PML | Plymouth Marine Laboratory

UK Ocean Acidification Research Programme

EPOCA
European Project on OCean Acidification

European Science Foundation
SETTING SCIENCE AGENDAS FOR EUROPE

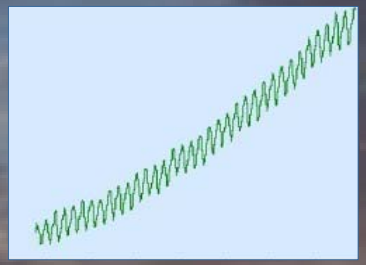
Marine Matters

Ocean Acidification: the Other CO_2 Problem

Carol Turley

PML | Plymouth Marine Laboratory

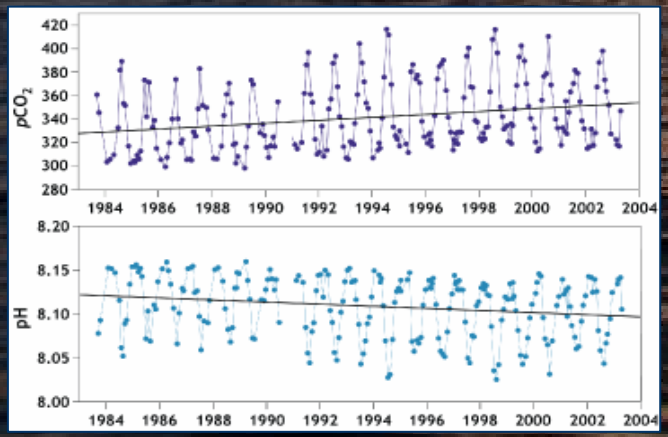
What is Ocean Acidification?



This is resulting in increased carbon dioxide (CO_2) in the atmosphere causing global warming

Mankind is burning fossil fuel

Oceans are vast and are taking up the CO_2

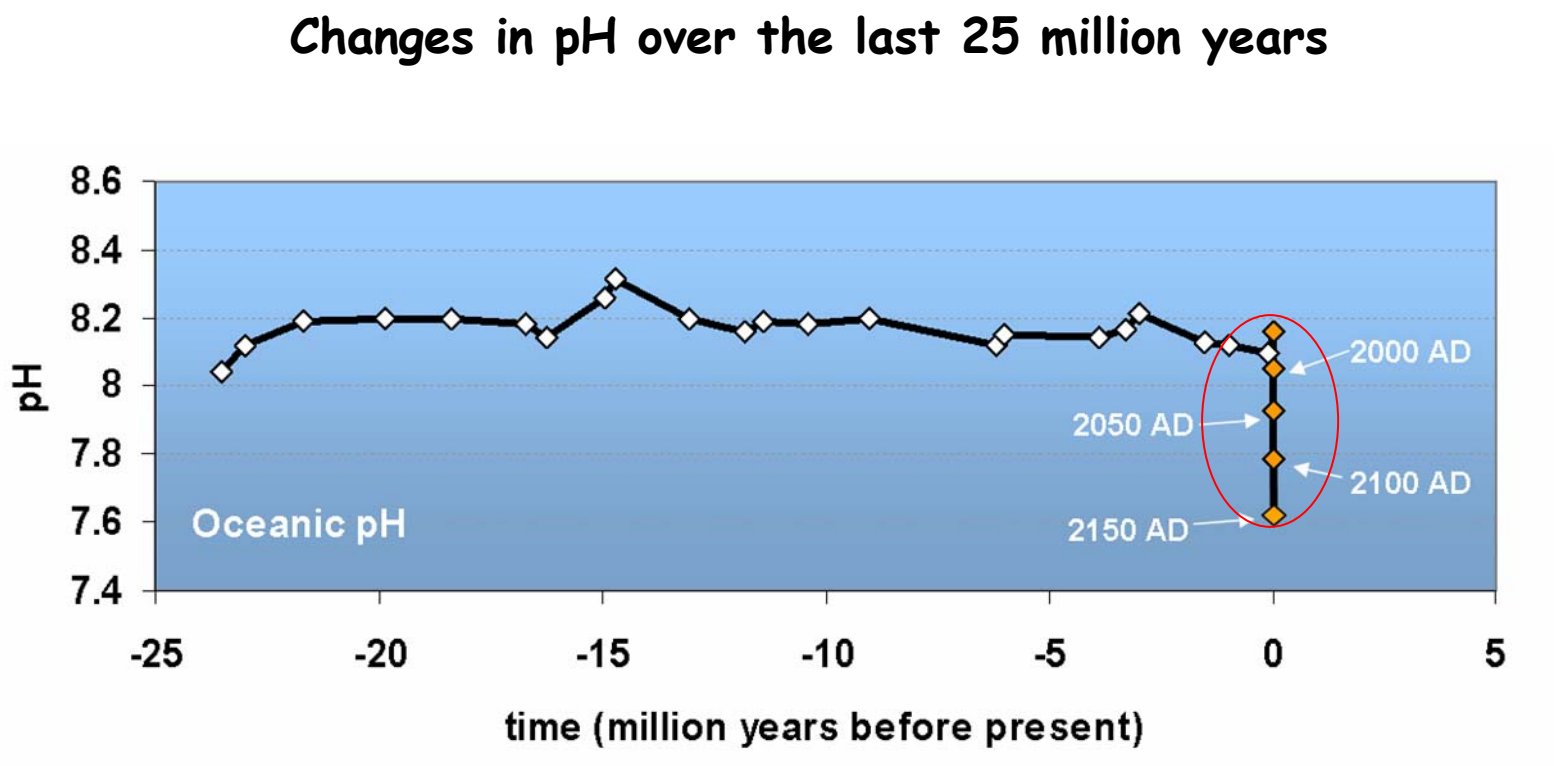


When CO_2 is added to water it becomes an acid…

…so the oceans have become 30% more acidic, lowering the pH of seawater

….by 2060 the oceans could become 120% more acidic

Oceans are Acidifying Fast …….



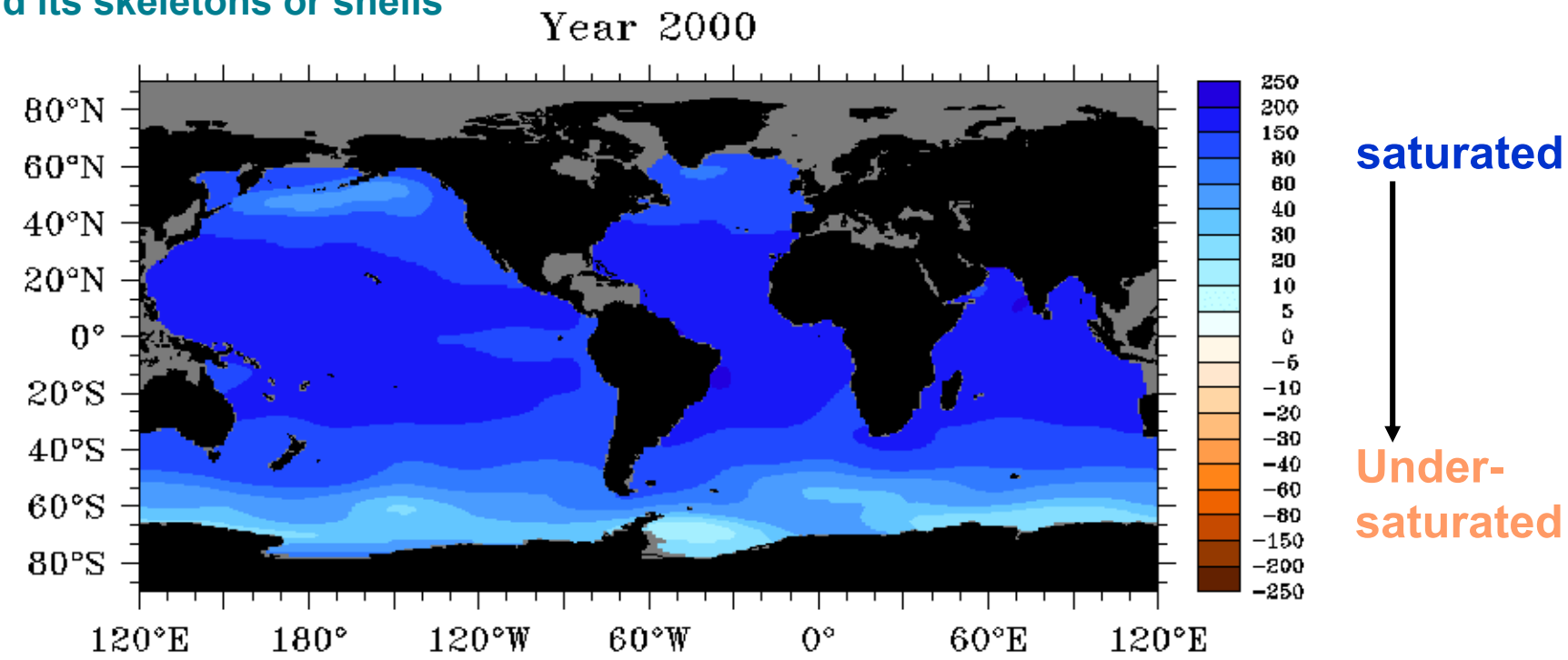
It is happening now, at a rate and to a level not experienced by marine organisms for ~ 20MY

Turley et al. 2006

Present and Future Global Aragonite Saturation States……

Aragonite is used by many organisms to make their shells and skeletons.

The extent of aragonite saturation controls the rate an organism such as a reef forming coral can build its skeletons or shells



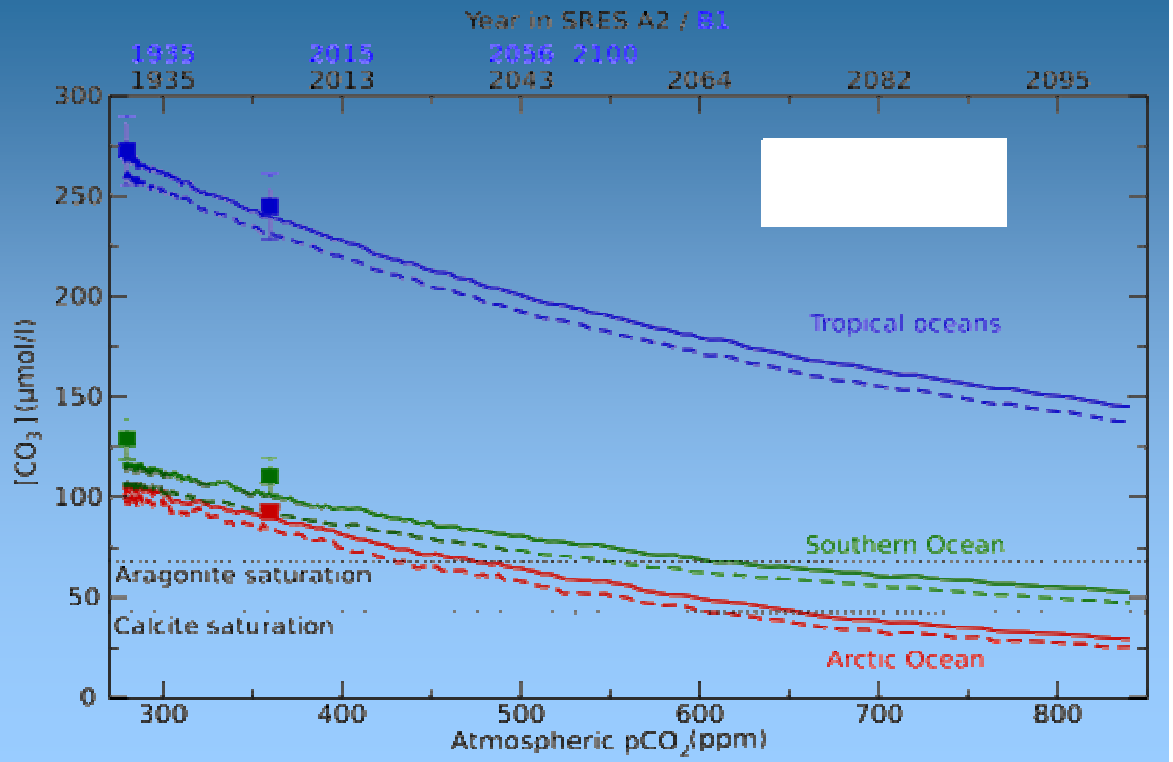
- **Overall decline in aragonite saturation in the global ocean - coral reef calcification < natural erosion = decline in reef structures**
- **Polar and subpolar waters become undersaturated**
- **Upwelling waters rich in CO_2 also vulnerable**

Orr et al. 2005

Polar Oceans are Vulnerability too….

If CO_2 emissions continue to rise as today (Orr et al.):

- 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

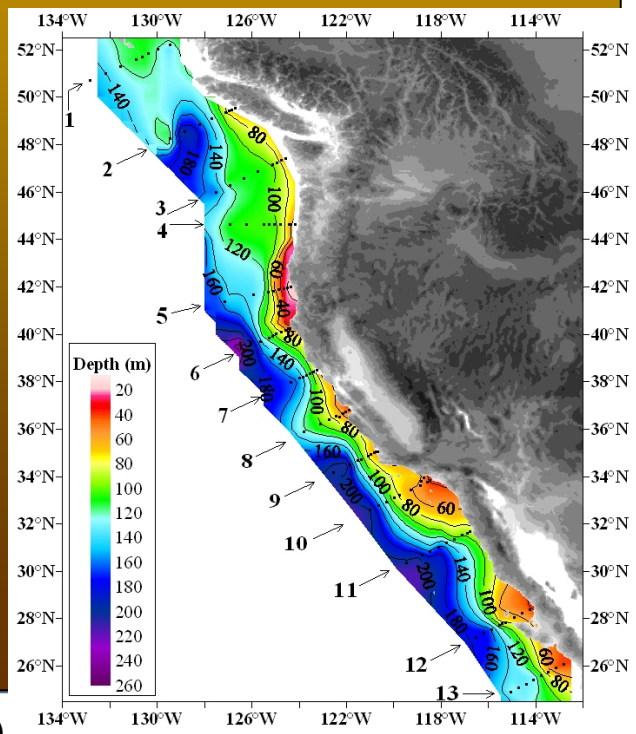
Seasonal Invasion of Corrosive Waters on West Coast North America

Inflow of corrosive waters across shelf and over extensive, productive ecosystems

upwelling of undersaturated waters (Ωarag values < 1.0) on to shelf seas

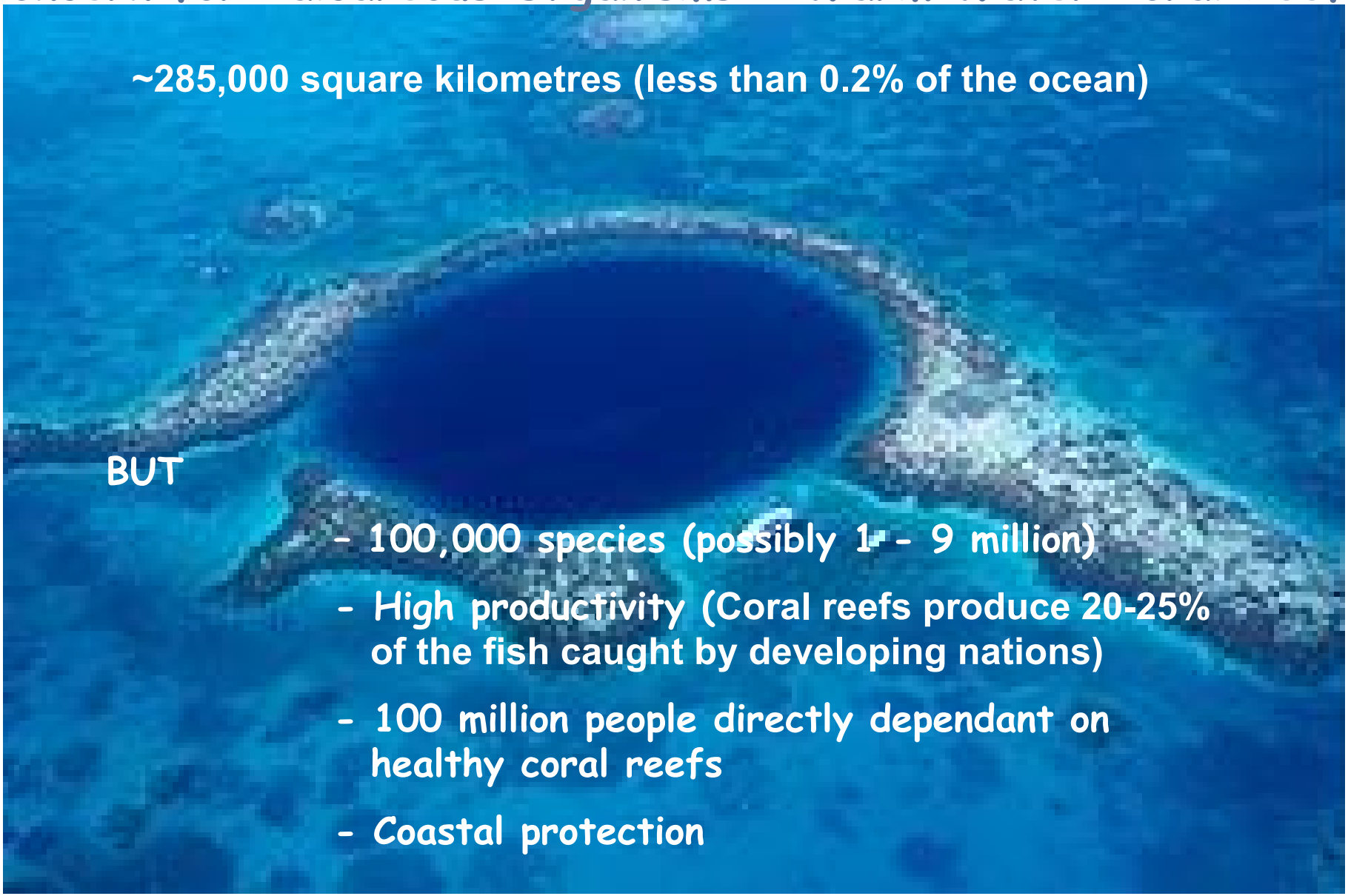
ASH (Ωarag values = 1.0) shoaling: 1m/a

Intermediate CO_2 rich corrosive waters (Ωarag values < 1.0)



Feely et al. Science (2008)

Concern for Calcareous Organisms - Warm Water Coral Reefs

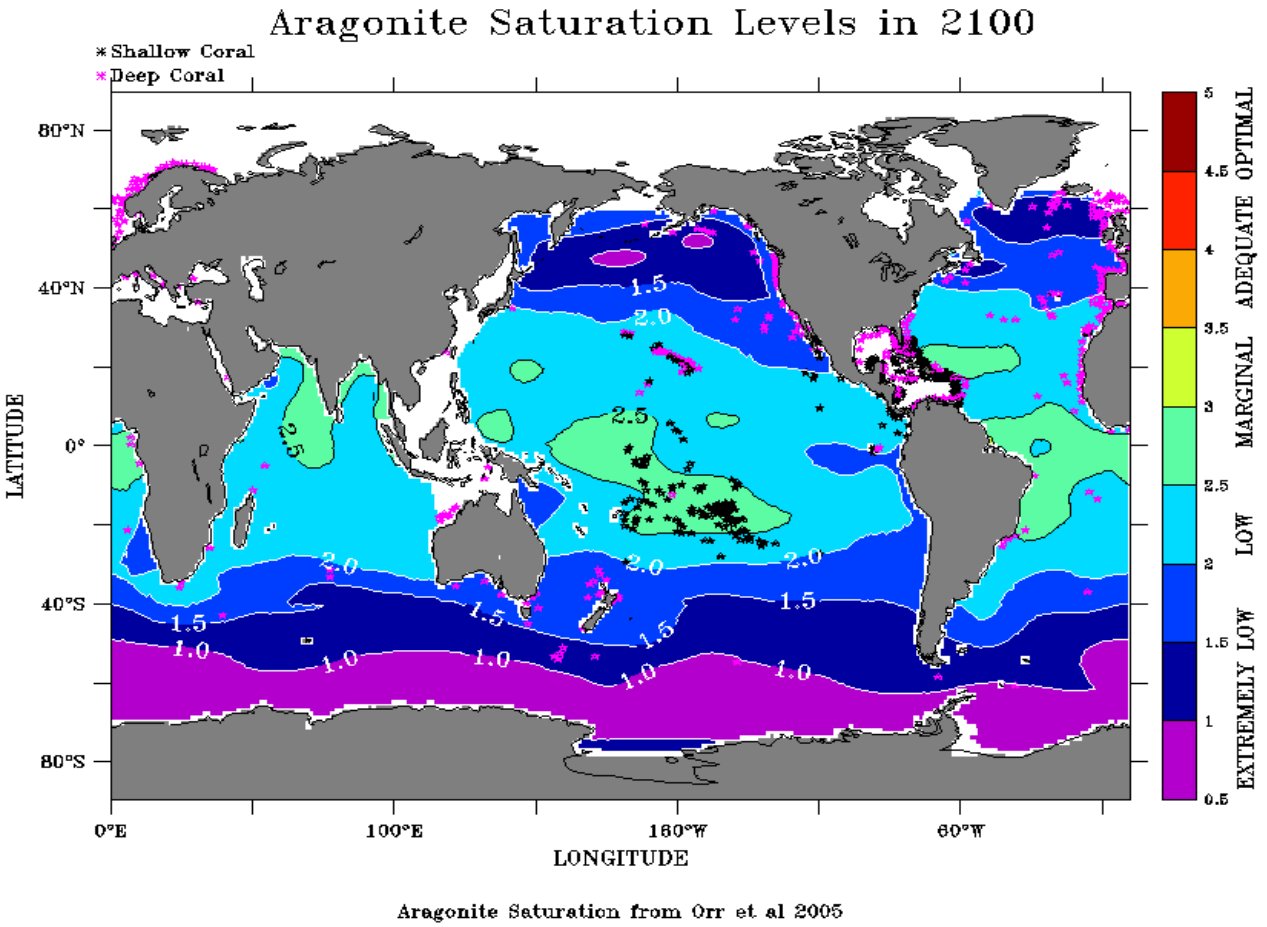


Projections of Aragonite Saturation Levels With Time

Corals like warm, sunlit waters saturated in aragonite

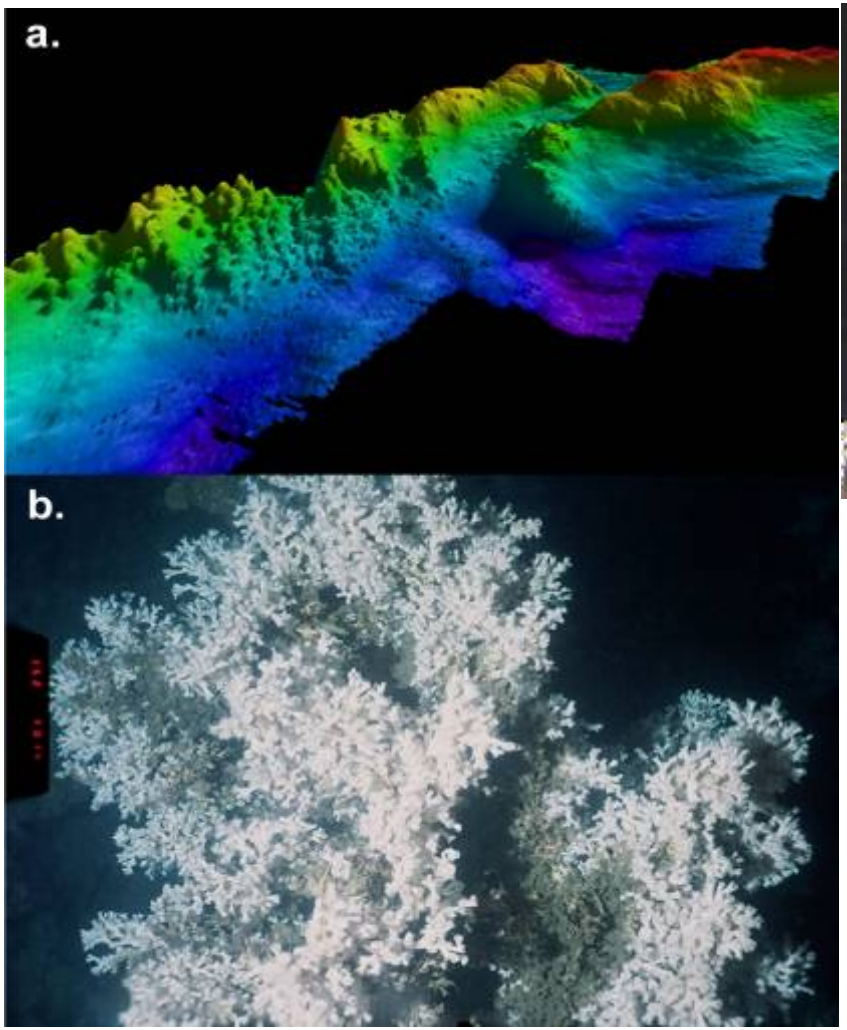
Coral Reef calcification
- 1765 Adequate
- 2000 Marginal
- 2100 Low

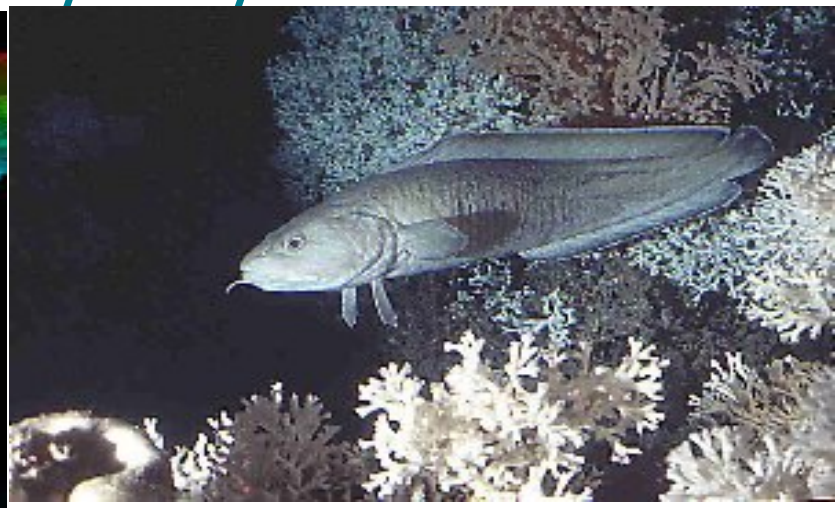
Calcification rates in the tropics may decrease by 30% over the next century



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

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

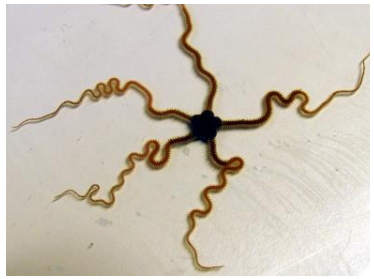
Fish use the coral thickets as a feeding ground and for shelter

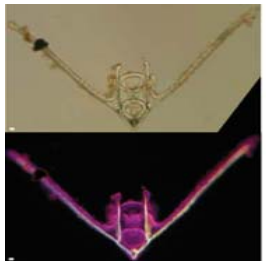
Reefs up to 8000 yrs old

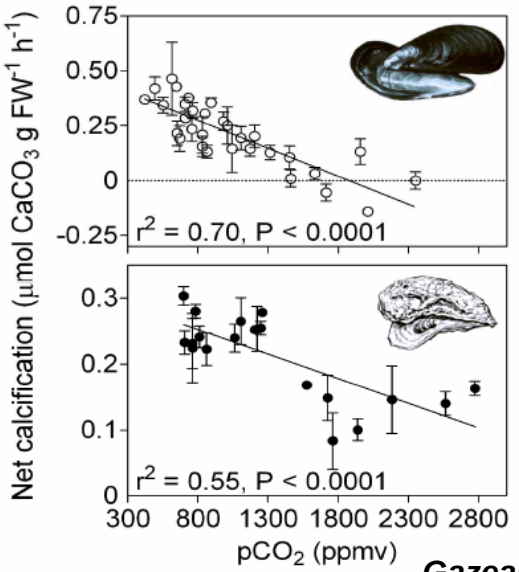
The majority (70%) of deep-sea corals will be in undersaturated waters by 2100

Guinotte et al 2006; Turley, Roberts and Guinotte 2007

Serious Effects on Marine Organisms, Especially those that Produce Shells and Skeletons ……..





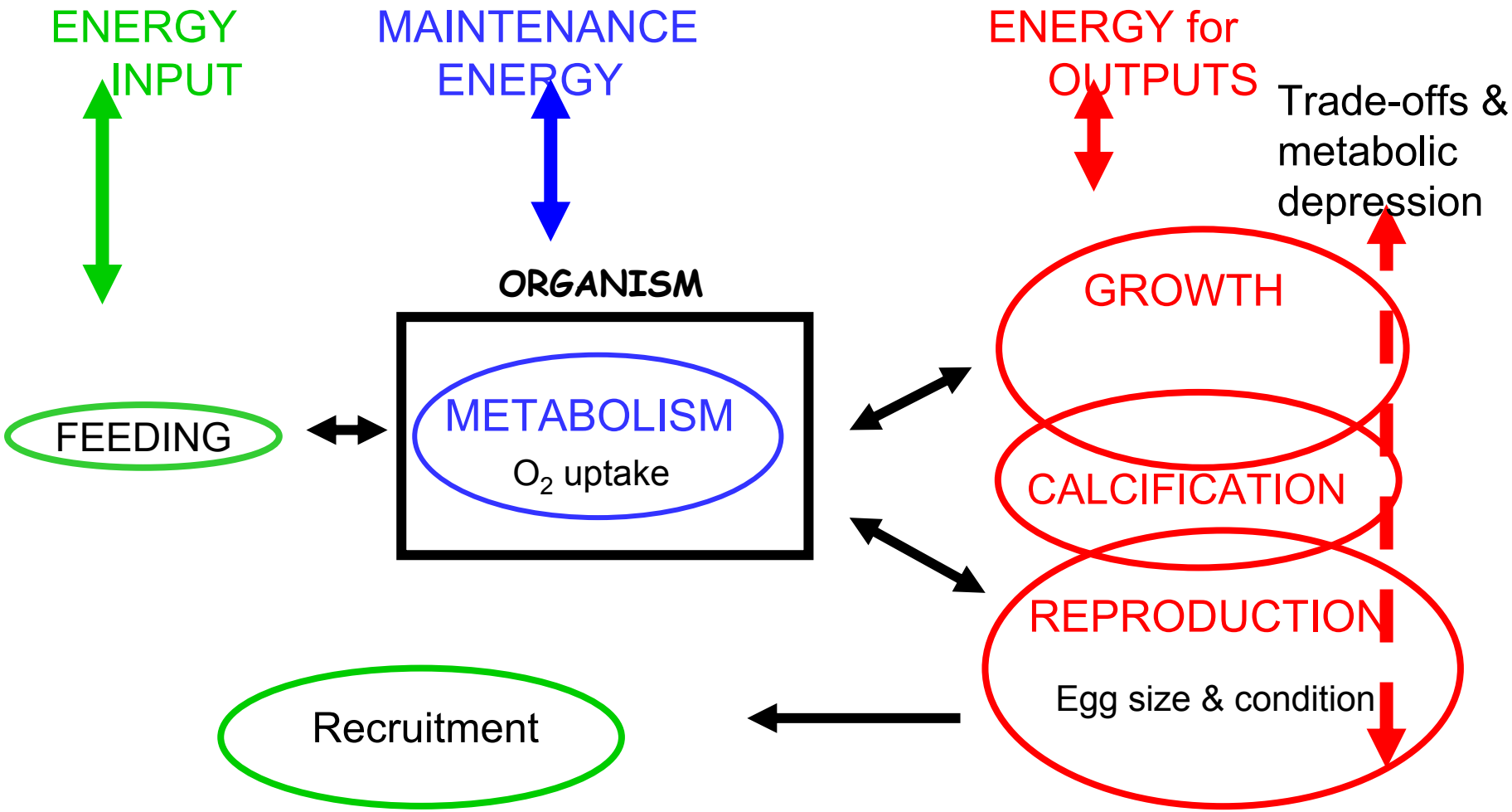


Gazeau 2007

- **Both adults and juveniles sensitive**
- **Shellfish and corals are especially vulnerable**
- **Some species more sensitive than others**
- **Physiology and behaviour impacted in some species**
- **Many sensitive species are directly or indirectly of great cultural, economic or biological importance**

Whole Organism Physiology – needed to assess impacts

Key Survival Processes



CO_2 Vents: "Windows" into High CO_2 Ocean to Assess Ecosystem Impacts

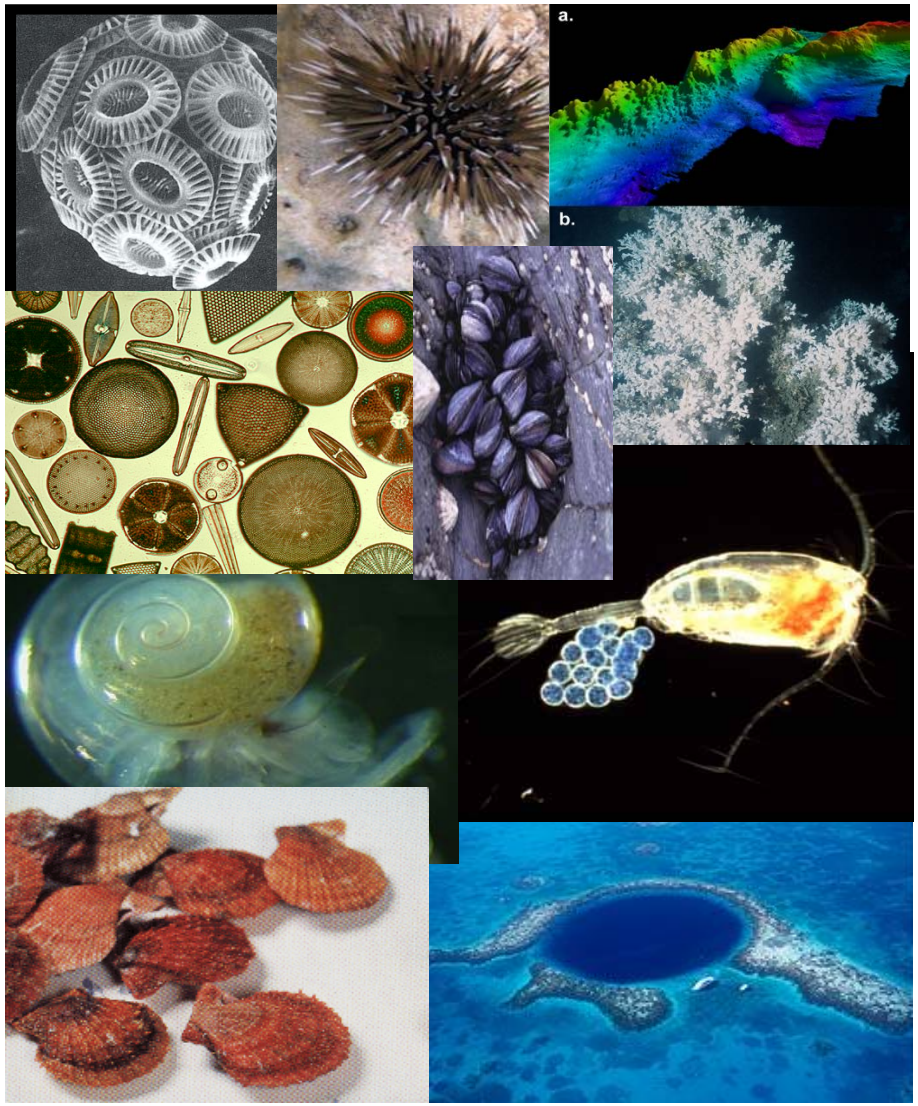
Hall-Spencer et al. Nature (2008)

Studies in the shallow waters of the Mediterranean and deep-sea show:

- total loss of some calcareous species
- reduced biodiversity
- "regime shifts": totally different ecosystems

e.g. Sea grass benefit but so do invasive species

Mounting Grave Concern for Survival of Many Marine Organisms, Food Webs and Ecosystems …….



- What will ocean ecosystems look like in a future high CO_2 world?
- And what will they be able to provide Mankind?
- Ocean acidification may impact food security:
  - Indirectly through food webs
  - Directly on food providing organisms
  - Many poorer countries depend nearly totally on fish as their main protein source

➢There may be winners and losers and some organisms that don't react at all

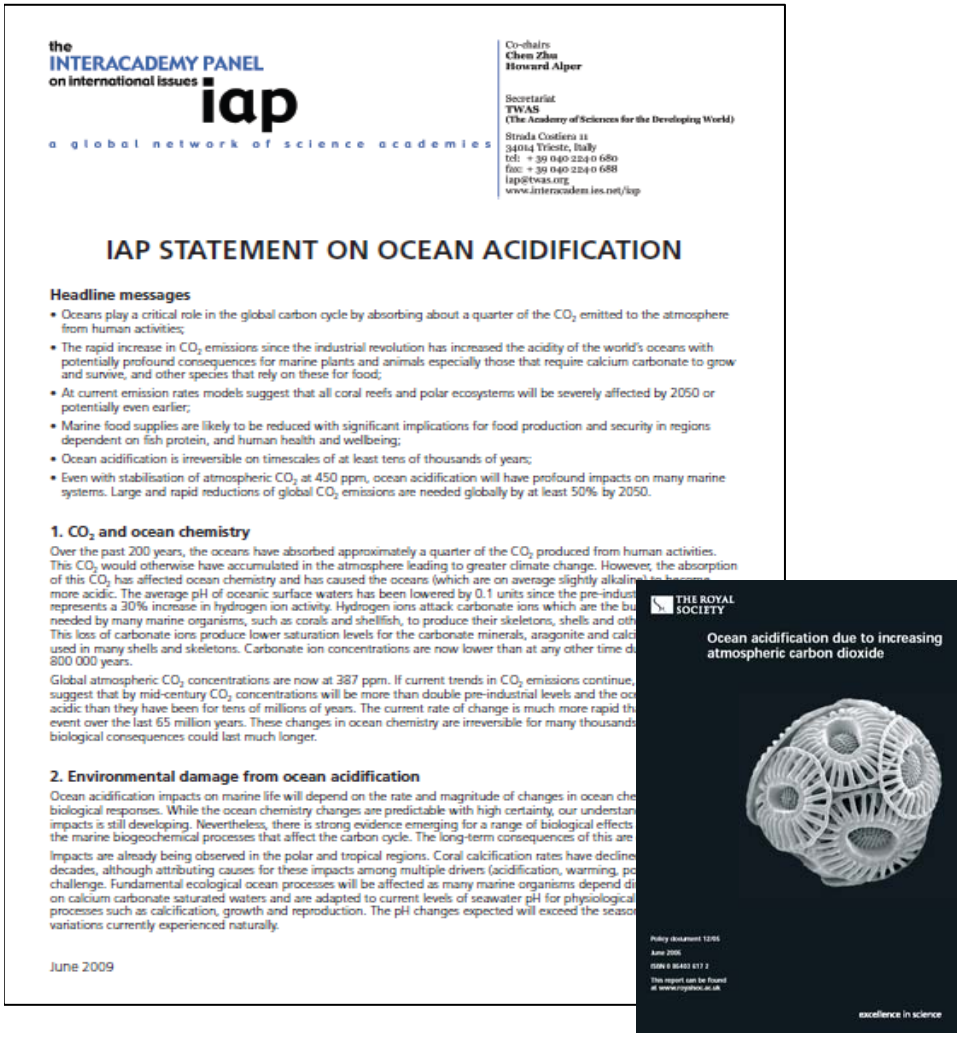
C. Turley

Getting the Message to Stakeholders – a concerted international effort

Since 2005 there has been a growing number of reports highlighting the issue, the concerns and research needs

IGBP-SCOR Fast Track Initiative "Ocean Acidification"

National Academies ……



the
INTERACADEMY PANEL
on international issues
iap
a global network of science academies

Co-chairs
Chen Zhu
Howard Alper

Secretariat
TWAS
(The Academy of Sciences for the Developing World)
Strada Costiera 11
34014 Trieste, Italy
tel: + 39 040 2240 680
fax: + 39 040 2240 688
iap@twas.org
www.interacademies.net/iap

IAP STATEMENT ON OCEAN ACIDIFICATION

Headline messages

- Oceans play a critical role in the global carbon cycle by absorbing about a quarter of the CO_2 emitted to the atmosphere from human activities;
- The rapid increase in CO_2 emissions since the industrial revolution has increased the acidity of the world's oceans with potentially profound consequences for marine plants and animals especially those that require calcium carbonate to grow and survive, and other species that rely on these for food;
- At current emission rates models suggest that all coral reefs and polar ecosystems will be severely affected by 2050 or potentially even earlier;
- Marine food supplies are likely to be reduced with significant implications for food production and security in regions dependent on fish protein, and human health and wellbeing;
- Ocean acidification is irreversible on timescales of at least tens of thousands of years;
- Even with stabilisation of atmospheric CO_2 at 450 ppm, ocean acidification will have profound impacts on many marine systems. Large and rapid reductions of global CO_2 emissions are needed globally by at least 50% by 2050.

1. CO_2 and ocean chemistry

Over the past 200 years, the oceans have absorbed approximately a quarter of the CO_2 produced from human activities. This CO_2 would otherwise have accumulated in the atmosphere leading to greater climate change. However, the absorption of this CO_2 has affected ocean chemistry and has caused the oceans (which are on average slightly alkaline [illegible] more acidic. The average pH of oceanic surface waters has been lowered by 0.1 units since the pre-indust represents a 30% increase in hydrogen ion activity. Hydrogen ions attack carbonate ions which are the bu needed by many marine organisms, such as corals and shellfish, to produce their skeletons, shells and oth This loss of carbonate ions produce lower saturation levels for the carbonate minerals, aragonite and calci used in many shells and skeletons. Carbonate ion concentrations are now lower than at any other time d 800 000 years.

Global atmospheric CO_2 concentrations are now at 387 ppm. If current trends in CO_2 emissions continue, suggest that by mid-century CO_2 concentrations will be more than double pre-industrial levels and the oc acidic than they have been for tens of millions of years. The current rate of change is much more rapid th event over the last 65 million years. These changes in ocean chemistry are irreversible for many thousands biological consequences could last much longer.

2. Environmental damage from ocean acidification

Ocean acidification impacts on marine life will depend on the rate and magnitude of changes in ocean che biological responses. While the ocean chemistry changes are predictable with high certainty, our understan impacts is still developing. Nevertheless, there is strong evidence emerging for a range of biological effects the marine biogeochemical processes that affect the carbon cycle. The long-term consequences of this are

Impacts are already being observed in the polar and tropical regions. Coral calcification rates have decline decades, although attributing causes for these impacts among multiple drivers (acidification, warming, po challenge. Fundamental ecological ocean processes will be affected as many marine organisms depend di on calcium carbonate saturated waters and are adapted to current levels of seawater pH for physiological processes such as calcification, growth and reproduction. The pH changes expected will exceed the seaso variations currently experienced naturally.

June 2009

Four years after its 2005 Report on Ocean Acidification Royal Society took on an InterAcademies Panel Statement
With remarkably 70 other national academies sign up.

….Key message picked up by press....

“Don’t leave ocean acidification out of COP15 … stabilization of atmospheric CO_2 at 450 ppm will have profound impacts on marine systems”

European Science Foundation

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

SCIENCE POLICY BRIEFING • August 2009 37

Impacts of Ocean Acidification

Contents

Foreword

There is growing scientific evidence that, as a result of increasing anthropogenic carbon dioxide (CO_2) emissions, absorption of CO_2 by the oceans has already noticeably increased the average oceanic acidity from pre-industrial levels. This global threat requires a global response. According to the Intergovernmental Panel on Climate Change (IPCC), continuing CO_2 emissions in line with current trends could make the oceans up to 150% more acidic by 2100 than they were at the beginning of the Anthropocene.

Acidification decreases the ability of the ocean to absorb additional atmospheric CO_2, which implies that future CO_2 emissions are likely to lead to more rapid global warming. Ocean acidification is also problematic because of its negative effects on marine ecosystems, especially marine calcifying organisms, and marine resources and services upon which human societies largely depend such as energy, water, and fisheries. For example, it is predicted that by 2100 around 70% of all cold-water corals, especially those in the higher latitudes, will live in waters undersaturated in carbonate due to ocean acidification. Recent research indicates that ocean acidification might also result in increasing levels of jellyfish in some marine ecosystems. Aside from direct effects, ocean acidification together with other global change-induced impacts such as marine and coastal pollution and the introduction of invasive alien species are likely to result in more fragile marine ecosystems, making them more vulnerable to other environmental impacts resulting from, for example, coastal deforestation and wide-scale fisheries.

The Marine Board-ESF Position Paper on the *Impacts of Climate Change on the European Marine and Coastal Environment – Ecosystems*[1] indicated that preventing ocean acidification issues to policy makers is a key issue and challenge. Indeed, as the consequences of ocean acidification are expected to emerge rapidly and drastically, but are often not well known or are completely unknown, a strategic workshop was organised by the ESF Standing Committee for Life, Earth and Environmental Sciences (LESC) in cooperation with the ESF EUROCORES Programme EuroCLIMATE. The aim was to address the issue of the impacts of ocean acidification on both the natural and socio-economic systems, and to identify the gaps of knowledge in this field. The present Science Policy Briefing resulting from this strategic workshop has undergone external international peer review and has been approved by both the Marine Board-ESF and LESC.

The ESF considers this Science Policy Briefing on the *Impacts of Ocean Acidification* an important step towards raising awareness amongst a wide range of research actors, policy makers and funding agencies. Taking into account the range of priorities and key areas of research requiring action at the pan-European level, a series of recommendations for European actions have been drawn up under the following five headings: (i) increase understanding and improve quantification of the organismal and ecosystem responses to ocean acidification; (ii) include the human dimension by increasing collaboration and integration efforts between natural and social sciences; (iii) rationalise, improve and focus monitoring and data gathering, management, processing and accessibility efforts; (iv) increase dissemination, outreach and capacity-building efforts, in particular related to communicating ocean acidification to stakeholders (policy makers, research funders, public, media, etc.); and (v) improve coordination of ocean acidification research and collaboration both at the national and international levels.

Professor Marja Makarow, Chief Executive, ESF
Professor Reinhart Ceulemans, Chair, LESC
Mr. Lars Horn, Chair, Marine Board-ESF

Box 1: Key Recommendations for European Actions

Key recommendations for European actions in order to fully understand the impacts of ocean acidification are as follows:

1) quantify further the biological and biogeochemical responses to ocean acidification from the organismal to the ecosystem level
2) integrate natural and social sciences to help mitigate ocean acidification and develop adaptation strategies, taking into account the socio-economic impacts on natural resources and human communities. The full cost of abating CO_2 emissions, and of carbon capture and storage should be also considered
3) ensure adequate and sustainable monitoring of key marine ecosystems and environmental services
4) facilitate dissemination and capacity building to help deliver scientific knowledge-based advice to research funders and policy makers, to share best practices among researchers and success stories with the general public, and to raise the profile of this issue in future environmental change assessments
5) coordinate and strengthen European research on the impacts of ocean acidification, including sharing of research infrastructure, resources and knowledge.

www.esf.org

A Science Policy Briefing highlighting the socio-economic aspects of ocean acidification

National and International Research Programmes…

- European Project on OCean Acidification (EPOCA) – €6M+ (EU)
- German Programme (BIOACID) - €8.5M (BMBF)
- UK Ocean Acidification Programme – £12M (NERC, Defra and Dti)
- The Federal Ocean Acidification Research and Monitoring (FOARAM) Act signed by President Obama in 2009 requiring NOAA, NSF and other federal agencies to develop a national programme in 2010.
- Other research programmes around the world (Korea, Japan, China, Ireland, Australia)
- Ocean acidification in the Mediterranean Sea - €3M (EU call 2009)
- IGBP has formed an International SOLAS-IMBER Working Group on Ocean Acidification

PML | Plymouth Marine Laboratory

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

Oceans will become more acidic – very high certainty.

The impact on ocean food webs, ecosystems and biogeochemical cycles and the goods and services they provide could be serious.

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

International research efforts are required to reduce uncertainties concerning the impacts of ocean acidification and whether adaptations could be possible.