

# Natural CO<sub>2</sub> vents reveal ecological tipping points due to ocean acidification

**A new direction for international research into ocean acidification**

doi:10.1038/nature07051

nature

LETTERS

**Volcanic carbon dioxide vents show ecosystem effects of ocean acidification**

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

**CSM, Monaco**



**Q. How will OA affect marine ecosystems?**

**A. Not known**

Studies in aquaria and mesocosms have alerted us to potential affects (e.g. global loss of coral reefs) and are revealing the mechanisms by which acidification affects growth, reproduction, embryo development, physiology and immunology (Guinotte & Fabry, 2008; Fabry *et al.* 2008; Widdicombe & Spicer in press).

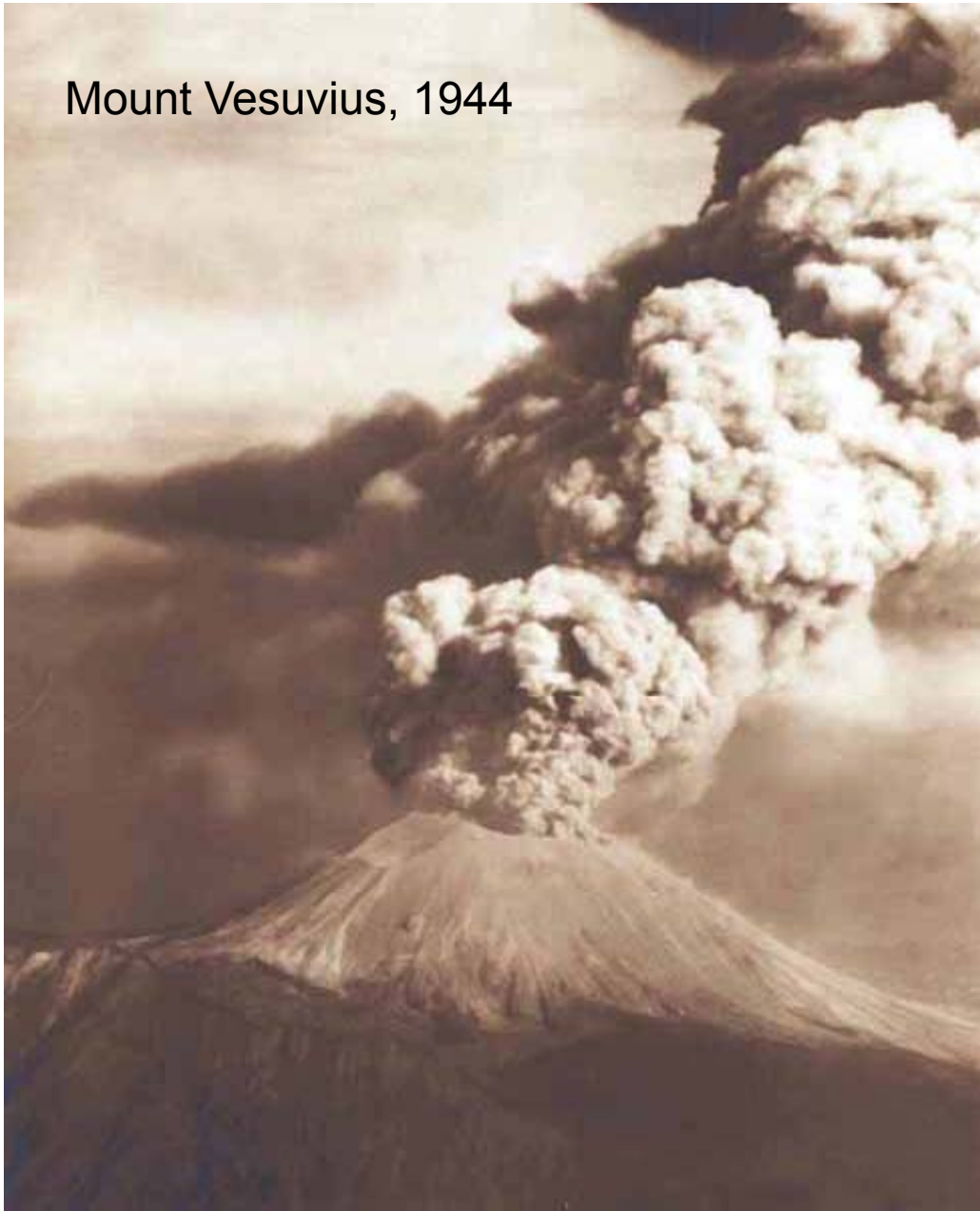
Its difficult to imitate ocean acidification conditions *in situ* for sufficient periods to see how these changes affect marine communities.

Naturally low pH areas help us predict how things will change



**Riebesell**

Mount Vesuvius, 1944

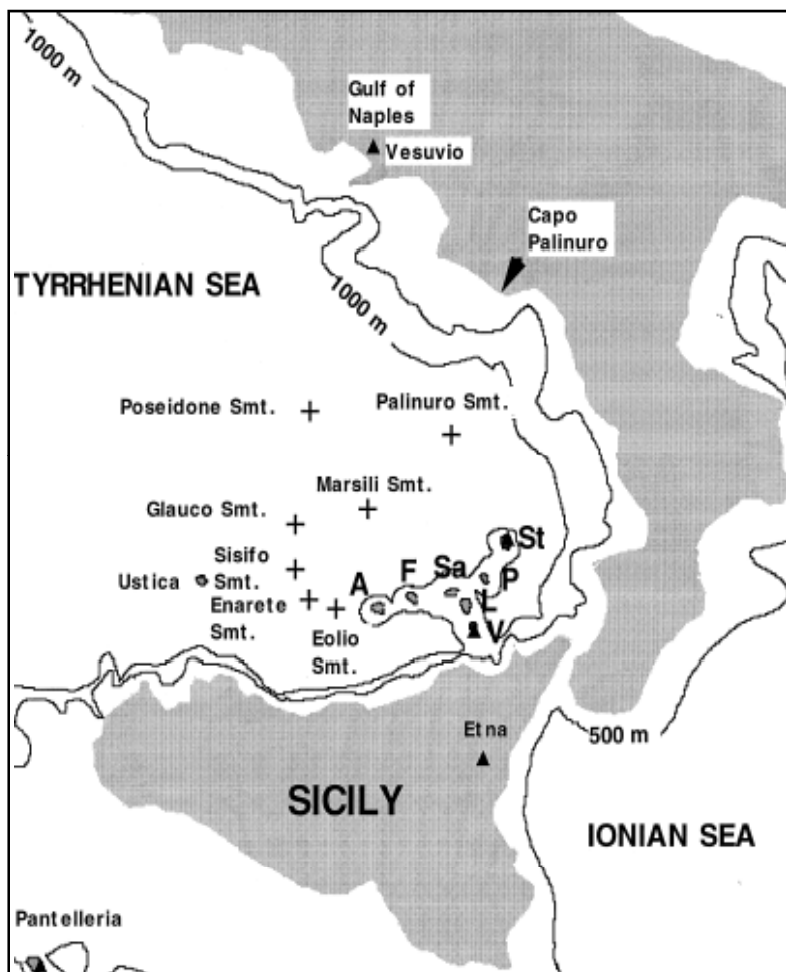


European volcanoes are of global significance in geological CO<sub>2</sub> flux.....

ca 10<sup>8</sup> kg d<sup>-1</sup>

Etna alone produces 10% of annual global flux from sub-aerial volcanoes.

What about submerged ones?



Aeolian Islands	°C	% CO <sub>2</sub>	% H <sub>2</sub> S
Vulcano A <sup>1</sup>	101	100	
Vulcano B <sup>1</sup>	86	98	
Panarea A <sup>2</sup>	27	97	3
Panarea B <sup>2</sup>	26	93	n.d.
Panarea C <sup>2</sup>	27	90	n.d.
Panarea D <sup>2</sup>		93	6

<sup>1</sup> Baubron *et al.* 1990 180t CO<sub>2</sub> per day at Vulcano

<sup>2</sup> Italiano & Nuccio 1991

Similar vents known in Iceland, the Azores, Spain, Greece and Turkey – but a trial was needed to test the concept of their use in ocean acidification studies

**Fieldwork:** Maria-Cristina Buia, Maria-Christina Gambi, Mariamichela Cigliano, Lucia Porzio (Anton Dohrn Laboratory, Italy), Riccardo Rodolfo-Metalpa, Emma Ransome, Sonia Rowley, Bonnie Laverock, Denise Cummings, Helen Findlay (Plymouth, UK), Sophie Martin (Villefranche/Monaco, France), Maoz Fine, Dan Tchernov (Eilat, Israel), Sue Turner, Frances Hopkins (East Anglia, UK), Dario Tedesco (Naples, Italy) Phil Kerrison (Essex, UK) and Claire Goodwin (Ulster, UK).



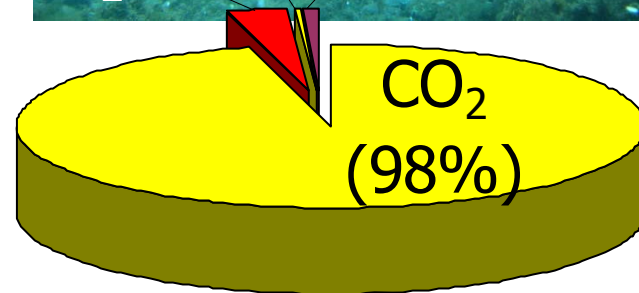
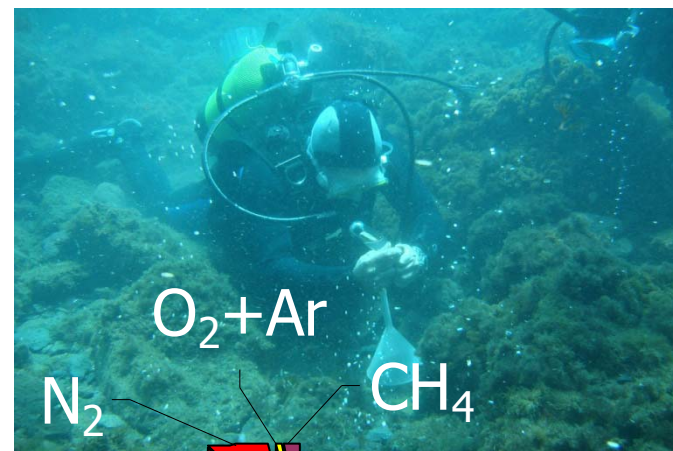


## Venting rates:

>2 million litres gas per day

## Gas composition:

- All three sites
- 98% CO<sub>2</sub> (no sulphur)
- ambient temperature



## 2007-2008 Monitoring

### Carbonate chemistry

pH (total scale), Total Alkalinity, Salinity, and Temperature to calculate  $p\text{CO}_2$ ,  $\text{CO}_3^{2-}$ ,  $\text{HCO}_3^-$ , DIC,  $\Omega_{\text{arag}}$ ,  $\Omega_{\text{calcite}}$

### Biodiversity

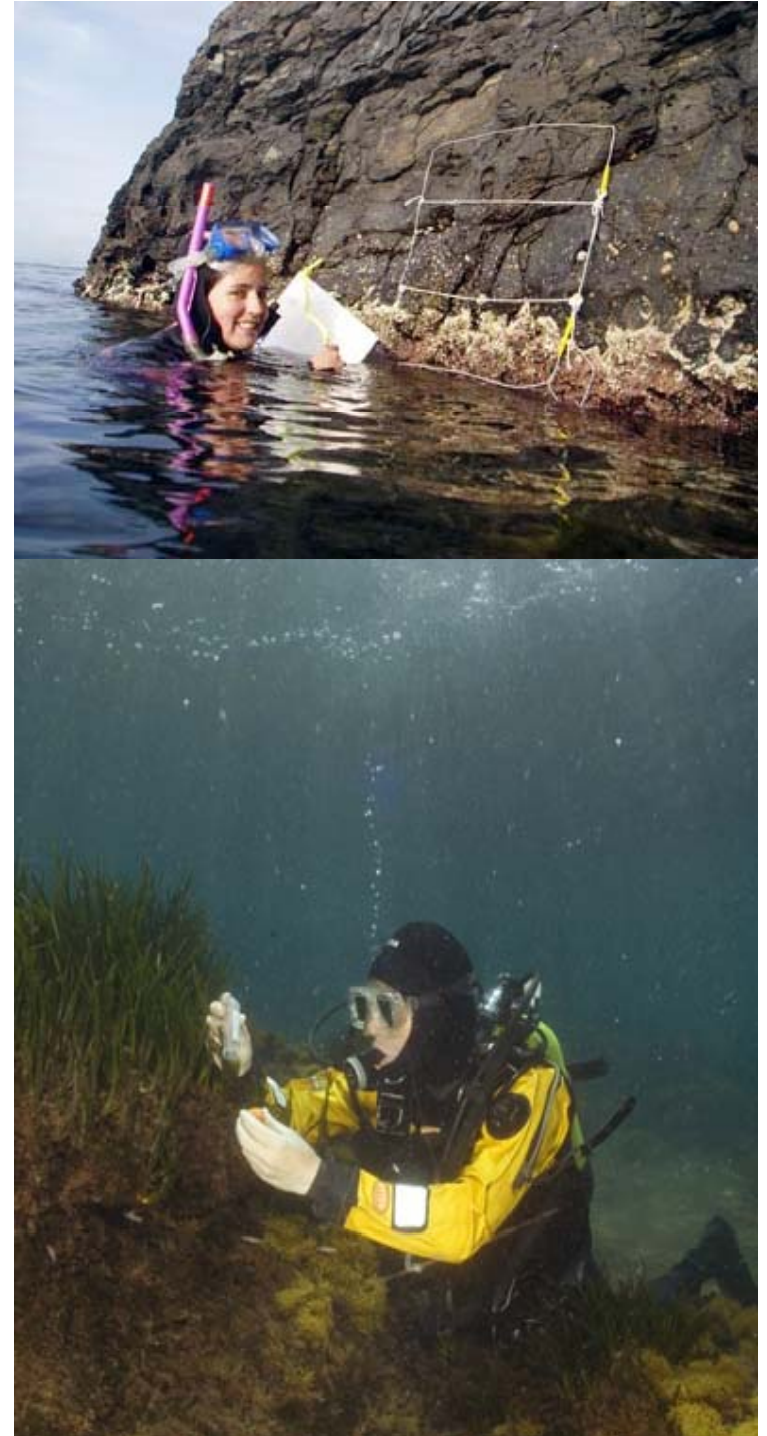
Both intertidal and subtidal abundances of macroflora and macrofauna

### Ecology

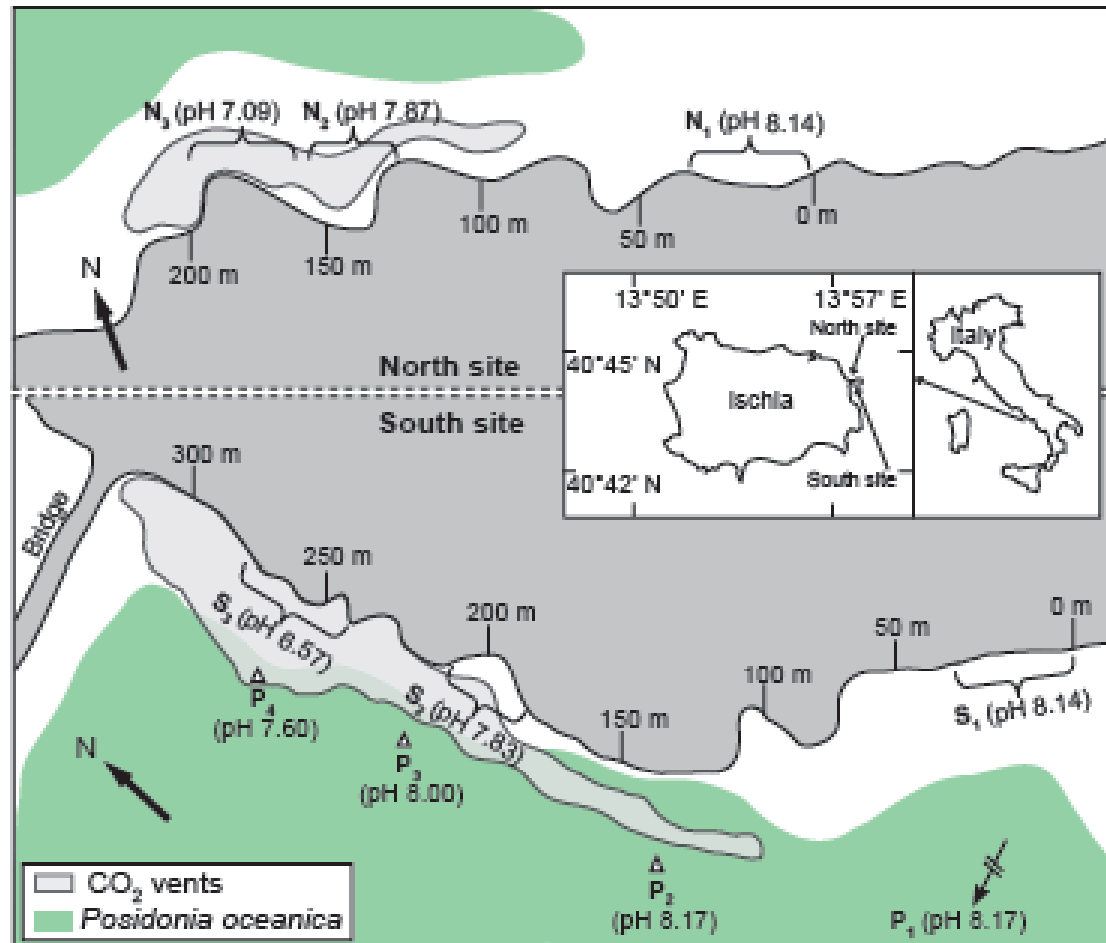
e.g. seagrass abundance, age, biomass, photosynthetic efficiency, epiphytic calcium carbonate

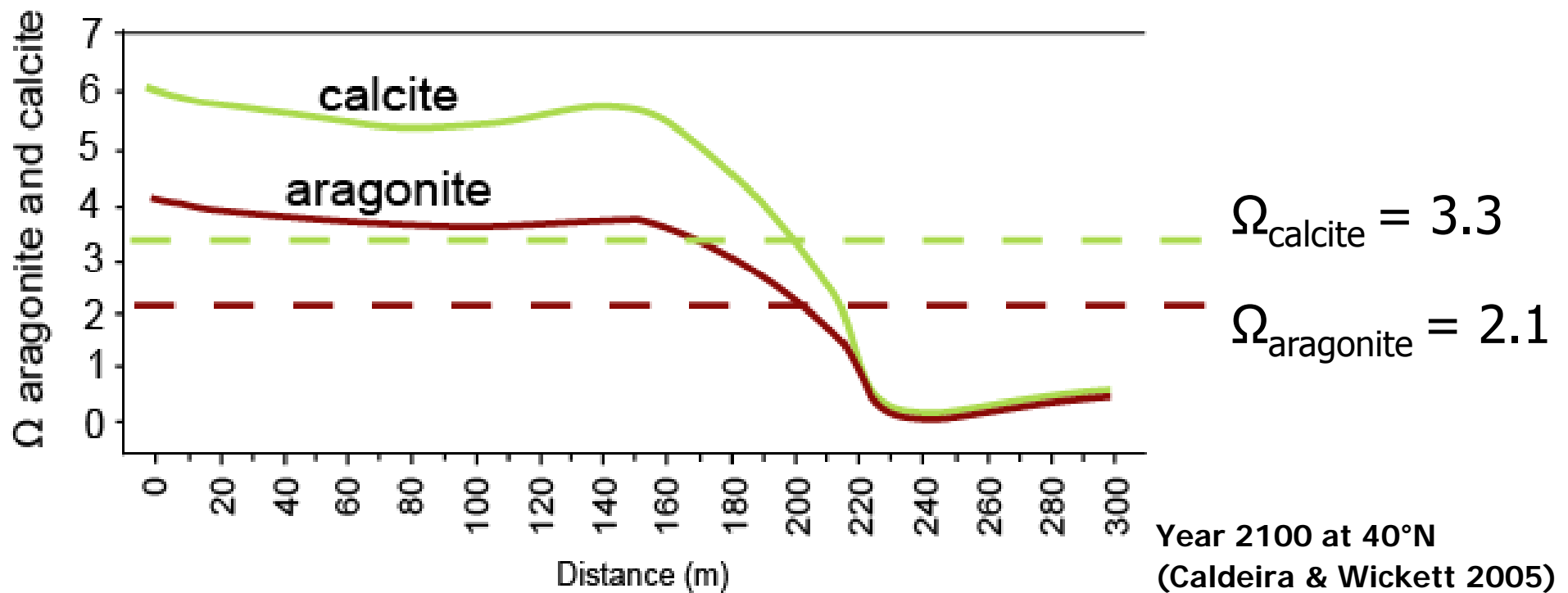
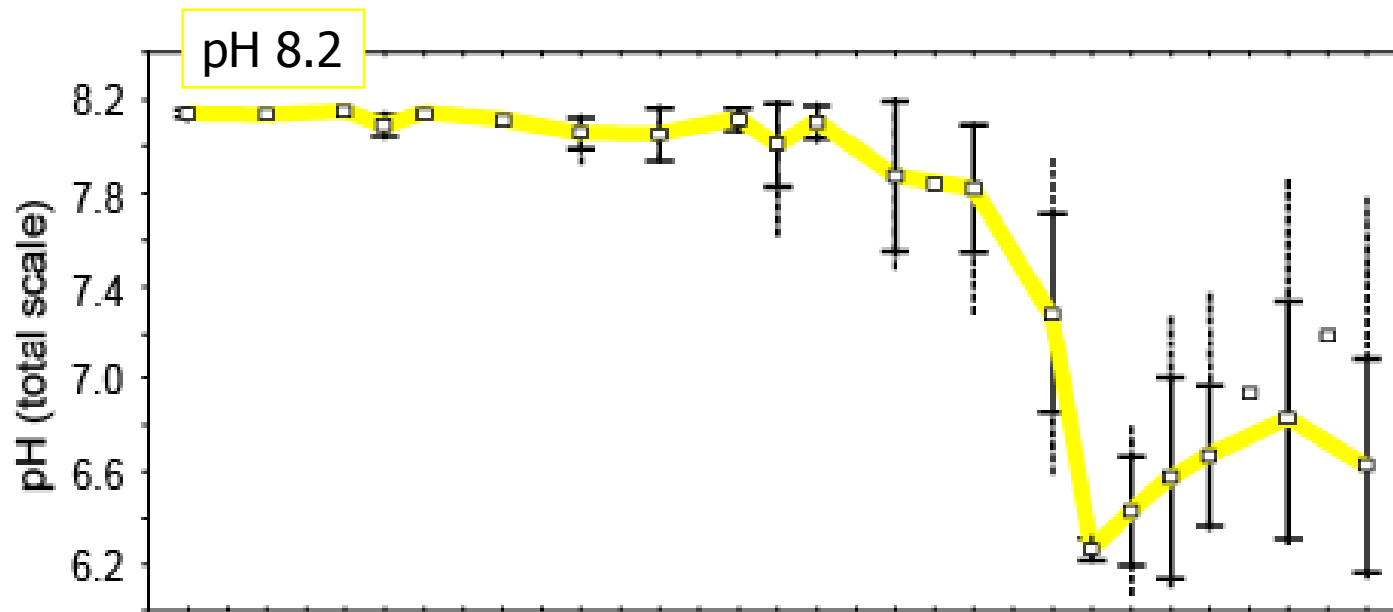
### Transplantation/Recruitment

e.g. corals and bryozoa



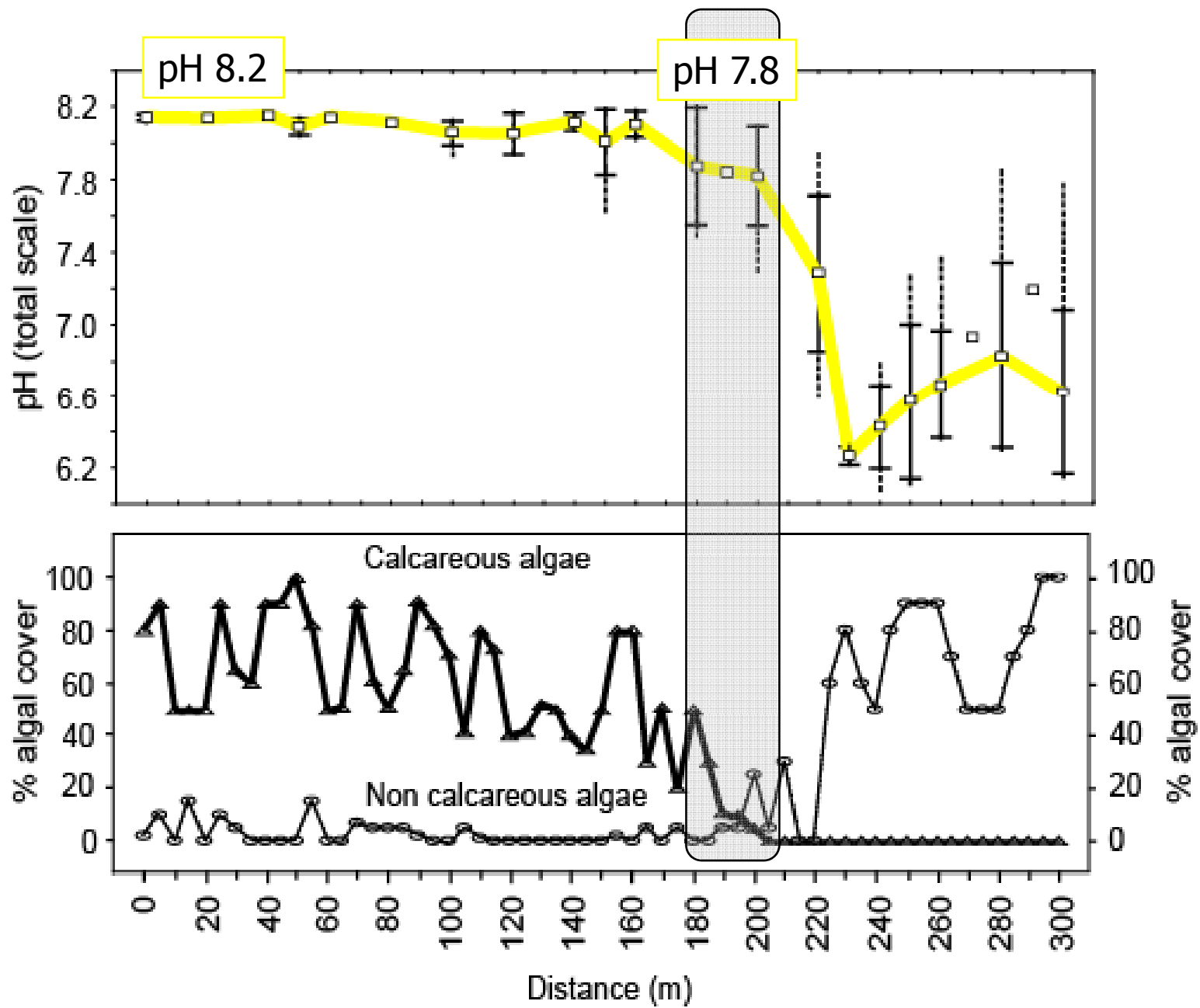
# Castello Aragonese



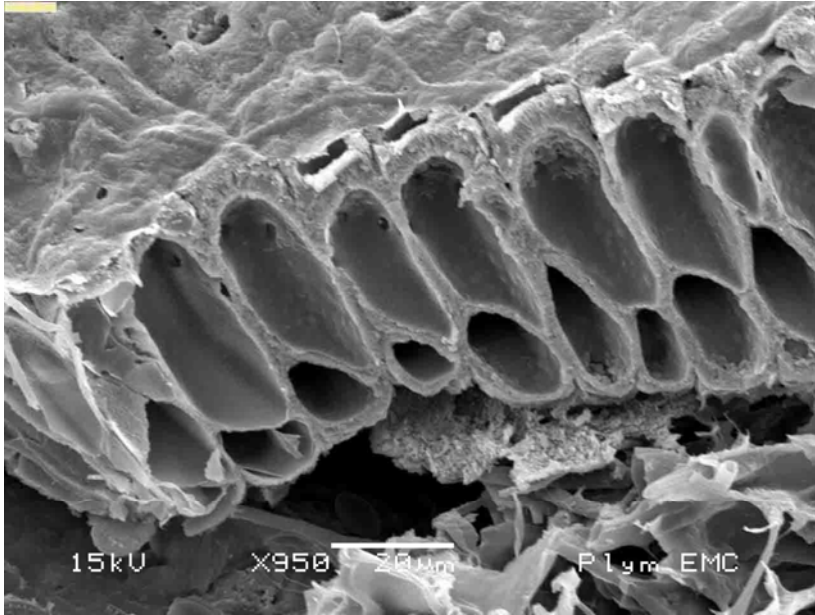


## 30% reduction in biodiversity at mean pH 7.8

<b>Algae</b>	<b>pH 8.2</b>	<b>pH 7.8</b>	<b>pH 6.6</b>
Green	15	12	4
Red	20	11	3
Brown	17	13	11
<b>Total</b>	<b>52</b>	<b>36</b>	<b>18</b>
<b>Fauna</b>			
Sponges	8	7	1
Cnidarians	8	4	2
Annelids	4	3	0
Crustaceans	5	3	2
Molluscs	29	17	6
Echinoderms	6	6	0
Fish	9	9	0
<b>Total</b>	<b>69</b>	<b>49</b>	<b>11</b>

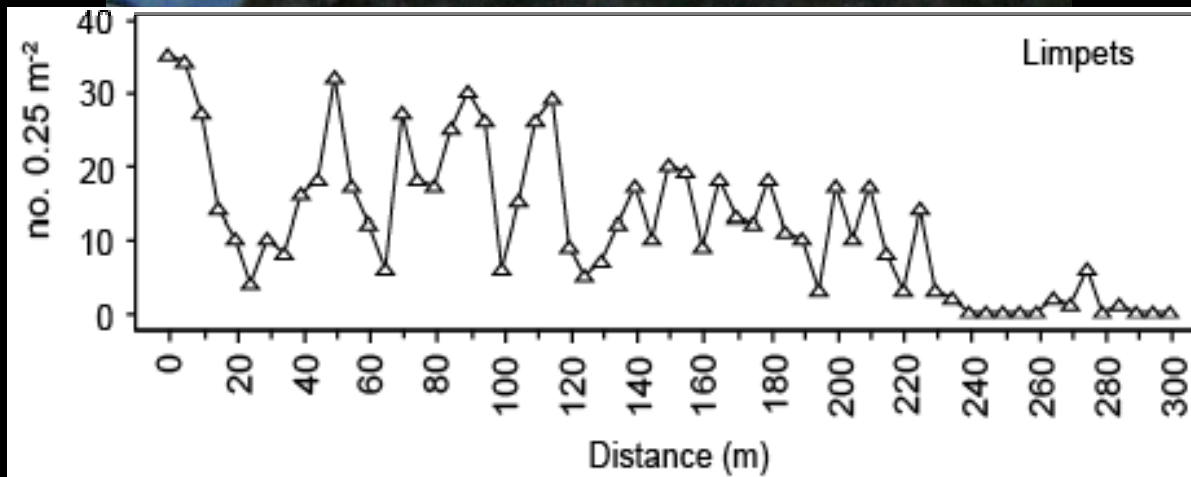
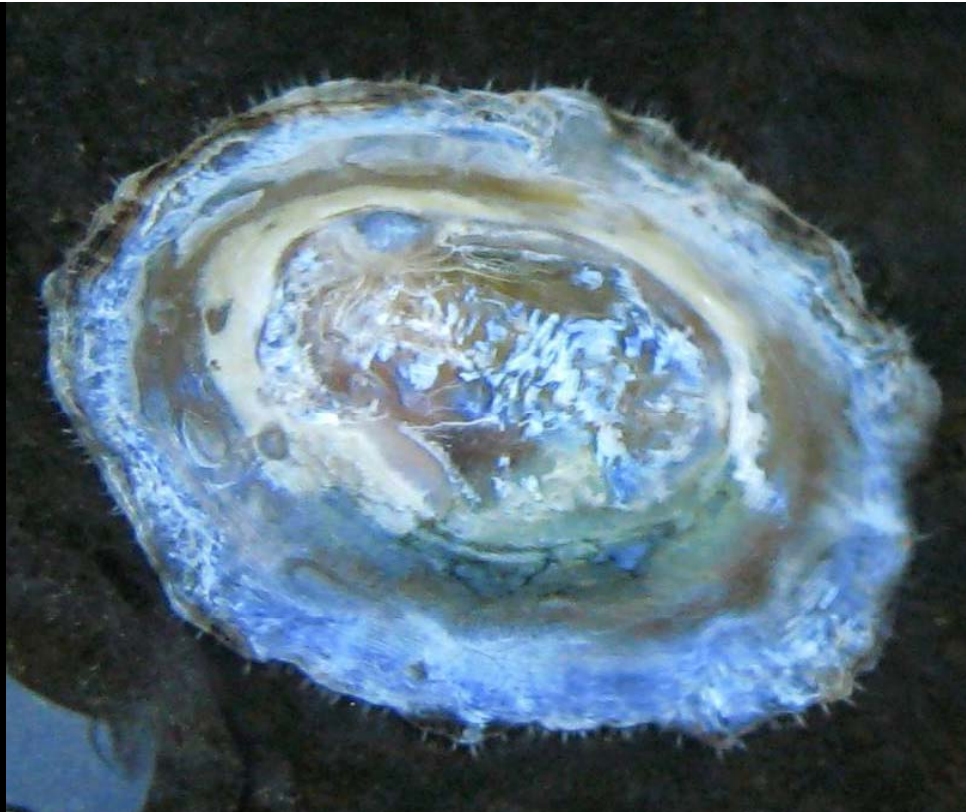


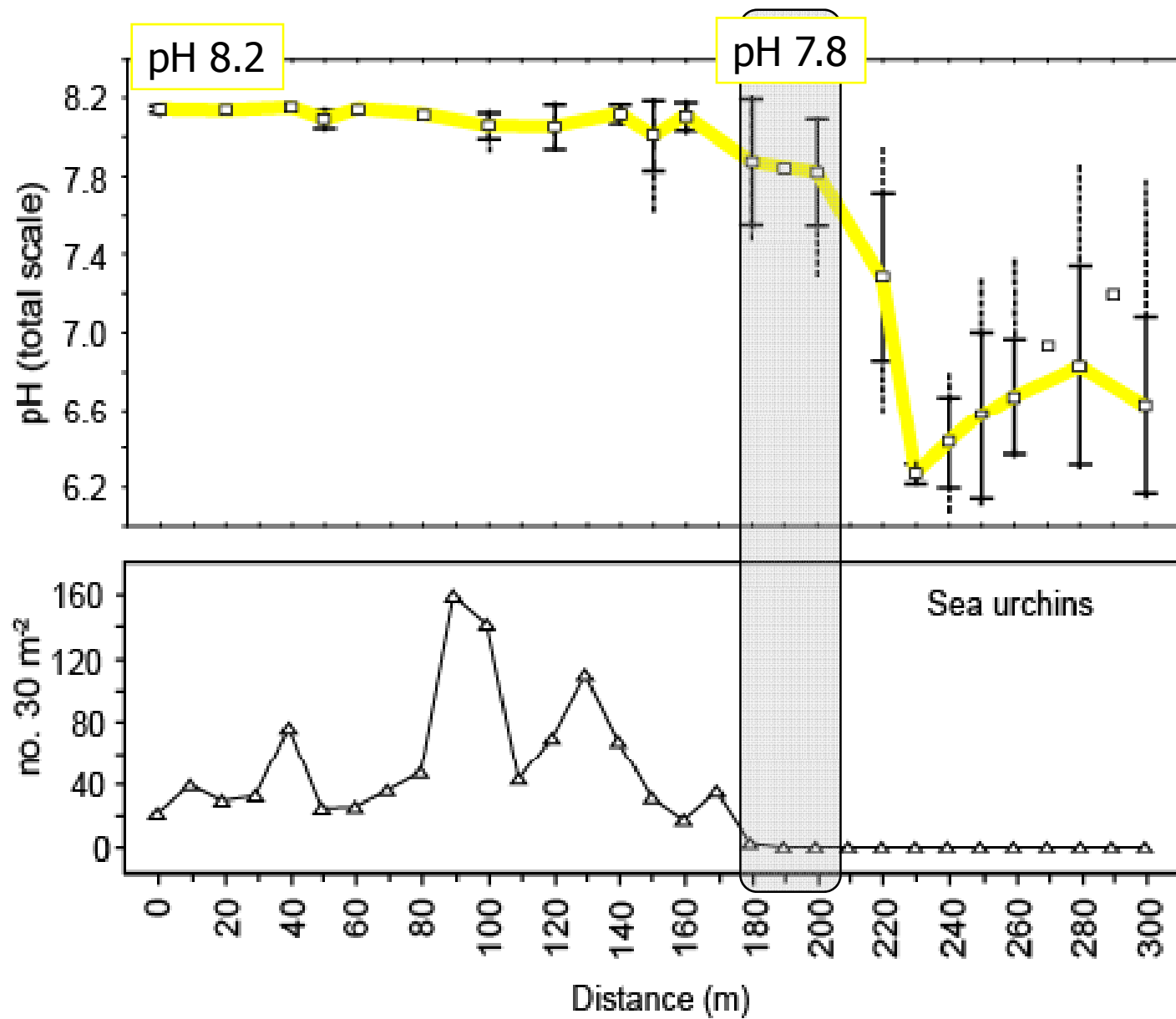
pH 8.2 Coralline algae abundant



pH <7.8 Calcified algae absent  
Invasive genera common







# Shift in seagrass ecology

An underwater photograph showing a dense seagrass meadow. The seagrass is green and appears to be covered with small, white, calcareous epibionts. The water is clear and blue, with sunlight filtering through from above, creating a bright, slightly hazy atmosphere. The seagrass is growing on a rocky or sandy seabed.

biology  
**letters**

*Biol. Lett.*

doi:10.1098/rsbl.2008.0412

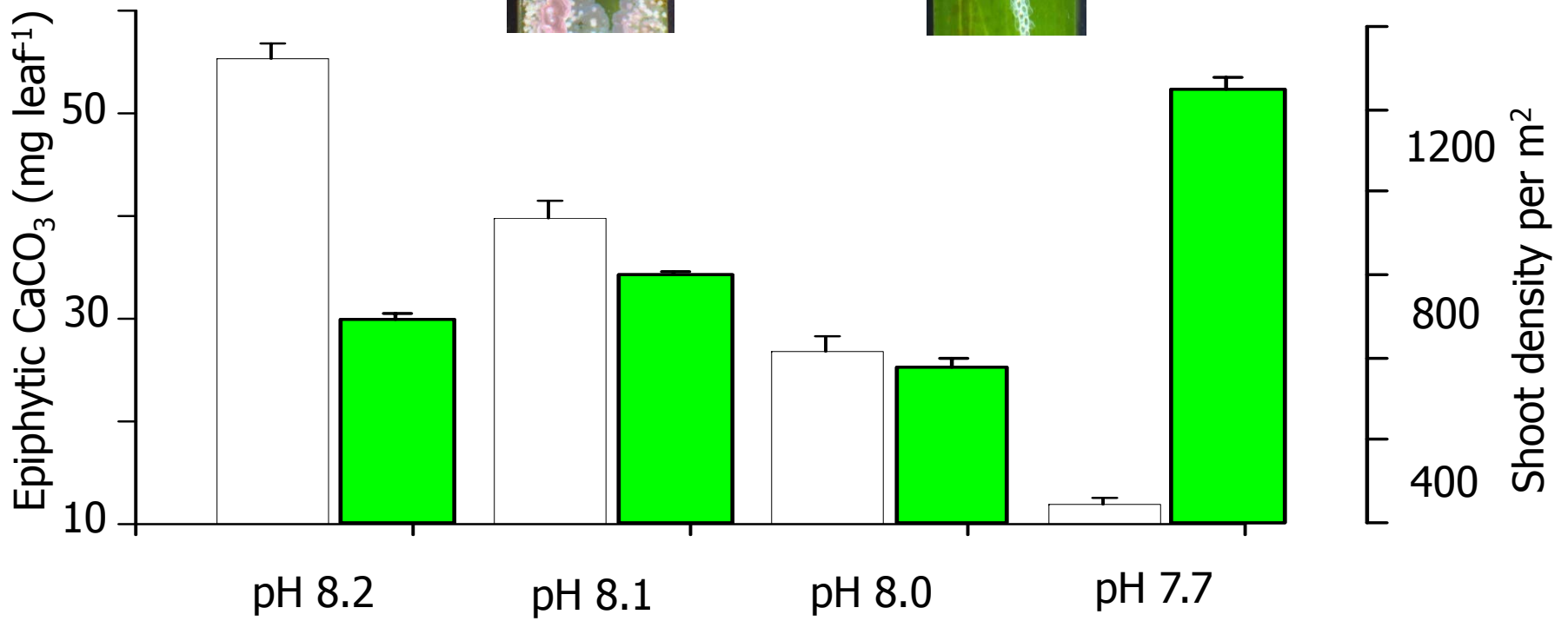
*Published online*

**Global change biology**

## Effects of naturally acidified seawater on seagrass calcareous epibionts

Sophie Martin<sup>1,\*</sup>, Riccardo Rodolfo-Metalpa<sup>2</sup>,  
Emma Ransome<sup>2</sup>, Sonia Rowley<sup>2</sup>,  
Maria-Christina Buia<sup>3</sup>, Jean-Pierre Gattuso<sup>1</sup>  
and Jason Hall-Spencer<sup>2</sup>

pH 8.2 → pH 7.7



Our pilot studies have established that major ecological tipping points occur along gradients of increasing CO<sub>2</sub> levels;

- acidification dissolves the shells of calcified species such as corals, sea urchins and snails, which were absent in areas with a pH <7.4
- high CO<sub>2</sub> favours the production of seagrass and removes its calcareous epiphytes
- the amount of calcified algae, which bind coral reefs together in the tropics, fell from more than 60% cover outside the vent areas to zero within these areas
- invasive alien species, which cause damage to ecosystems worldwide, may thrive at high CO<sub>2</sub> levels

## Summary

### Natural CO<sub>2</sub> vents - a new tool for ocean acidification research

- integrate effects on biogeochemical cycles over millenia
- provide test systems for modelling work and to scale-up laboratory and mesocosm experiments
- allow study of long-term effects of high CO<sub>2</sub> on groups of social and economic importance, such as fish and shellfish.
- help communicate what ocean acidification can do to our seas