RISKS OF CLIMATE CHANGE in the ocean:

Ocean acidification and beyond

Hans-O. Pörtner: Co-Chair WGII AR6
AR5: CLA WGII CH. 6, Ocean Systems,
Ocean products in TS and SPM, CC-Boxes, SYR, SED

BIOACID Biological Impacts of Ocean ACIDification

PRINCE ALBERT II OF MONACO FOUNDATION

IAEA | Ocean Acidification International Coordination Centre OA-ICC

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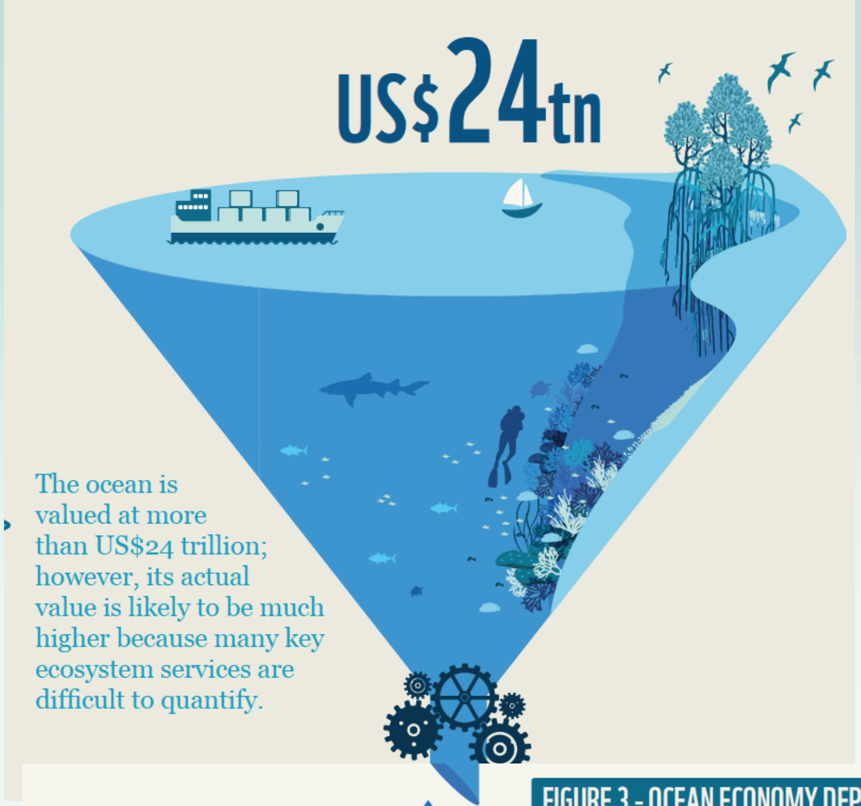
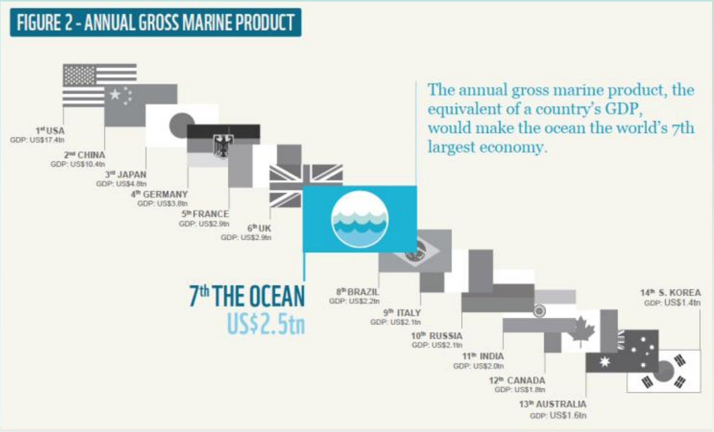
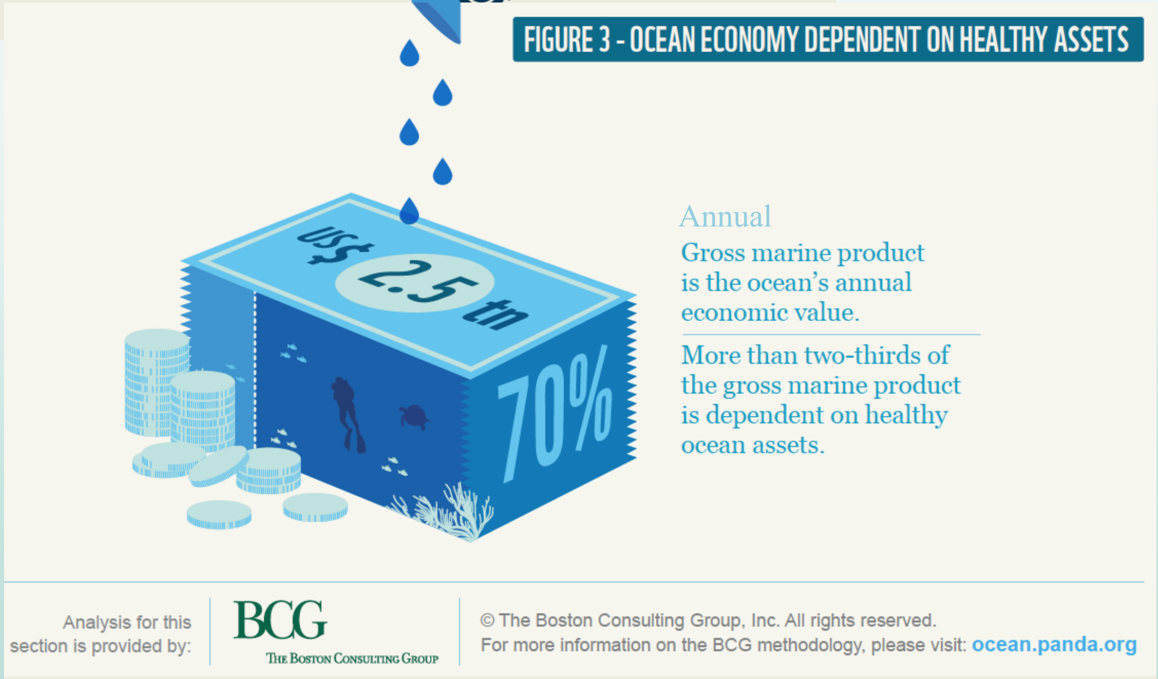


Annual gross marine product



...no. 7 in the world...



......depending on healthy oceans

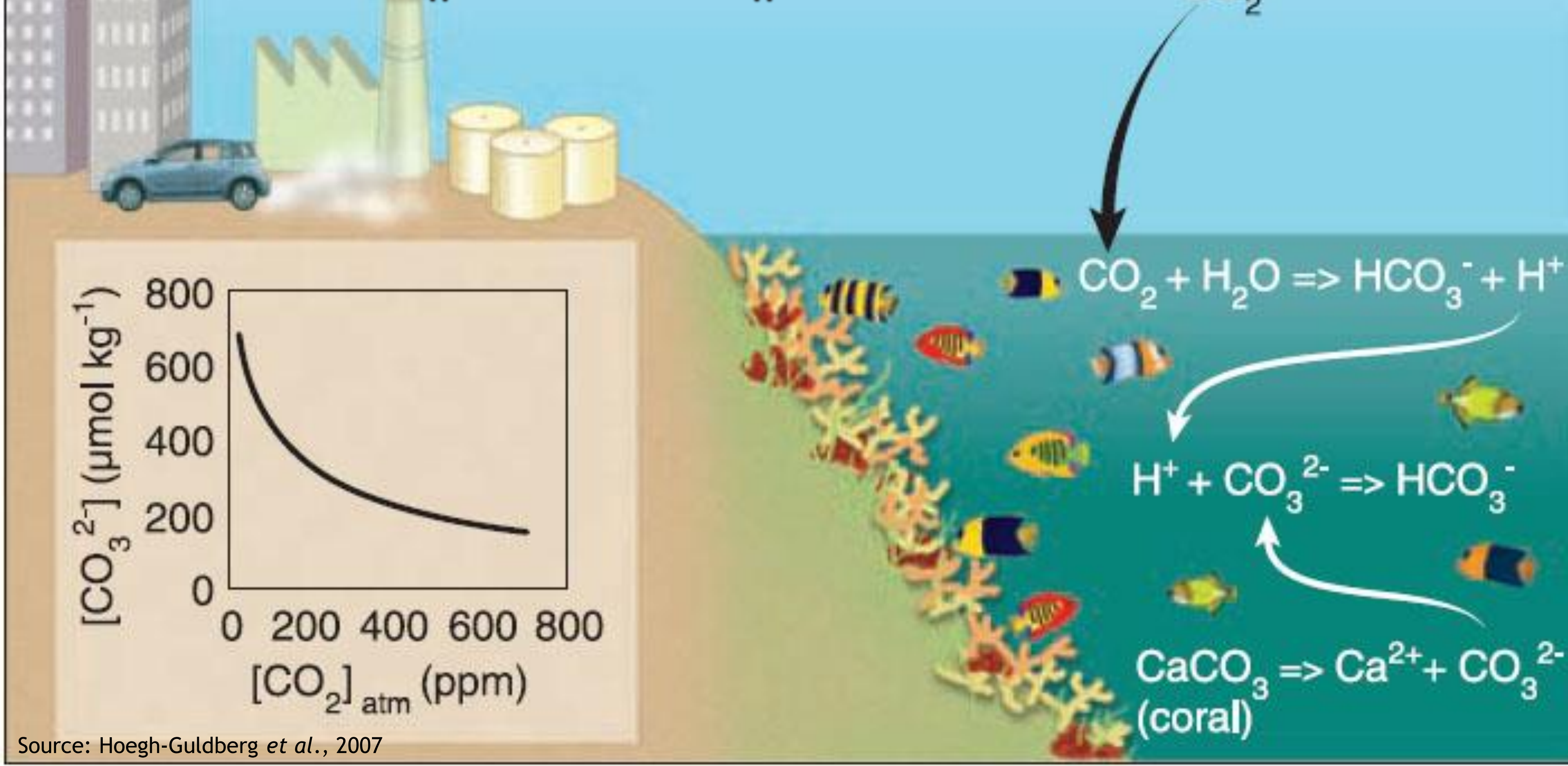
WWF 2015

Challenges to ocean health:

Ocean Acidification (OA) involves changes in:

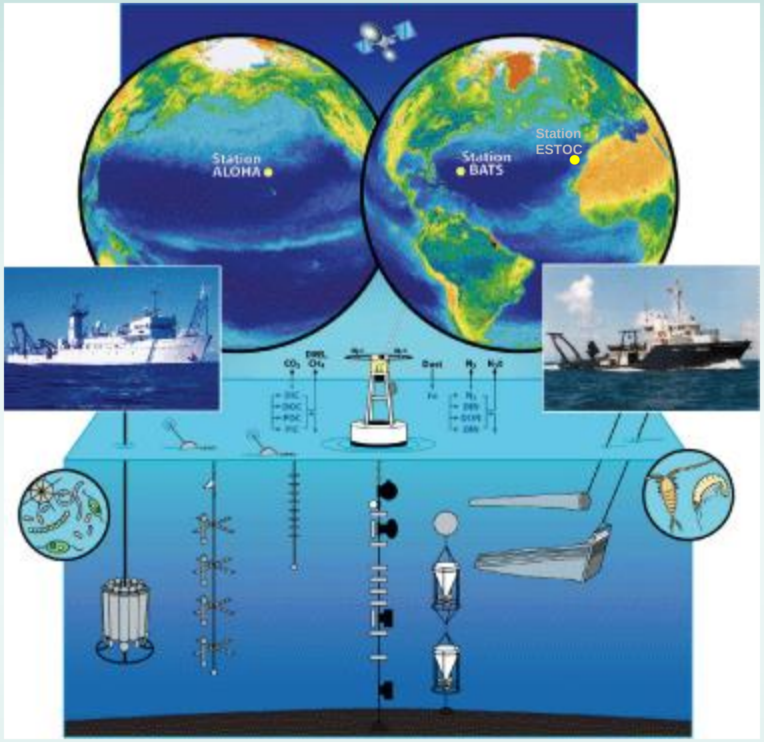
pH_w, CO_2 partial pressure $(P_{CO_2})_w$

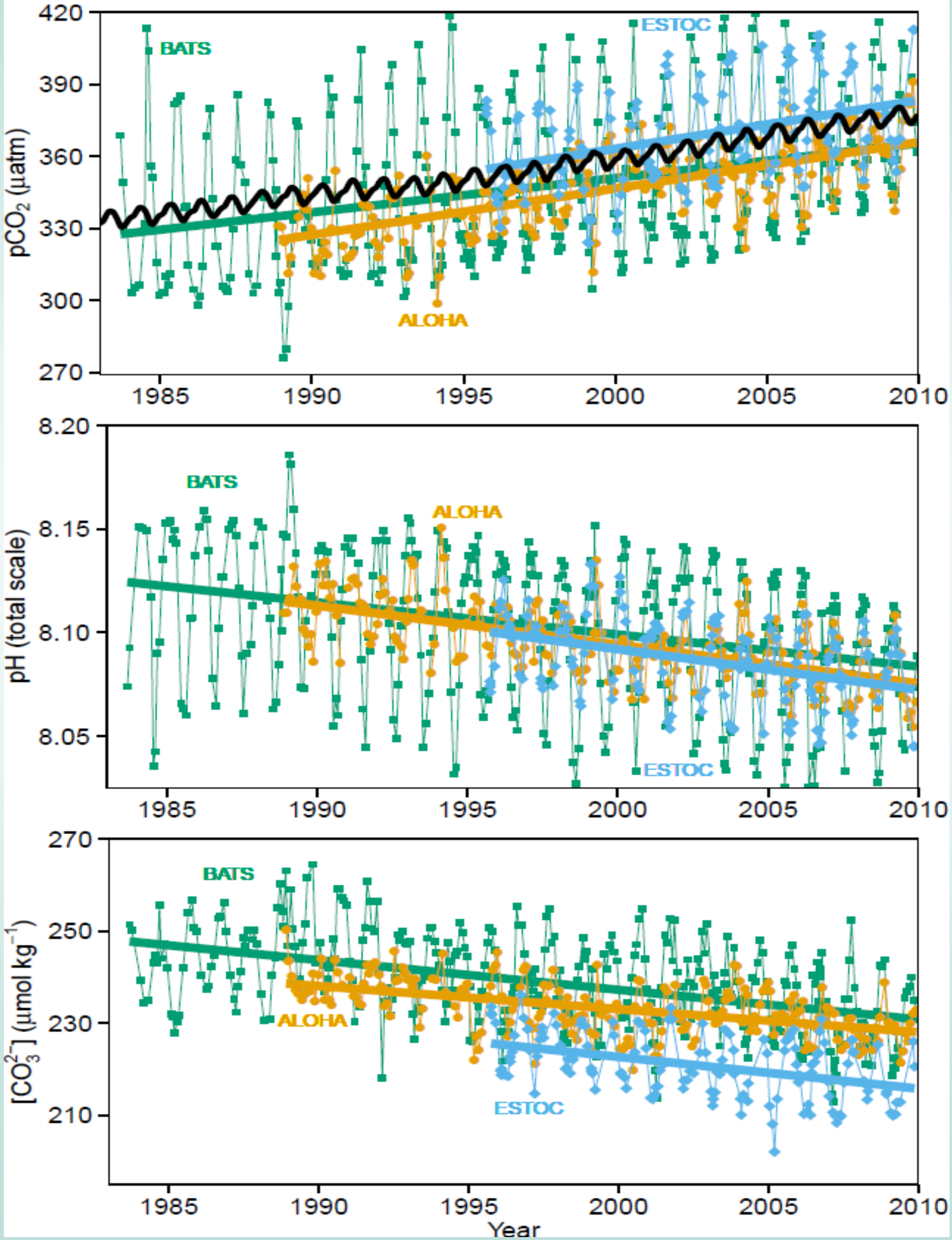
$bicarbonate_w$, $carbonate_w$



Source: Hoegh-Guldberg *et al.*, 2007

Change in pH from ocean acidification already measurable





Data:
Bates (2007)
Dore et al. (2009)
Santana-Casiano et al. (2007)
Gonzàles-Dàvila et al. (2010)

IPCC AR5 WG1 Report, Chap. 3 (2013)

These corrosive conditions dissolve shells of sea butterflies

Movie: Brad Seibel, University of Rhode Island

Sea butterfly shells ($CaCO_3$) exposed to corrosive conditions expected by 2100

Image: Victoria Fabry, California State University San Marcos

Orr et al. (2005)

Fabry et al. (2008)

Comeau et al. (2009; 2011; 2012)

Lischka et al. (2011); Lischka & Riebesell (2012)

Bednarsek et al. (2012)

Ocean areas naturally rich in CO_2 confirm expected future trends

- Less biodiversity
- Fewer calcifiers
- More fragile shells
- More invasive species
- More seagrasses, degraded corals

CO_2 bubbles rise from seafloor at Ischia, Bay of Naples, a natural lab to study acidification

Hall-Spencer et al. (2008)

Rodolfo-Metalpa et al. (2008)

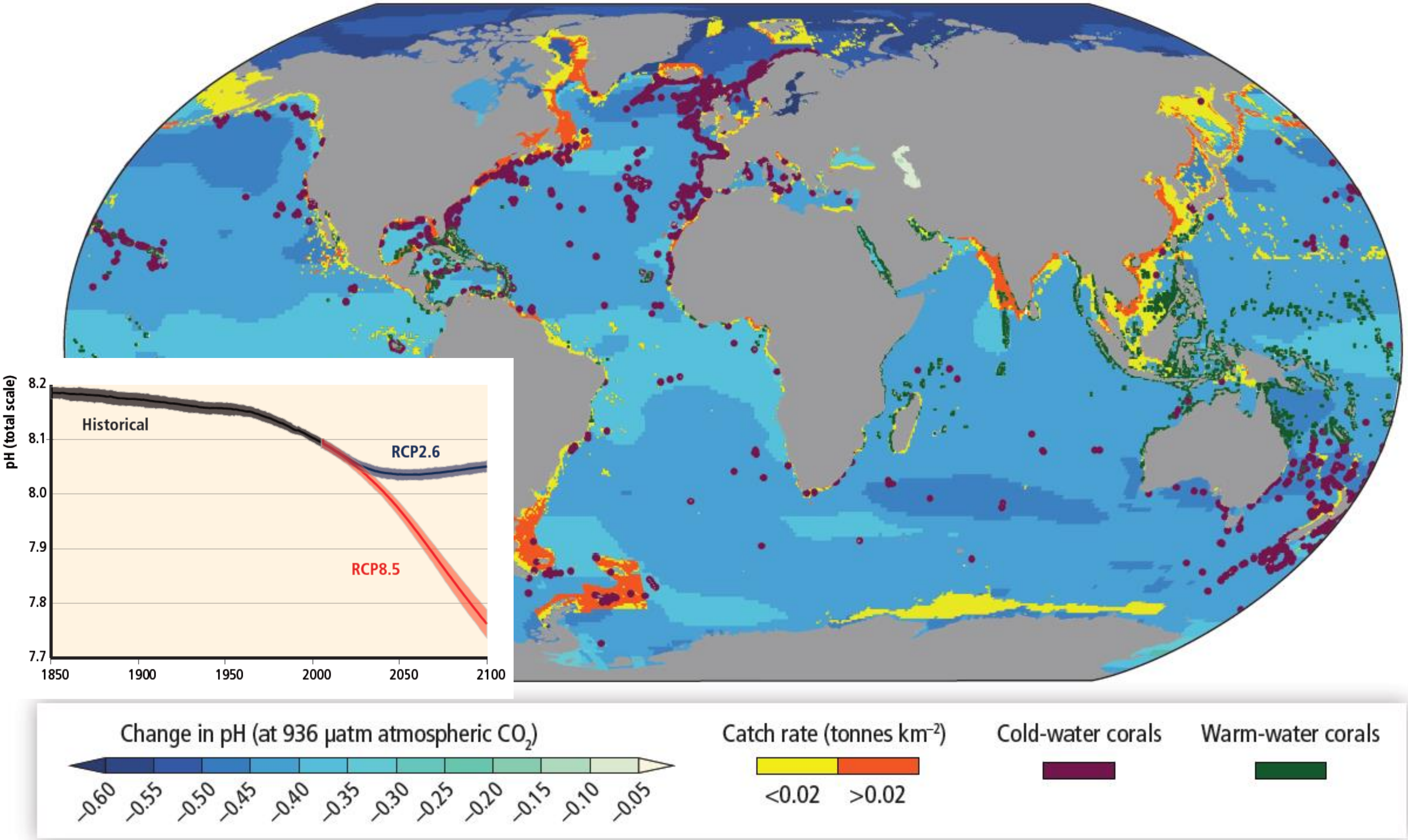
Photo: Jason Hall-Spencer, University of Plymouth

Photo: Steve Ringman, Seattle Times

Another natural CO_2 vent site in Papua, New Guinea, used to study effects of acidification on corals

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

>>2 °C

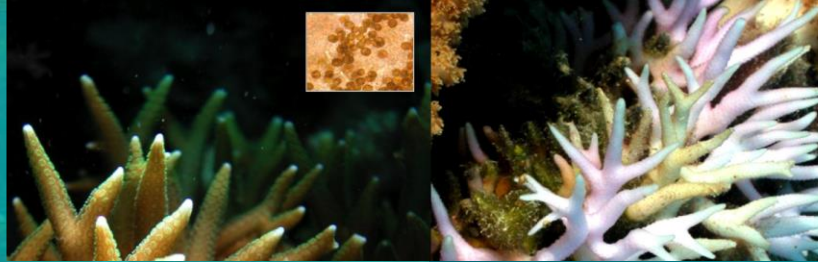


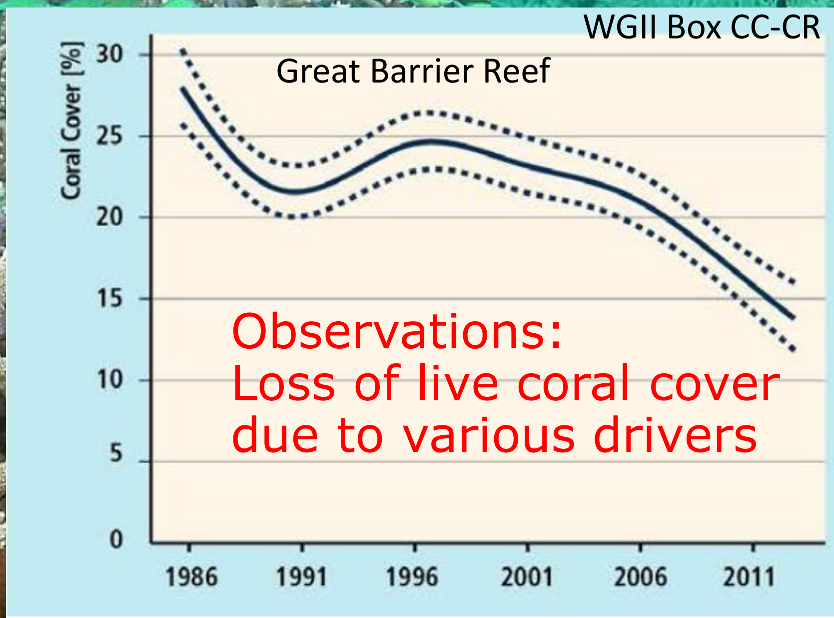
IPCC WGII AR5 Fig. 6.10

0.8°C

Vulnerable ecosystems

Warm water coral reefs under combined pressures:



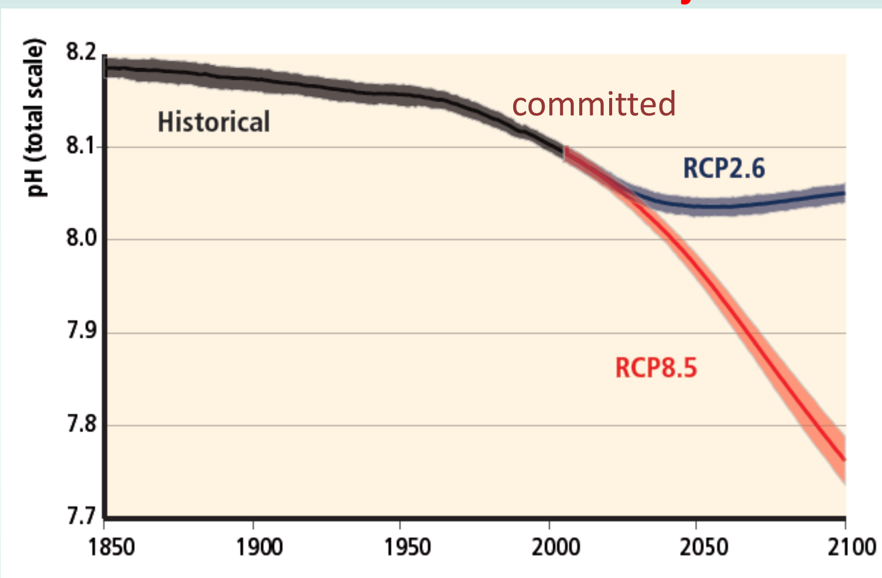


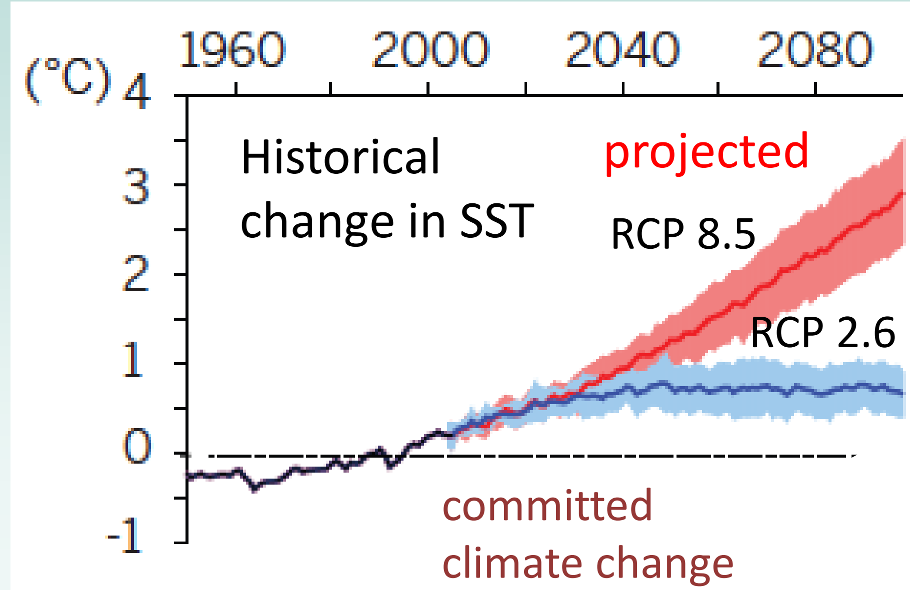
Verons 2009

According to emission scenarios oceans are: ... warming

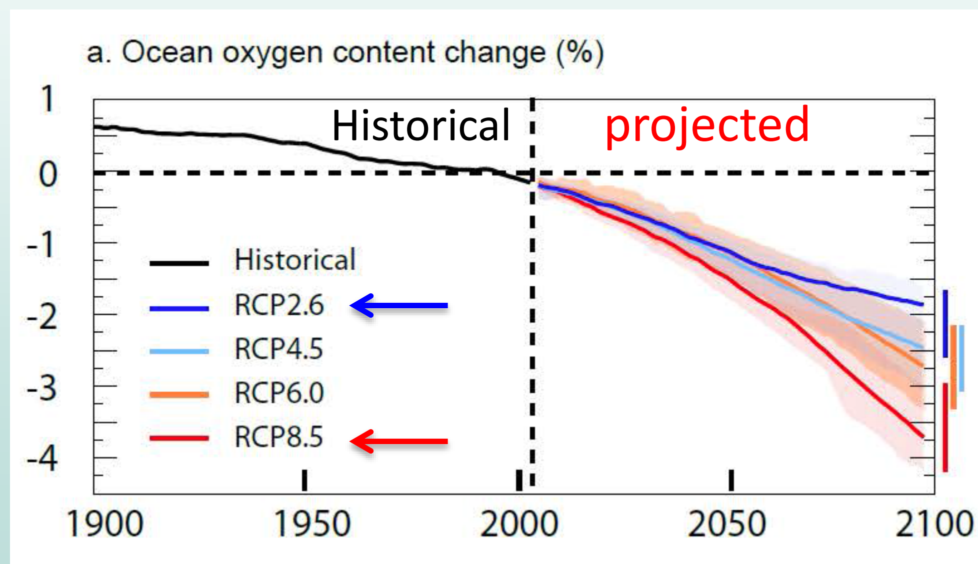
...acidifying

Historical ➔ Projections





... losing oxygen



CMIP5 model runs

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WGI Figure 6.30

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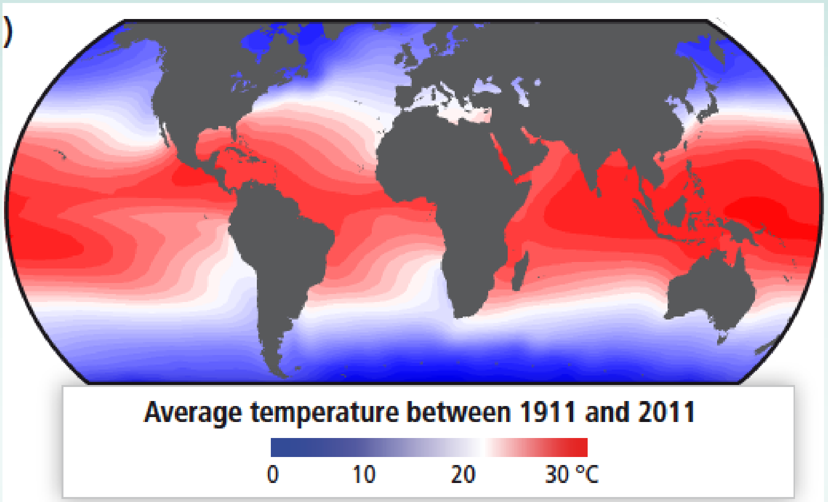
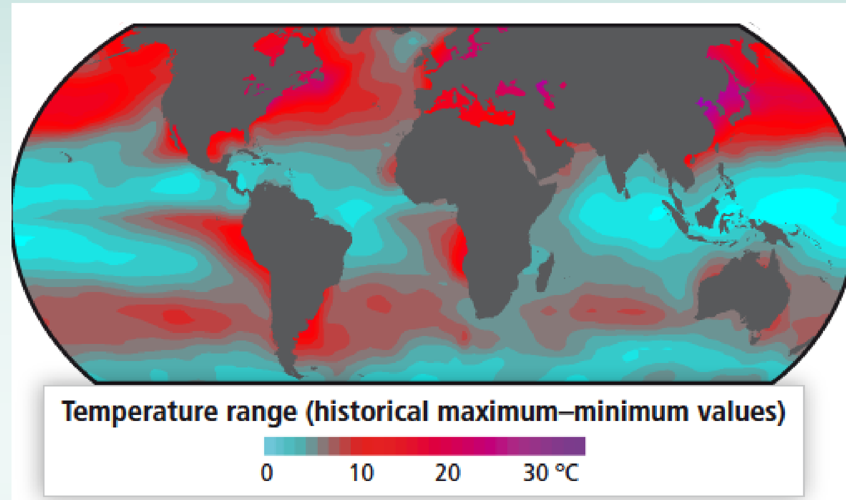
Gattuso et al., 2015

Warming, acidification, expanding hypoxia
occur on top of regional and natural variability:
➔ functional changes may depend on climate zone



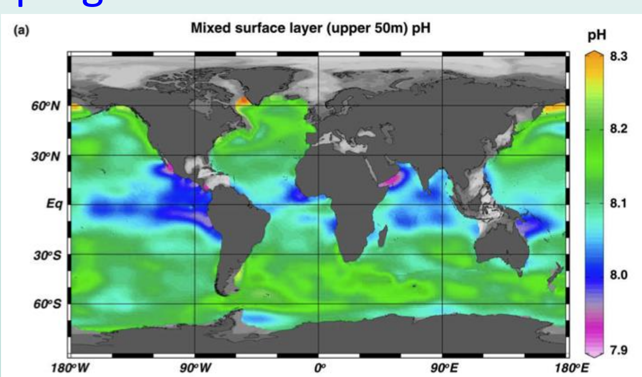
warming on top of means and variability

Pörtner et al. 2014



true also for: **light, nutrients, food**

progressive acidification

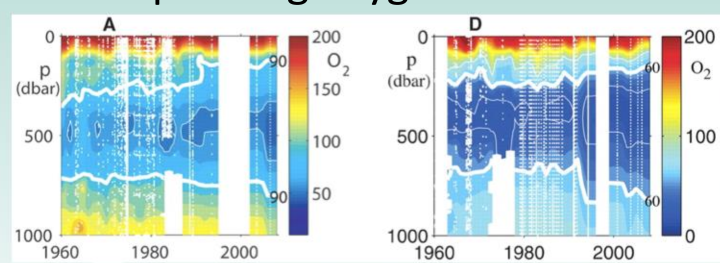


In ocean surface layers

(Pelejero et al., 2010)

expanding oxygen minimum zones

depth (m)



dissolved oxygen (μmol kg^{-1})

(A) Eastern tropical North Atlantic (10° to 14°N, 20° to 30°W)

(D) Eastern equatorial Pacific Ocean (5°S to 5°N, 105° to 115°W)

(Stramma et al., 2008)

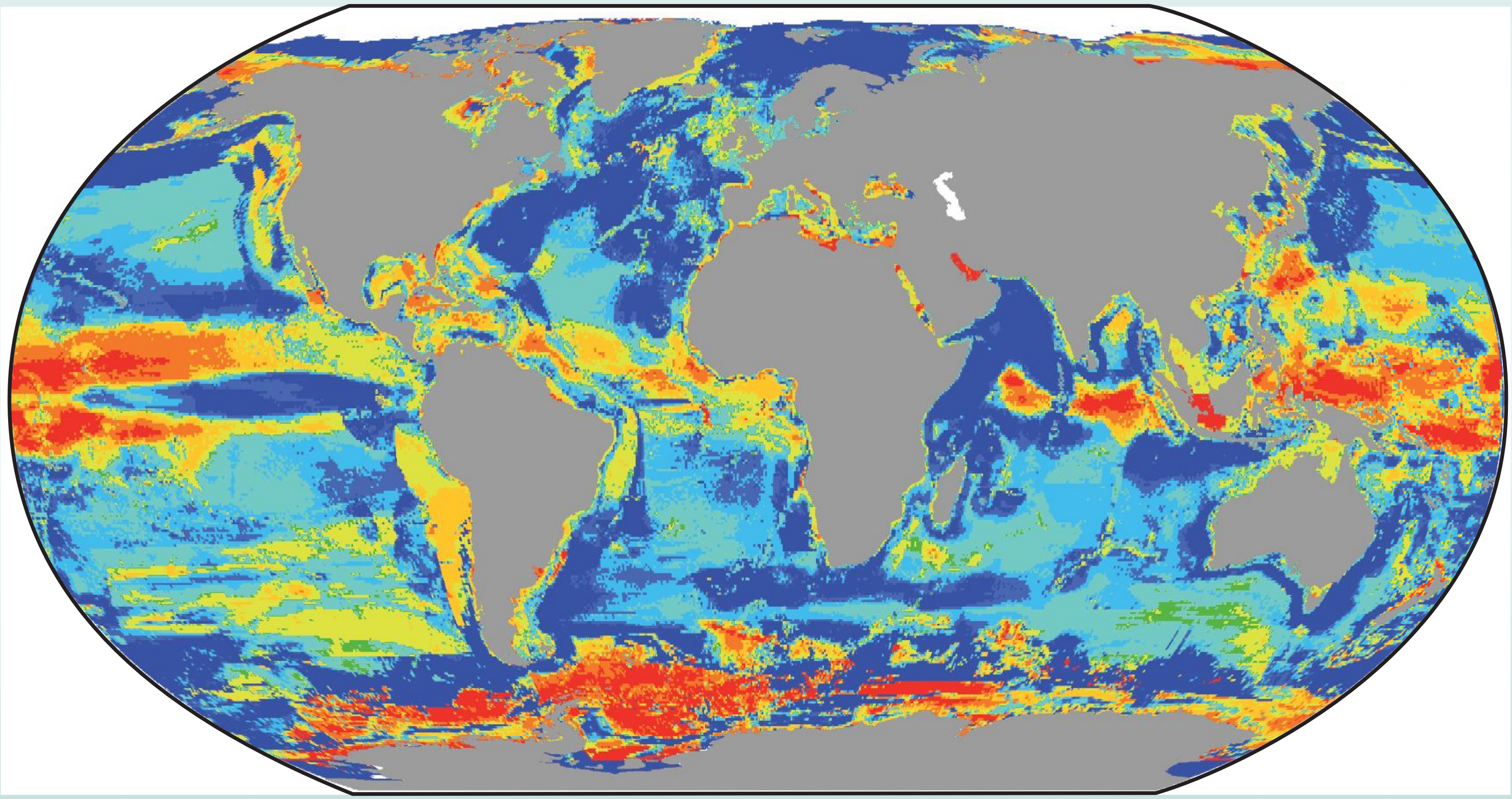
Food security constrained: ....Fisheries

2°C

2051-60: displaced and reduced fish and invertebrate biodiversity

CHANGE IN MAXIMUM CATCH POTENTIAL (2051-2060 COMPARED TO 2001-2010, SRES A1B, 2°C warming of global surface T 0.7°C warmer Sea Surface T)

<50%	-21 – 50%	-6 – 20%	-1 – 5%	No data	0 – 4%	5 – 19%	20 – 49%	50 – 100%	>100%



WGII, 6-14, SPM.6, SYR 2.6

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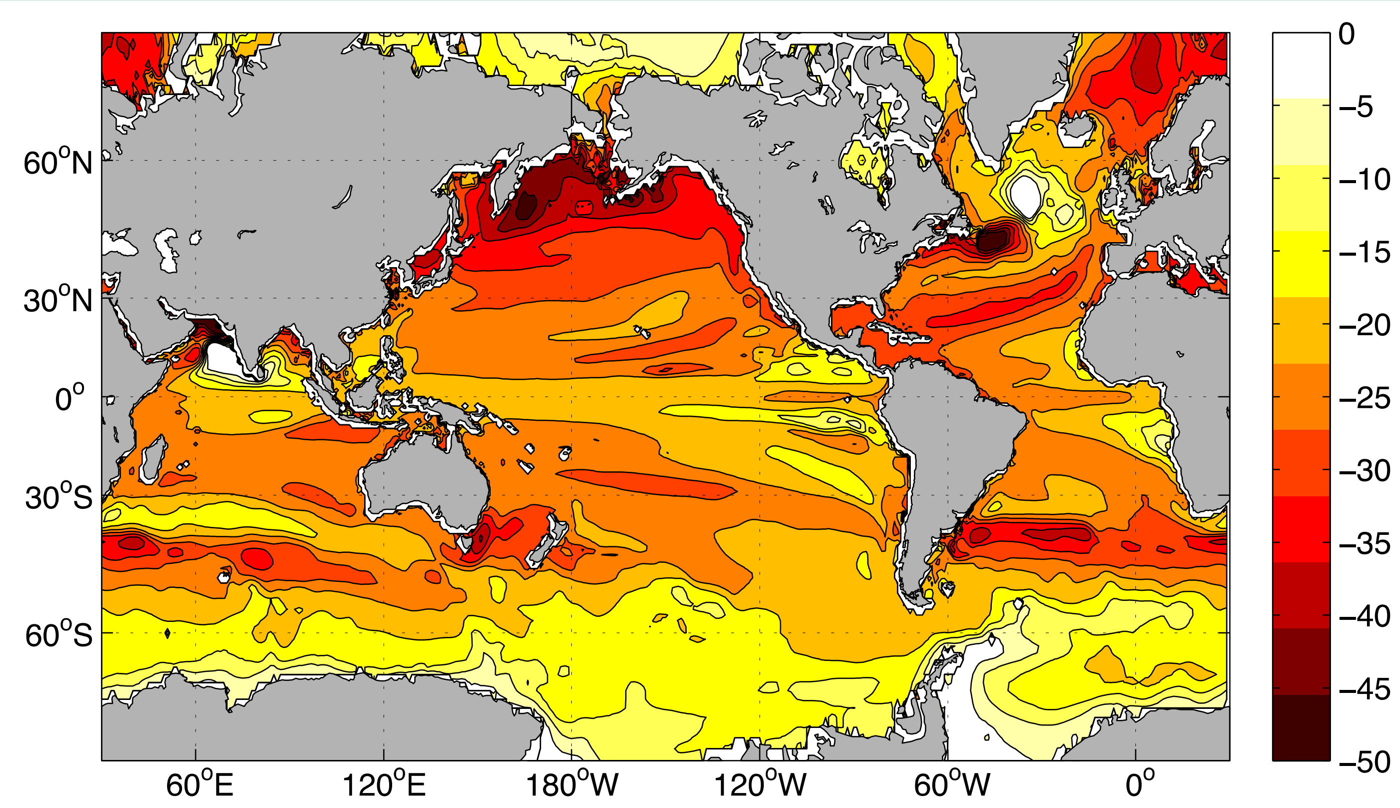
REDUCED HABITAT range of marine fishes and invertebrates due to thermal constraints combined with oxygen loss in the oceans…an additional role for CO_2?

>>2°C



% Decline in Metabolic Index Φ (= routine metabolic scope in marine animals)

by ~20% overall

Northern High Latitudes: by ~40%

2071-2100, 0-200m
IPCC Earth System Model mean, RCP8.5 scenario

Deutsch et al., *2015 Science*

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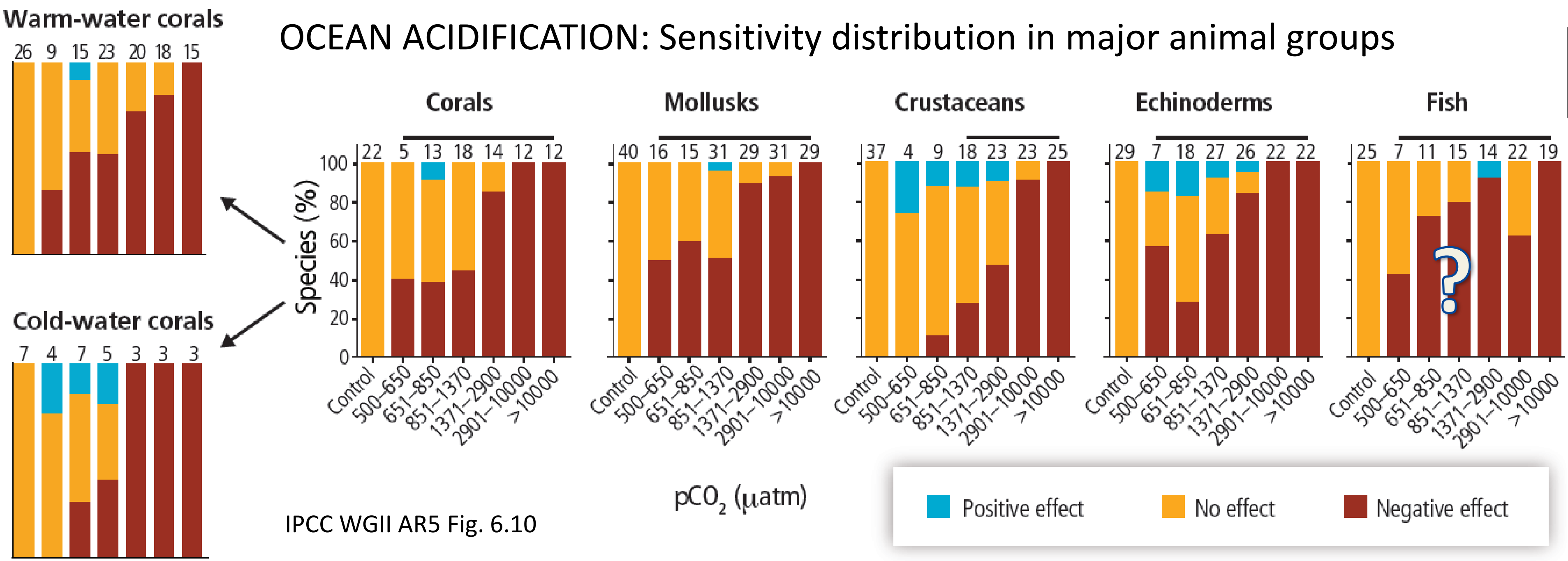
OCEAN ACIDIFICATION: Sensitivity distribution in major animal groups

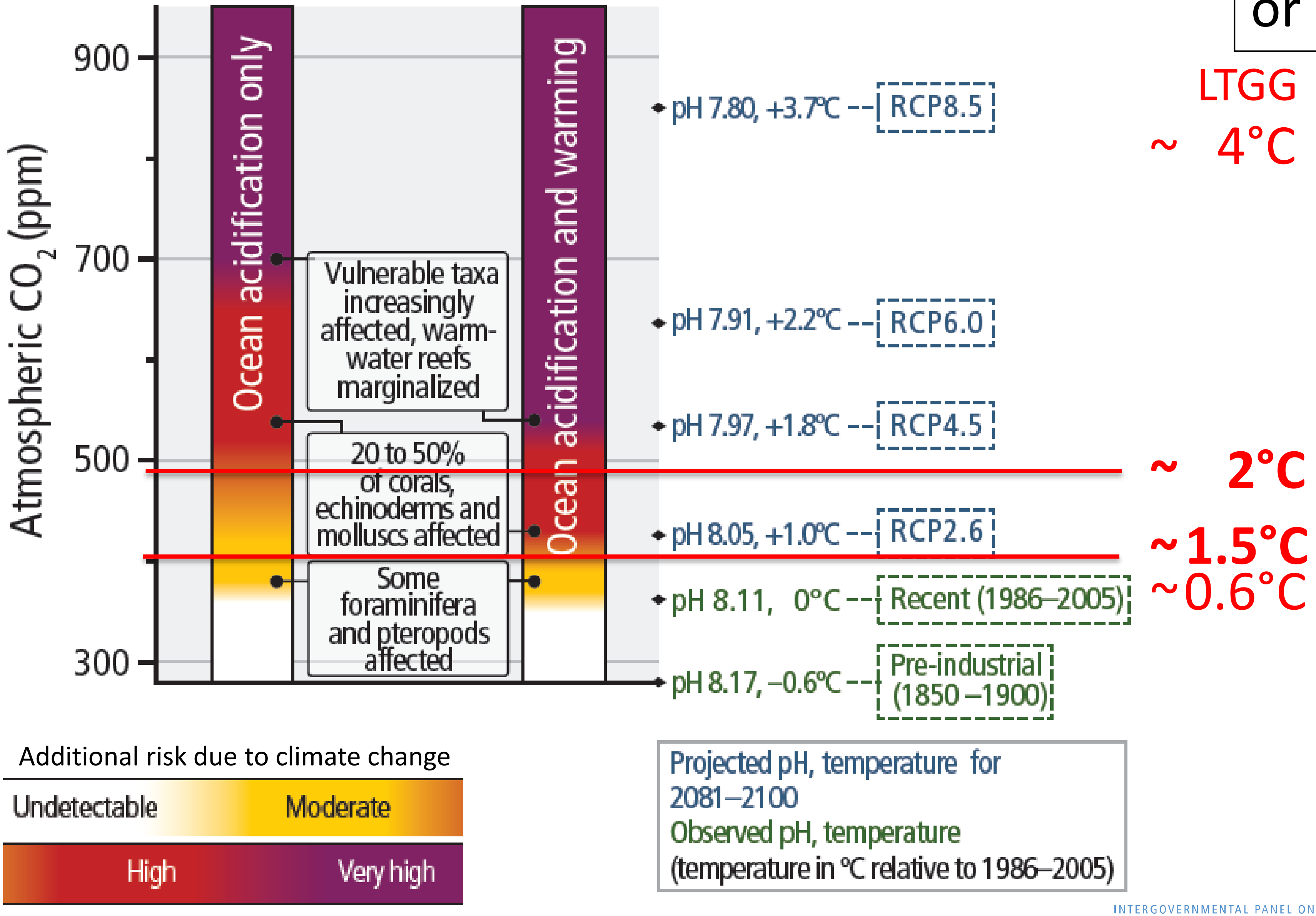


IPCC WGII AR5 Fig. 6.10

.....effects exacerbated by warming extremes...

Risks due to combined impacts of **ocean warming** and **acidification** ... Setting Long Term Global Goals (LTGG)

1.5°C
vs. 2°C
or >>2°C



SYR 2.5

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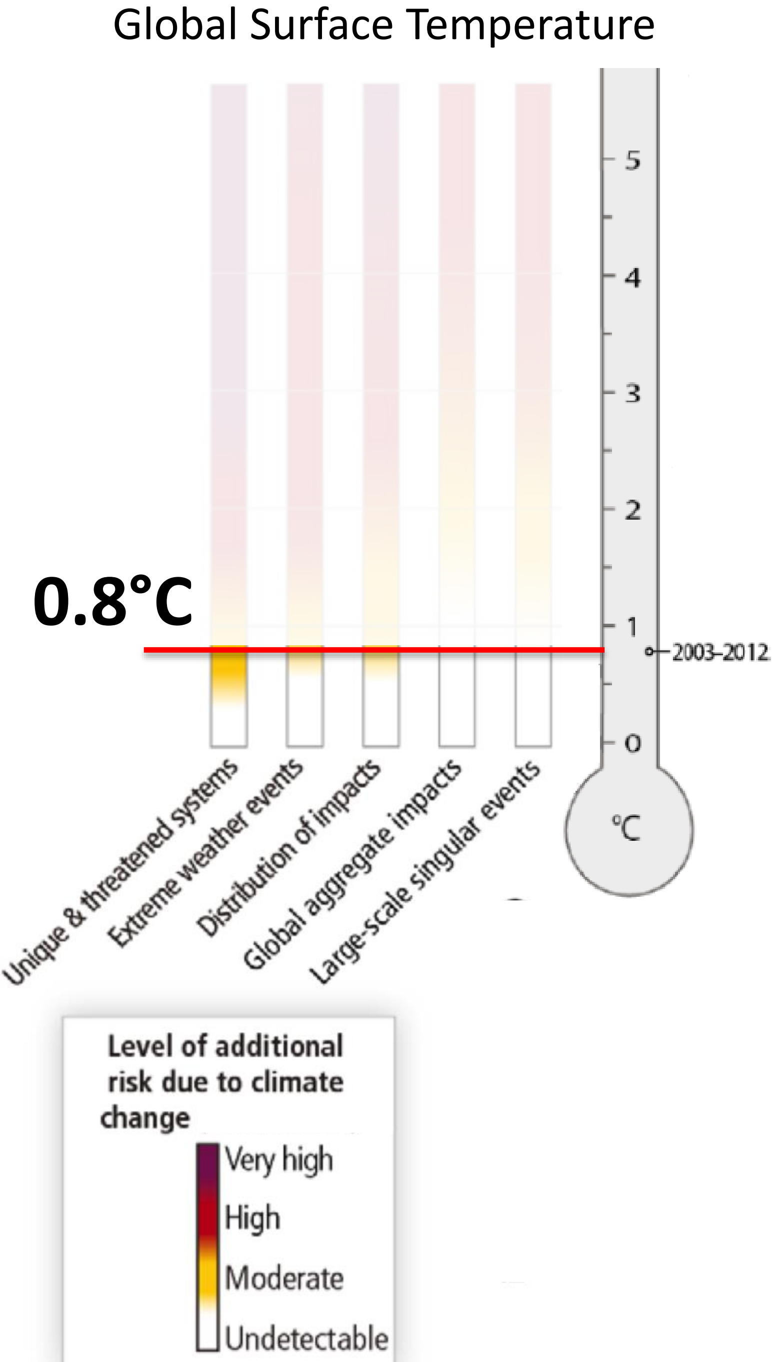
ADAPTATION IS ALREADY OCCURRING

- **Ocean acidification:** Defending oyster cultures at the US Westcoast against inflow of acidified water.

- **Marine Protected Areas:** Enhancing the resilience of coral reefs and their fish stocks against warming and acidification.

- **Restoration** of Mangrove Forests

…but adaptation capacity is highest under moderate climate change,
≤ 1.5°C

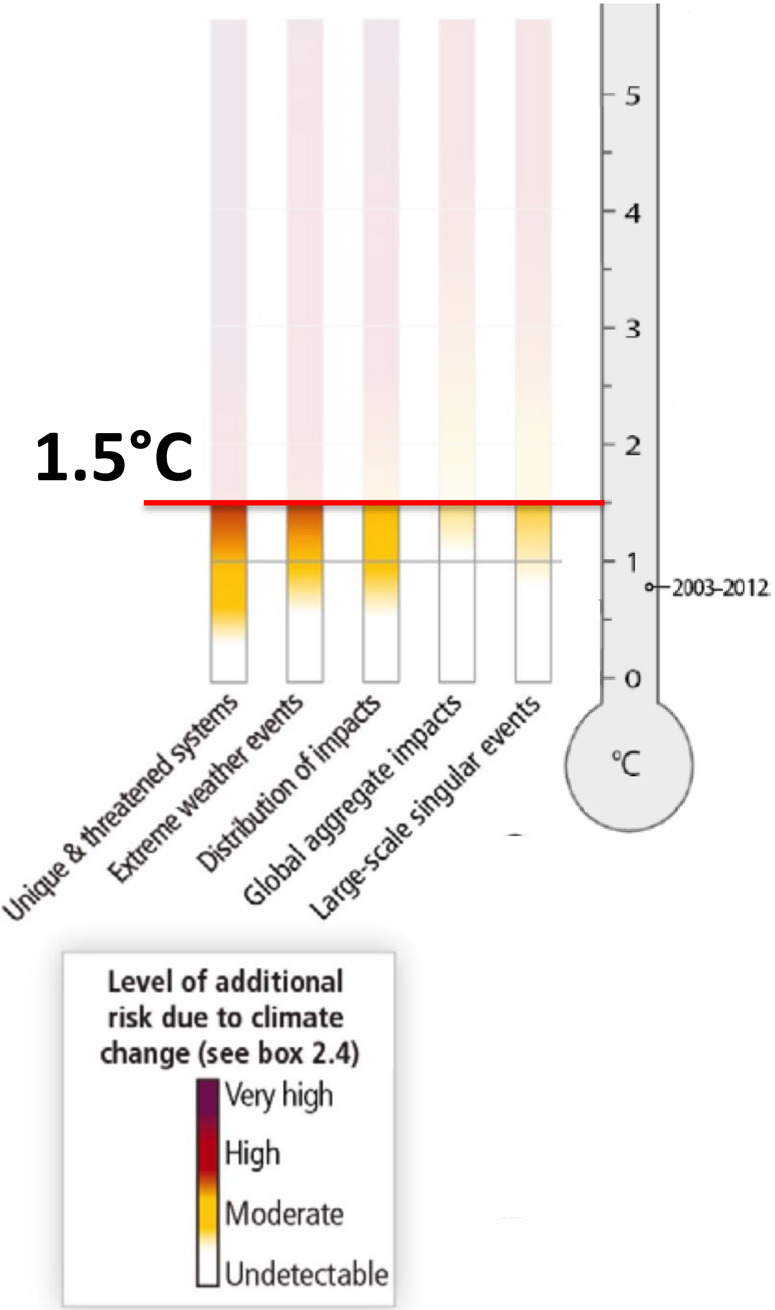


RECENT global surface T:

.... observed ecosystem impacts on all continents and in all oceans, e.g.

...in the oceans:

- **Species are displaced**
- Some **unique systems (coral reefs, summer sea ice systems) are losing resilience and spatial cover**
- **Pteropods, foraminifera and bivalve cultures show effects of ocean acidification**
- ...Risks are still moderate but **may rise** as climate change combines with other pressures



....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 intact**.
- **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**.

Working Group II : Impacts, Adaptation, and Vulnerability

Thank you!

IPCC WGII Ocean Reprint Collection:
http://ipcc-wg2.gov/publications/ocean/

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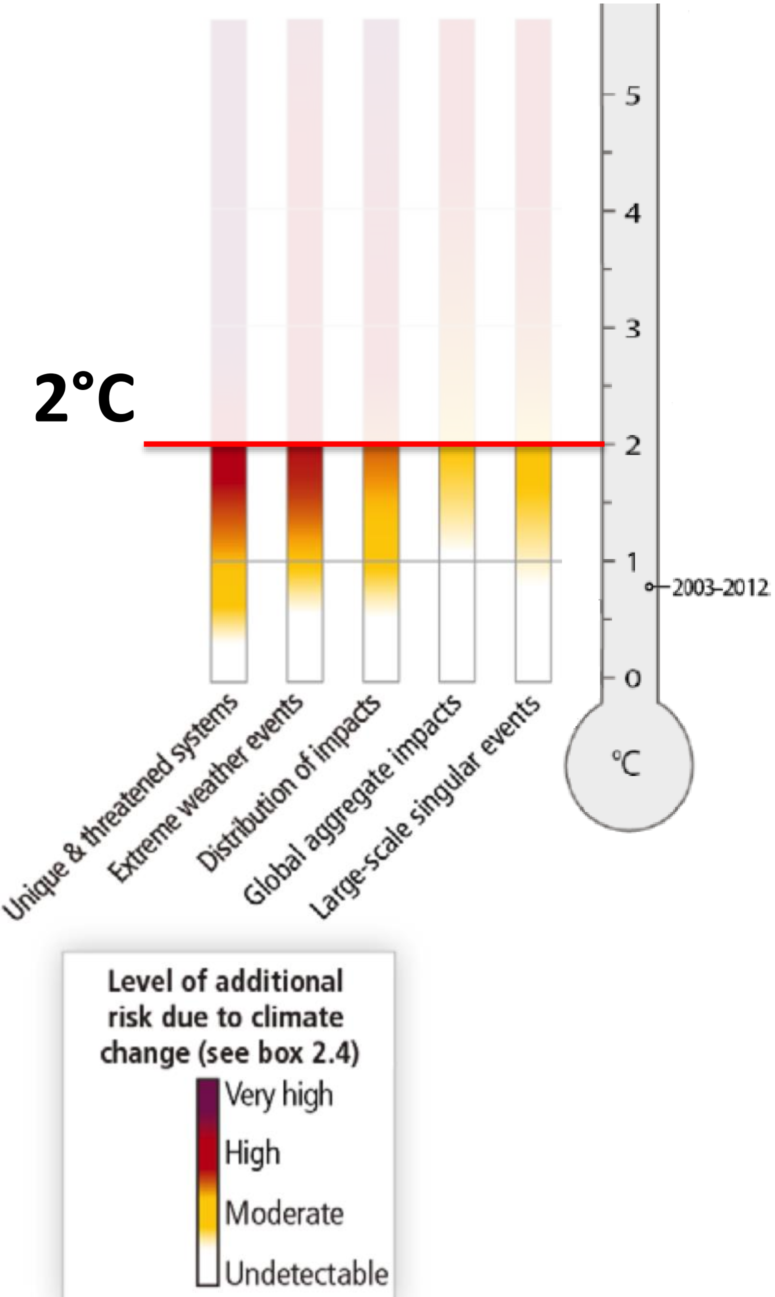
....climate change: ....avoided impacts ....projected impacts

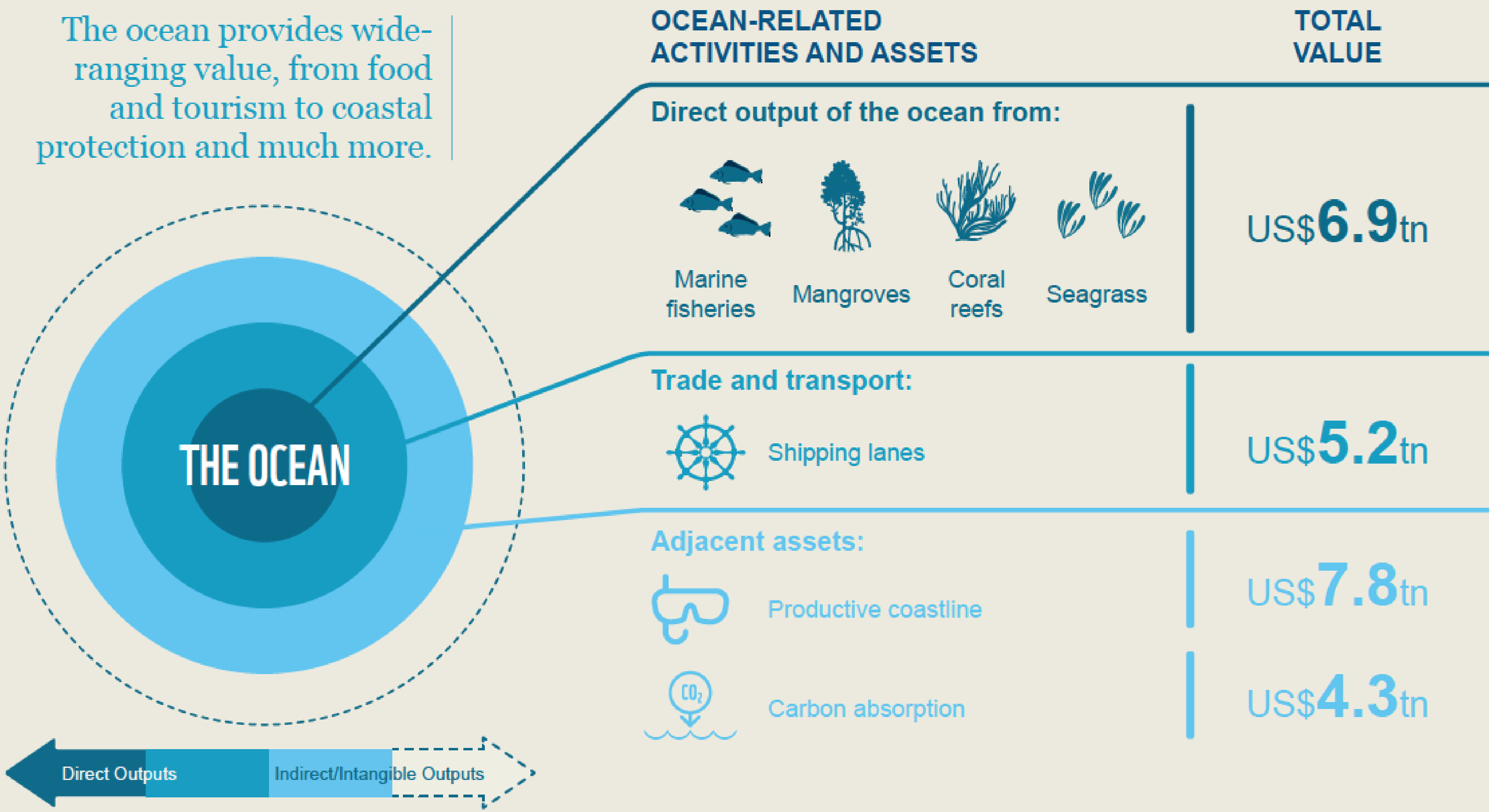


- climate change velocity becomes too high for some species to move sufficiently fast.
- long-term sea level rise may exceed 1 m: coastal habitat loss, flooding, seawater inundation.
- Arctic summer sea ice may be lost.
- some unique systems at very high risk.

  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

BOX 2 OCEAN ASSET VALUES

FIGURE 1 - GLOBAL OCEAN ASSET VALUE



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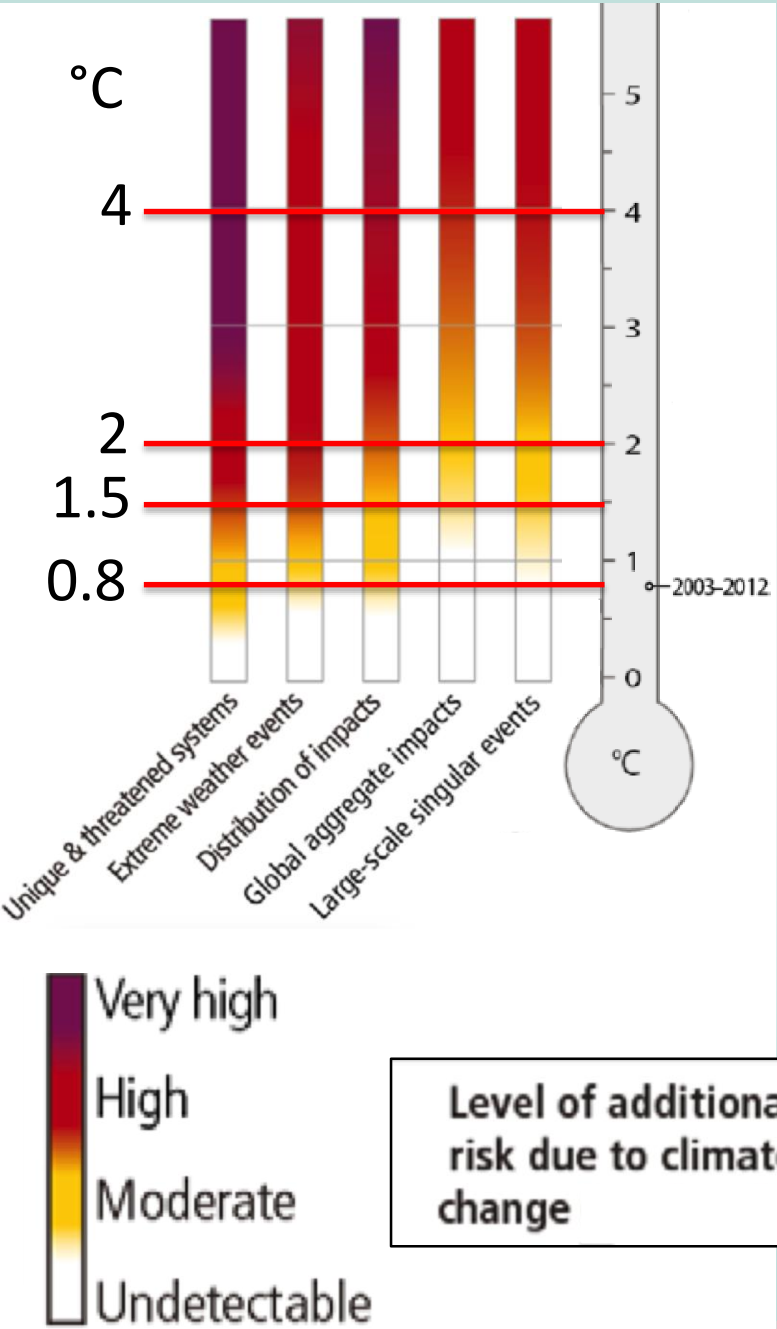

Level of additional risk due to climate change

A role for natural marine systems to guide the setting of **long-term global goals** (LTGG, relative to preindustrial), considering levels of **risk**

LTGG

4°C

2°C

1.5°C

0.8°C

Coastal protection

Biodiversity

Photo credits: Dan Laffoley, Catlin Seaview Survey