

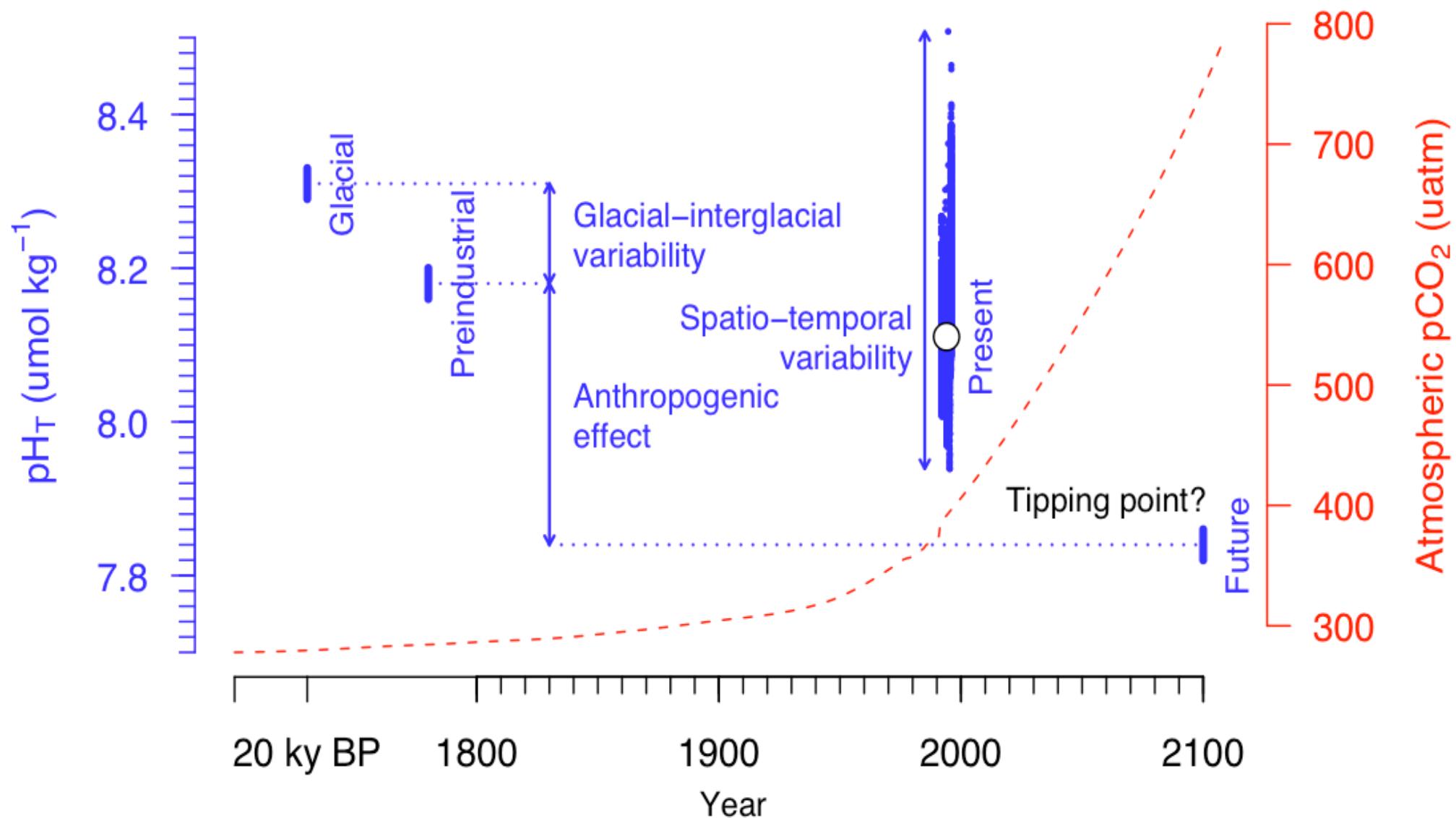
Ocean acidification: knowns, unknowns and perspectives

**Jean-Pierre Gattuso¹, Jelle Bijma, Marion Gehlen,
Ulf Riebesell & Carol Turley**

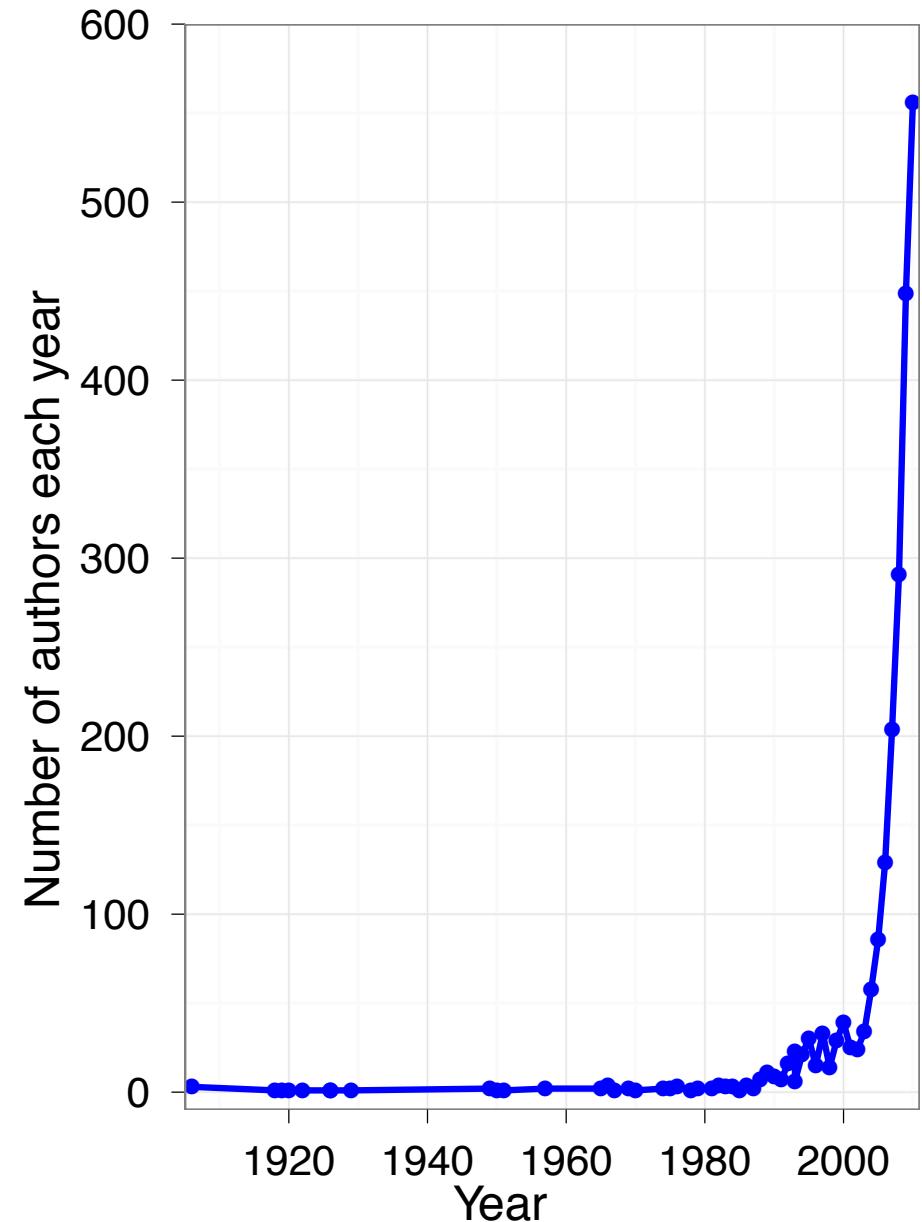
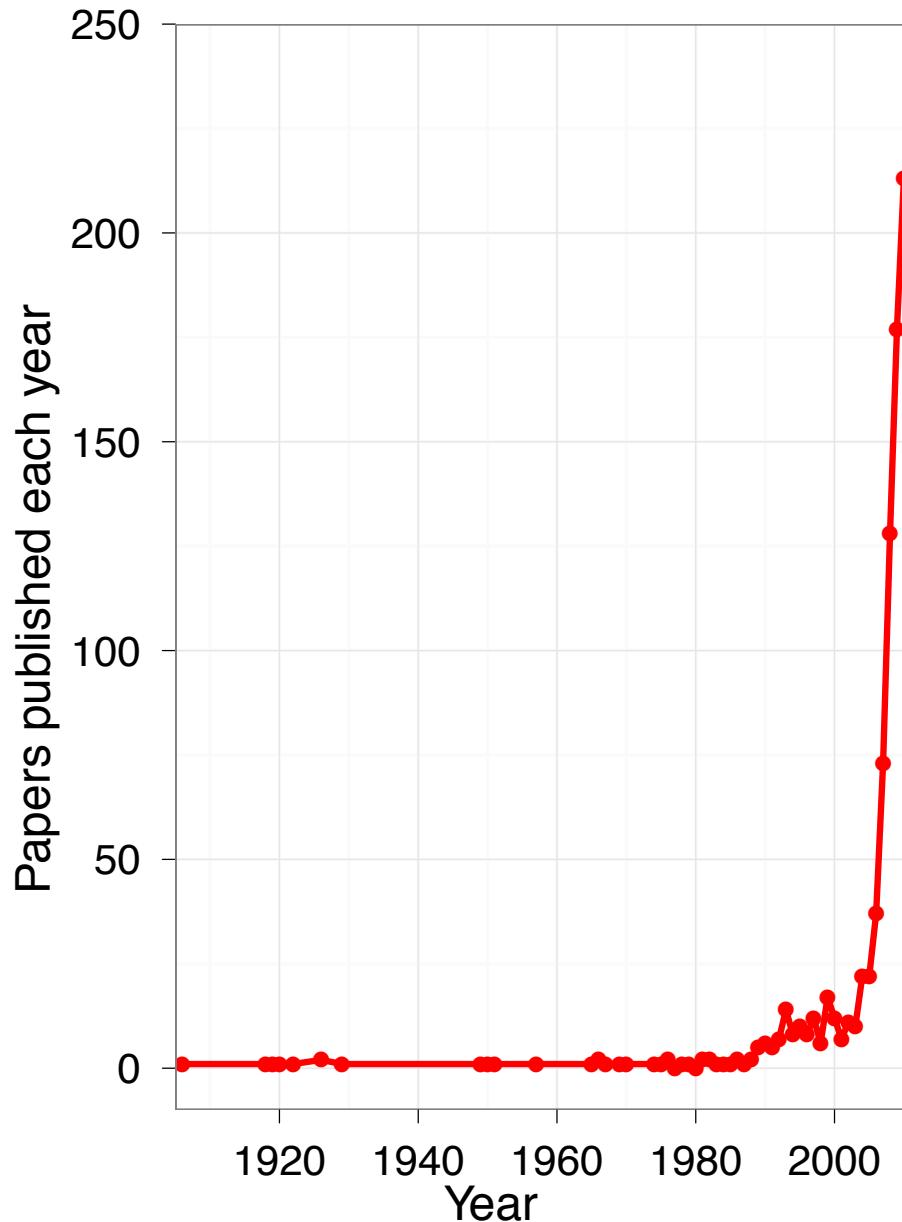
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CNRS-Université Pierre et Marie Curie



What is ocean acidification? Chemistry 101



Considerable increase in research efforts

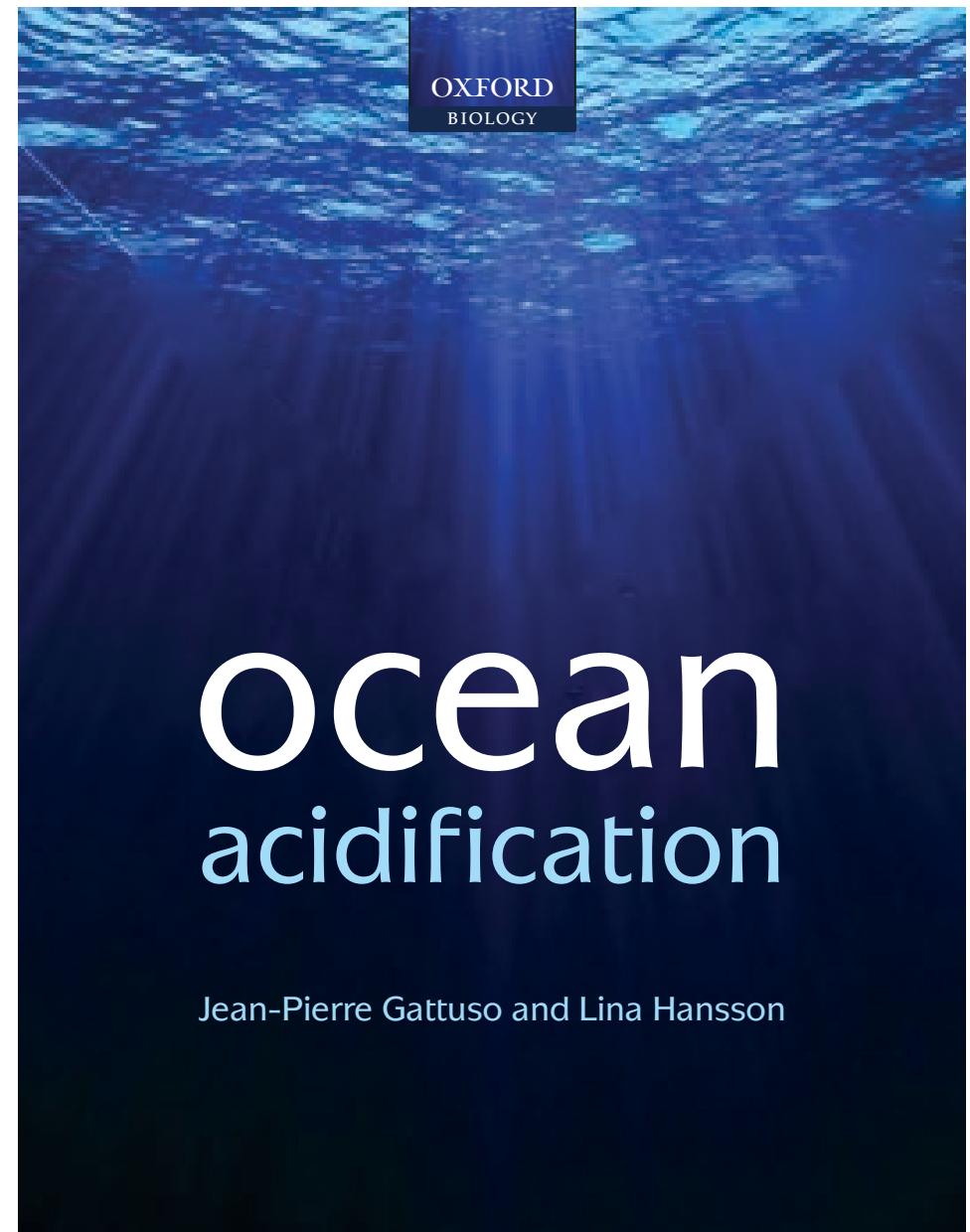


Biological response: meta-analyses

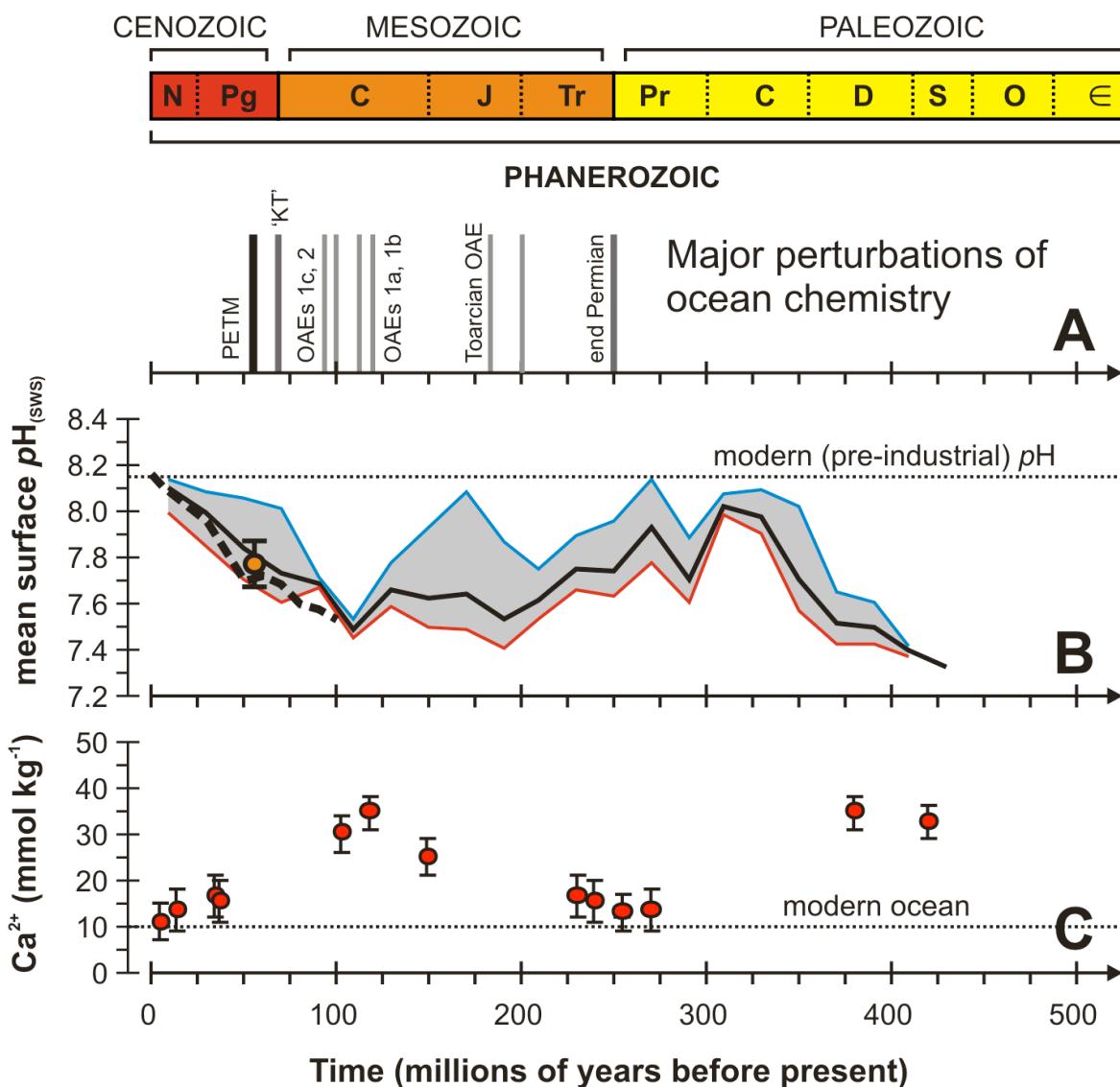
- **Hendriks & Duarte (2010):** ... *limited impact of experimental acidification on organism processes... except on calcification*
- **Kroeker et al. (2010):** ... *biological effects of ocean acidification are generally large and negative...*
- **Liu et al. (2010):** *This review and analysis ... suggest that ... the rates of several (microbial) processes will be affected by ocean acidification, some positively (N_2 fixation...), others negatively.*

OA: knowns, unknowns and perspectives

1. Ocean acidification: background and history (Gattuso & Hansson)
2. Past changes of ocean carbonate chemistry (Zeebe & Ridgwell)
3. Recent and future changes in ocean carbonate chemistry (Orr)
4. Skeletons and ocean chemistry: the long view (Knoll & Fischer)
5. Effect of ocean acidification on the diversity and activity of heterotrophic marine microorganisms (Weinbauer et al.)
6. Effects of ocean acidification on pelagic organisms and ecosystems (Riebesell & Tortell)
7. Effects of ocean acidification on benthic processes, organisms, and ecosystems (Andersson et al.)
8. Effects of ocean acidification on nektonic organisms (Pörtner et al.)
9. Effects of ocean acidification on sediment fauna (Widdicombe et al.)
10. Effects of ocean acidification on marine biodiversity and ecosystem function (Barry et al.)
11. Effects of ocean acidification on the marine source of atmospherically-active trace gases (Hopkins et al.)
12. Biogeochemical consequences of ocean acidification and feedback to the Earth system (Gehlen et al.)
13. The ocean acidification challenges facing science and society (Turley & Kelvin)
14. Impact of climate change mitigation on ocean acidification projections (Joos et al.)
15. Ocean acidification: knowns, unknowns and perspectives (Gattuso et al.)



OA occurred in the past

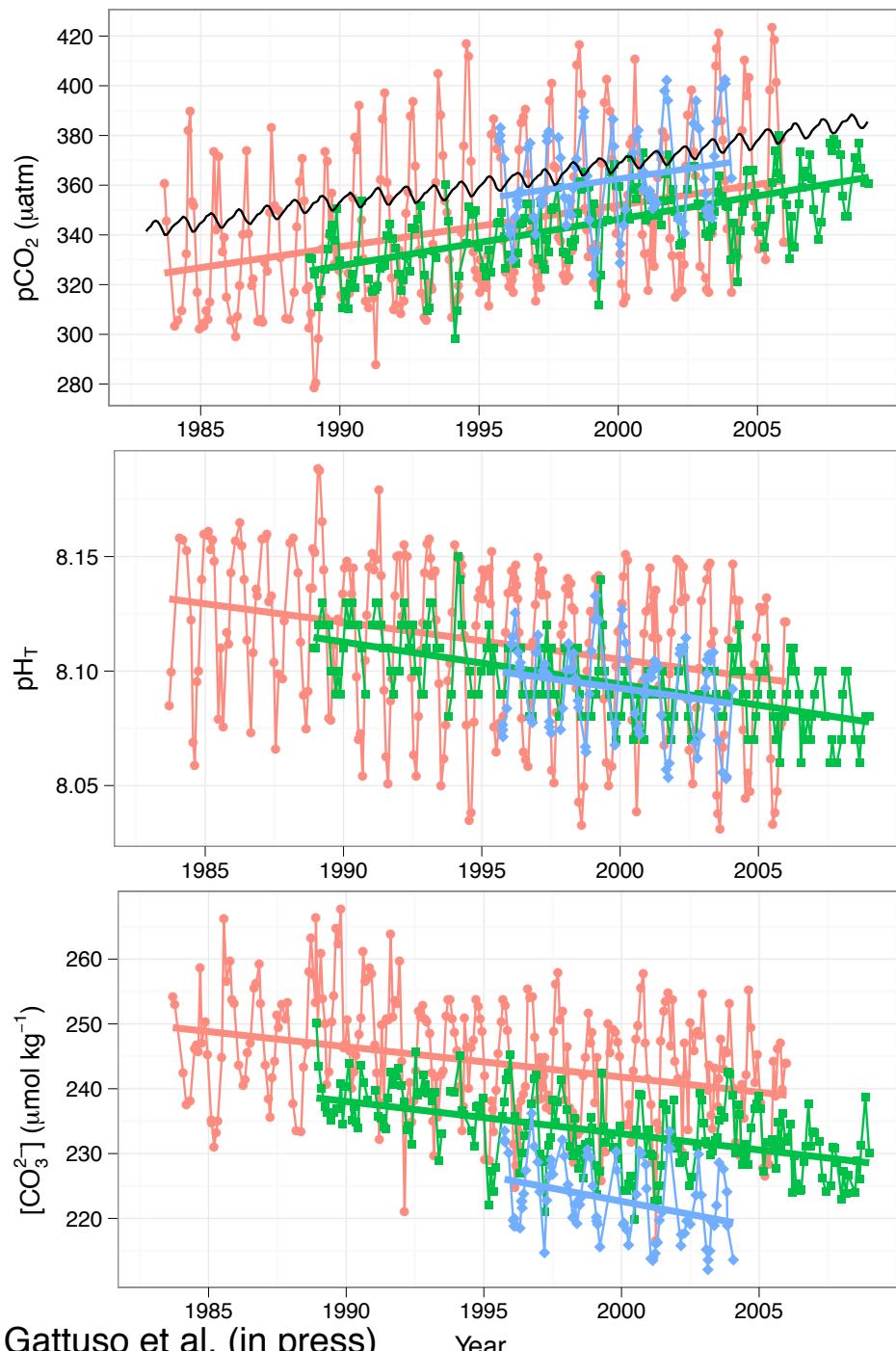


Evidence	Confidence				
	VL	L	M	H	VH
L					
M					
R					Red

Challenge:
Better constrain paleo-reconstructions of the carbonate system

OA is in progress

HOT
BATS
ESTOC

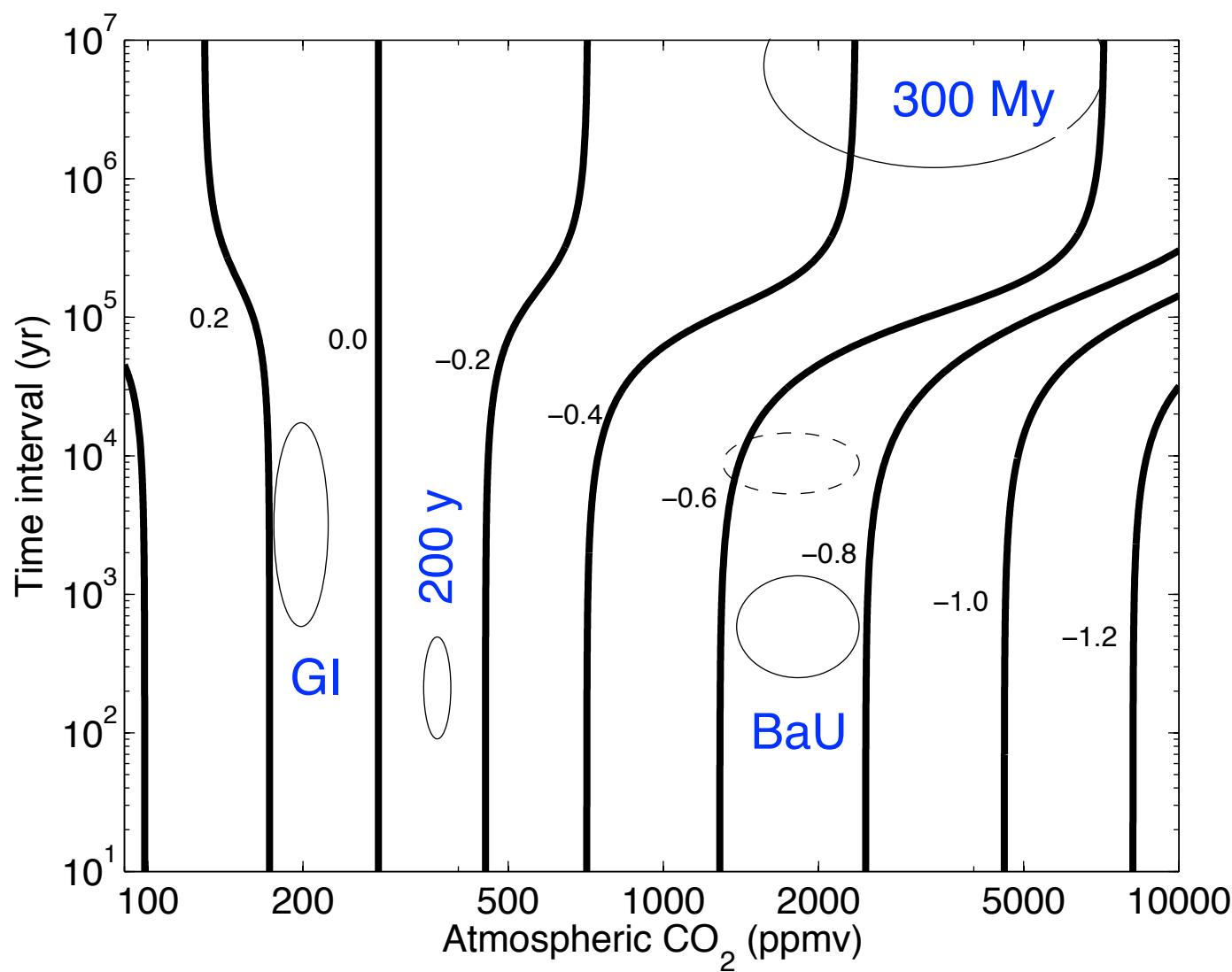


Orr (in press); Gattuso et al. (in press)

Evidence	Confidence				
	VL	L	M	H	VH
L					
M					
R					

Challenge:
Better monitoring of key areas (e.g., coastal sites, coral reefs, polar regions and the deep sea)

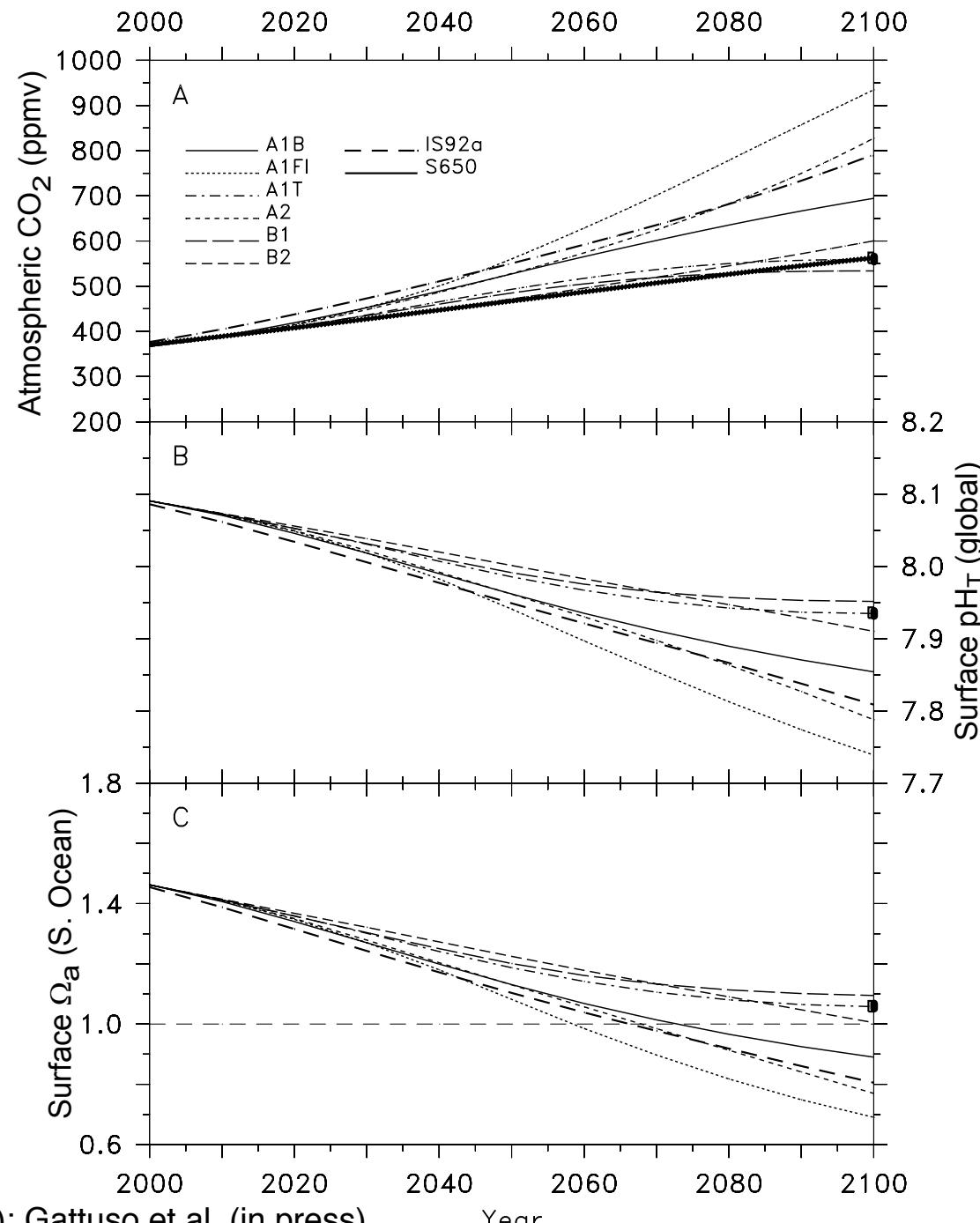
OA will continue at a rate never encountered in the past 55 Myr



Evidence	Confidence				
	VL	L	M	H	VH
L					
M					
R					Red Box

Challenge:
Find two independent carbonate chemistry proxies to reconstruct the ocean carbonate chemistry with a high degree of confidence

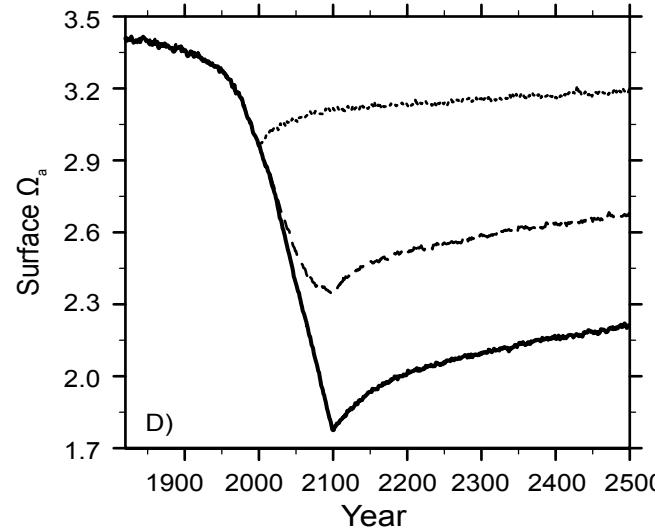
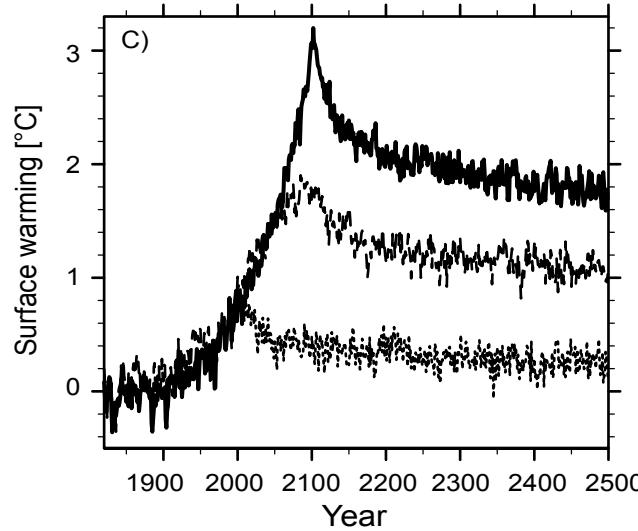
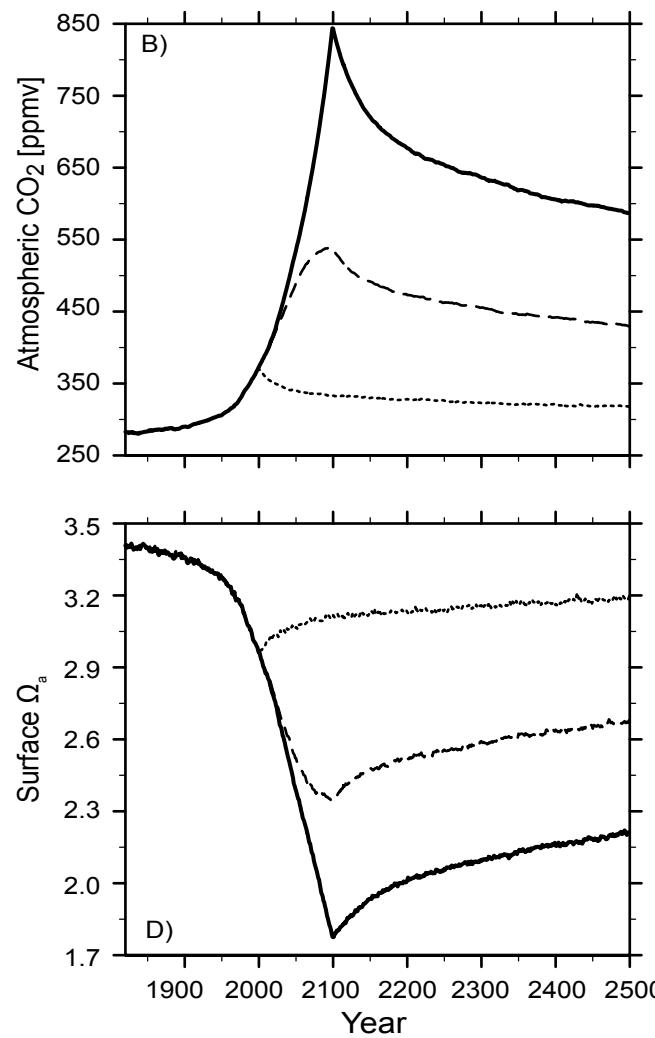
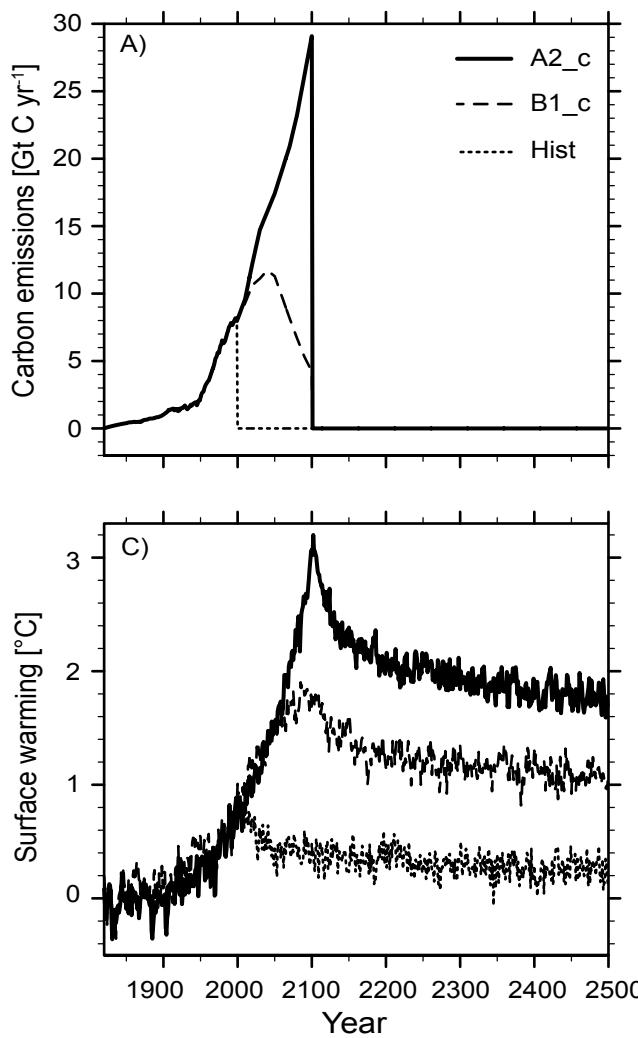
Future OA depends on emission pathways



Evidence	Confidence				
	VL	L	M	H	VH
L					
M					
R					

Challenge:
Improve the representation of physical regimes at the regional scale to derive regional estimates

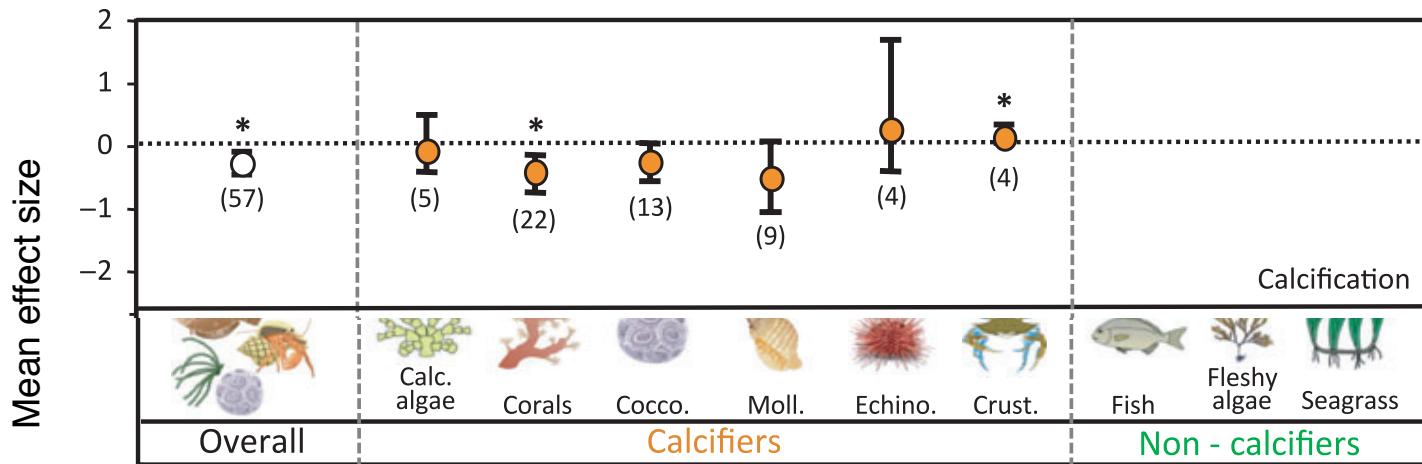
The legacy of historical fossil fuel emissions on OA will be felt for centuries



		Confidence				
		VL	L	M	H	VH
Evidence	L					
	M					
	R					Red Box

Challenge:
Improve the representation of physical regimes at the regional scale to derive regional estimates

OA will adversely affect calcification



		Confidence				
		VL	L	M	H	VH
Evidence	L					
	M				H	
	R					

Challenges:

- Determine the mechanisms explaining why a few calcifiers are not affected or stimulated
- Estimate the energetic and physiological trade-offs
- Gain field evidence in addition to that available from CO₂ vents
- Identify approaches to improve attribution on field observations

OA will stimulate photosynthetic carbon fixation

Group	Response	References
Diatoms	↑	Riebesell <i>et al.</i> (1993), Burkhardt and Riebesell (1997), Burkhardt <i>et al.</i> (1999), Gervais and Riebesell (2001), Wu <i>et al.</i> (2010)
Coccolithophores	↑	Buitenhuis <i>et al.</i> (1999), Riebesell <i>et al.</i> (2000), Rost <i>et al.</i> (2002), Zondervan <i>et al.</i> (2002), Leonardos and Geider (2005), Feng <i>et al.</i> (2008), Barcelos e Ramos <i>et al.</i> (2010), Shi <i>et al.</i> (2009), De Bodt <i>et al.</i> (2010), Müller <i>et al.</i> (2010), Rickaby <i>et al.</i> (2010)
	↓	Sciandra <i>et al.</i> (2003)
	↔	Langer <i>et al.</i> (2006)
Dinoflagellates	↑	Burkhardt <i>et al.</i> (1999), Rost <i>et al.</i> (2006)
Cyanobacteria	↑	Barcelos e Ramos <i>et al.</i> (2007), Hutchins <i>et al.</i> (2007, 2009), Levitan <i>et al.</i> (2007), Fu <i>et al.</i> (2008), Kranz <i>et al.</i> (2009)
	↔	Czerny <i>et al.</i> (2009)
Natural assemblages	↑	Hein and Sand-Jensen (1997), Tortell <i>et al.</i> (2002, 2008), Riebesell <i>et al.</i> (2007), Bellerby <i>et al.</i> (2008), Egge <i>et al.</i> (2009)

Evidence	Confidence				
	VL	L	M	H	VH
L					
M					
R					

Challenges:

More work needed at the community level and under field conditions to better assess the global magnitude of the response

OA will stimulate nitrogen fixation

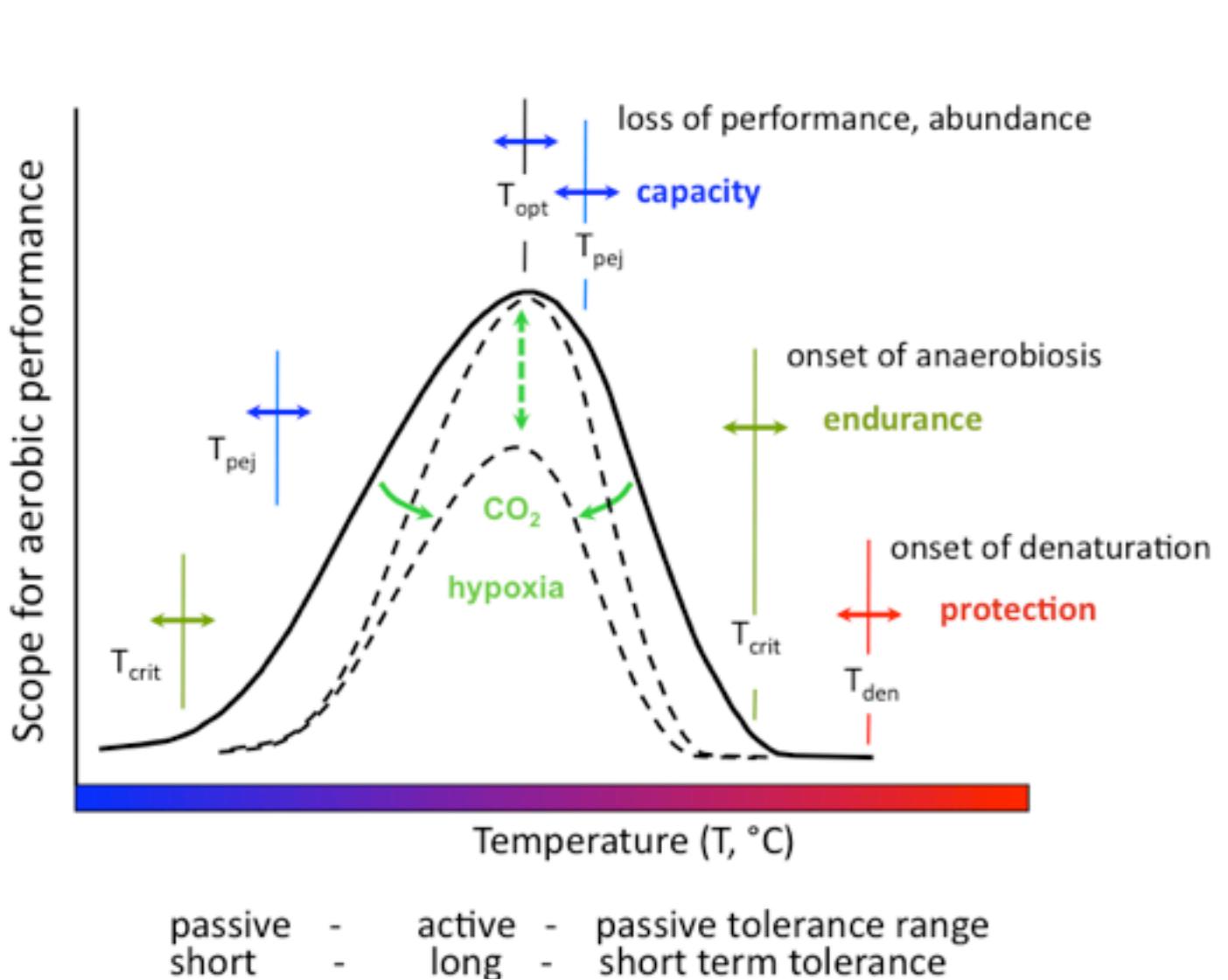
Evidence	Confidence				
	VL	L	M	H	VH
L					
M				█	
R					

Species	Response	References
<i>Trichodesmium erythraeum</i>	↑	Barcelos e Ramos <i>et al.</i> (2007), Hutchins <i>et al.</i> (2007), Levitan <i>et al.</i> (2007), Kranz <i>et al.</i> (2009, 2010)
natural colonies of <i>Trichodesmium</i>	↑	preliminary data reported in Hutchins <i>et al.</i> (2009)
<i>Crocospaera watsonii</i>	↑ ↔	Fu <i>et al.</i> 2008
<i>Nodularia spumigena</i>	↓	Czerny <i>et al.</i> 2009

Challenges:

- Investigate more species to test whether it is a widespread response.
- Determine the interaction with other variables in order to better assess the global magnitude and biogeochemical consequences

Some species or strains are tolerant to OA



Confidence

	VL	L	M	H	VH
L					
M					
R					

Challenges:
Gain a better understanding of the molecular and biochemical mechanisms underlying processes such as calcification

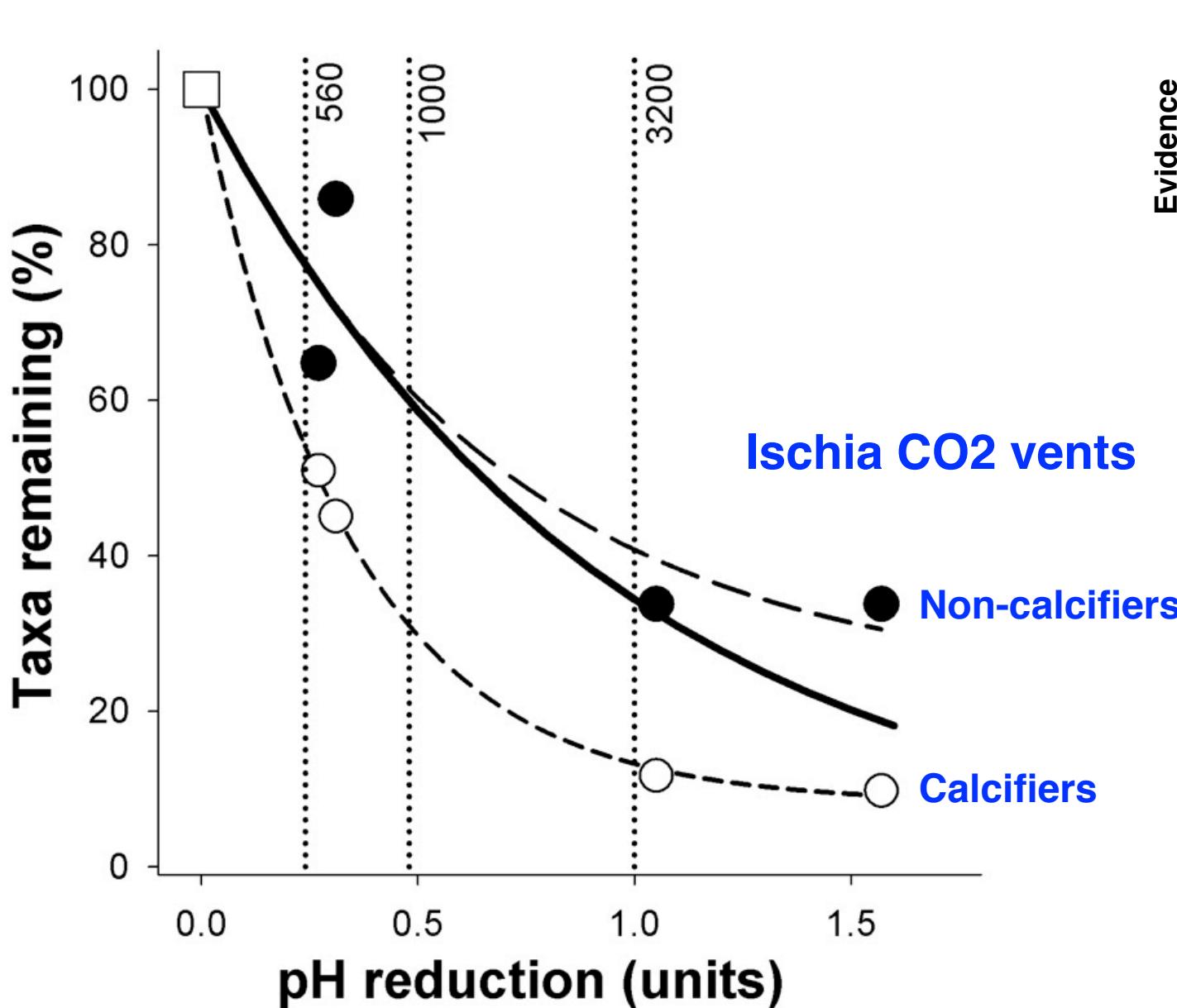
Some taxonomic groups will be able to adapt to OA

		Confidence				
		VL	L	M	H	VH
Evidence	L					
	M					
	R					

- Two mechanisms to consider:
 - phenotypic plasticity
 - genetic (evolutionary) changes
- Geologic record: increased rate of extinction when environmental changes are fast

- Challenges:**
- Initiate long-term experiments
 - Identify approaches and tools to estimate the adaptation potential

OA will change the composition of communities

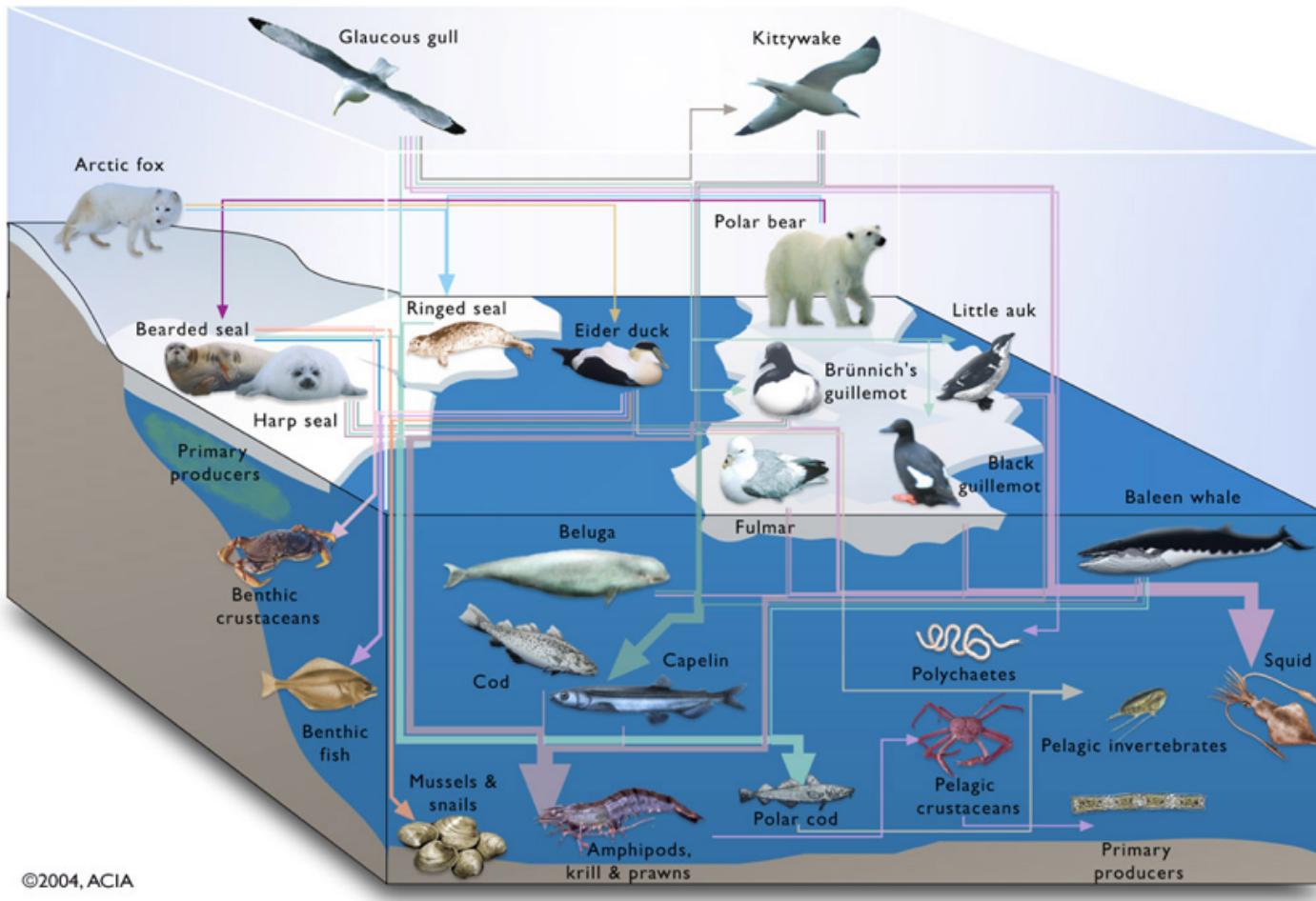


		Confidence				
		VL	L	M	H	VH
Evidence	L					
	M					
R					■	

Challenges:

- Collect better information on non-calcifiers in the paleorecord
- Determine the magnitude of the change in present key ecosystems

OA will impact food webs and higher trophic levels



Evidence	Confidence				
	VL	L	M	H	VH
L					
M					
R					

Challenges:

- Determine how species that may disappear will be replaced
- Will replacement species have a similar nutritional value?

OA will have biogeochemical consequences at the global scale

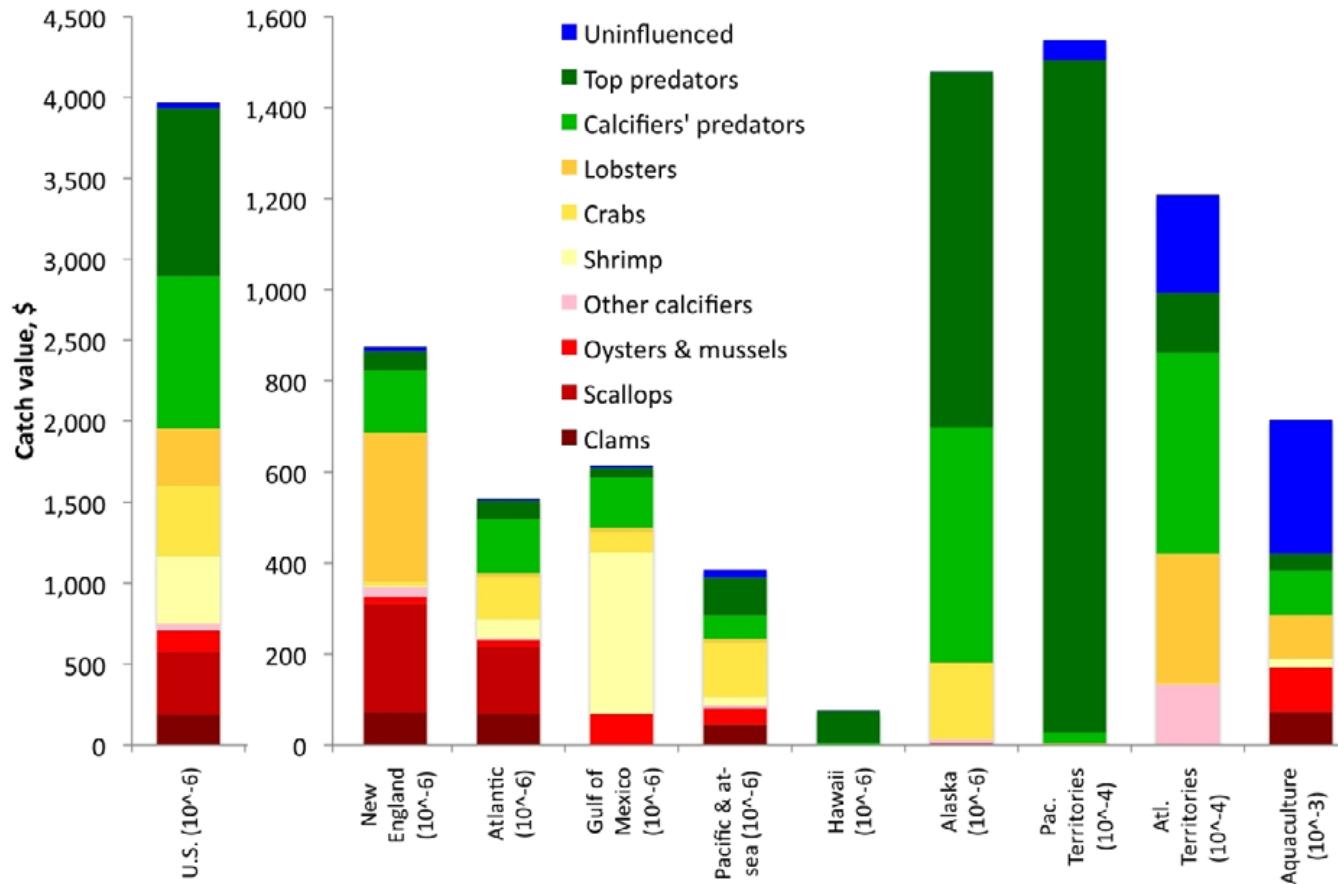
Evidence	Confidence				
	VL	L	M	H	VH
L					
M					
R					

Process	Sign of feedback	Sensitivity	Capacity	Longevity
Calcification	negative	+ ¹	+	+ ¹
Ballast effect	positive		+++	+++
Extracellular organic matter prod.	negative	++ ¹	+++	²
Stoichiometry	negative	++ ¹	++	++
Nitrogen fixation	negative	++ ¹	+	²

Challenges:

Better understanding of key processes as a function of carbonate system variables needed to improve model parametrization

There will be socio-economic consequences

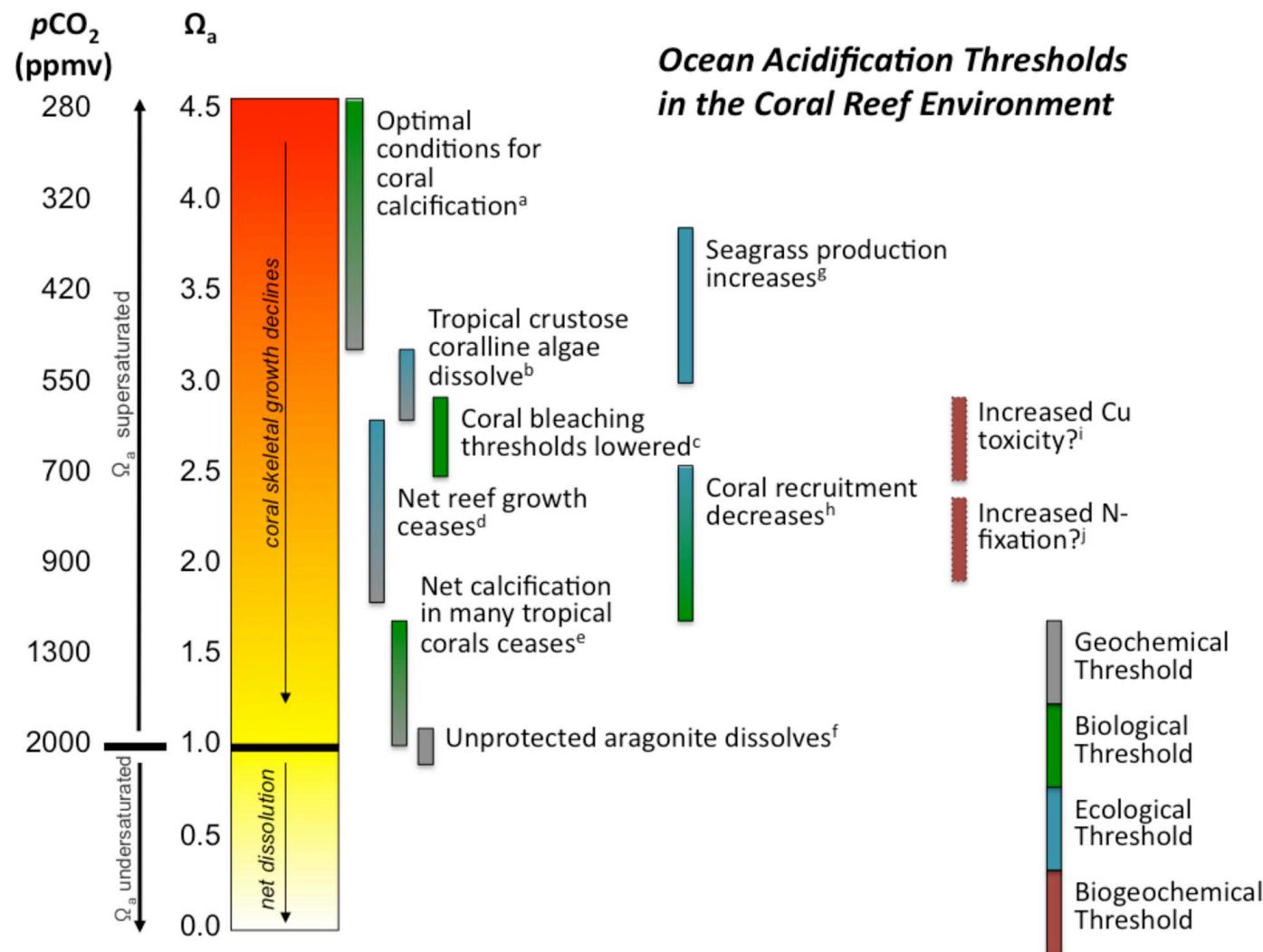


		Confidence				
		VL	L	M	H	VH
Evidence	L					
	M					
	R					

Challenges:

- Quantify the monetary value of the goods and services that oceans provide
- Assess how these may be impacted by ocean acidification.

An OA threshold that must not be exceeded can be defined



		Confidence				
		VL	L	M	H	VH
Evidence	L					
	M					
	R					

Challenges:

- Initiate and sustain an international effort to compile the increasing number of data being published in order to define threshold(s)
- Investigate the need to consider thresholds based on geographic location, species and ecosystems to advise decision-makers

Summary on statements

- **Chemical effects:** robust evidence and high certainty
- **Biological and ecological effects:** much less certain
 - calcification, primary production, nitrogen fixation and biodiversity will be altered but with an unknown magnitude
 - some cannot be assessed
- **Biogeochemistry, society and the economy** may change; whether it will be significant or not is also unknown

Systems at risk

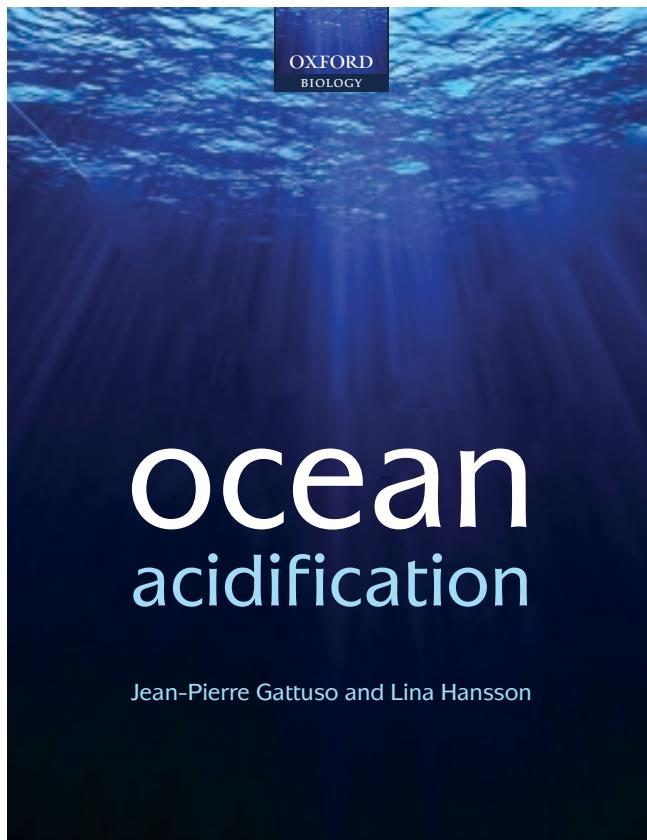
- Polar areas
- Deep-sea environments
- Coral reefs
- Nearshore ecosystems

Past limitations and future prospects

- Limited workforce and funding
- Inappropriate or inconsistent methods
- Duration of experiments
- Interactions with other stressors
- Lack of field evidence other than around CO₂ vents
- Limited work at the community level
- Difficulties to perform meta-analysis
- Model development
- Need for a coordinated international effort

More information

- **Project web site:** epoca-project.eu
- **Ocean acidification blog**
- **Blog EPOCA Arctic campaigns**
- **Movie “Tipping Point”**
- **Book:** Oxford University Press,
Sep. 2011



TIPPING POINT

A film by Laurence Jourdan
Camera:Marine Tadié,Editing :Françoise Bouleque
Underwater filming : Yves Gladu

A photograph showing several researchers in bright orange waterproof suits and hats standing on a grey metal boat. They are positioned around some large, white, dome-shaped scientific instruments or artificial reef structures that are partially submerged in the water. The background features a vast, cold landscape with snow-covered ground and mountains under a hazy sky. In the bottom left corner of the image frame, there is a small white logo box with the word "EPOCA" in blue.

Increasing levels of CO₂ in the atmosphere are not only causing Global warming, Oceans are absorbing huge quantities of CO₂ which in turn is changing their chemical composition and severely damaging the marine environment.

By following leading international researchers, **Tipping Point** will take us around the world and under water to discover how ocean acidification is changing marine ecosystems and what scientific solutions can be found to solve the problem.

Through beautifully shot under-sea images and a careful scientific approach, the film tackles the main issues of this relatively new phenomenon by providing solutions before it's too late!

From the producer/director of **Public Enemy Number 1: Carbon** and **Gulf Stream** successfully distributed worldwide.

The film will be available for public projections and events after the 15/12/2010.
For screeners or dvds please contact:

Georama TV Productions
2 rue de la Mairie
F-31480 Cadours
France
tel: +33 953 856250,
mob: +33 671 419549
email: georamativ@free.fr

GEORAMATV

A photograph of a scuba diver in full gear, including a wetsuit and fins, swimming in clear blue water. The diver is holding a professional video camera and appears to be filming something in the distance. The background shows a sandy ocean floor with some aquatic plants.

« Tipping Point » © Georama TV,52 min HDCAM,Scientific Advisers:Jean Pierre Gattuso, Ulf Riebesell
Locations : France, Allemagne, Norvège, Islande, Ny-Ålesund (Spitzberg), USA
Shooting: Mai à Oct 2010,Delivery December 2010
Versions : French and English

TERRANOVA **ERT** **RTP** **Ushuaïa TV** **NRKTE** **EUROPEAN COMMISSION** **PRINCE ALBERT II DE MONACO FOUNDATION** **EUROPEAN RESEARCH AREA** **Eurovision** **TOTAL FOUNDATION**

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