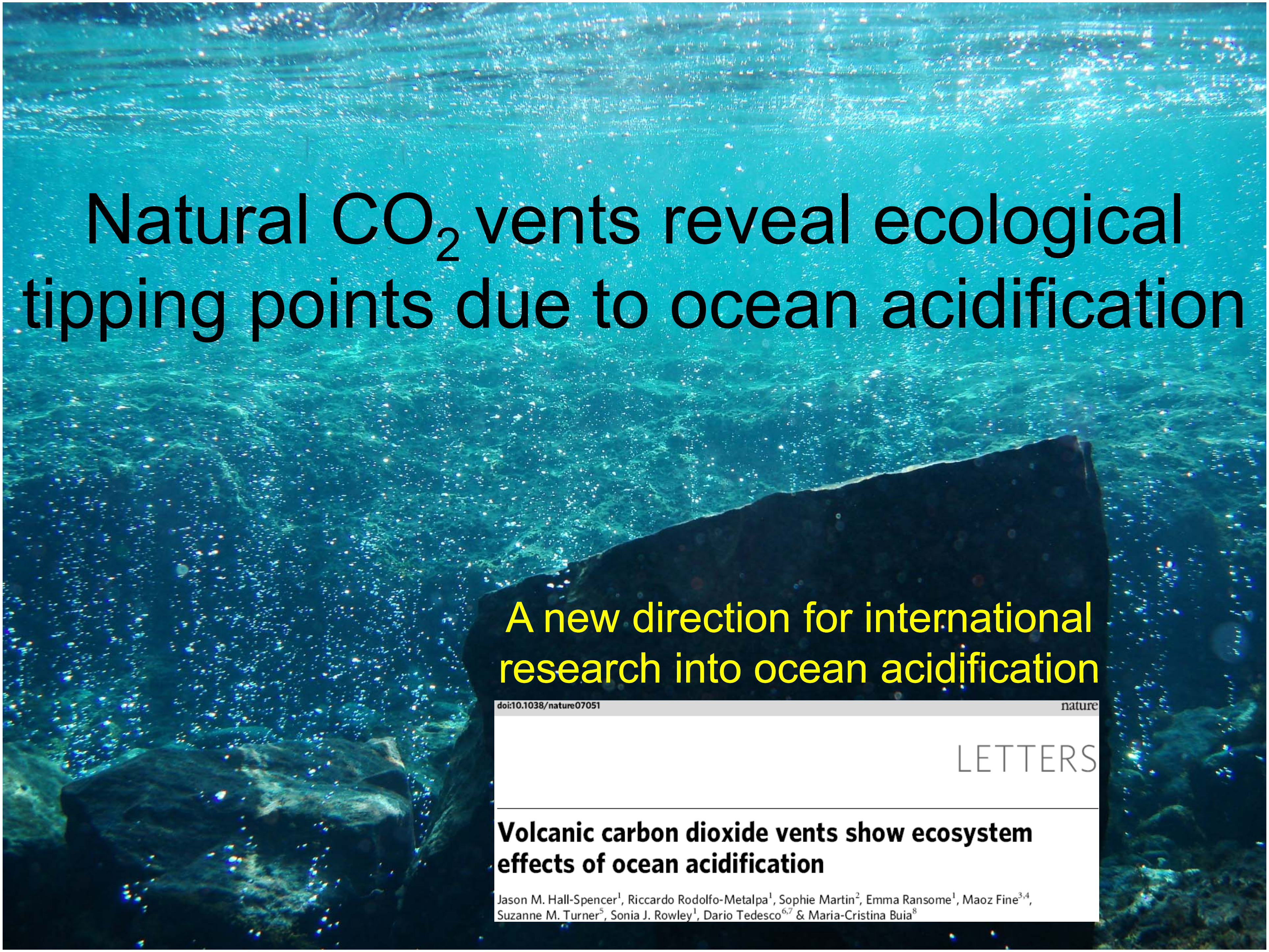
Natural CO_2 vents reveal ecological tipping points due to ocean acidification



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LETTERS

Volcanic carbon dioxide vents show ecosystem effects of ocean acidification

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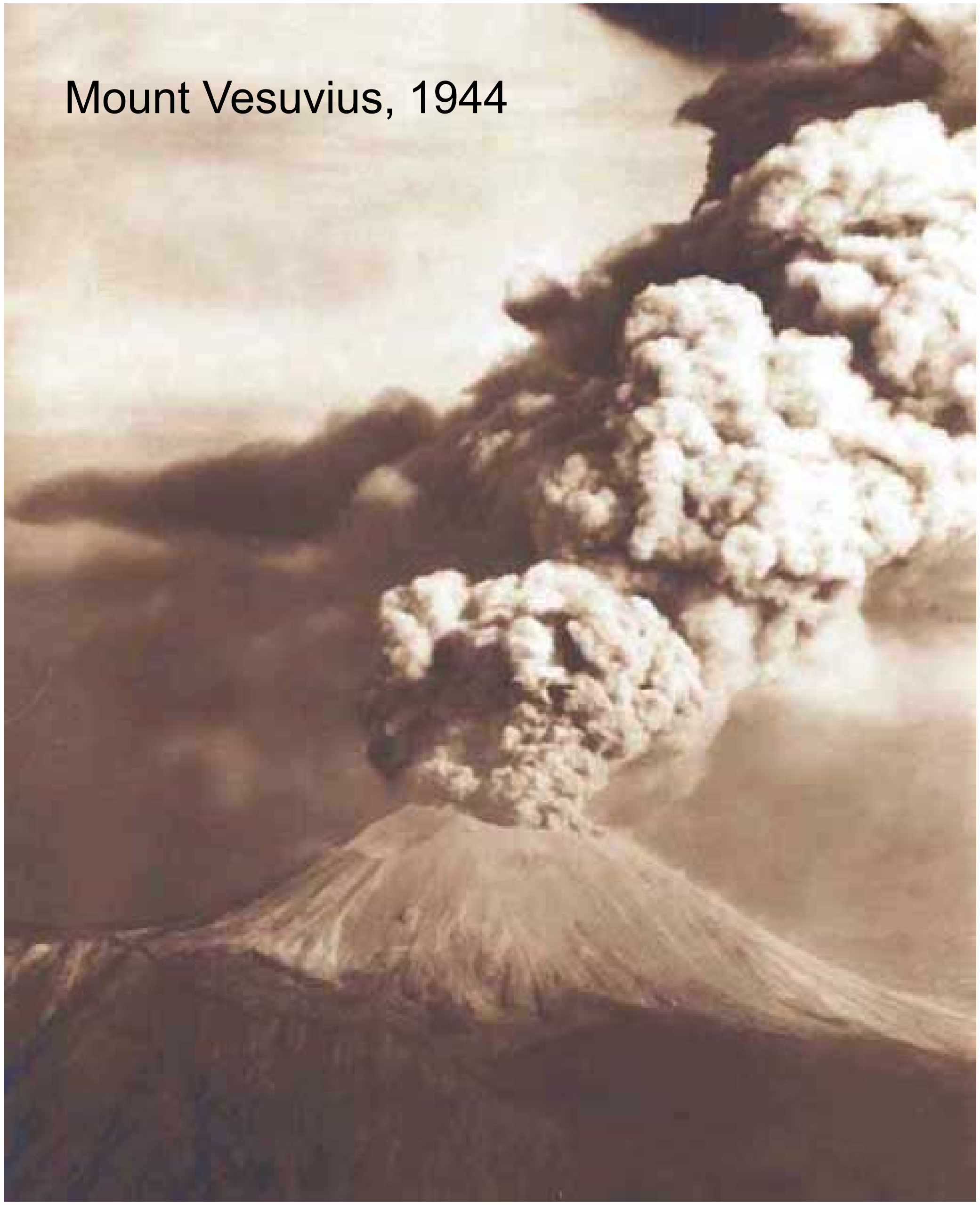
Q. How will OA affect marine ecosystems?

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

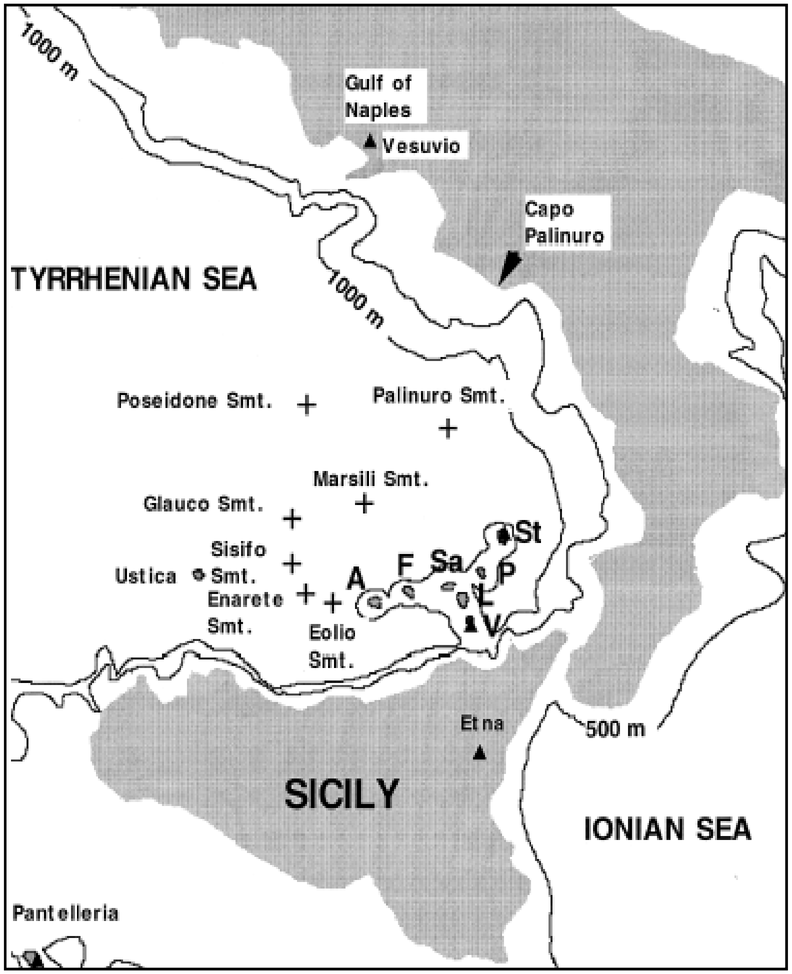


European volcanoes are of global significance in geological CO_2 flux…..

ca 10^8 kg d^{-1}

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

What about submerged ones?

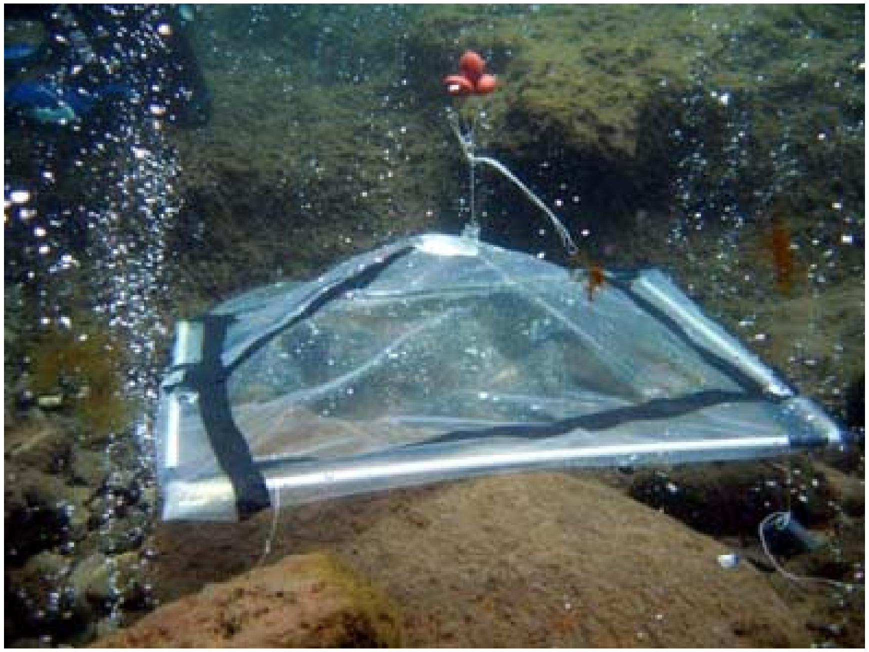


Aeolian Islands	°C	% CO_2	% H_2S
Vulcano A[1]	101	100	
Vulcano B[1]	86	98	
Panarea A[2]	27	97	3
Panarea B[2]	26	93	n.d.
Panarea C[2]	27	90	n.d.
Panarea D[2]		93	6

[1] Baubron *et al*. 1990 180t CO_2 per day at Vulcano
[2] 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).

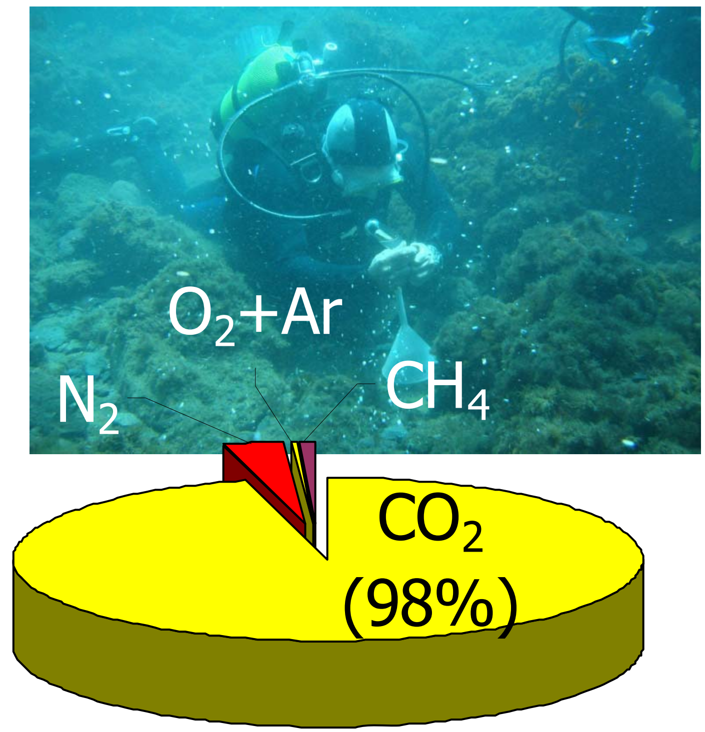


Venting rates:

>2 million litres gas per day

Gas composition:

- All three sites
- 98% CO_2 (no sulphur)
- ambient temperature



2007-2008 Monitoring

Carbonate chemistry

pH (total scale), Total Alkalinity, Salinity, and Temperature to calculate pCO_2, CO_3^{2-}, HCO^{3-}, DIC, Ω_{arag}, $\Omega_{calcite}$

Biodiversity

Both intertidal and subtidal abundances of macroflora and macrofauna

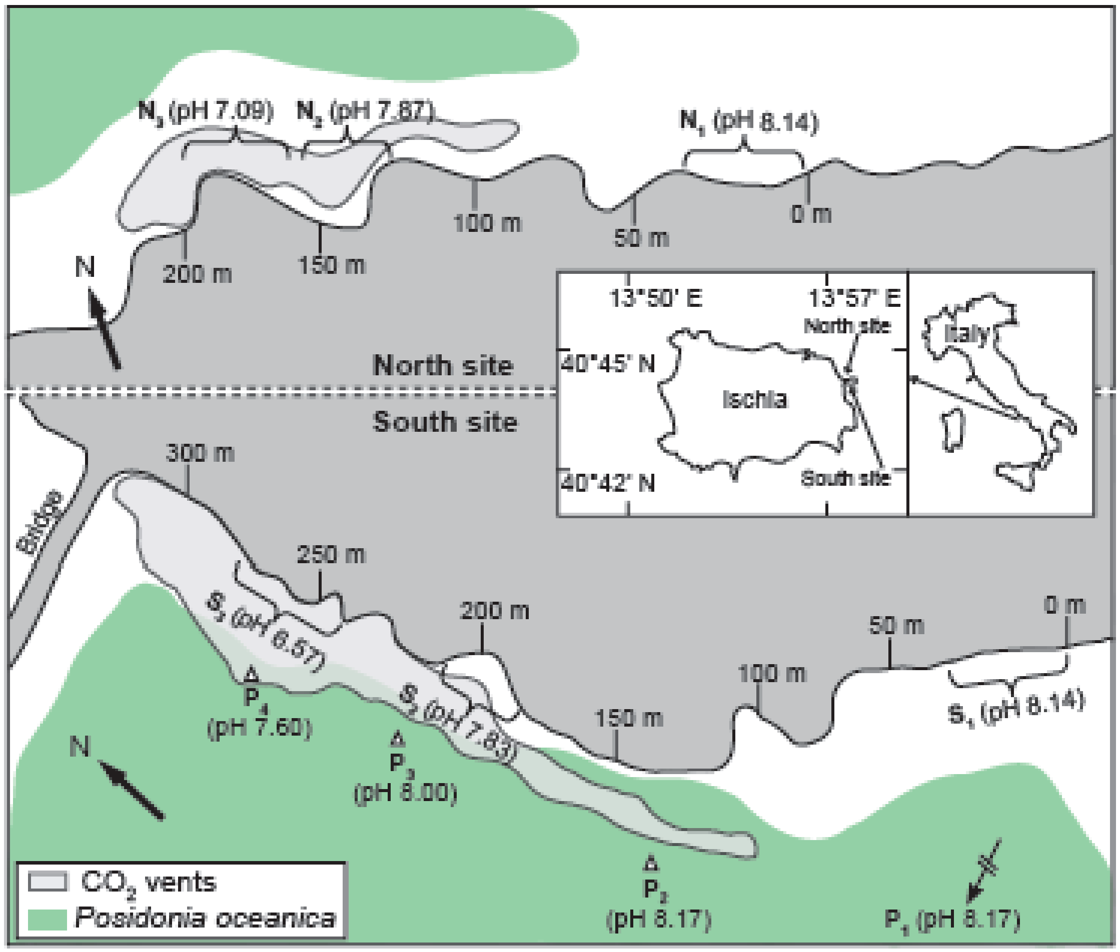
Ecology

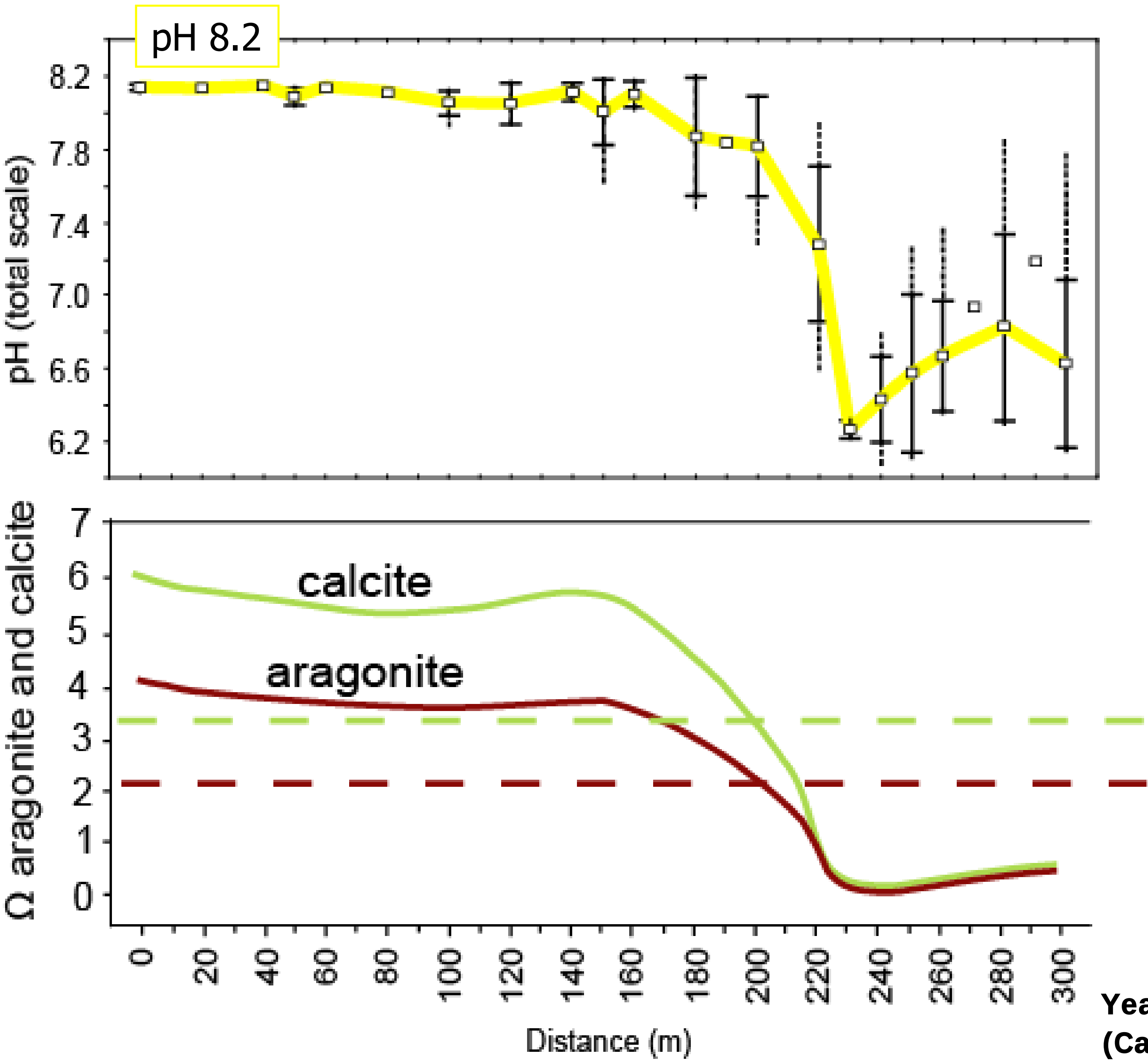
e.g. seagrass abundance, age, biomass, photosynthetic efficiency, epiphytic calcium carbonate

Transplantation/Recruitment

e.g. corals and bryozoa


Castello Aragonese


N_3 (pH 7.09)
N_2 (pH 7.87)
N_1 (pH 8.14)
100 m
50 m
0 m
200 m
150 m
N
North site
South site
13°50' E
13°57' E
North site
40°45' N
Ischia
40°42' N
South site
Italy
300 m
Bridge
250 m
S_3 (pH 6.57)
200 m
50 m
0 m
100 m
S_2 (pH 7.83)
150 m
S_1 (pH 8.14)
P_4
(pH 7.60)
P_3
(pH 8.00)
N
P_2
(pH 8.17)
P_1 (pH 8.17)
CO_2 vents
Posidonia oceanica



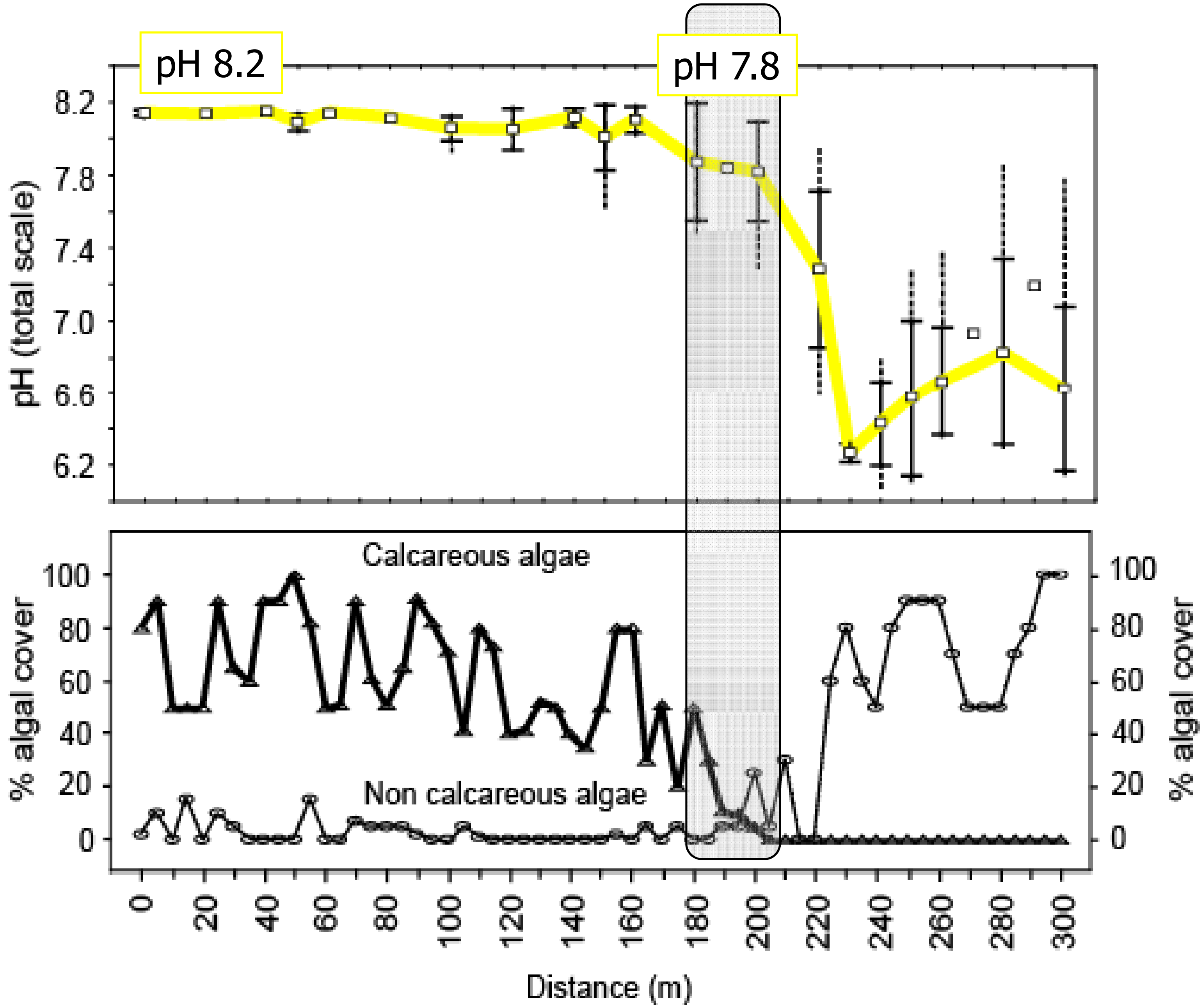
$\Omega_{calcite} = 3.3$

$\Omega_{aragonite} = 2.1$

Year 2100 at 40°N
(Caldeira & Wickett 2005)

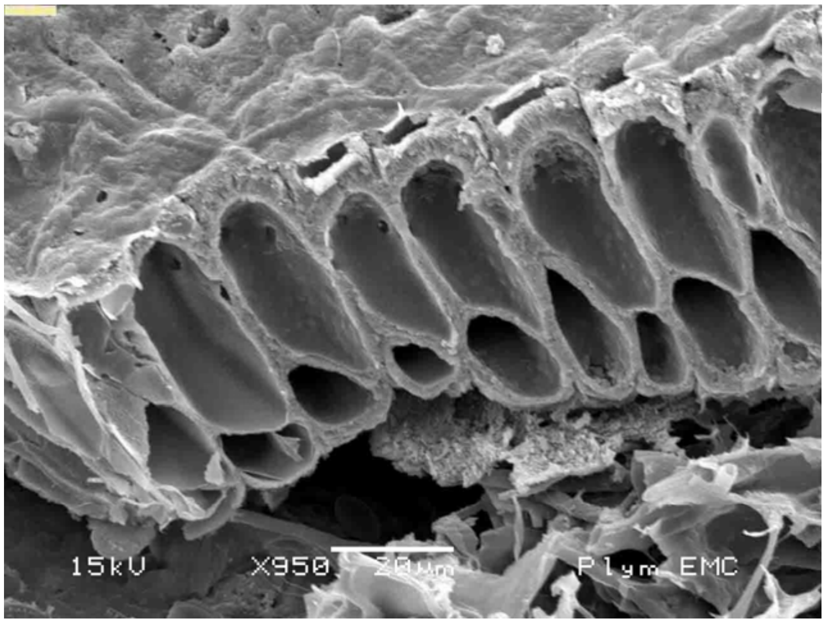
30% reduction in biodiversity at mean pH 7.8

Algae	**pH 8.2**	**pH 7.8**	**pH 6.6**
Green	15	12	4
Red	20	11	3
Brown	17	13	11
Total	**52**	**36**	**18**
Fauna			
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
Total	**69**	**49**	**11**

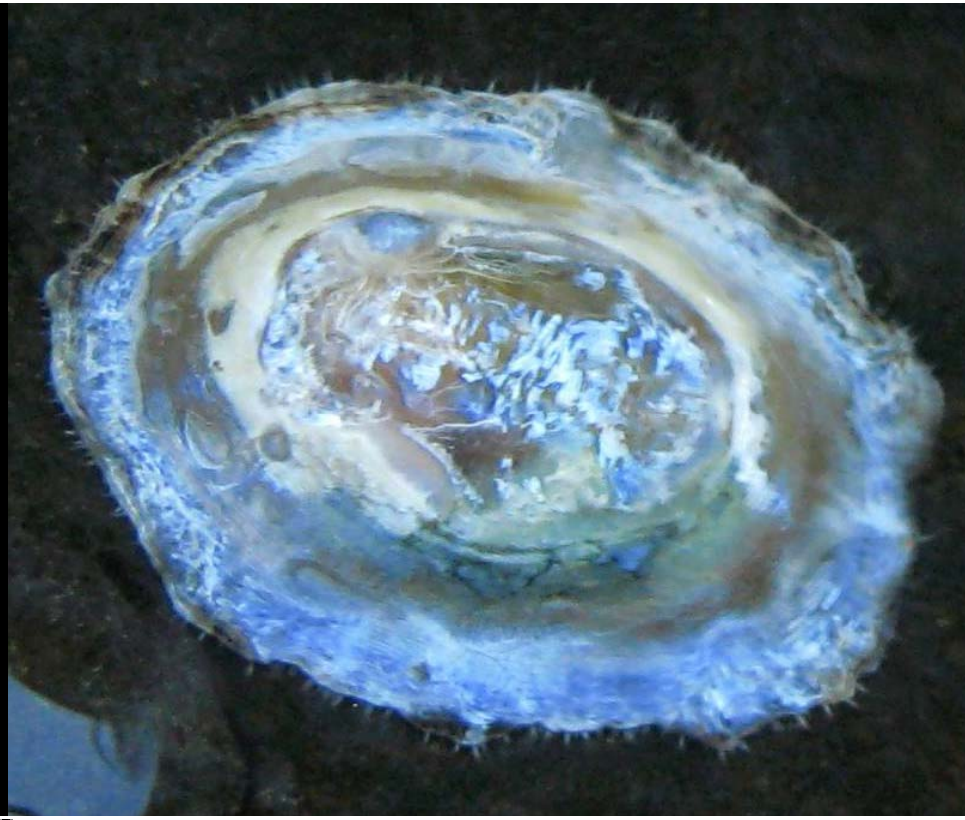


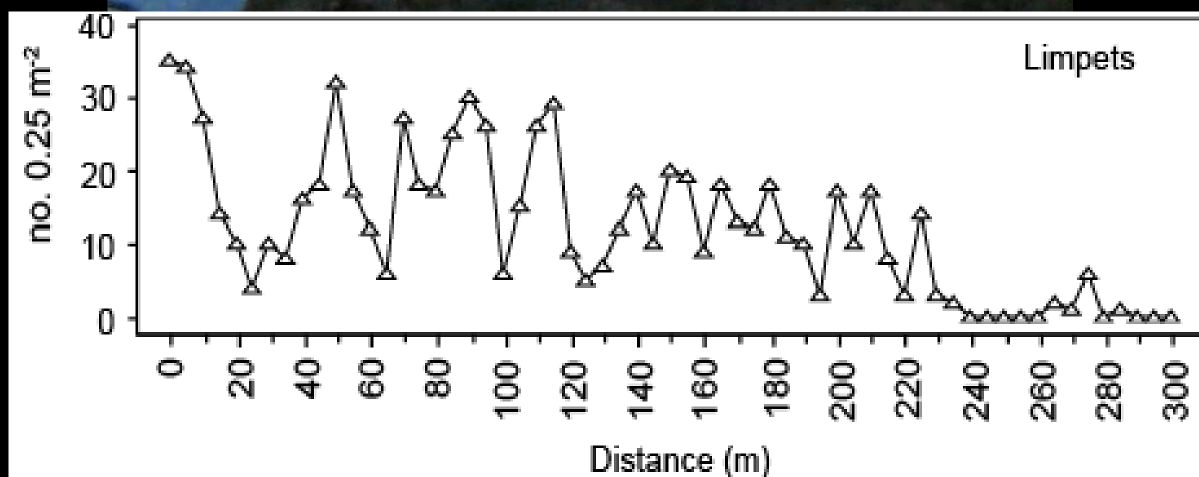
pH 8.2
pH 7.8
pH (total scale)
8.2
7.8
7.4
7.0
6.6
6.2
Calcareous algae
Non calcareous algae
% algal cover
100
80
60
40
20
0
Distance (m)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300

pH 8.2 Coralline algae abundant

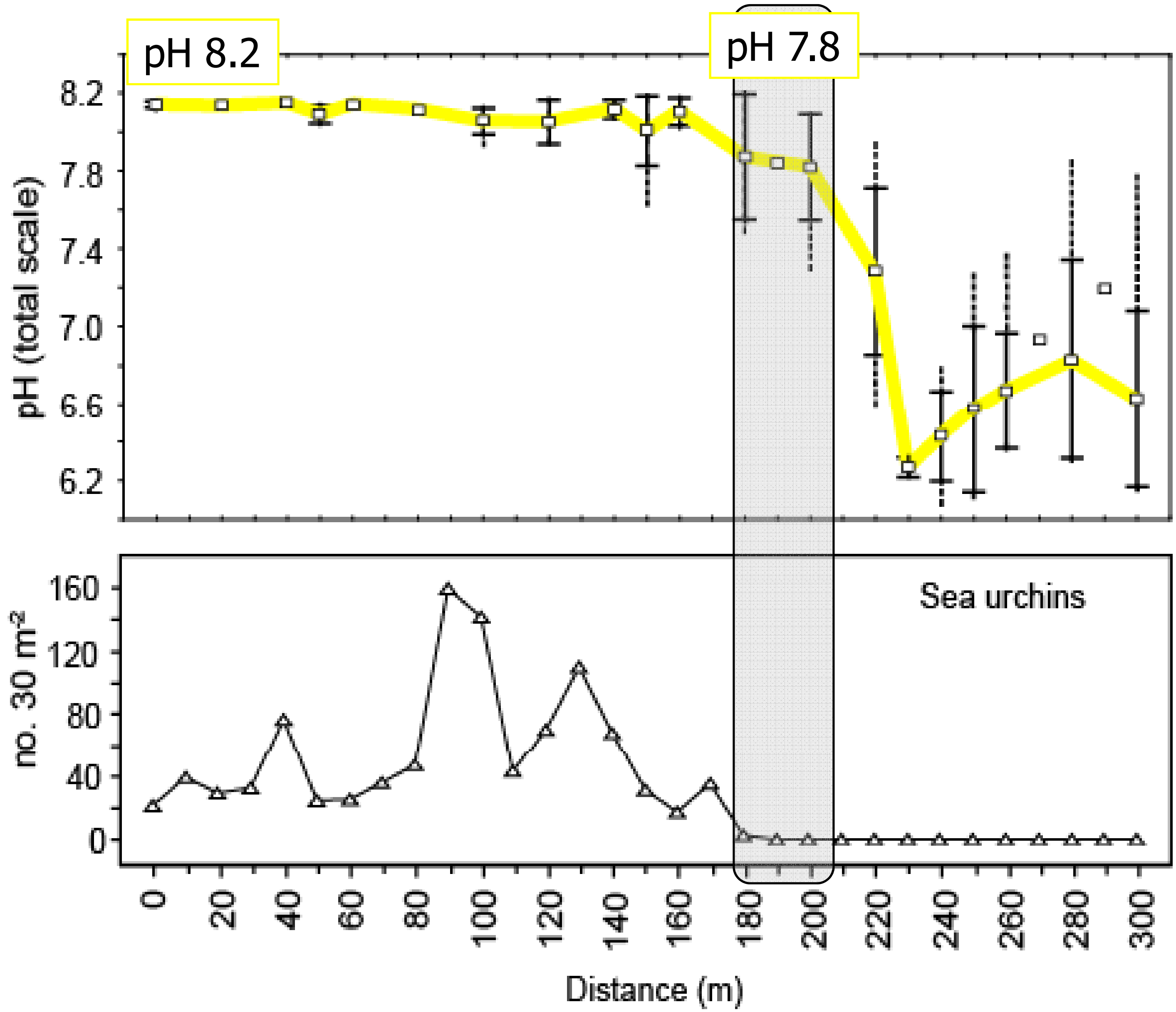


pH <7.8 Calcified algae absent
Invasive genera common



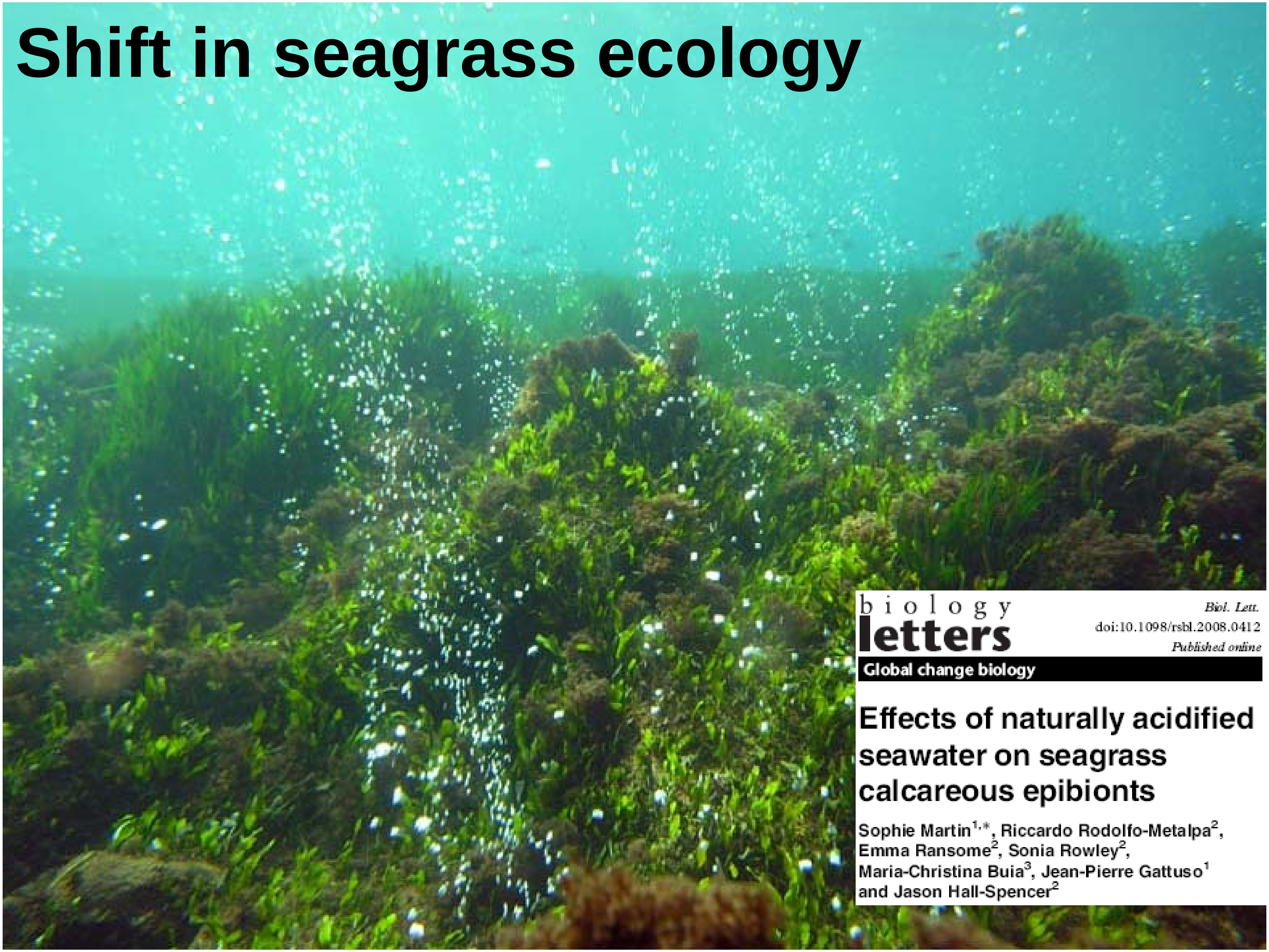


Limpets
no. 0.25 m⁻²
Distance (m)
0
10
20
30
40
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300



pH 8.2
pH 7.8
pH (total scale)
8.2
7.8
7.4
7.0
6.6
6.2
Sea urchins
no. 30 m-2
160
120
80
40
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Distance (m)

Shift in seagrass ecology



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Global change biology

Effects of naturally acidified seawater on seagrass calcareous epibionts

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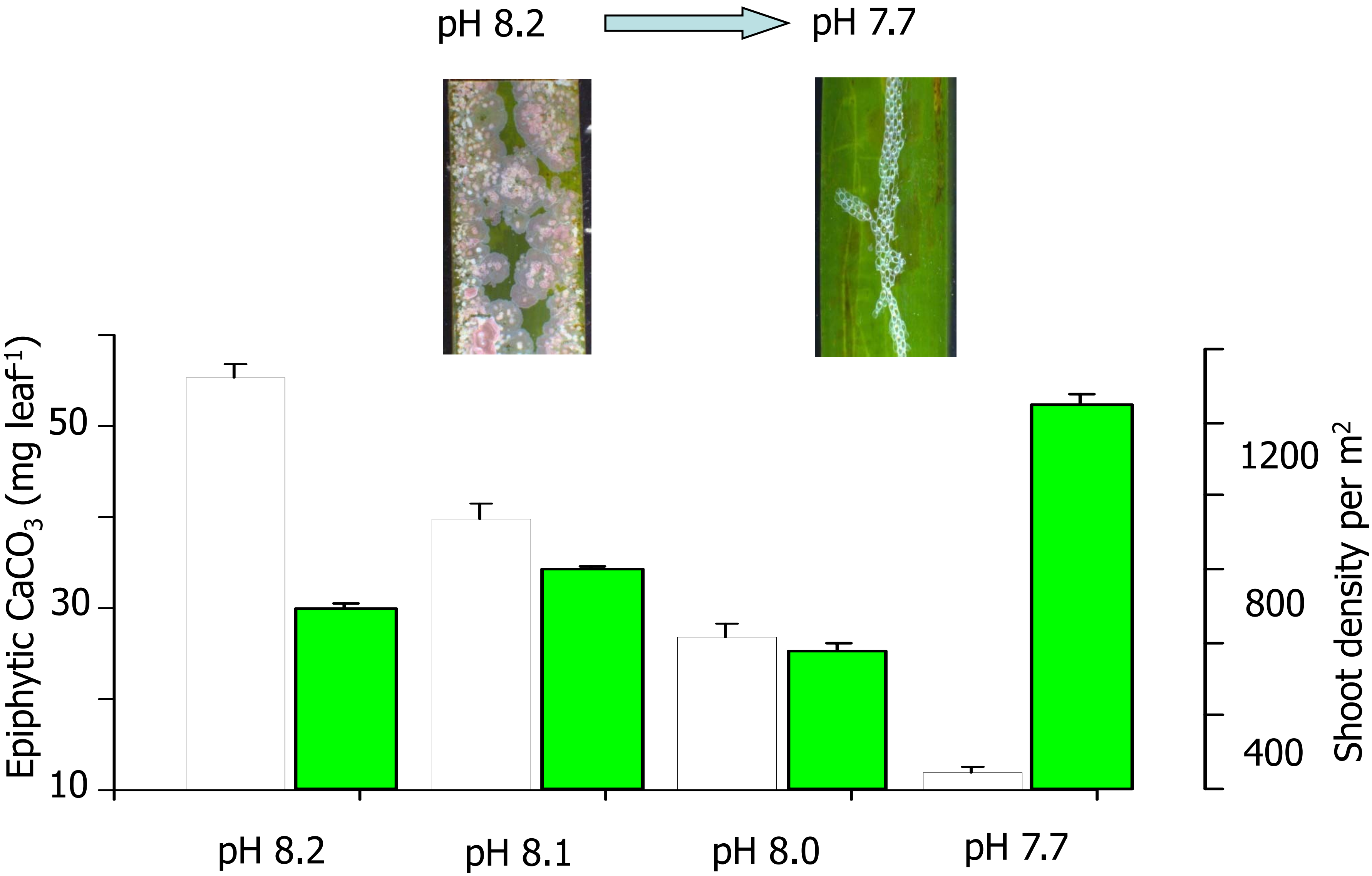

Martin et al. (2008) Biology Letters

Our pilot studies have established that major ecological tipping points occur along gradients of increasing CO_2 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_2 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_2 levels

Summary

Natural CO_2 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_2 on groups of social and economic importance, such as fish and shellfish.
- help communicate what ocean acidification can do to our seas