# Ocean acidification

RIO+20
the future we want

Rio+20 outcome document, paragraph 166:

*"We call for support to initiatives that address ocean acidification and the impacts of climate change on marine and coastal ecosystems and resources. In this regard, we reiterate the need to work collectively to* ***prevent further ocean acidification****, as well as* ***enhance the resilience*** *of marine ecosystems and of the communities whose livelihoods depend on them, and to* ***support marine scientific research, monitoring and observation*** *of ocean acidification and particularly vulnerable ecosystems, including through* ***enhanced international cooperation in this regard****."*

At Rio+20 the IAEA launched the PUI project:

*Ocean Acidification International Coordination Centre (OA-ICC)*

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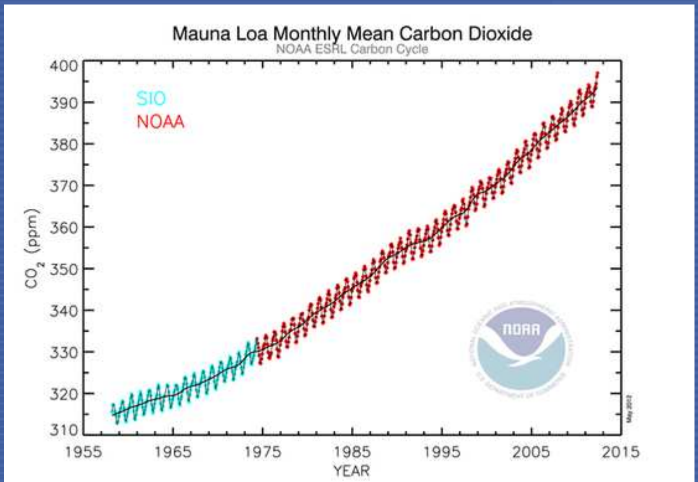
# Ocean acidification

Ocean Acidification is a major, global environmental pressure due to increasing atmospheric $CO_2$ concentration in surface marine water.




It is predicted to have **major impact** on key marine ecosystems, including on biodiversity, safety and security of seafood resources and ecosystems services, especially in fragile ecosystems such as tropical coral reefs and polar regions.

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# Ocean acidification - numbers

- Ocean/atmosphere exchanges of $CO_2$ are very important
- Net uptake by oceans of 25-30% of man-made $CO_2$ emissions: ***24 million tons*** $CO_2$ per day!
- Key defence (buffer) against global warming, but drawback: causing an increase in acidity (decrease in pH).
- Acidity of the oceans has increased by ***30%*** since the onset of the industrial revolution.
- If $CO_2$ emissions continue at the current rate, acidity will increase by ***150%*** by 2100 (highest acidity experienced by marine ecosystems since at least ***800 000 years***).
- The current rate of pH change is unprecedented for ***300 millions years***.

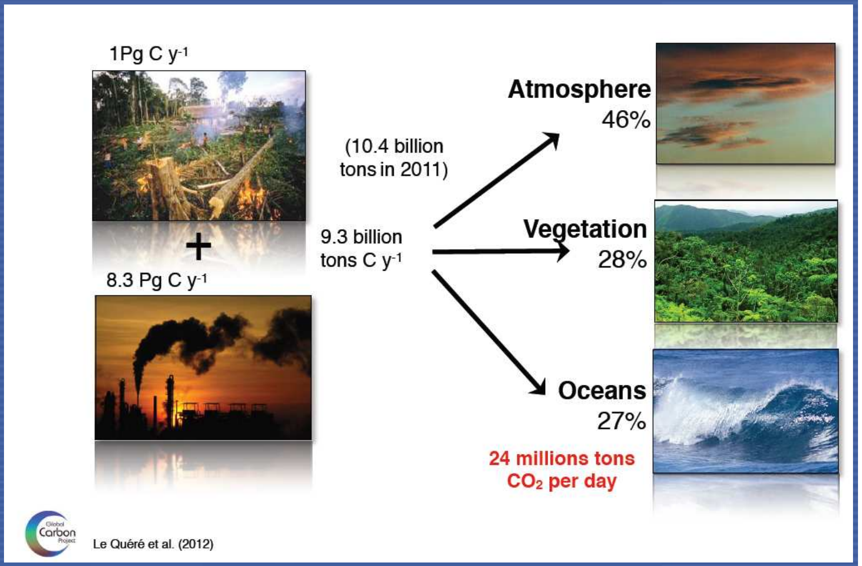



*Image courtesy of **J.-P. Gattuso***

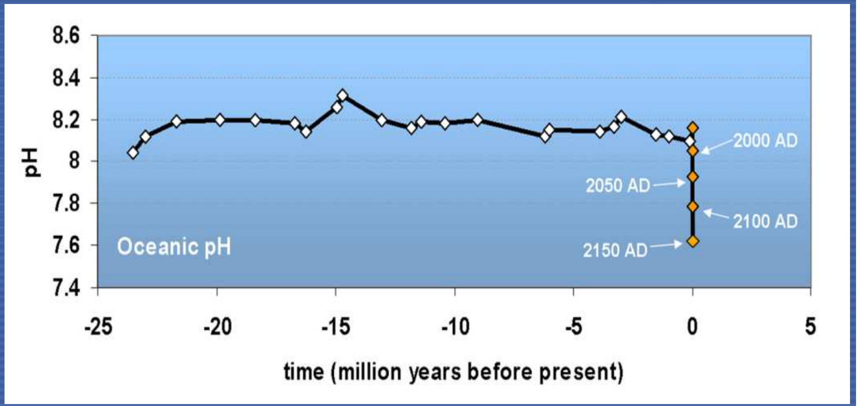
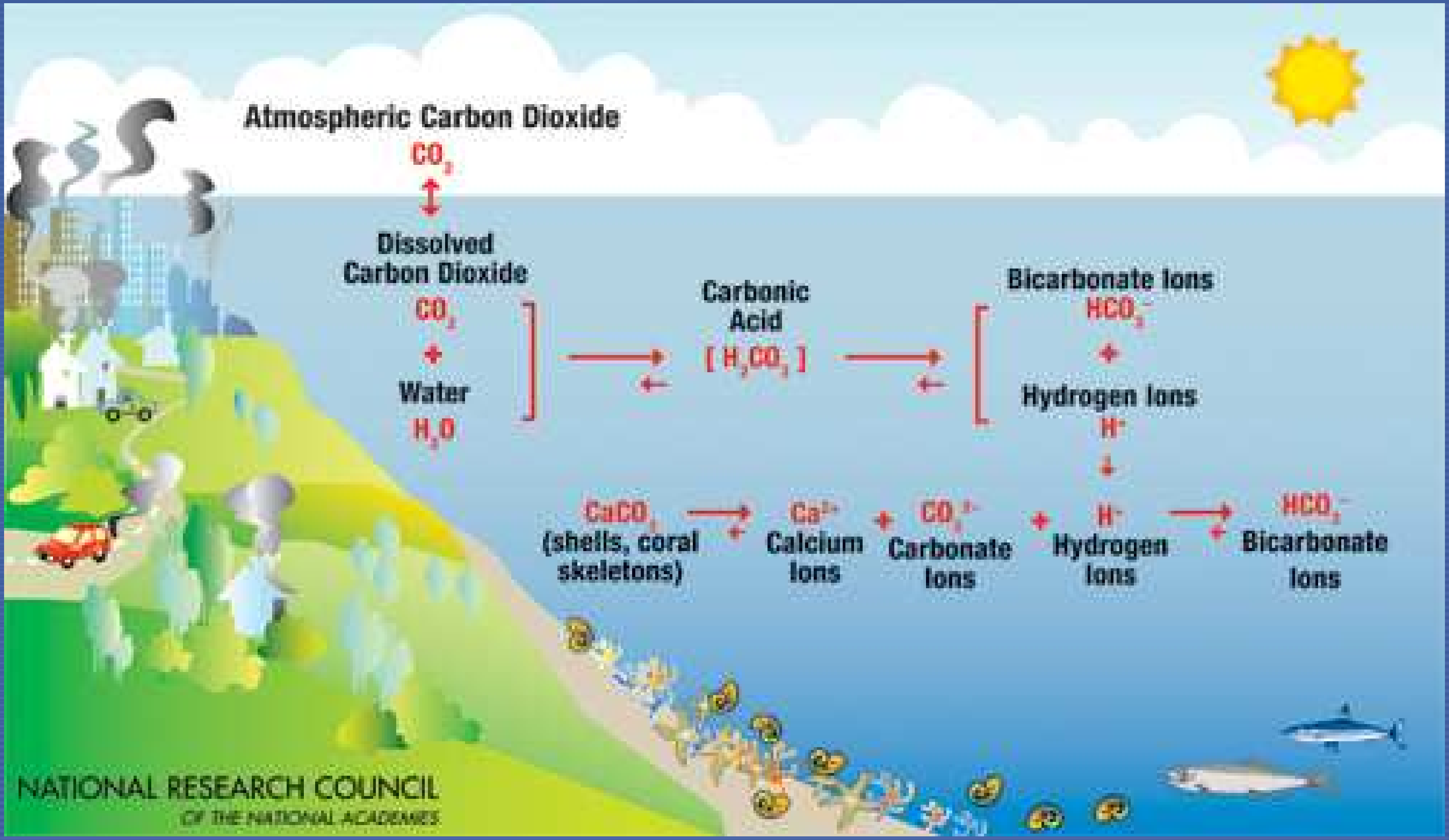



*Image courtesy of **C. Turley***

# Ocean Acidification = a chemical reaction

$$CO_2 + H_2O \Longleftrightarrow H_2CO_3 \Longleftrightarrow CO_3^{-2} + HCO_3^{-} + H^{+}$$

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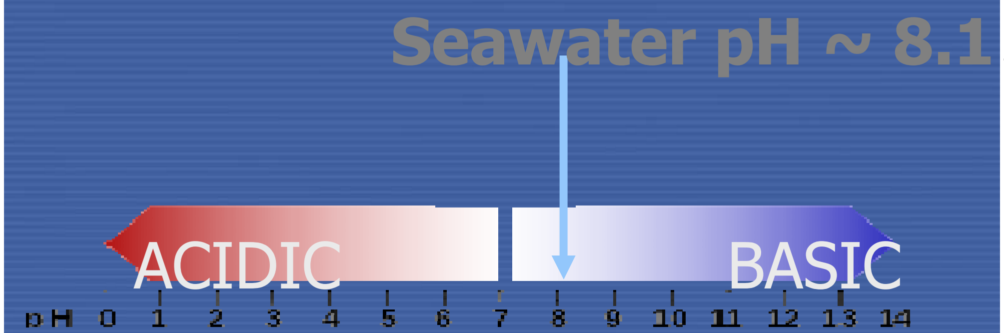
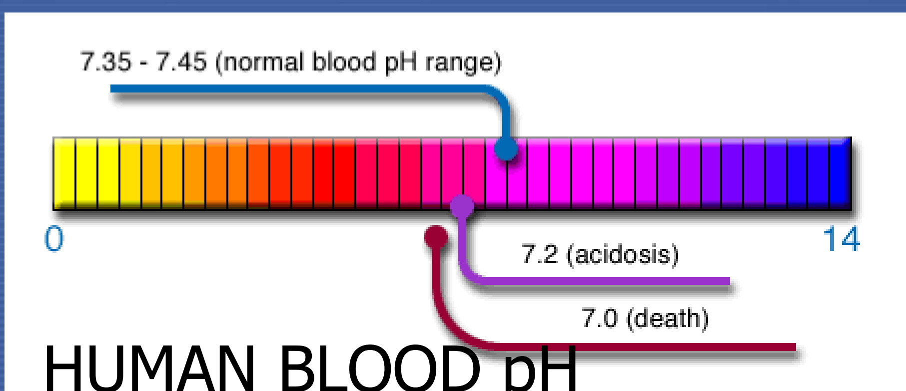
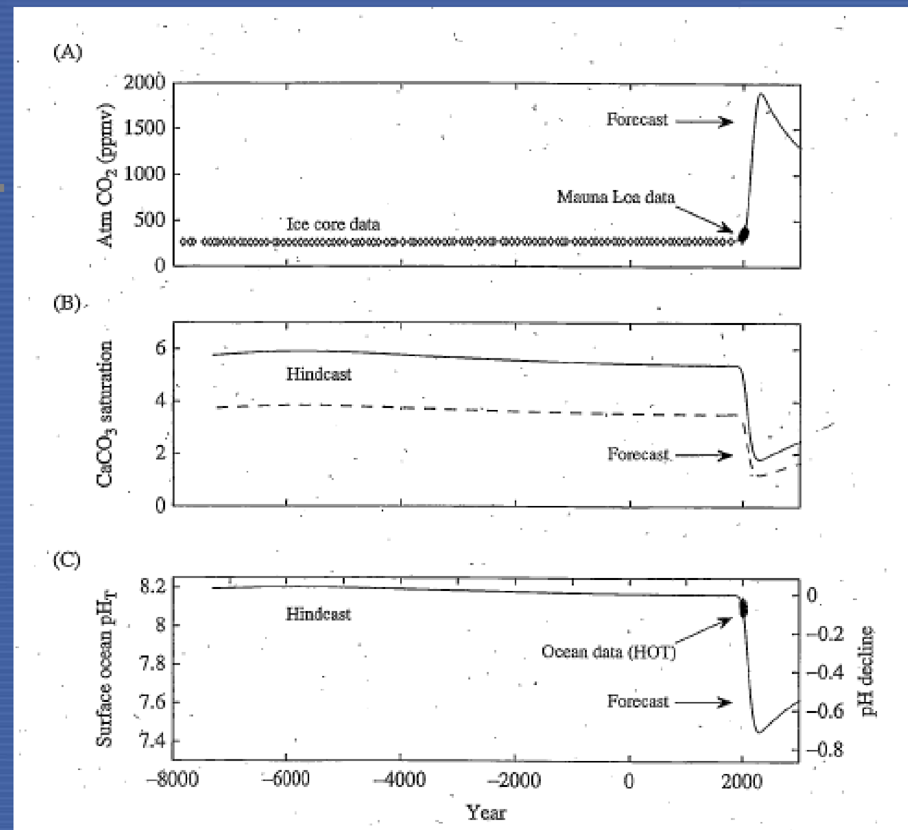
# Ocean Acidification = a chemical shift

# pH === -log[$H^+$]

# pH = 7 equivalent to [ ] = 1 x $10^{-7}$ $H^+$ ions




Zeebe and Ridgwell (2011) *Past changes in ocean carbonate chemistry.*

A. Atmospheric $CO_2$ [ppmv]

B. $CaCO_3$ Saturation

C. Surface Ocean $pH_T$

# Ocean Acidification Stress Guide (Turley *et al*, 2011)

| Stressor | Cause | Result | Direct Effects | Impacts | Feedback to climate |
|---|---|---|---|---|---|
| ACIDIFICATION | Increasing carbon dioxide emissions | Rapid change to carbonate chemistry | Reduced calcification, growth, and reproduction rates | Impeded shell/skeletal growth and physiological stress in many species, including juvenile and larval stages | Reduced ocean uptake of carbon dioxide |
| | Coastal nutrient enrichment | Ocean becomes corrosive to shelled animals/corals | Changes to carbon/nitrogen composition of organic material | Change to biodiversity and ecosystems, and the goods and services they provide | Changes to export of carbon to ocean interior |
| | | | | Cold and upwelling waters with key fisheries and aquaculture likely to be especia vulnerablelly | Higher oxygen use in the water column due to changing composition of organic material |

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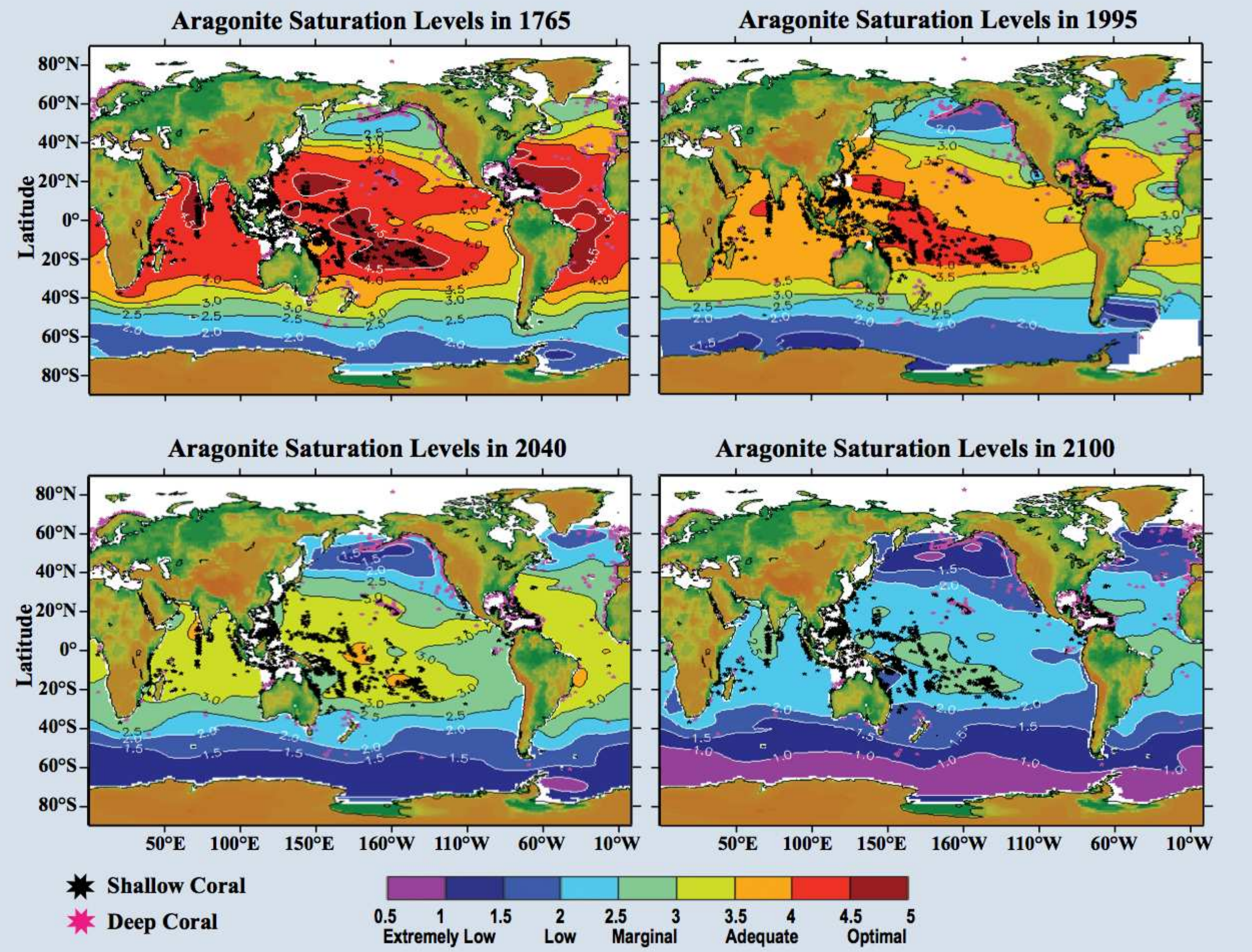
# **Ocean acidification** - Unequal impact at regional level

Ω aragonite

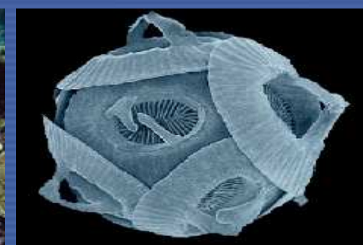



Estimated aragonite saturation states of the surface ocean for the years 1765, 1995, 2040, and 2100 (Feely *et al.*, submitted), based on the modeling results of Orr *et al.* (2005) and a Business-As-Usual $CO_2$ emissions scenario. The distributions of deep-sea coral banks are from Guinotte *et al.* (2006).

# **Ocean acidification** - Impacts

## Possible impacts on marine organisms and ecosystems

- Growth
- Calcification
- Photosynthesis
- Reproduction
- Behavior
- Food web
- Biodiversity



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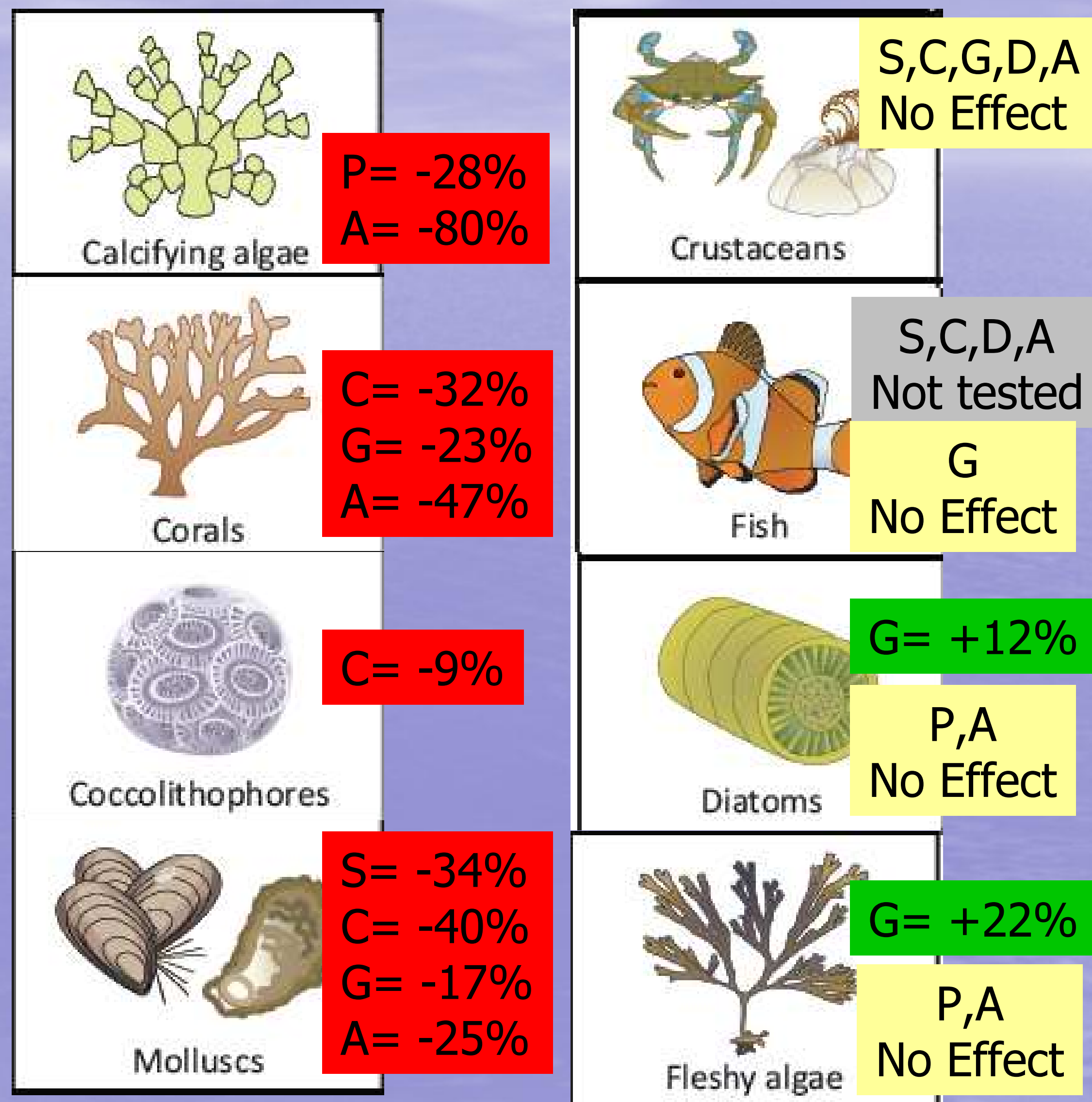
# Ocean Acidification ~ biological effects

- Growth
- Photosynthesis
- Reproduction
- Behavior
- Calcification
- Abundance
- Survival
- Food web…?

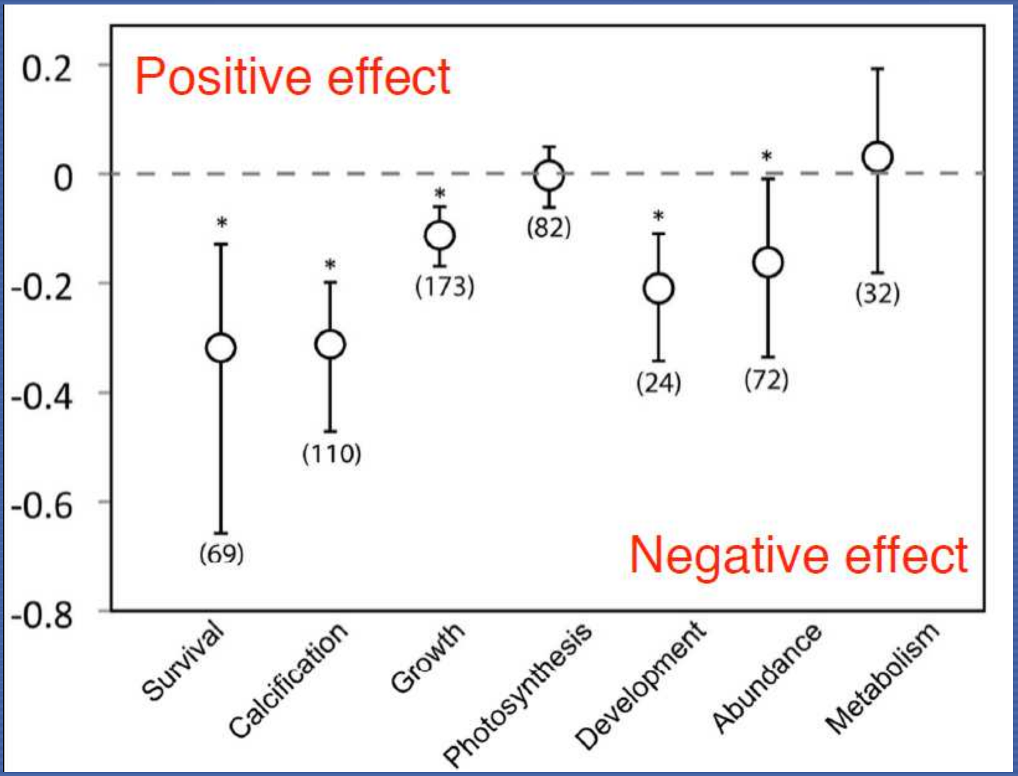



Kroeker *et al* (submitted) 228 studies

# **Ocean acidification** – Recent results

Analysis of data from 228 scientific articles show significant negative effects on:

- survival
- calcification
- growth
- development
- abundance




Kroeker at al., in press

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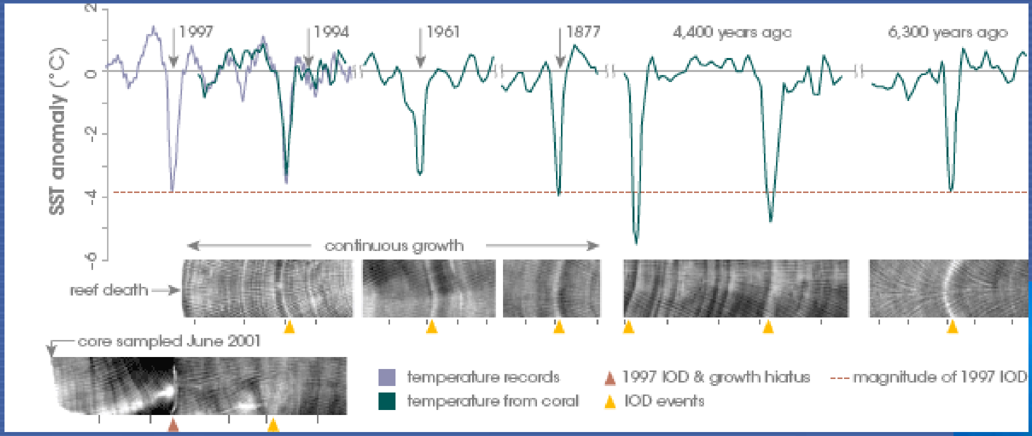
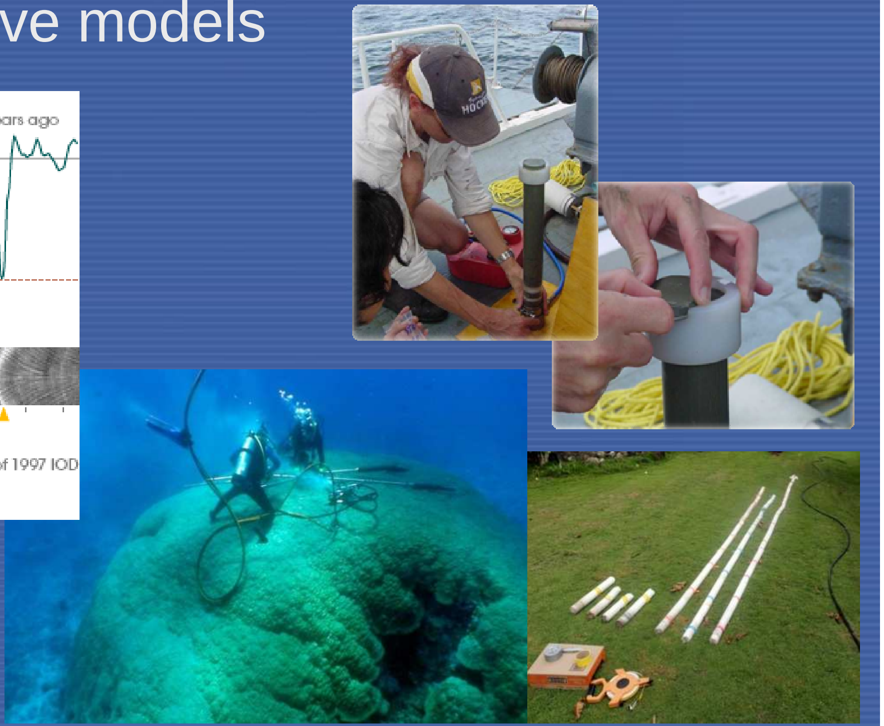
# **Ocean acidification** – Nuclear and isotopic applications

Geochronology (radiological dating)+ Paleo-climatology (isotopic ratio analysis): powerful tool that allows reconstructing prevailing environmental conditions over last decades to millennia to calibrate and improve descriptive and predictive models



Environmental recorders:
- sediment cores
- coral skeleton

Isotopes used as proxies :
e.g., B-11/B-10 for past pH

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# **Ocean acidification** – Nuclear and isotopic applications

Unique tools to assess biological effects under projected $pCO_2$ scenarios, identify vulnerable organisms, evaluate potential coastal economic impacts (fisheries, aquaculture, ecosystem services), e.g.:

- Use of Ca-45 to assess growth and calcification rates
- Use of C-14 to assess primary production of marine phytoplankton
- Use of radio-tracers to assess change in pollutant availability

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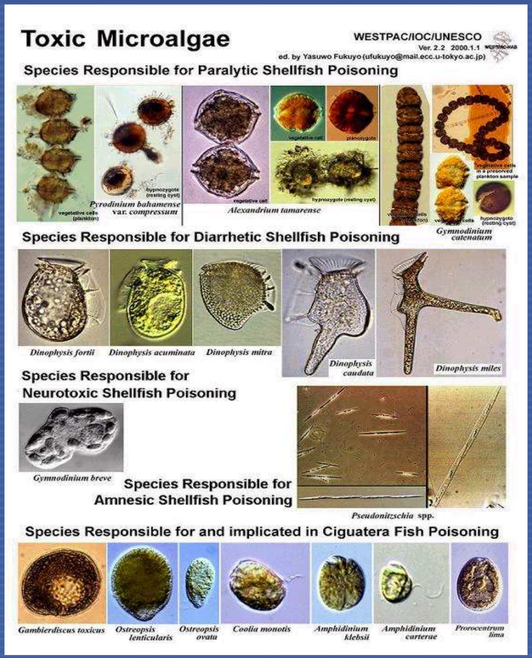
# **Ocean acidification** – Seafood Safety

## Harmful Algal Blooms (red tides)




- HABs are (with hypoxia) the most severe indication of eutrophication, and likely of temperature and *p*$CO_2$ increase.
- Major public health and socioeconomic problem
- Threat to resource diversity and stocks, sustainable coastal fisheries, and human health.

HABs Management Tool:
radio-ligand Receptor Binding Assay (RBA)

AOAC First Action Official Method[SM] (ref. 2011.27)

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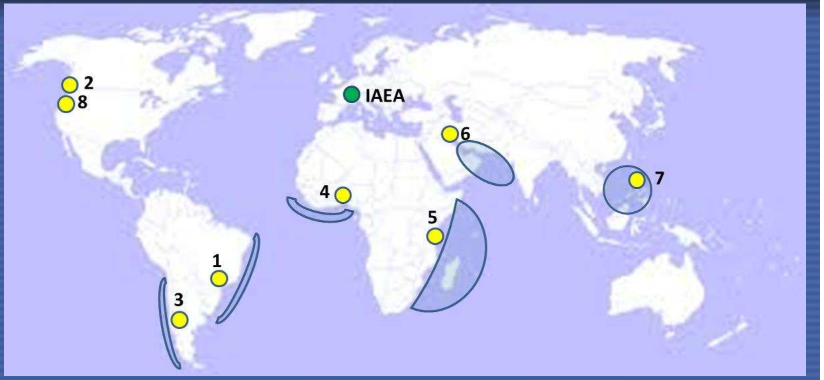
# Coordinated Research Project:
# "Ocean Acidification and Economic Impacts on Fisheries"

## Background:

US-supported extra-budgetary CRP (Coordinated Research Project) funded for 4 years

## Overall objectives:

- Assess biological and social effects due to ocean acidification in key ecological sites south of 30°N.
- Identify vulnerable regions and communities.
- Evaluate coastal economic impacts from ocean chemistry change on a regional scale using bio-economic models.




**Activities 2011/2012:**

- October 2011: Consultancy Meeting
- Sep 2012: Start of CRP (8 contracts)
- Nov 2012: 1st Coordination Meeting

**Upcoming:**

- 2013: Project development and additional participants
- 2014: Regional training workshop on OA impact modelling

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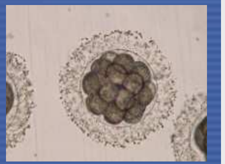
# Coordinated Research Project:
# "Ocean Acidification and Economic Impacts on Fisheries"

**GHANA**
OA impacts on fisheries & livelihoods

**BRAZIL**
$CO_2$ effects on calcification*
[$^{45}$Ca] of mussel larvae



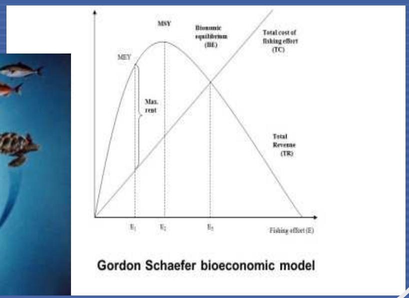

**PHILIPPINES**
pH effects on fish eggs/larvae & economic valuation of OA impact on fisheries

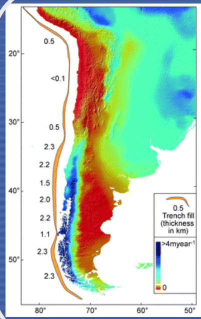
**KENYA**
OA impacts on reefs, fish & livelihoods


**KUWAIT**
$CO_2$ effects on coral calcification*
[$^{45}$Ca] ; OA reef impacts

**CANADA**
Training in use of BCE Model of OA effects on fisheries for coupled bio-physical and socio-economic factors

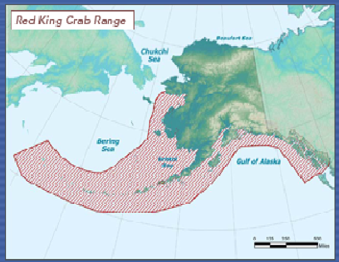
Based on MEY of the modified Gordon-Schaefer model for Bio-economics



**CHILE**
upwelled $CO_2$ effects on adult mussel aquaculture

**USA**
NOAA collaboration in use of Rational Expectations Models based on MEY in fisheries for OA impacts




*CASE STUDY of Bristol Bay King Crab Fishery*

# Bridging the gap between ocean acidification impacts and economic valuation

- Several policy briefs, including the Monaco Declaration signed by 155 scientists in 2008, have highlighted the need for scientists and economists to work together on ocean acidification to make sure to consider issues important for society.

- In response to these recommendations, the IAEA and the *Centre Scientifique de Monaco* initiated multidisciplinary activities on ocean acidification, including a series of International Workshops on Economics of Ocean Acidification.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# Bridging the gap between ocean acidification impacts and economic valuation

First International Workshop on Economics of Ocean Acidification held in Nov 2010
Second International Workshop held in Nov 2012 : 55 Experts - Impacts on fisheries and aquaculture

Workshop recommendations include education and training for coastal communities, monitoring for OA, and the adaptation of aquaculture and fishing practices (*brochure for policy makers* released in Apr 2013).



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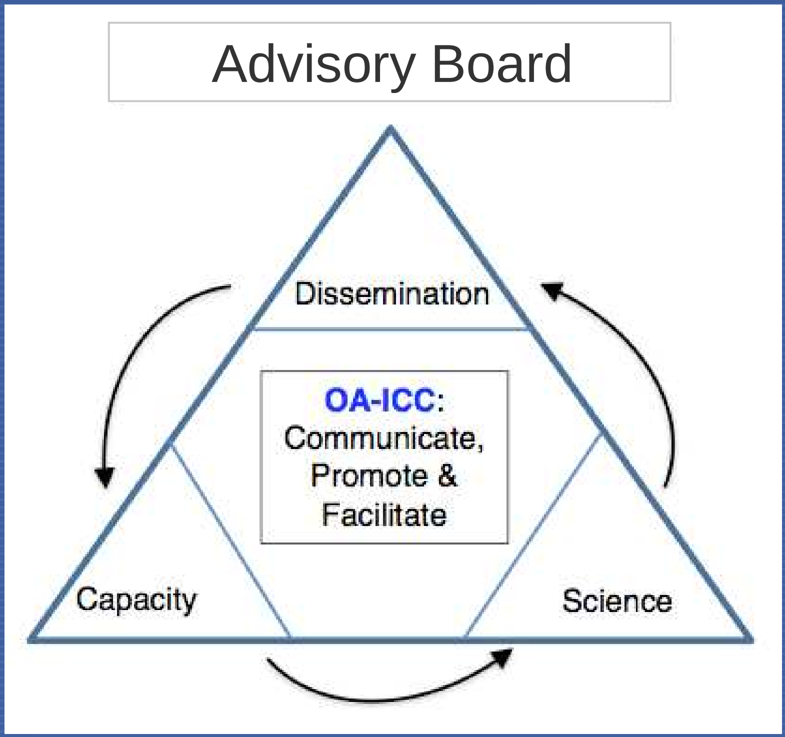
# Ocean Acidification International Coordination Centre (OA-ICC)

*Communicating, promoting and facilitating global actions in a changing ocean world*




- **Project** supported by MSs and major OA Programmes; operated by the Environment Laboratories in Monaco under the IAEA Peaceful Uses Initiative (PUI)

- **Objective**: act as a platform to communicate, promote and facilitate a number of overarching activities on ocean acidification by building on previous and current efforts and research investments.

- **End-Users**: scientific community and science users (policy makers, media, general public)

www.iaea.org/nael/OA-ICC

www.iaea.org/nael/OA-ICC

www.oceanacidification.wordpress.com

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Thank you
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