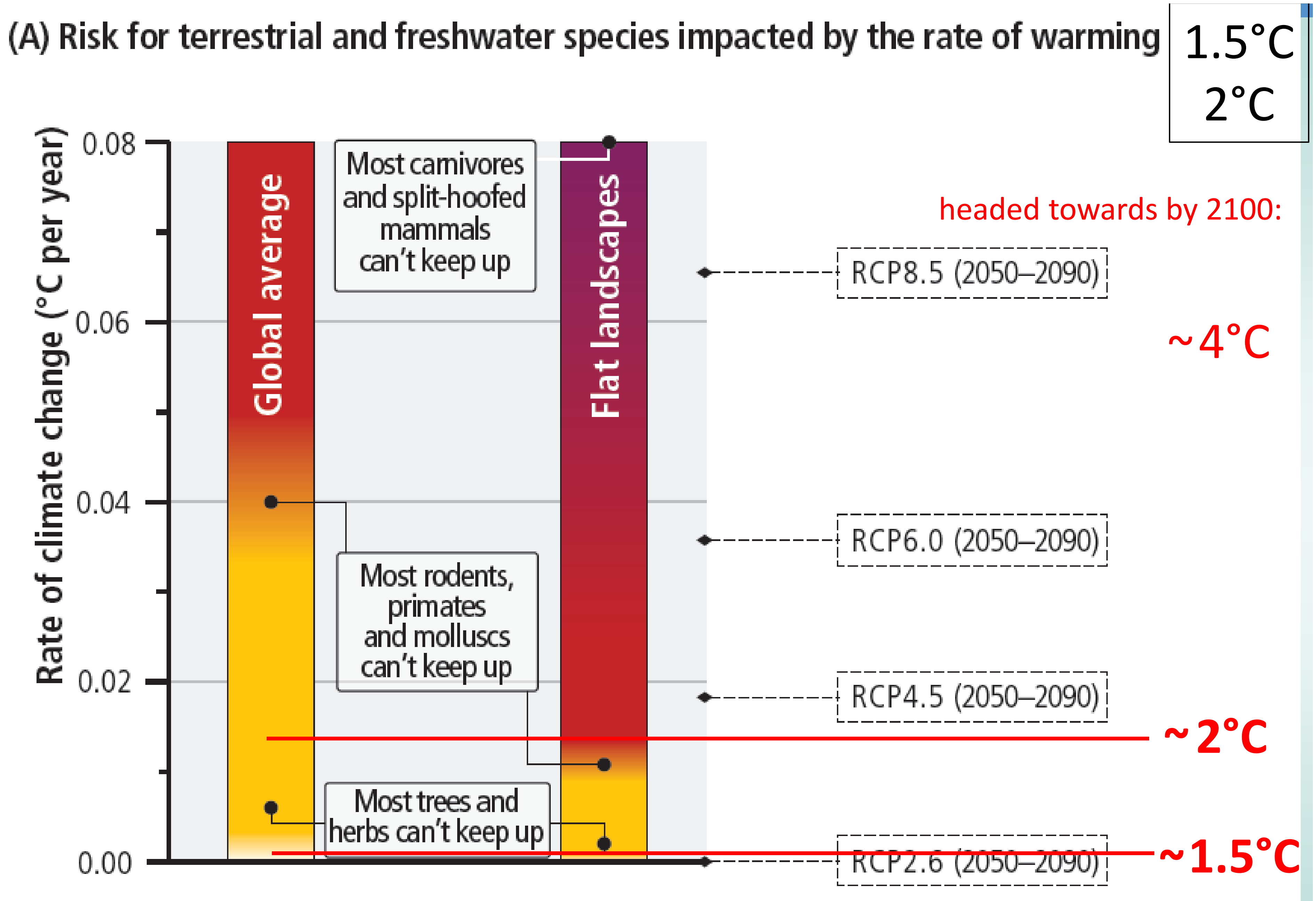

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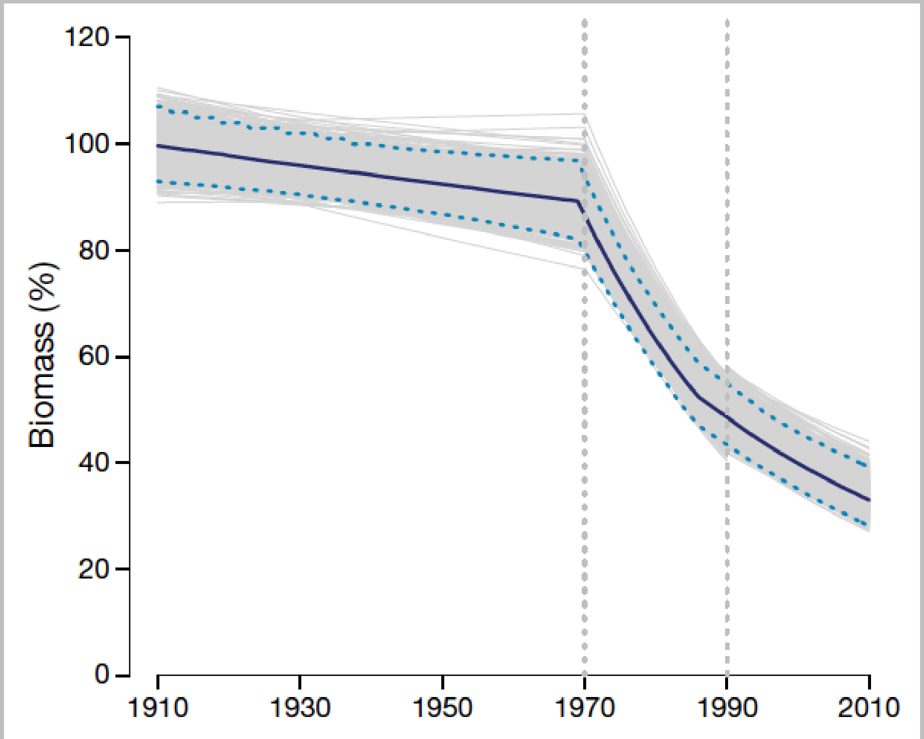
Food security constrained: ....Fisheries

2°C

2051-60: displaced and reduced fish and invertebrate biodiversity

..... 2°C:

Combined human pressures: oceans are warming, acidifying, losing oxygen, affecting presently overexploited stocks.

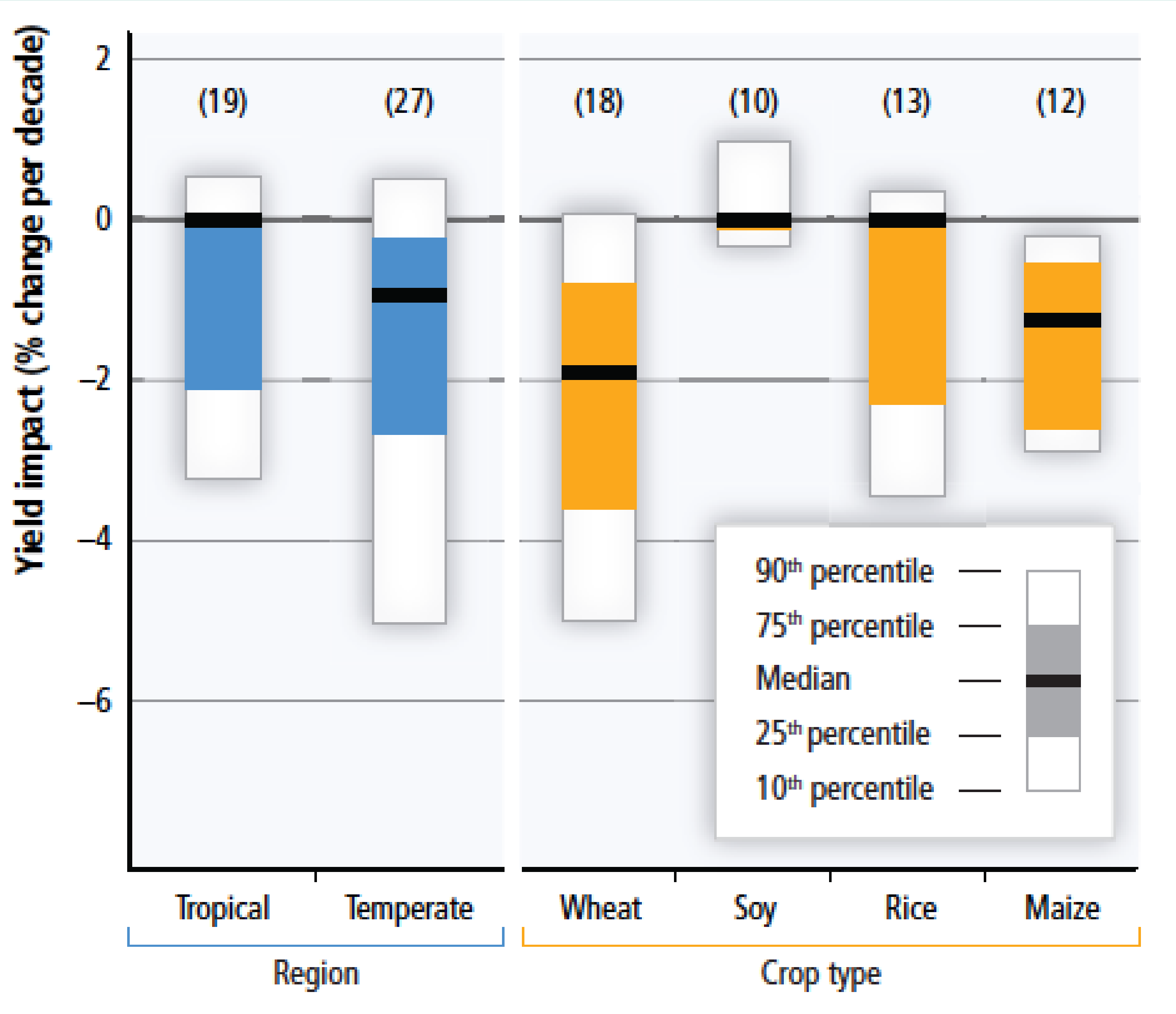


BACKGROUND:
OVERFISHING caused predatory fish biomass to decline
(by ≈ 70%!)

MEPS 512: 155–166, 2014

Food security constrained: increase in crop production reduced

0.8°C



WGII, SPM.2

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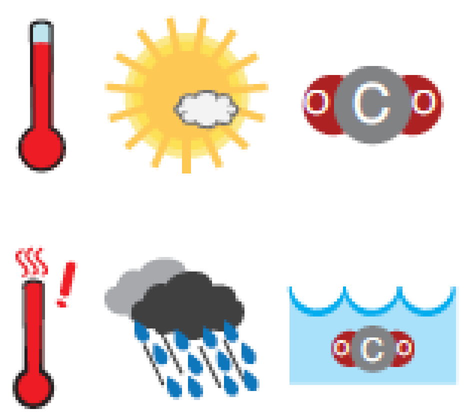
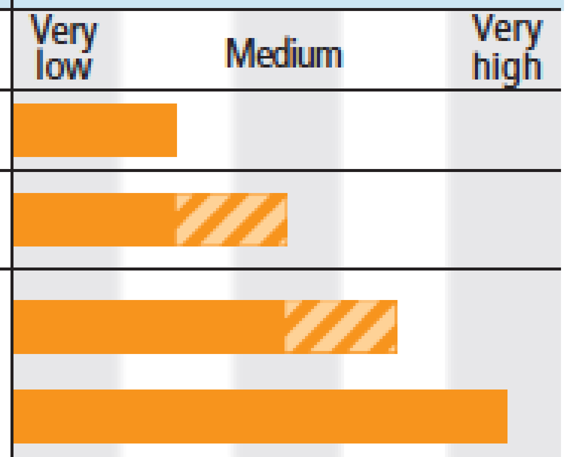
Food security constrained:
>1.5°C: high risk of more severe impacts after 2050

>1.5°C

Key risk	Adaptation issues & prospects
Reductions in mean crop yields because of climate change and increases in yield variability. (*high confidence*) [7.2, 7.3, 7.4, 7.5, Box 7-1]	With or without adaptation, negative impacts on average yields become *likely* from the 2030s with median yield impacts of 0 to –2% per decade projected for the rest of the century, and after 2050 the risk of more severe impacts increases. ...includes effects of redistributed precipitation, heat and drought events

Climatic drivers	Timeframe	Risk & potential for adaptation
	Present Near term (2030 – 2040) Long term (2080 – 2100) 2°C / 4°C	

Crop yields increasingly declining with climate change

WGII, Table TS.4, SYR Table 2.3

INTERGOVERNMENTAL PANEL ON climate change

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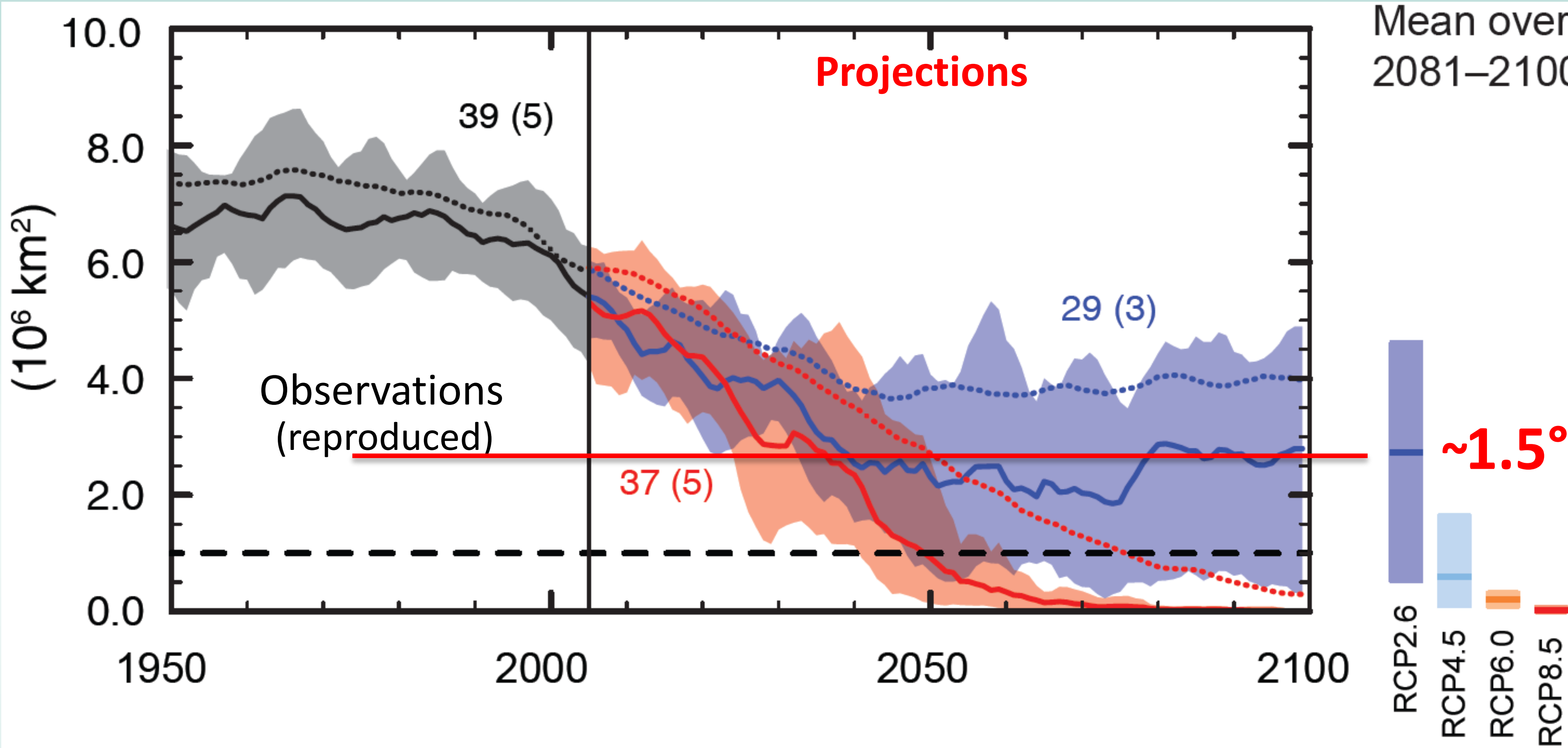
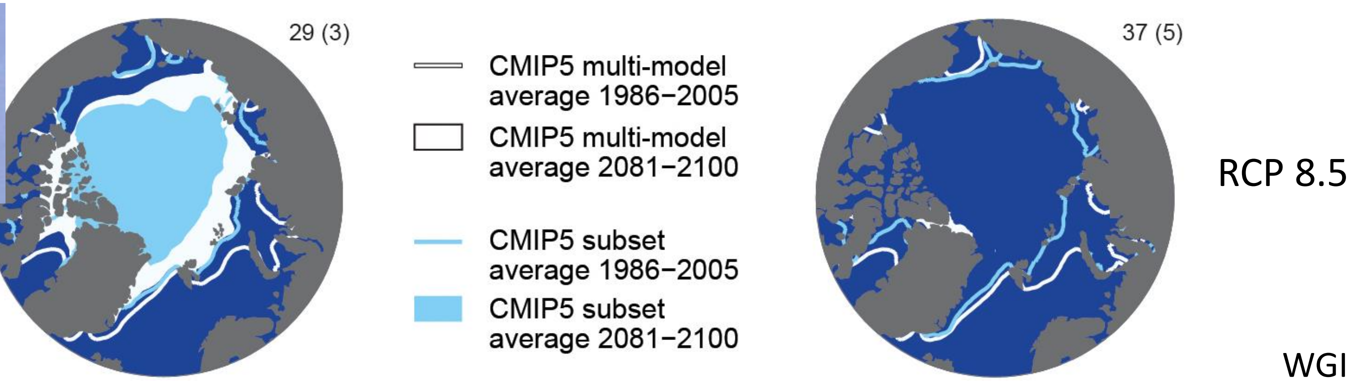
Some Arctic summer sea ice may be protected under RCP2.6

1.5°C



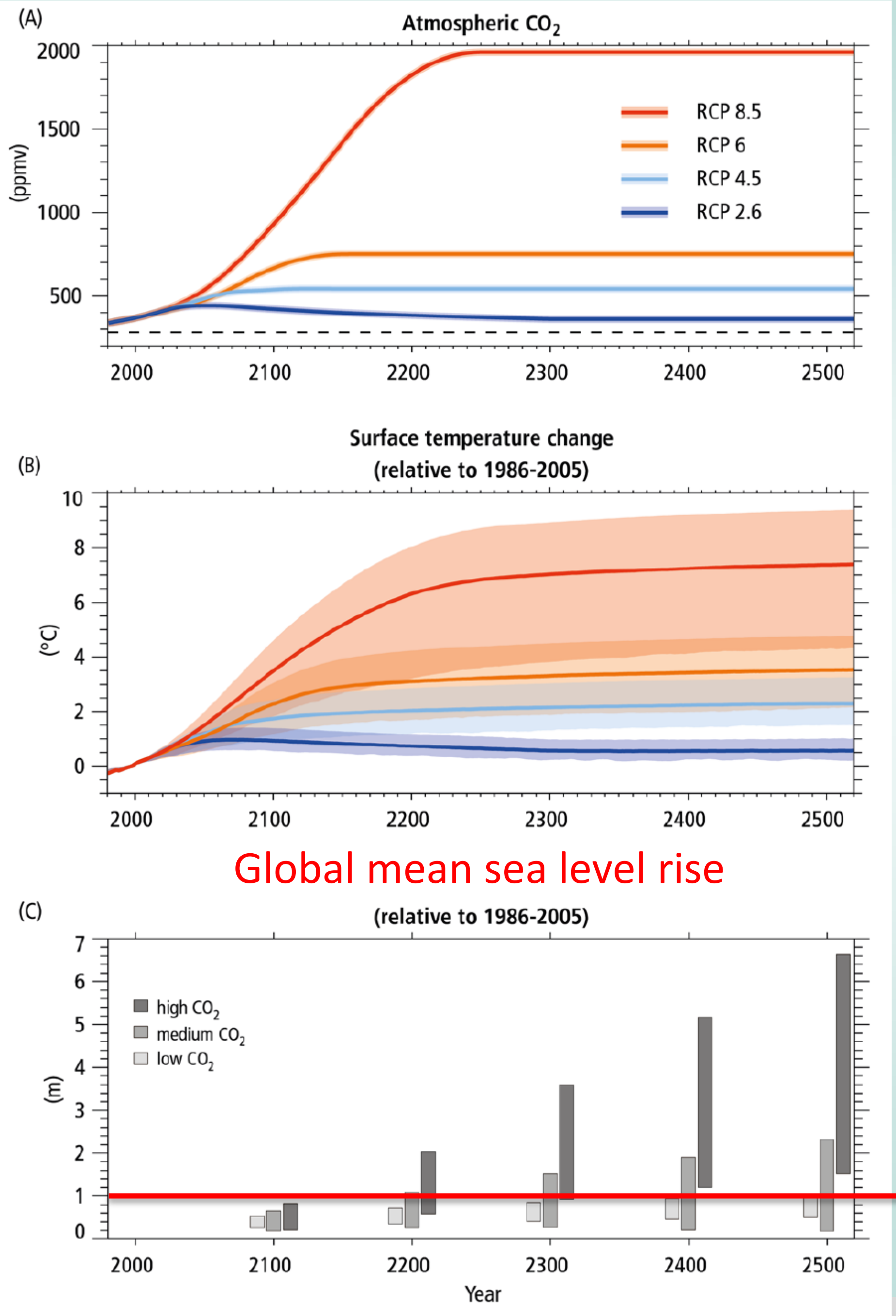
Northern Hemisphere September sea ice extent (average 2081−2100)



WGI SPM.7b, 8c

Sea level rise beyond 2100 may challenge natural and human systems:

1.5°C



....affecting habitat, freshwater resources, human society through flood events

Paleo-observations

5-9 m : ...during the last interglacial (Eemian, 125.000 ya, at 0.7-2°C above pre-industrial)

>7m : ...last time when the atmosphere had 400 ppm CO_2 (in Pliocene, 3-5 Mya)

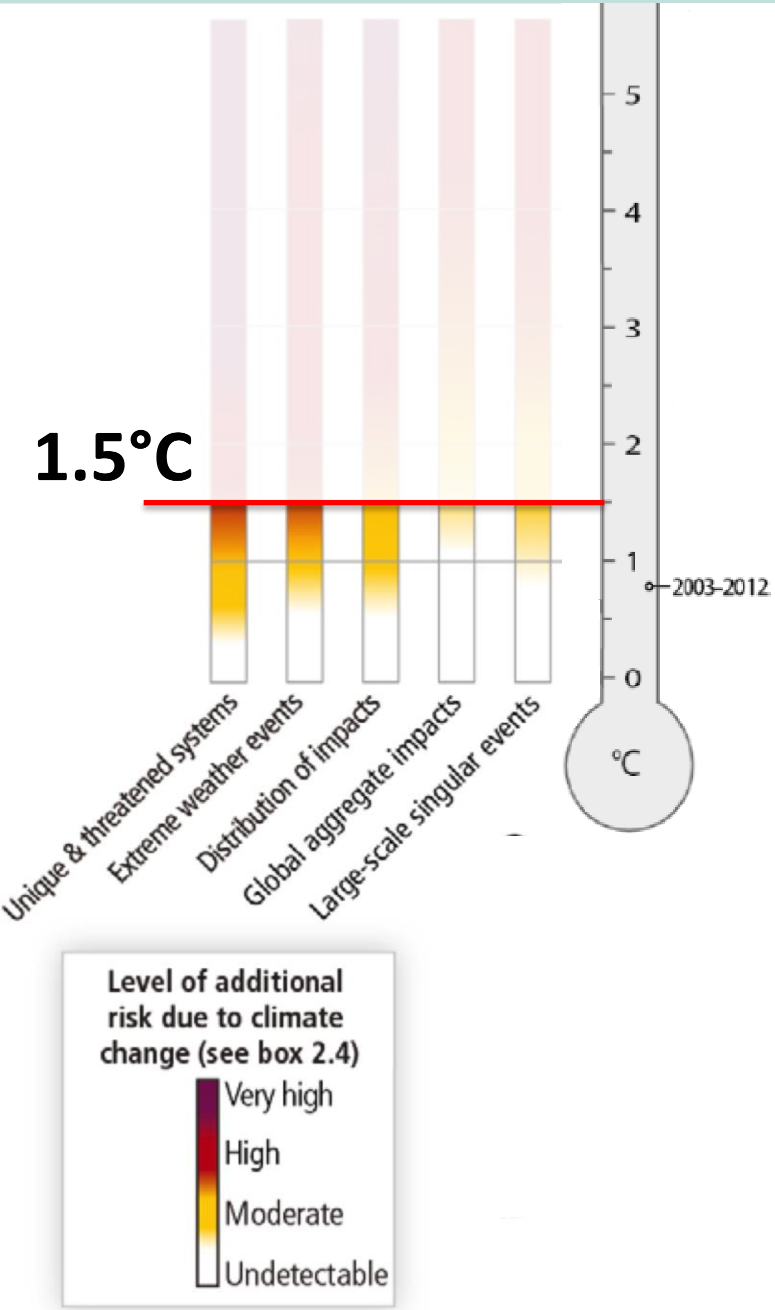
RCP6.0, 8.5

WGI Figure 12.43 and Table 13.8 SYR 2.8

RCP4.5

~1.5°C

RCP2.6

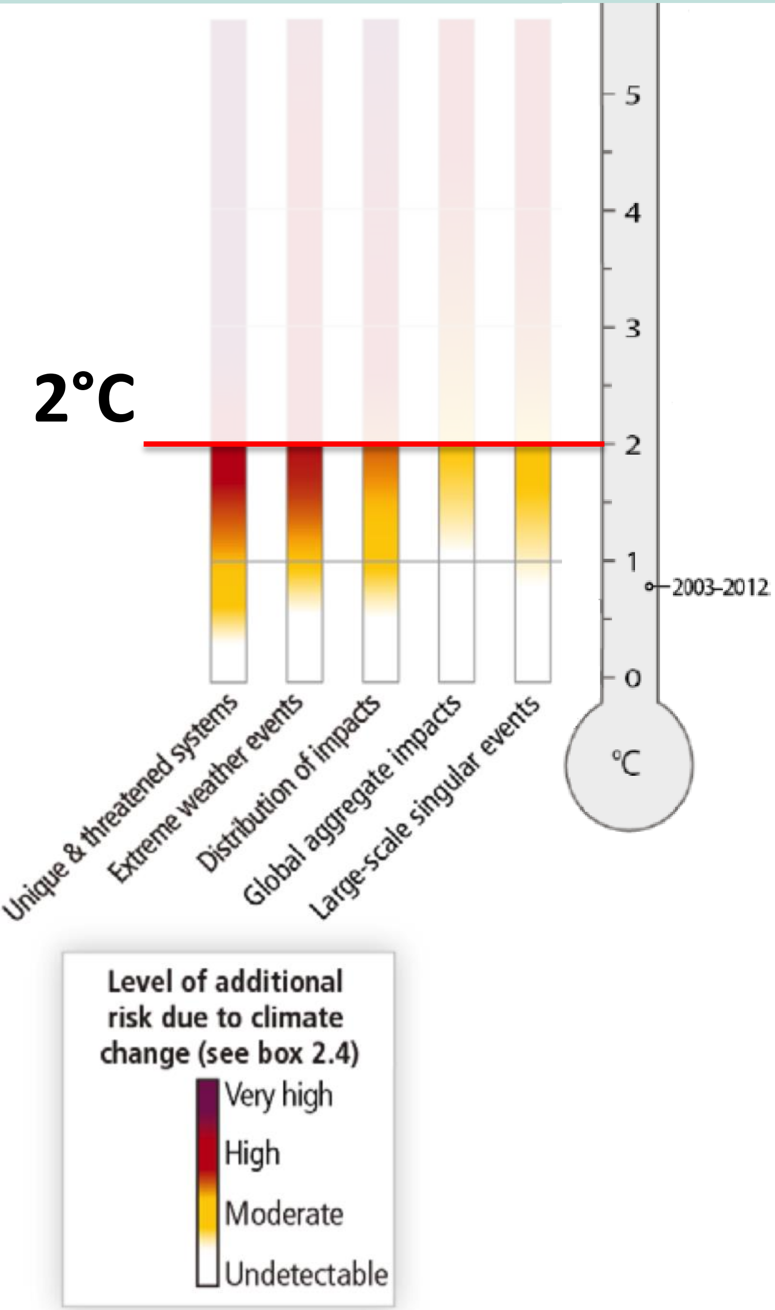


....climate change: ....avoided impacts ....projected impacts

- **climate change velocity slow enough** for most terrestrial and freshwater organisms to follow.
- up to **half of coral reefs may remain**.
- **sea level rise** may remain **below 1 m**.
- some Arctic **summer sea ice may remain**.
- **ocean acidification** impacts at **moderate** levels.

- **Capacity to increase food production reduced further** with some scope for adaptation.
- **some unique systems at high risk**.
- **more than half of coral reefs may be lost.**
- **risks of combined ocean acidification and warming become more prominent**.

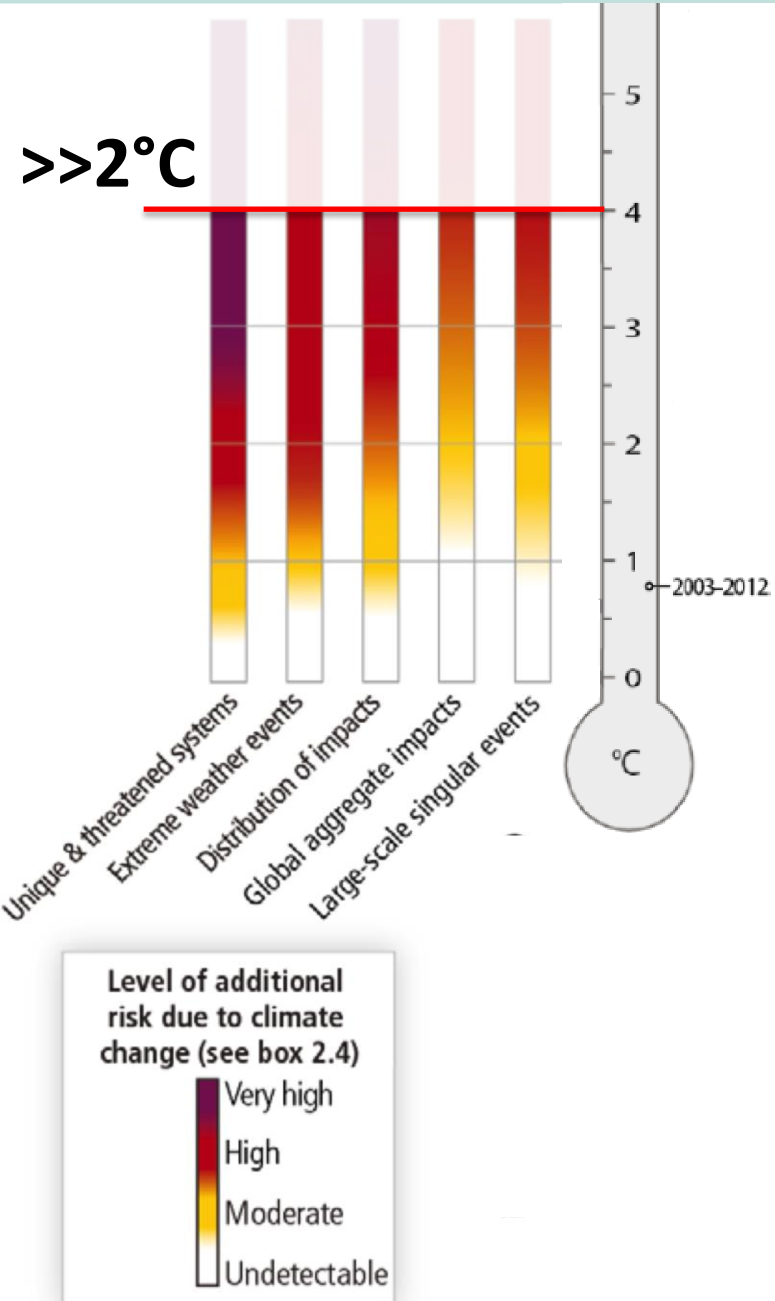
....climate change: ....avoided impacts
....projected impacts



- **climate change velocity becomes too high** for some species to move sufficiently fast.
- **long-term sea level rise may exceed 1 m:** coastal habitat loss, flooding, seawater inundation.
- Arctic **summer sea ice may be lost.**
- some **unique systems at very high risk.**

  e.g. coral reefs and sea ice systems marginalized.
- **risks of combined ocean warming and acidification become high.**
- **crop production at high risk** with some room for adaptation

....climate change: ....avoided impacts ....projected impacts

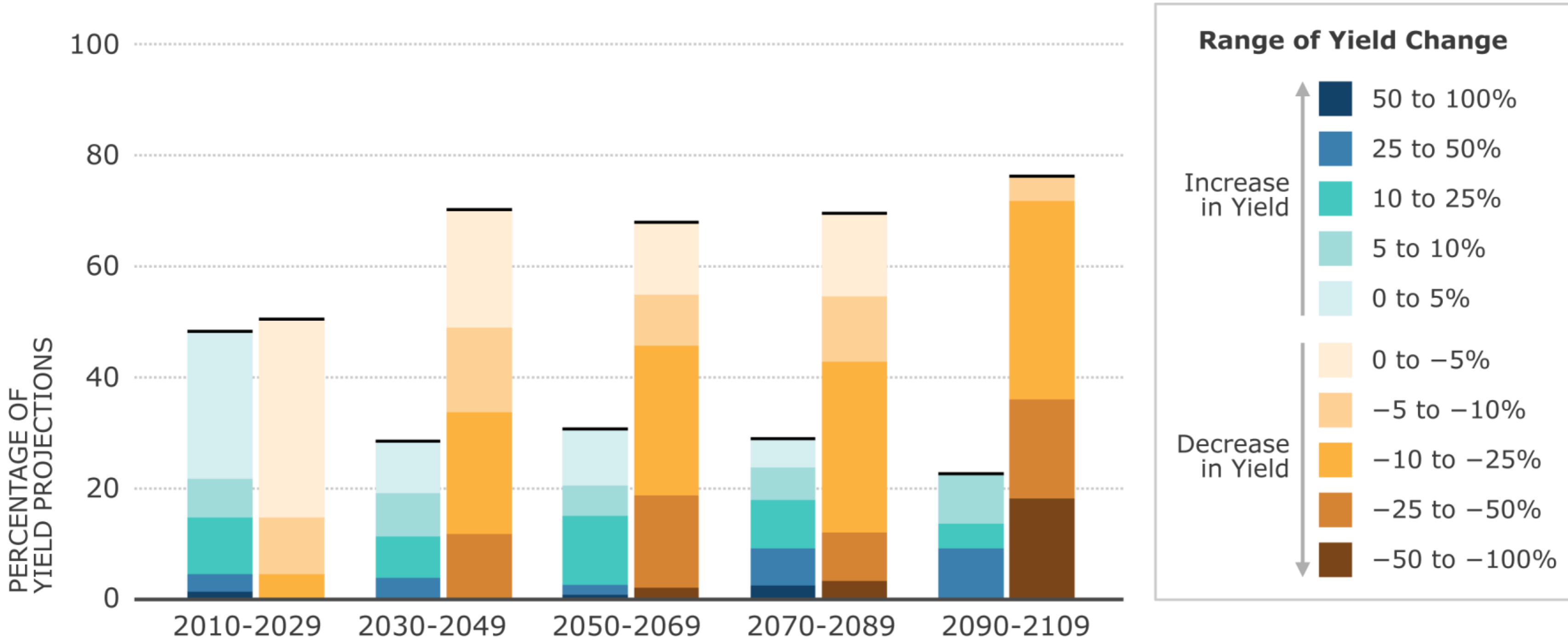


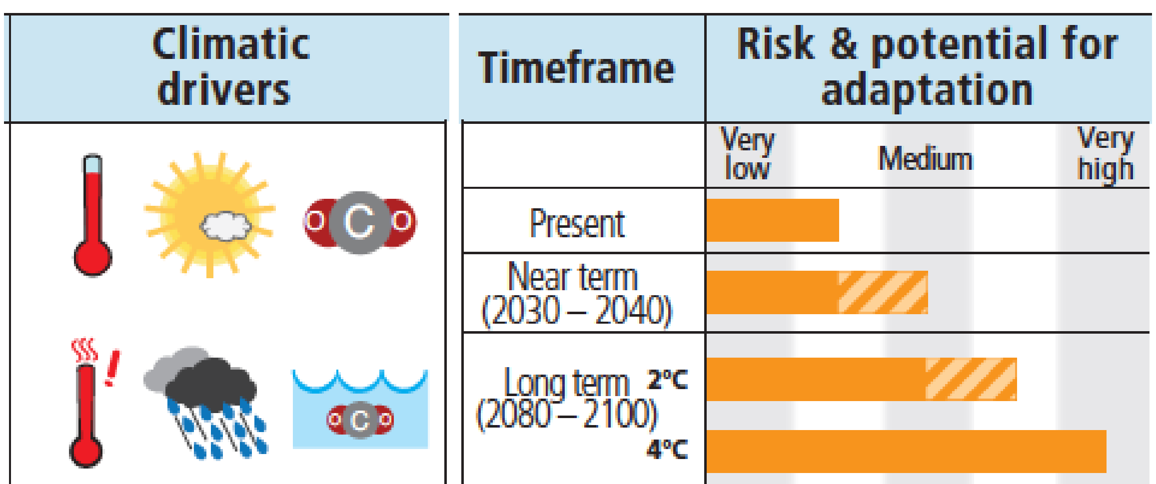
- most projected ecosystem impacts effective at high risk levels
- loss of biodiversity, highly reduced fisheries catch potential
- crop production at very high risk.
- climate change velocity much too high for terrestrial and freshwater species to move sufficiently fast.
- long-term sea level rise by far exceeds 1 m: coastal loss, flooding, seawater inundation.
- Arctic summer sea ice lost.
- some unique systems marginalized.
- risks of combined ocean warming and acidification become very high.

Thank you!

Food security constrained:
>1.5°C: high risk of more severe impacts after 2050

>1.5°C





Crop yields increasingly declining with climate change

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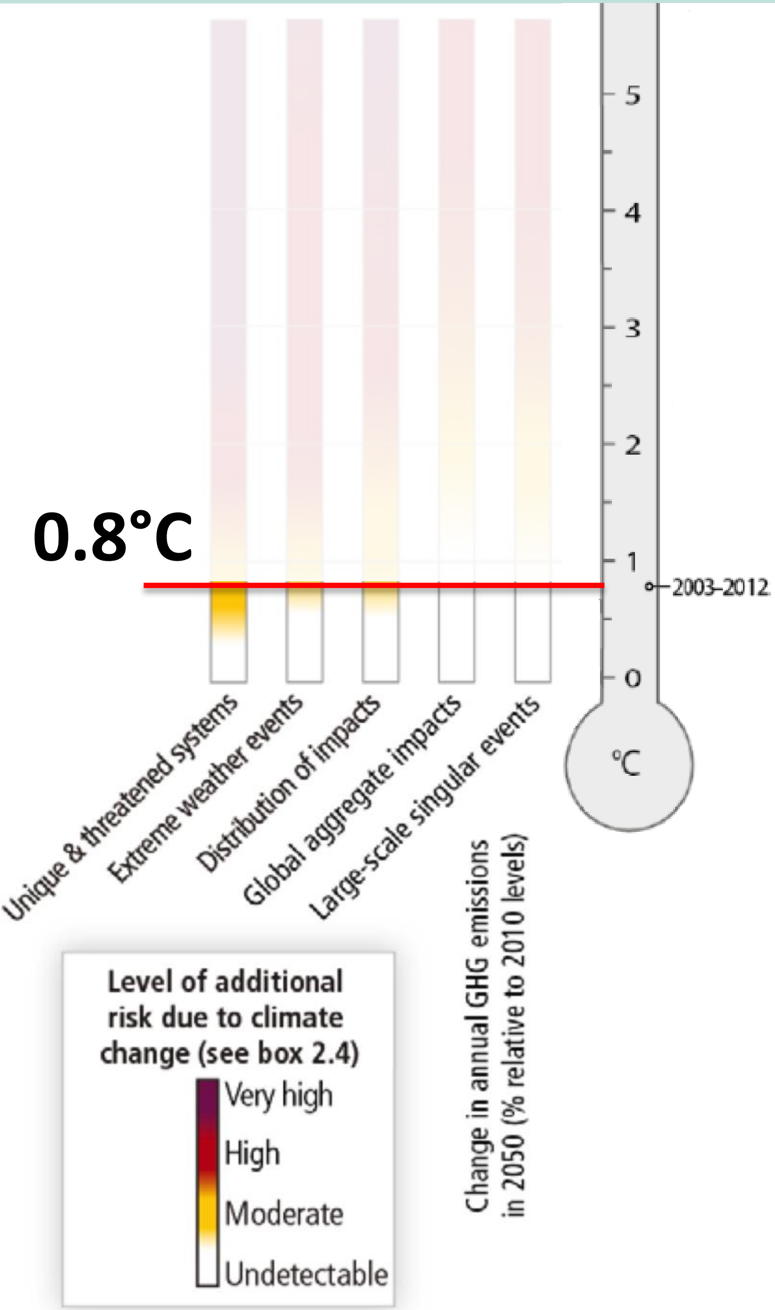
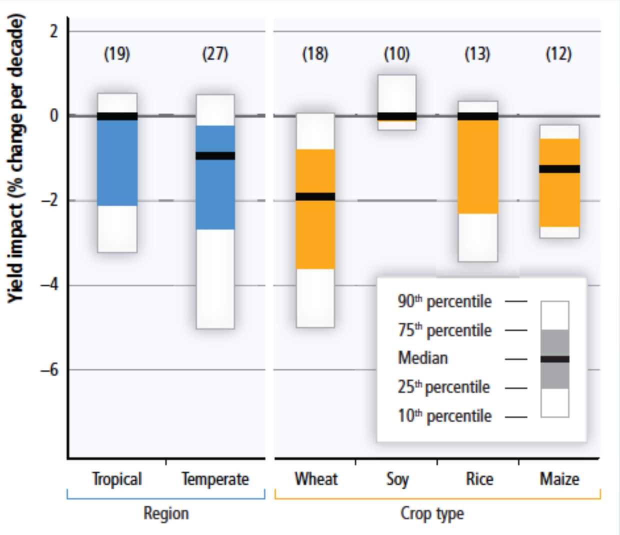
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

...allow ecosystems to adapt naturally...
...ensure that food production
is not threatened...

....climate change impacts observed on all continents and in all oceans



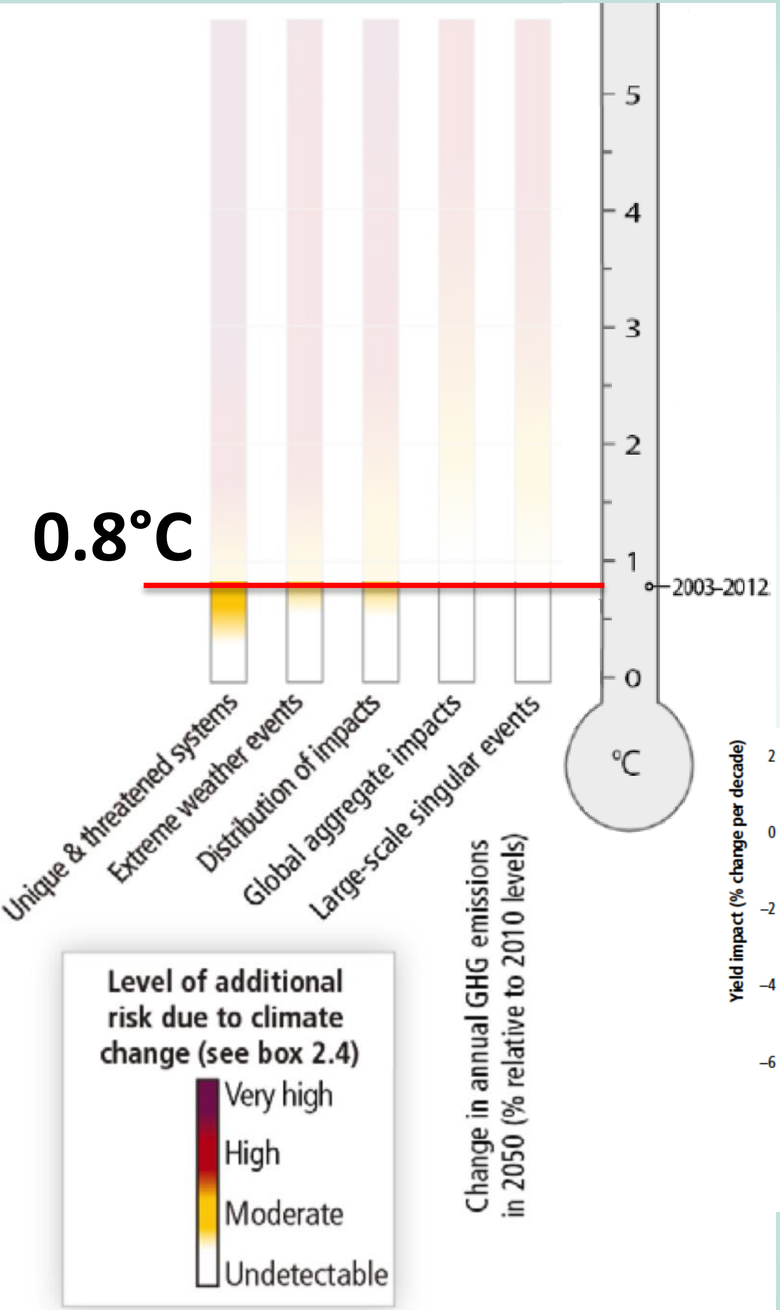
- World-wide species displacements due to climate change, marine, freshwater and terrestrial
- Increase in crop production reduced by climate change
- some systems at risk

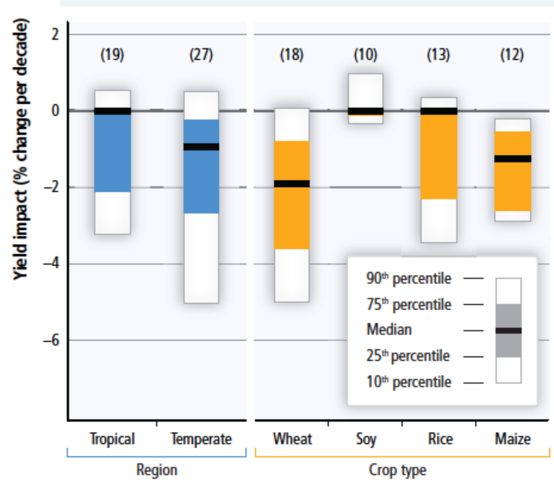


ipcc INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

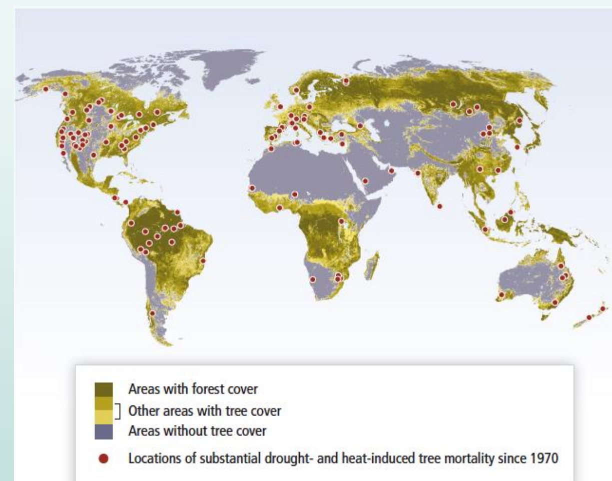
....climate change: observed impacts on all continents and in all oceans

- World-wide species displacements (marine, freshwater and terrestrial)
- Crop production increase constrained
- Forest dieback due to drought and heat
- Some unique systems at moderate risk from climate change (...risk rises if combined with other pressures)





crop yield reduction



forest dieback

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Oceans cover ~70% of the blue planet

- create half the oxygen (O_2) we use to breathe and burn fossil fuels.
- provide 20% of the animal protein consumed by 3 billion people.

- are home to diverse species and ecosystems valued in tourism
- offer rich biodiversity and resources for innovative drugs or biomechanics.
- sustain coral reefs and mangroves protecting coastlines from tsunamis and storms.

- sustain shipping of 90% of all goods the world uses.

Large-scale climate-related isssues in the global ocean

Oceans play a major role in climate regulation globally:

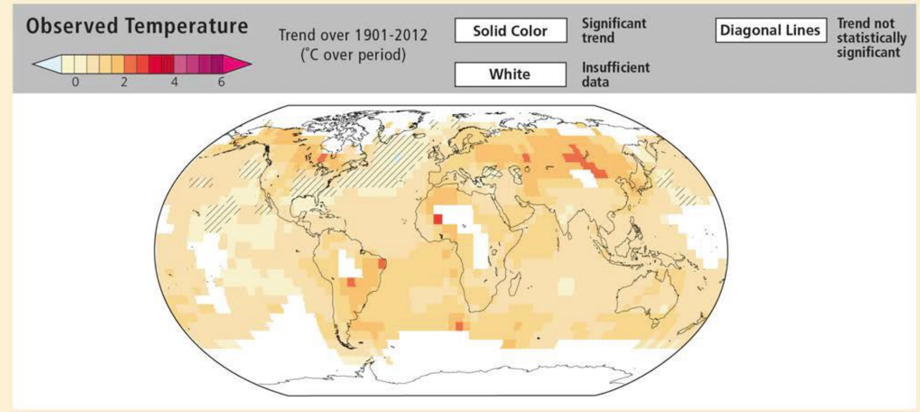
- absorb >90% of the heat accumulating in the atmosphere → ocean warming, hypoxia
- absorb 25% of man-made CO_2 → ocean acidification
- accumulate excess water from melting ice sheets → sea level rise
- redistribution of nutrients → productivity shifts

Human activities also influence ocean conditions locally:

- overfishing, pollution, eutrophication etc.

…with temperature presently being the predominant driver of ongoing global changes,
effects of ocean acidification and hypoxia reported in some areas

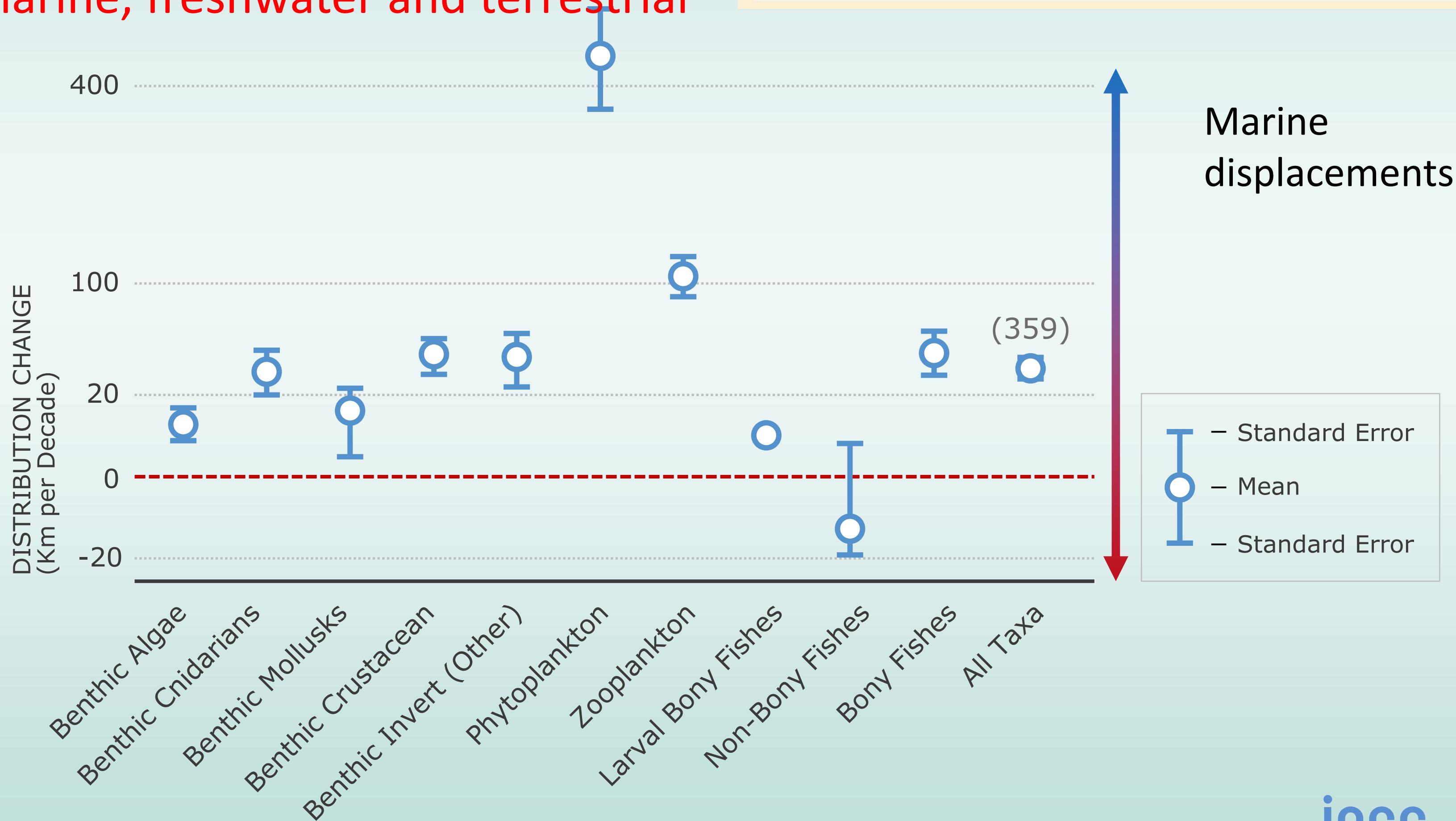
OBSERVATIONS IN ECOSYSTEMS



0.8°C:

World-wide species displacements due to climate change,

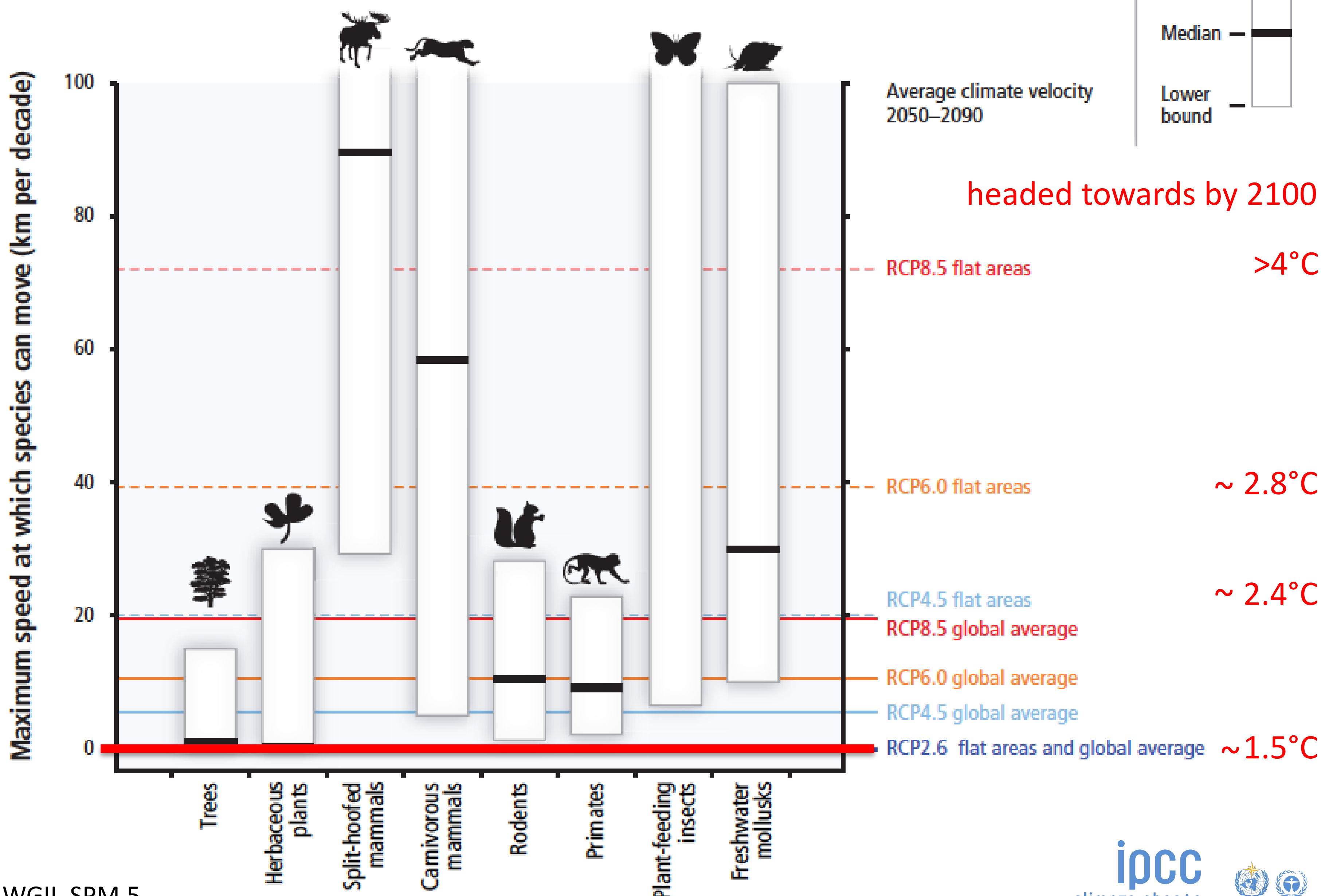
marine, freshwater and terrestrial



WGII, SPM.2

Climate change velocity can exceed the capacity of species to move:

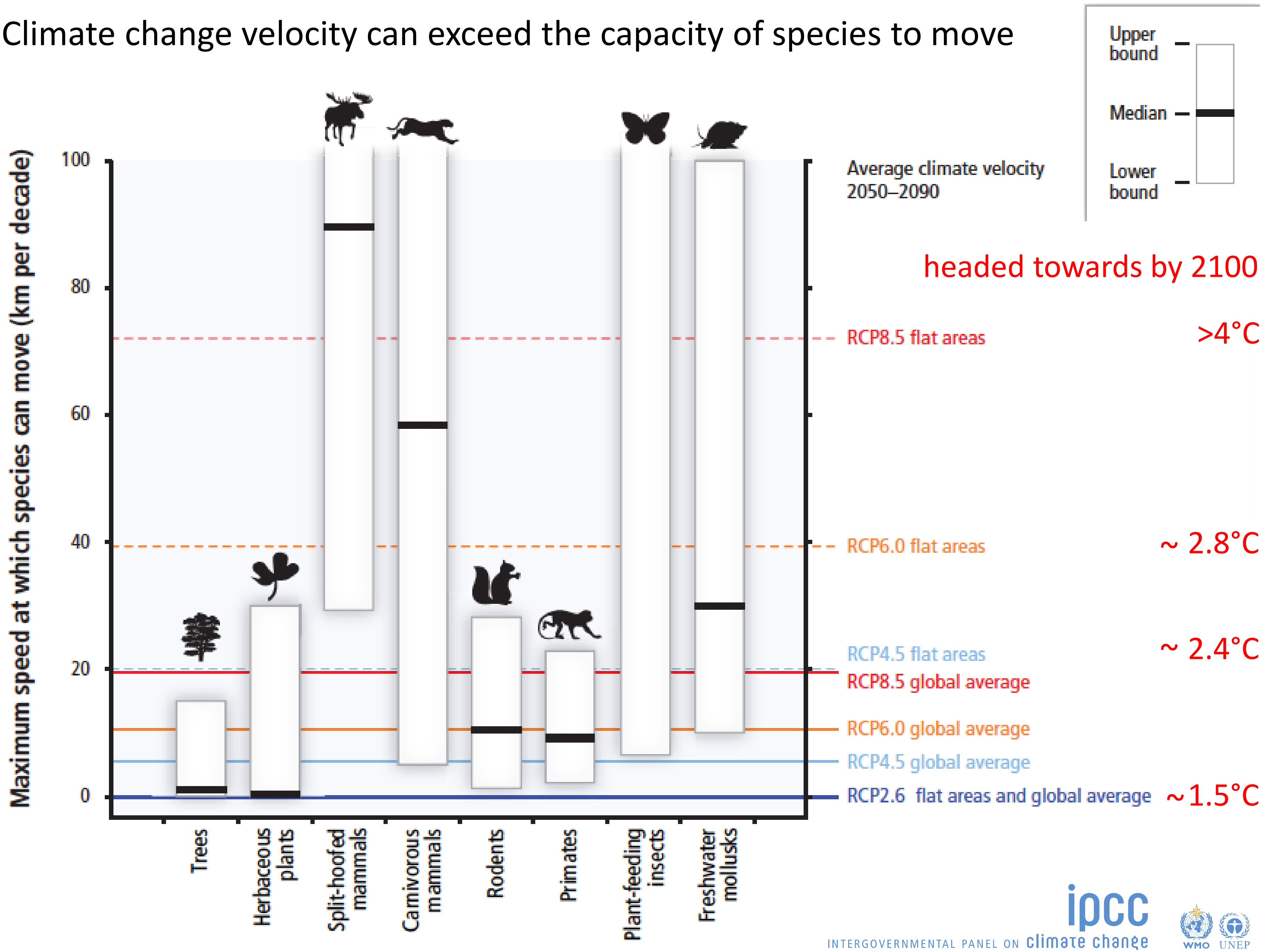
on the safe side under RCP 2.6



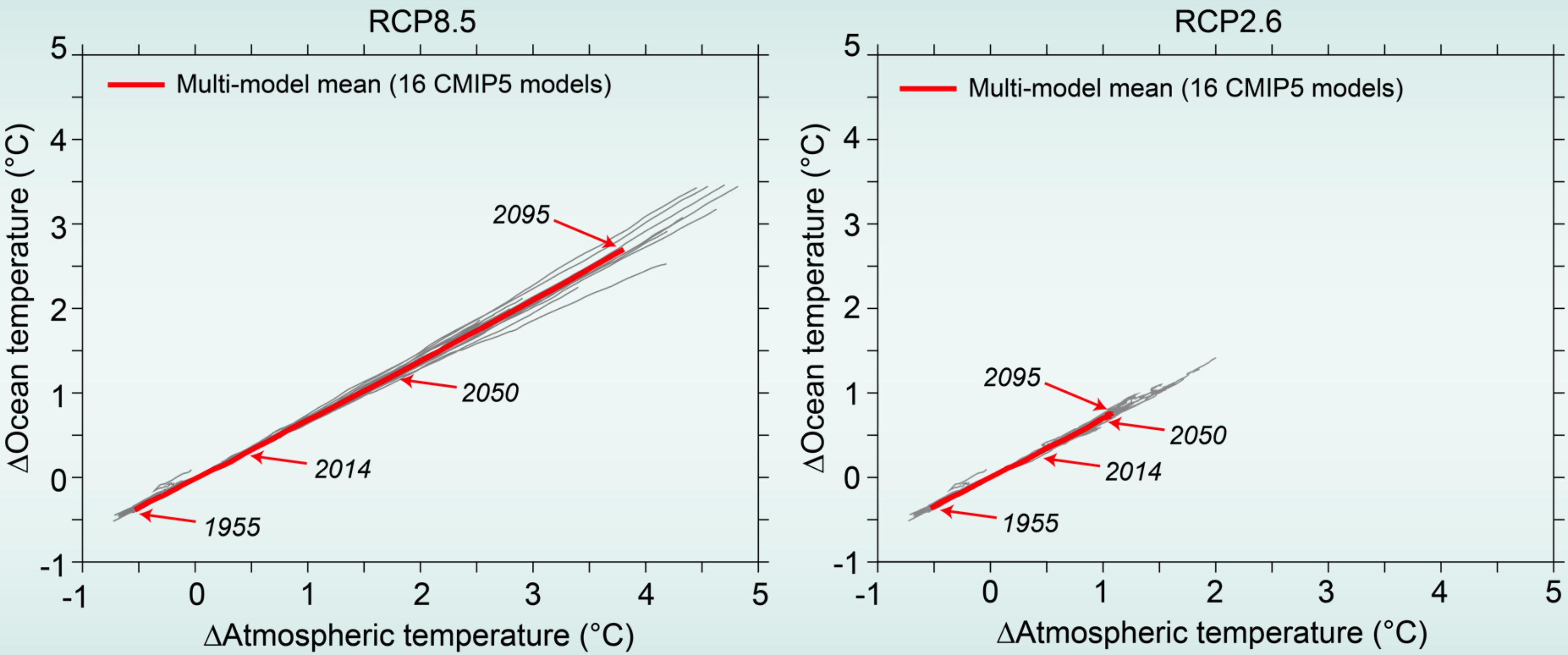
WGII, SPM.5

INTERGOVERNMENTAL PANEL ON climate change

Climate change velocity can exceed the capacity of species to move

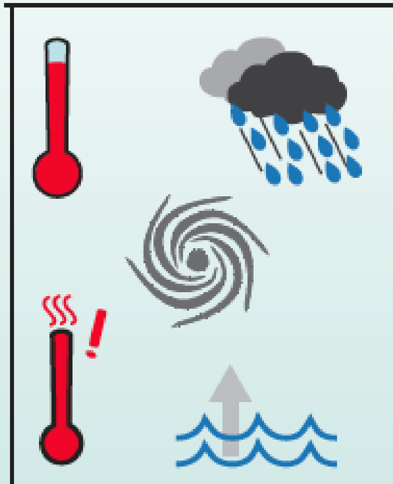


Ocean temperatures lag behind the global atmospheric mean

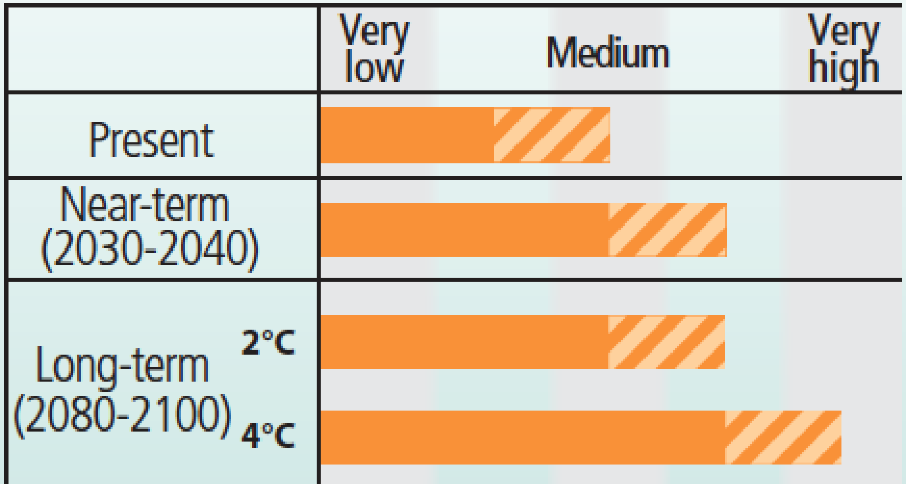


courtesy: T. Froelicher

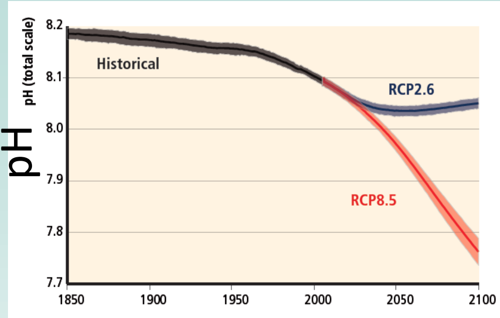
Key risk	Adaptation issues and prospects
Risks to fisheries	
Temperature driven stock displacement	
Reduced livelihoods and increased poverty (*medium confidence*)	Human adaptation options involve the large scale relocation of industrial fishing activities following the regional decreases (low latitude) versus increases (high latitude) in catch potential and shifts in biodiversity. Artisanal local fisheries are extremely limited in their adaptation options by available financial resources and technical capacities, except for their potential shift to other target species.



6.4.1-2,
30.6.2,
30.6.5,
Table 30-3

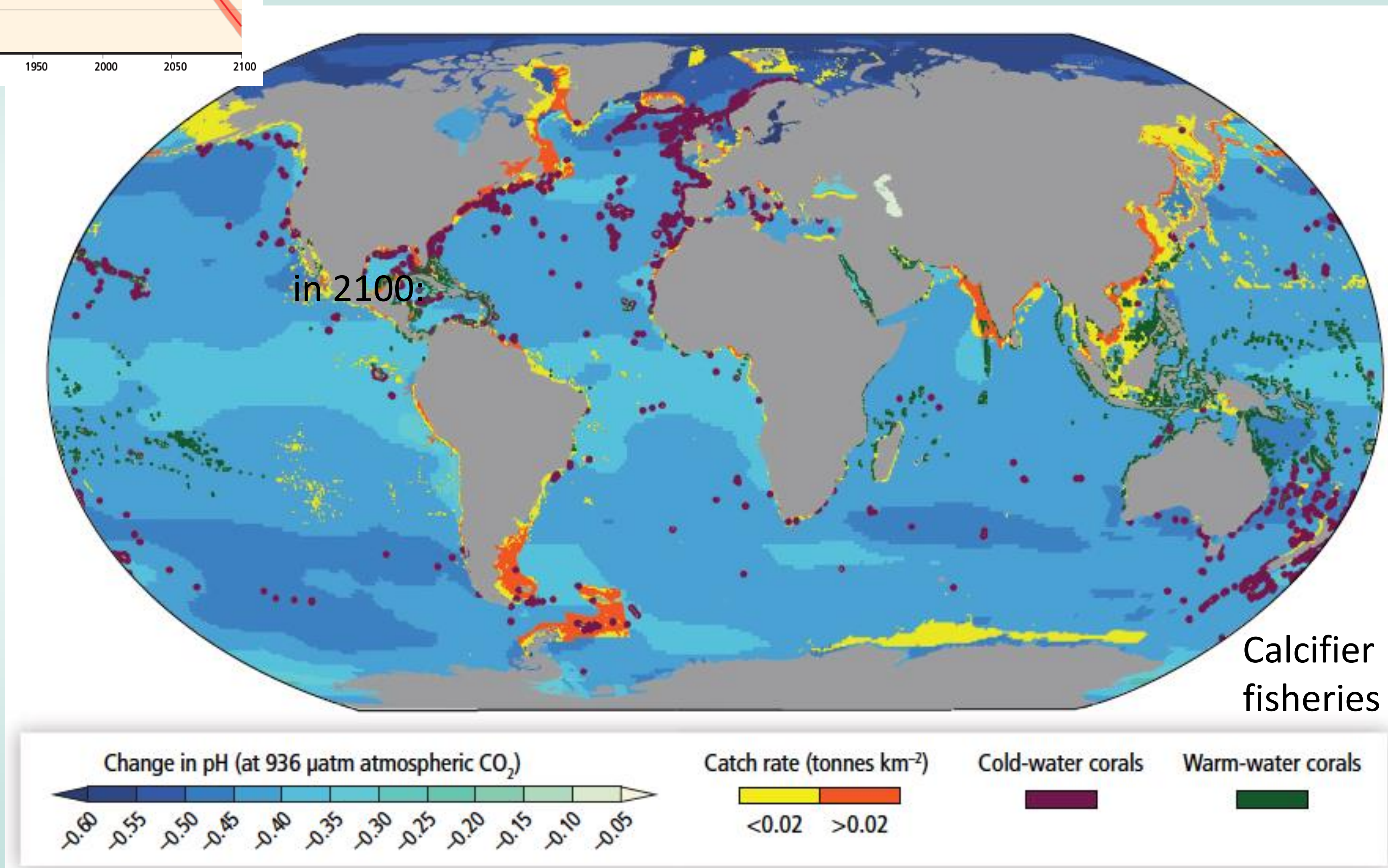


observed projected



The emerging risk: Ocean acidification

Special vulnerabilities of polar species?



IPCC AR5 WGII Figure 6.10, SPM.6

proofs2

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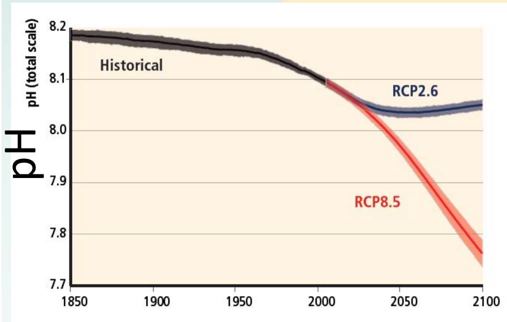
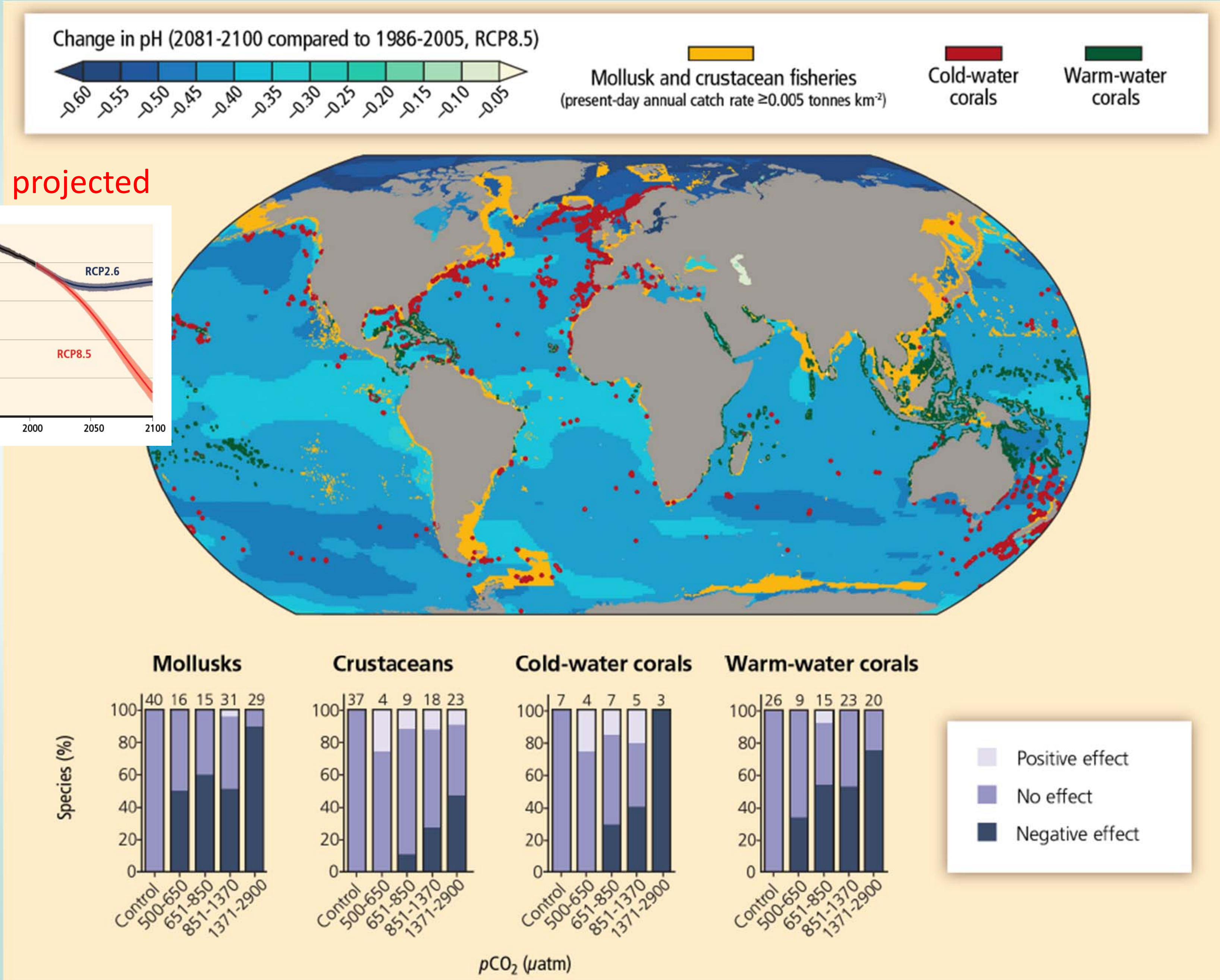
Projections: Ocean acidification, risks for mollusk and crustacean fisheries and coastal protection by coral reefs

WGII, SPM.6
SYR Figure 2.6

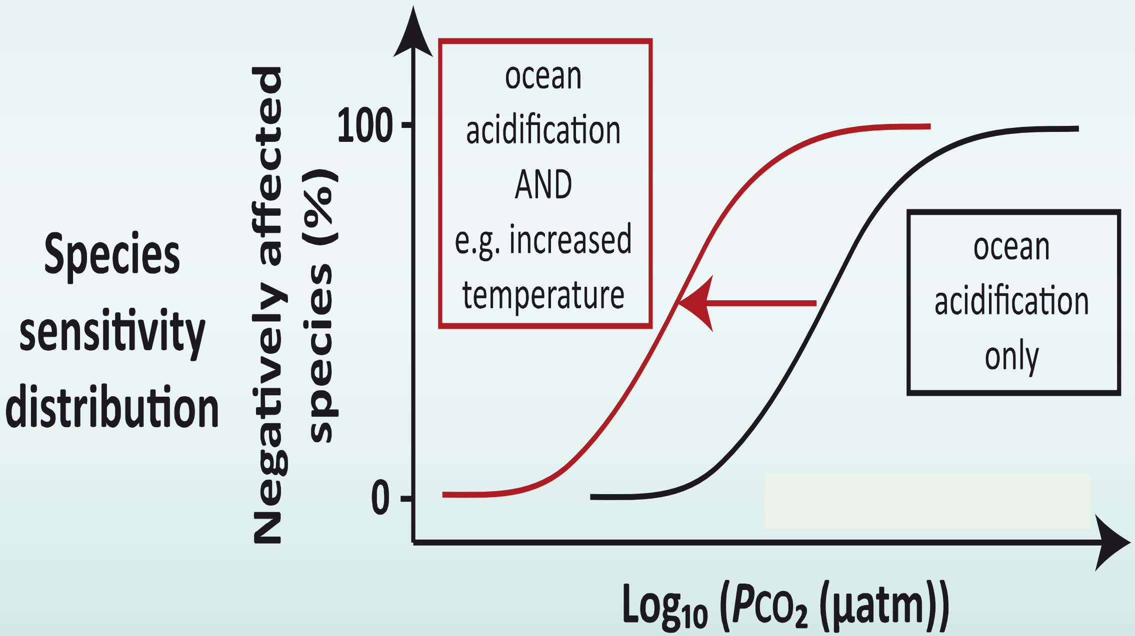
observed projected





Synergism of multiple stressors:

sensitivity distribution shifted to lower values of P_{CO_2}, a hypothesis



A. Wittmann, H.O. Pörtner, 2013

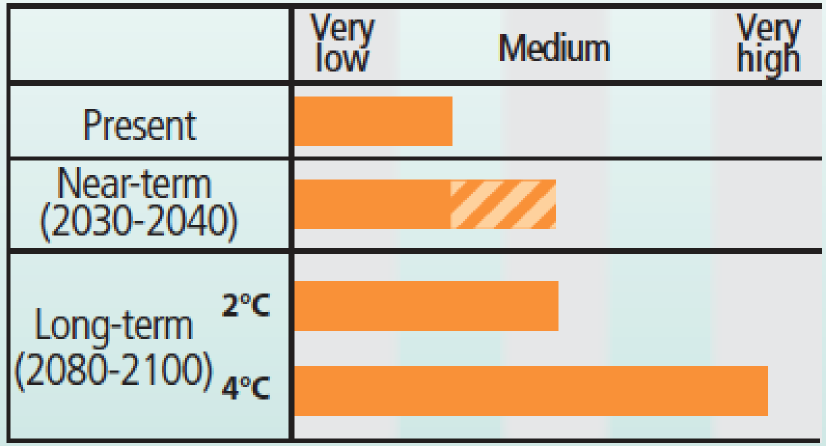
Key risk	Adaptation issues and prospects

Risks to fisheries

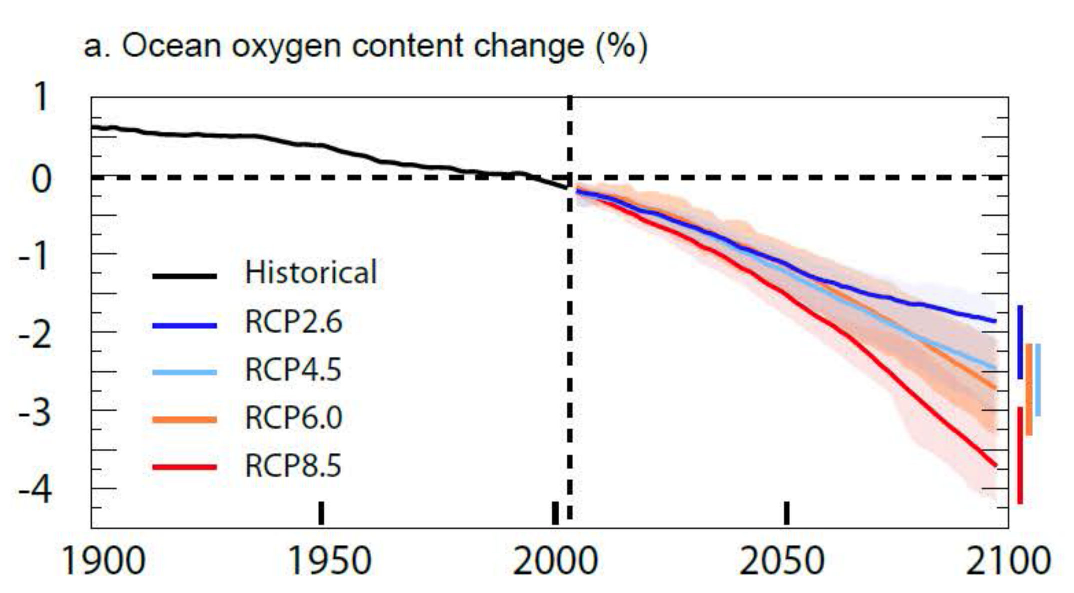
Ocean acidification affecting fisheries and ecosystem engineers (corals)

Ocean acidification: Reduced growth and survival of commercially valuable shellfish and other calcifiers, e.g., reef building corals, calcareous red algae (*high confidence*)	Evidence for differential resistance and evolutionary adaptation of some species exists but is likely to be limited at higher CO_2 concentrations and temperatures reached; adaptation options include the shift to exploiting more resilient species or the protection of habitats with low natural CO_2 levels, as well as the reduction of other stresses mainly pollution and limiting pressures from tourism and fishing.

	5.3.3.5, 6.1.1, 6.3.2, 6.4.1.1, 30.3.2.2, Box CC-OA

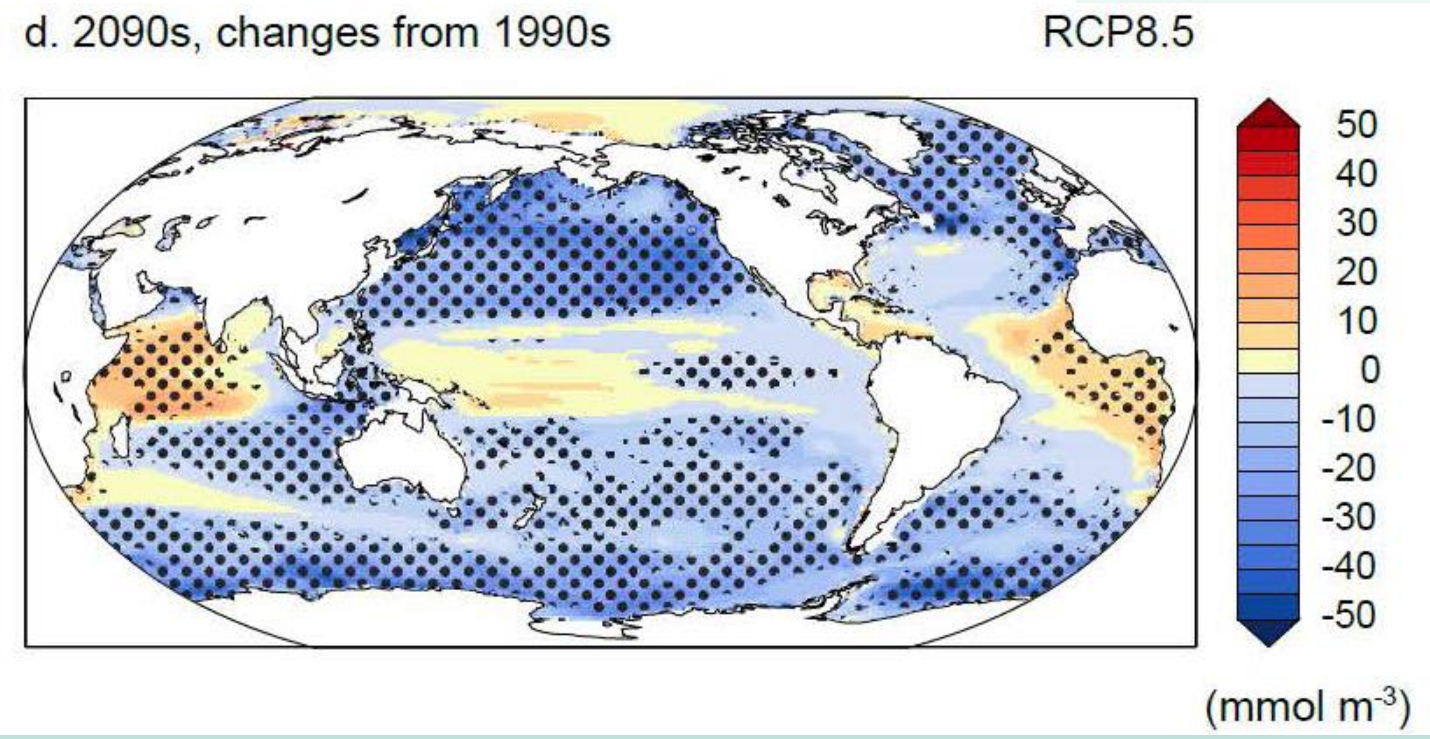


Observations and Projections: Deoxygenation



RCP8.5: Overall loss in oxygen also affecting Antarctic oceans

respiratory deoxygenation (e.g. deep water) exacerbates acidification

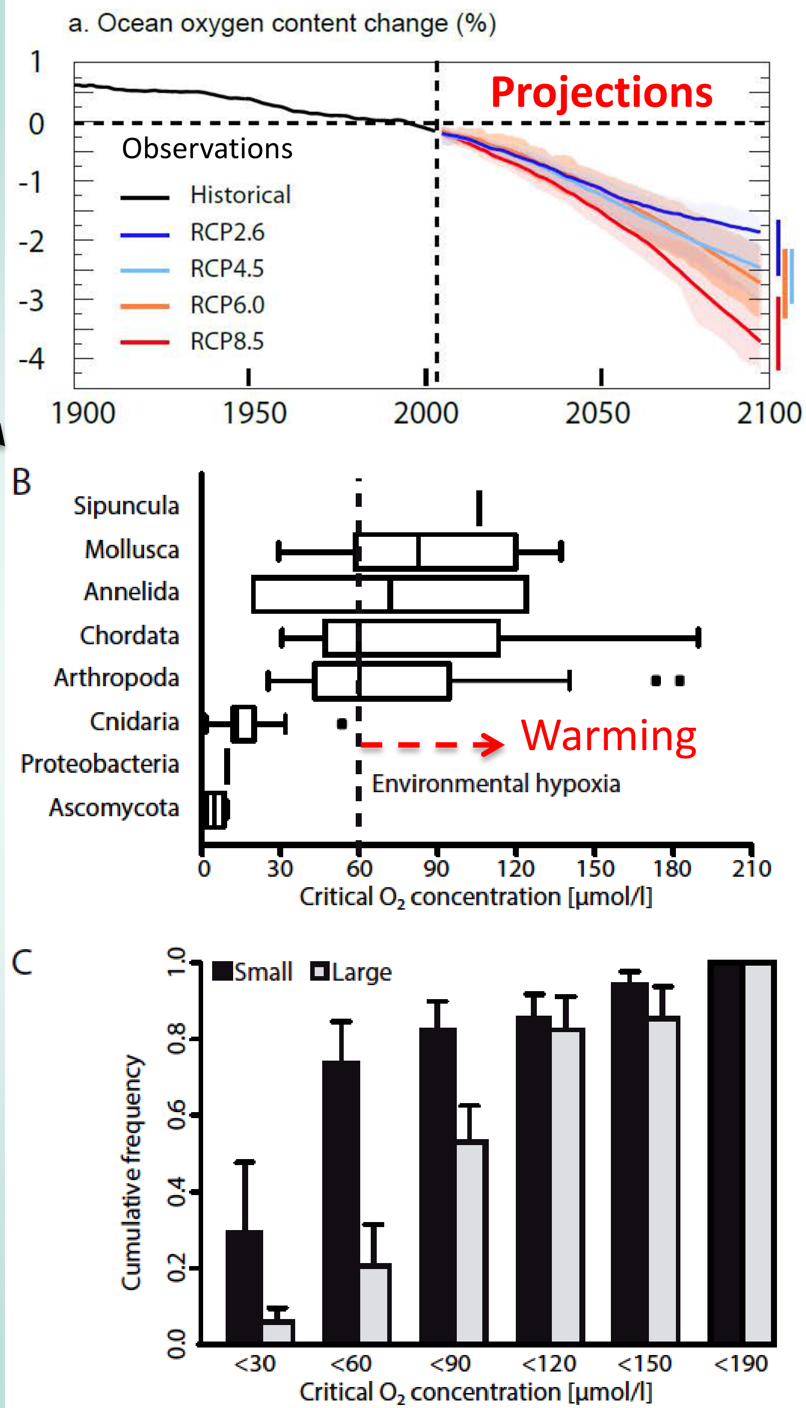


WGI Figure 6.30

Oceans are losing oxygen

Different tolerances to low oxygen levels
explain the shift to tolerant communities
(unicells and small animals)

below 60 µmol l^{-1}
....in cool midwater Oxygen Minimum Zones
....combined with CO_2 accumulation



WGI

WGII

Dependence on body size in animals

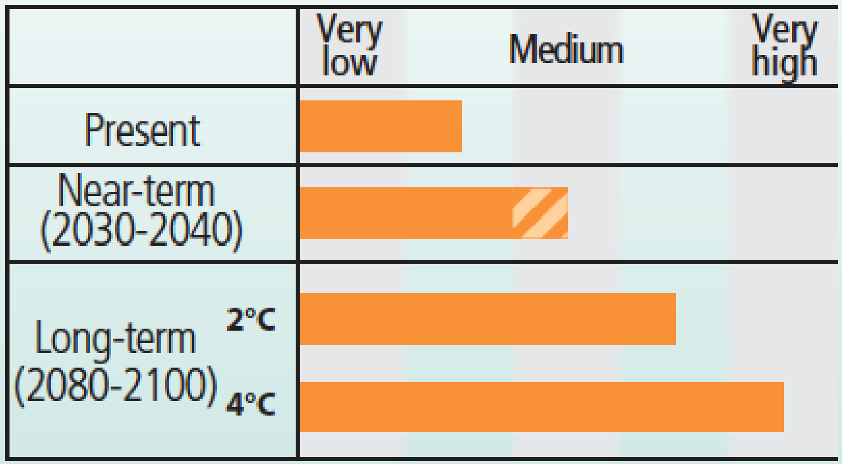
WGI, 6-30, WGII, 6-11
D. Storch et al., 2014

Key risk	Adaptation issues and prospects
Risks to fisheries	

Oxygen deficiency constraining fish habitat

High mortalities and loss of habitat to larger fauna including commercial species due to hypoxia expansion and effects, particularly in EBUE, some SES and CBS regions (*high confidence*)	Human adaptation options involve the large scale relocation of fishing activities as a consequence of the hypoxia induced decreases in biodiversity and fisheries catch of pelagic fish and squid. Specific fisheries may benefit (Humboldt squid). Reducing the amount of organic carbon running of coastlines by controlling nutrients and pollution running off agricultural areas can reduce microbial activity and consequently limit the extent of the oxygen drawdown and the formation of coastal dead zones.

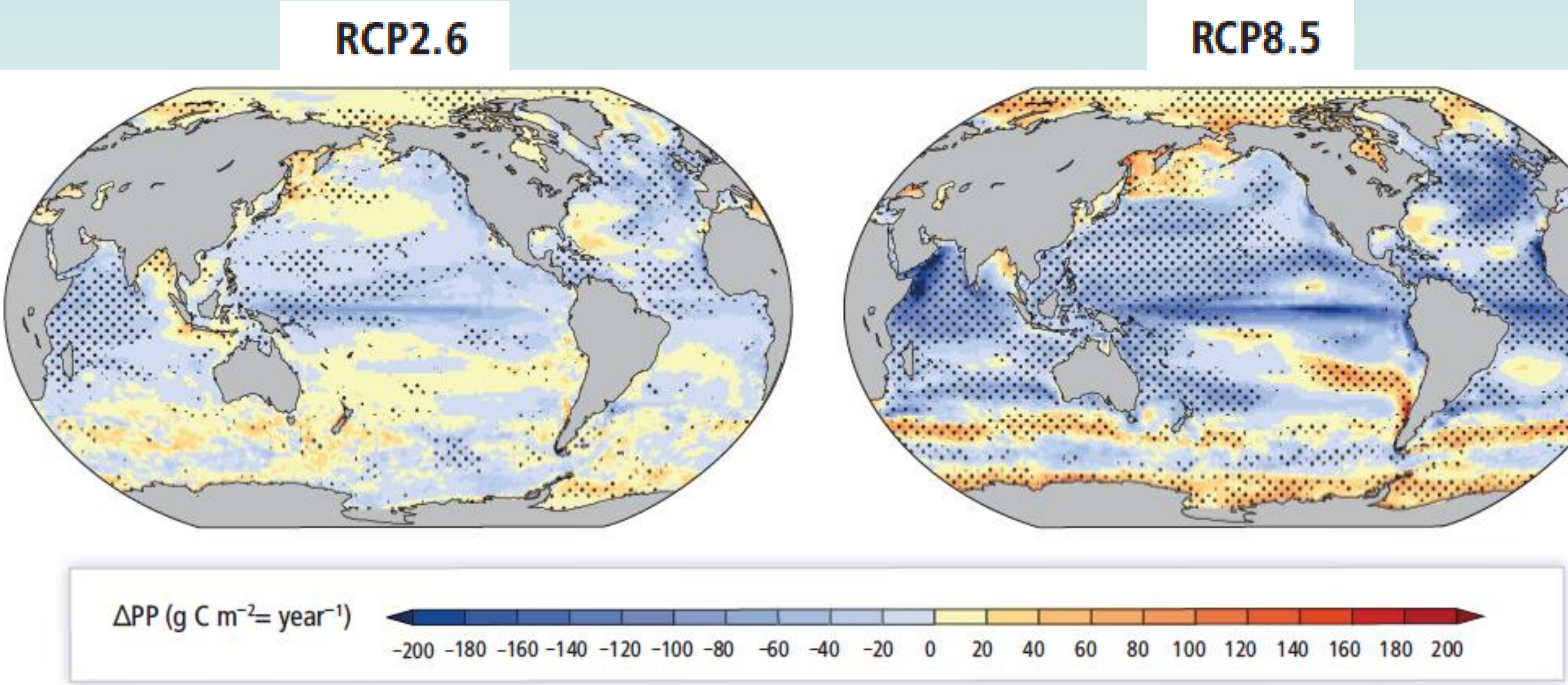
6.1.1, 6.3.3, 30.5.3-5



(1.5°C)

PROJECTIONS

Spatial changes....and a small decrease in ocean primary production



IPCC AR5 WGII Figure 6.13

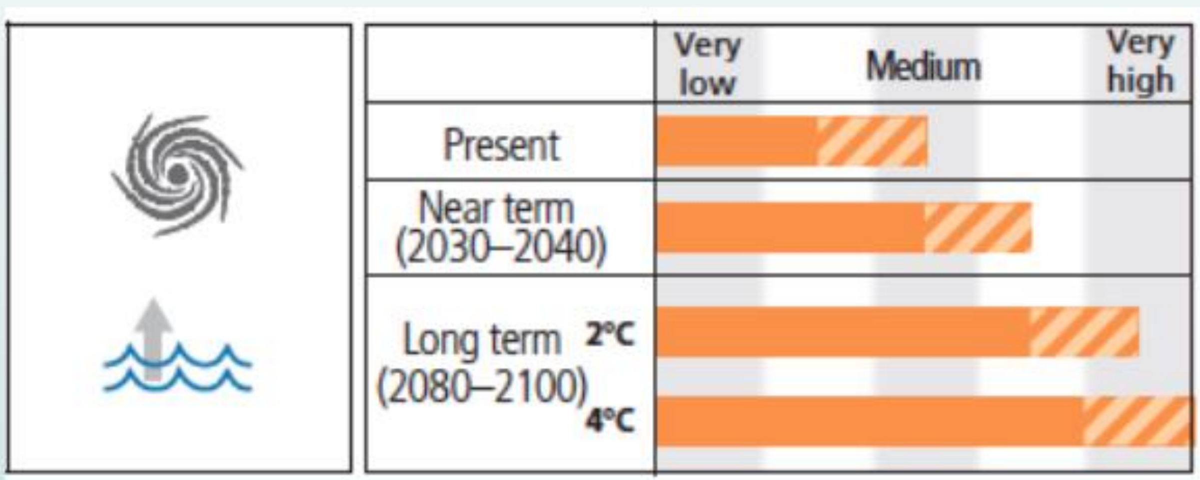
proof2

Small island risks

Key risk	Adaptation issues & prospects

Storm surges, swells, sea level rise

The interaction of rising global mean sea level in the 21st century with high-water-level events will threaten low-lying coastal areas (*high confidence*) [29.4, Table 29-1; WGI AR5 13.5, Table 13.5]	• High ratio of coastal area to land mass will make adaptation a significant financial and resource challenge for islands. • Adaptation options include maintenance and restoration of coastal landforms and ecosystems, improved management of soils and freshwater resources, and appropriate building codes and settlement patterns.



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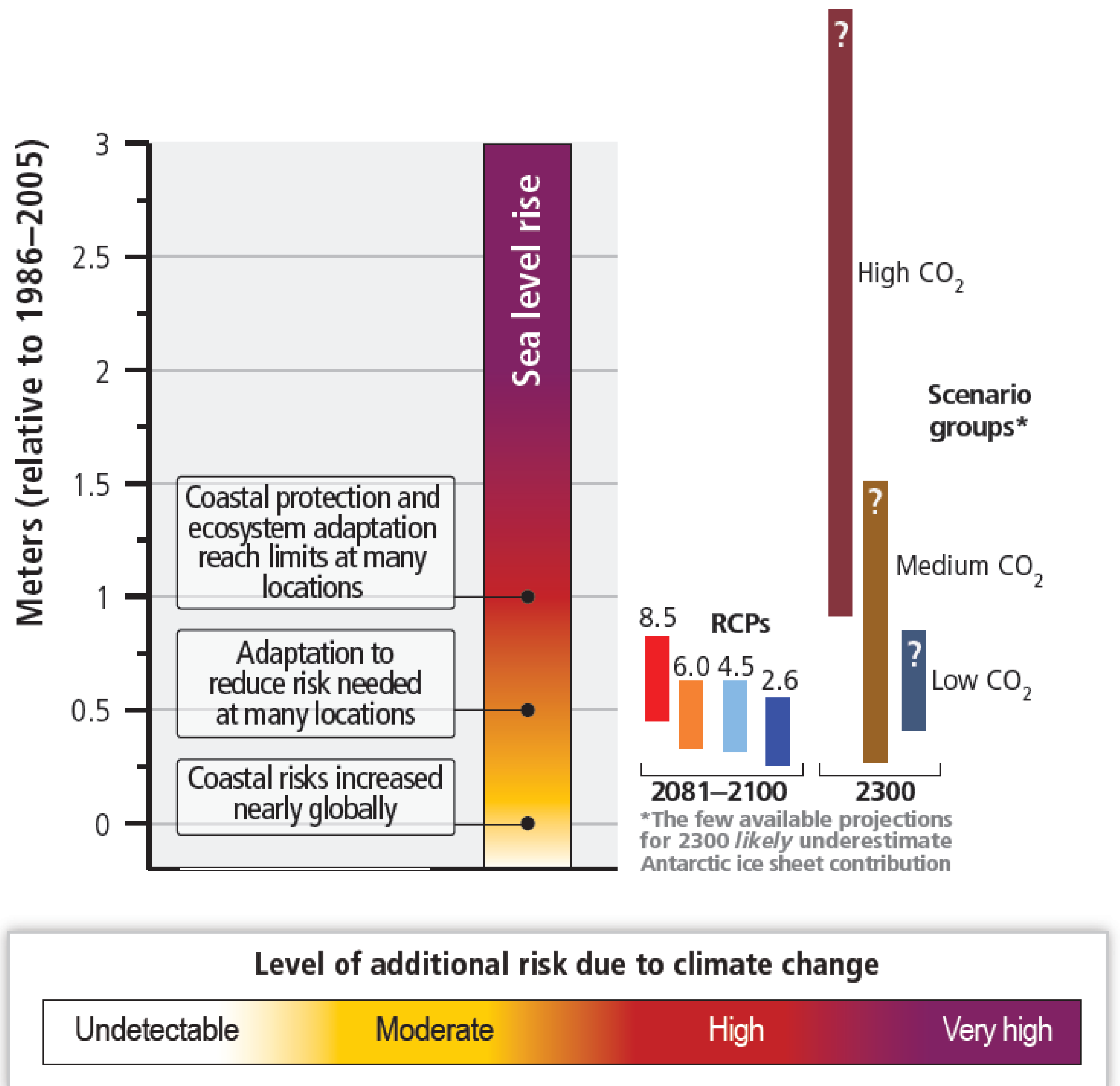
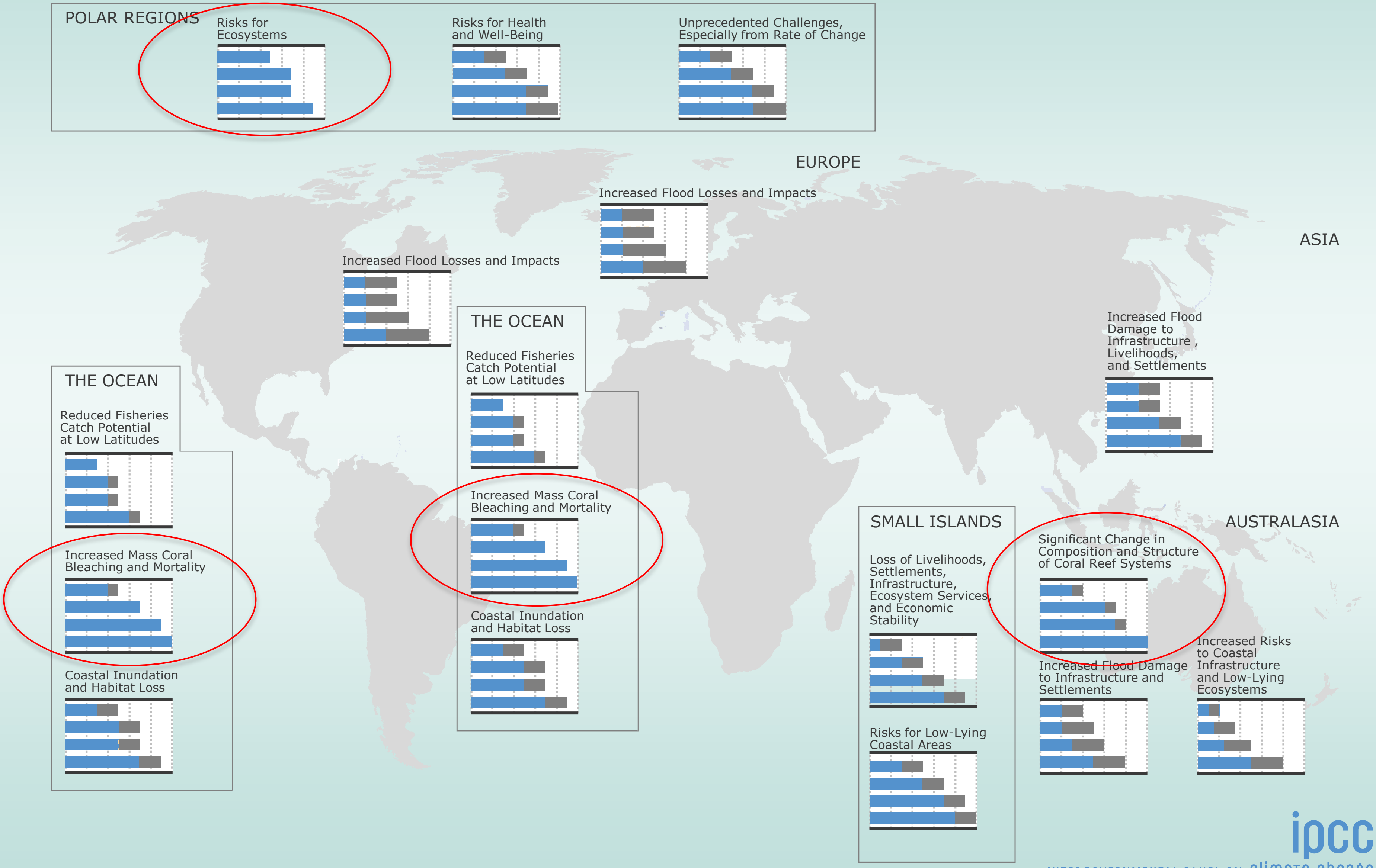
INTERGOVERNMENTAL PANEL ON climate change

(C) Risk for coastal human and natural systems impacted by sea level rise



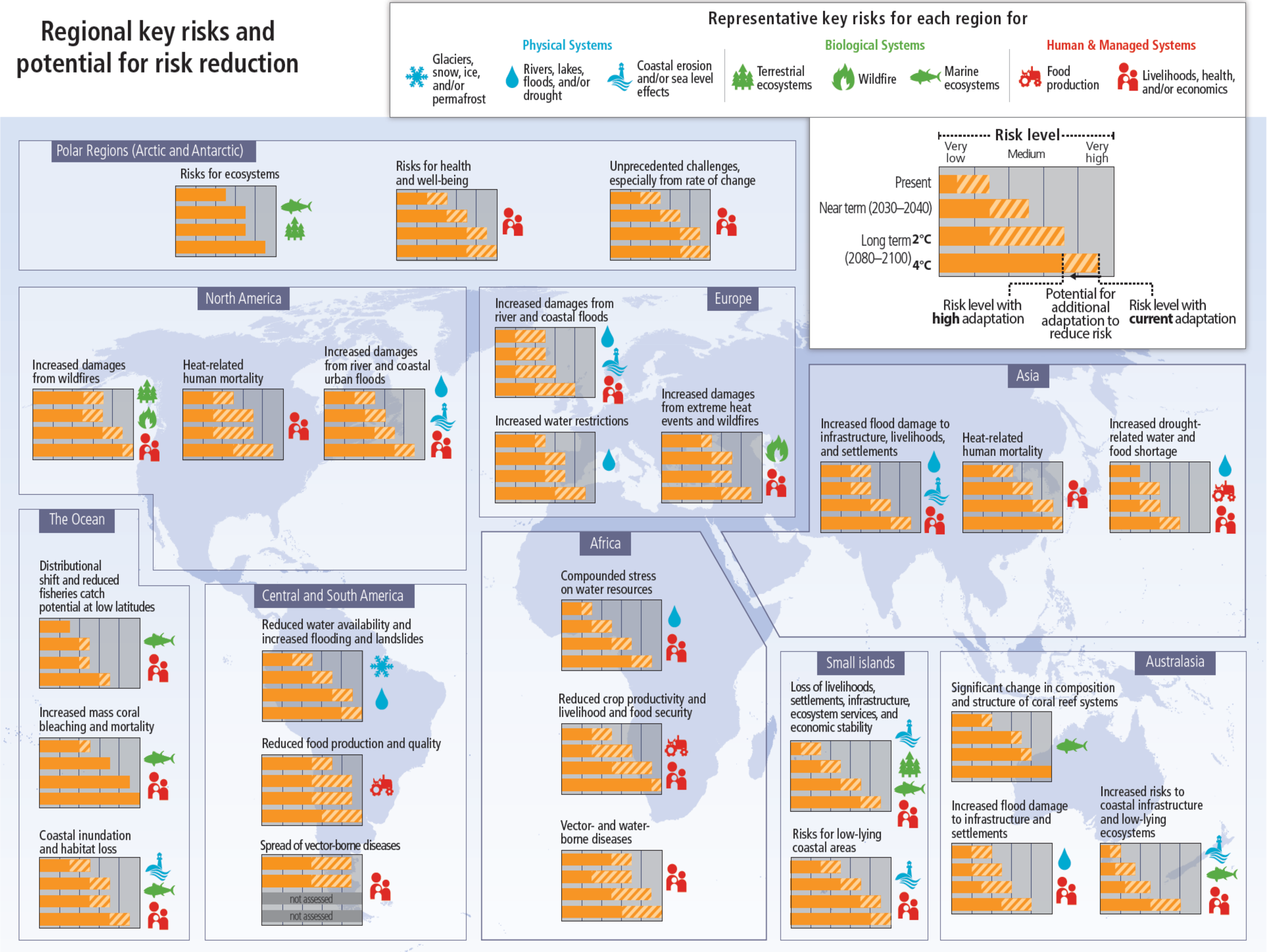
Risks involving the oceans, a global perspective:
.....is there risk reduction by adaptation?
.....very limited for some systems: marginalization of coral reefs and polar fauna



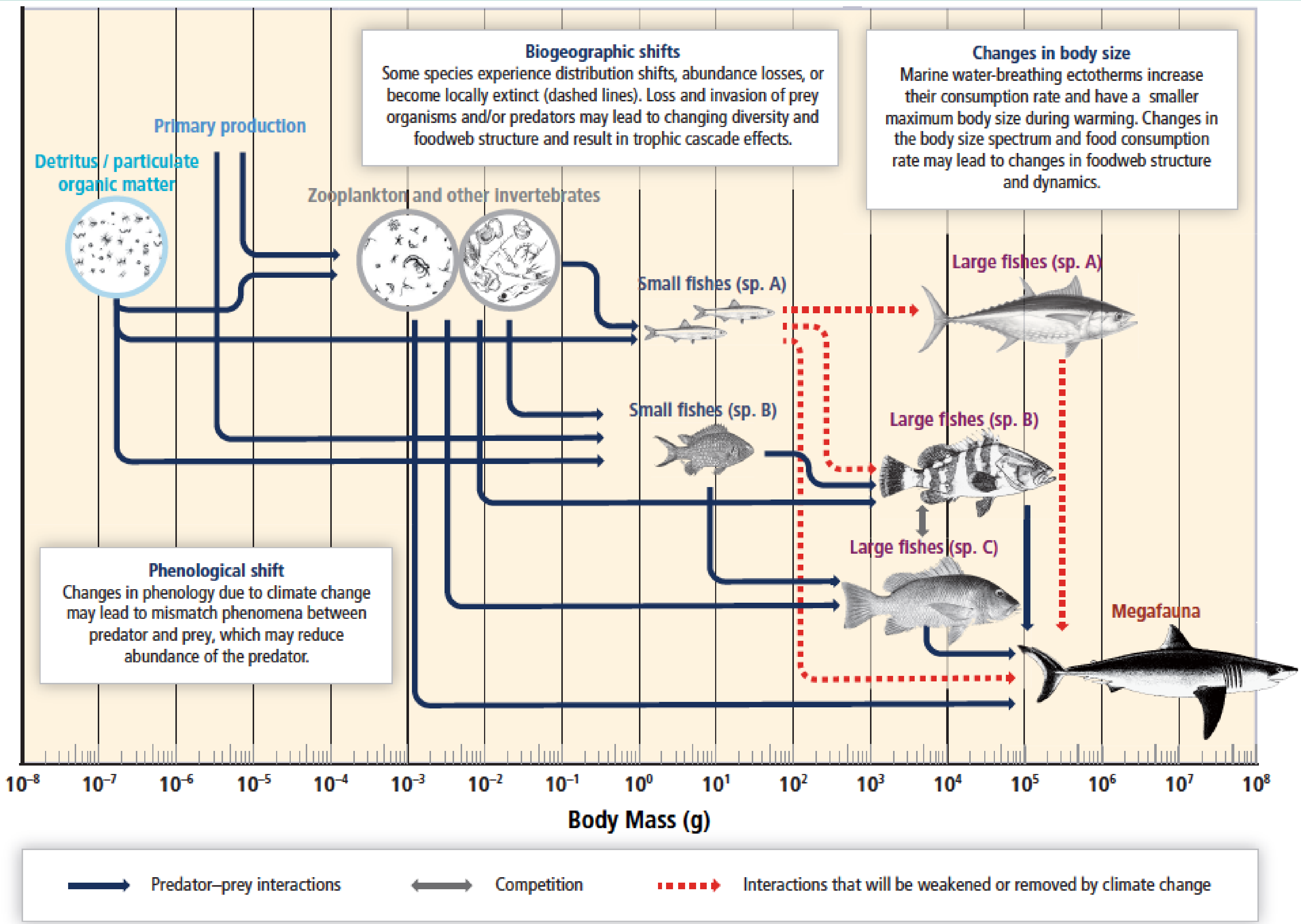
ipcc INTERGOVERNMENTAL PANEL ON climate change

WGII, SYR

Regional key risks and potential for risk reduction

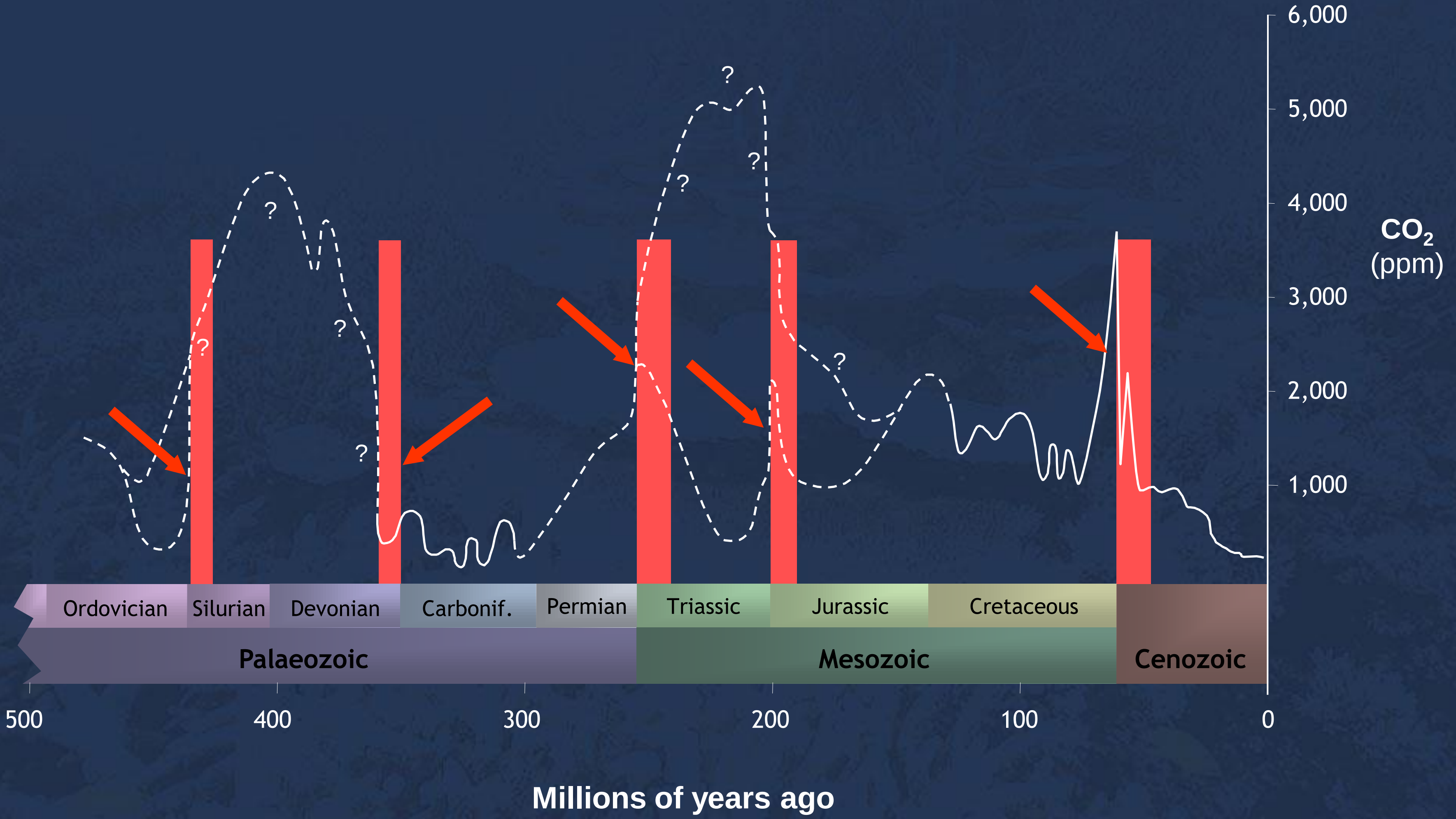


Perspectives: Foodweb consequences

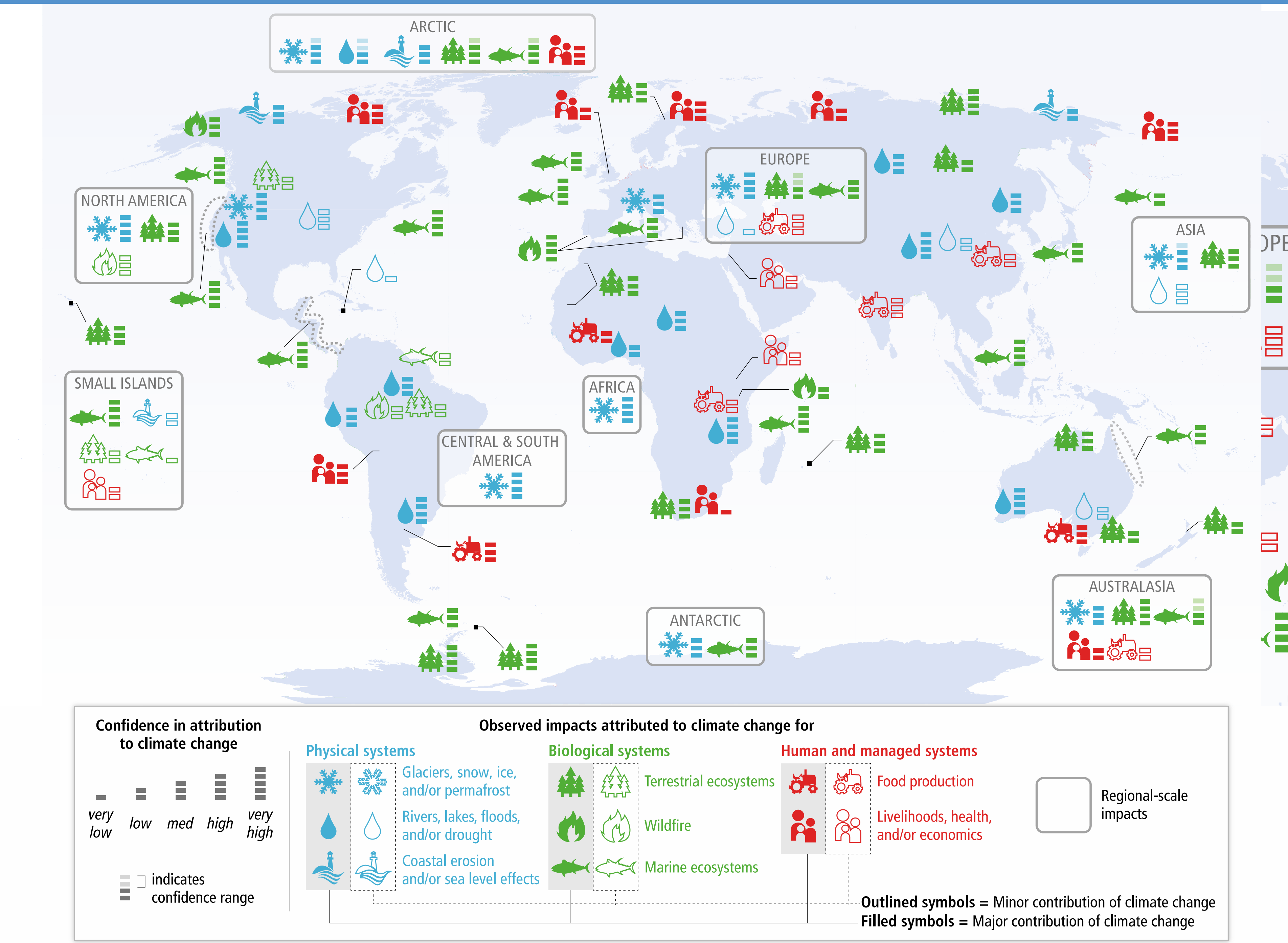


proofs2

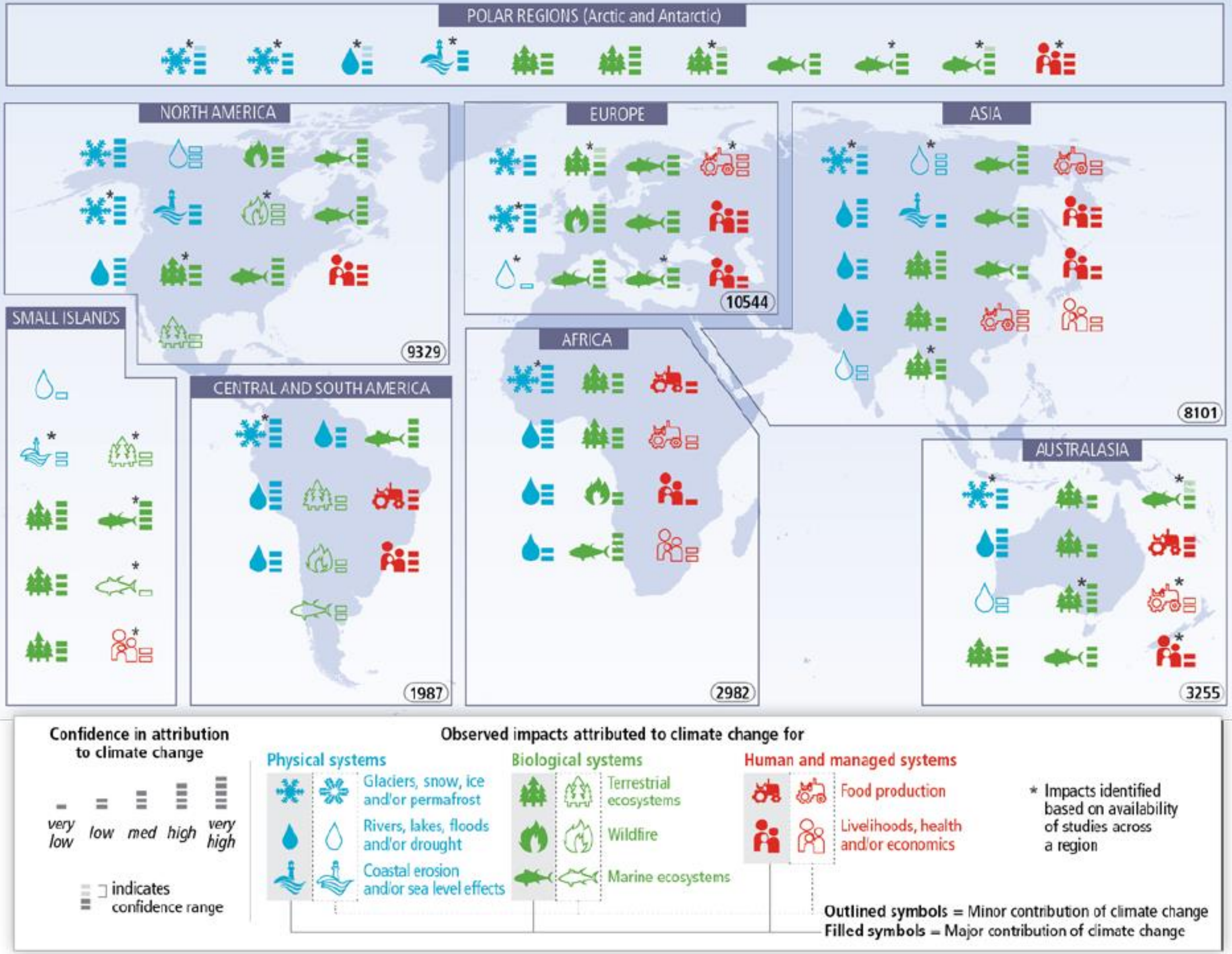
IPCC AR5 WGII Figure 6.12



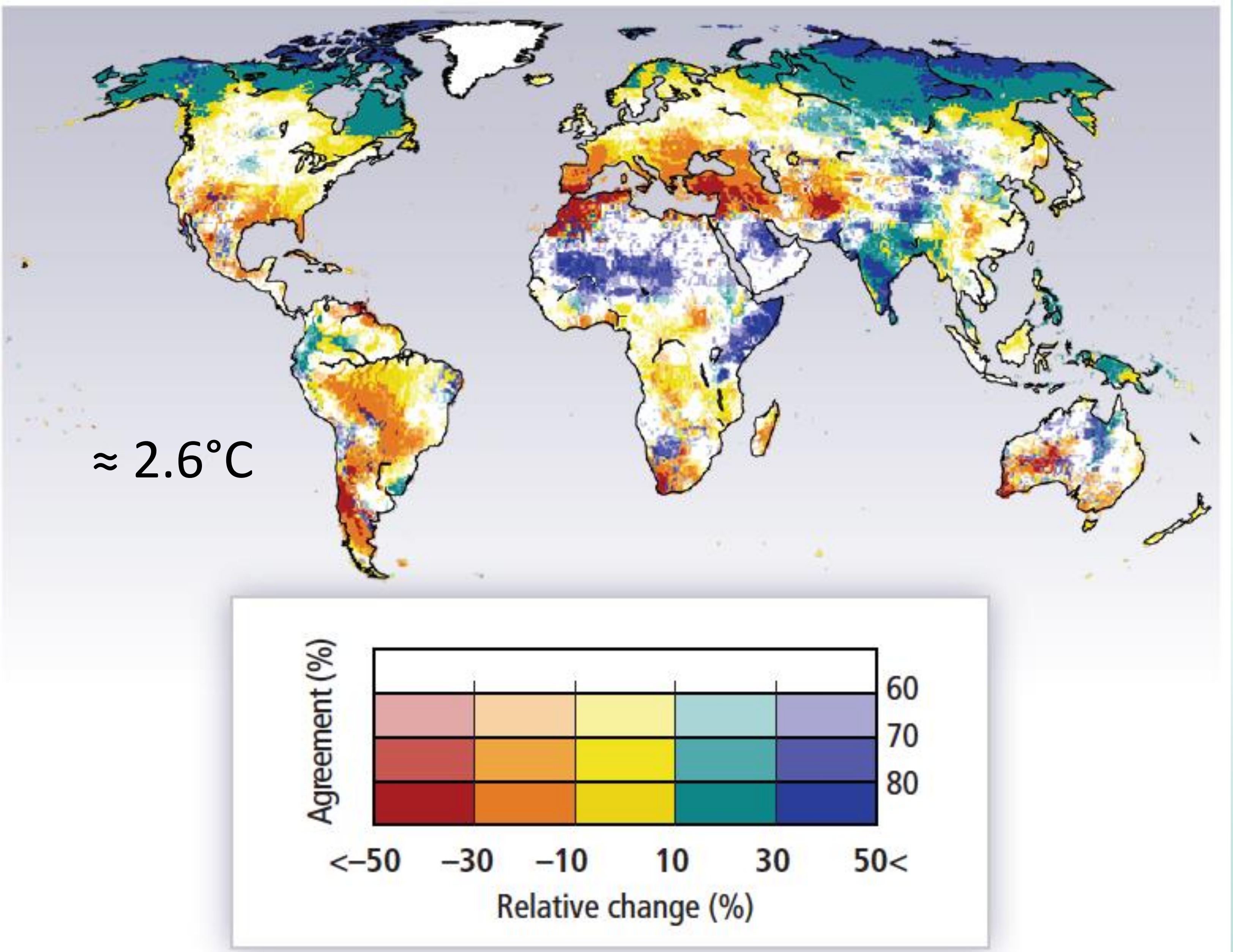
6,000
5,000
4,000
3,000
2,000
1,000
CO_2
(ppm)
?
Ordovician
Silurian
Devonian
Carbonif.
Permian
Triassic
Jurassic
Cretaceous
Palaeozoic
Mesozoic
Cenozoic
500
400
300
200
100
0
Millions of years ago

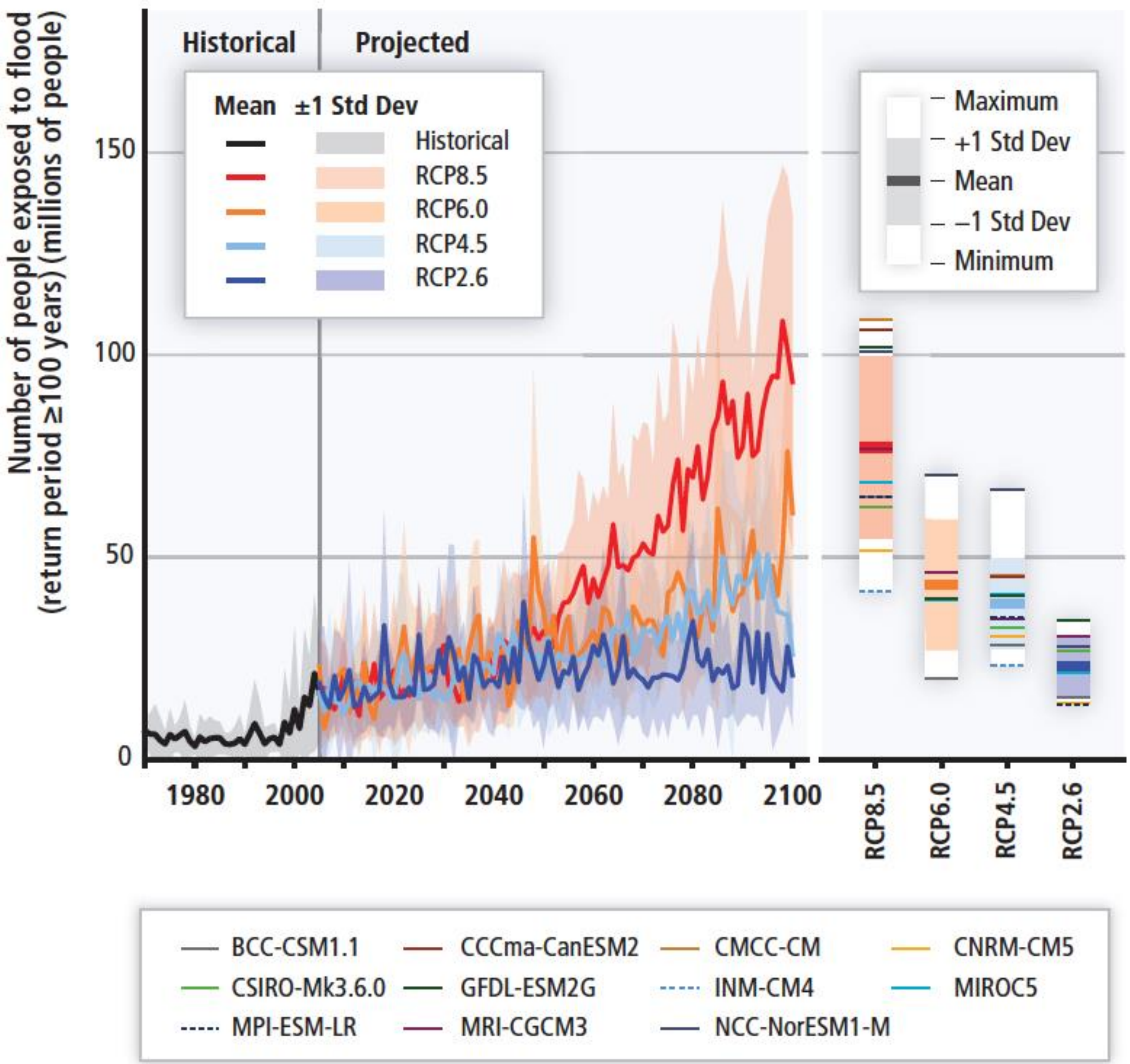

ARCTIC
NORTH AMERICA
EUROPE
ASIA
SMALL ISLANDS
AFRICA
CENTRAL & SOUTH AMERICA
ANTARCTIC
AUSTRALASIA
Confidence in attribution to climate change
very low
low
med
high
very high
indicates confidence range
Observed impacts attributed to climate change for
Physical systems
Glaciers, snow, ice, and/or permafrost
Rivers, lakes, floods, and/or drought
Coastal erosion and/or sea level effects
Biological systems
Terrestrial ecosystems
Wildfire
Marine ecosystems
Human and managed systems
Food production
Livelihoods, health, and/or economics
Regional-scale impacts
Outlined symbols = Minor contribution of climate change
Filled symbols = Major contribution of climate change

Widespread impacts attributed to climate change based on the available scientific literature since the AR4



Streamflow changes reflecting changes in freshwater supply to sectors, e.g. crop production




Number of people exposed to flood
(return period ≥100 years) (millions of people)
Historical
Projected
Mean
±1 Std Dev
Historical
RCP8.5
RCP6.0
RCP4.5
RCP2.6
Maximum
+1 Std Dev
Mean
–1 Std Dev
Minimum
0
50
100
150
1980
2000
2020
2040
2060
2080
2100
RCP8.5
RCP6.0
RCP4.5
RCP2.6
BCC-CSM1.1
CCCma-CanESM2
CMCC-CM
CNRM-CM5
CSIRO-Mk3.6.0
GFDL-ESM2G
INM-CM4
MIROC5
MPI-ESM-LR
MRI-CGCM3
NCC-NorESM1-M

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Africa

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation (Very low – Medium – Very high)
Reduced crop productivity associated with heat and drought stress, with strong adverse effects on regional, national, and household livelihood and food security, also given increased pest and disease damage and flood impacts on food system infrastructure (*high confidence*) [22.3-4]	• Technological adaptation responses (e.g., stress-tolerant crop varieties, irrigation, enhanced observation systems) • Enhancing smallholder access to credit and other critical production resources; Diversifying livelihoods • Strengthening institutions at local, national, and regional levels to support agriculture (including early warning systems) and gender-oriented policy • Agronomic adaptation responses (e.g., agroforestry, conservation agriculture)		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	

Asia

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation (Very low – Medium – Very high)
Increased risk of drought-related water and food shortage causing malnutrition (*high confidence*) [24.4]	• Disaster preparedness including early-warning systems and local coping strategies • Adaptive/integrated water resource management • Water infrastructure and reservoir development • Diversification of water sources including water re-use • More efficient use of water (e.g., improved agricultural practices, irrigation management, and resilient agriculture)		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	

Central and South America

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation (Very low – Medium – Very high)
Decreased food production and food quality (*medium confidence*) [27.3]	• Development of new crop varieties more adapted to climate change (temperature and drought) • Offsetting of human and animal health impacts of reduced food quality • Offsetting of economic impacts of land-use change • Strengthening traditional indigenous knowledge systems and practices		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation (Very low – Medium – Very high)
Reductions in mean crop yields because of climate change and increases in yield variability. (*high confidence*) [7.2, 7.3, 7.4, 7.5, Box 7-1]	With or without adaptation, negative impacts on average yields become *likely* from the 2030s with median yield impacts of 0 to –2% per decade projected for the rest of the century, and after 2050 the risk of more severe impacts increases.		Present Near term (2030 – 2040) Long term (2080 – 2100) 2°C / 4°C	

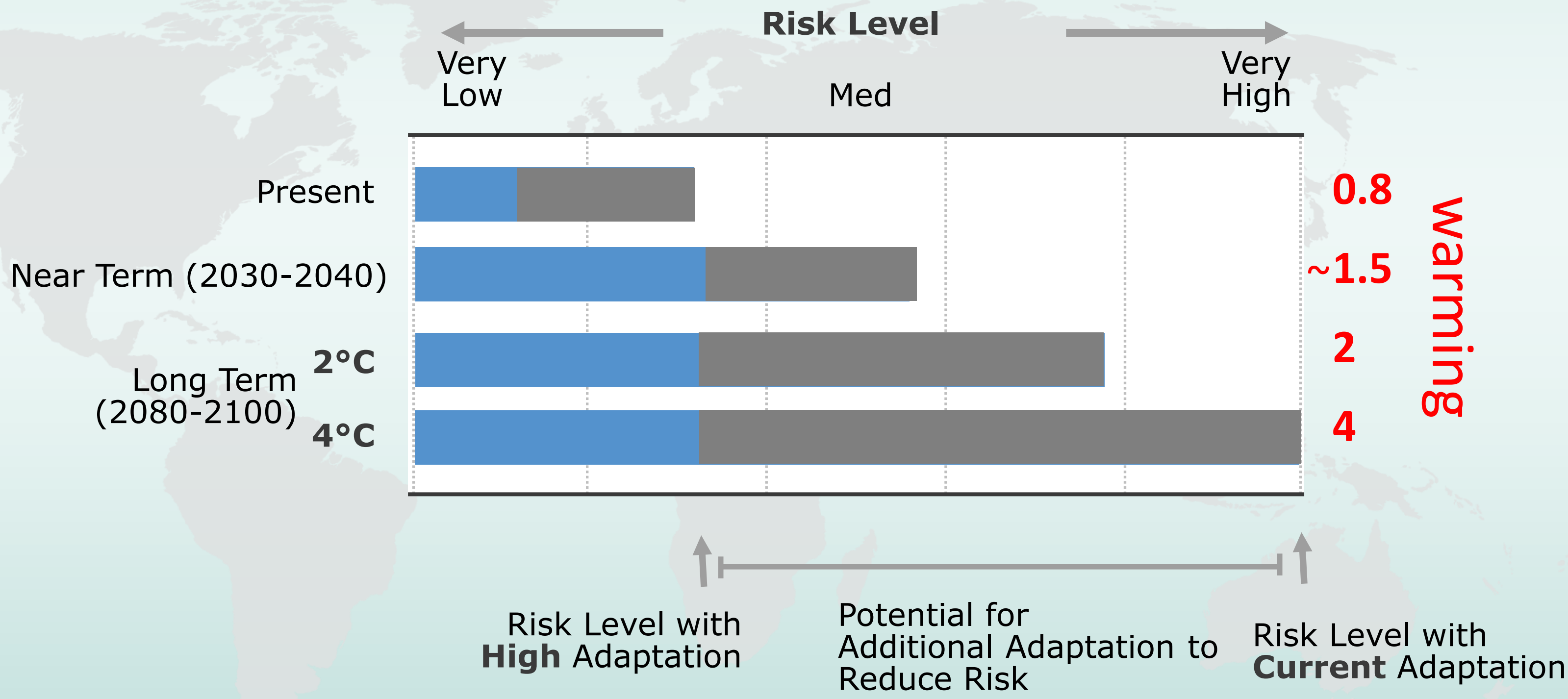
WGII, Tables TS.4, 5

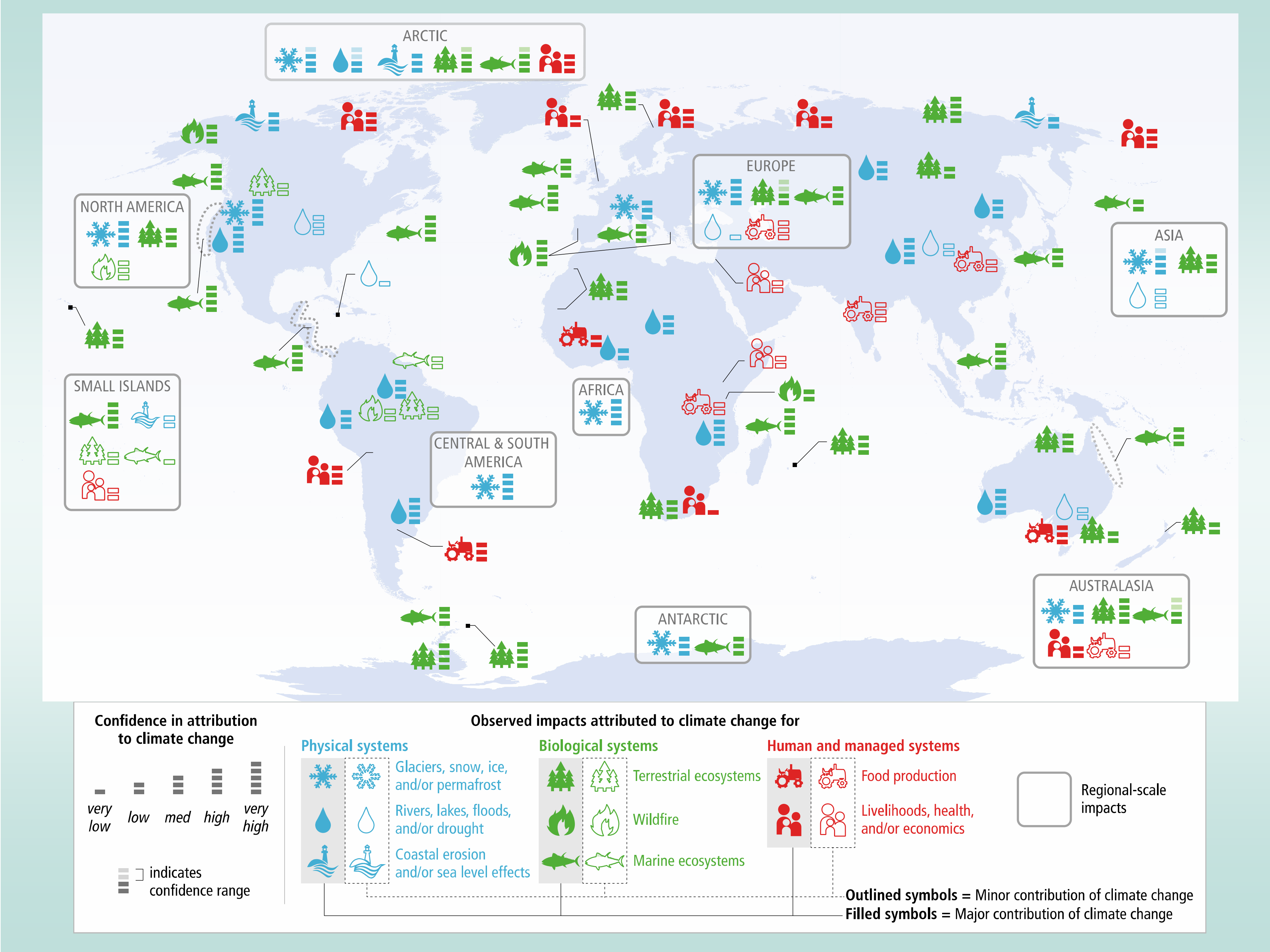
Climate change….causing risks

….which were assessed in AR5

(key risks are those relevant to article 2, UNFCCC “ dangerous anthropogenic interference with the climate system”)

PRINCIPLES





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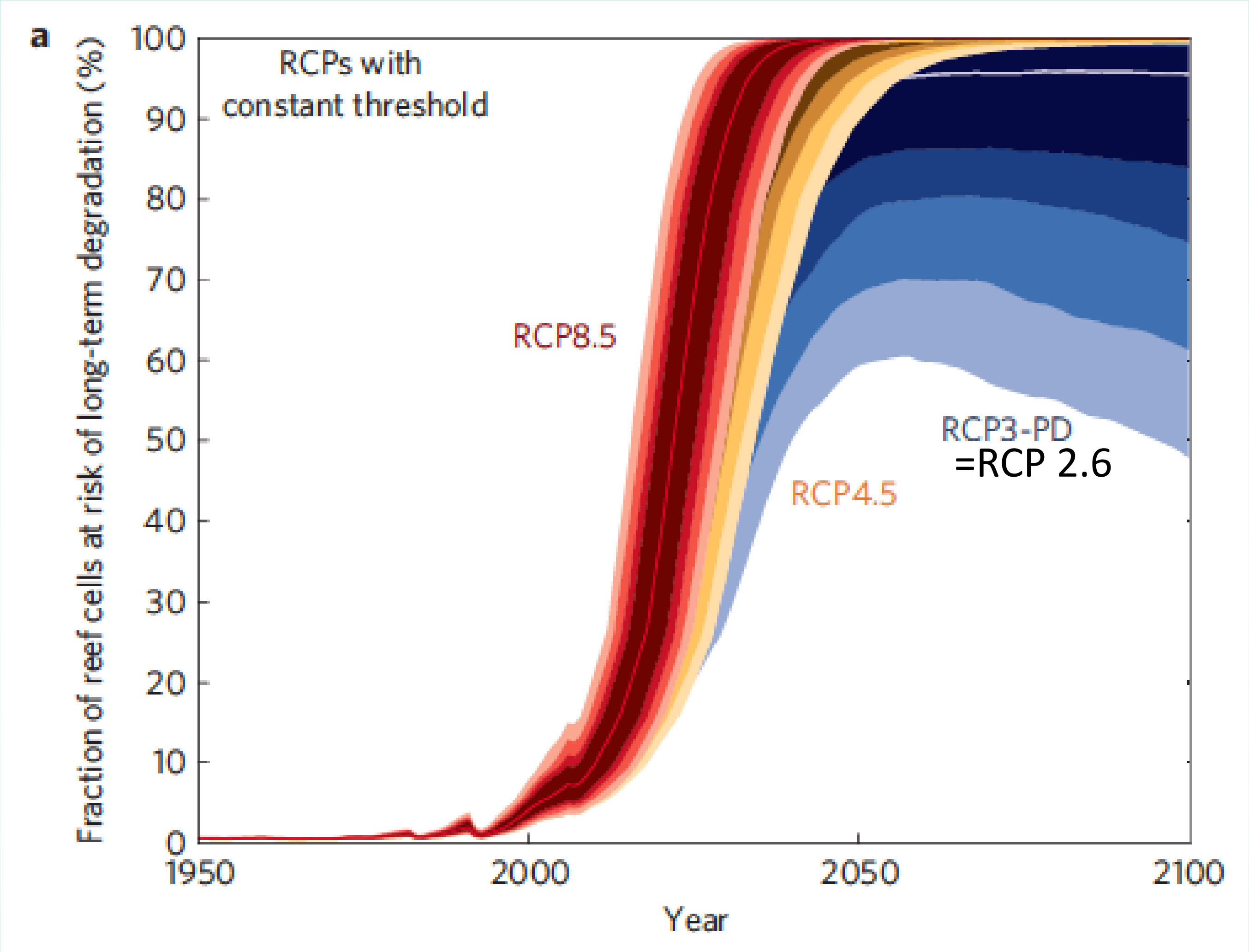
However, warm water coral reefs undergo degradation....

Mitigation to 1.5°C...

...losses beyond 50%!!

....not yet taking ocean acidification effects into account)



Frieler et al., 2013:

„To protect at least 50% of the coral reef cells, **global mean temperature change would have to be limited to 1.2° C (1.1 – 1.4° C)**, especially given the lack of evidence that corals can evolve significantly on decadal timescales and under continually escalating thermal stress."

WGII CC Box coral reefs

Key expected vs. avoided impact: e.g. oceans

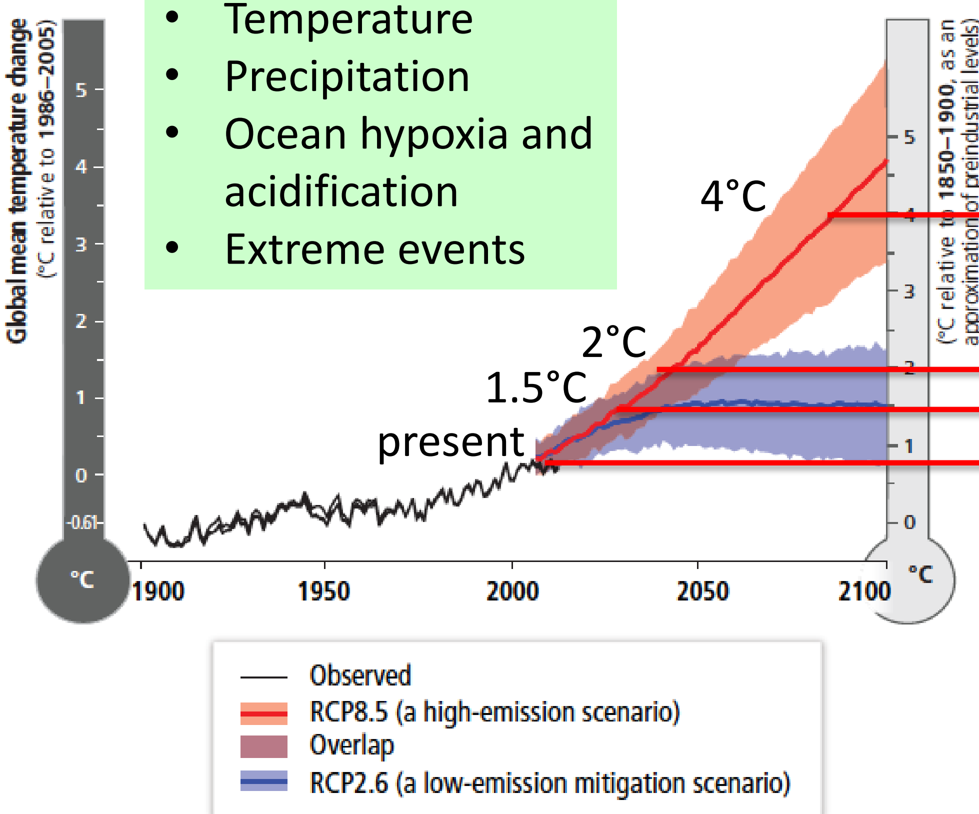
- present (0.85°C):
    - some redistribution of fish stocks
    - reduced growth and decline of some coral reefs
    - large scale shifts of fish stocks and reduced productivity
- 1.5°C:
    - high latitude species invasions
    - reduced productivity of low latitude fisheries
    - ≤ 50 % of warm water coral reefs maintained
    - some Arctic summer sea ice maintained
- 2°C:
    - largely reduced productivity of low latitude fisheries (20% overall)
    - high latitude species invasions, biodiversity loss
    - Arctic summer sea ice lost
    - << 50 % of warm water coral reefs maintained
- >2°C:
    - warm water coral reefs marginalized, loss of biodiversity, highly reduced catch potential
    - -

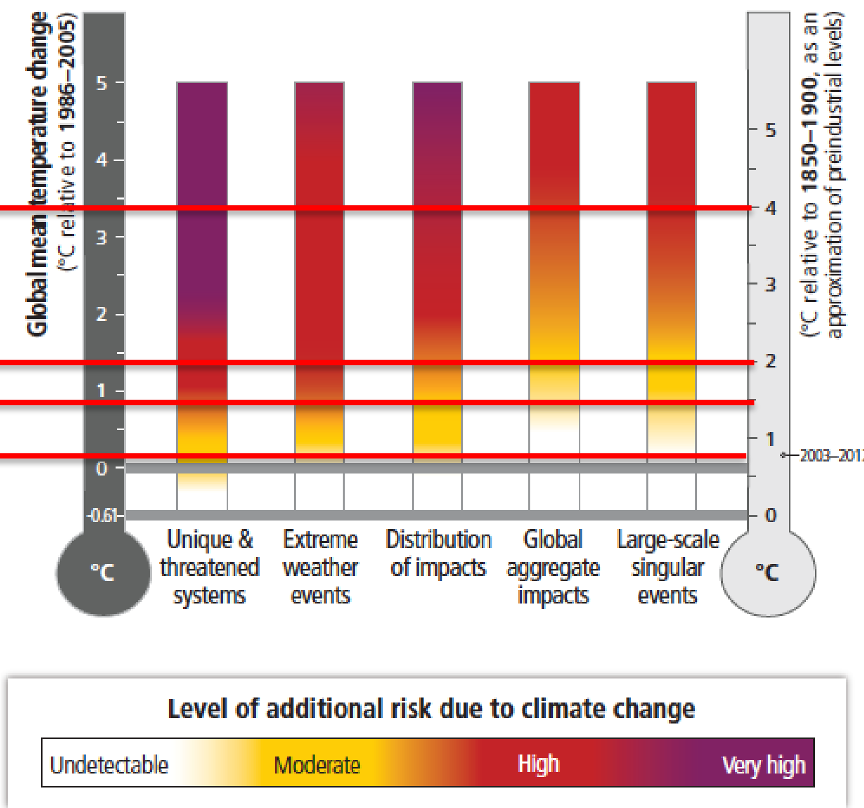
.....allow ecosystems to adapt naturally...
.....ensure that food production is not threatened...

Comparing long-term global goals..........with: Key risks of impacts
Avoided impacts

Key climate drivers:

- Temperature
- Precipitation
- Ocean hypoxia and acidification
- Extreme events





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