Climate change effects on fish and fisheries

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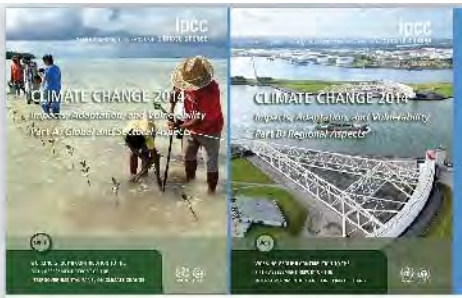
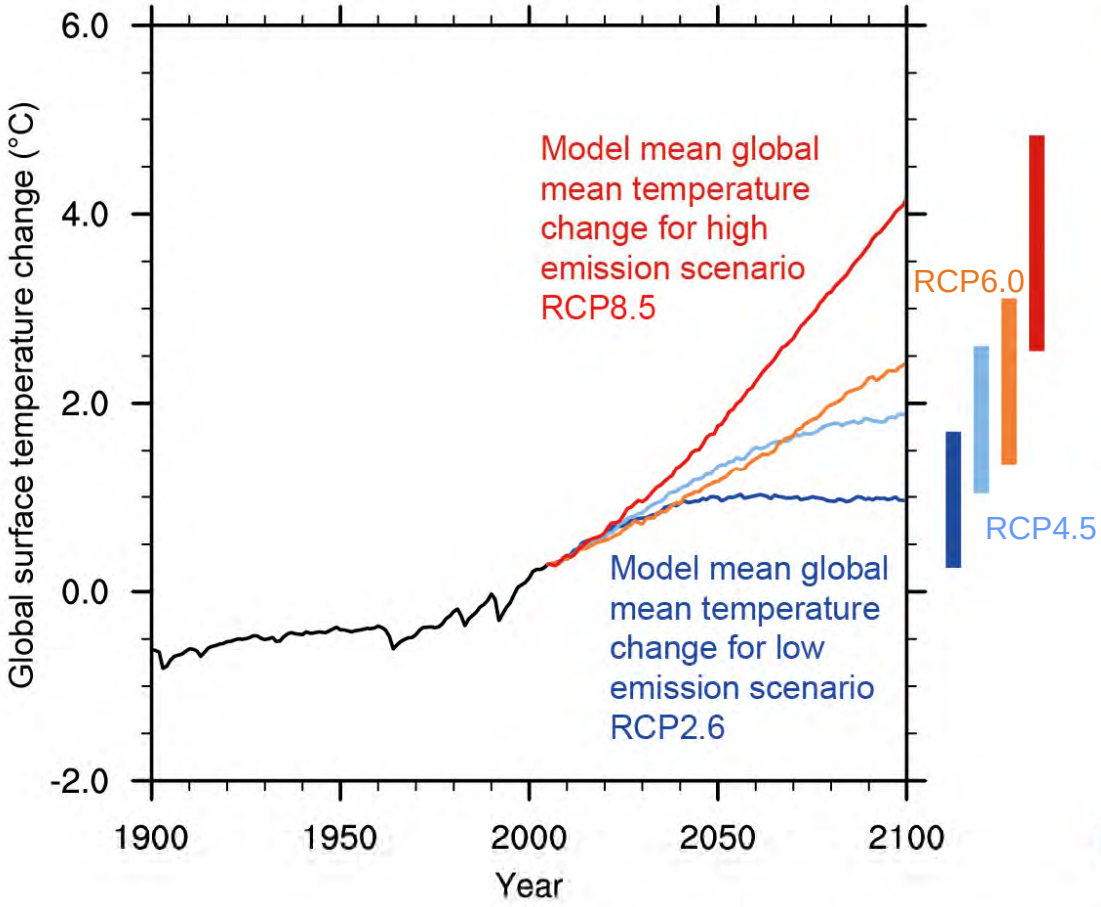


Climate Change 2014: Impacts, Adaptation, and Vulnerability (AR5)

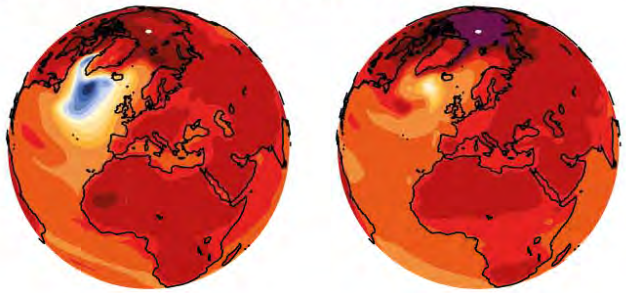
Summary for Policymakers
Technical Summary

http://ipcc-wg2.gov/AR5/

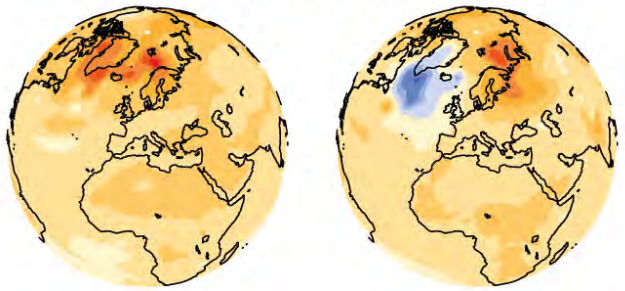
RCP emission scenarios of global mean temperature change (relative to 1986-2005)



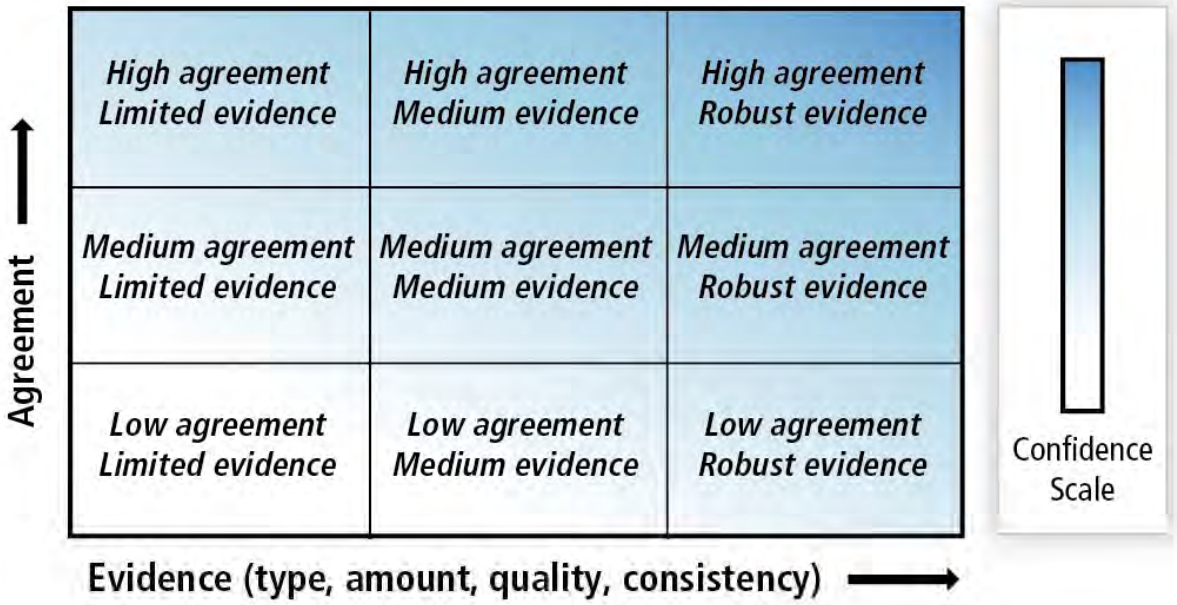
Possible temperature responses in 2081-2100 to high emission scenario RCP8.5



Possible temperature responses in 2081-2100 to low emission scenario RCP2.6



Communication of Uncertainty



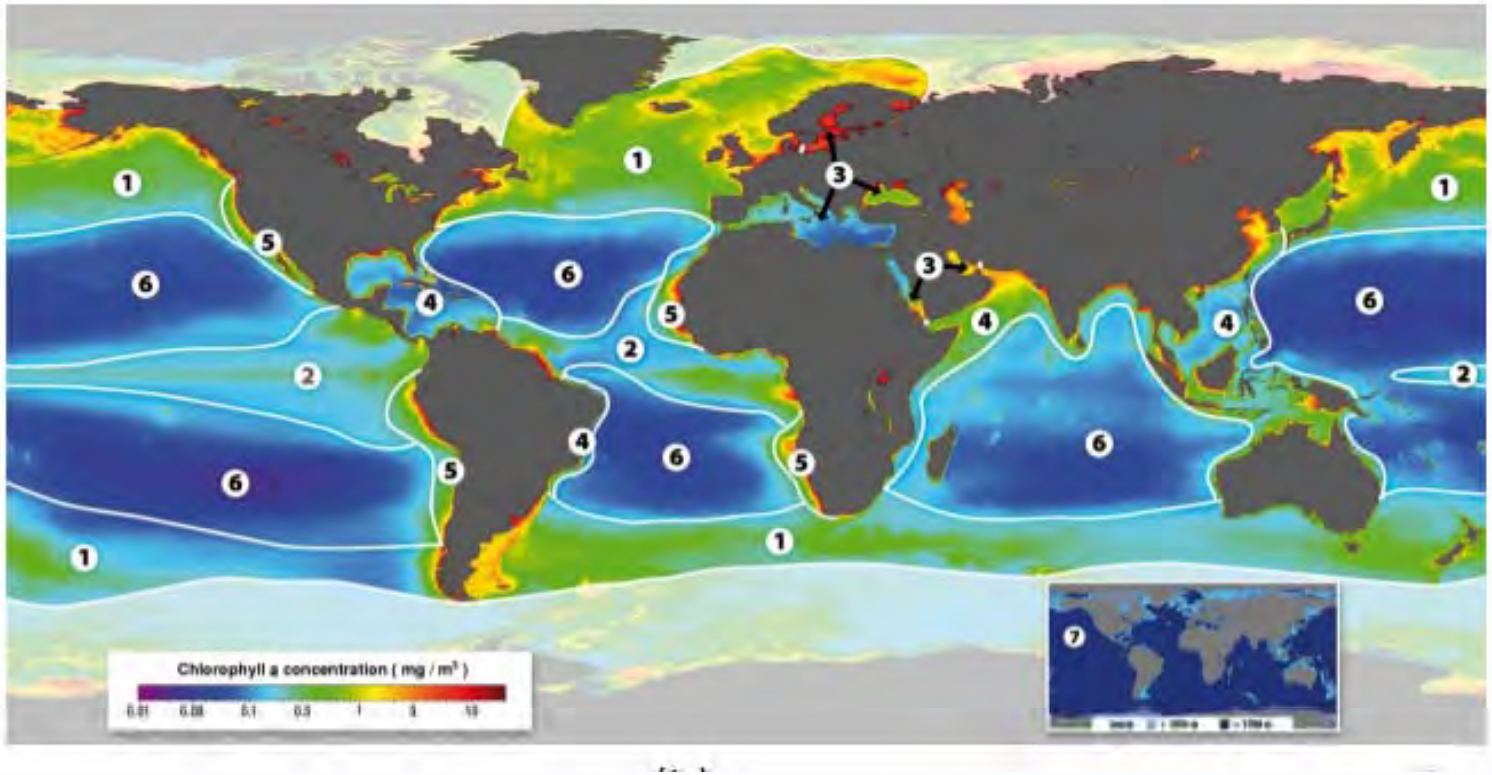
Confidence in the validity of a finding

Term*	Likelihood of the outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

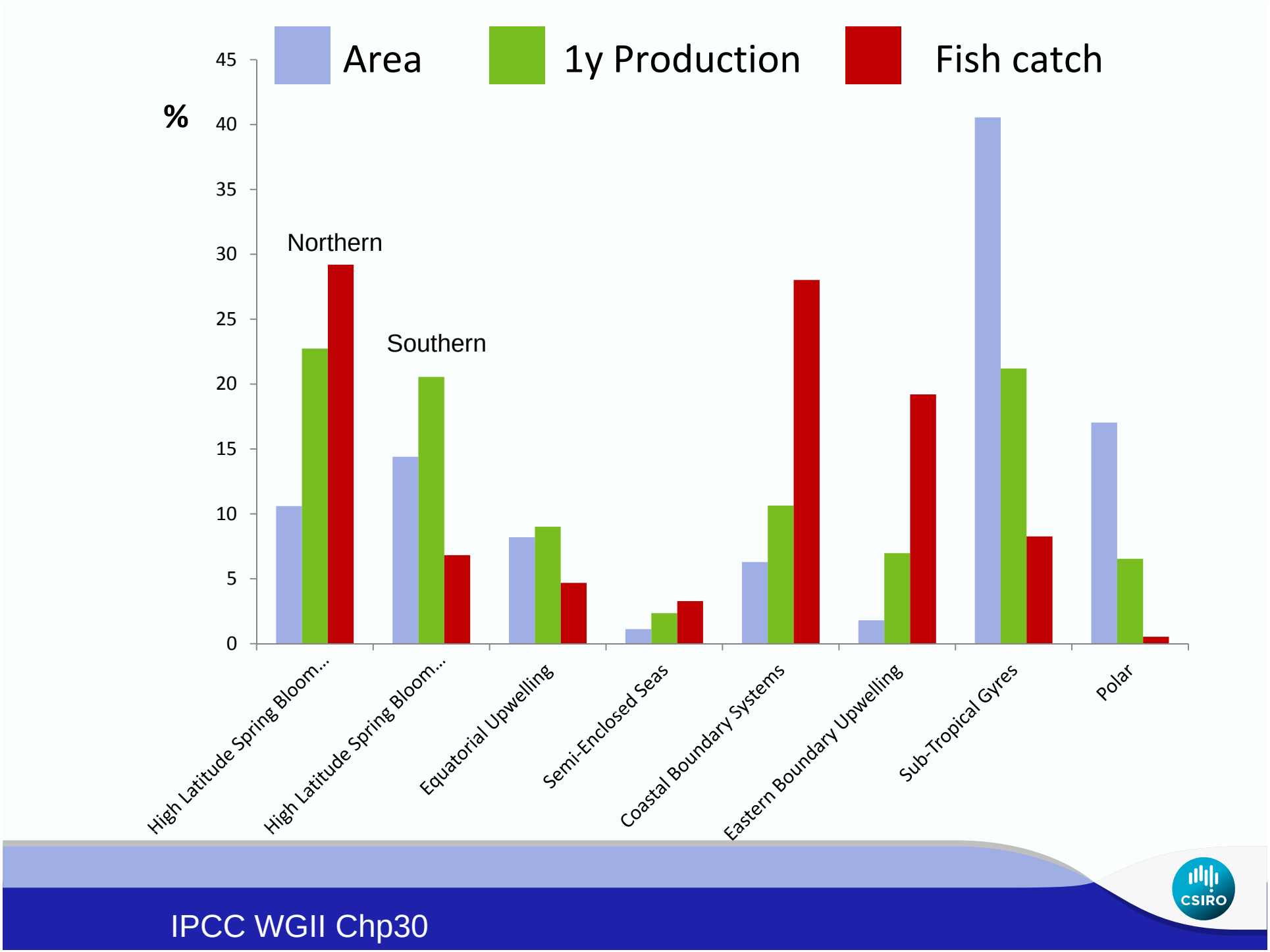
* Additional terms used more occasionally are *extremely likely*: 95–100% probability, *more likely than not*: >50–100% probability, and *extremely unlikely*: 0–5% probability.

Quantified measures of uncertainty in a finding

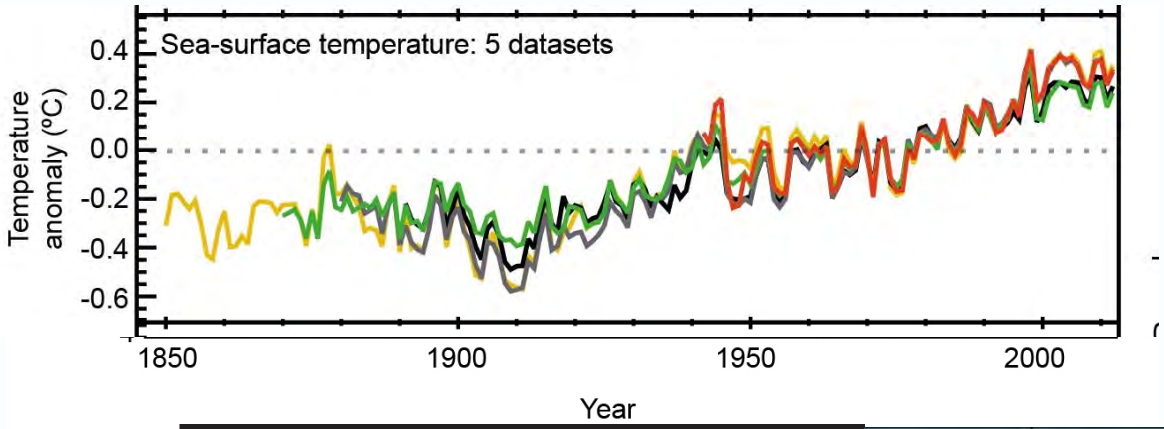
Chapter 30 Regionalisation



1: High Latitude Spring Bloom Systems
2: Equatorial Upwelling Systems
3: Semi-Enclosed Seas
4. Coastal Boundary Systems
5: Eastern Upwelling Systems
6: Sub-Tropical Gyres
7: Deep Sea (>1000m)
8: (grey region) Polar Oceans


Area
1y Production
Fish catch
%
45
40
35
30
25
20
15
10
5
0
Northern
Southern
High Latitude Spring Bloom...
High Latitude Spring Bloom...
Equatorial Upwelling
Semi-Enclosed Seas
Coastal Boundary Systems
Eastern Boundary Upwelling
Sub-Tropical Gyres
Polar

Global average sea surface temperatures have increased since both the beginning of the 20th Century and the 1950s (*virtually certain*).

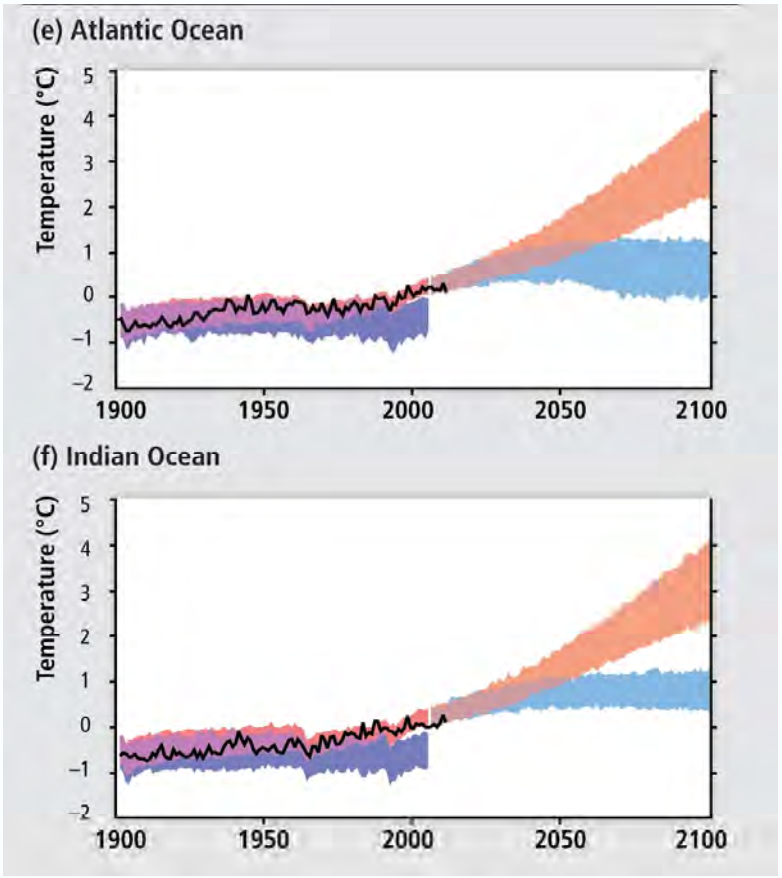


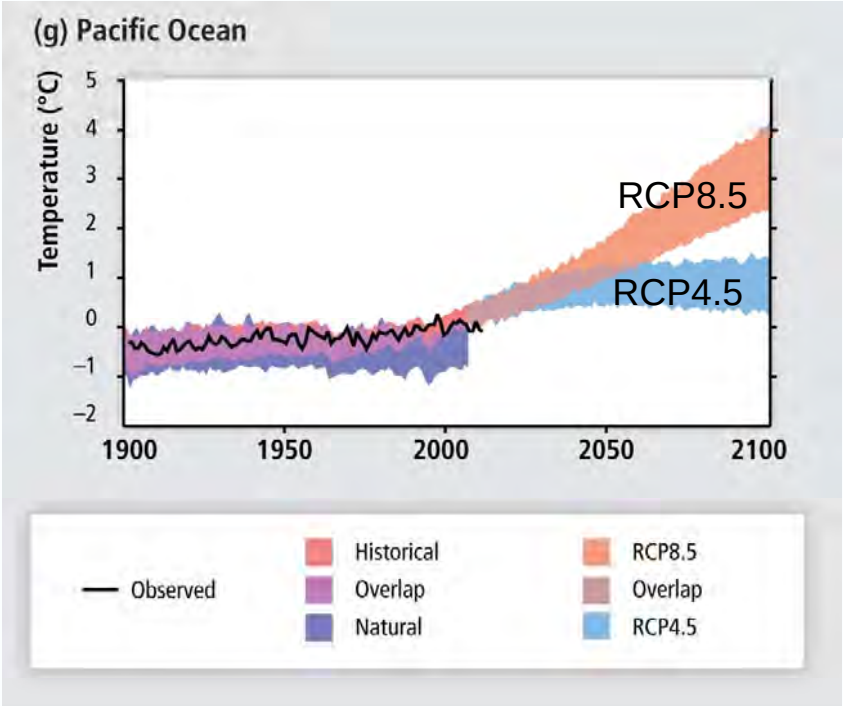
IPCC WGI Chp 2

Sub-region	Area	Change over 60 years (coolest month)	Change over 60 years (all months)	Change over 60 years (warmest month)
4. Coastal Boundary Systems (CBS)	Atlantic Ocean (west)	0.822	0.738	0.762
	Caribbean Sea/Gulf of Mexico	0.138	0.144	0.114
	Indian Ocean (west)	0.582	0.600	0.576
	Indian Ocean (east)	0.594	0.552	0.480
	Indian Ocean (east), Southeast Asia, Pacific Ocean (west)	0.864	0.804	0.642
5. Eastern Boundary Upwelling Ecosystems (EBUE)	Benguela Current	0.372	0.192	0.012
	California Current	0.702	0.732	0.456
	Canary Current	0.324	0.534	0.636
	Humboldt Current	0.306	0.354	0.624

Change SST 1950-2009; IPCC WGII Chp 30

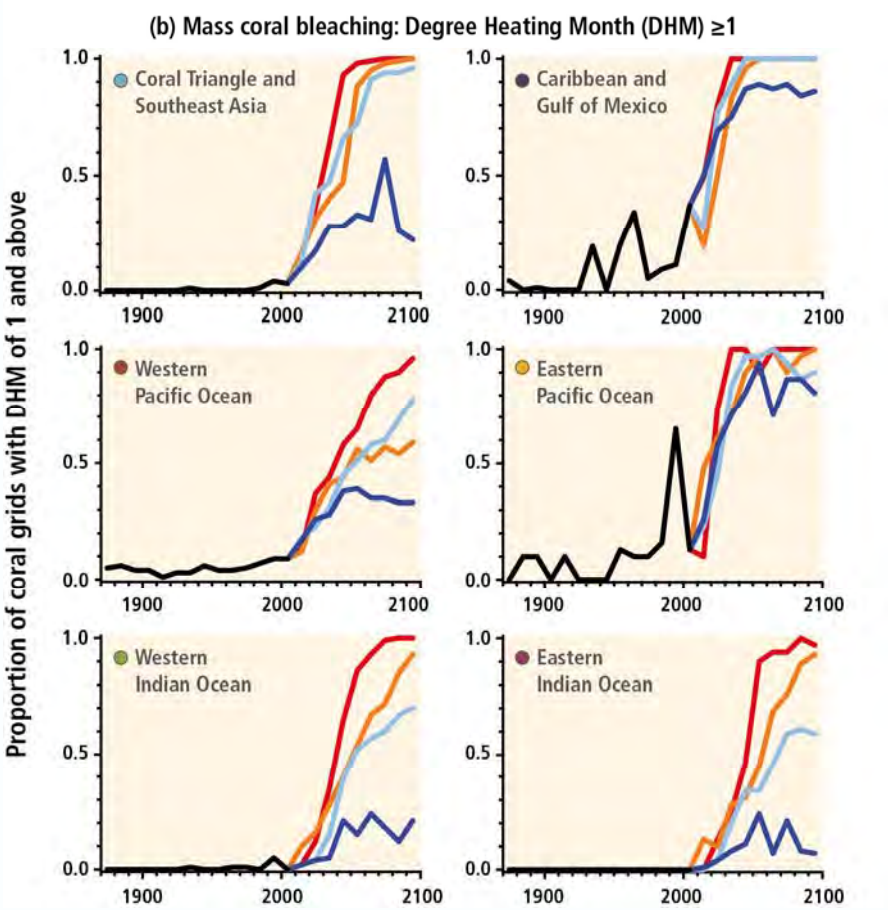
The ocean basins will continue warming under moderate (RCP4.5) to high (RCP8.5) emission trajectories (*high confidence)*





Observed warming includes a significant anthropogenic signal

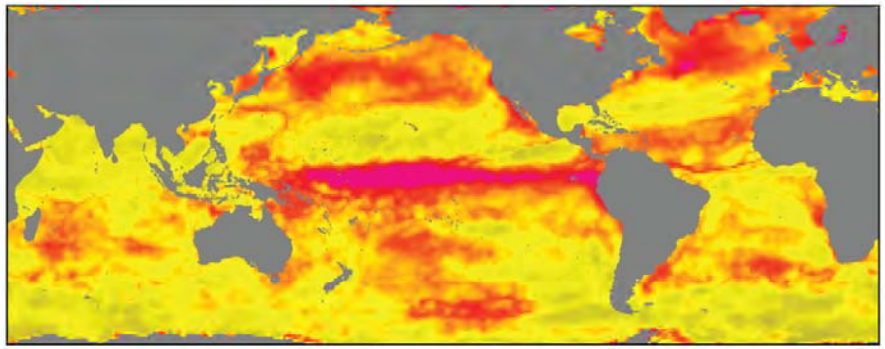
The frequency, intensity, duration, spatial extent and timing of extreme events will alter with greater associated risks for ecosystems and fisheries

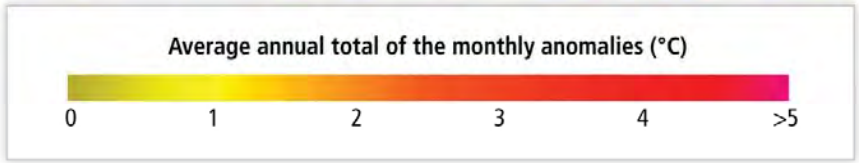


Historic
RCP 2.6
RCP 4.5
RCP 6.0
RCP 8.5

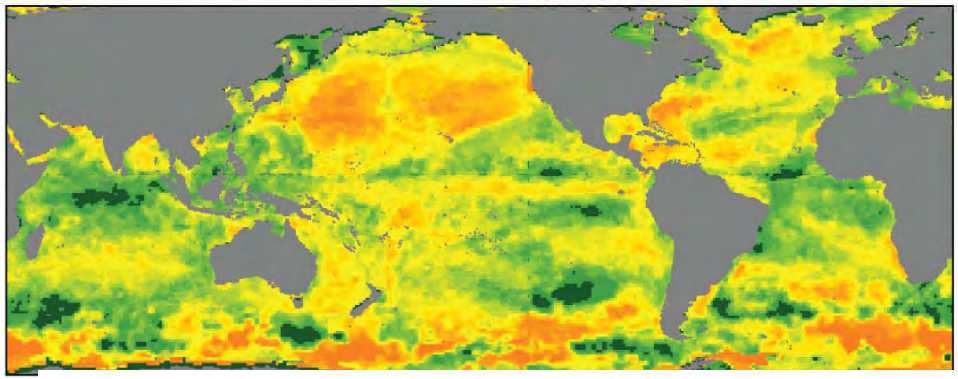
Recent accumulation of thermal stress

(a) Total thermal stress for the period 1981–2010

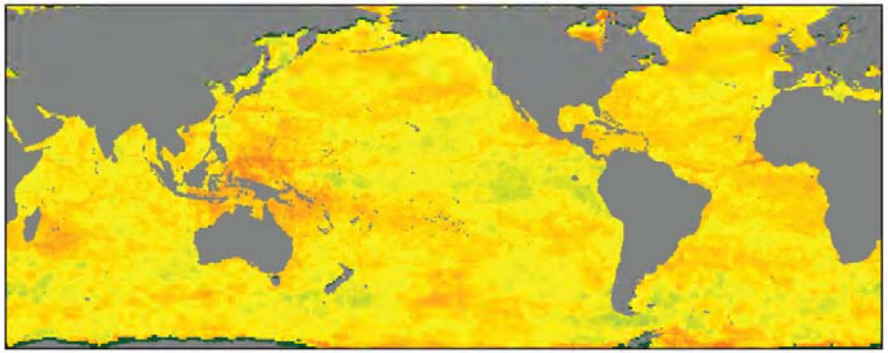


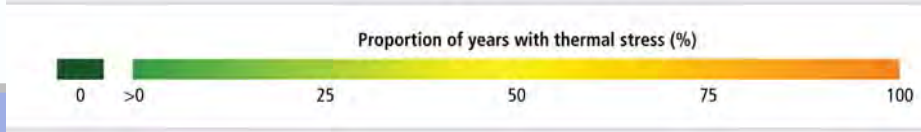


(c) Proportion of years with thermal stress (1951–1980)

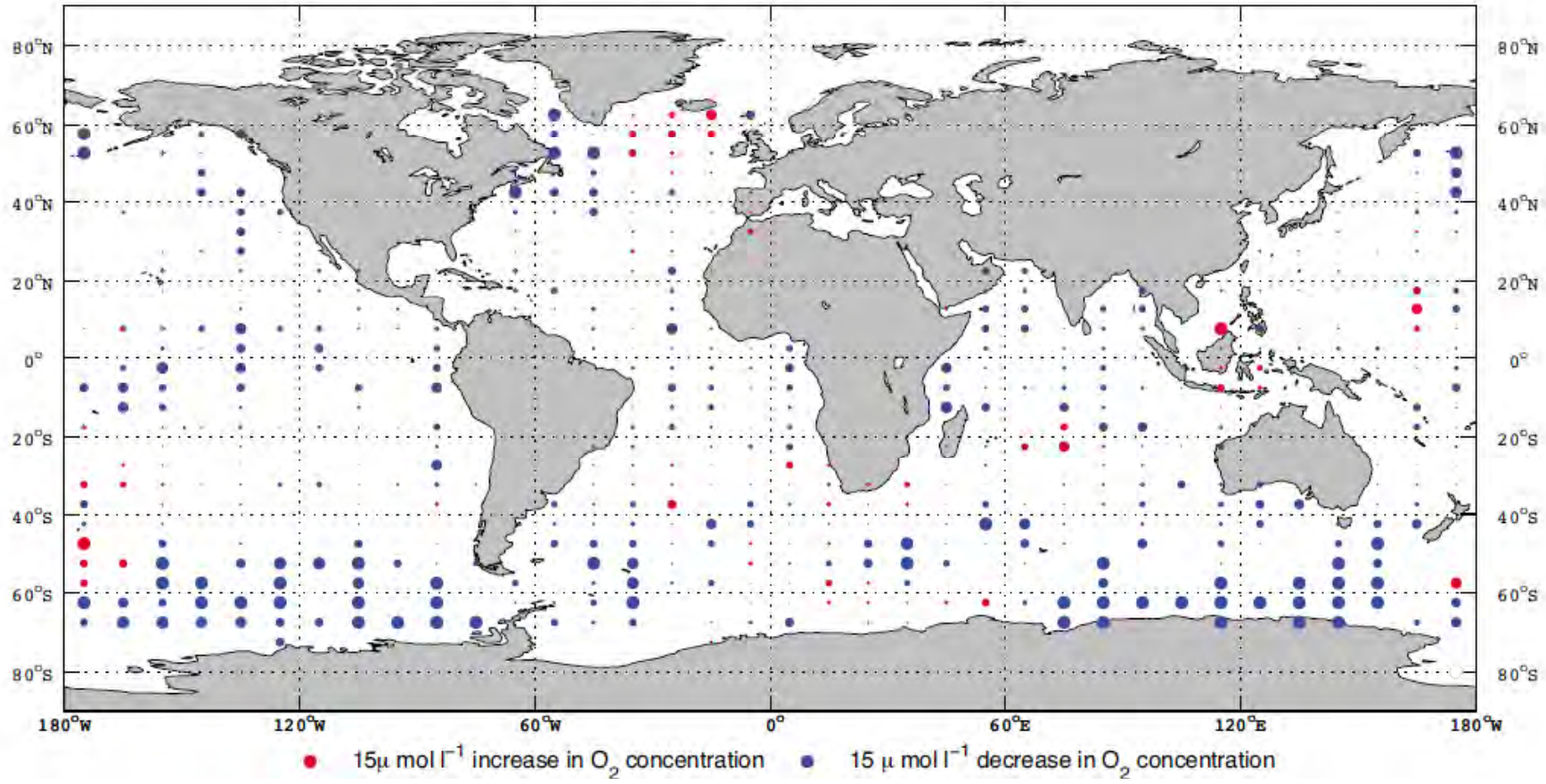


(d) Proportion of years with thermal stress (1981–2010)





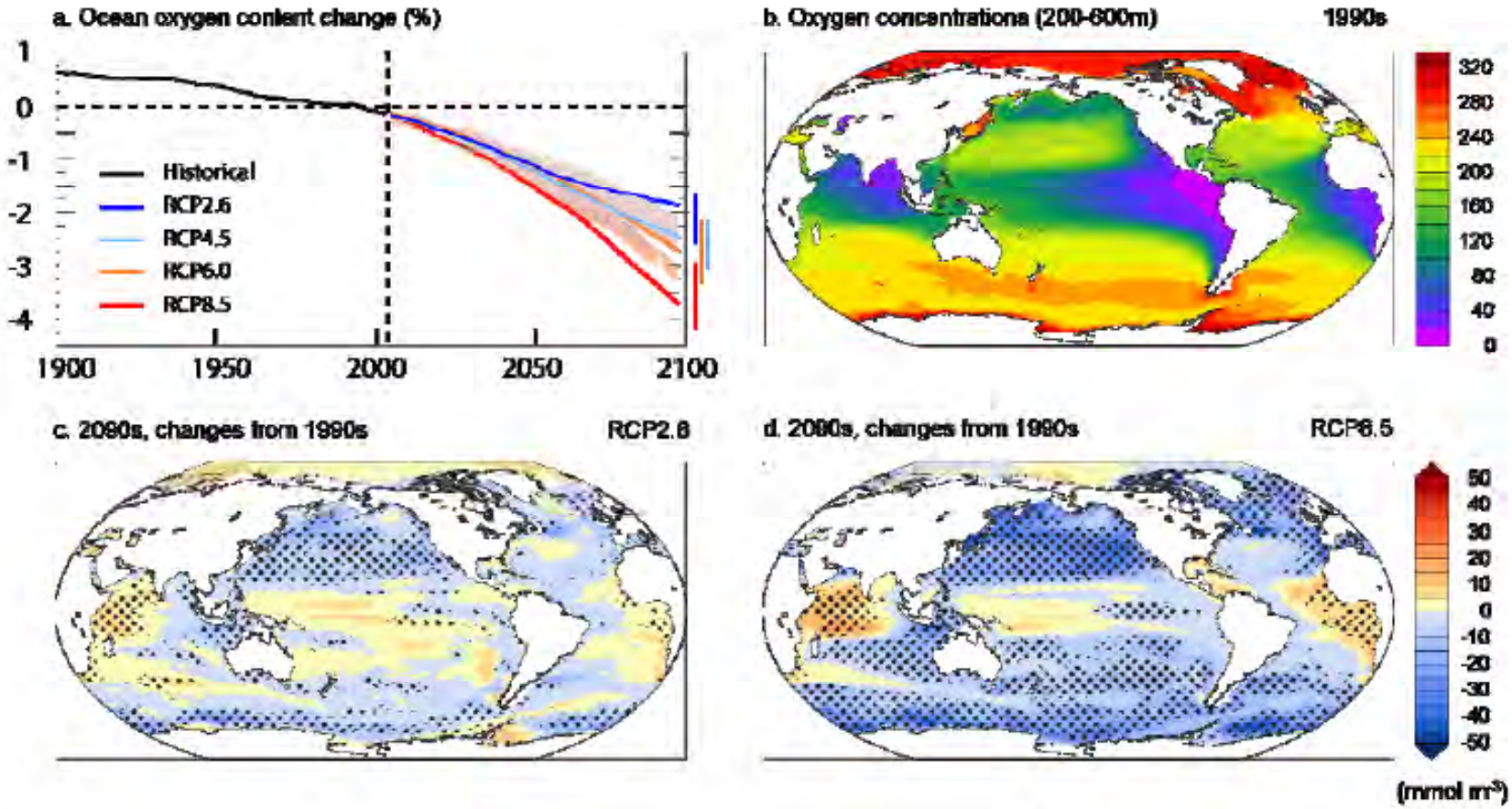
Recent declines in oxygen in the open ocean thermocline in many regions are a result of anthropogenic GHG



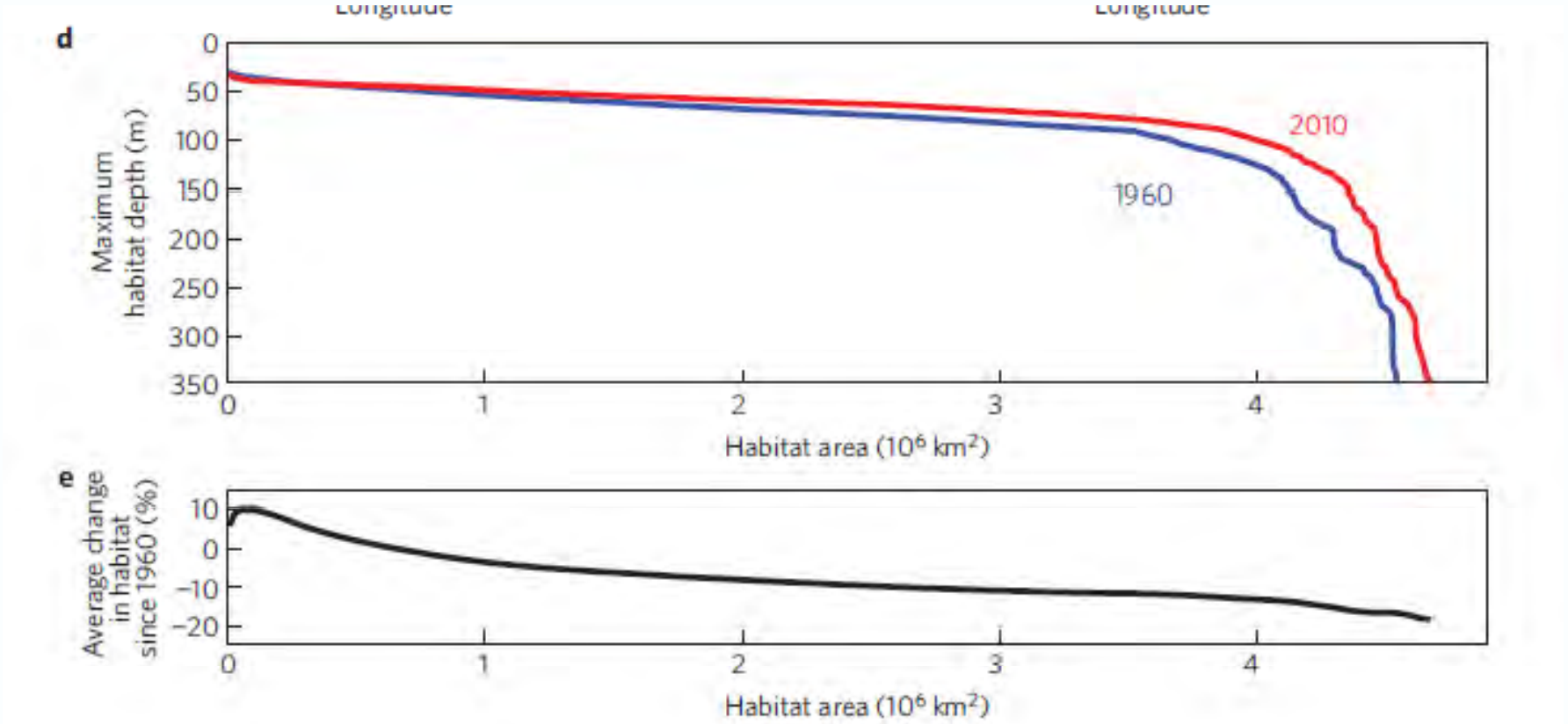
Oxygen changes 100-1000m for ~1970-1992

IPCC WGI Chp 3, Chp 6; WGII Chp 30; Helm et al 2011 Geophy Res Lett

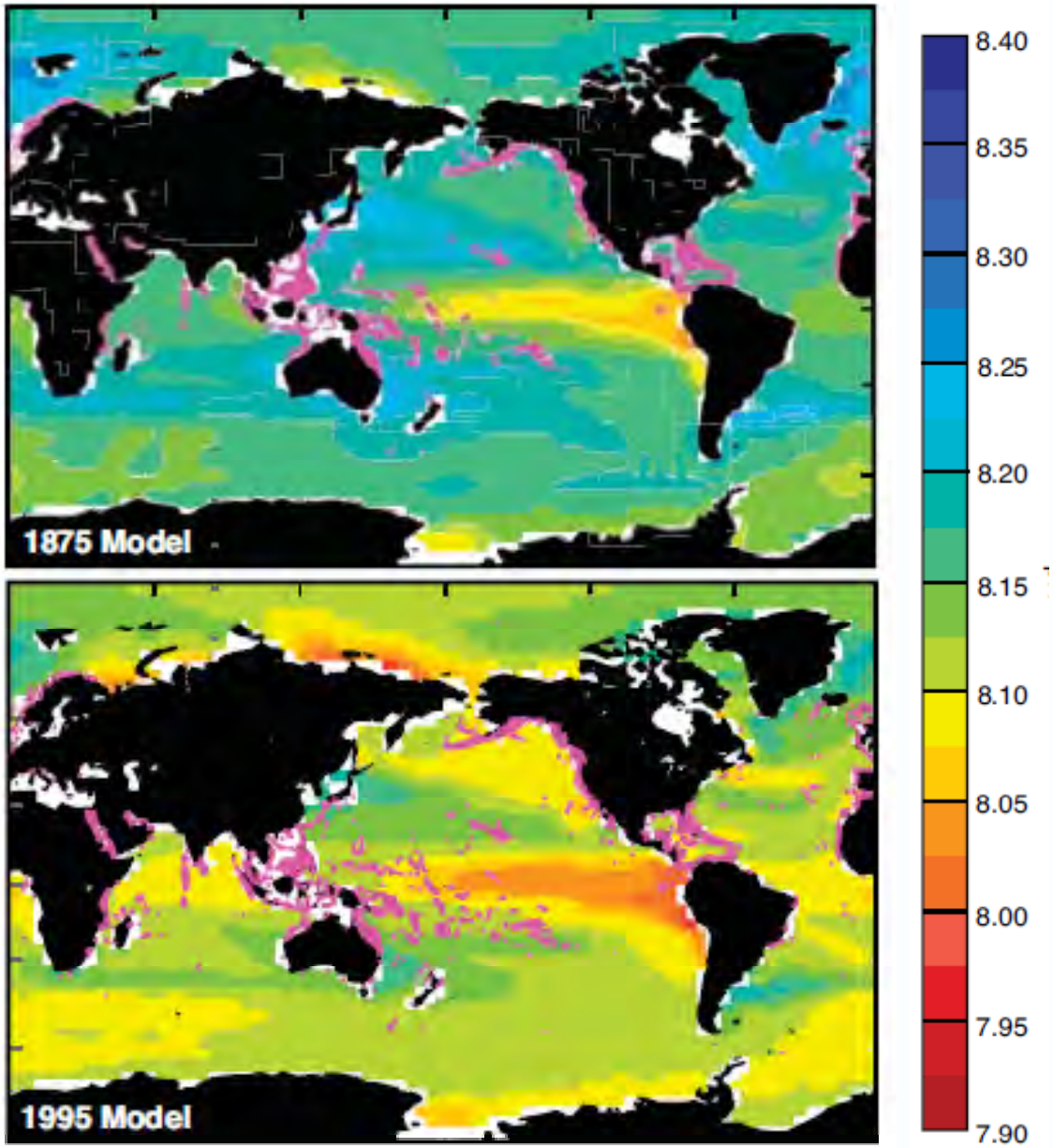
There is *high agreement* among modeling studies that O_2 concentrations will continue to decrease in most parts of the Ocean



Reduction of blue marlin habitat (Eastern Atlantic)



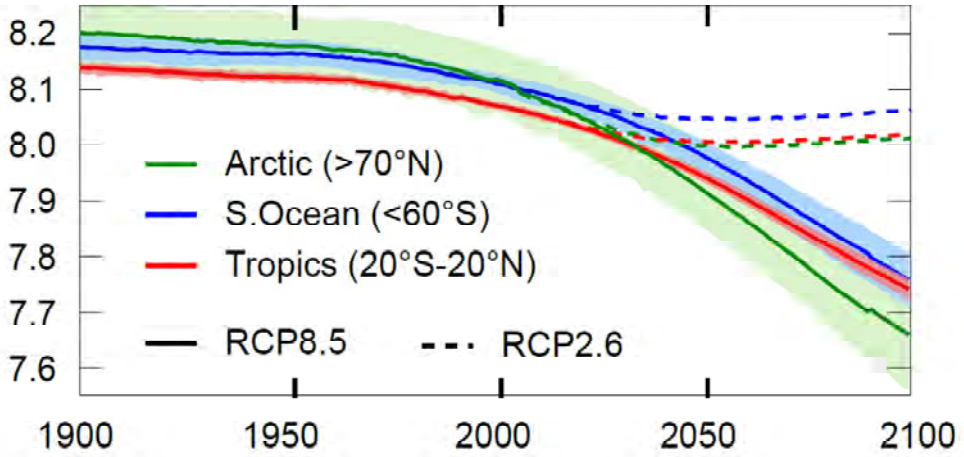
Stramma et al 2012 Nature Climate Change



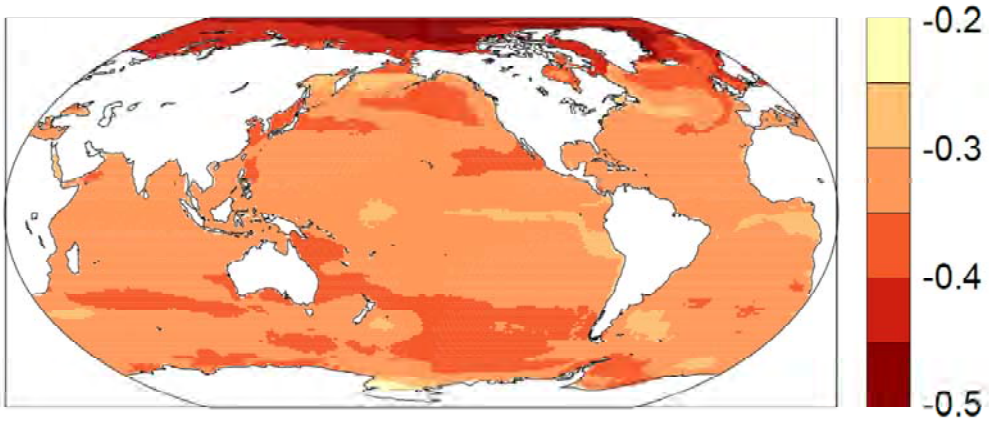
Modelled mean pH at surface

Uptake of CO_2 has decreased ocean pH (approximately 0.1 unit over 100 years) particularly at high latitudes (*high confidence*).

a. Surface pH

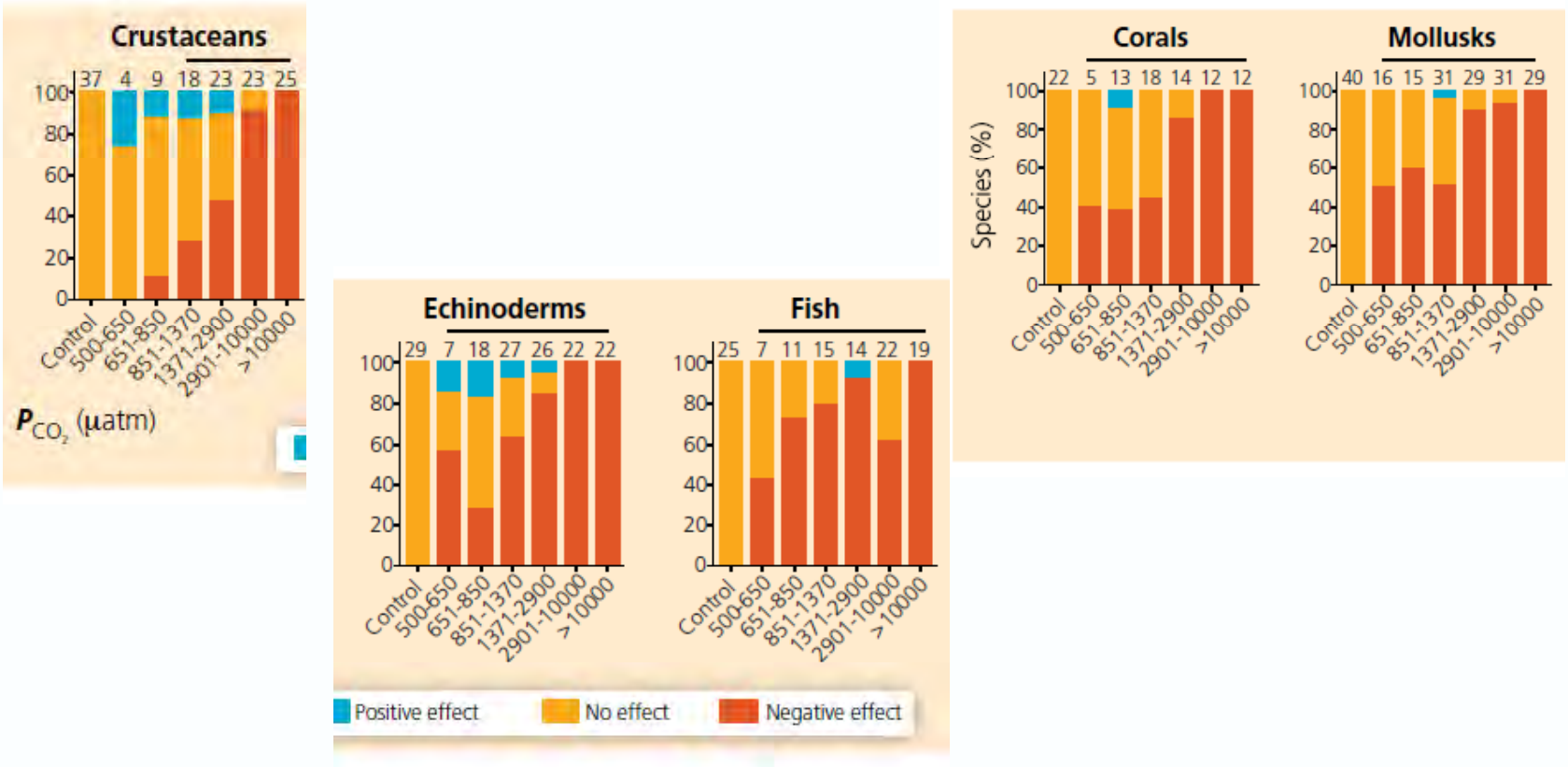


b. Surface pH in 2090s (RCP8.5, changed from 1990s)

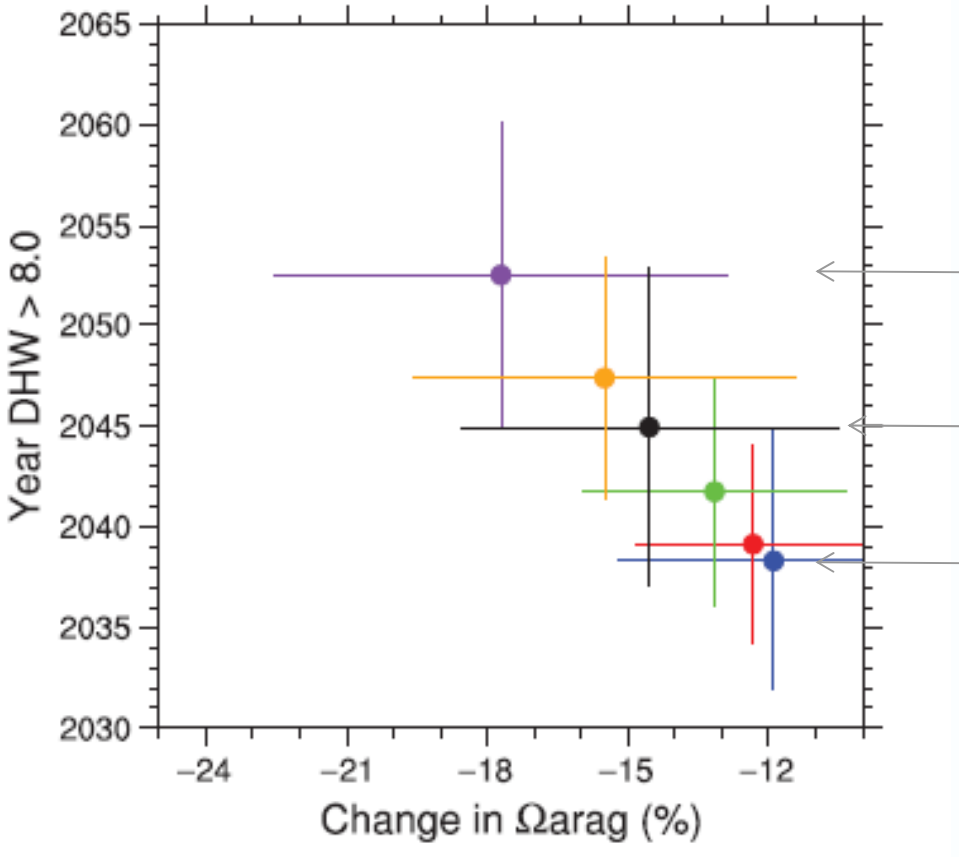


Further increases in atmospheric CO_2 are *virtually certain* to further acidify the Ocean and change its carbonate chemistry

Warming temperatures, declining pH and carbonate ion concentrations represent risks to the productivity of fisheries and aquaculture



Most, if not all, of the Ocean will continue to warm and acidify, although the rates will vary regionally (*high confidence*).



Coral Reef Zones

High Latitude > 20°

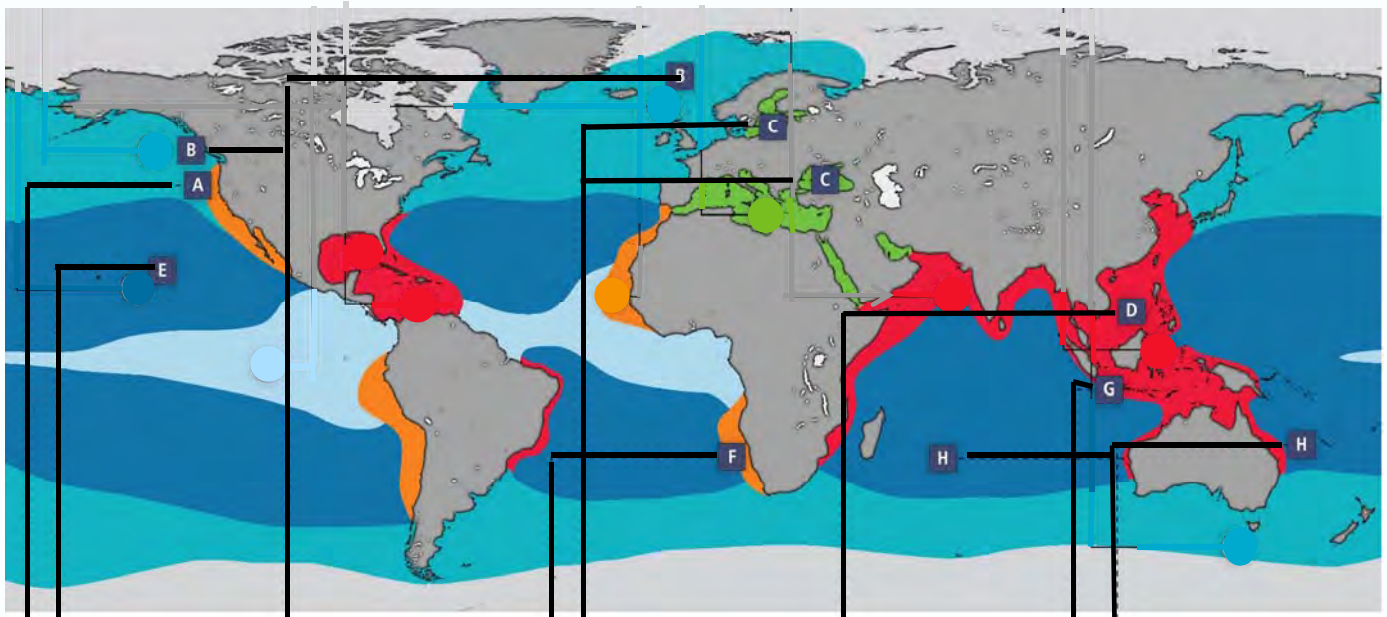
Mid Latitude 12-16°

Equatorial zone

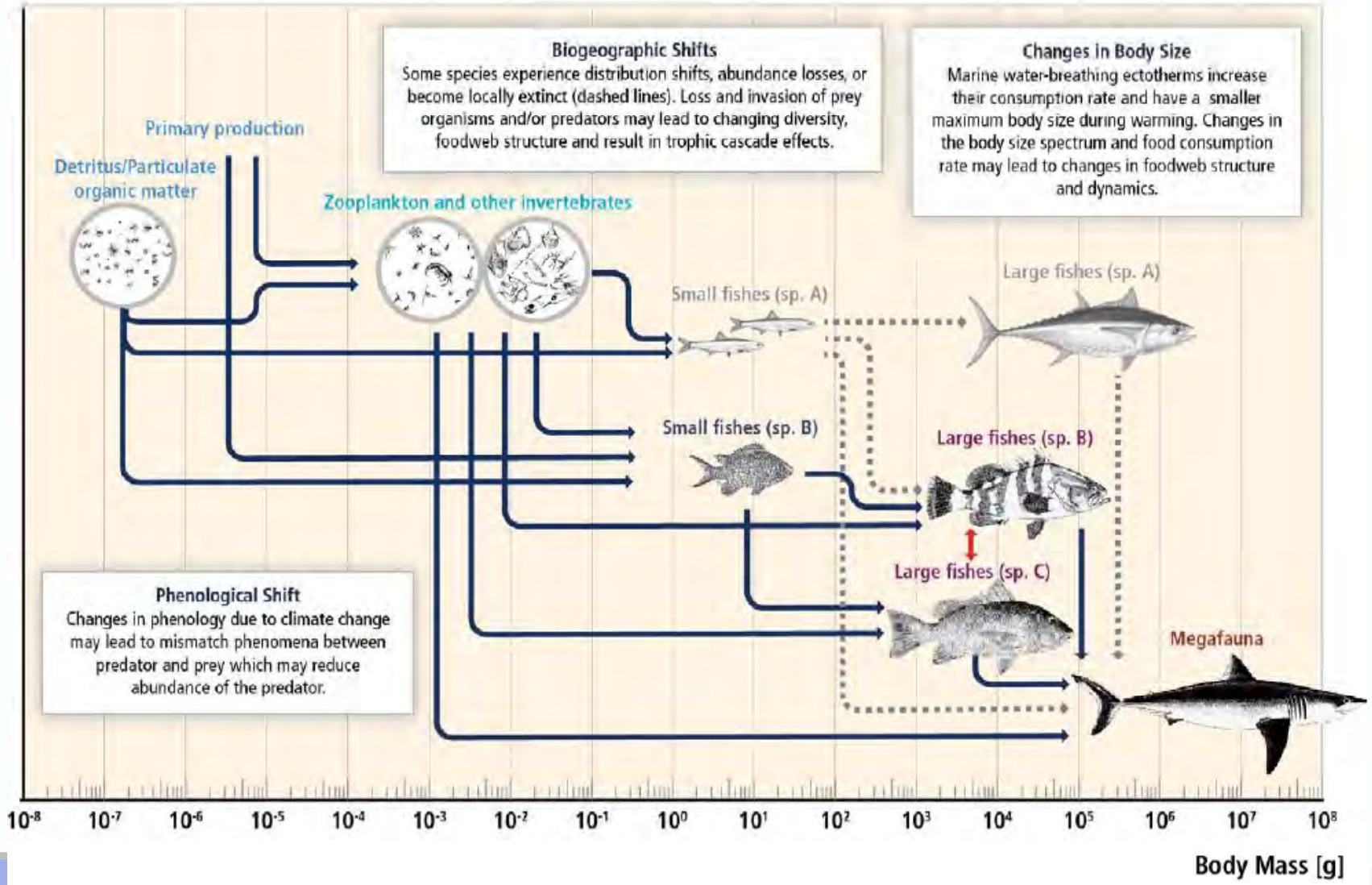
RCP8.5

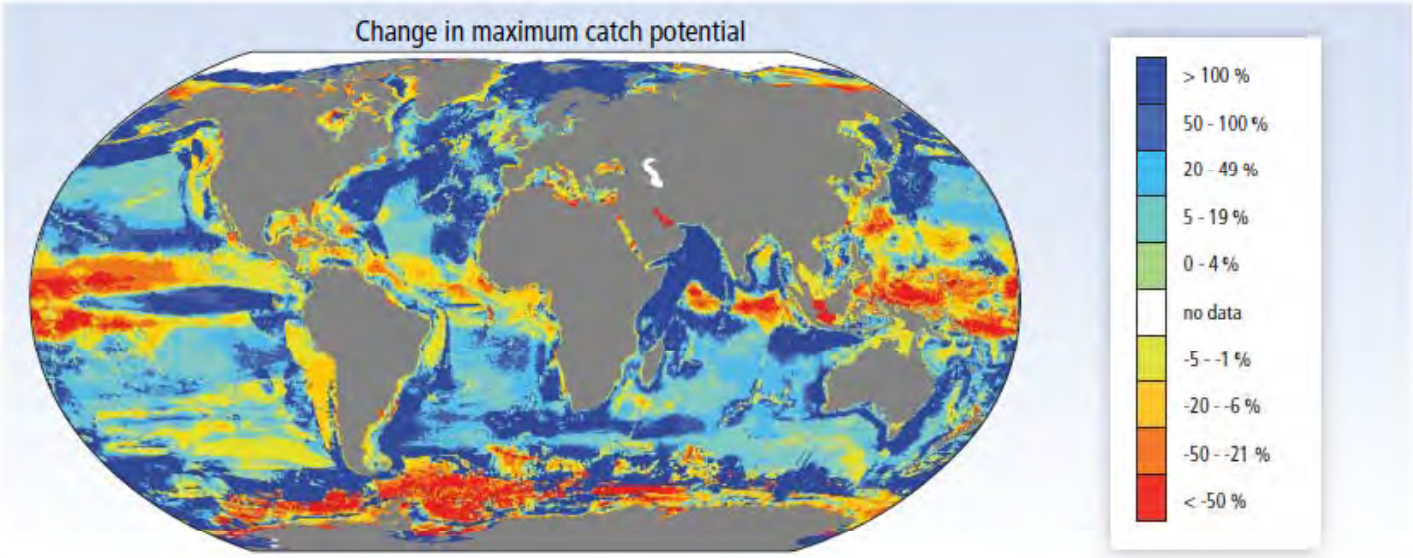
Van Hooidonk et al 2014 GCB,

Examples of risks to fisheries from observed and projected impacts

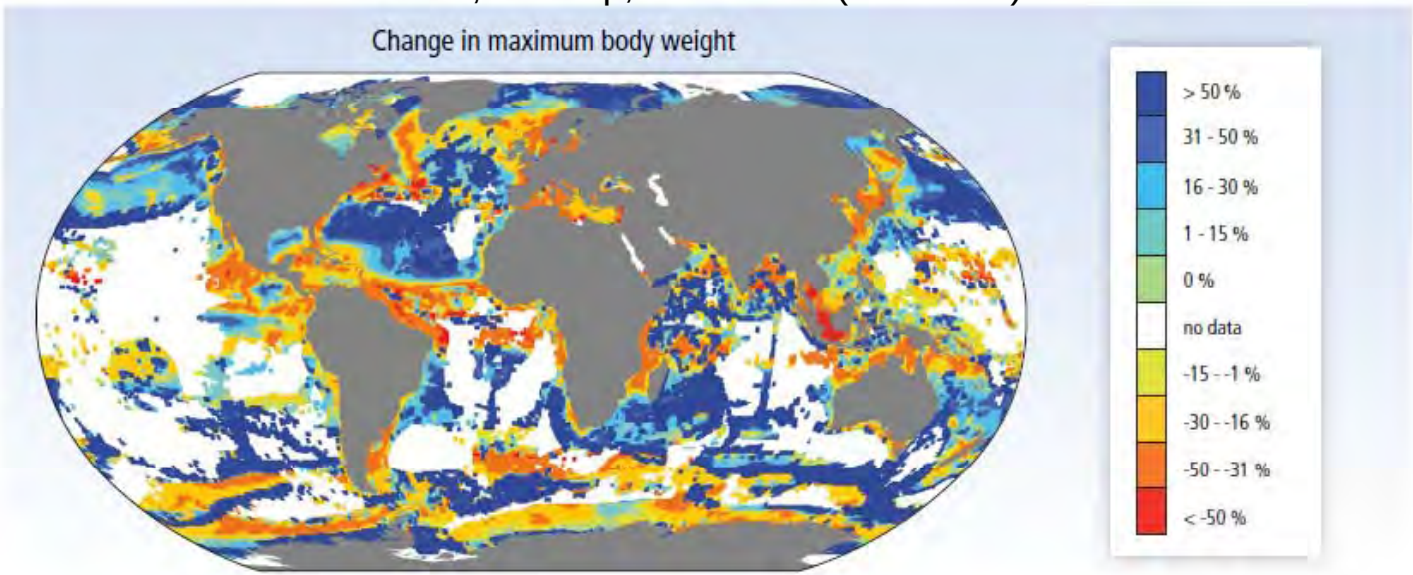


Relatively small changes in temperature and other variables can result in often large biological responses that range from simple linear trends to more complex non-linear outcomes





2001-2010 and 2051-2060; 1000 sp, SRES A1B (~RCP 6.0)

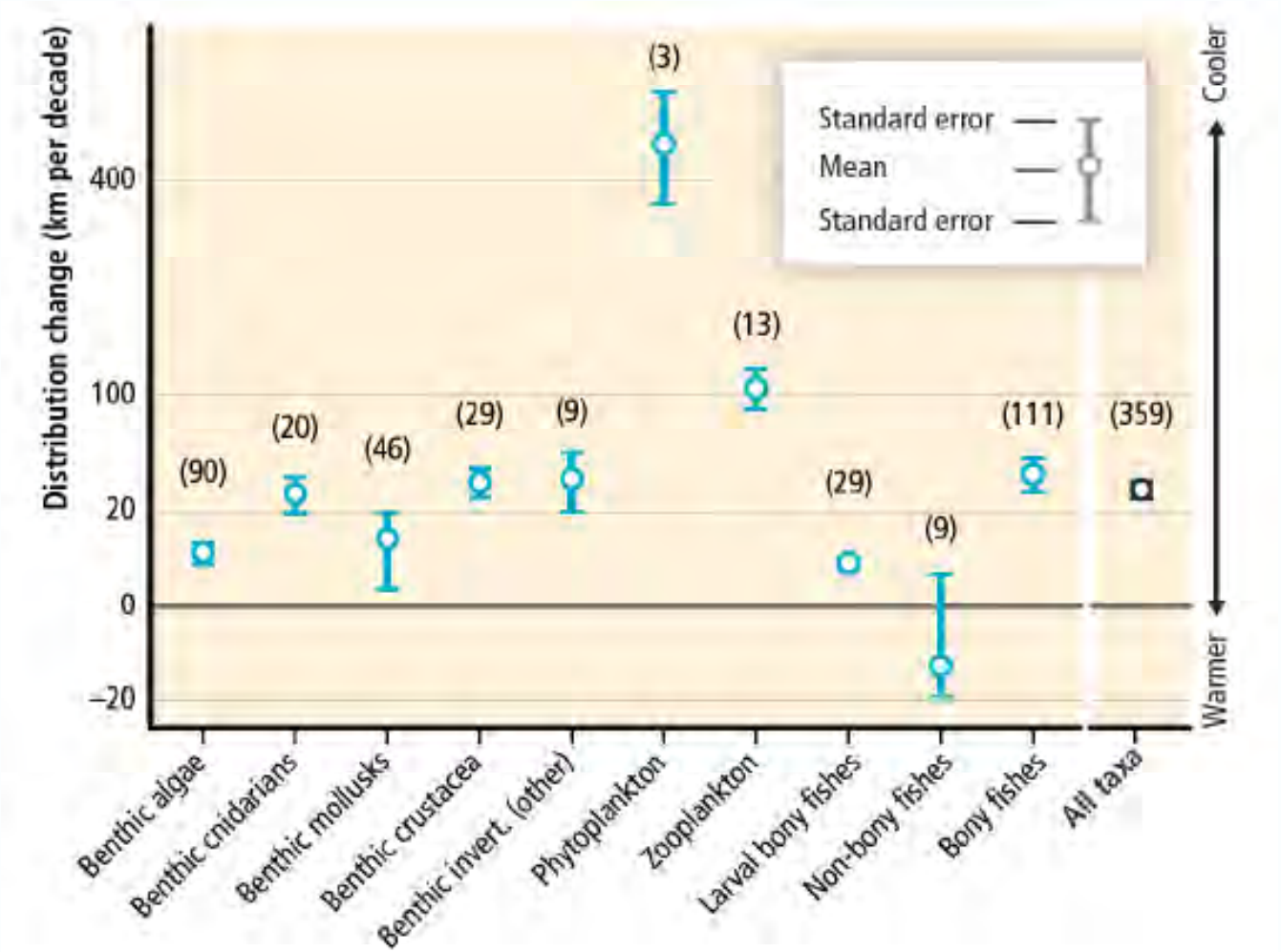


1991-2010 and 2041-2060; 610 sp, SRES A2 (~RCP 6.0-8.5)

The warming-induced shifts in species distributions and phenology will be paralled by reductions in maximum body size

IPCC WGII Chp 6, Cheung et al 2010 Global Change Biol 16, Cheung 2013 Nature Climate Change 3

Marine organisms are shifting to higher latitudes consistent with warming trends (*high confidence*)



Leading edge expansion

Ocean
72 km dec^{-1}
Land
6 km dec^{-1}

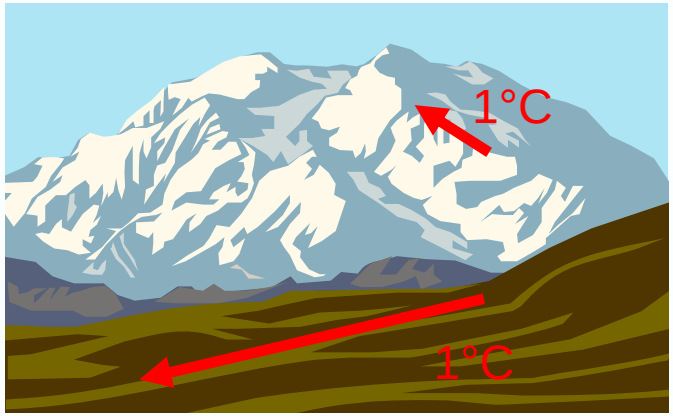
Poloczanska et al 2013 Nature Climate Change, IPCC WGII SPM

The velocity of climate change

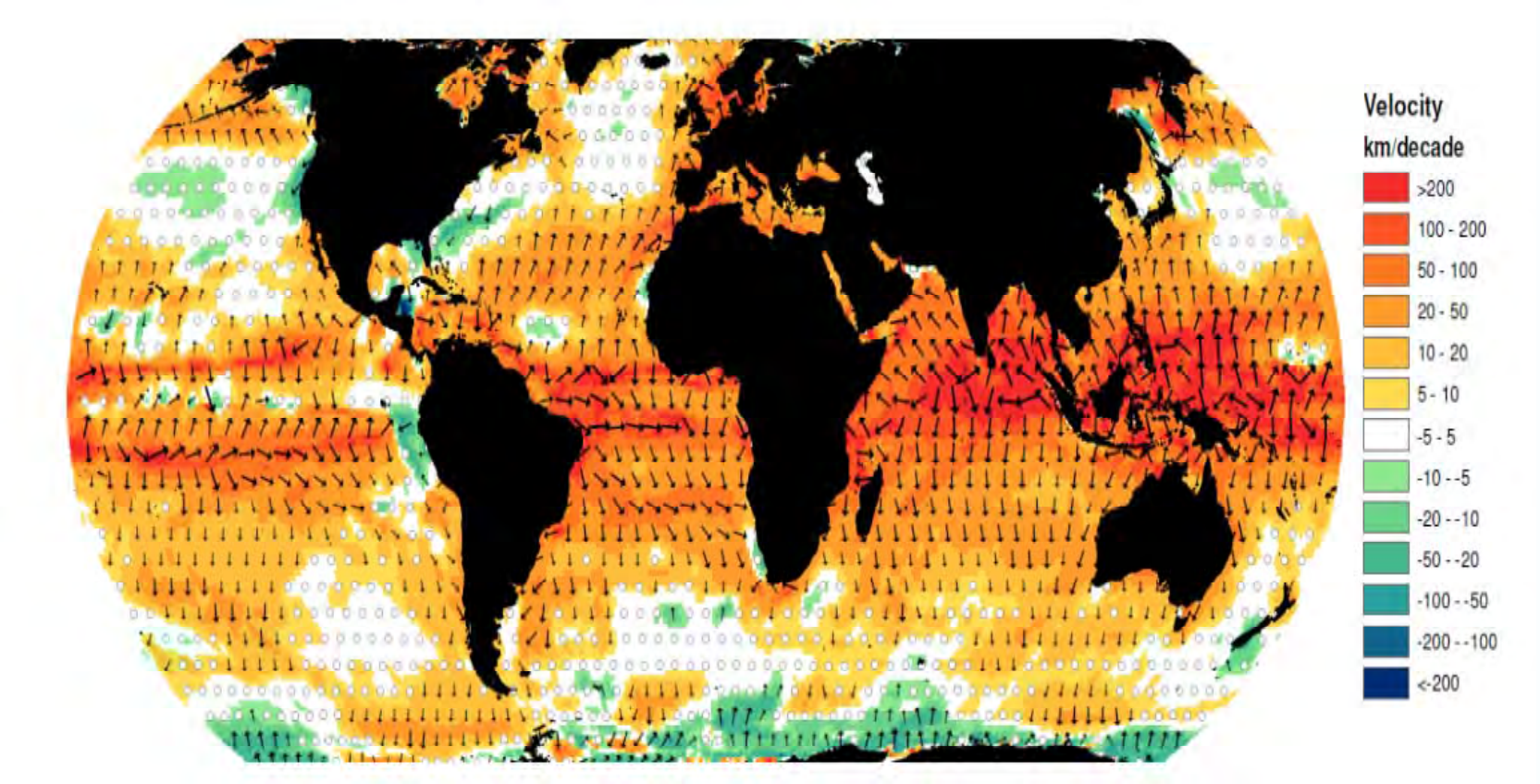
Velocity describes the SPEED and the DIRECTION that an organism would have to move to keep its current thermal environment

$$\text{Velocity} = \frac{\text{Temperature trend}}{\text{Spatial gradient}}$$

Consider velocities for an animal on the side of a mountain vs in the middle of a desert?
How fast would the animal need to move to experience 1°C change temperature?
In which direction?



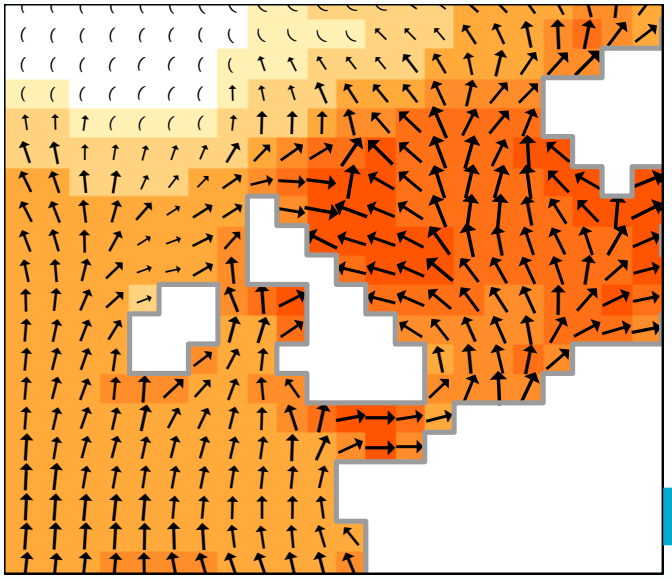
Velocity of climate change = speed and direction of isotherm movement



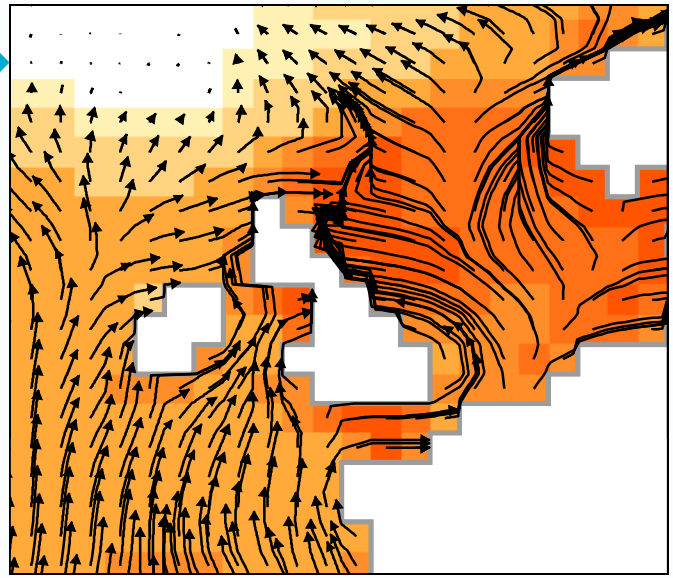
Surprise: ocean velocities are comparable to land velocities

Burrows et al 2011 Science, IPCC WGII Chp 30

From velocity to trajectories



string arrows
together to give
climate trajectories



Burrows et al. 2014 Nature

Emerging issues for the Ocean

1. Understanding the long-term variability of the Ocean and interaction with anthropogenic climate change
2. Developing a better understanding of distribution and changes in O_2 concentrations
3. The vulnerability of fisheries species and key habitats (eg coral reefs) to ocean acidification and interaction with other stressors
4. How oceanic primary production is likely to change in a warmer and more acidified ocean
5. The potential reorganisation of ecosystems and communities, and social and economic implications
6. Understanding cumulative and synergistic impacts both among climate change variables and with other drivers

Thank you