These presentation files have been put together to complement the ocean acidification resource:

The Ocean of Tomorrow

prepared by the NZ Marine Studies Centre.

Please do not print or re-use this presentation for any other purpose.

Unless otherwise stated, graphs are taken from the Intergovernmental Panel on Climate Change (IPCC) reports, 2008 – 2014.

NEW ZEALAND
MARINE STUDIES CENTRE
University of Otago

www.marine.ac.nz

Part 3

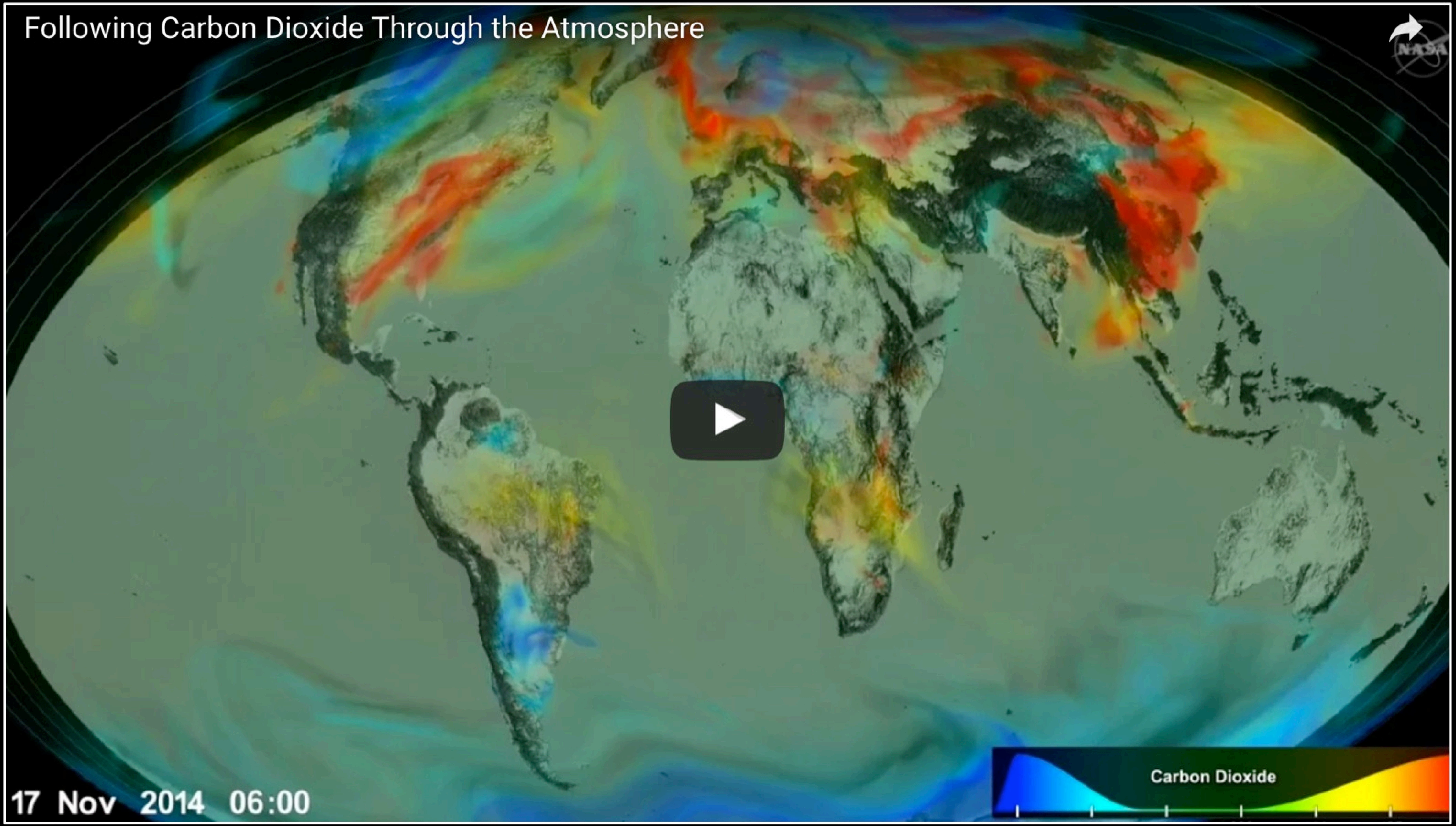
Predicting future changes.

Concerns and possible consequences.

Leading into Activity 4A and 4B.

How the future began

NASA's global view of CO_2



https://www.youtube.com/watch?v=syU1rRCp7E8

Credits: NASA's Goddard Space Flight Center/K. Mersmann, M. Radcliff, producers

The future

• Pre-industrial	280 ppm	8.16
• Present	400 ppm	8.05
• Double	560 ppm	7.91
• Triple	840 ppm	7.76

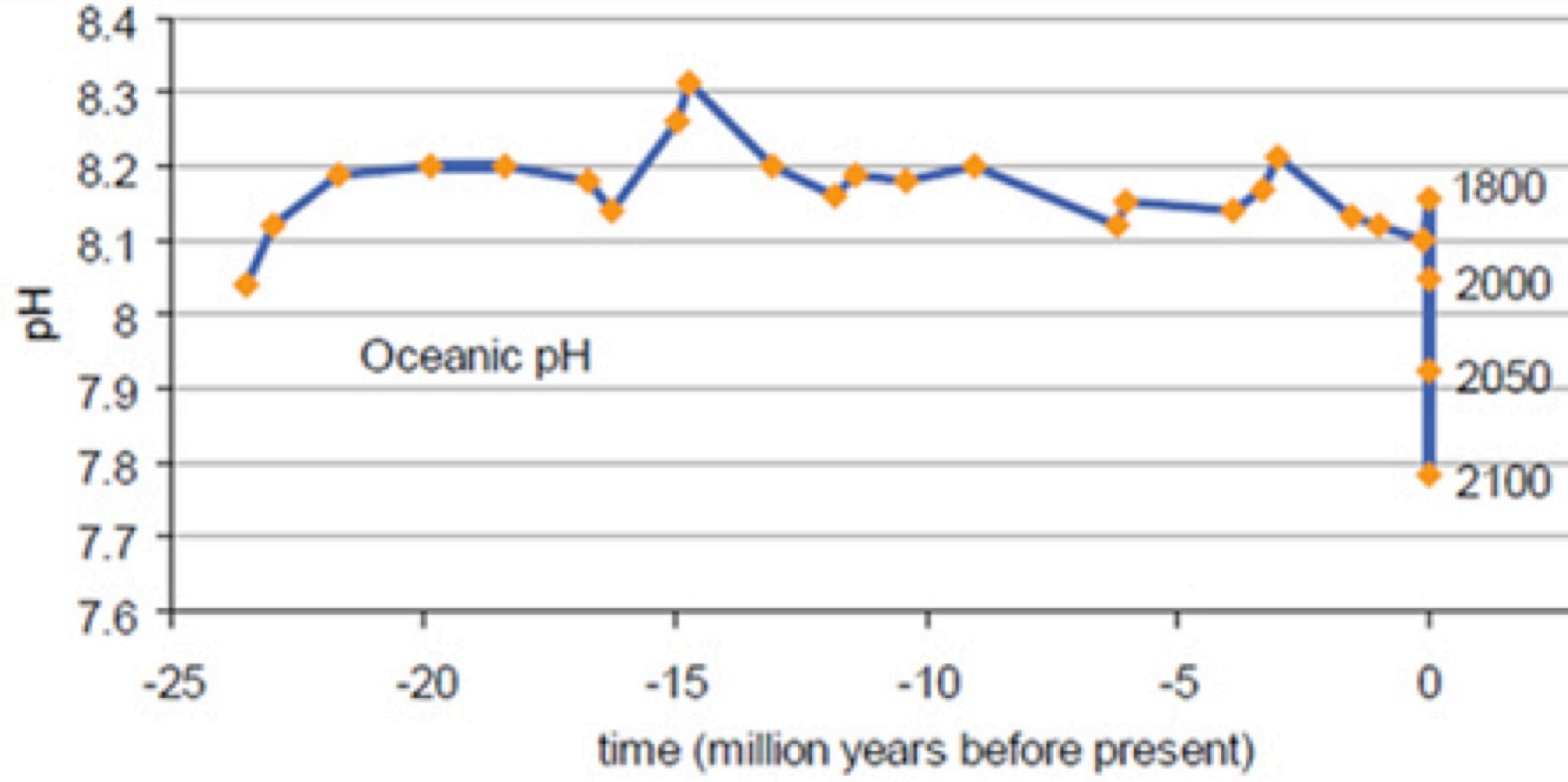
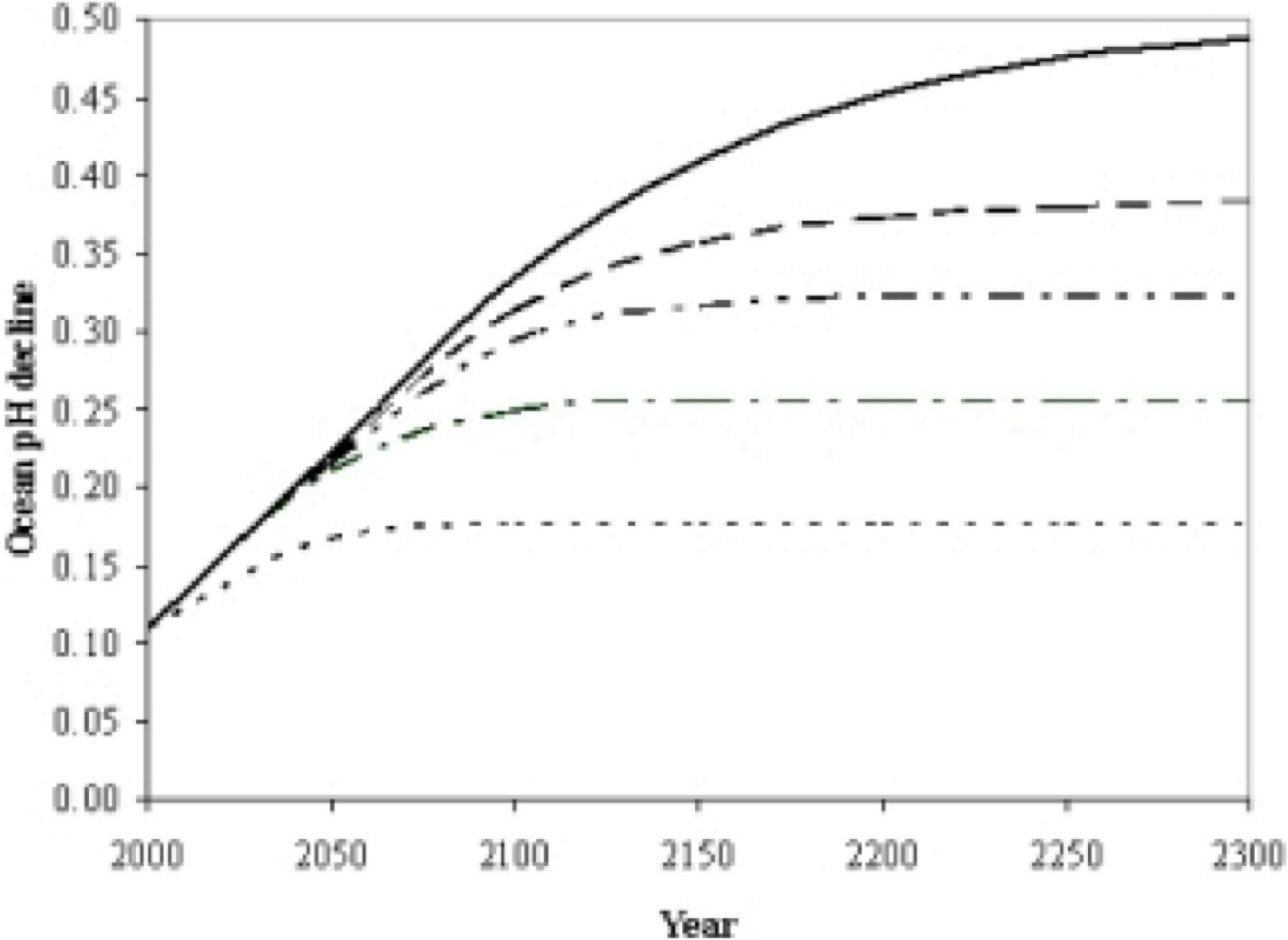


Figure 1. Past and contempory variability of marine pH. Future predictions are model derived values based on IPCC mean scenarios (from Turley *et al*, 2006. Cambridge University Press, 8, 65-70).

Future levels

- If current CO_2 emissions trends persist, H^+ ion concentration could triple by 2100
- pH would go down to about 7.8
- Is this a lot?



Ocean pH decline
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2000
2050
2100
2150
2200
2250
2300
Year

So who cares?

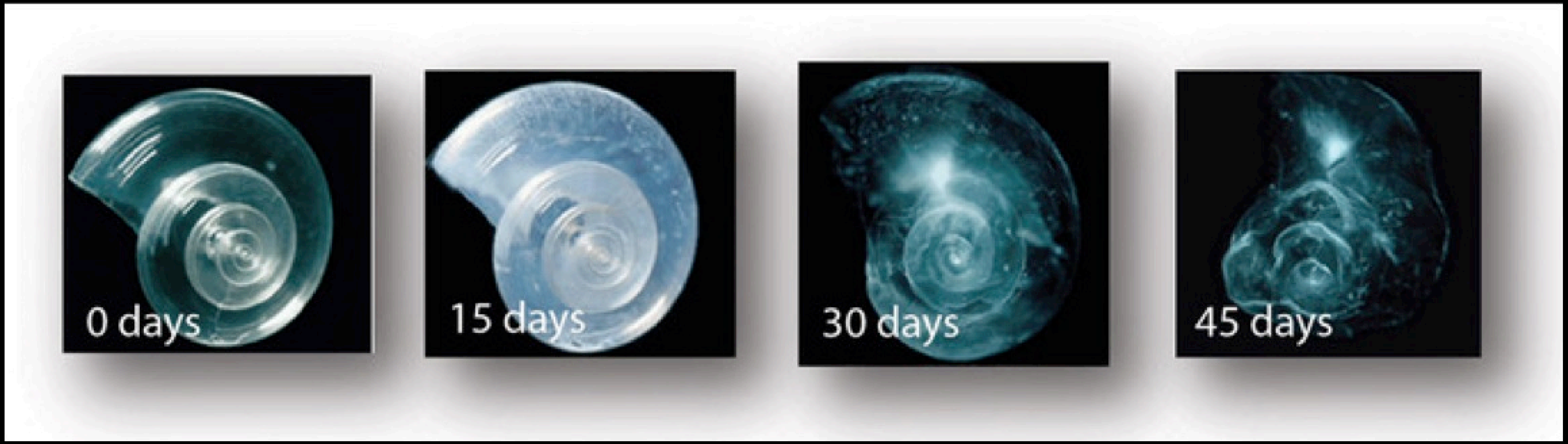
- Calcifying organisms do
- It could be harder to make a shell in lower pH conditions
- Existing shells dissolve more easily in lower pH
- Change is so rapid that evolution may not be able to keep up

It could be harder to make a shell in lower pH conditions

- Loss of skeletal volume
- Change of skeletal mineralogy
- Environmental displacement
- Inability to calcify
- Inability to reproduce
- Mortality (of various life stages)

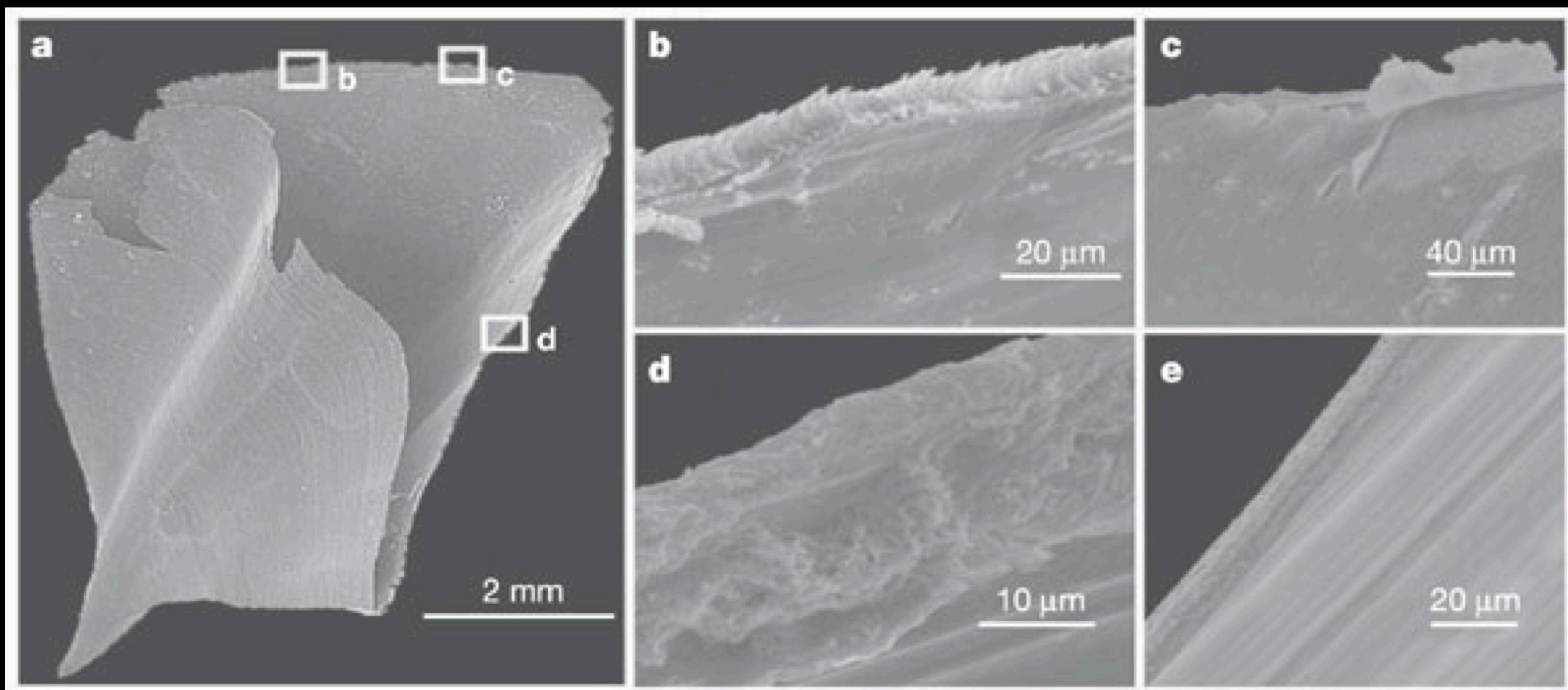
(Orr et al., 2005; Raven et al., 2005)

What happens to different shells under lowered pH?



Structure?
Weight?
Loss of material?

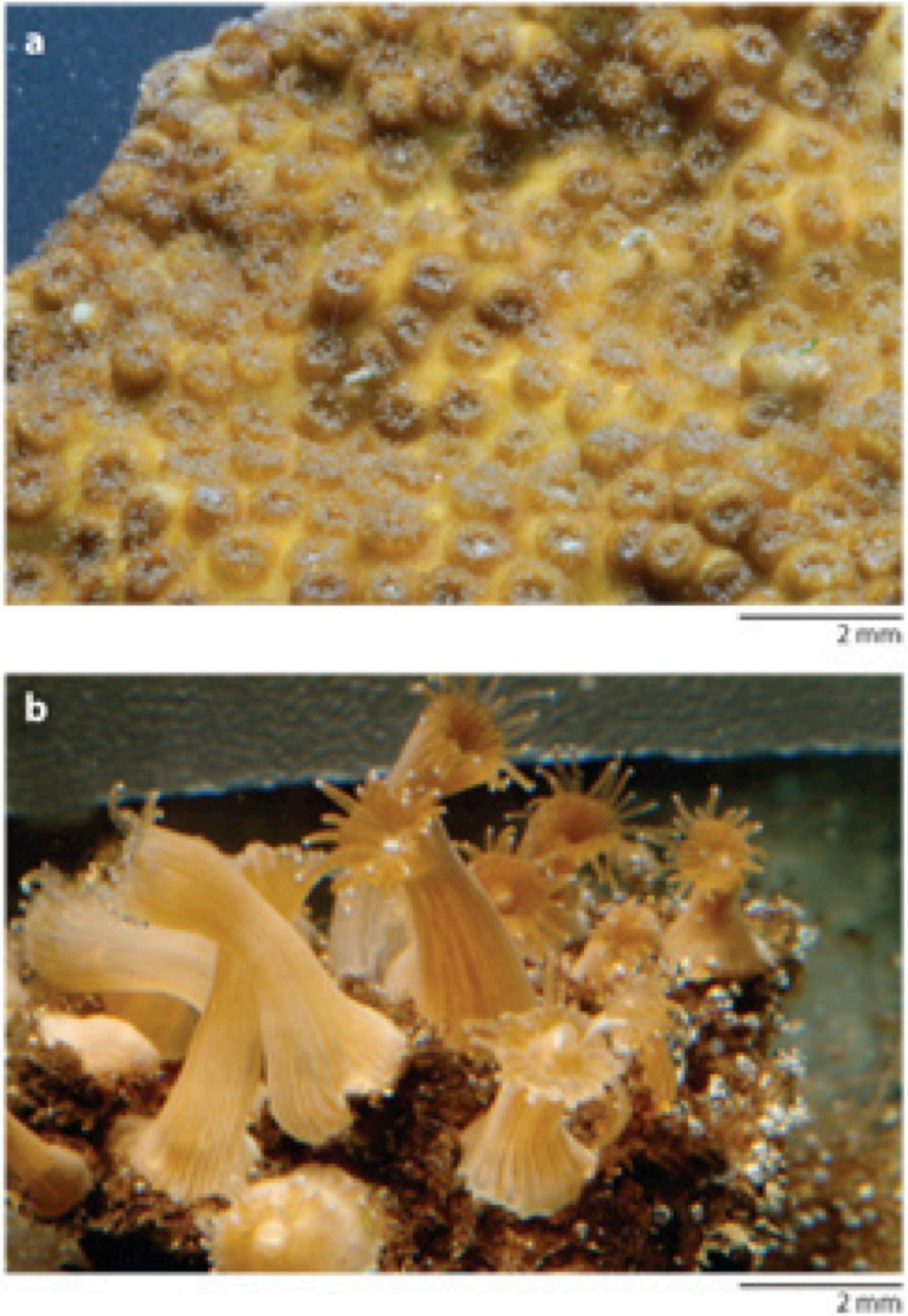
Pteropods



A-D: Pteropod exposed 48 hours in low pH water.
E: normal

(Orr et al, 2005)

Corals

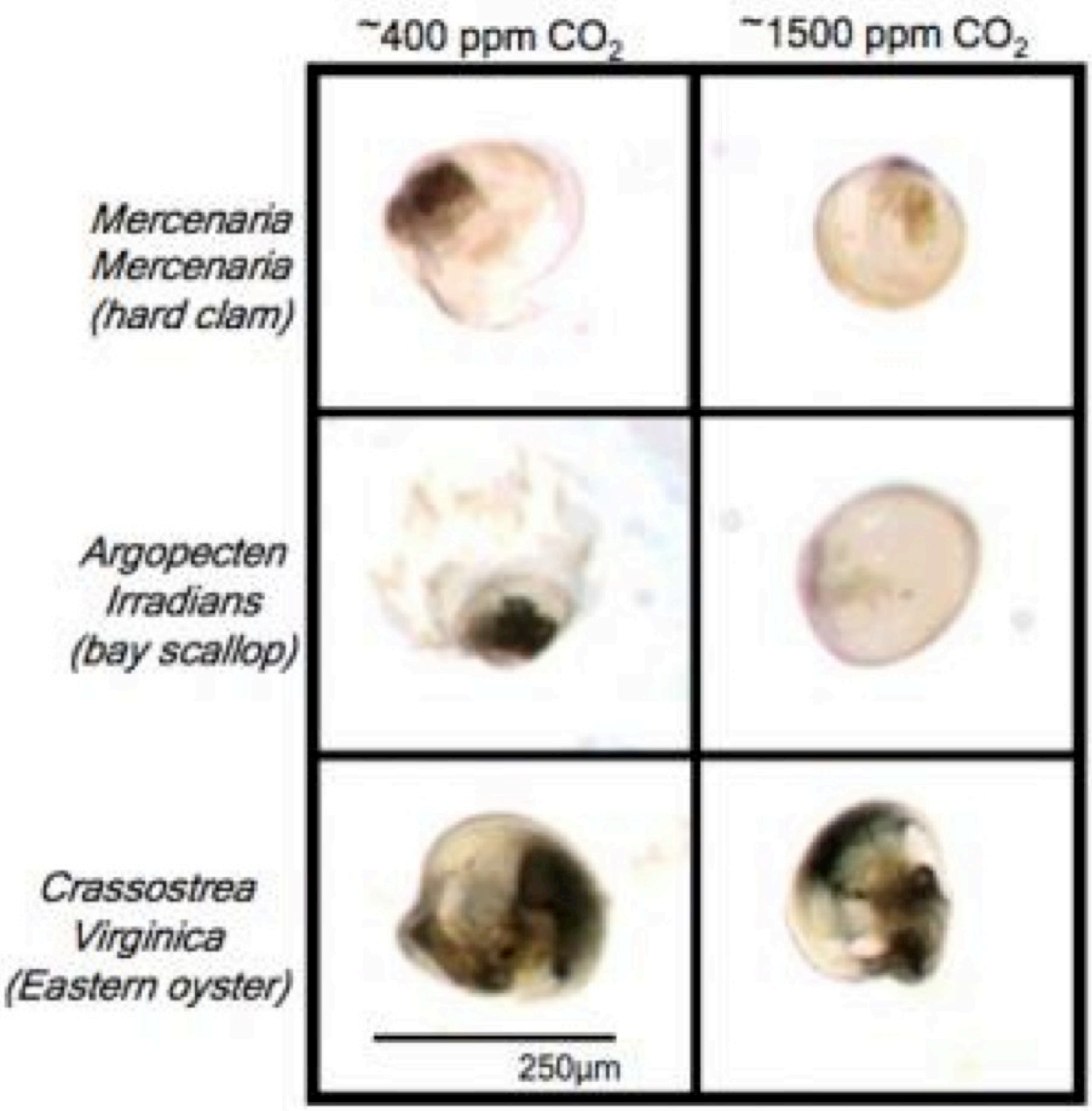


pH = 8.2

pH = 7.6

(Doney et al 2009)

Shellfish larvae



- Reduced survival of larvae
- Smaller, slower developing larvae
- More malformed larvae

(Talmage & Gobler, 2009)

Consequences

- Thinner, damaged, malformed shells
- Different materials used for skeleton
- No skeleton at all

- Inability to reproduce, survive
- Lowered protection from energy/predation
- Lack of structural support
- Loss of habitat (reefs)

Activity 4A and 4B:
Investigating the impact of increased acidity and small size on corrosive effect of lower pH

- Are smaller pieces corroded more by acid than larger pieces?
- What might this mean for organisms in an ocean with decreasing pH?
- Do solutions with lower pH cause more corrosion than solutions with higher pH?
- What might this mean for life in an ocean with decreasing pH?

OCEAN ACIDIFICATION

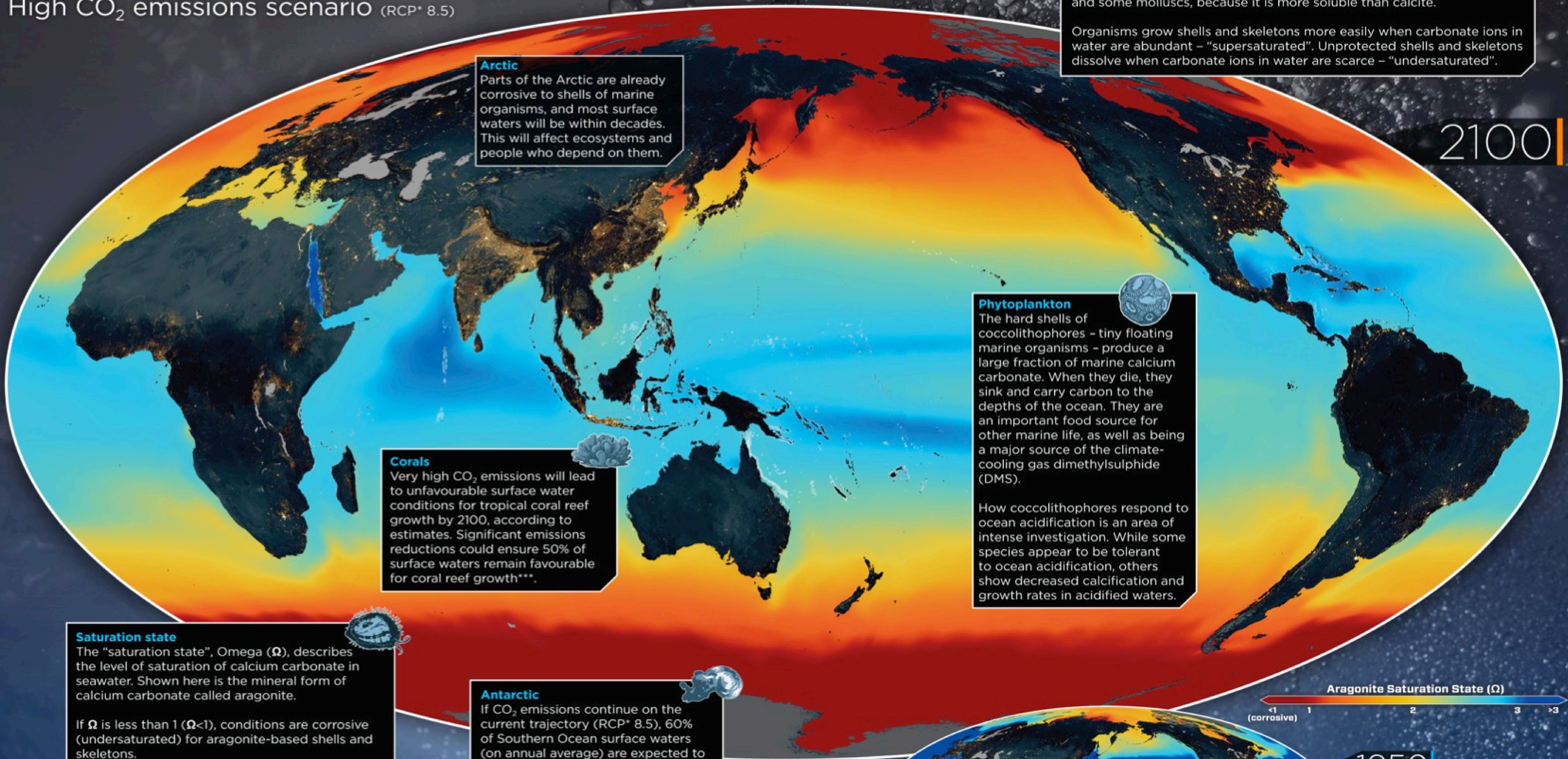
Aragonite saturation in 2100

High CO_2 emissions scenario (RCP* 8.5)

Shells and skeletons

The shells and skeletons of many marine organisms are made from either calcite or aragonite; both are forms of calcium carbonate. Scientists are particularly interested in aragonite, which is produced by many corals and some molluscs, because it is more soluble than calcite.

Organisms grow shells and skeletons more easily when carbonate ions in water are abundant – "supersaturated". Unprotected shells and skeletons dissolve when carbonate ions in water are scarce – "undersaturated".



Arctic

Parts of the Arctic are already corrosive to shells of marine organisms, and most surface waters will be within decades. This will affect ecosystems and people who depend on them.

Phytoplankton

The hard shells of coccolithophores – tiny floating marine organisms – produce a large fraction of marine calcium carbonate. When they die, they sink and carry carbon to the depths of the ocean. They are an important food source for other marine life, as well as being a major source of the climate-cooling gas dimethylsulphide (DMS).

How coccolithophores respond to ocean acidification is an area of intense investigation. While some species appear to be tolerant to ocean acidification, others show decreased calcification and growth rates in acidified waters.

Corals

Very high CO_2 emissions will lead to unfavourable surface water conditions for tropical coral reef growth by 2100, according to estimates. Significant emissions reductions could ensure 50% of surface waters remain favourable for coral reef growth***.

Saturation state

The "saturation state", Omega (Ω), describes the level of saturation of calcium carbonate in seawater. Shown here is the mineral form of calcium carbonate called aragonite.

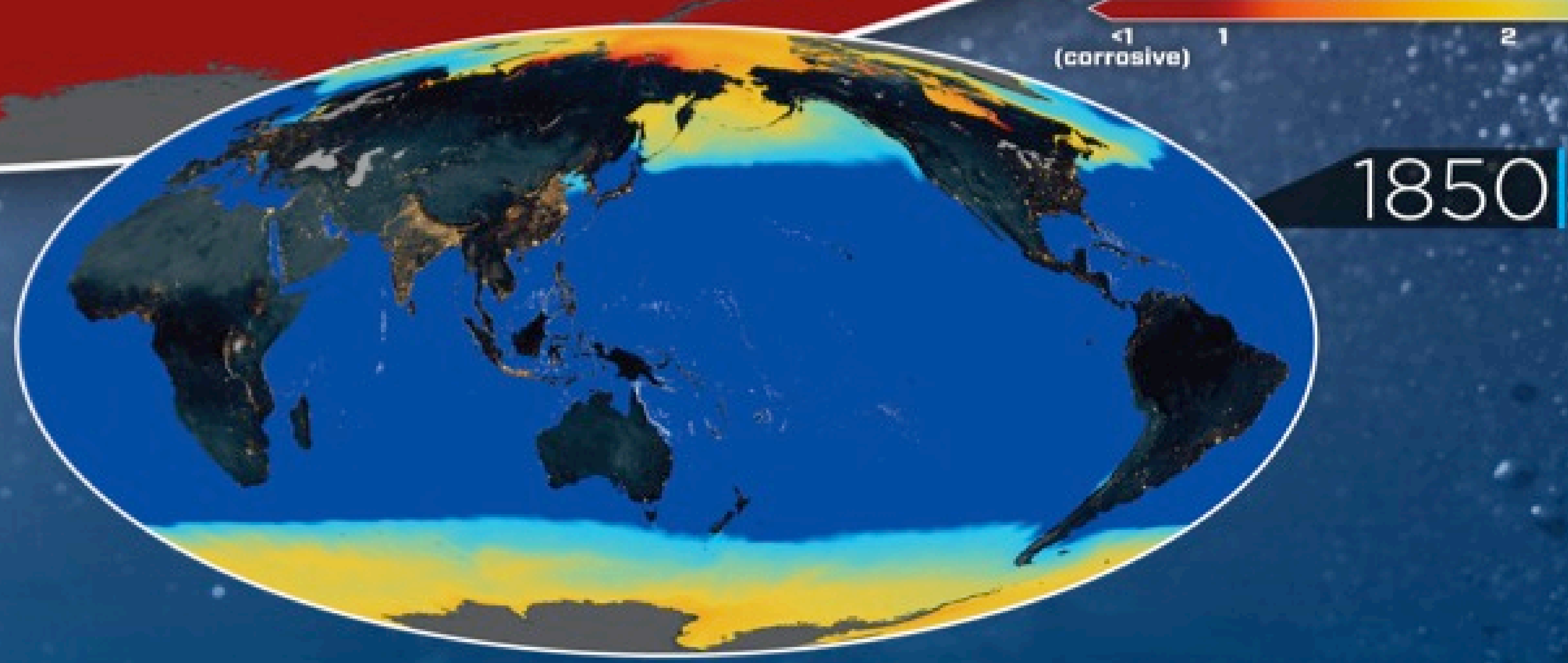
If Ω is less than 1 ($\Omega<1$), conditions are corrosive (undersaturated) for aragonite-based shells and skeletons.

When $\Omega>1$, waters are supersaturated with respect to calcium carbonate and conditions are favourable for shell formation. Coral growth benefits from $\Omega\geq3$.

By 2100, computer model projections show that Ω will be less than 3 in surface waters around tropical reefs if CO_2 emissions continue on the current trajectory***.

Antarctic

If CO_2 emissions continue on the current trajectory (RCP* 8.5), 60% of Southern Ocean surface waters (on annual average) are expected to become corrosive to the aragonite-shelled organisms, for example pteropods, which are part of the marine food web. Substantial emissions reductions (RCP* 2.6) could prevent most of the Southern Ocean surface waters from becoming corrosive to the shells of aragonitic organisms**.



* Intergovernmental Panel on Climate Change emissions scenarios — Representative Concentration Pathways (reference 1).
** Personal communication: Joos & Steinacher, after Steinacher *et al.*, 2013 (reference 10).
*** Ricke *et al.*, 2013 (reference 11).

Ocean acidification maps: model data provided by Tatiana Ilyina from Ocean Biogeochemistry Group, Max Planck Institute for Meteorology.
Design: Félix Pharand-Deschênes, Globaïa.

This infographic is part of the *Ocean Acidification Summary for Policymakers – Third Symposium on the Ocean in a High-CO_2 World*, sponsored by IGBP, IOC-UNESCO and SCOR.
More information: www.igbp.net.