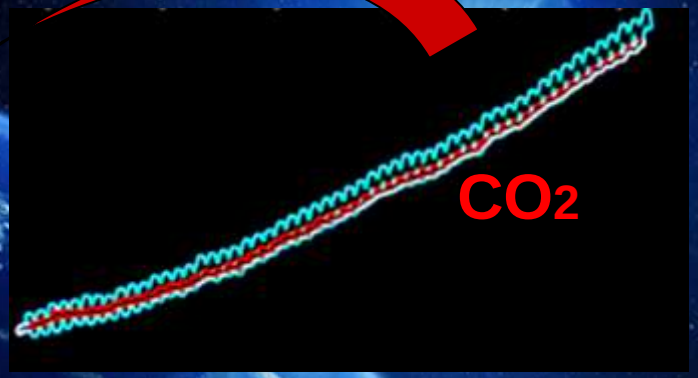
Ocean Acidification: a global issue with a particular concern for high latitude ecosystems



Dr Carol Turley
Plymouth Marine Laboratory
UK Ocean Acidification research programme

AVOID2 FCO Roshydromet workshop, Moscow
19 March 2015

PML | Plymouth Marine Laboratory

UK Ocean Acidification Research Programme

AVOID 2

The ocean absorbs over a quarter of man-made CO_2 emissions

Fossil fuels

91%

Deforestation

9%

45% CO_2 stays in atmosphere

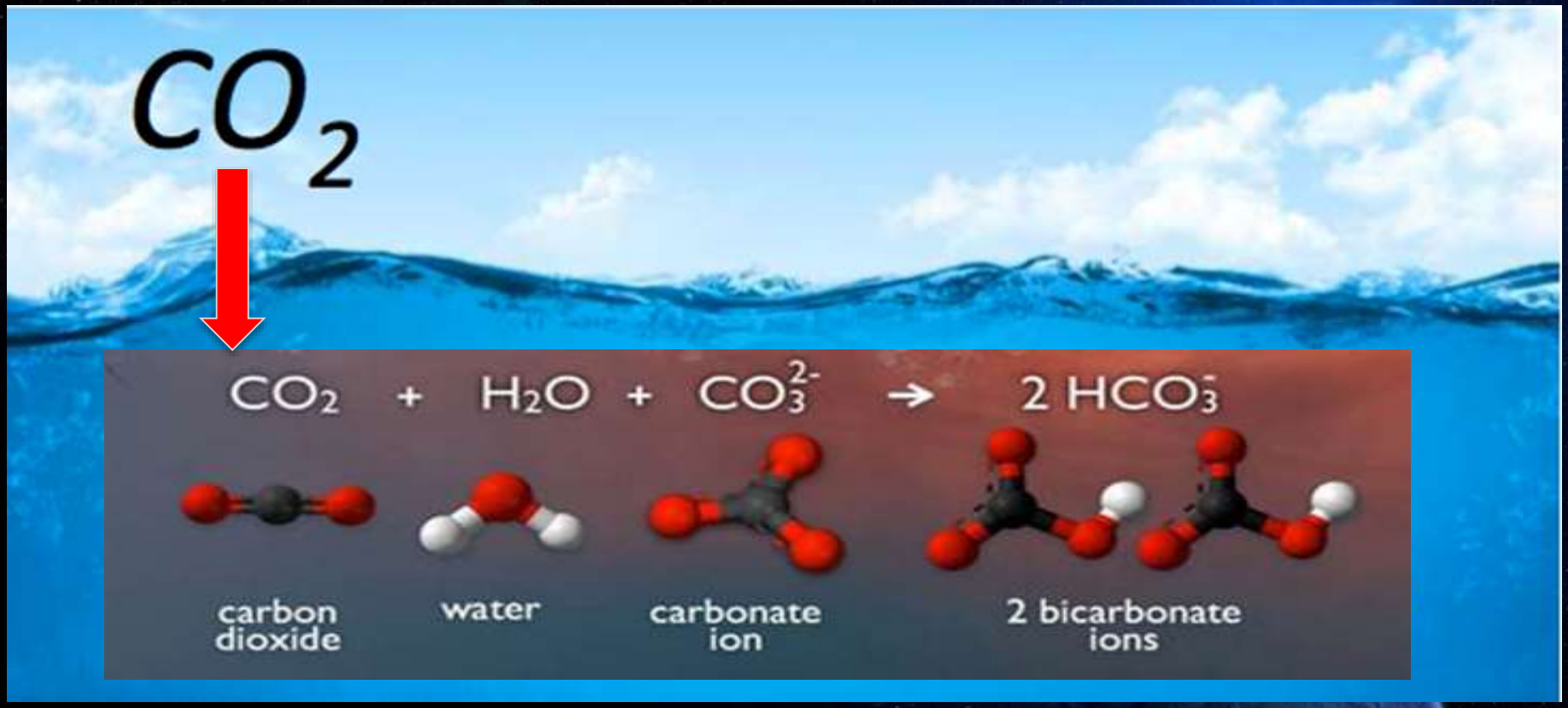
27%

Land uptake

27%

Ocean uptake

The ocean is going through major changes to its basic chemistry

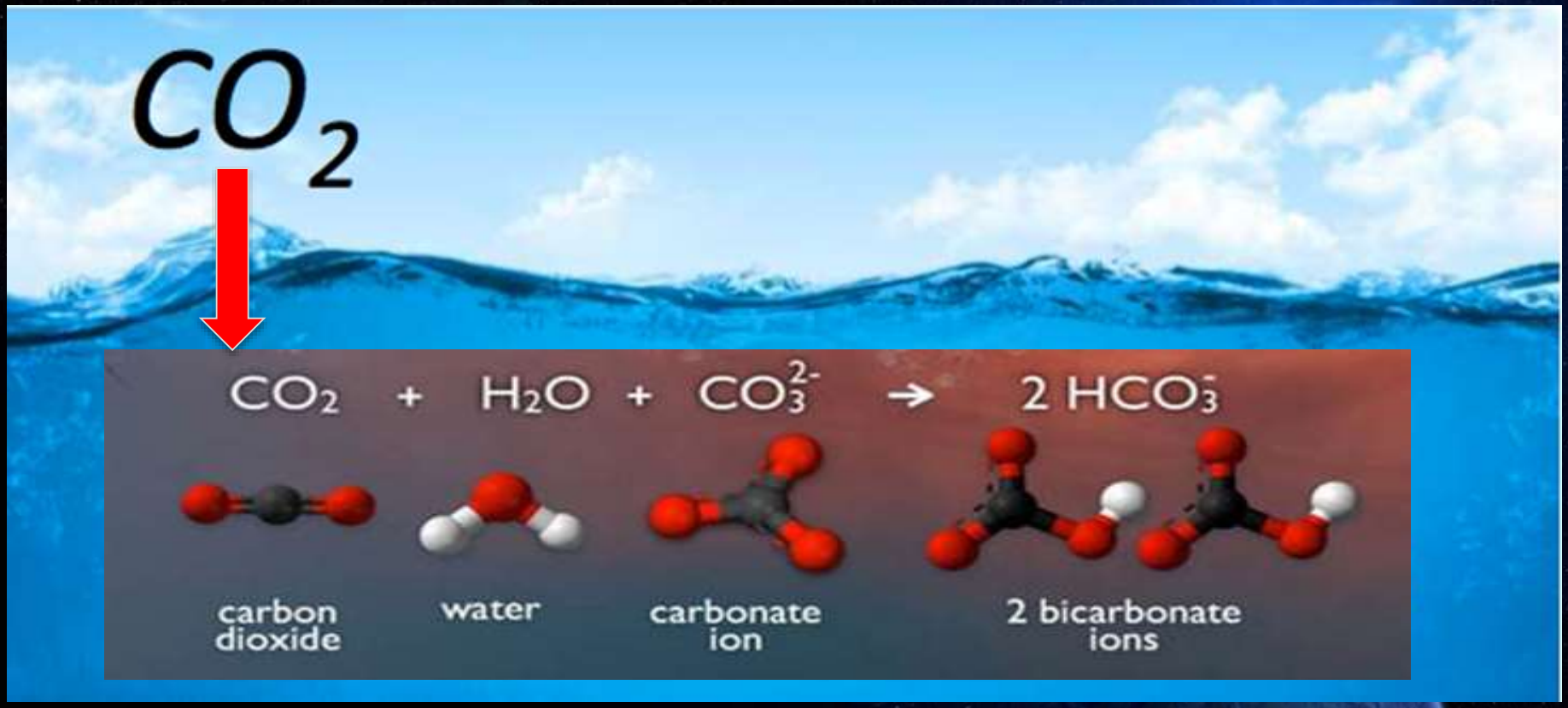


- CO_2 is an acid gas (it produces acid when combined with water, reducing pH)
- Ocean acidity up by 30% since start of industrial age, most of that only in last 40 yr
- Ocean acidity is projected to increase by 100 to 150% by 2100

Change (online 2 Dec)

Graphic s: PMEL

The ocean is going through major changes to its basic chemistry

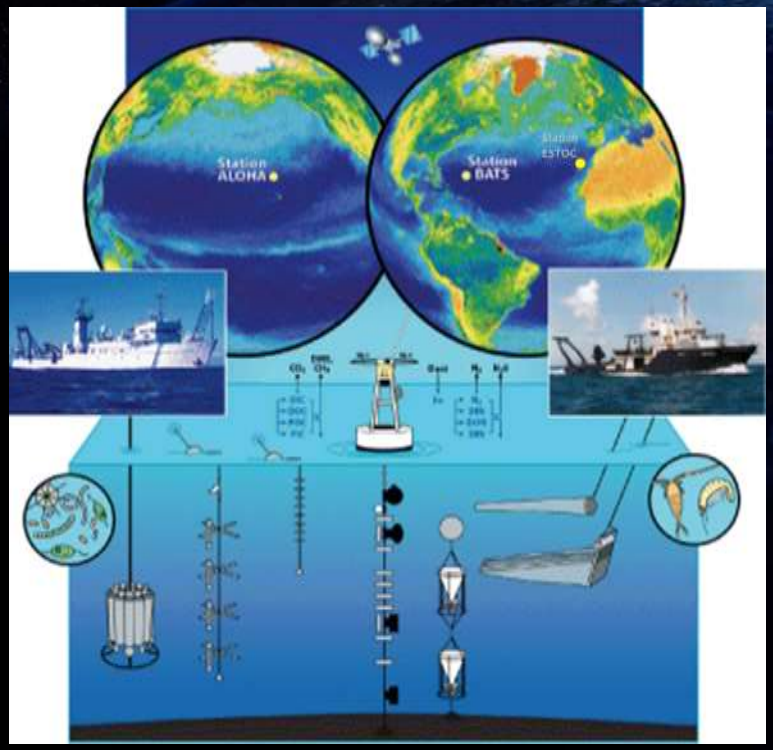


- CO_2 is an acid gas (it produces acid when combined with water, reducing pH)
- Ocean acidity up by 30% since start of industrial age, most of that only in last 40 yr
- Ocean acidity is projected to increase by 100 to 150% by 2100
- Acidification is 10 times faster than at any time during at least the last 65 million yr
- If it continues at BAU it will take 10,000 yrs for ocean chemistry to recover

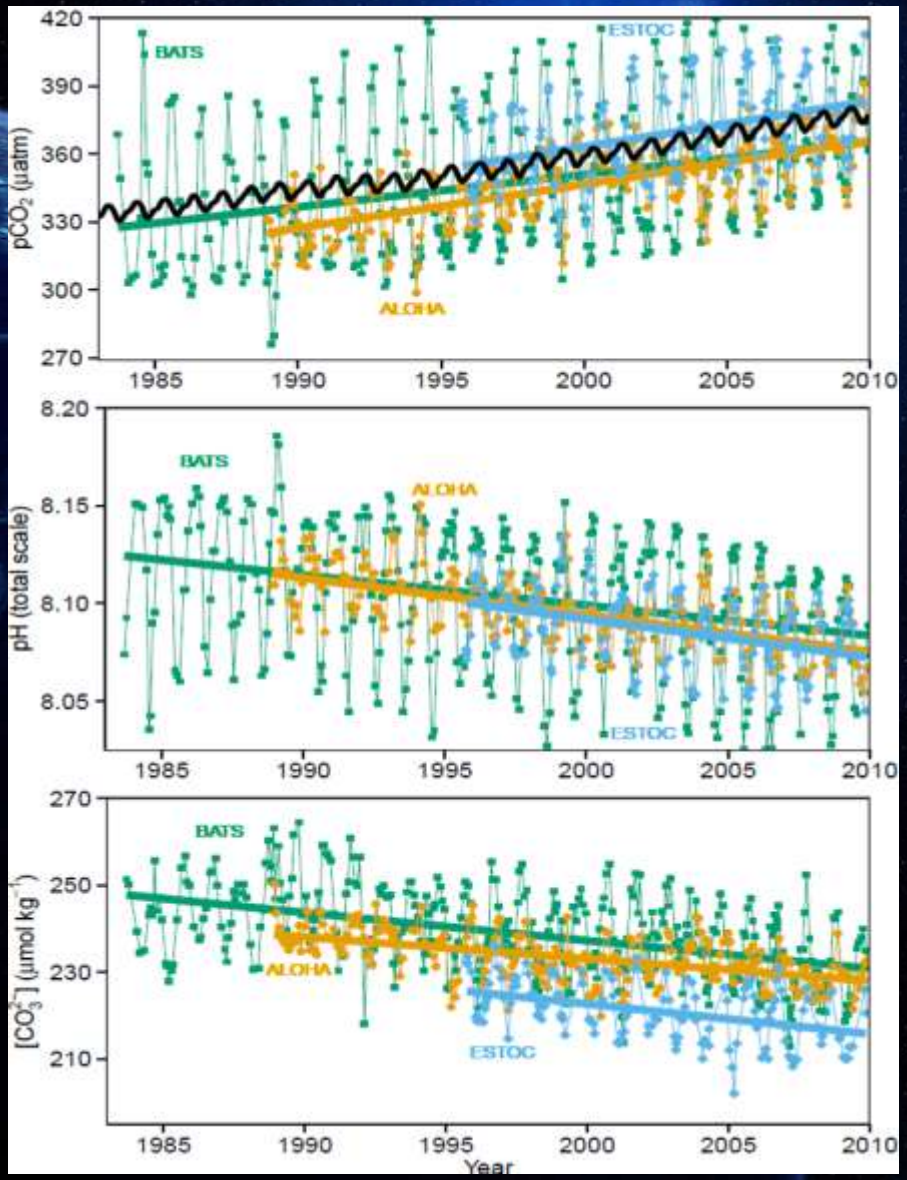
Graphic s: PMEL

CO_2 in the atmosphere is increasing…

3 long-term monitoring stations



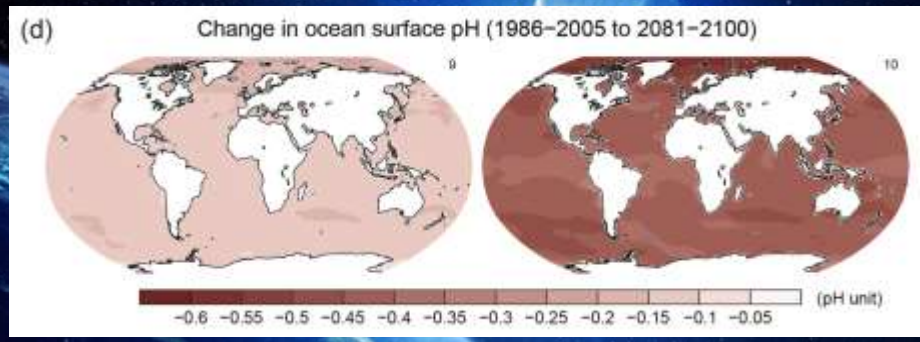
Data:
Bates (2007)
Dore et al. (2009)
Santana-Casiano et al. (2007)
Gonzàles-Dàvila et al. (2010)

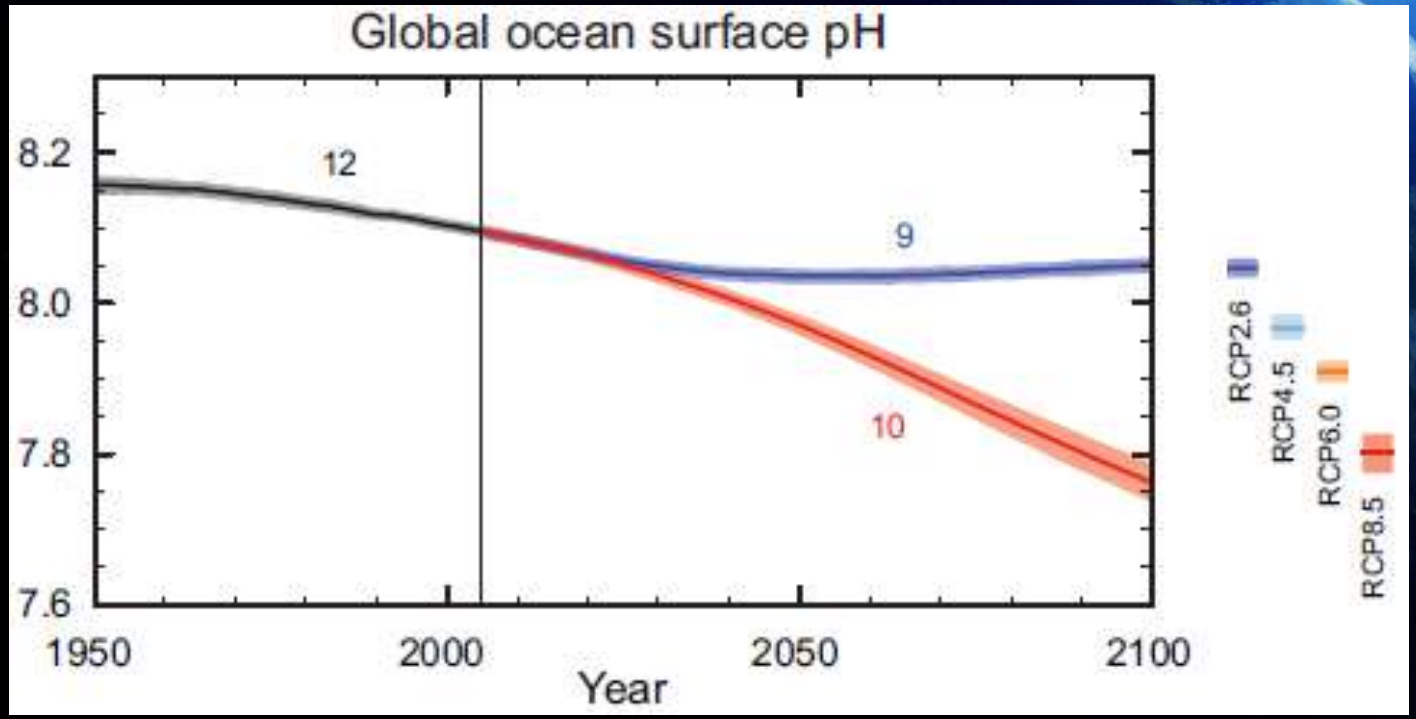


IPCC AR5 WG1 Report, Chap. 3 (2013)

The ocean is becoming more acidic and will continue to do so as it absorbs more CO_2 …….

Less CO_2 in the atmosphere means less acidification



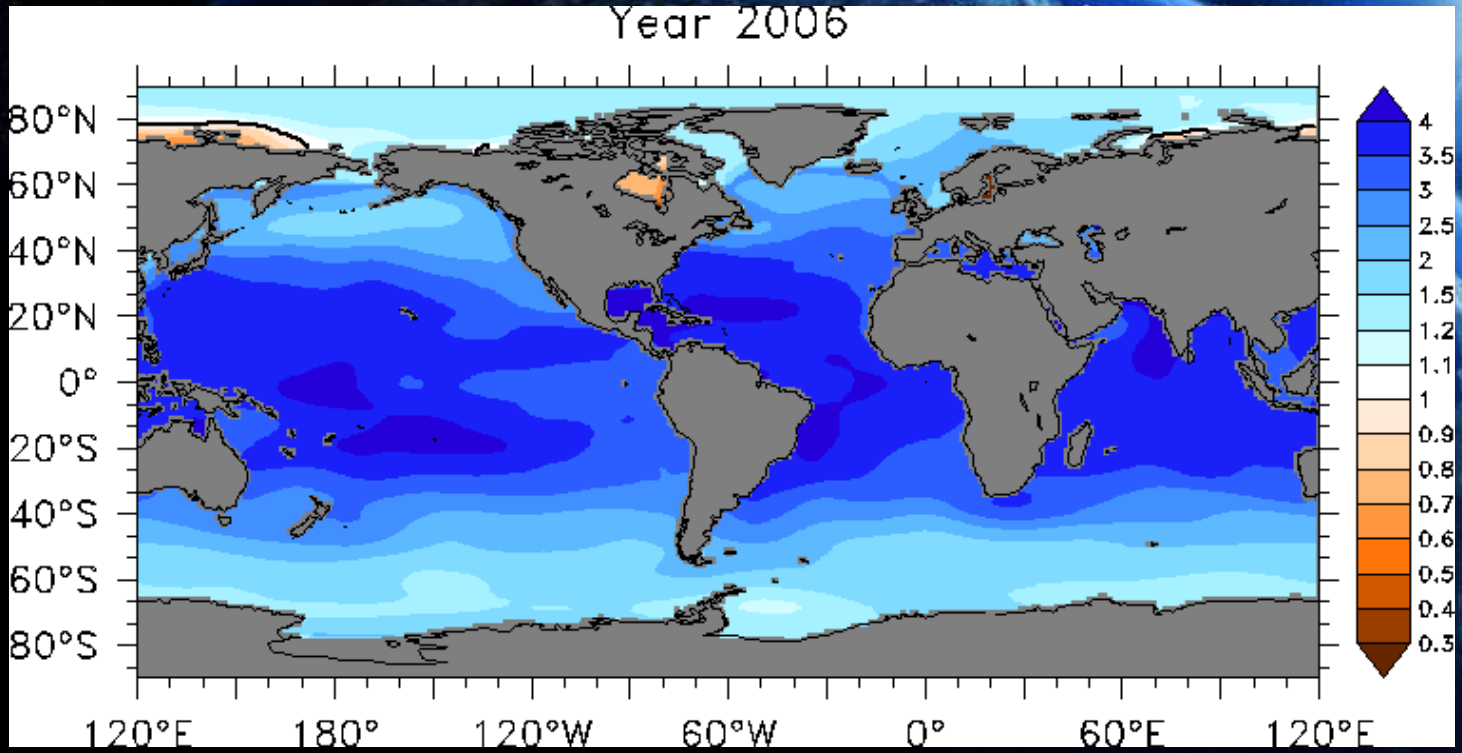


After Bopp et al. 2013

CMIP5 model simulations for global ocean surface pH. (from IPCC AR5 WGI)

Polar oceans become corrosive to shell material within decades

Models project that cold waters soon become corrosive to aragonite, a ($CaCO_3$) mineral in some marine shells & skeletons



Corrosivity of waters to aragonite (when < 1, aragonite dissolves)

Animation: J. Orr

Latest model projections (IPCC AR5 WG1, 2013)

Confirms original findings: Orr et al. (2005, Nature), Calderia & Wickett (2005), Steinacher et al. (2009)

Change (online 2 Dec)

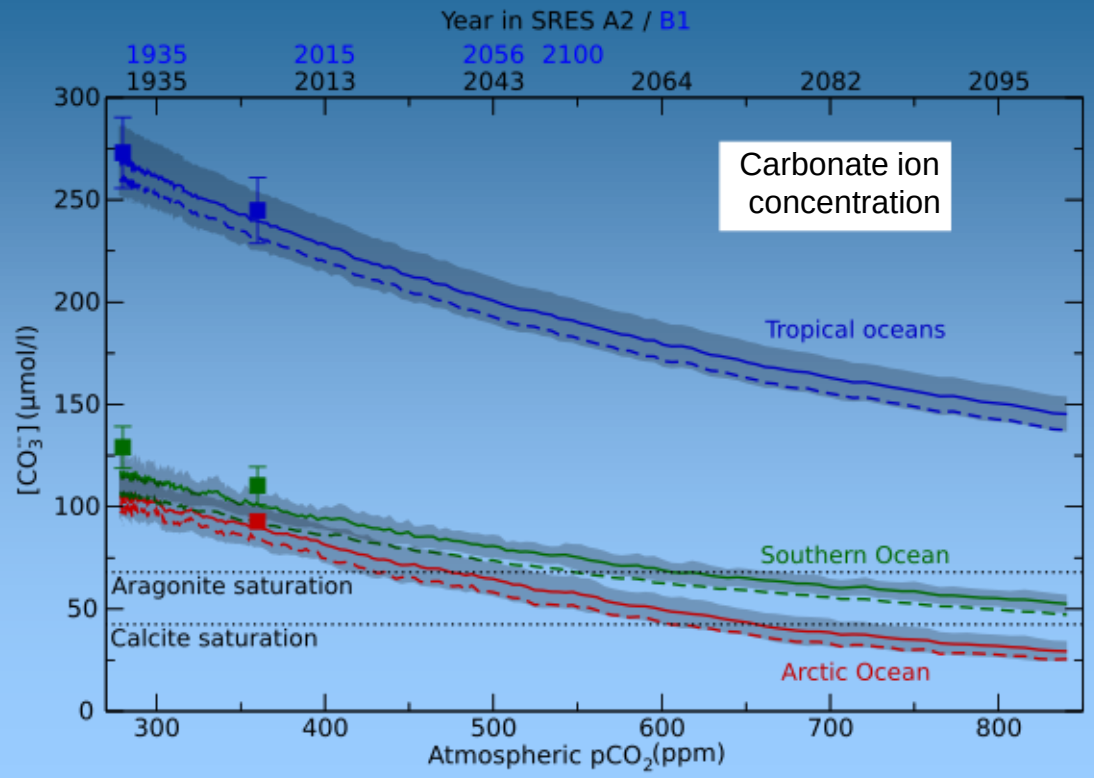
Early vulnerabilities….

If CO_2 emissions continue to rise as today:

- 10% of Arctic surface waters will be corrosive by 2018

- 50% by 2050

- 100% by the end of the century

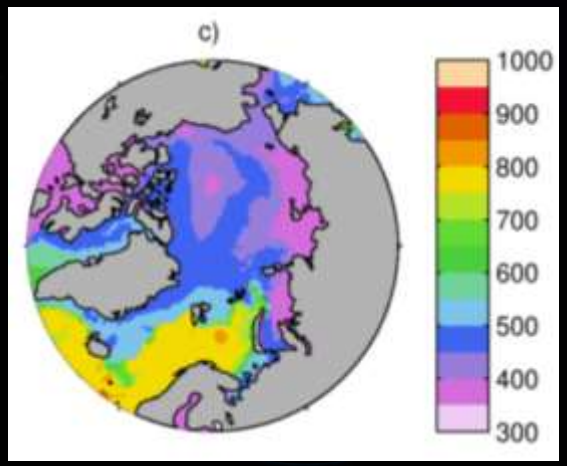


Steinacher et al. 2008, Orr et al. 2009

Arctic - first ocean with widespread undersaturation

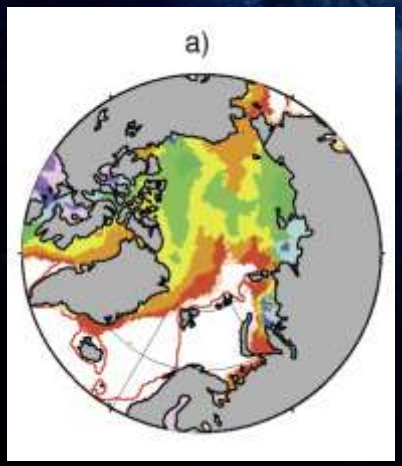
- Heterogeneity driven by sea-ice loss / impacts
- Strongly underlines importance of model resolution and accuracy of sea-ice simulation

Atmospheric pCO_2 at undersaturation

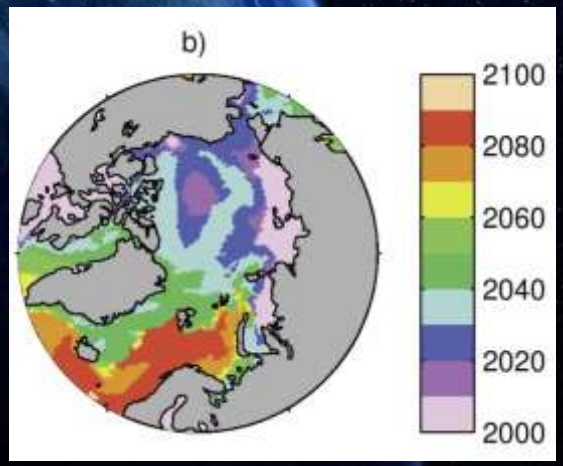


Time-to-undersaturation

Calcite



Aragonite

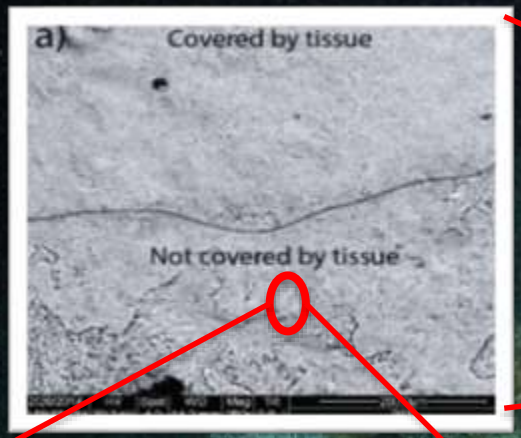


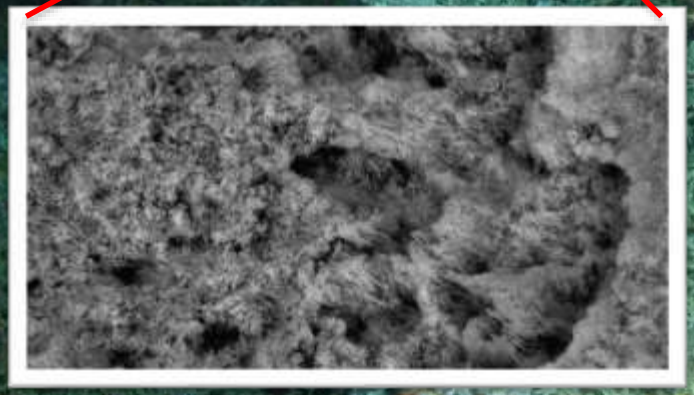
Change (online 2 Dec)

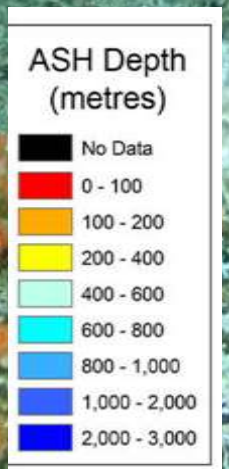
A Yool, National Oceanography Centre

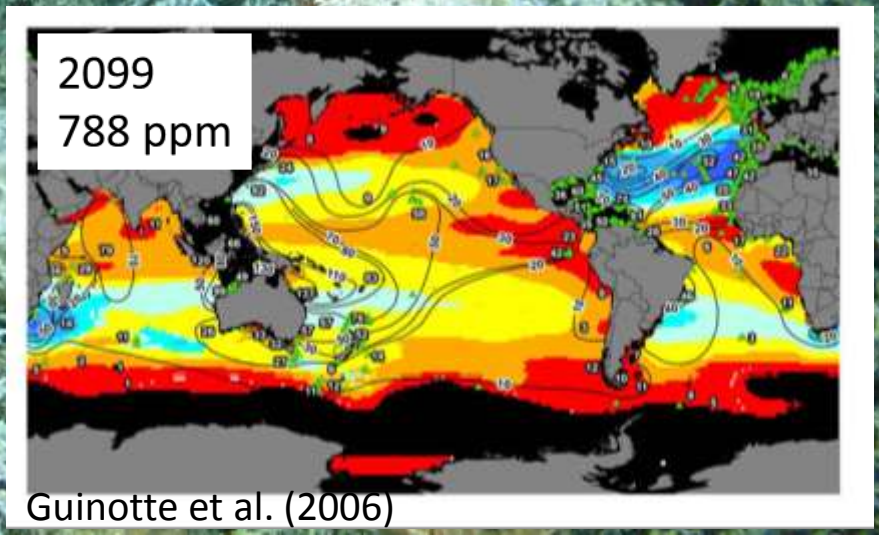
Cold water coral ecosystems very vulnerable due to shoaling of the aragonite saturation horizon

Unprotected skeletons will dissolve so these extensive ecosystems are threatened especially in high latitudes







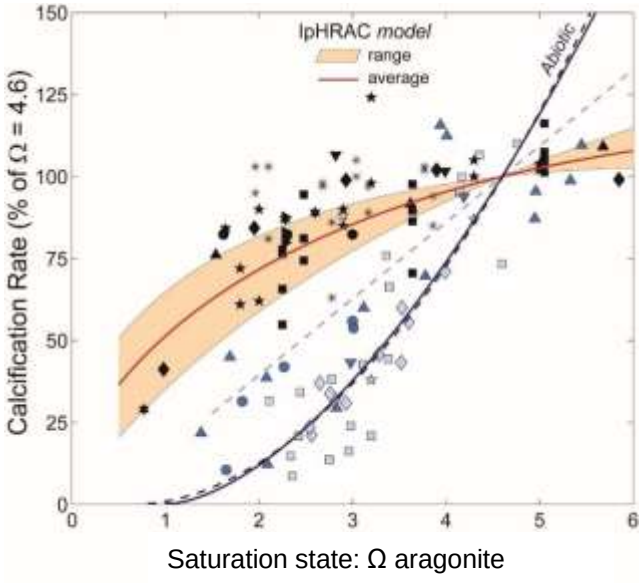


Guinotte et al. (2006)

Climate, Biodiversity and Ocean Acidification (OA)

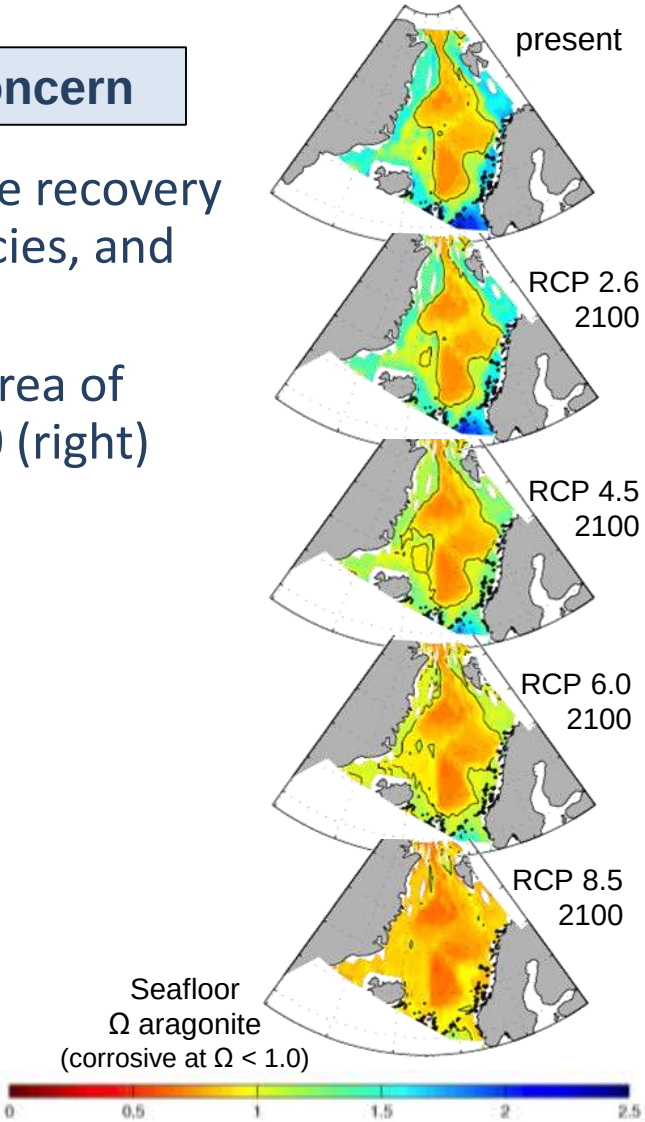
OA effects on corals: a particular concern

- Acidification slows calcification (below), and hence recovery from bleaching. Reef loss affects many other species, and increases the impacts of sea-level rise
- Cold-water corals are at risk from the increasing area of seafloor experiencing aragonite saturation of <1.0 (right)



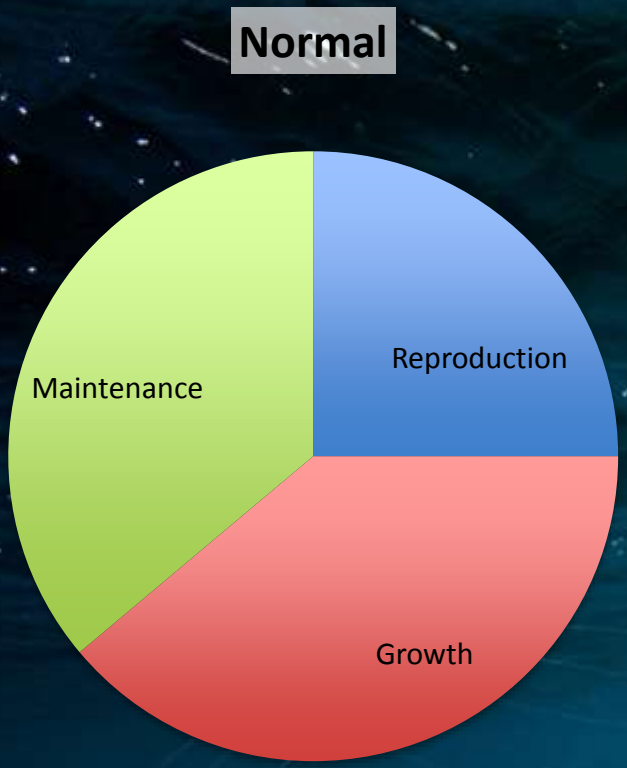
Saturation state: Ω aragonite

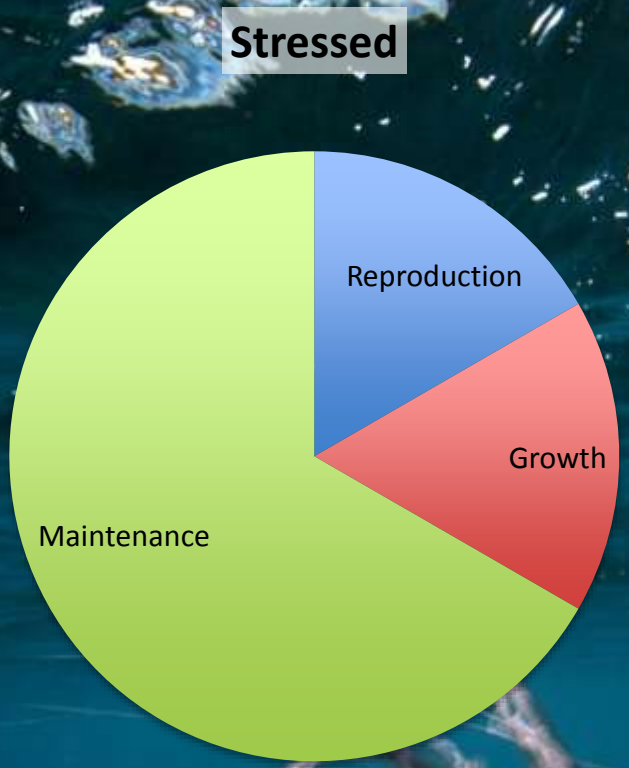
McCulloch et al (2012)
Nature Climate Change



A Olsen & J Tjiputra; OSPAR-ICES OA Study Group

Ocean acidification and impacts on energetic budgets



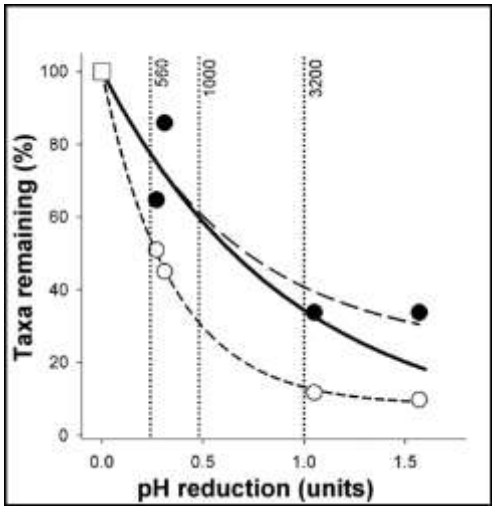


- Ocean acidification causes internal imbalance
- This can suppress metabolism, reduce protein synthesis and impact long-term fitness
- Energy budgets may be altered to cope

Graphic redrawn from Barry et al. (2011) In: Ocean Acidification, Oxford University Press

Shift in Ecosystems as pH Decreases Near Natural CO_2 Vents

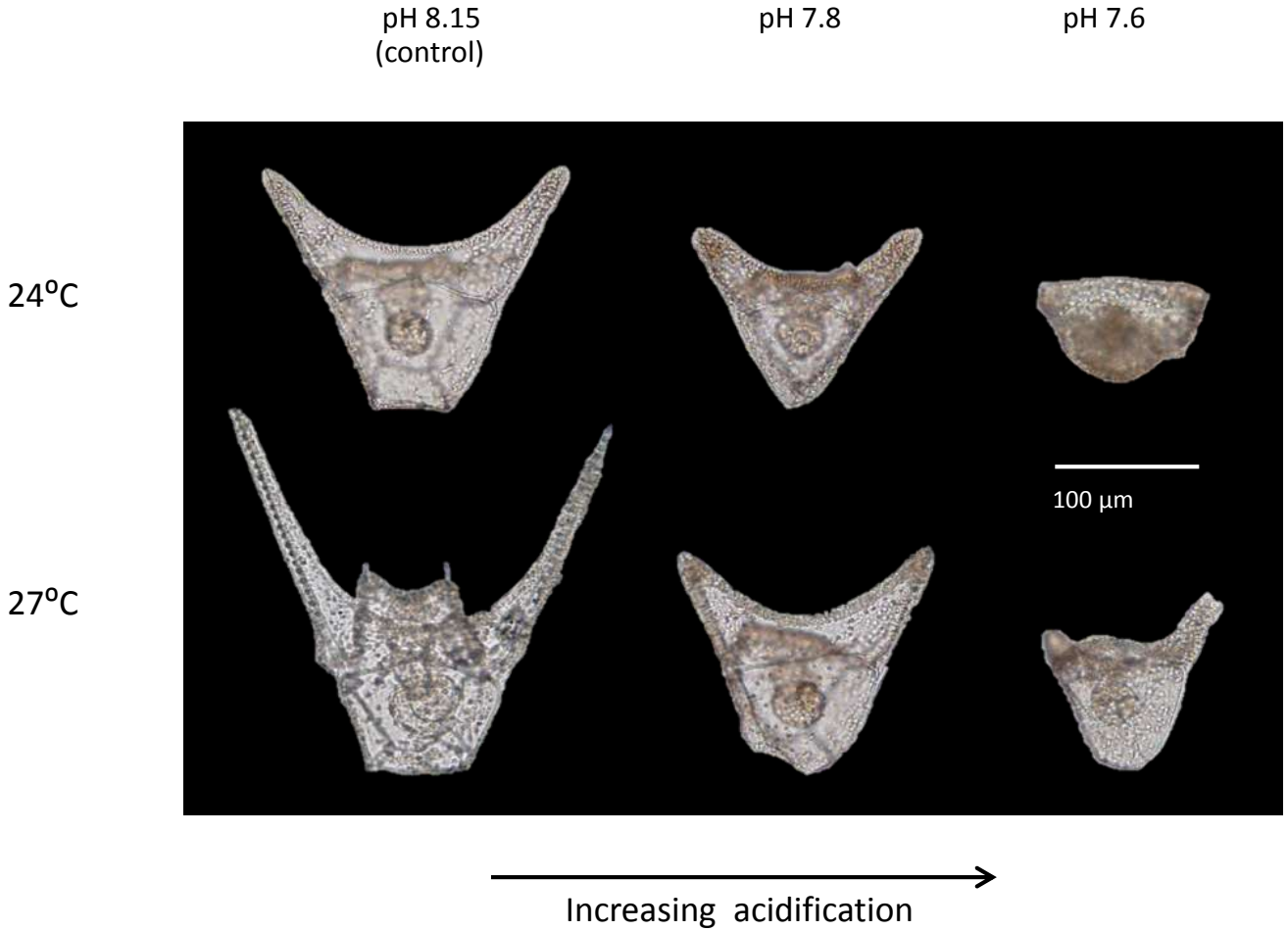
Closer to vent



- Total loss of some calcareous species
- The habitat is less biodiverse
- Some species benefit but so do invasive species e.g. seaweed production increases and sea anemones may thrive but other grazers decrease
- "Regime shifts" to totally different ecosystems are clearly visible

Hall-Spencer et al. (2008); Johnson et al. (2012); Suggett et al. (2012)

Fertilization, early life & settlement



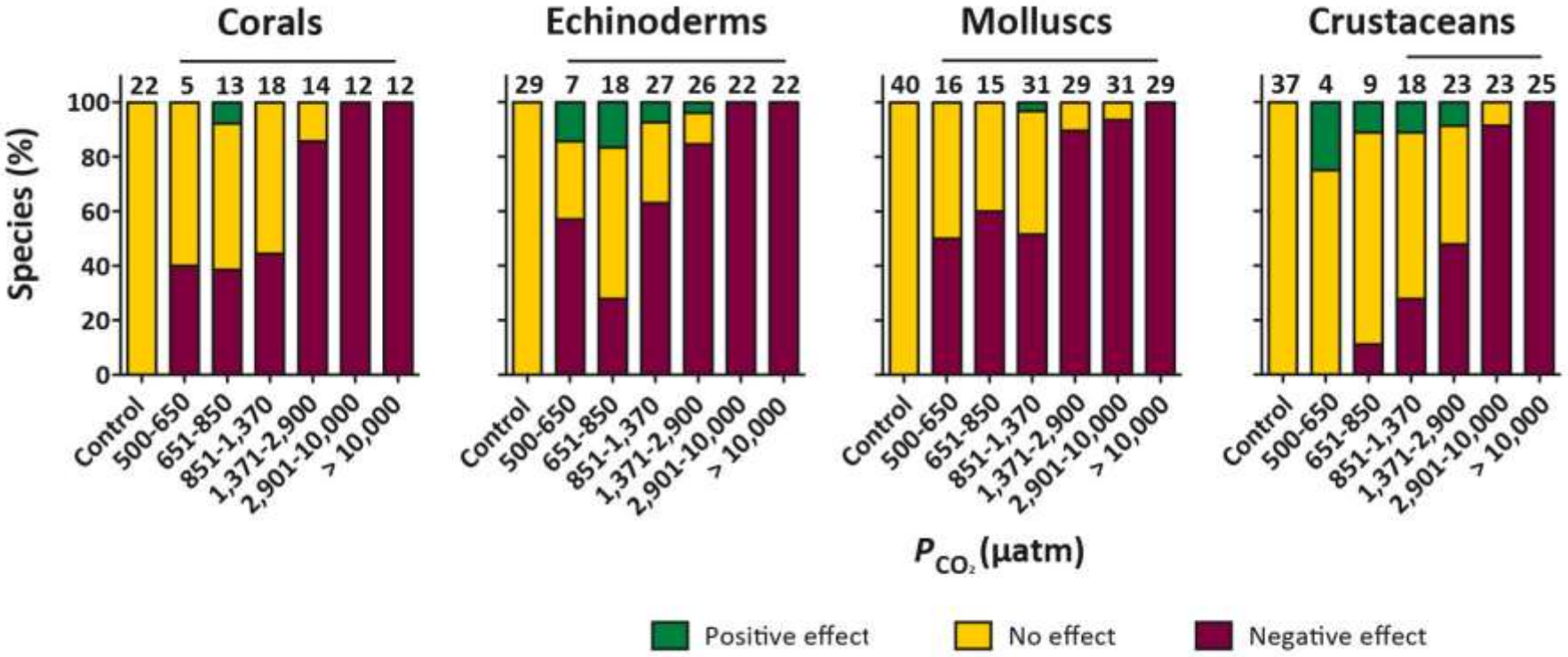
Larval development of the sea urchin *Tripneustes gratilla*

- Increased temperature reduced the negative effect of pH on larval growth
- Affects future growth
- May increase predation

Source Maria Byrne and co-workers (2012)

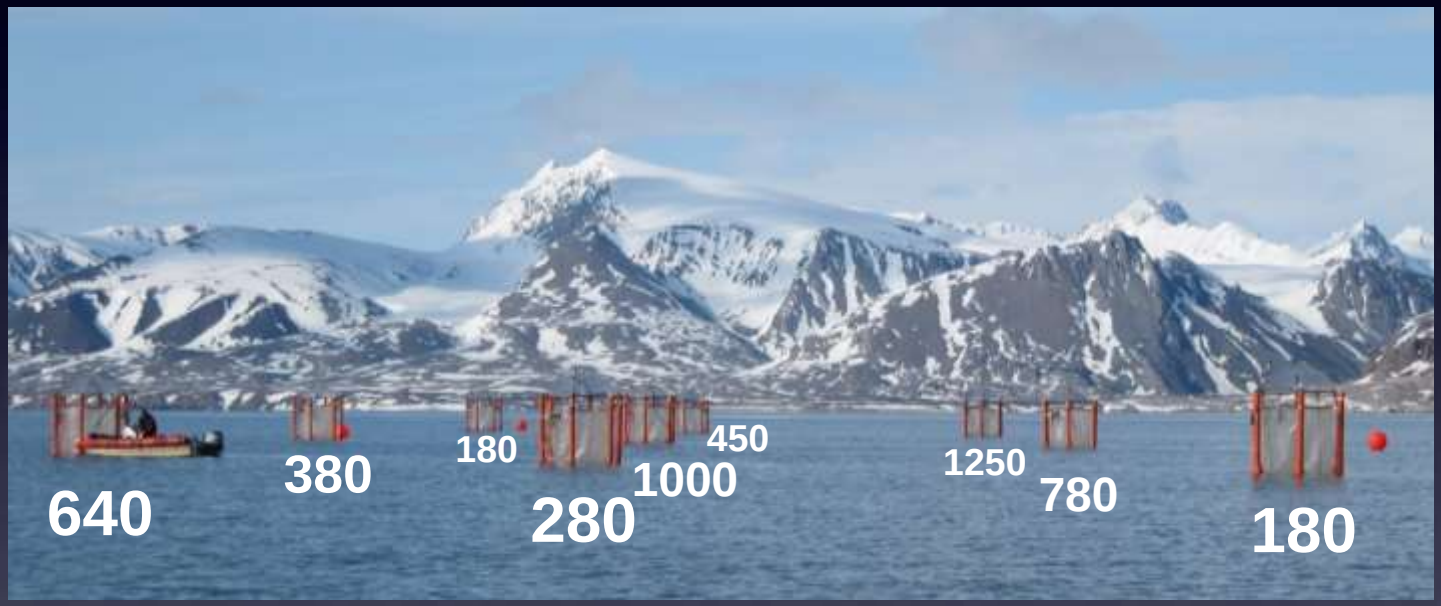
Benthic communities

- Responses very variable, but most taxa show lower growth & survival
- Corals generally negatively affected vs. crustaceans relatively resilient



Wittmann AC, Portner H-O (2013) Nature Climate Change 3: 995-1001

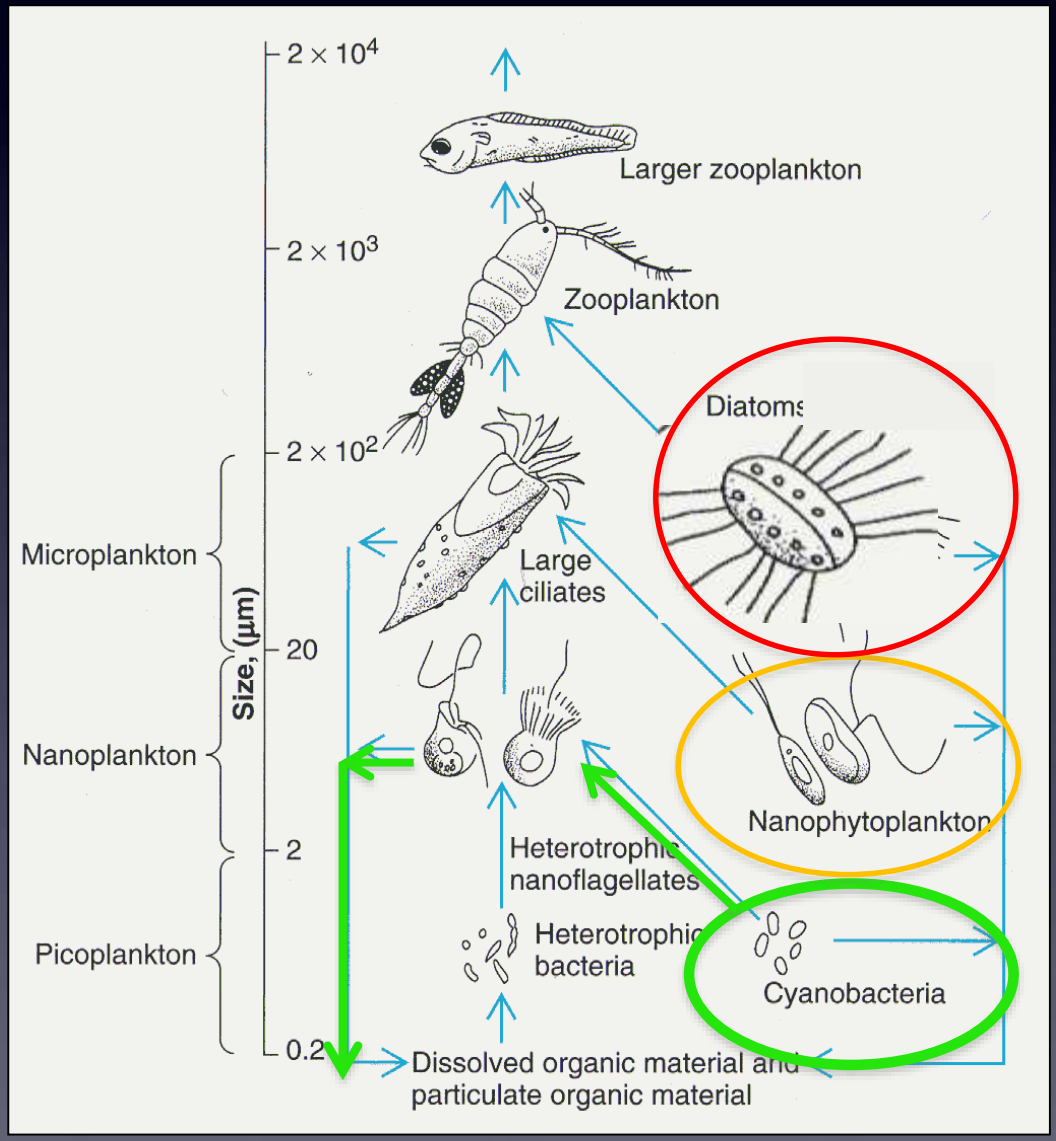
Svalbard 2010: CO_2 enriched pelagic mesocosms



35 participants from 12 partner institutes

EPOCA
European Project on OCean Acidification

Major Changes at the Base of the pelagic foodweb



.... with likely consequences for higher trophic levels and foodwebs

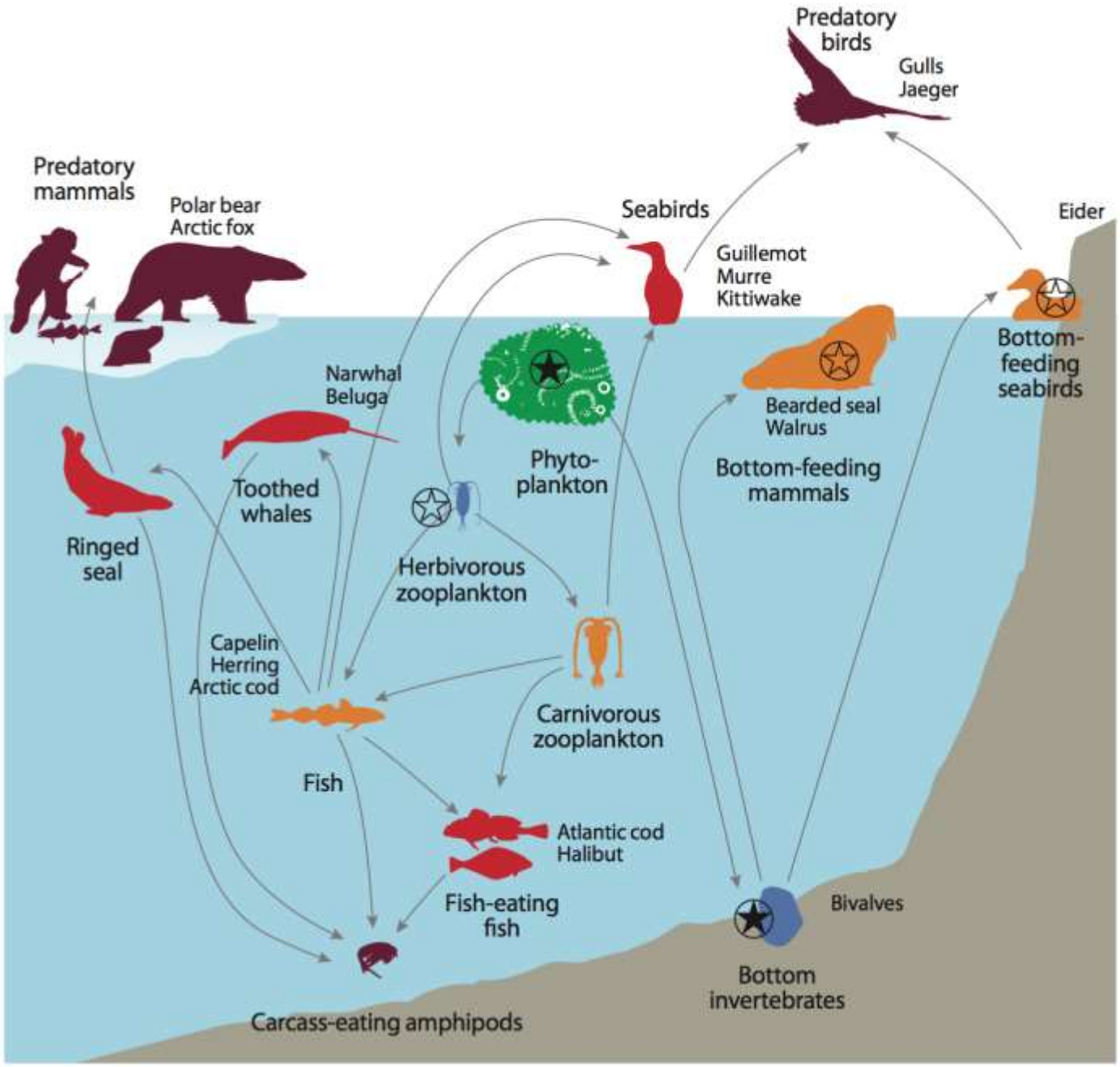
outcompeted at high CO_2

moderately stimulated at high CO_2

strongly stimulated at high CO_2

(unpublished data coutesy Ulf Reibesell, BIOACID and EPOCA)

Generalized Arctic food web



Direct effects likely

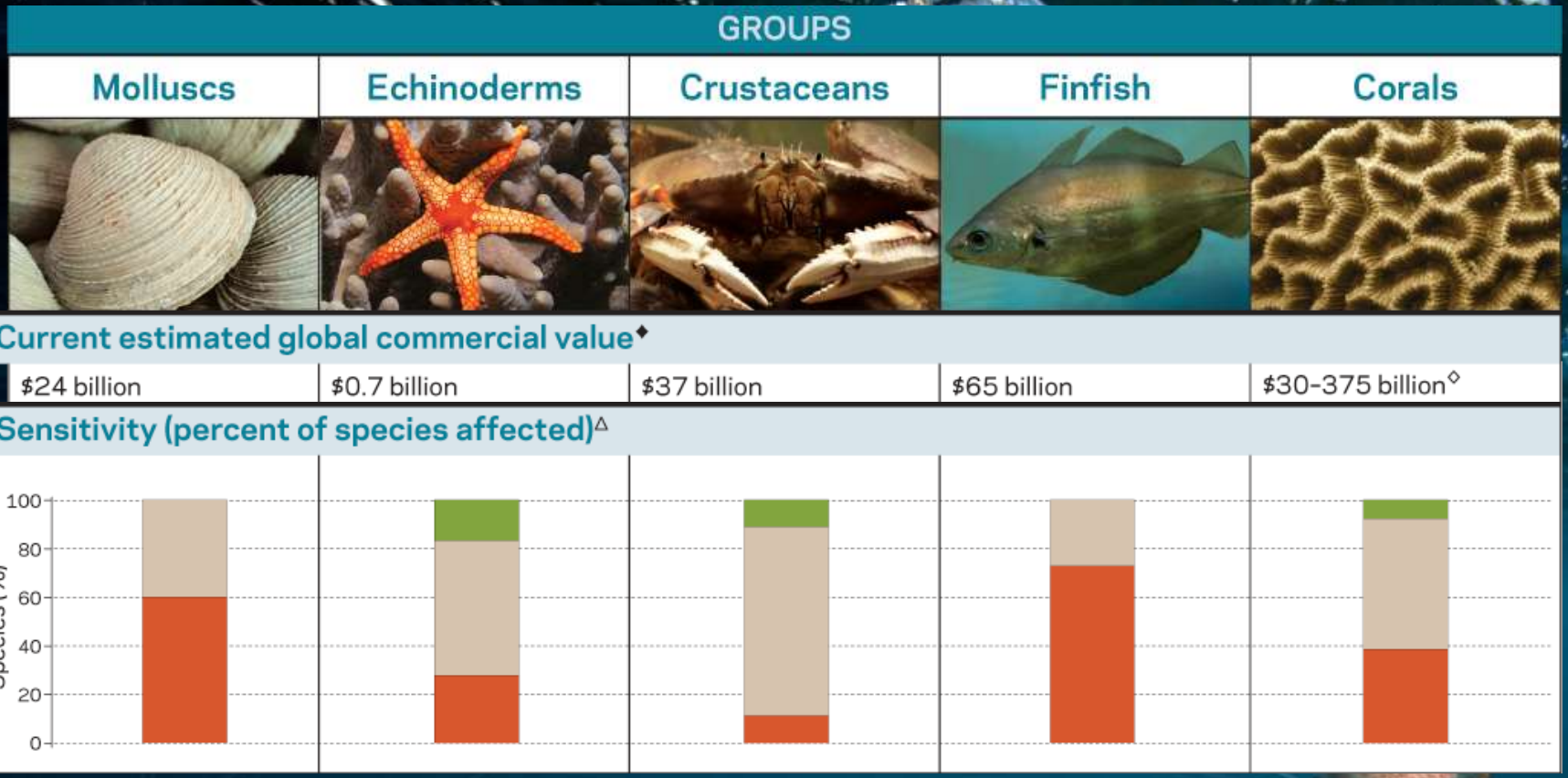
Indirect effects likely (e.g. altered predator-prey relationships)

From: AMAP Assessment 2013: Arctic Ocean Acidification (adapted from original by Murray et al. 1998)

From: AMAP Assessment 2013: Arctic Ocean Acidification (adapted from original by Murray et al. 1998)

Ocean acidification will also affect humans

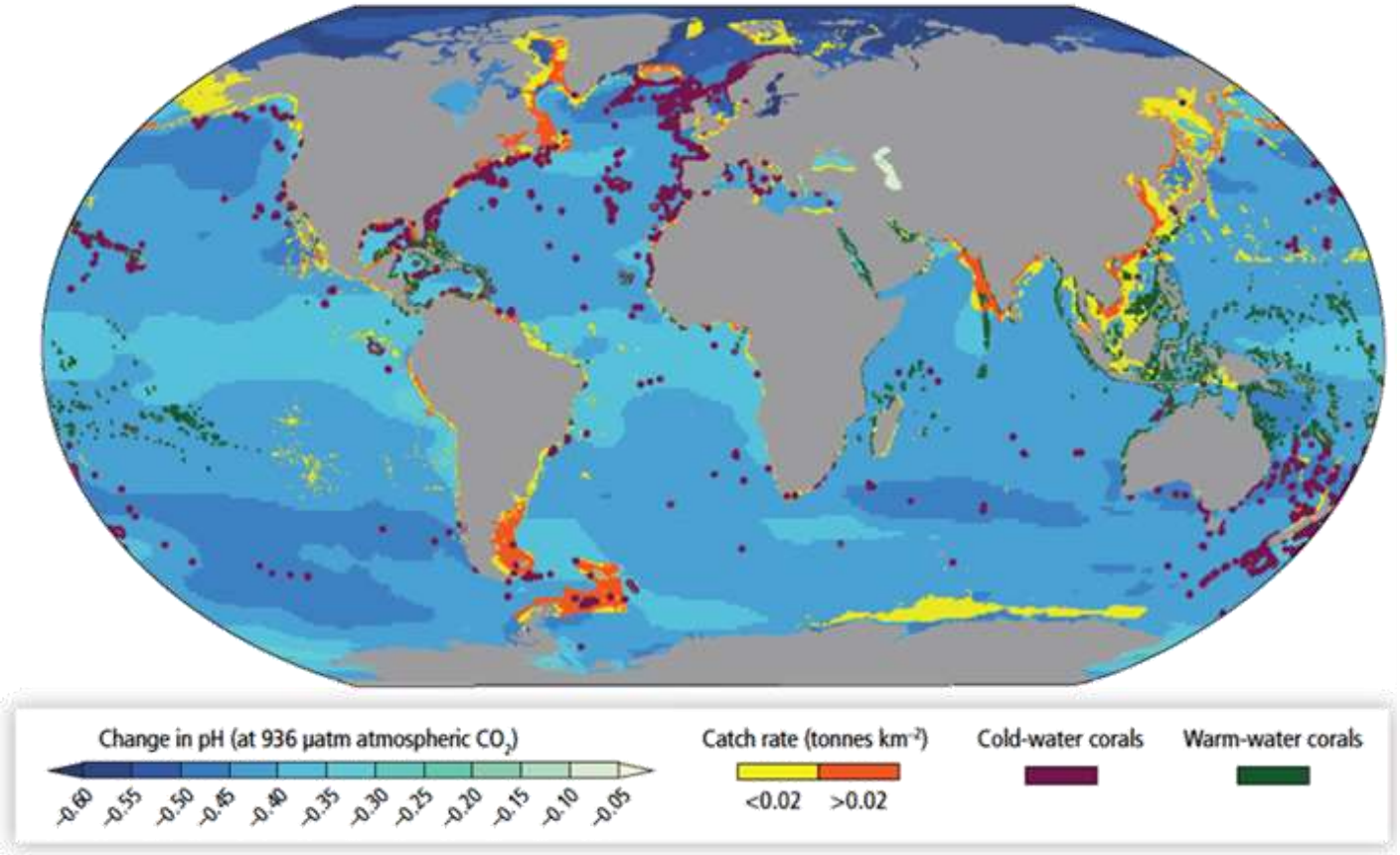
- Commercially important organisms



Ocean acidification may affect aquaculture, fisheries, and human livelihoods

Species vulnerable to ocean acidification - of high socio-economic or ecological importance

Arctic particularly vulnerable to fisheries loss and regime shift in key ecosystems

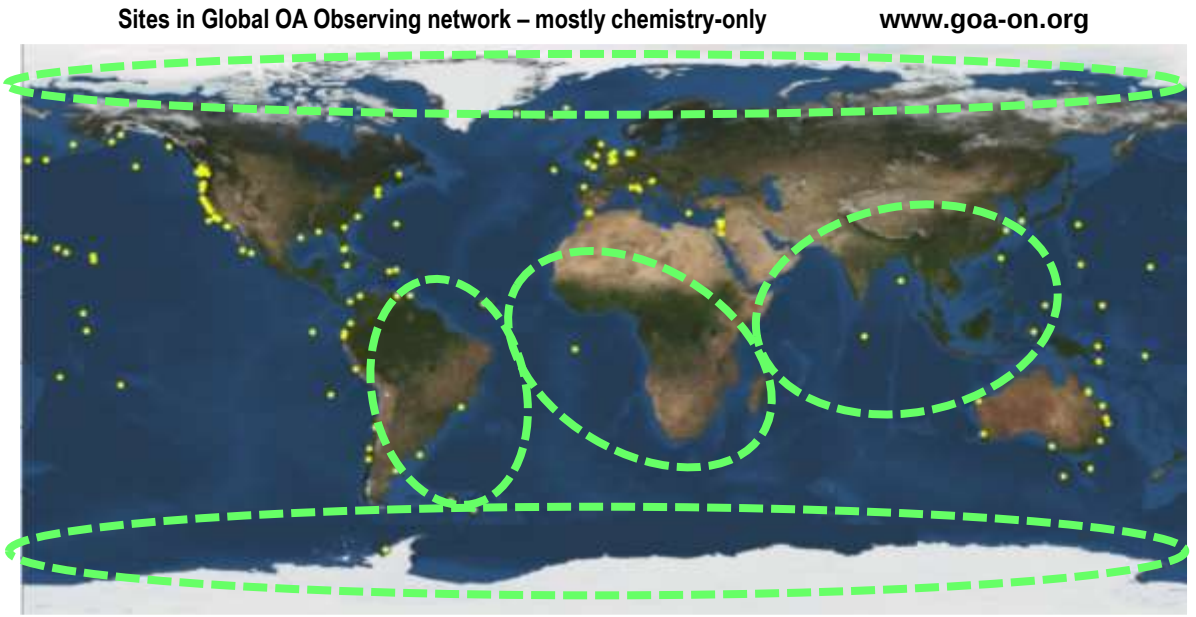


IPCC AR5 WGII Figure 6.10, SPM.6

Climate, Biodiversity and Ocean Acidification (OA)

Detecting impacts: increased CO_2 = increased risk

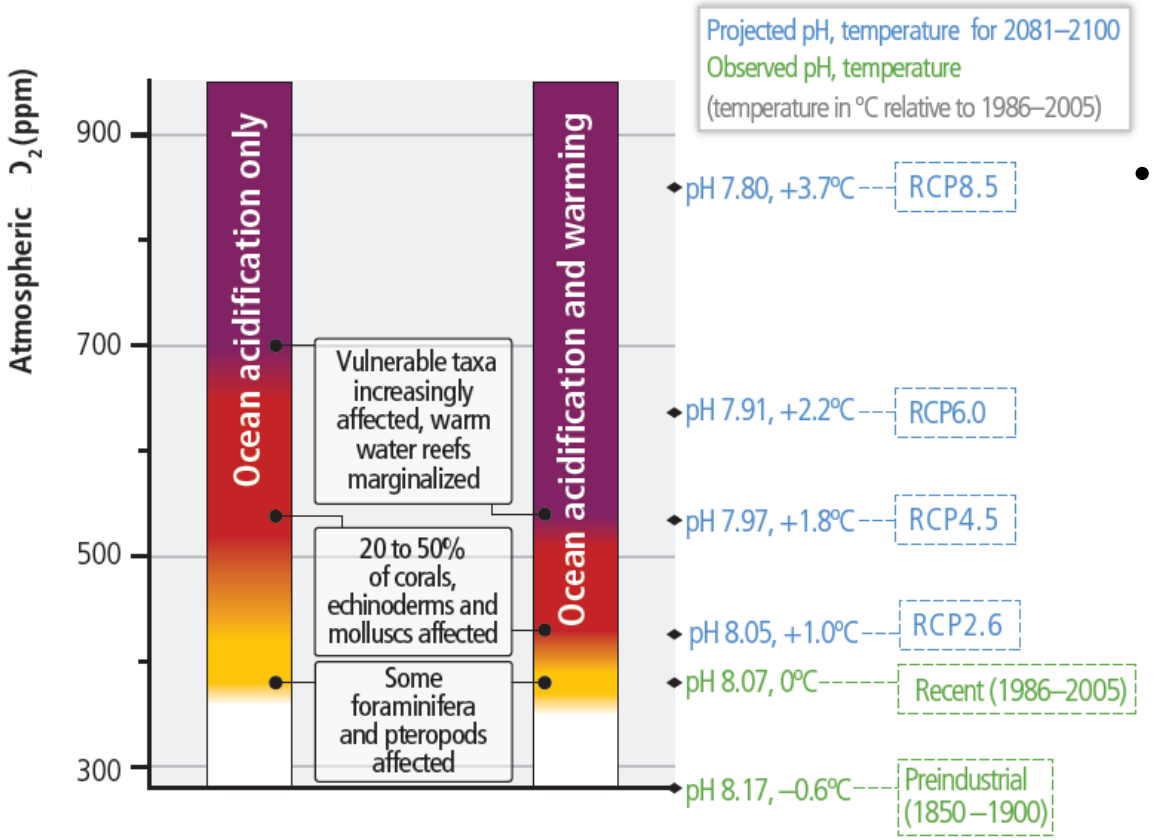
- OA impacts are evident in US oyster hatcheries, and seem to be increasing shell erosion of pteropods (planktonic molluscs) and slowing coral growth
- A global OA observing network is being developed to relate chemical and biological changes, but there are currently many gaps in coverage



Climate, Biodiversity and Ocean Acidification (OA)

The difference between 1.5º and 2.0ºC: increased risk

(B) Risk for marine species impacted by ocean acidification only, or additionally by warming extremes

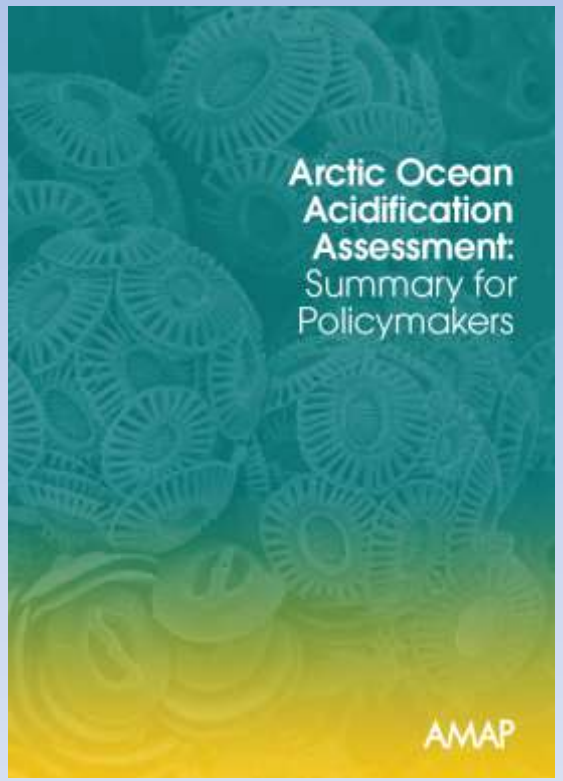


IPCC SYR 2.5

- Combined impact of ocean warming and acidification increases the risk to biodiversity

AMAP Assessment 2013

Arctic Ocean Acidification



http://amap.no/documents/

Key Findings: Socio-economic implications

Key finding 8
Ocean acidification is one of several factors that may contribute to alteration of fish species composition in the Arctic Ocean

Key finding 9
Ocean acidification may affect Arctic fisheries

Key finding 10
Ecosystem changes associated with ocean acidification may affect the livelihoods of Arctic peoples

Arctic commercial fisheries catch in excess of 7 million tonnes of fish, crabs and shrimp each year, worth billions of US$ and forming a significant contribution to many northern economies.

Richard Bellerby, AMAP

And finally - can you can taste the difference?

The Swedes can taste the difference in their beloved shrimp dish when grown at high CO_2.

Dupont et al. 2014

Thank you!

And thanks also to the many scientists that contributed their work to this presentation