Why coral reefs should care about ocean acidification: general consensus, misconceptions and future research priorities

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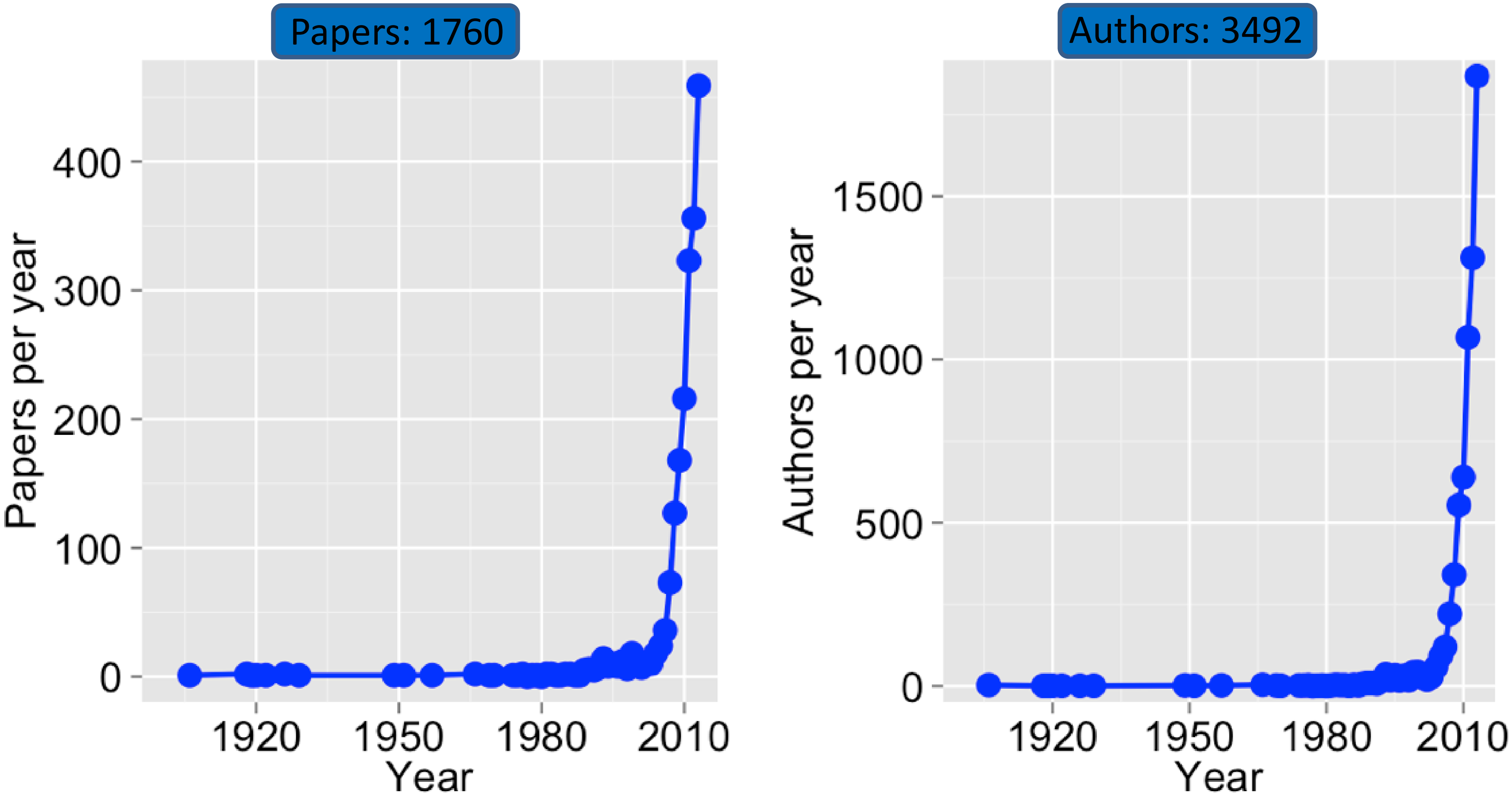
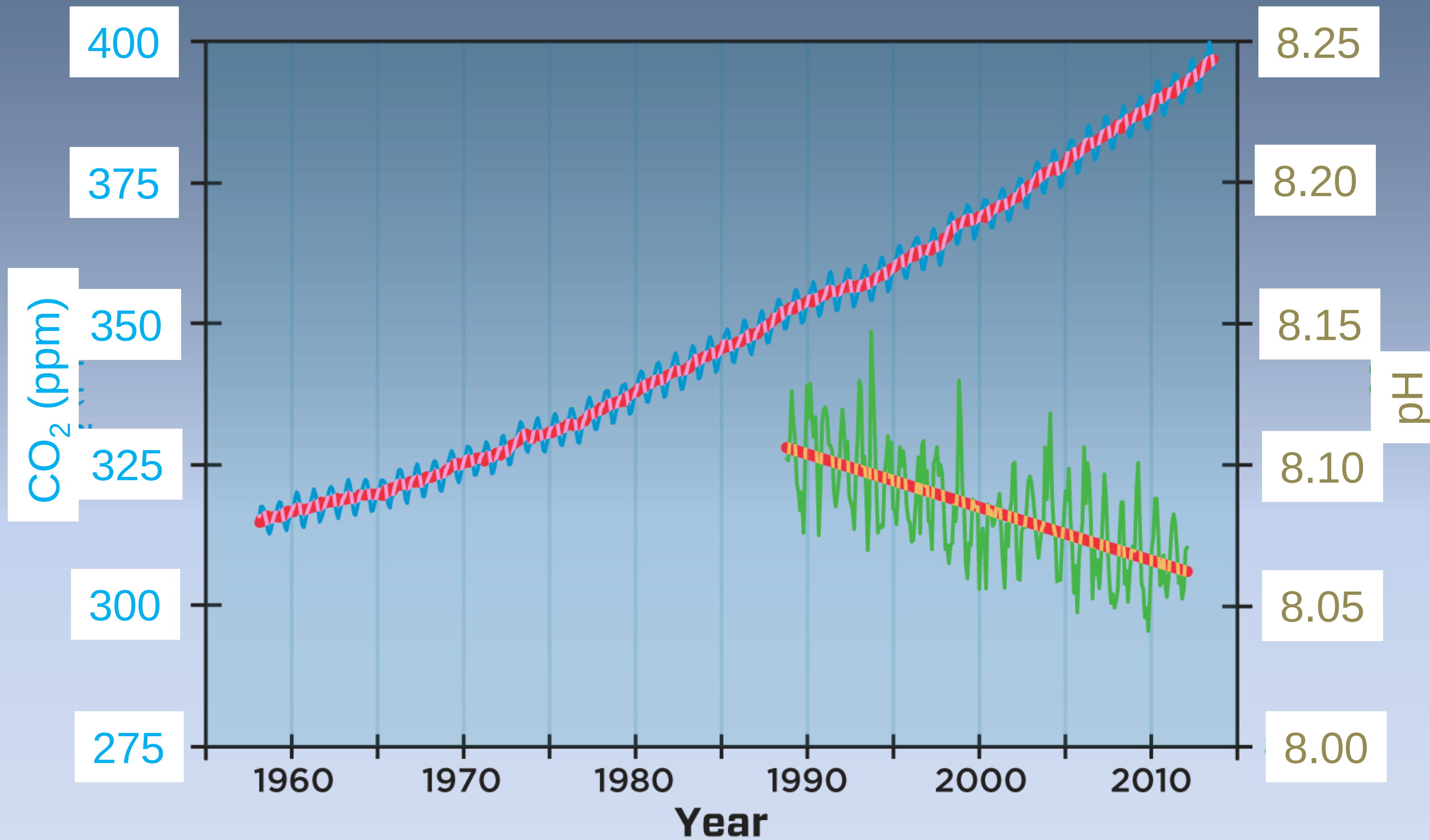
OA is a young field of research

(Gattuso & Hansson 2011)



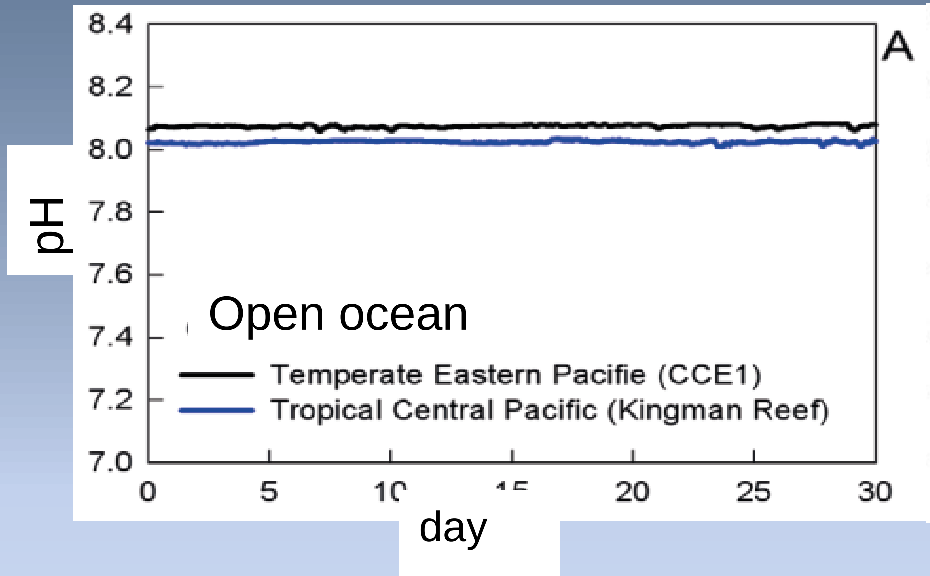
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
papers	18	24	36	73	127	168	216	323	356	459
authors	58	92	120	221	341	554	640	1068	1312	1868

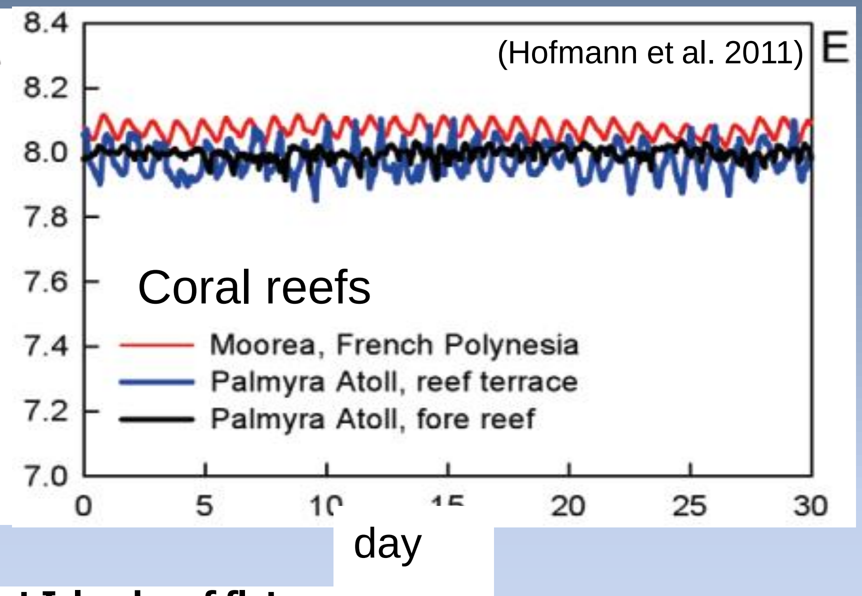
Are atmospheric CO_2 and ocean pH changing?

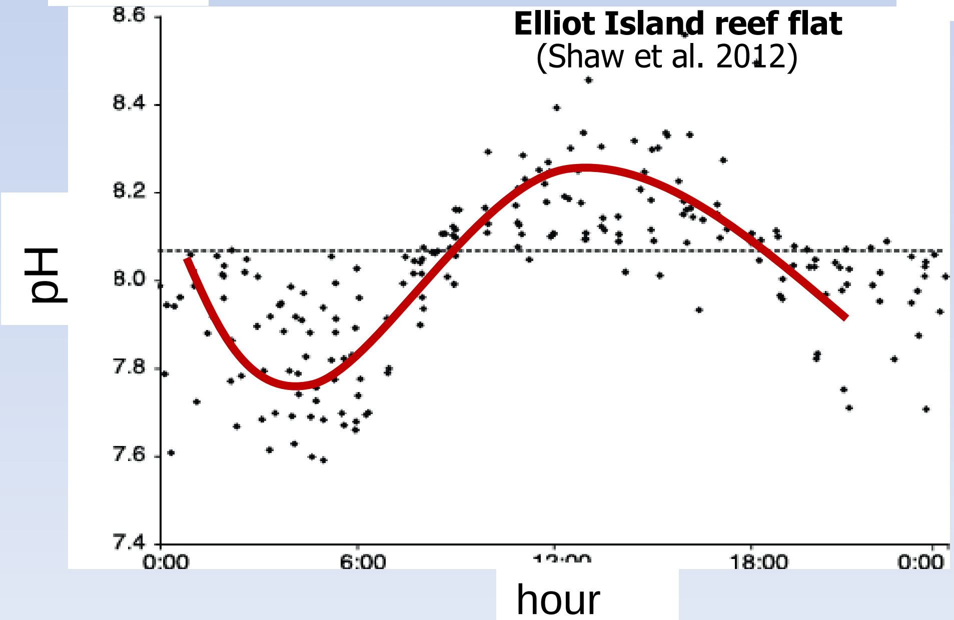


V **Anthropogenic ocean acidification is currently in progress and is measurable** [VERY HIGH CONFIDENCE]

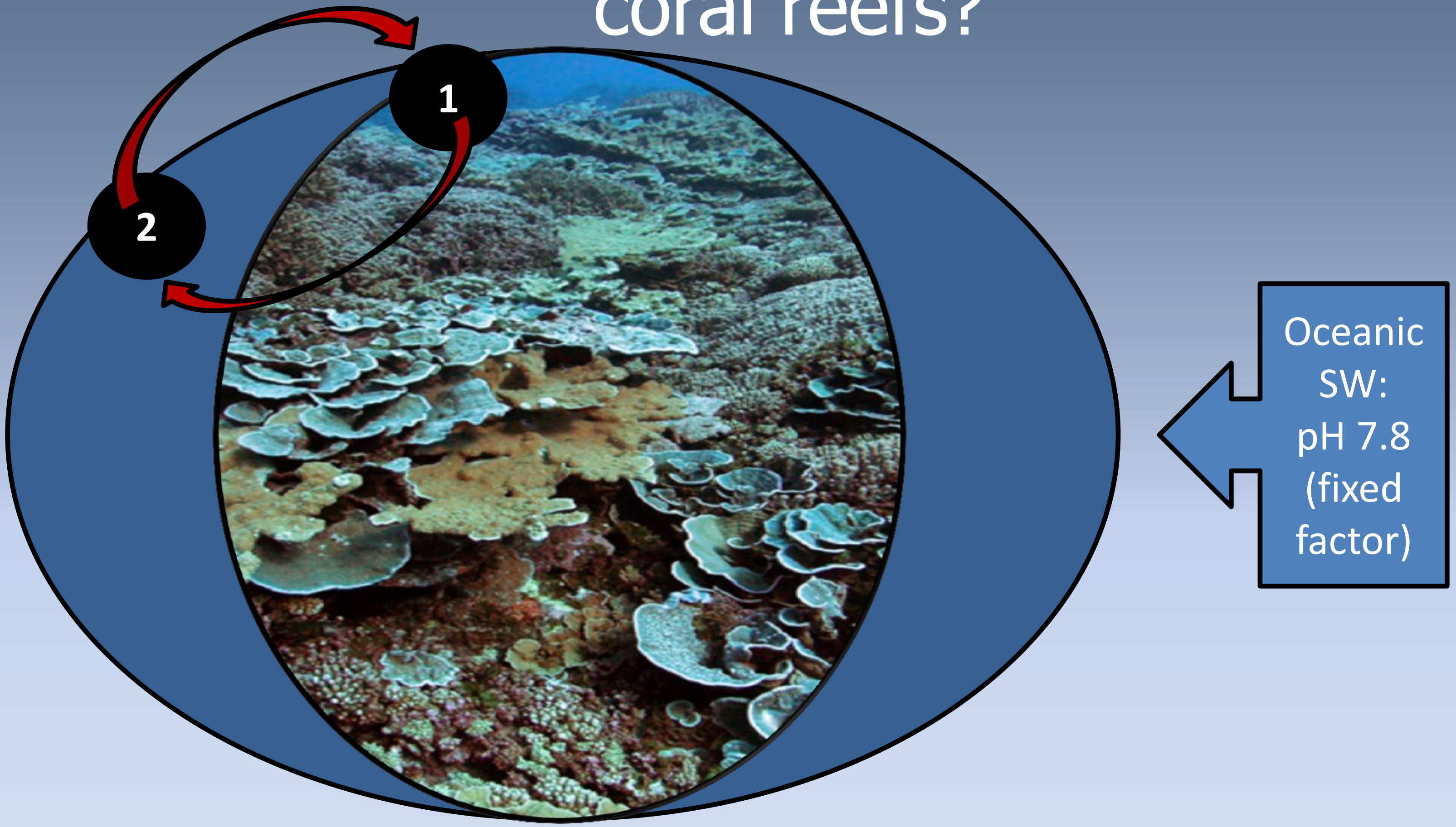
Do we know present-day pH variability around coral reefs?







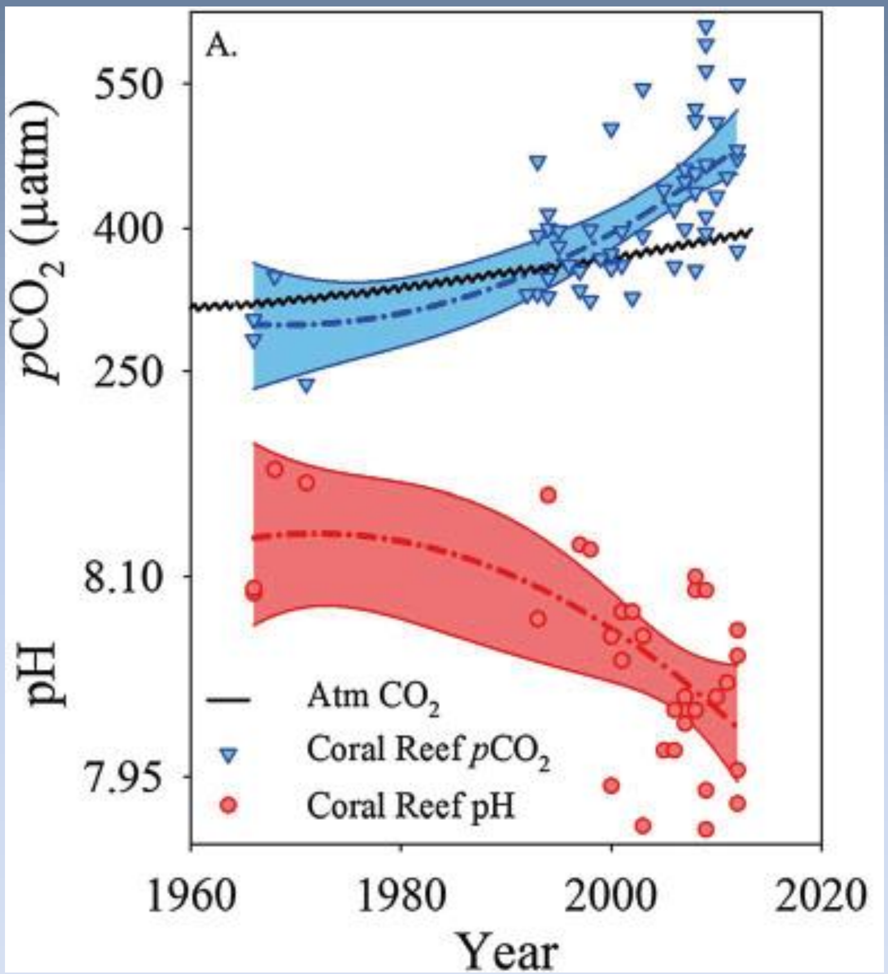
Do we know present-day pH variability around coral reefs?

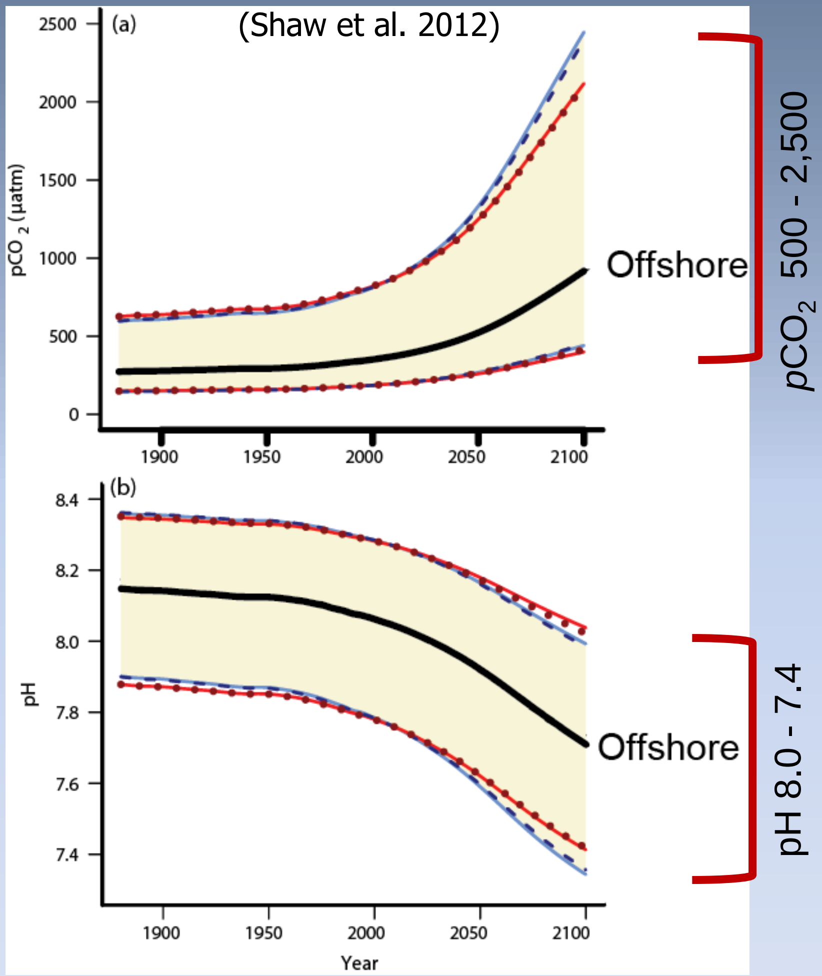


1. Coral reefs:
- reef metabolism regulates local SW chemistry (e.g. pH)

2. Local environment (SW chemistry & environmental parameters):
- local environment controls reef metabolism

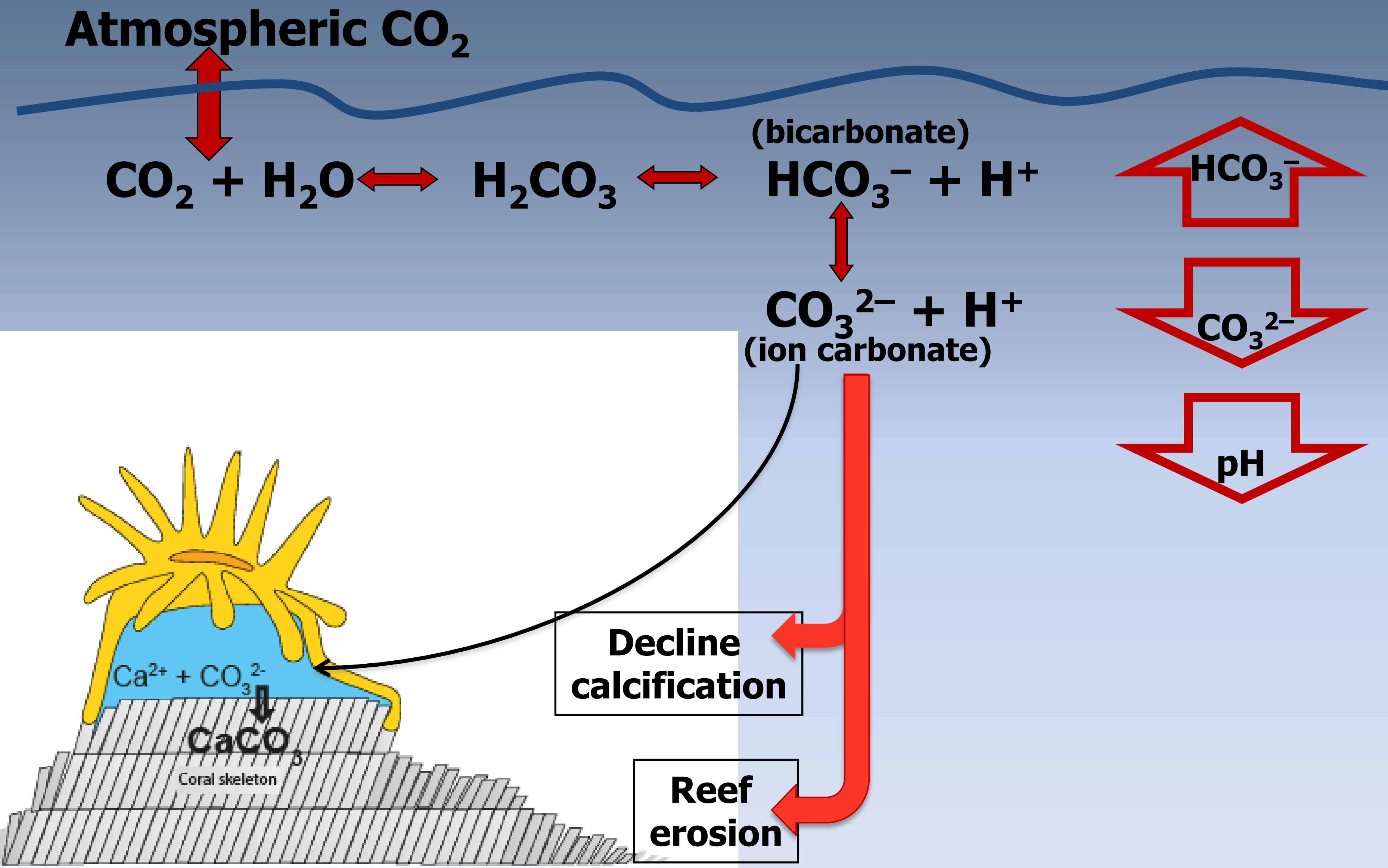
Are climate model scenarios suitable to predict future coral reef pH?





Coral reefs $p\text{CO}_2$ has increased 3.5 fold faster than in the open ocean over the past 20 y (Cyronak et al. 2014)

What is the effect of OA on coral reefs?

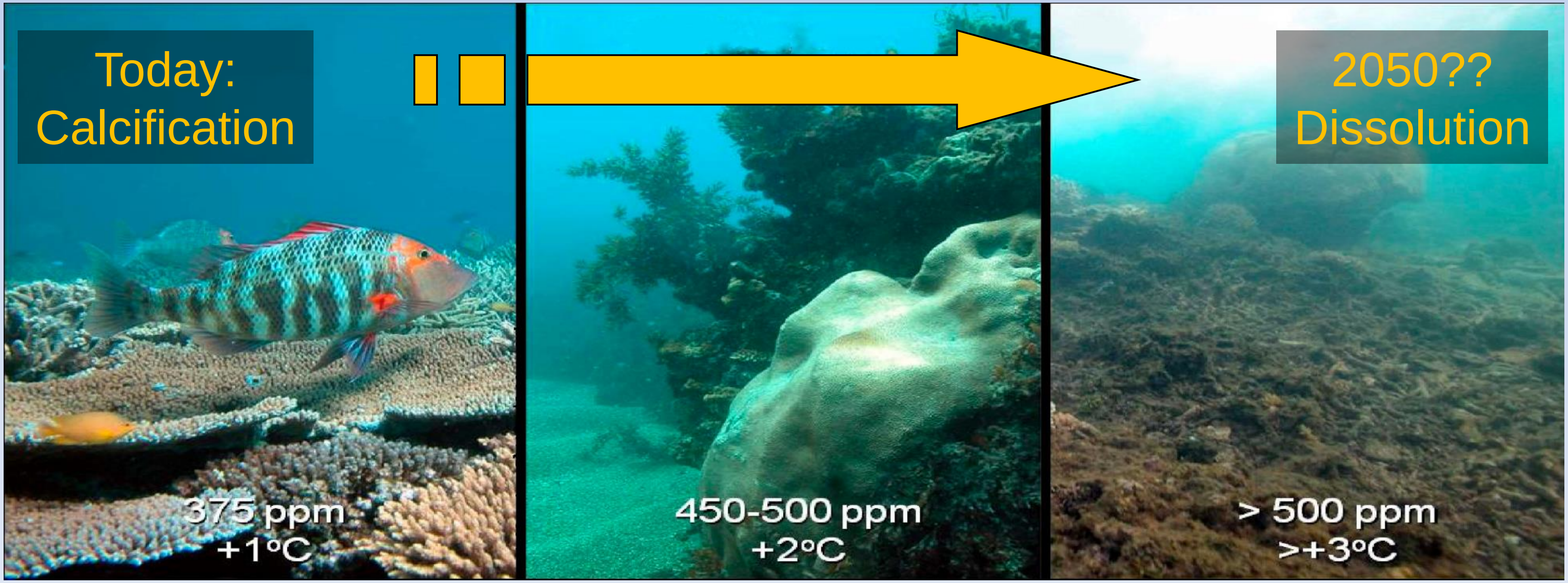


IPCC scientists predict loss of tropical reefs by 2050

Coral reefs response to OA: General consensus

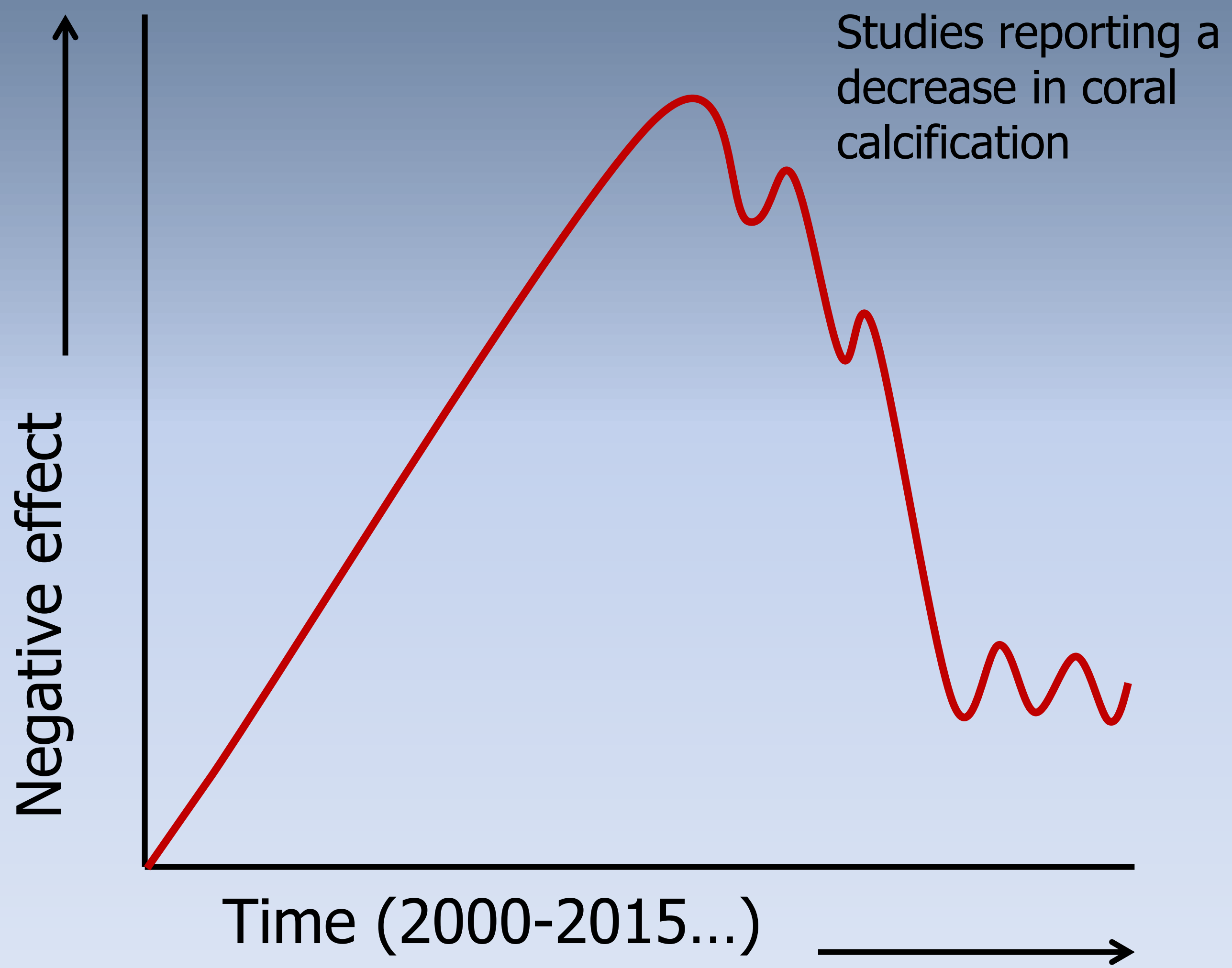
- Acidification will decrease coral calcification rates up to 56% by the end of century (Kleypas et al. 2006)

- Coral and molluscs are expected to decrease calcification drastically by 2050 (Hoegh-Guldberg et al. 2007) and may stop to calcify and dissolve by 2100 (Silverman et al. 2009; Gazeau et al. 2009)



http://www.noaanews.noaa.gov

Coral reefs response to OA: Growing consensus



Apparently, OA impact seems less obvious than previously thought

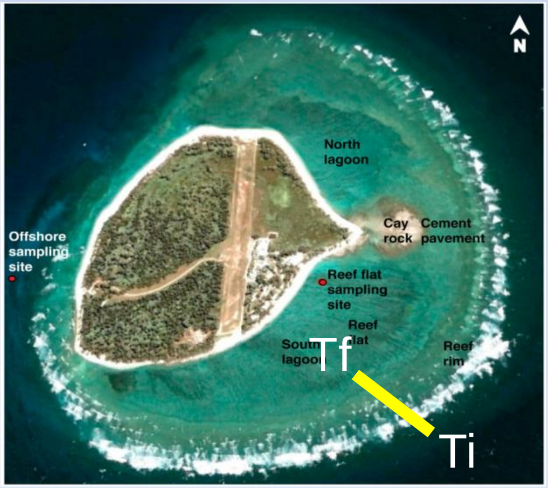
Methods used to simulate OA

Low-volume aquaria

Large aquaria (mesocosm)

Underwater mesocosm

Natural pH variations across reefs



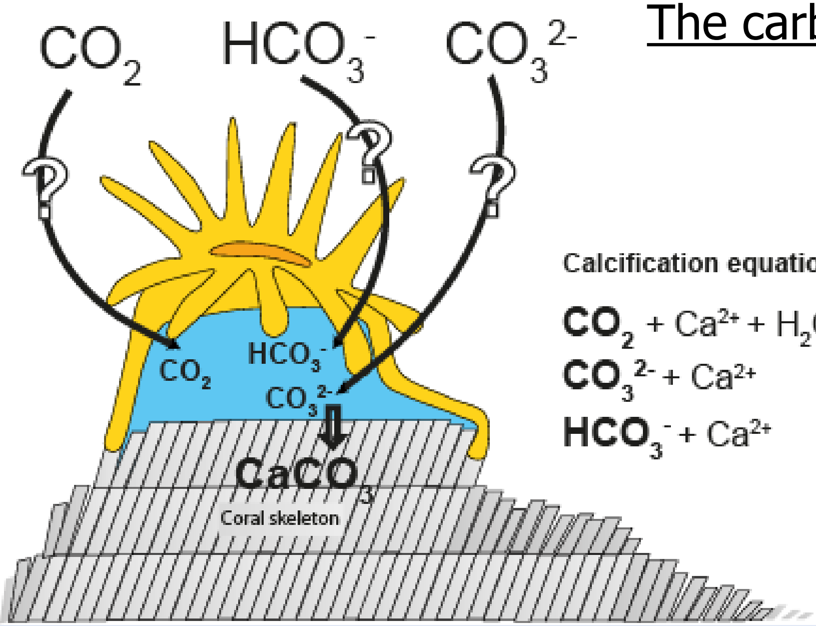
Natural low pH environments at volcanic CO_2 emissions

Methods used to simulate OA: aquaria

1) <u>Experiment in aquaria are not ecologically relevant</u>
2) Methods used to acidify seawater might change responses
3) The duration of the experiments might change responses
4) Light, water flow, food, etc…might change responses
5) Methods used to measure calcification might result in contradictory results

Poor knowledge on coral calcification mechanisms

<u>The carbon source</u>



Calcification equations

$CO_2 + Ca^{2+} + H_2O \Rightarrow CaCO_3 + 2H^+$

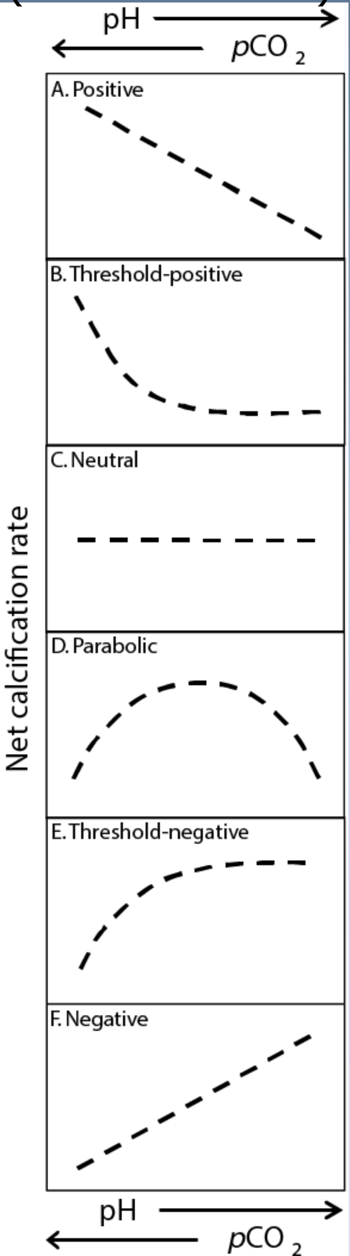
$CO_3^{2-} + Ca^{2+} \Rightarrow CaCO_3$

$HCO_3^- + Ca^{2+} \Rightarrow CaCO_3 + H^+$

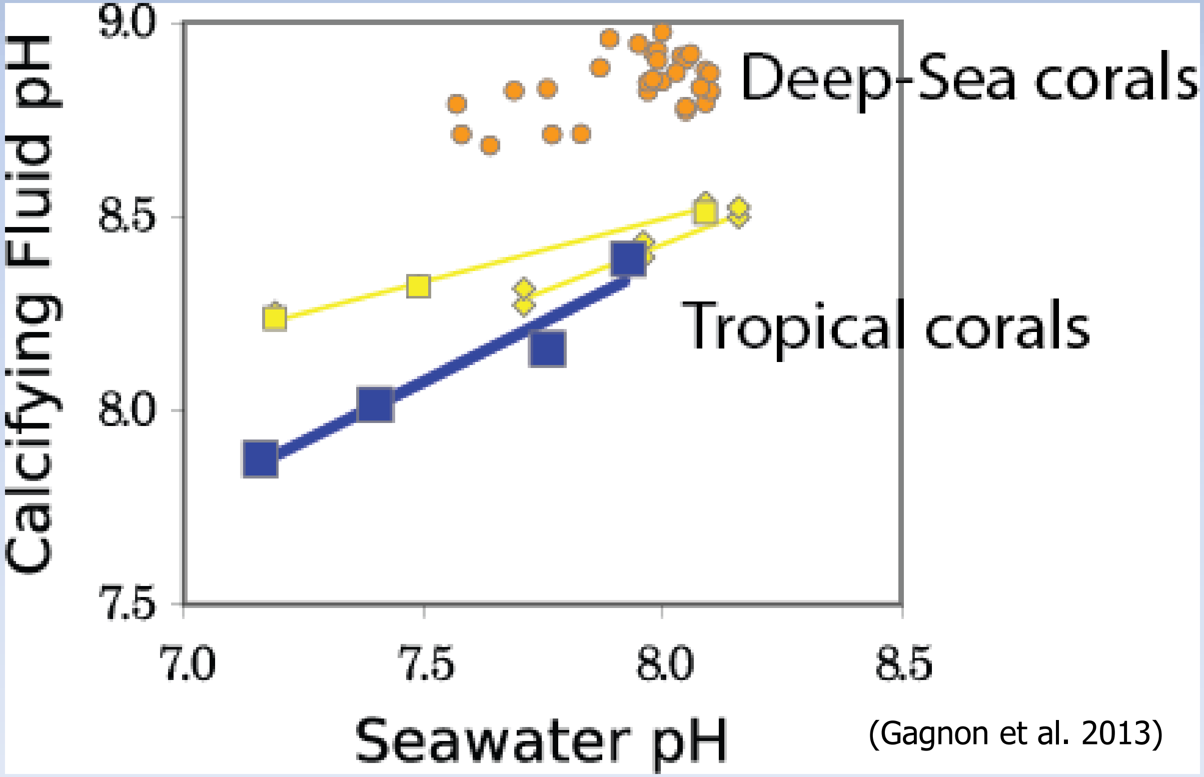
Reconsidering previous misconceptions & biases: declines in coral calcification will be ca. 20% by 2100 (Chan & Connolly 2013)

Methods used to simulate OA: aquaria

(Ries et al. 2009)

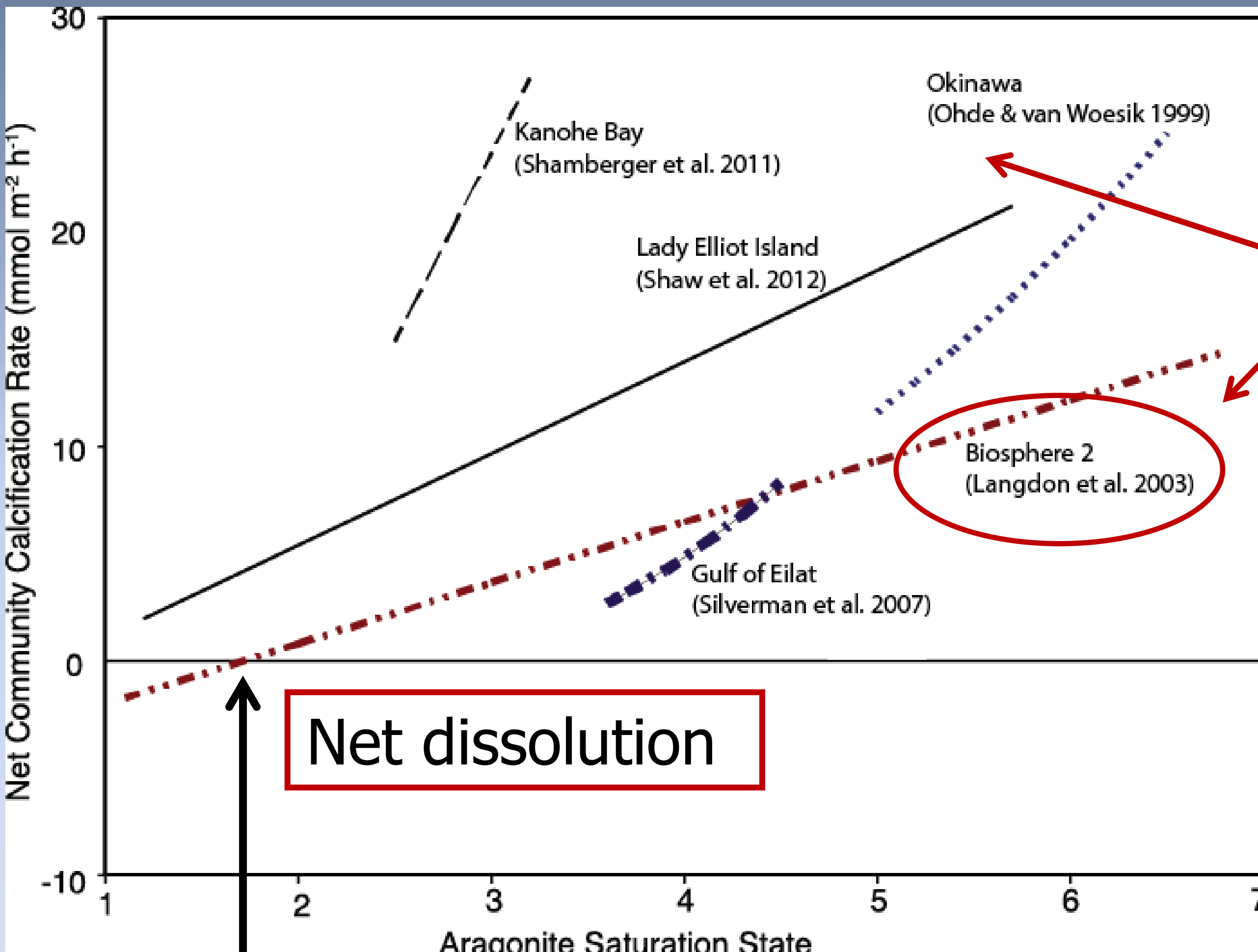


Species-specific responses depend on ability to keep high pH values at calcification sites (Venn et al. 2011; McCulloch et al. 2012)



(Gagnon et al. 2013)

Methods used to simulate OA:
Mesocosms & natural variations

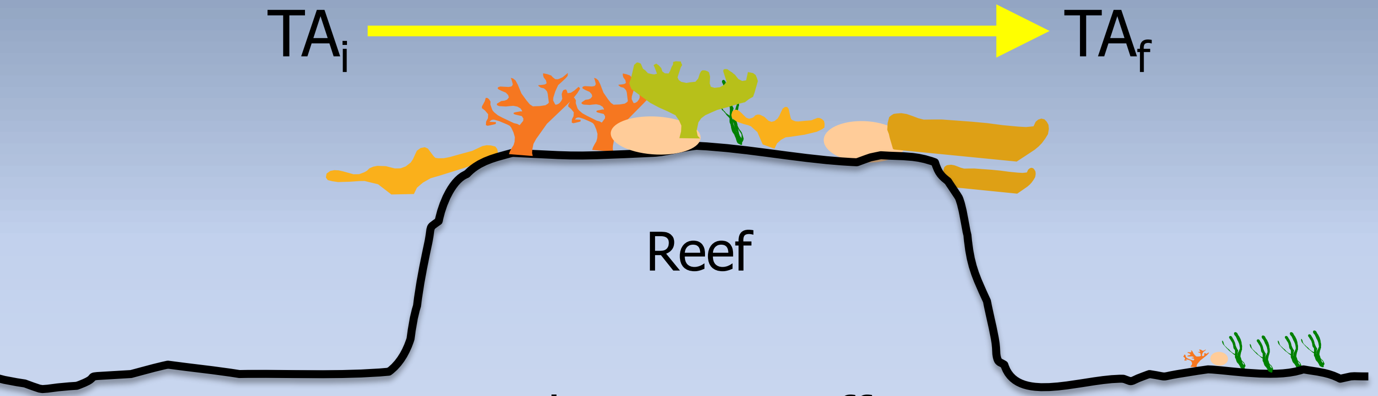


pH = 7.7-7.8

Why these studies found net dissolution?

Methods used to simulate OA:
Mesocosms & natural variations

Traditional techniques:
Variation of Total Alkalinity over the reef



- Animal excretion affects TA
- Reef composition affects TA
- Environmental parameters affect TA
- **It does not decipher calcification & dissolution**
- Sediment dissolution explains > 50% TA changes

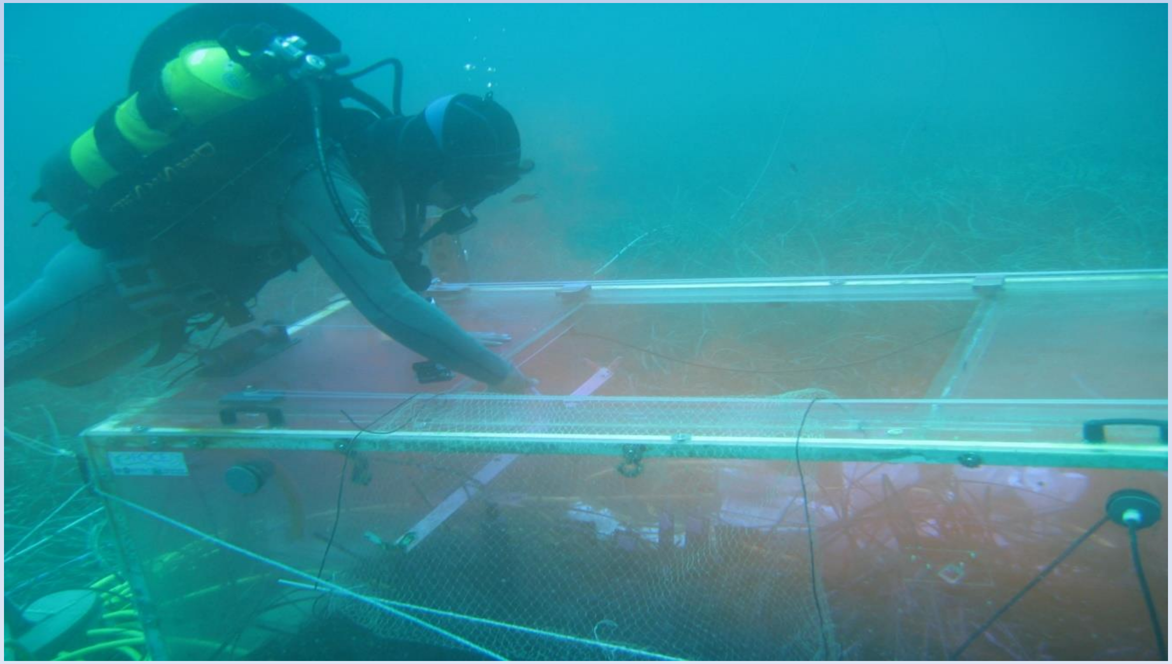
(Eyre et al. 2014; Murillo et al. 2014; Comeau et al. 2015)

Changes in net coral reef calcification could be due mainly to increased sediment dissolution rather than decreased calcification

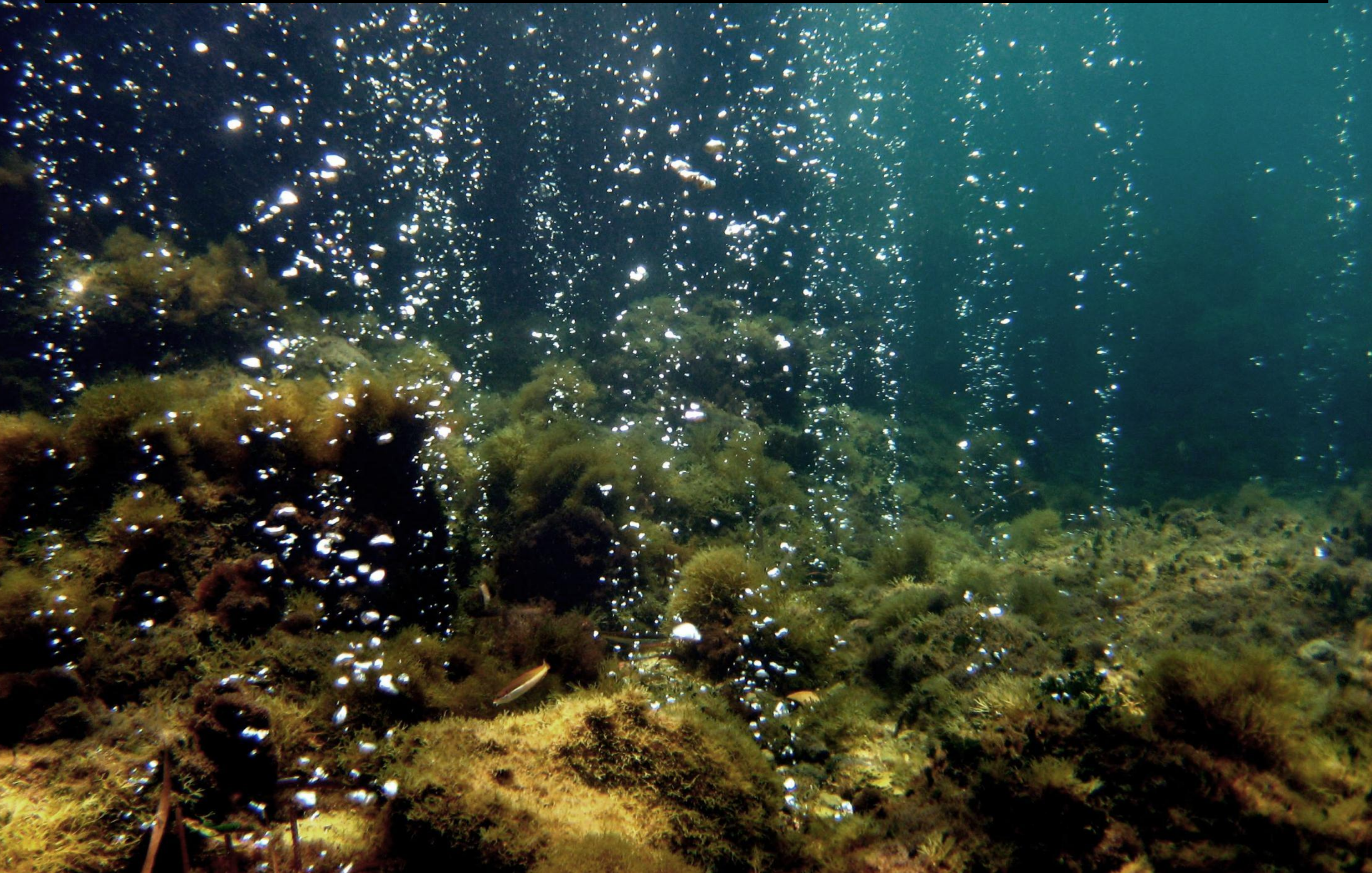
Methods used to simulate OA:
in situ mesocosm

FOCE: underwater mesocosm

- Impressive high cost!!
- Not consistent data



Methods used to simulate OA:
CO_2 volcanic emissions



Methods used to simulate OA:
CO_2 volcanic emissions





doi:10.1038/nature07 051

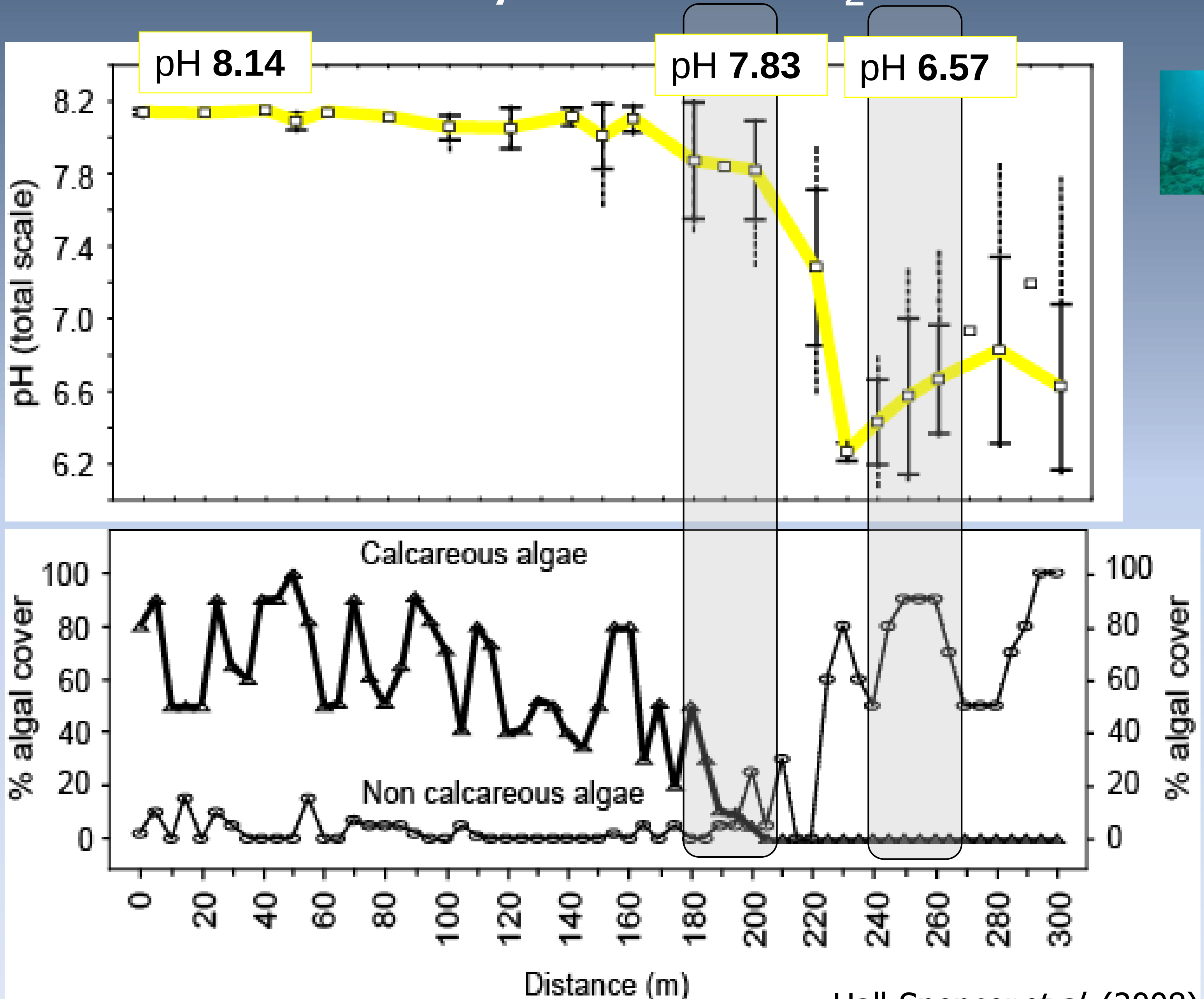
nature

LETTERS

Volcanic carbon dioxide vents show ecosystem effects of ocean acidification

Jason M. Hall-Spencer[1], Riccardo Rodolfo-Metalpa[1], Sophie Martin[2], Emma Ransome[1], Maoz Fine[3,4], Suzanne M. Turner[5], Sonia J. Rowley[1], Dario Tedesco[6,7] & Maria-Cristina Buia[8]

Community shift at CO_2 vents

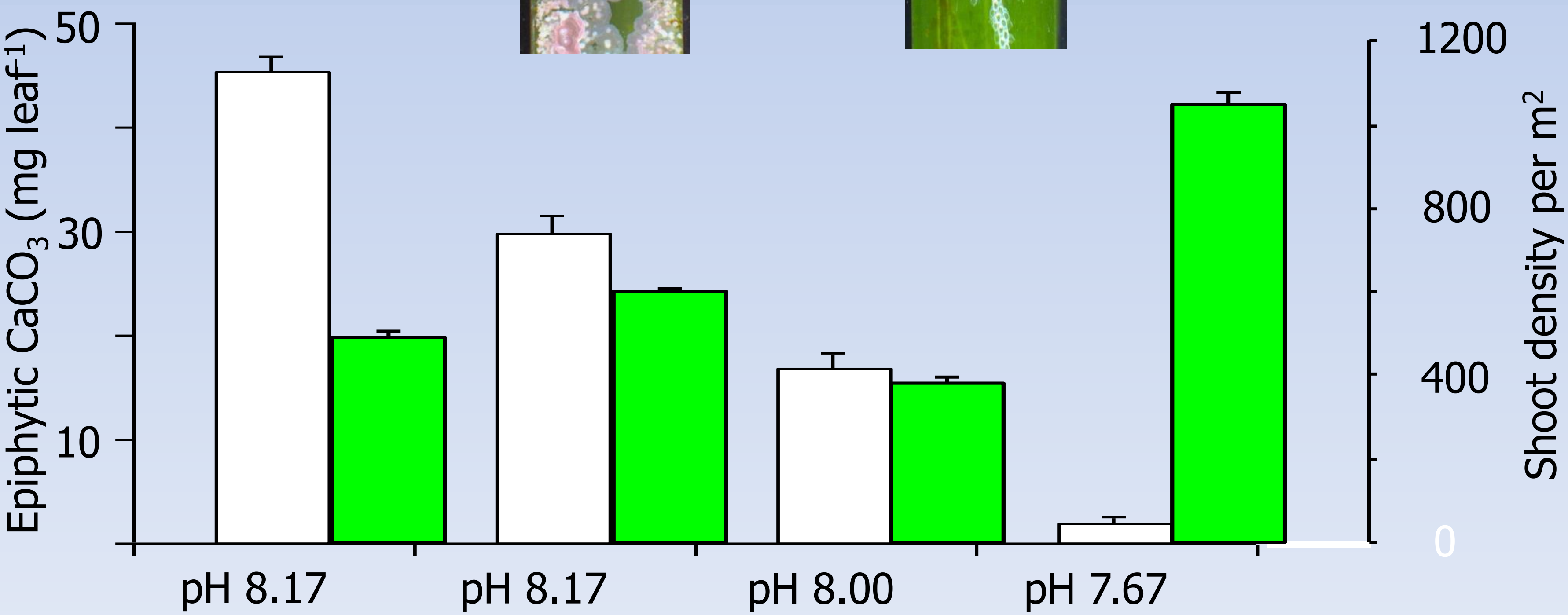


Hall-Spencer *et al.* (2008) Nature

Community shift at CO_2 vents

pH 8.17 → **pH 7.67**

Martin *et al*. (2008) Biol. Letters



The seagrass is less able to defend itself from grazing fish, the habitat is less biodiverse and invasive algae thrive.

Arnold *et al*. (2012) PlosONE

Coral reefs response to ocean acidification:

Methods: CO_2 volcanic emissions

LETTERS
PUBLISHED ONLINE: 21 AUGUST 2011 | DOI: 10.1038/NCLIMATE1200
nature climate change

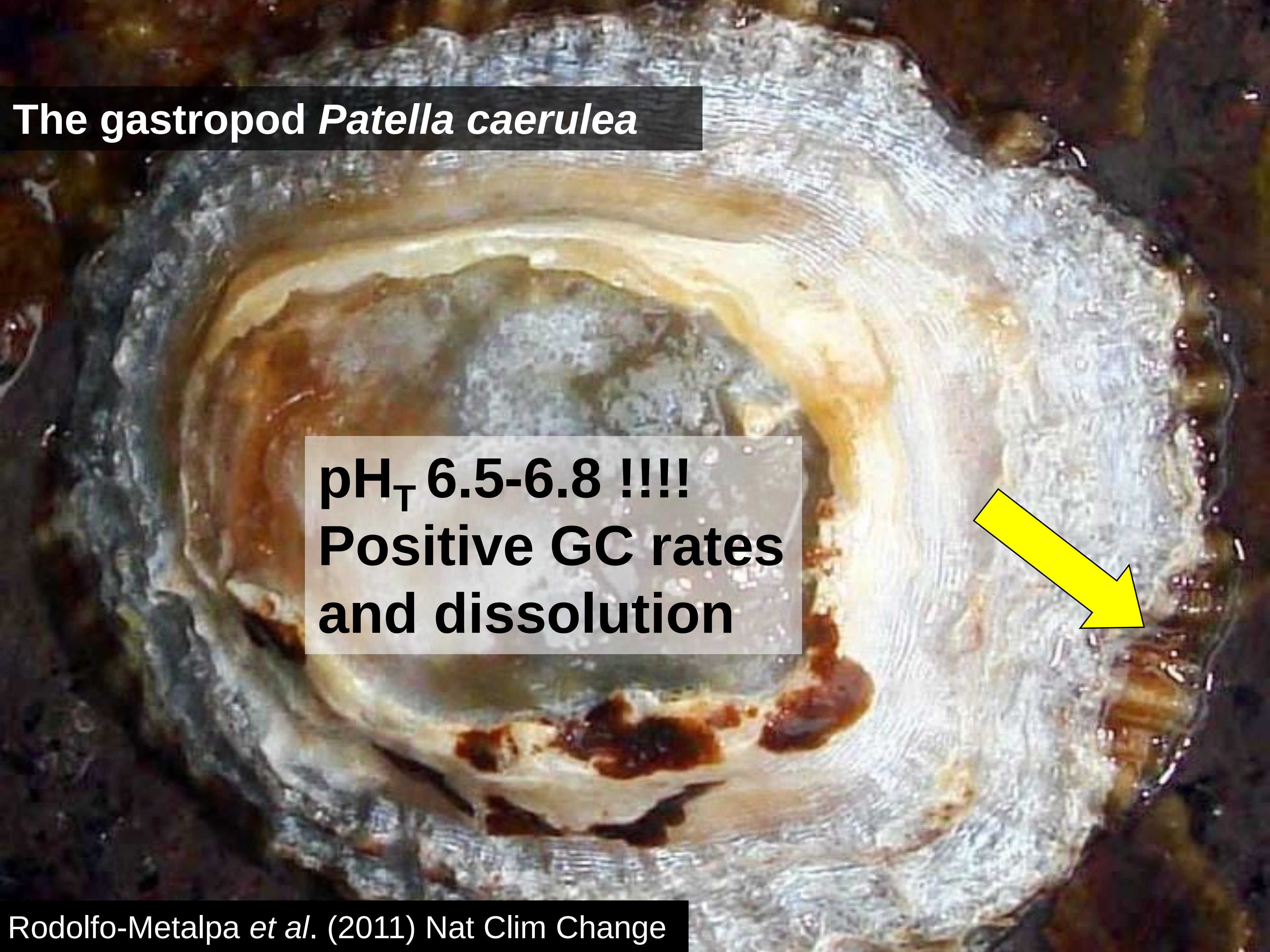
Coral and mollusc resistance to ocean acidification adversely affected by warming

R. Rodolfo-Metalpa [1,2*], F. Houlbrèque [1†], É. Tambutté [3], F. Boisson [1], C. Baggini [2], F. P. Patti [4], R. Jeffree [1†], M. Fine [5,6], A. Foggo [2], J-P. Gattuso [7,8] and J. M. Hall-Spencer [2]

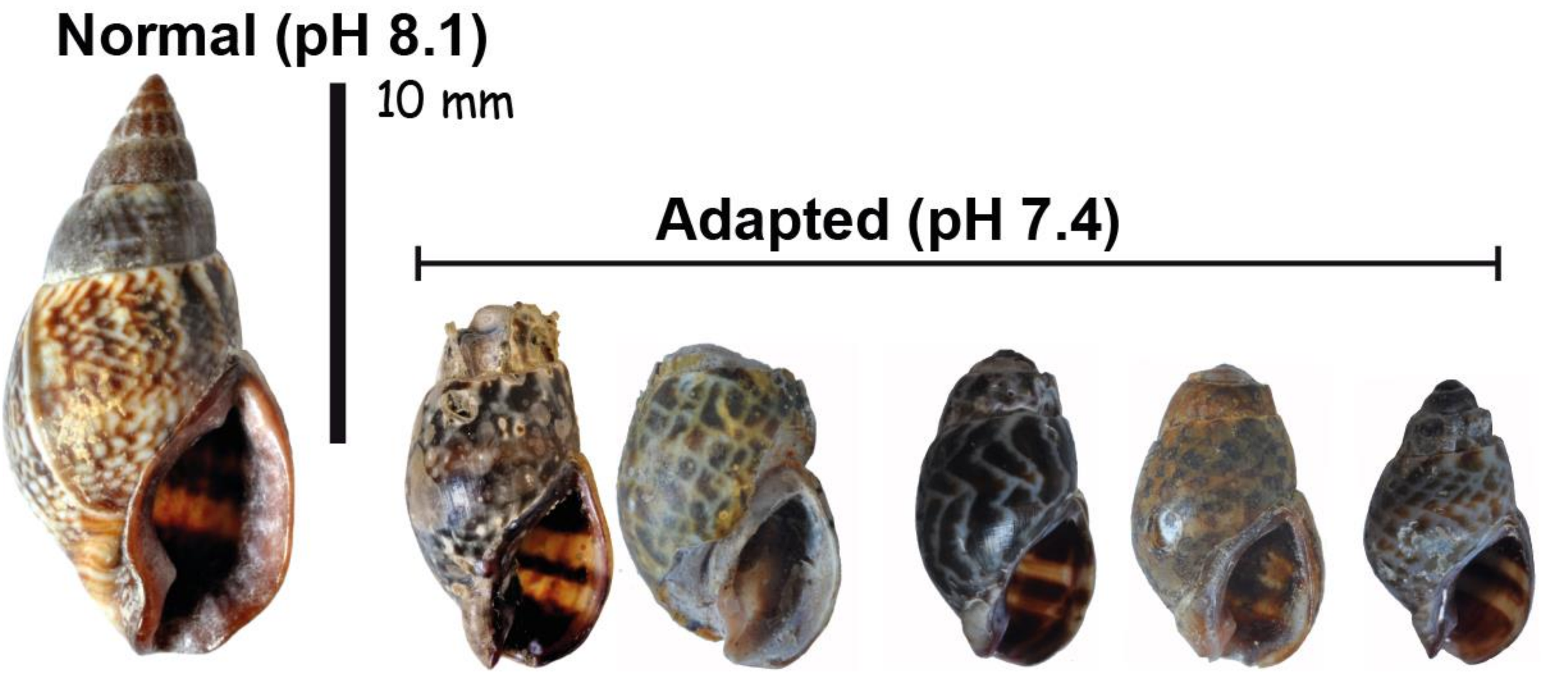
LETTERS
PUBLISHED ONLINE: 20 APRIL 2015 | DOI: 10.1038/NCLIMATE2616
nature climate change

Physiological advantages of dwarfing in surviving extinctions in high-CO_2 oceans

Vittorio Garilli [1*†], Riccardo Rodolfo-Metalpa [2,3*†], Danilo Scuderi [4], Lorenzo Brusca [5], Daniela Parrinello [6], Samuel P. S. Rastrick [7], Andy Foggo [8], Richard J. Twitchett [9], Jason M. Hall-Spencer [8] and Marco Milazzo [10]

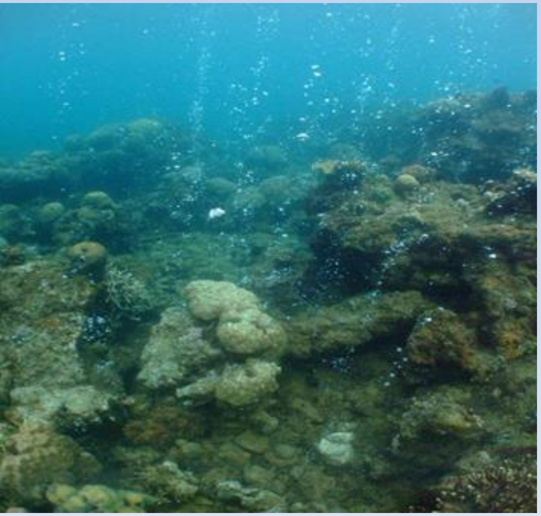

The gastropod *Patella caerulea*
pH_T 6.5-6.8 !!!!
Positive GC rates
and dissolution
Rodolfo-Metalpa *et al*. (2011) Nat Clim Change

The gastropod *Nassarius corniculus*



Garilli, Rodolfo-Metalpa *et al*. (2015) Nat Clim Change

Coral reef acclimatization to OA at CO_2 seeps

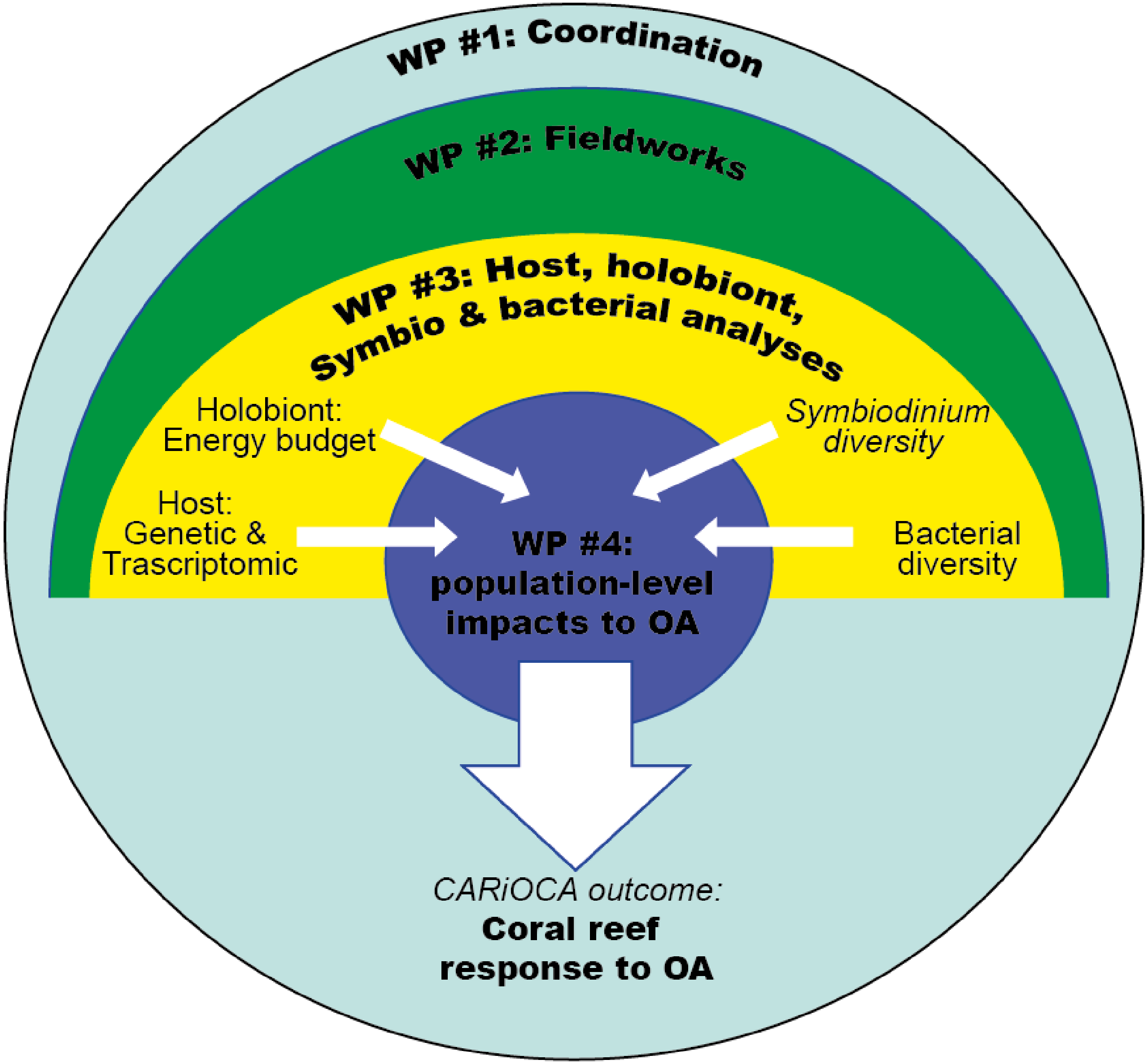


LETTERS
PUBLISHED ONLINE: 29 MAY 2011 | DOI: 10.1038/NCLIMATE1122
nature climate change

Losers and winners in coral reefs acclimatized to elevated carbon dioxide concentrations

Katharina E. Fabricius [1*], Chris Langdon[2], Sven Uthicke [1], Craig Humphrey [1], Sam Noonan[1], Glenn De'ath [1], Remy Okazaki [2], Nancy Muehllehner [2], Martin S. Glas [3] and Janice M. Lough[1]

CARiOCA will start September 2016



Agence Nationale de la Recherche ANR

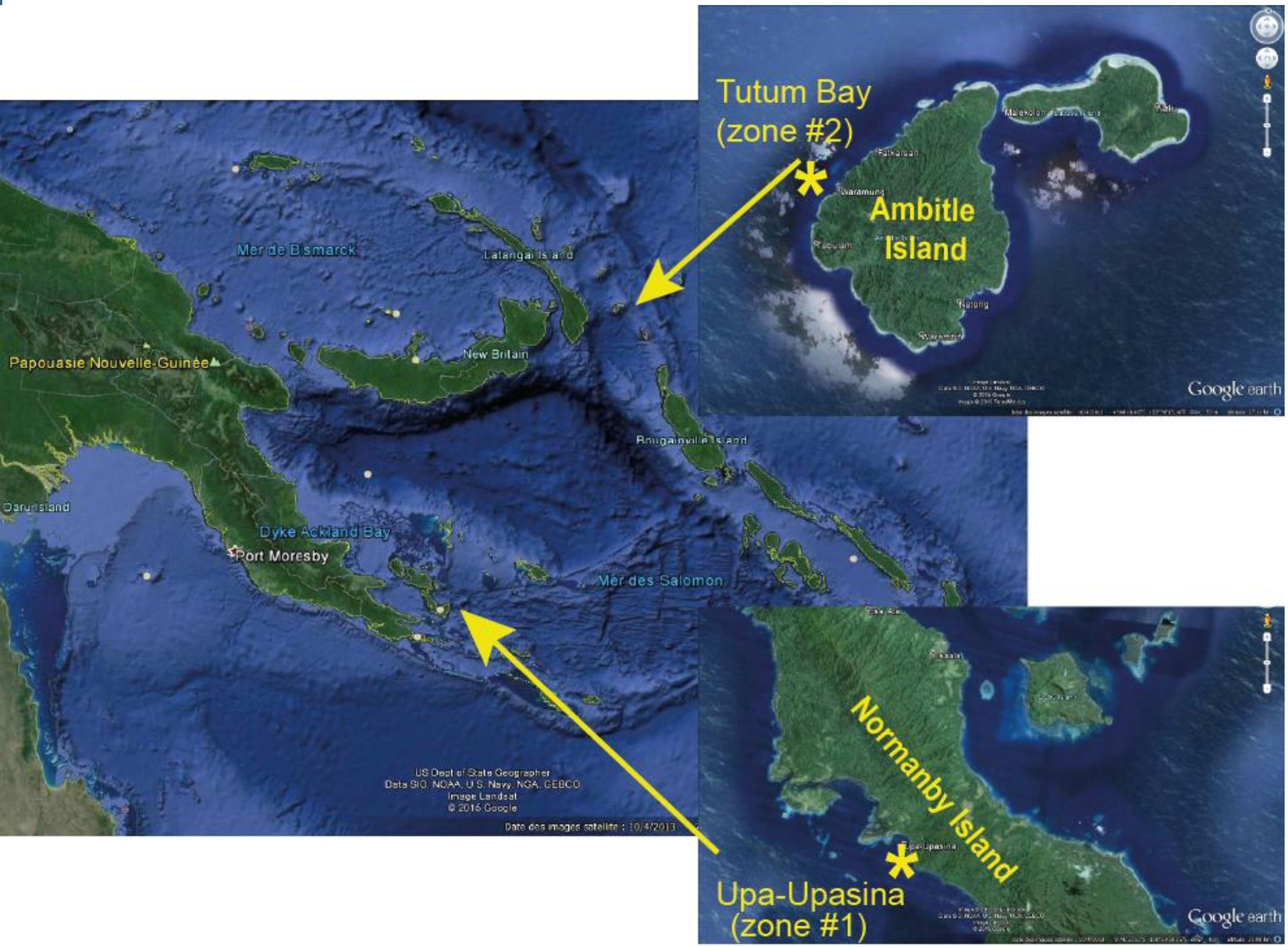
IRD Institut de recherche pour le développement

cnrs dépasser les frontières

JAMES COOK UNIVERSITY AUSTRALIA

AIMS Australian Institute of Marine Science

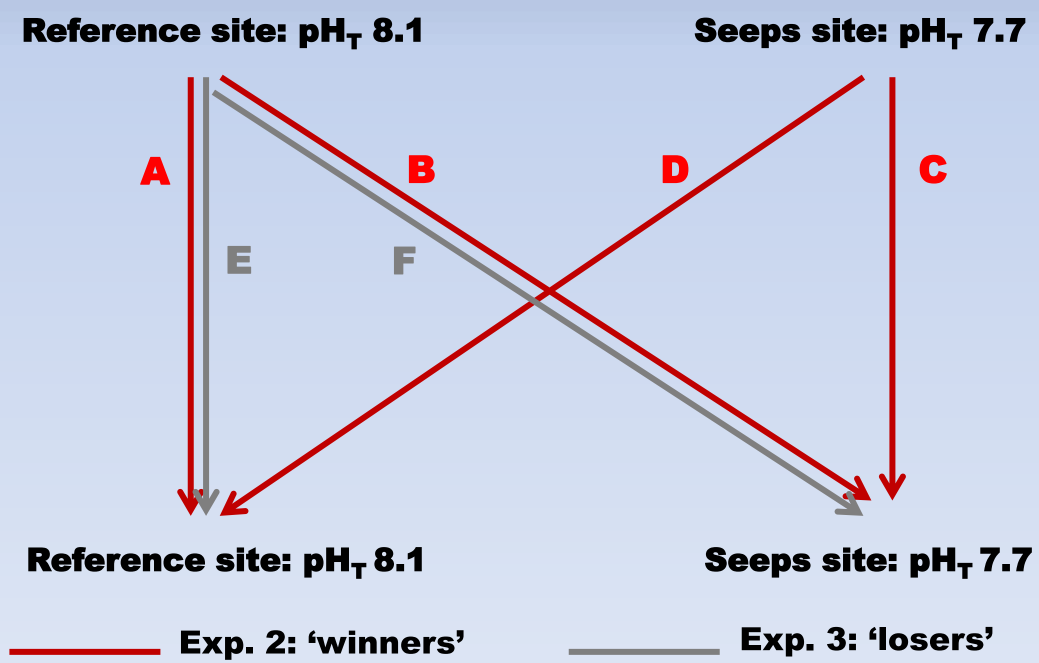
CARiOCA study sites



Site 2:
pH 7.7-7.8 & T +2-3°C (Pichler & Dix 1996 Geology)

Site 1:
pH 7.7-7.8 (Fabricius et al. 2011 Nature Clim Change)

CARiOCA reciprocal transplants



Outcome:

1- whether winners are physiologically acclimated or adapted;

2- why losers lack acclimation;

3- how rapidly the phenotypic changes that confer tolerance occur.

Future perspectives and research priorities

pH change (monitoring)

Open Ocean

Coastal ecosystems

Global model

Local model

Impact on coral reefs

Improving methods

Which species are more resistant and able to adapt