Ocean Acidification: The Other Half of the CO_2 problem: Getting the Message across to Policy Makers

Carol Turley
Plymouth Marine Laboratory
ct@pml.ac.uk

With thanks to the many scientists who have contributed to the contents of this presentation

Geoscience information for Teachers (GIFT) Workshop, Austria Centre Vienna, 15 April 2008

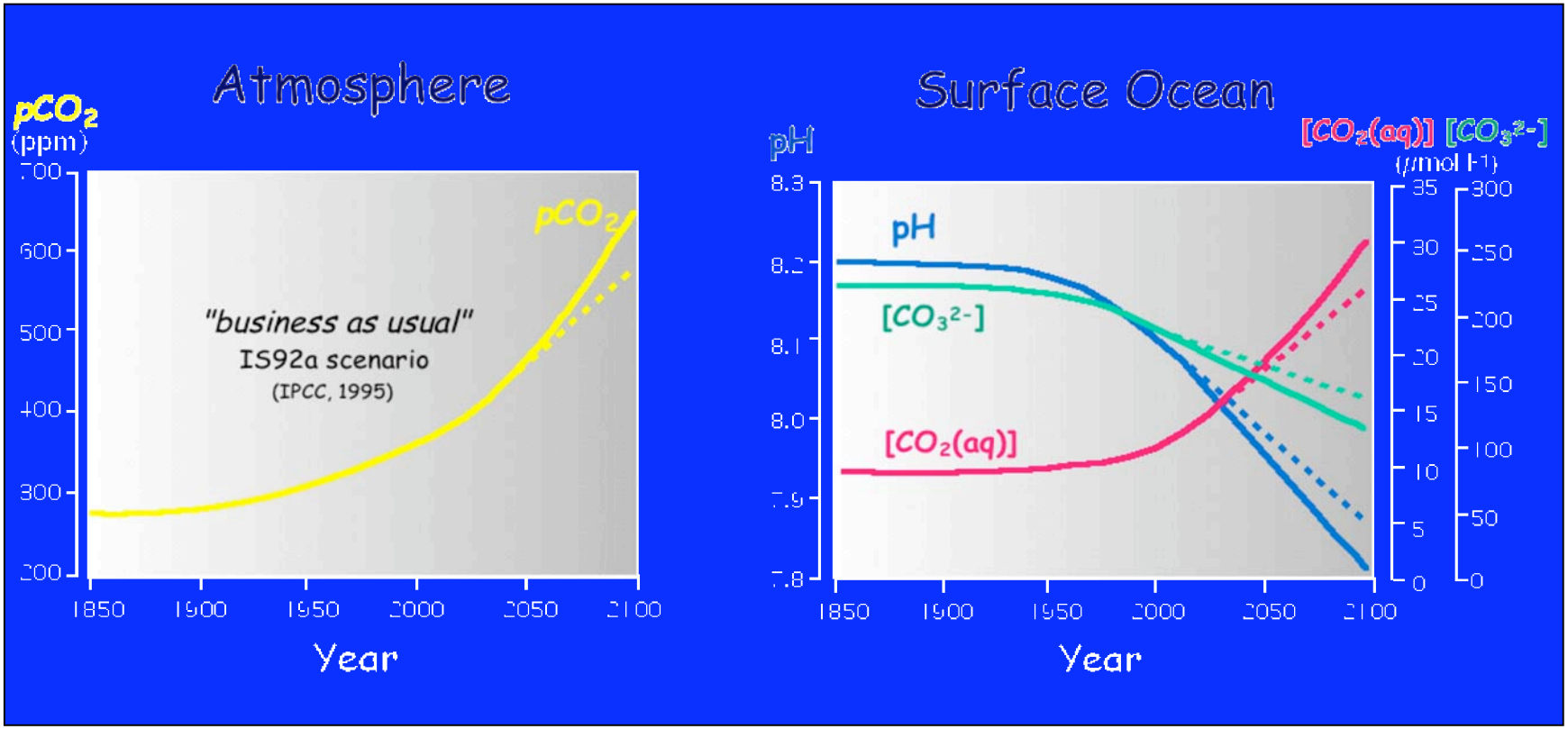
Oceanic Acidification

Atmosphere

CO_2 (g)

$CO_2 + H_2O \leftrightarrow HCO_3^- + H^+ \leftrightarrow CO_3^{2-} + 2H^+$

Surface Ocean

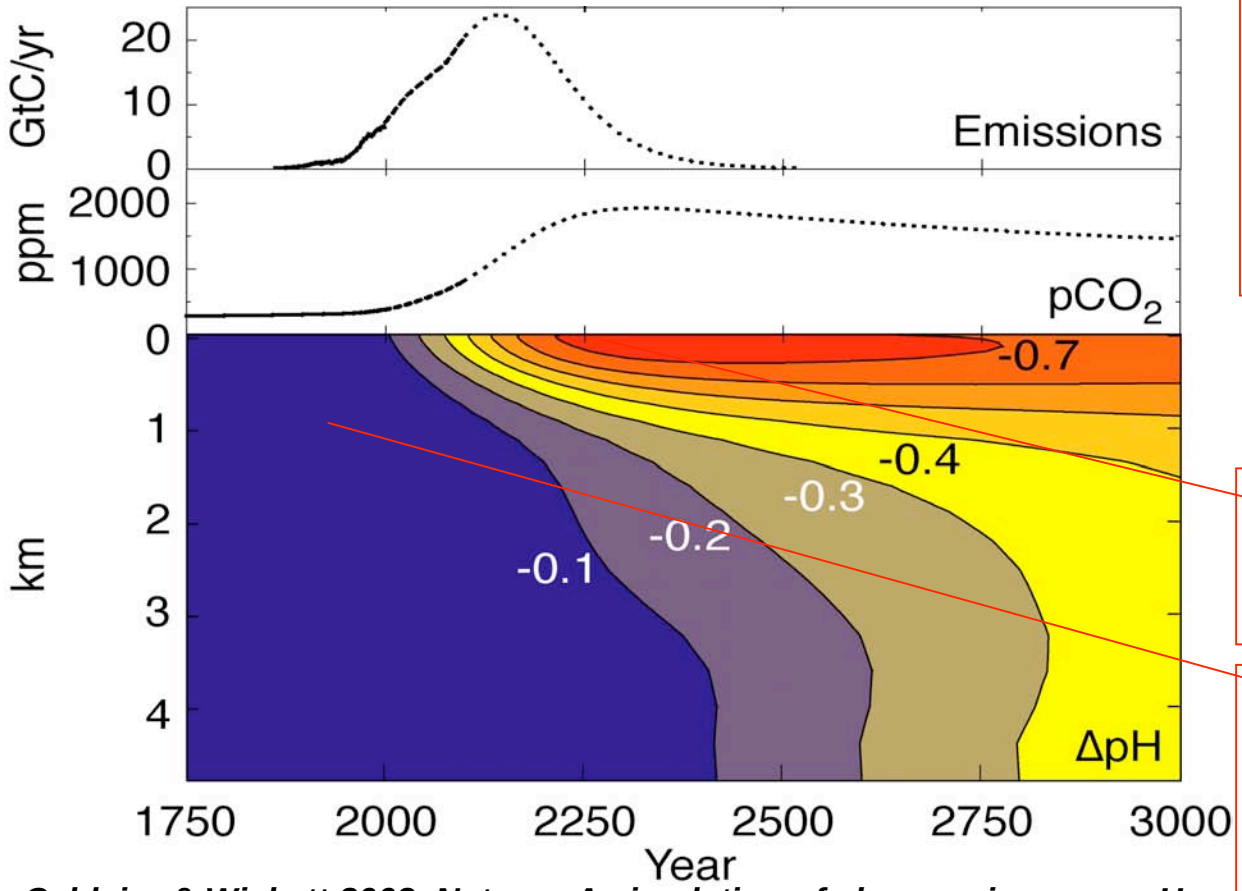


The Oceans are becoming more acid as they take up more CO_2

Modified from Wolf-Gladrow, Riebesell, Burkhardt, Bijma (1999) Tellus 51B, 461

The Ocean Acidification Timeline

While climate change has uncertainty, these geochemical changes are highly predictable.



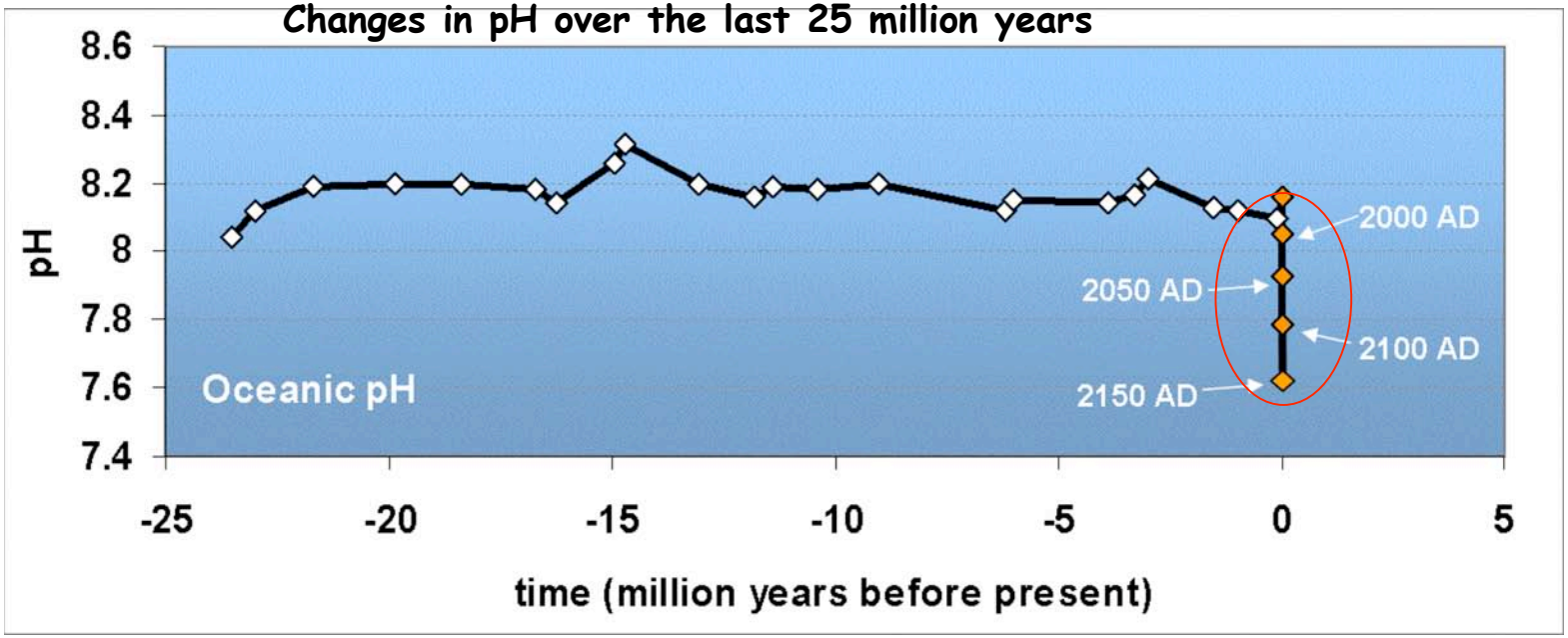
Caldeira & Wickett 2003, Nature: A simulation of changes in ocean pH assuming continued usage of known fossil fuel reserves

Oceans are an important reservoir for CO_2 with c. 50% of CO_2 produced from fossil fuel burning taken up by oceans (Sabine et al. 2004 *Science*) – effectively buffering climate change

CO_2 produced by humans is predicted to decrease surface ocean pH by 0.77

pH has already changed by 0.1 in surface waters due to absorption of anthropogenic CO_2

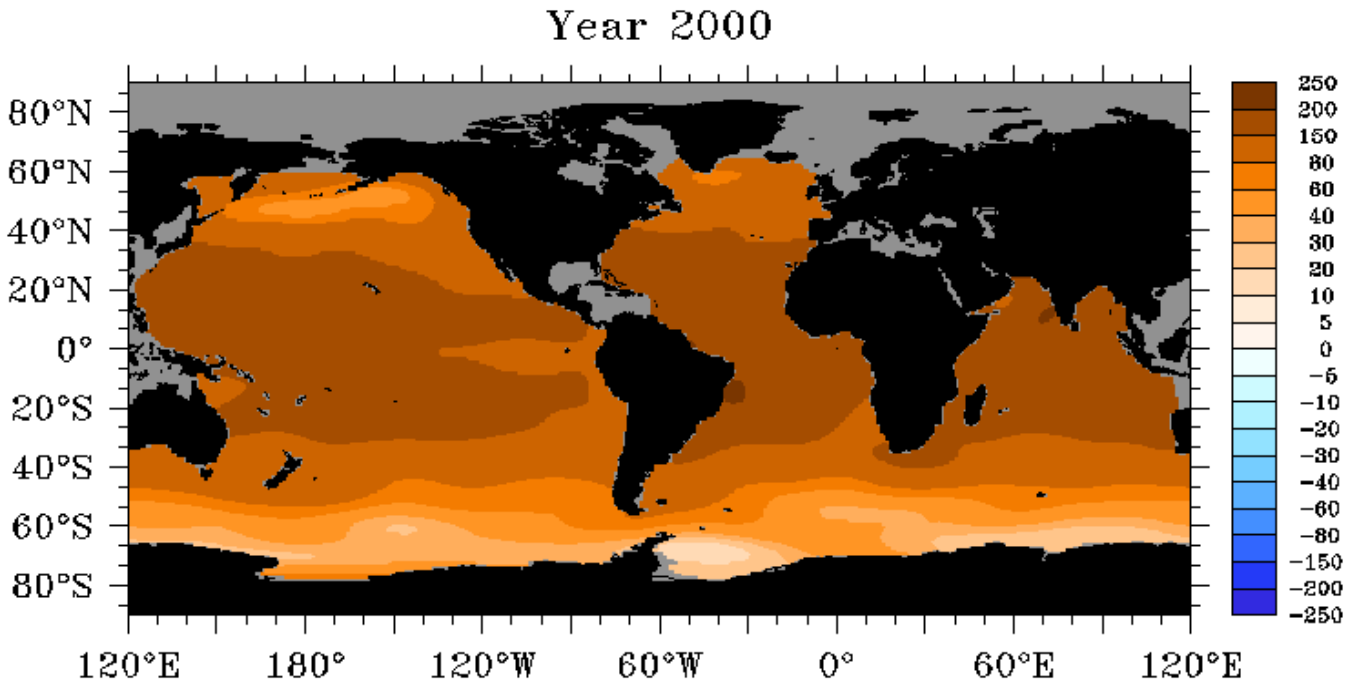
……the Oceans are Acidifying Fast



It is happening now, at a rate and to a level not experienced by marine organisms for ~ 20MY

Turley et al. 2006; Blackford & Gilbert 2007

Present and Future Aragonite Saturation States

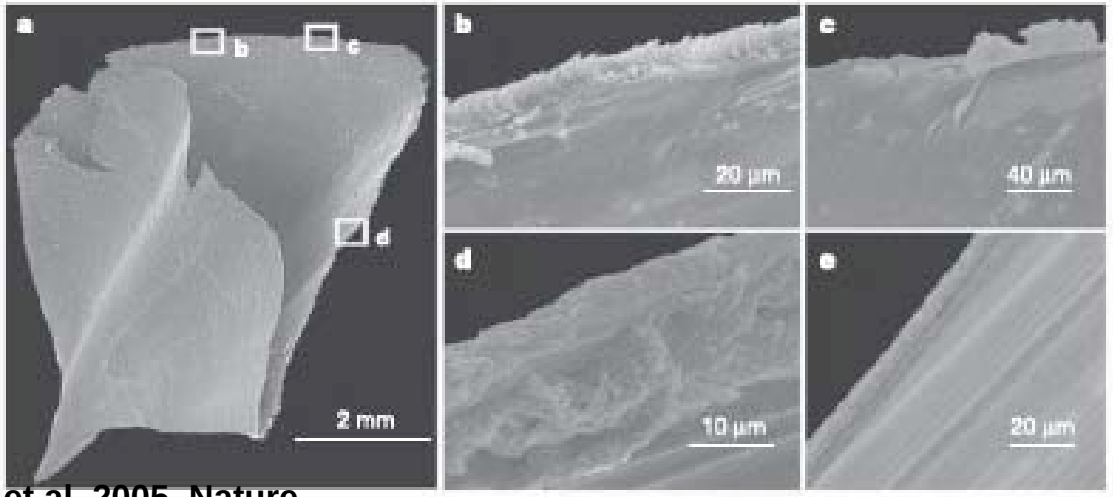


Aragonite Saturation State of Surface Waters
(Orr et al. Nature 2005)

Polar and Subpolar waters

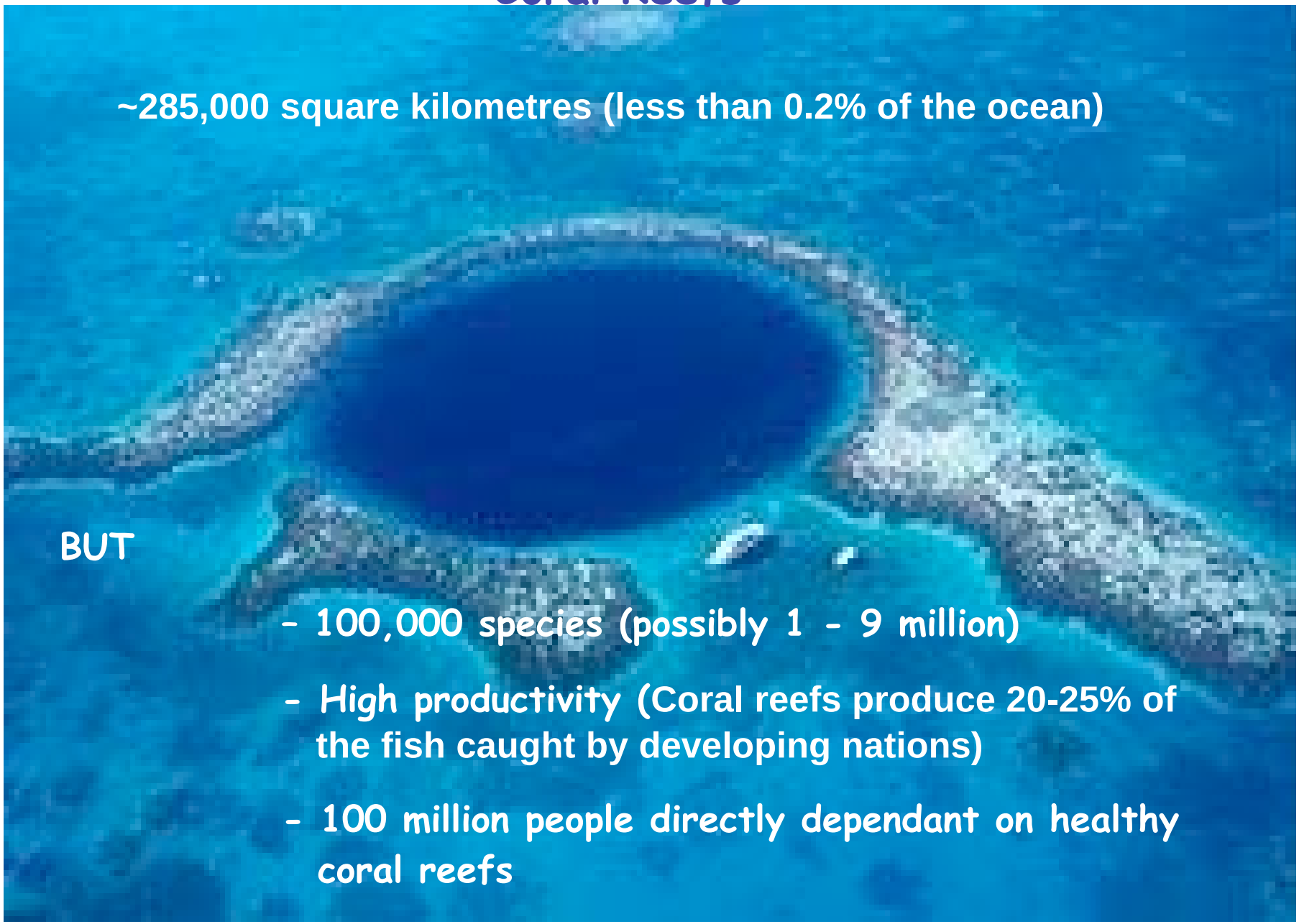
- **Pteropod population density high in polar and subpolar waters (100s-1000's per m^3)**
- **Integral part of the food webs**
- **Can dominate the flux of carbonate and organic carbon**
- **Shells of live pteropods dissolve rapidly once surface waters become undersatuated with aragonite**
- **Not expected to survive in waters undersaturated with aragonite**

Shell dissolution in the live pteropod *Clio pyramidata*



Orr et al. 2005, Nature

Concern for Calcareous Organisms - Warm Water Coral Reefs



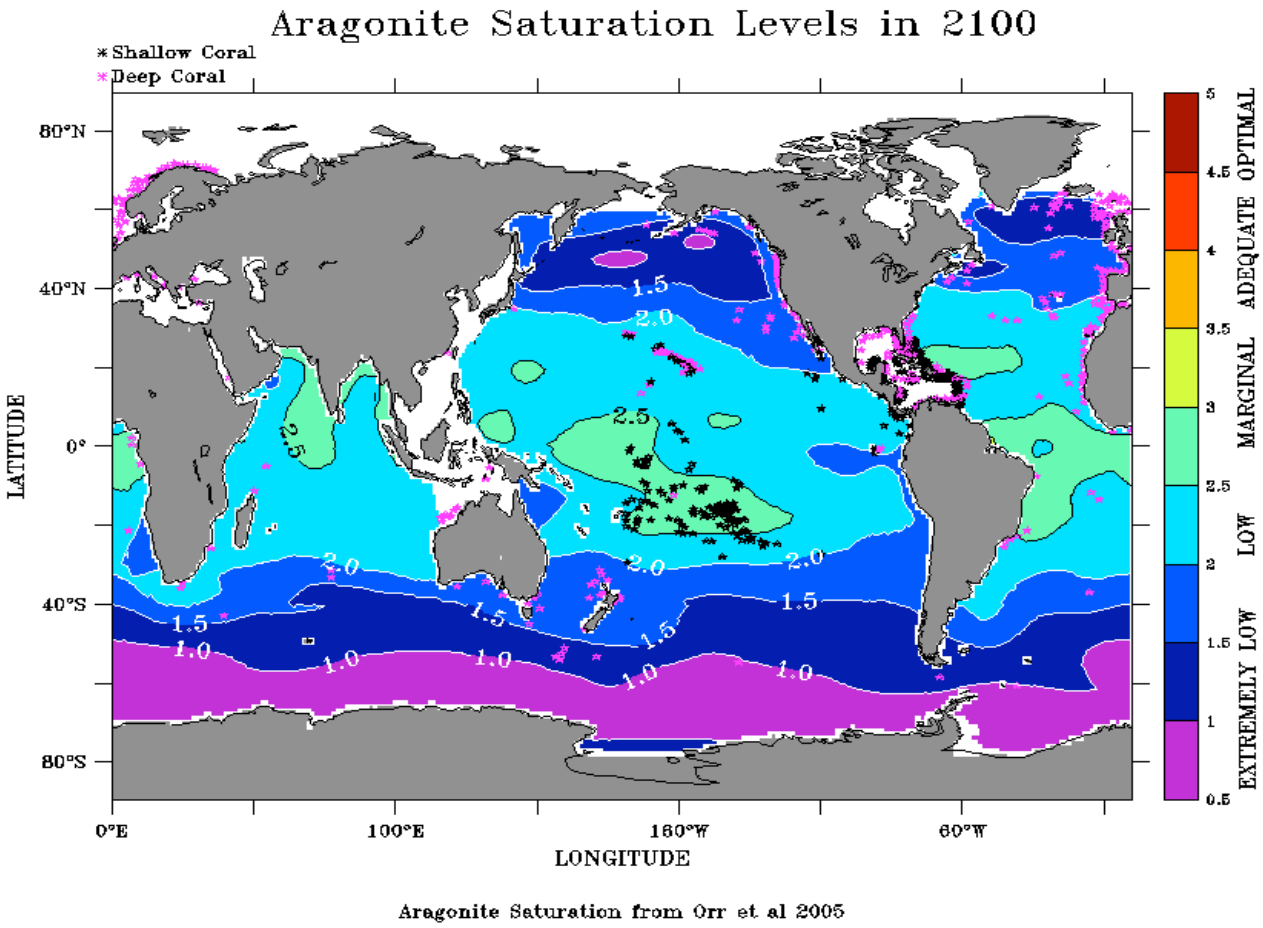
Projections of Aragonite Saturation Levels With Time

Corals like warm, sunlit waters saturated in aragonite

Coral Reef calcification

- 1765 Adequate
- 2000 Marginal
- 2100 Low

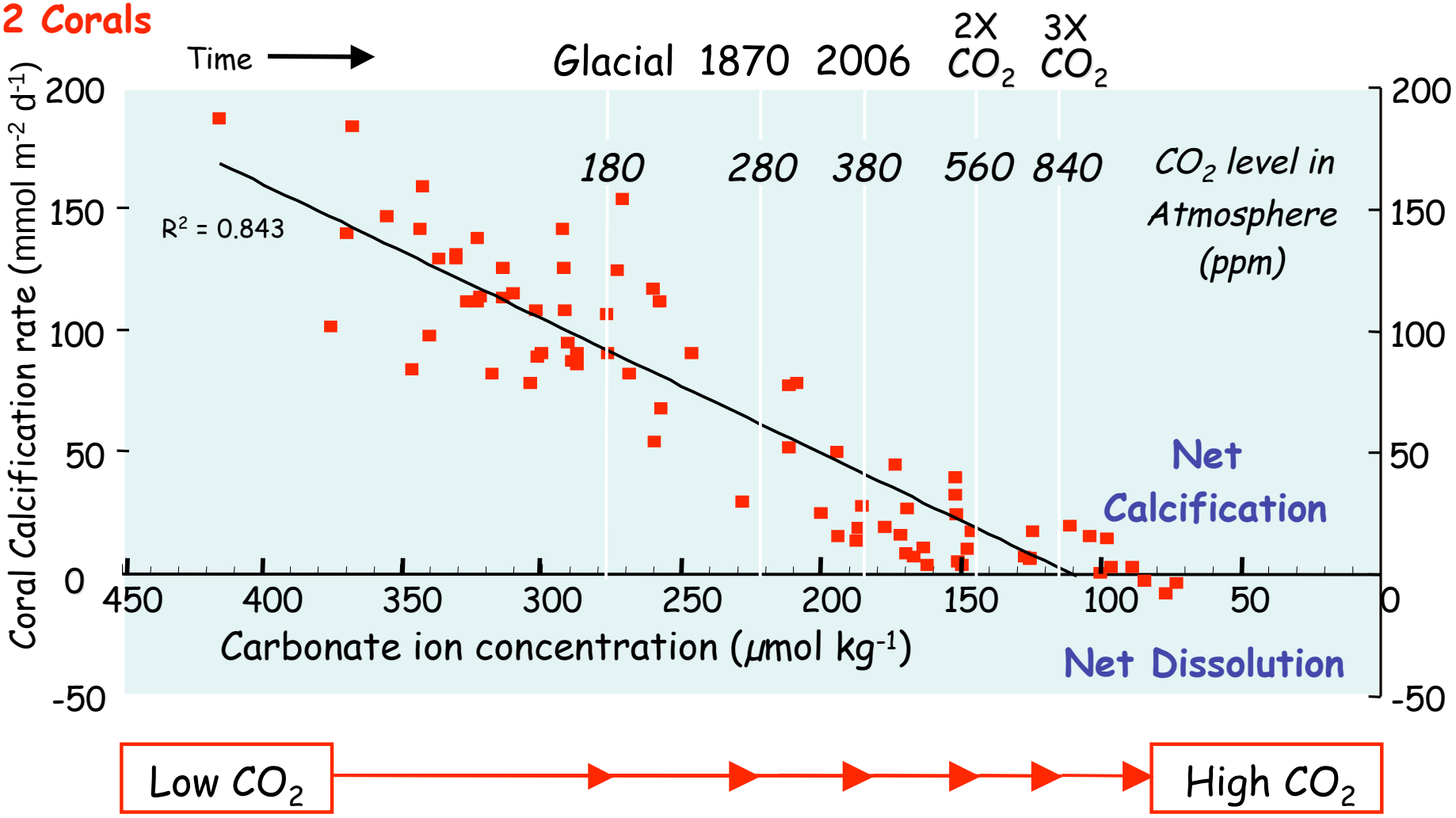
Calcification rates in the tropics may decrease by 30% over the next century



After Feely et al (in press) with Modeled Saturation Levels from Orr et al (2005)

Coral Calcification in a High CO_2 World

There appears to be a linear decrease in the calcification rate of coral reef systems with decreasing carbonate ion concentrations in Biosphere 2 Corals

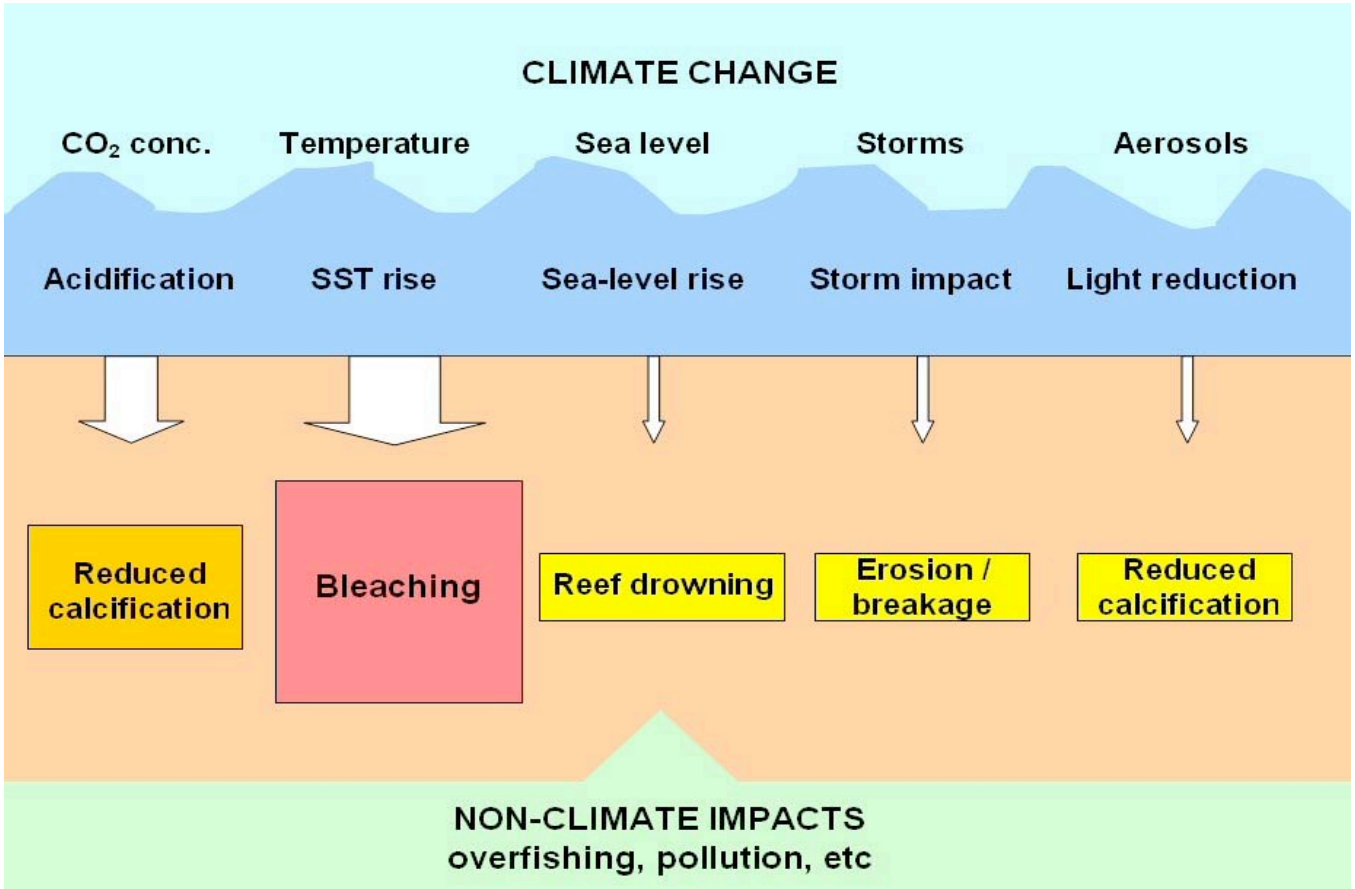


Langdon & Atkinson, (2005)

Threats to Coral Reefs

Sea surface warming and bleaching:

- **~1ºC (SST): increasing loss of warm-water coral reefs due to bleaching**
- **~2ºC (SST): loss of warm-water corals globally –adaptive symbionts unlikely to function**

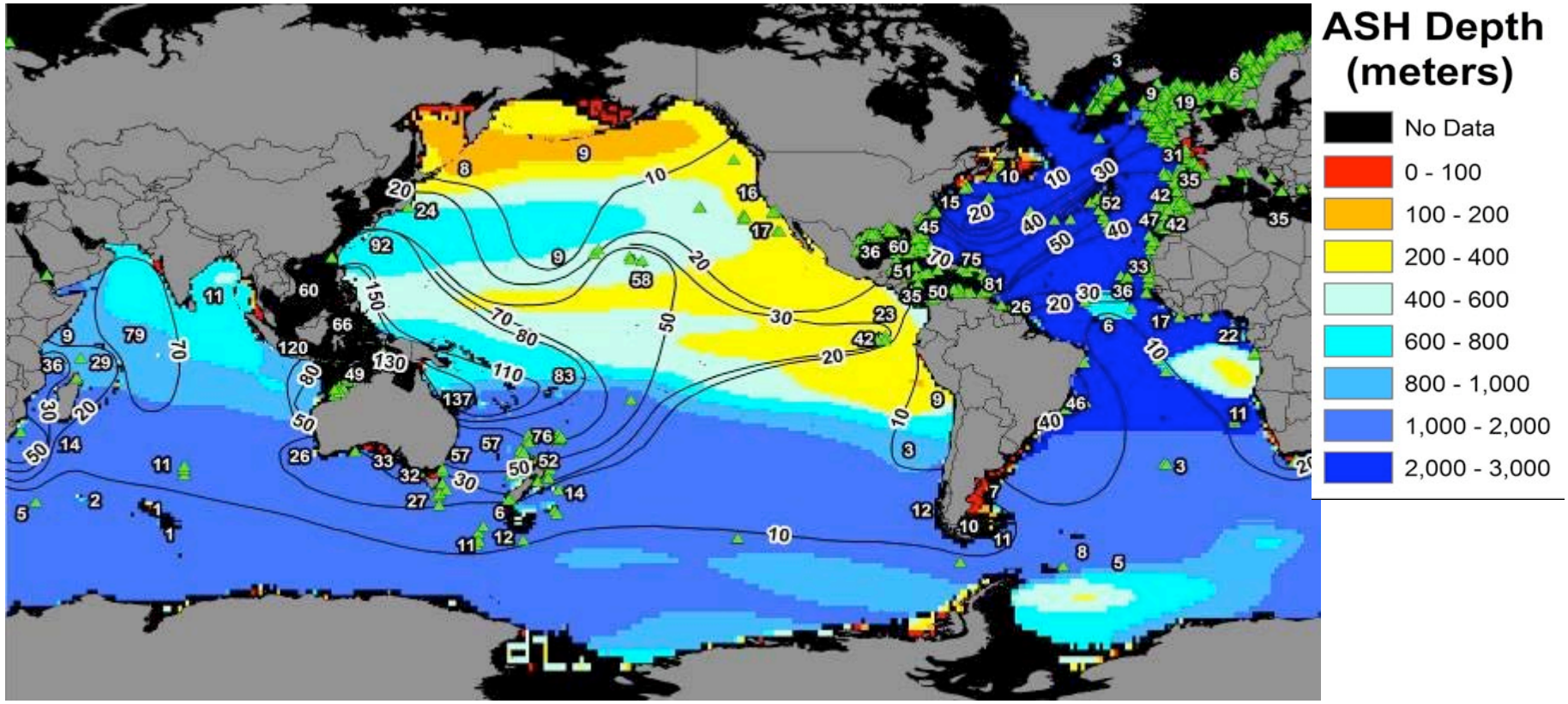


Two-thirds of coral reef nations are developing countries (UNDP, 2002)

(modified from Kleypas and Langdon, 2002)

Vulnerability of Cold Water Corals

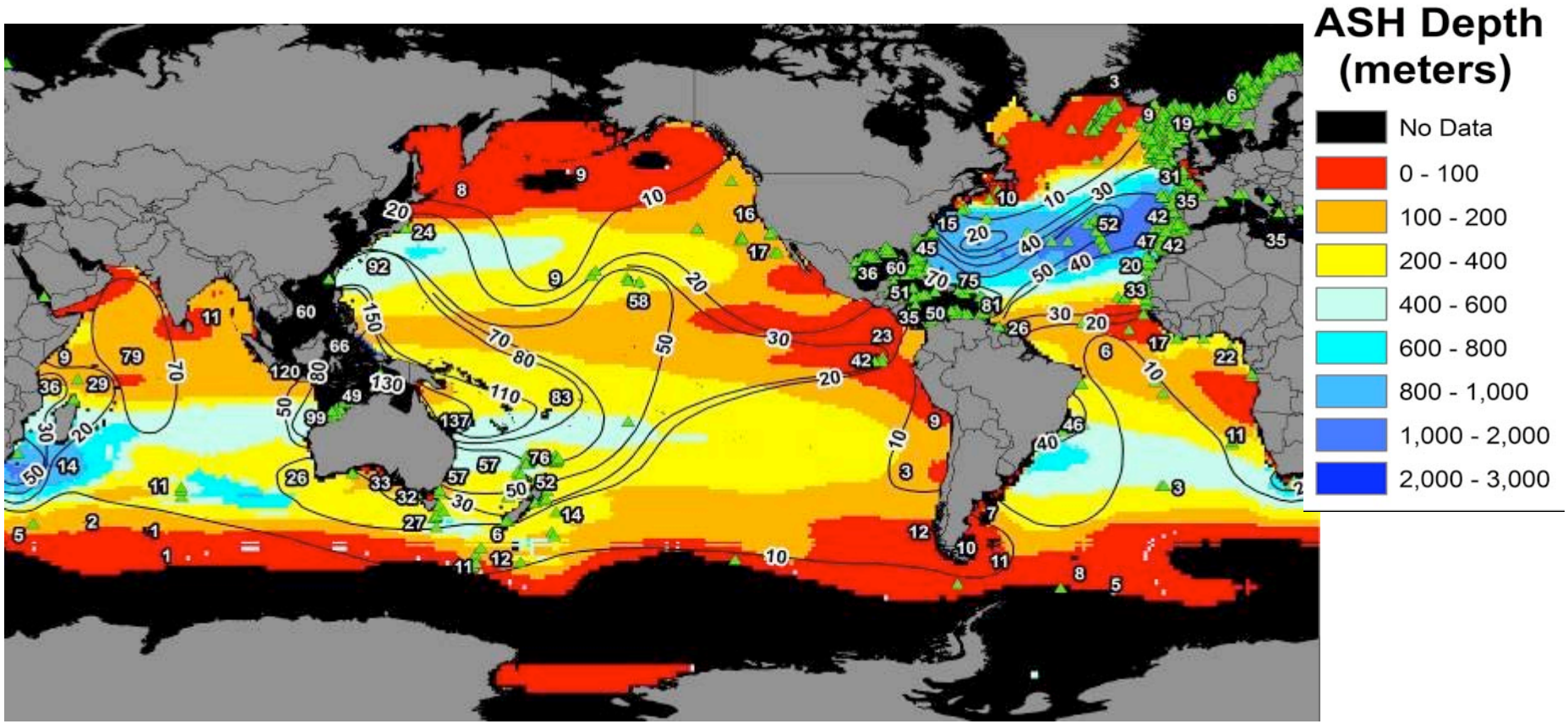
Projected Aragonite Saturation Horizon Depth for Year 1765, pCO2=278 ppmv



From Guinotte et al. Front. Ecol. Environ. 2006

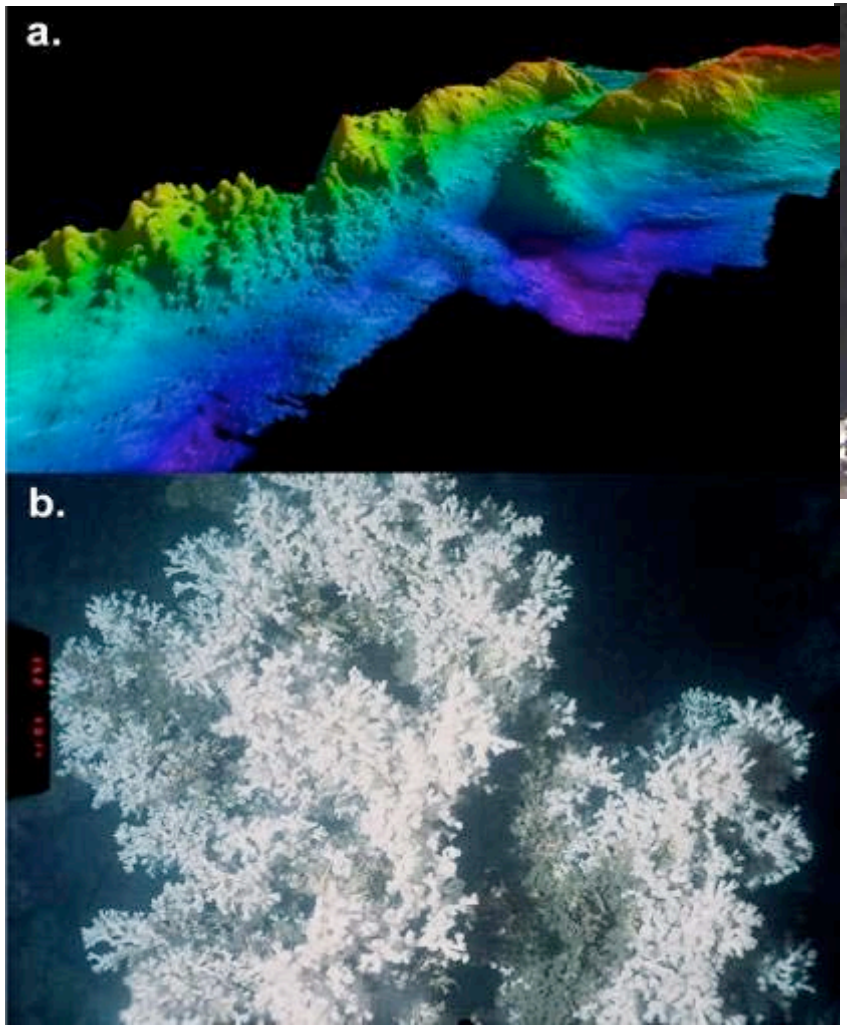
Vulnerability of Cold Water Corals

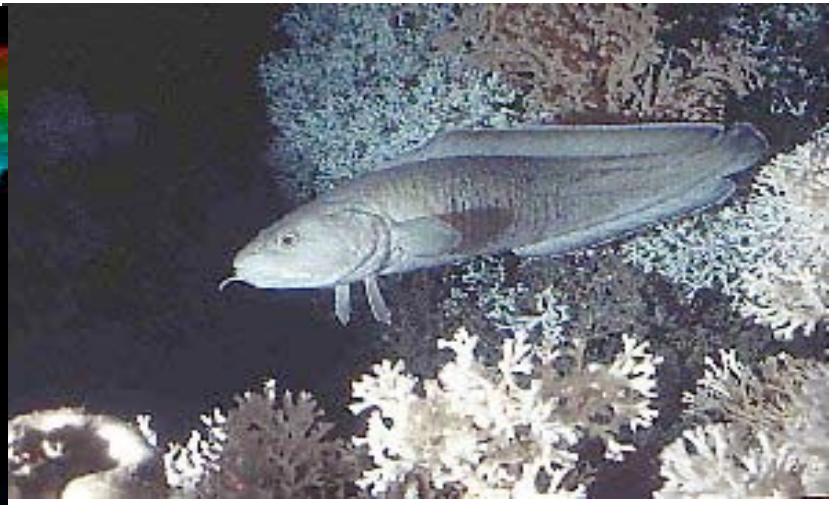
Projected Aragonite Saturation Horizon Depth for year 2099 pCO2=788 ppmv



From Guinotte et al. Front. Ecol. Environ. 2006

Cold Water Corals Such as *Lophelia pertusa*





Colonies of *Lophelia* grow to form large structures more than 20 m in height and 100 m in width

Grow at depths of 50->1000m depth

Fish use the coral thickets as a feeding ground and for shelter

Reefs up to 8000 yrs old

The majority (70%) of deep-sea corals will be in undersaturated waters by 2100

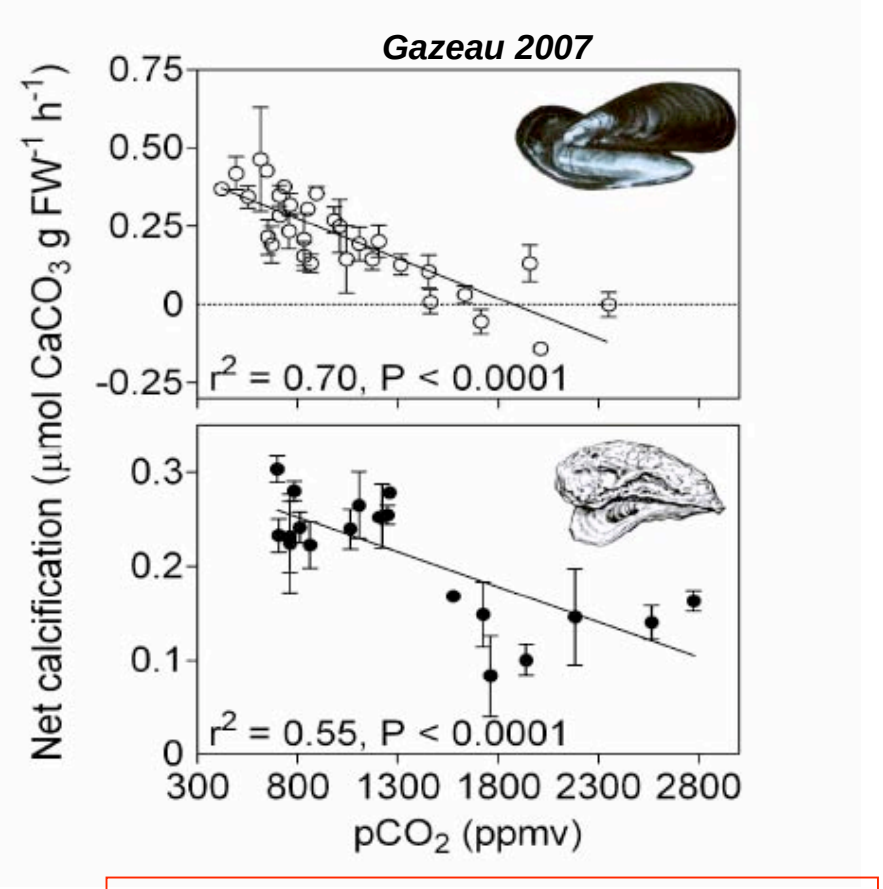
Guinotte et al. Front. Ecol. Environ 2006; Turley, Roberts and Guinotte, Coral Reefs 2007

Effects on Calcareous Benthic Invertebrates

50% growth reduction in mussels at pH 7.3, a pH value expected for the year 2300.

Measurable impacts on growth rates and survival of echinoderms and gastropods at 560ppm the 2050 projected levels

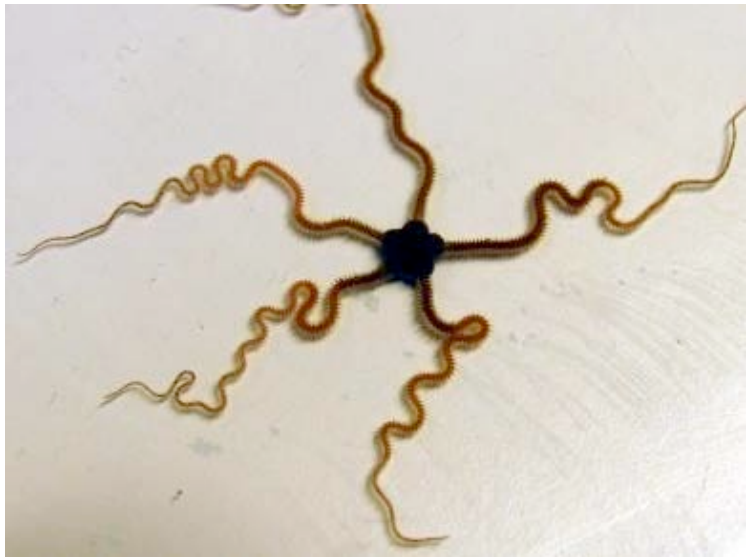
100% mortality of scallops at pH 7



- **Increasing CO_2 results in slower growth and lower final weight**
- **These are adults but what about spats and juveniles, recruitment and settlement?**

Harris et al. 1999; Bamber 1990; Smith 1979;Yuan et al. 2000; Knutzen 1981; Morris et al. 1989; Lorentz & Taylor 1992; Dwyer & Burnett 1996; Burnett et al. 1997; Tamburri et al. 2000; Shiramura 2002; Michaelidis et al., 2005;

Common Brittlestar *Ophiothrix fragilis*

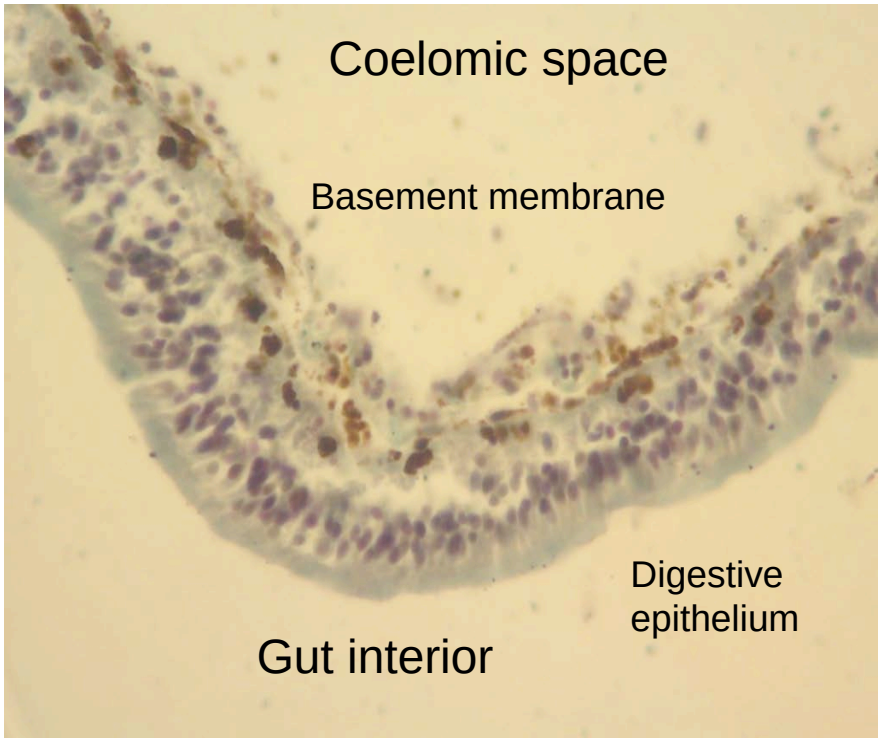


- Fish nibble the calcareous arms which are regenerated
- 80% flatfish gut content are arms – important food source for fish
- Regeneration of arms may be impacted by OA – research in Plymouth and Kristineberg Marine Laboratories underway

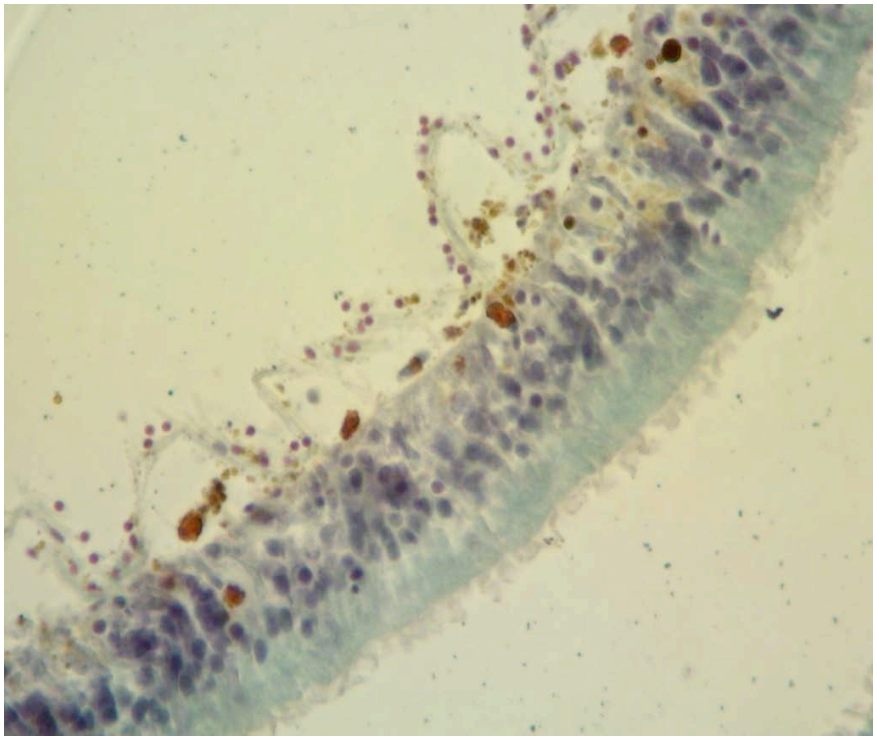
Heart Urchin Digestive Tract Disruption

Echinocardium cordatum intestine

pH 8



pH 7.2



Extensive mortalities at pH 6.8 in *Echinocardium cordatum* and thickening of the epithelial surface and slight disruption of the basement membrane of digestive tract at pH 7.2

Digestive tract changes will effect nutrient uptake, growth and reproductive potential

From David Lowe et al. PML

" A PROJECT TO ASSIST MOTHER NATURE TO RESPOND TO MODERN PRESSURES"

OCEAN ACIDIFICATION RESEARCH AT THE NATIONAL LOBSTER HATCHERY, PADSTOW, UK

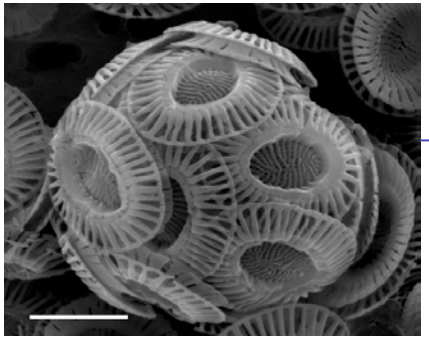
Larval stages

Egg Development I II III IV Post larvae

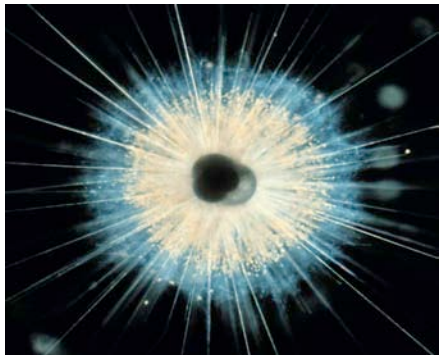
Experiments growing larval lobsters at future CO_2 levels show that their ability to calcify their shells is reduced by larval stage IV

These experiments indicate that by the year 2100, the predicted increase in CO_2 levels in surface waters are expected to cause reduced weight and calcification rates in larval lobsters unless we significant and urgently reduce our CO_2 emissions

Experiments on Major Planktonic Calcifiers



V. Fabry



H. Spero

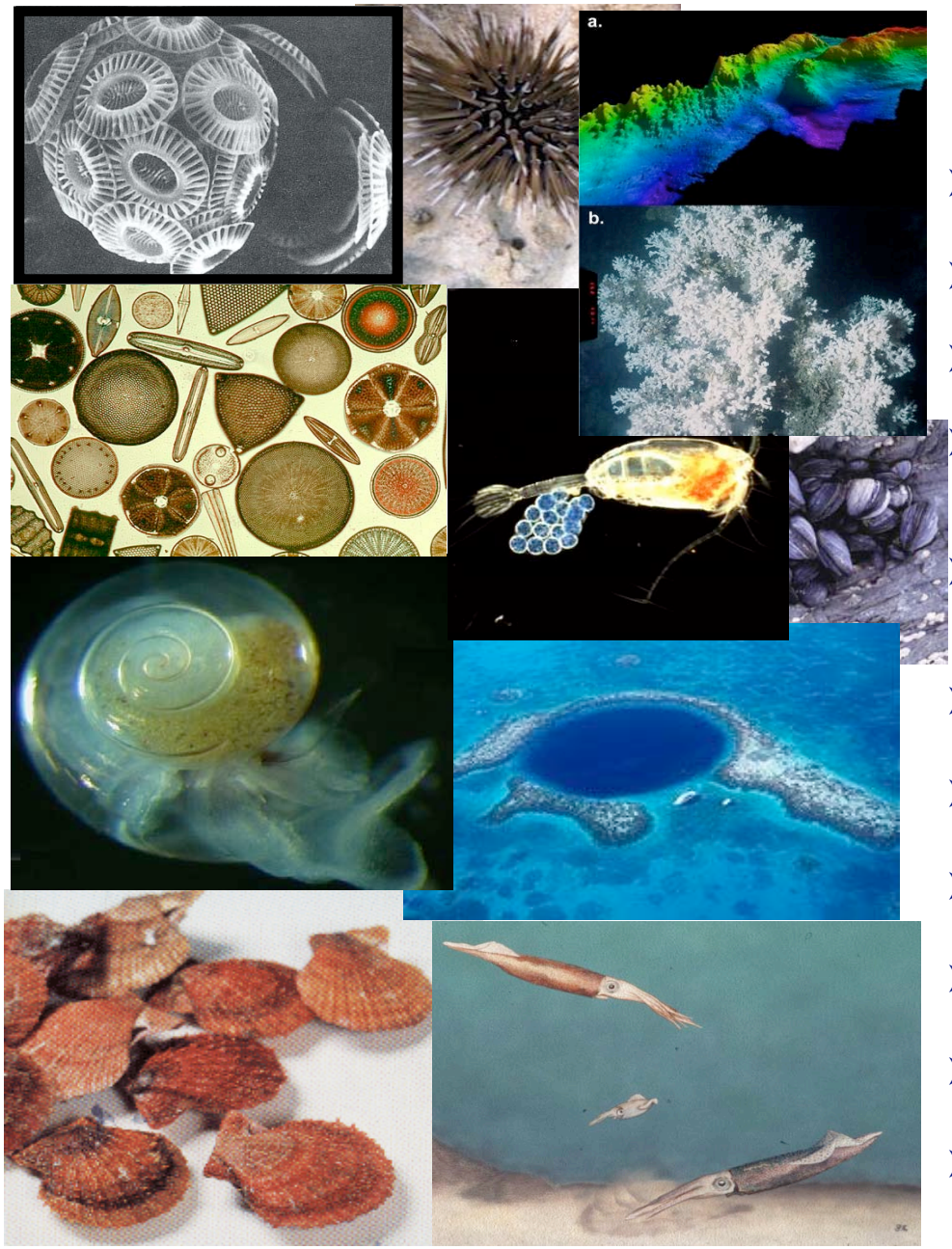
V. Fabry

	# Extant species	Mineral form	Generation time
Coccolithophores (autotrophs)	~ 250	calcite	days
Foraminifera (heterotrophs)	~ 50	calcite	weeks
Euthecosomatous Pteropods (heterotrophs)	~ 32	aragonite	months to year?

- **CO_2 sensitivity experiments limited to 6 species**
- **5 out of 7 species showed 6-60% decrease in calcification**
- **<2% of major calcifying groups studied**

From Vicki Fabry CSUSM

Concern for Many Marine Organisms and Ecosystems



- Reduced calcification rates
- Significant shift in key nutrients
- Shift in phytoplankton diversity
- Reduced growth, production and life span of adults, juveniles & larvae
- Reduced tolerance to other environmental fluctuations
- Changes to species biogeography
- Changes to biodiversity
- Changes to key biogeochemical cycles
- Changes to food webs
- Changes to ecosystem & their services
- Uncertainities great – research required

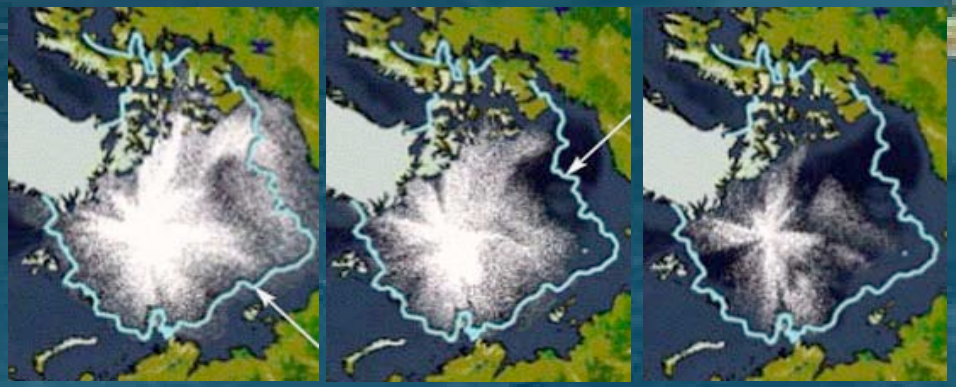
Multiple Impacts of Climate Change and Ocean Acidification on Arctic Waters

2040 = Aragonite undersaturation

2070 = Calcite undersaturation

Projected Arctic Ice Melt due to Warming

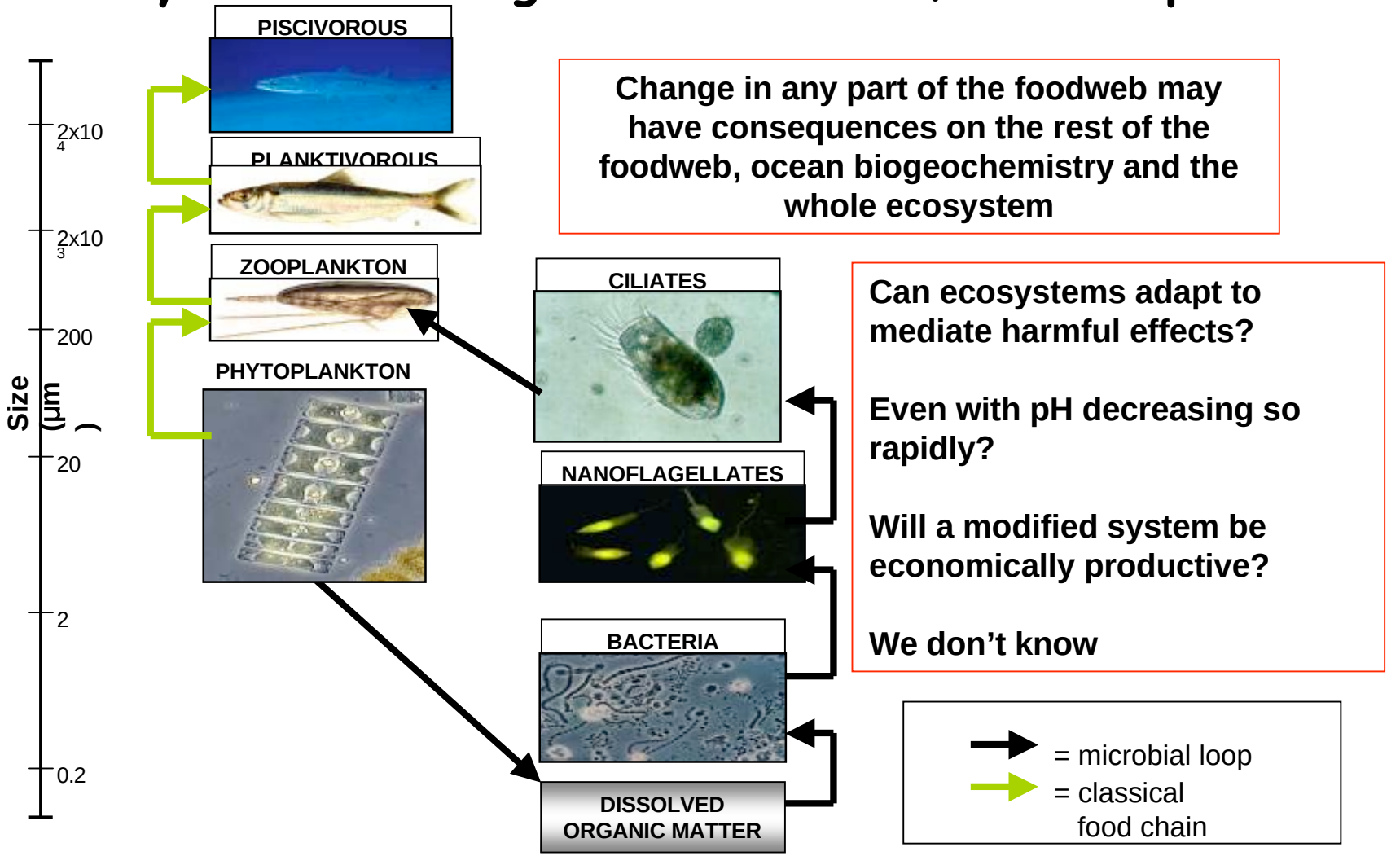
2030 **2060** **2090**



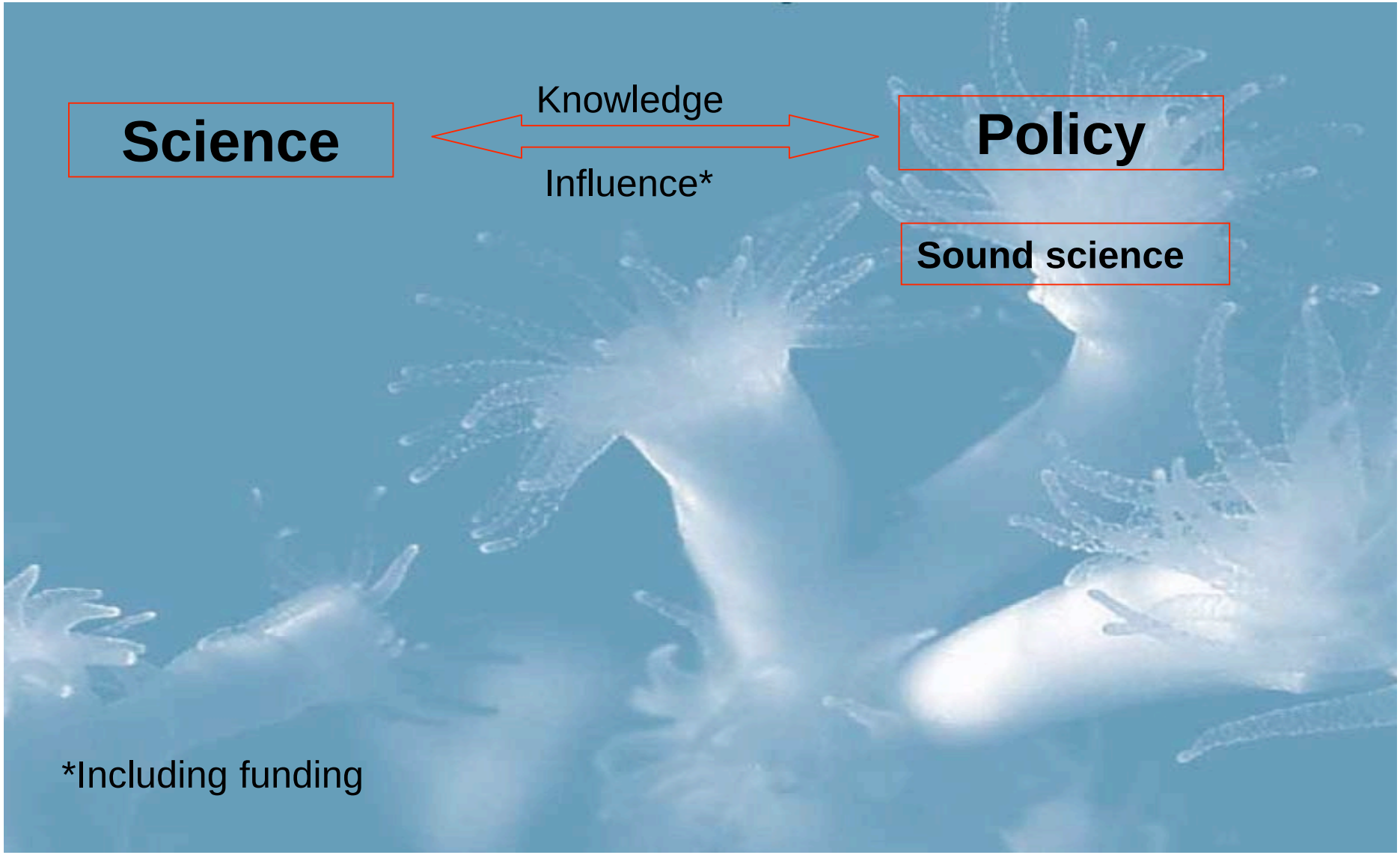
+ Ocean warming

- **Same time, same place**
- **Does this mean multiple impacts for the Arctic Ecosystem?**

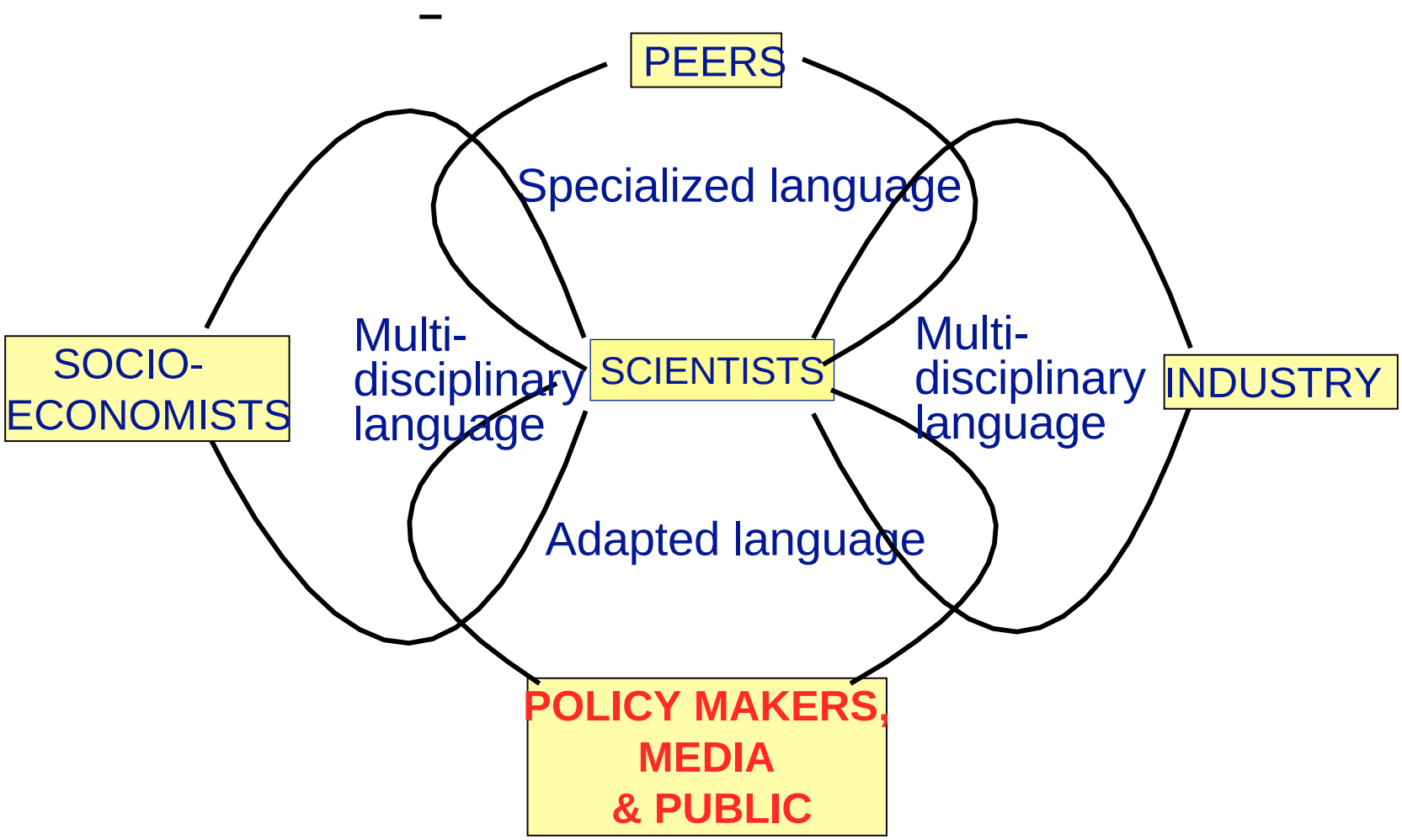
Ecosystem Impacts: from lab studies to ecosystems, where many different organisms interact, can we predict?



The Science and Policy Link



Taking the Science to Stakeholders: Getting the Language Right



Know your audience and speak their language

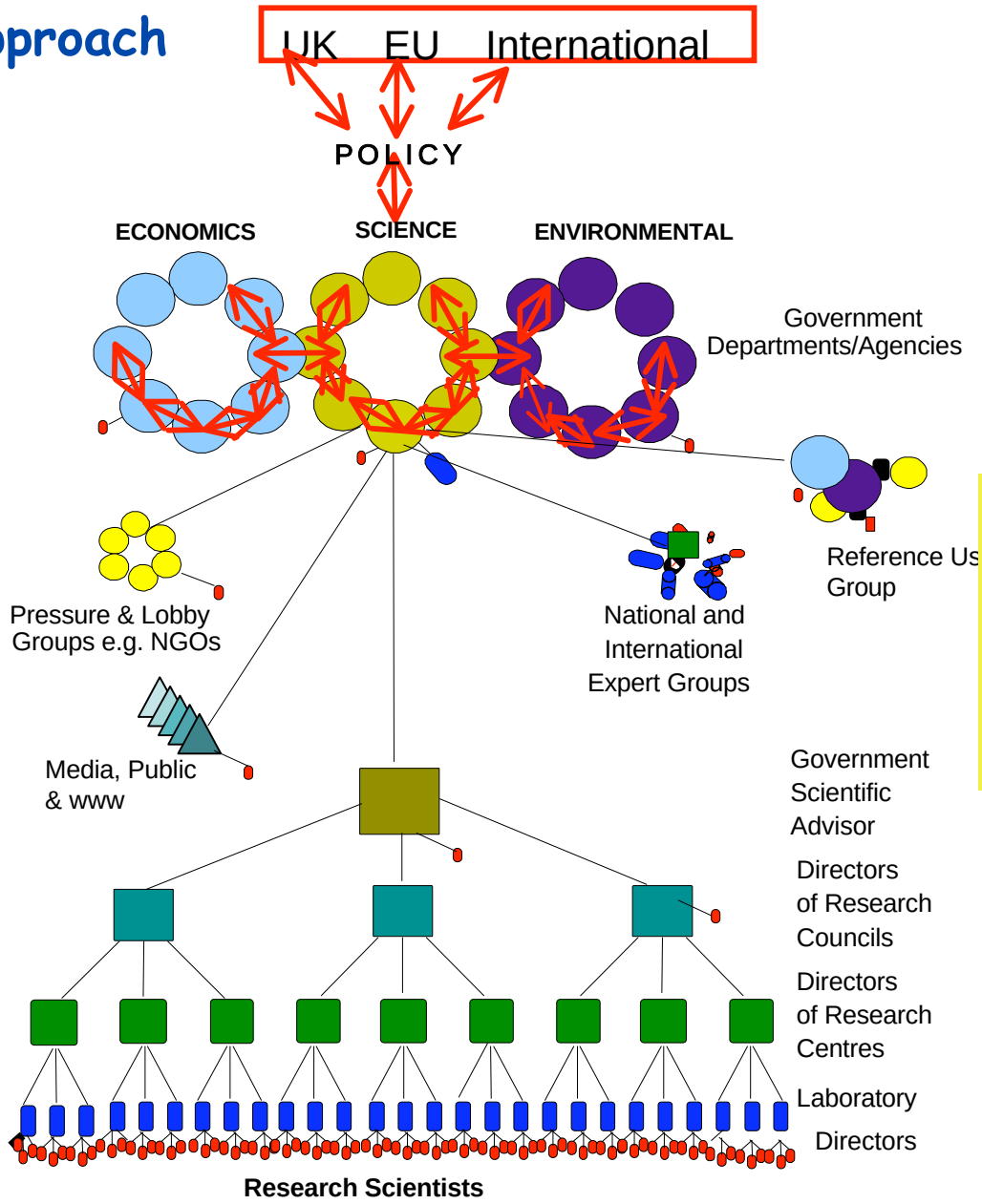
Turley 1999

Strategy: Information Flow to Policy Makers -

a multi-pronged approach

INFORMATION FLOW DANGERS:

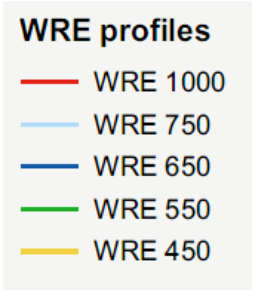
- Misconstrued
- Misinterpreted
- Generalization
- Quality loss
- Loss of context
- Probabilities became facts



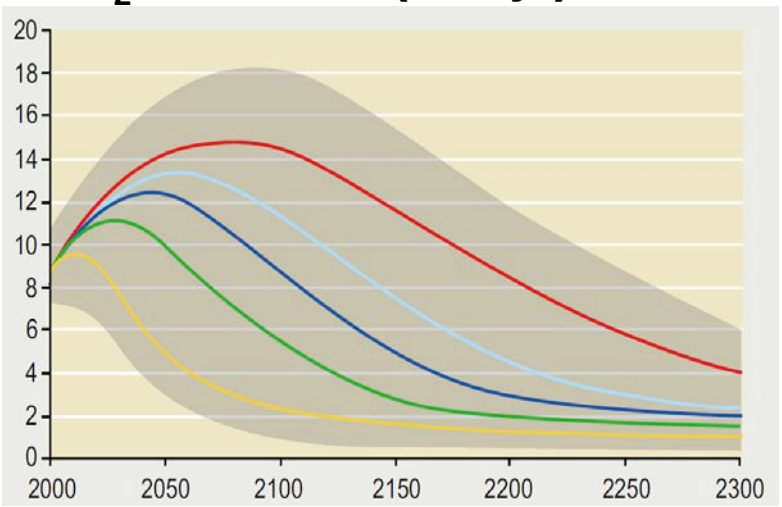
PML CO2 RUG: Government departments, agencies, business, industry, NGOs, independent scientists

Turley 1999

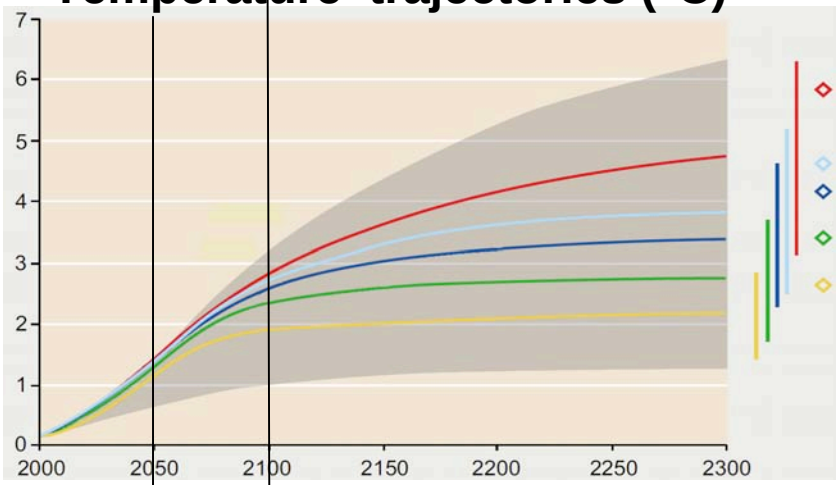
Linking to IPCC Climate Change Scenarios:



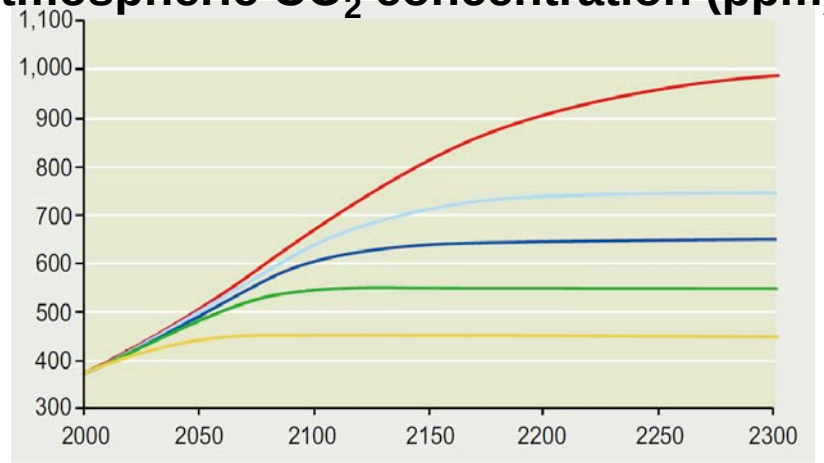
CO_2 emissions (GtC/yr)



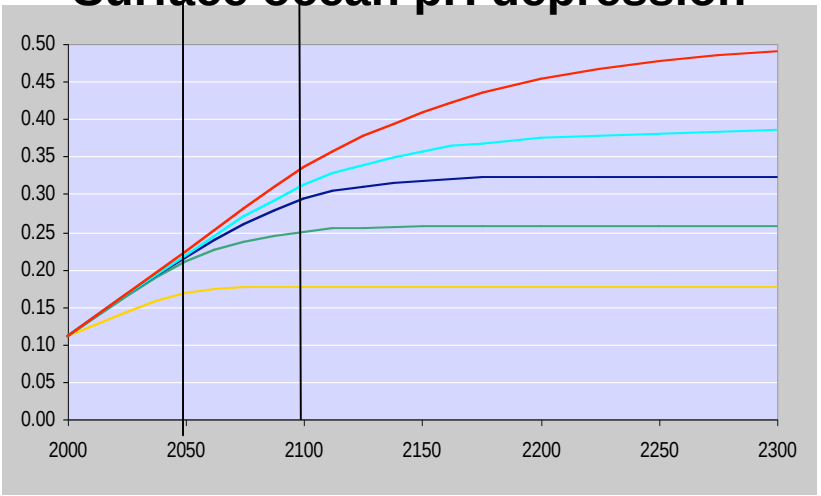
Temperature trajectories (°C)



Atmospheric CO_2 concentration (ppm)



Surface ocean pH depression

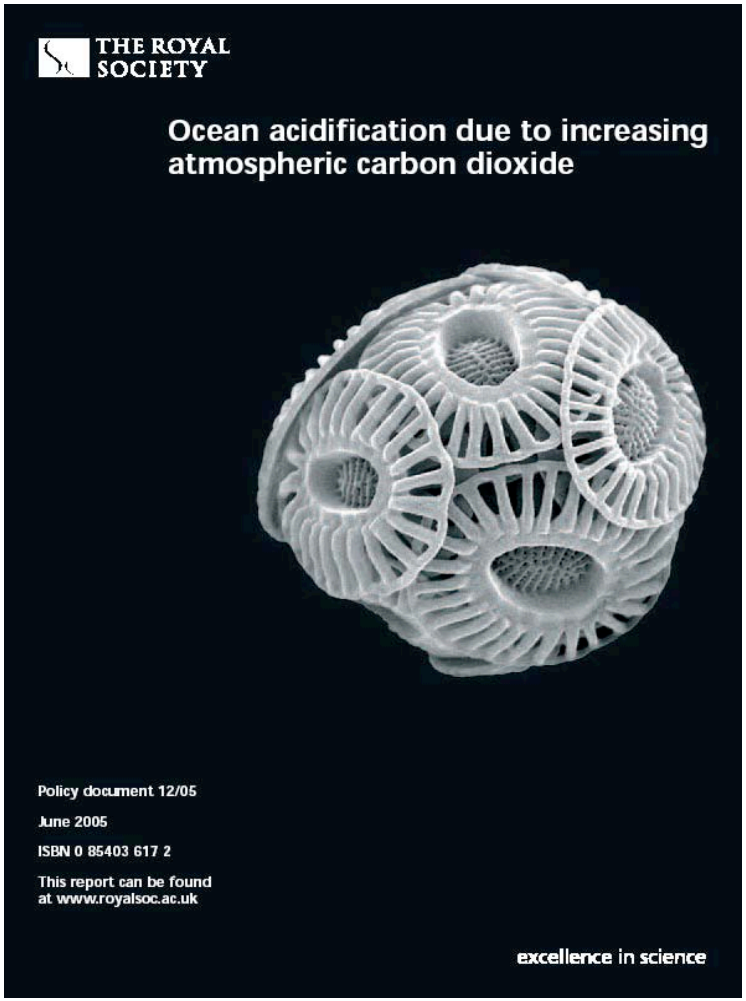


Turley 2006

Drivers for a change in energy policy

The Power of Reports:

The Royal Society Working Group Report on Ocean Acidification - 2005



- Ocean acidification is potentially as serious for marine ecosystems as climate change
- Research is in its infancy
- Global research effort urgently needed
- In the future we must investigate the combined impacts of Climate Change and Ocean Acidification

http://www.royalsoc.ac.uk/document.asp?id=3249

Scientists Getting the Message to Stakeholders – a concerted international effort

IGBP-SCOR Fast Track Initiative "Ocean Acidification"

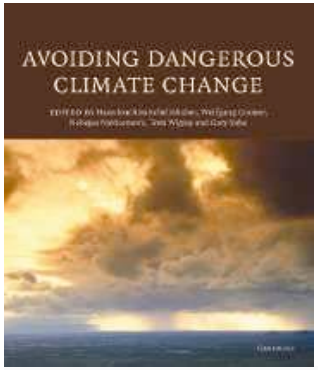
The Power of Reports!

Interest and uptake by:

- **National and International Research Funders**
- **International Agencies (IWC, WWF, EEA)**
- **National Governments**
- **United Nations Framework on Climate Change**
- **Intergovernmental Organisations (IGBP, SCOR, IOC, G8, Montreal Protocol, OSPAR & London Conventions)**
- **Intergovernmental Panel on Climate Change FAR**
- **Non-governmental organisations**
- **EU-FP7**

Government policy makers and funders listening and investing

Engaging the Climate Change Policy Community …….



Avoiding Dangerous Climate Change

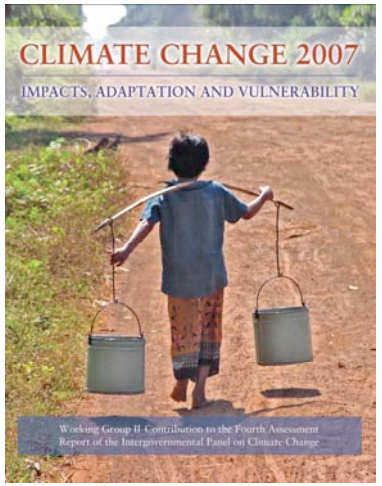
Presentation at the ADCC Symposium at the Met Office, Exeter 1-2 February 2005 + Publication

Presentation at UNFCCC Twenty-Second Sessions of the Subsidiary Bodies and seminar of governmental experts, Bonn May 2005

United Nations Framework Convention on Climate Change

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO UNEP



New IPCC report in 2007 – will help drive new framework on climate change i.e. post Kyoto.
Ocean acidification included for the first time and made it through to the IPCC Synthesis Report

The IPCC Process: Established WMO & UNEP

Policymakers need an objective source of information about the causes of climate change, its potential environmental and socio-economic consequences and the adaptation and mitigation options to respond to it.

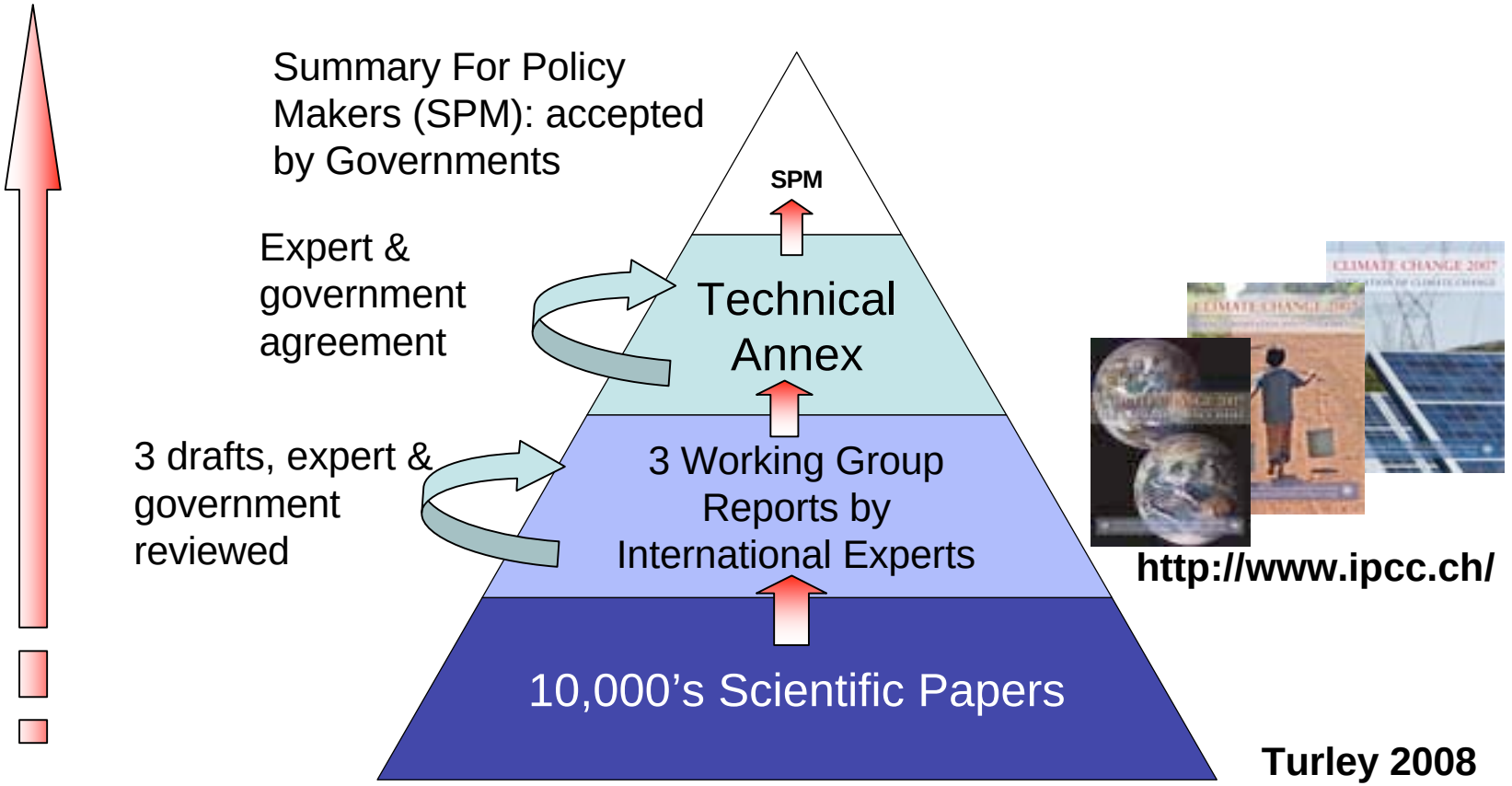
IPCC 1st Assessment Report (1990) - Rio de Janeiro Summit in 1992

IPCC 2nd Assessment Report (1995) - Kyoto Protocol in 1997

IPCC 3rd Assessment Report (2001) - development of the UNFCCC & Kyoto Protocol

IPCC 4th Assessment Report (2007) - Bali roadmap, post 2012 deal on climate change

Objective assessment of human induced climate change: information flow of certainty and current scientific opinion



http://www.ipcc.ch/

Turley 2008

Ocean Acidification Recognised by IPCC in 2007 for the First Time:

"The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic with an average decrease in pH of 0.1 units."

"Increasing atmospheric CO_2 concentrations lead to further acidification."

"Projections based on SRES scenarios give a reduction in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century."

"While the effects of observed ocean acidification on the marine biosphere are as yet undocumented, the progressive acidification of oceans is expected to have negative impacts on marine shell-forming organisms (e.g. corals) and their dependent

Ocean acidification needs to be remain part of the climate mitigation and adaptation process – post 2012

Public Understanding – Media, Articles & Art

- Summer 2004: Press Releases from IGBP, NOAA, PML and The Royal Society - Some take up by Radio and Broadsheets
- Reports in 2005/6 stimulated large media uptake
- BBC1 Climate Chaos Series "Are We Changing Our Planet" staring David Attenborough 2006
- Major articles in New Scientist, New Yorker, New Statesman, The Marine Scientist in 2005/6
- Numerous articles in the broadsheets and TV, radio, newspaper interviews – UK and internationally
- 34 Google News hits between 27 Dec 2007 and 23 Jan 2008
- Children's and university books on climate change
- Take up by Artists

Crystallized whale skeleton: Cape Farewell Project

Search hits on “ocean acidification”:

October 2003 = 17

June 2006 = 267,000

February 2007 = 326,000

August 2007 = 356,000

April 2008 = 94,800

Search hits on “ocean acidification”:

April 2008 = 941,000

Key Policy Questions for the Future:

Are there detectable impacts already?

Can organisms/ecosystems adapt or acclimatise to such rapid future changes?

What are the feedbacks to Planet Earth?

What will ocean ecosystems look like in the future?

How is this going to affect humans?

What can be done about it?

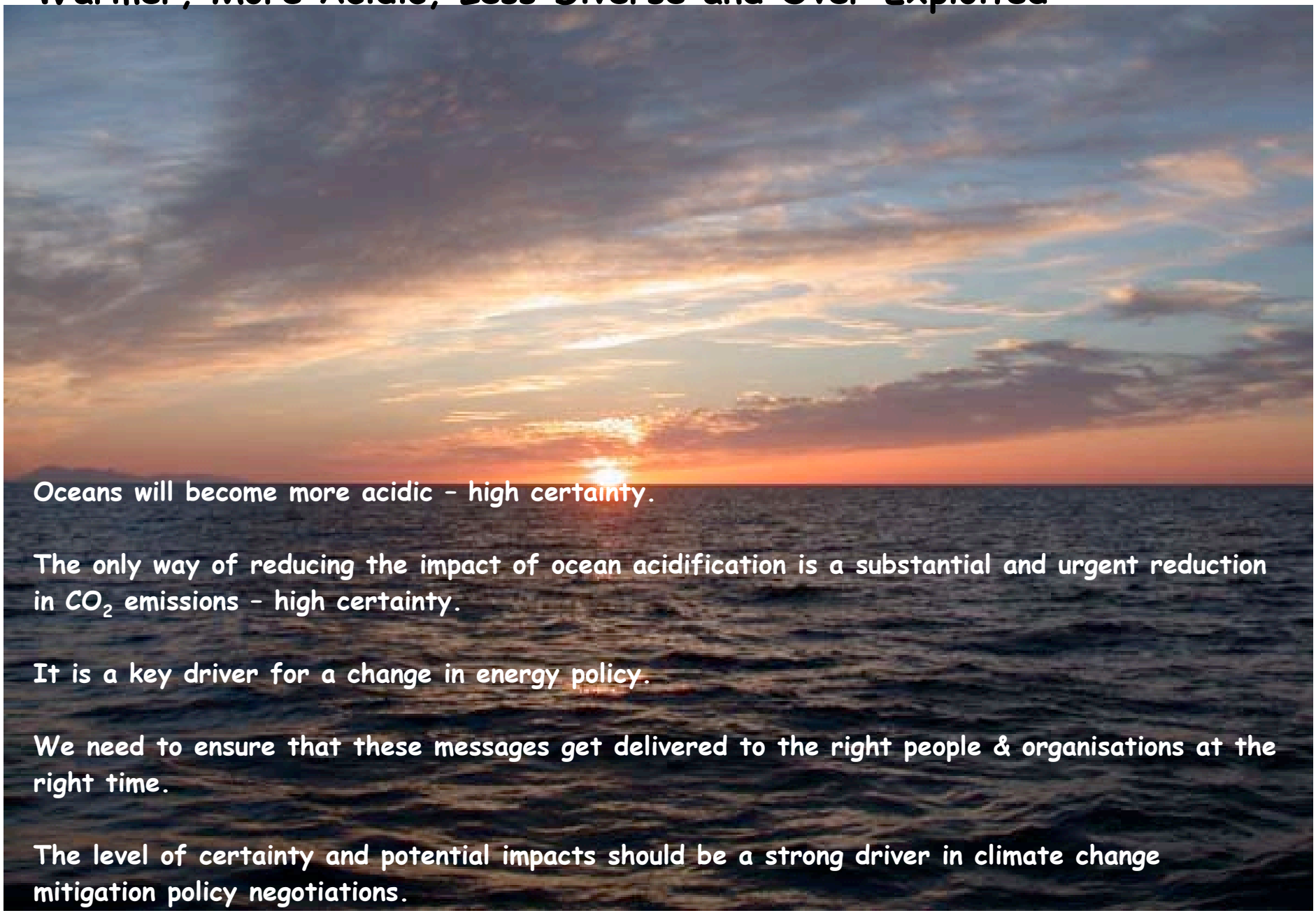
What are the certainties and uncertainties?

What level of pH change is dangerous?

Are there important "tipping points" in ocean acidification that could be important in the CO_2 emission mitigation discussions?

What level of emissions mitigation have acceptable impacts?

Sunset Over an Ocean with Man's Footprint Now Detectable – Warmer, More Acidic, Less Diverse and Over Exploited



Oceans will become more acidic – high certainty.

The only way of reducing the impact of ocean acidification is a substantial and urgent reduction in CO_2 emissions – high certainty.

It is a key driver for a change in energy policy.

We need to ensure that these messages get delivered to the right people & organisations at the right time.

The level of certainty and potential impacts should be a strong driver in climate change mitigation policy negotiations.