euromarinenetwork.eu

EUROMARINE
EUROPEAN MARINE RESEARCH NETWORK

EUROMARINE SUMMER SCHOOL

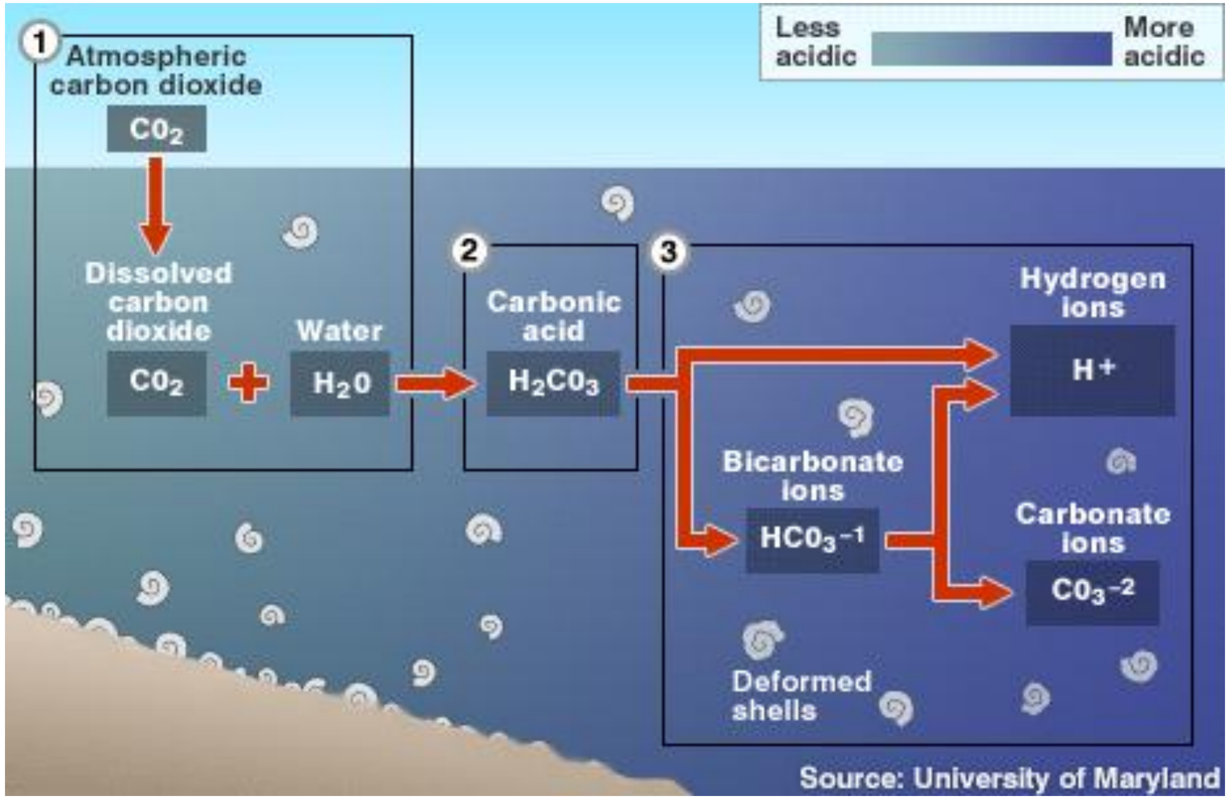
Field research at the CO_2 vents along the coast of Ischia

Núria Teixidó, Ischia Marine Center - SZN & Laboratoire d'Océanographie de Villefranche

Ocean Acidification

Global-scale change in the basic chemistry of the ocean

~ 25% CO_2



Net effect for biology:

↑	HCO_3^-	photosynthesis
↓	pH	acid/based
↓	CO_3^{2-}	calcification

→ *Steeve, Irene*

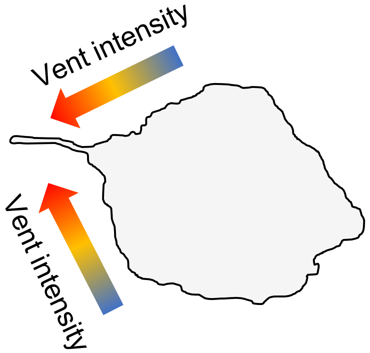
Insights into the future: Volcanic CO_2 Vents

95-98% CO_2
Ambient Temperature

Photo: Pasquale Vassallo

CO_2 vents: natural analogues for future OA conditions

Key insights on the direct and indirect effects

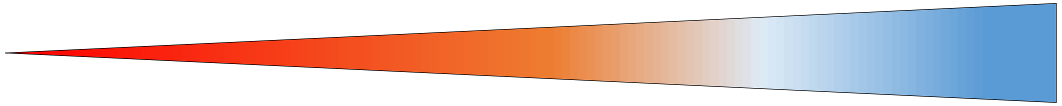


Extreme Low
pH ~ 6.6 – 7.2

Low
pH ~ 7.8 – 7.5

Ambient
pH ~ 8.0

pH

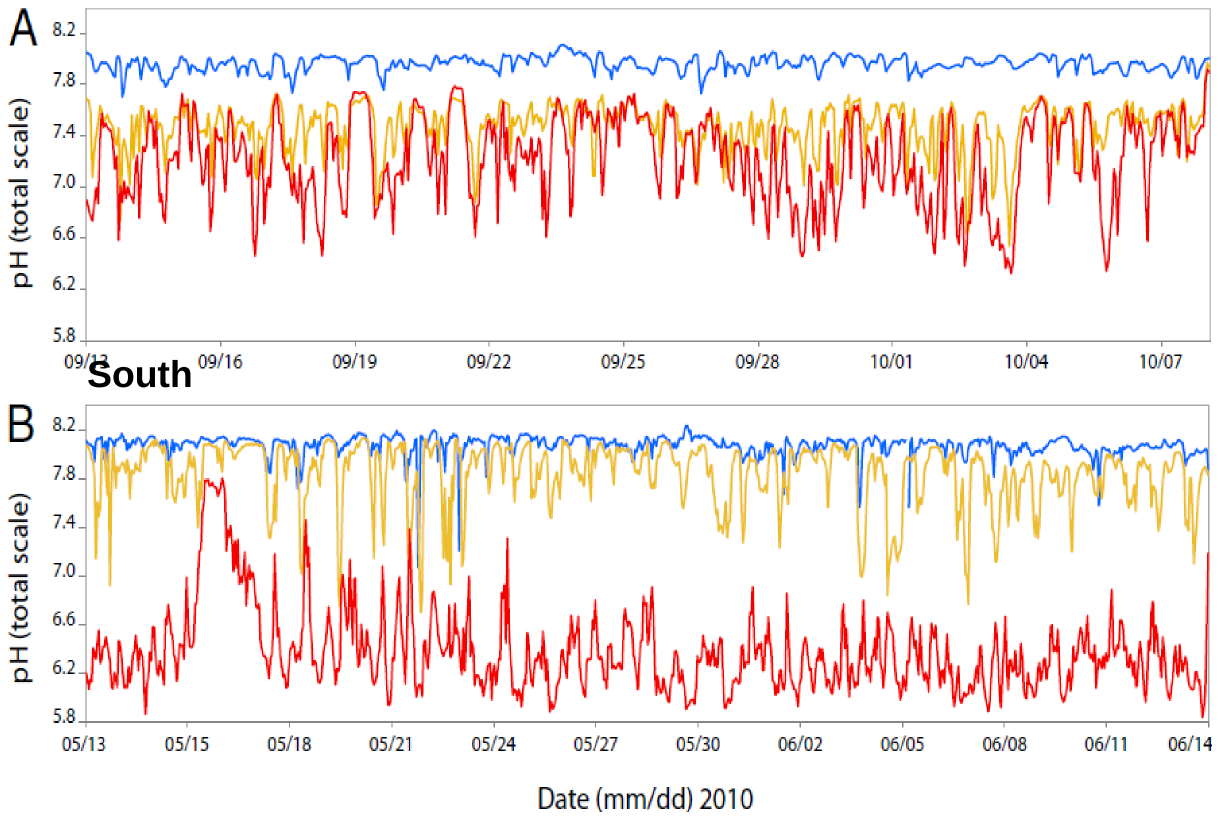


1.5 pH units

Hall-Spencer et al (2008) Nature, Kroeker et al (2011) PNAS, Kroeker et al (2013) Nat Clim Change, Foo et al (2018) Oceangr Mar Biol Annu Rev, Teixidó et al (2018) Nat Comms, Signorini et al (2025) Env Res, Carlot et al (submitted)

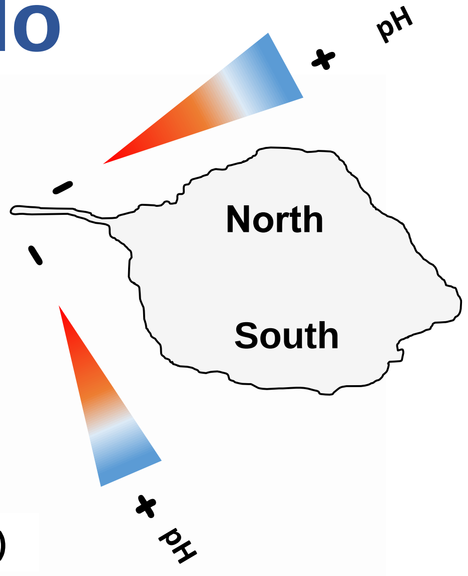
Seawater pH along the Castello

North



- **Ambient (pH_T= 7.95 ± 0.06)**
- **Low (pH_T= 7.77 ± 0.19)**
- **Extreme low (pH_T= 7.21 ± 0.34)**

- **Ambient (pH_T= 8.06 ± 0.09)**
- **Low (pH_T= 7.75 ± 0.31)**
- **Extreme low (pH_T= 6.59 ± 0.51)**

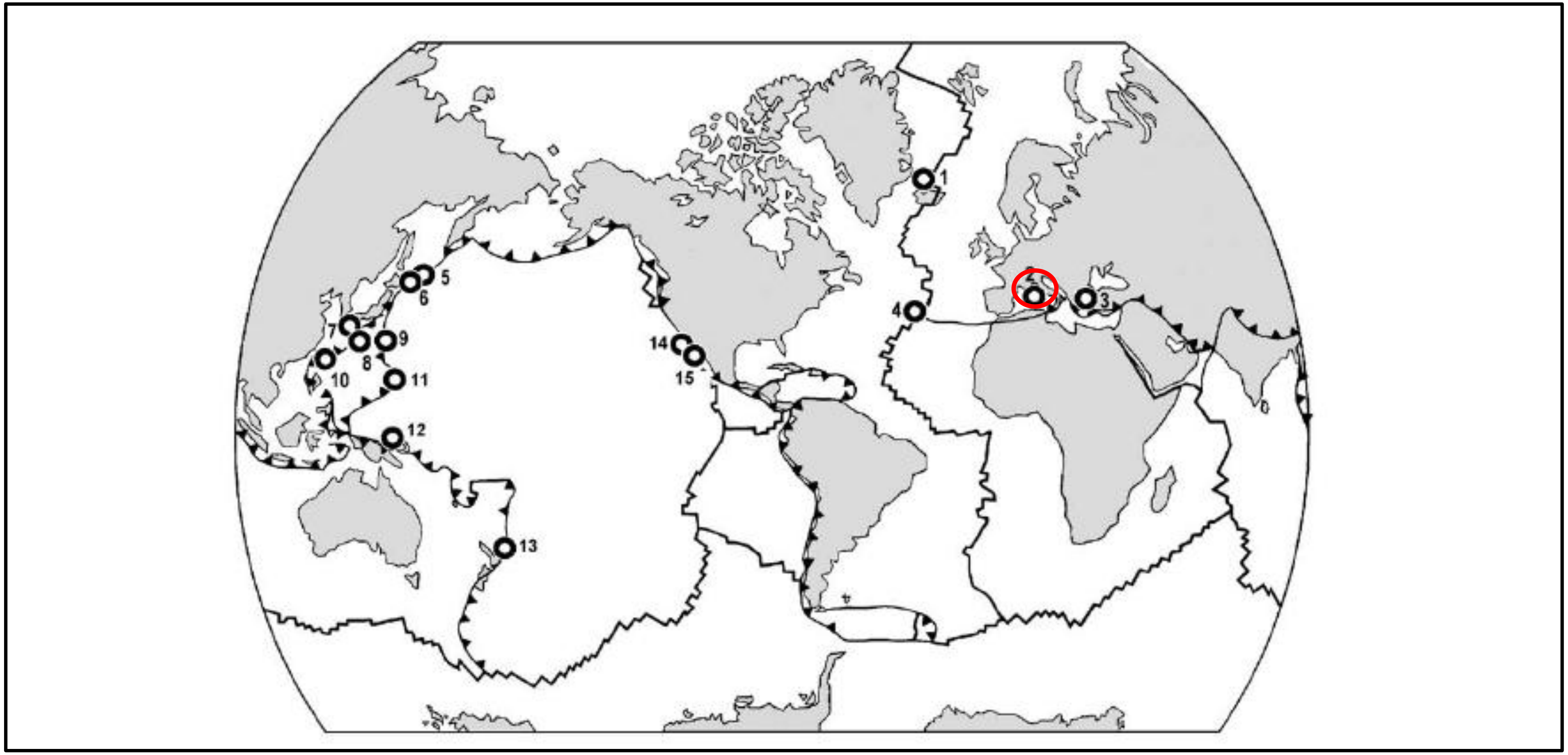


Kroeker et al 2011 (PNAS)


Jordi Boada (CEAB-CSIC)
Ambient pH
$pH_T \sim 8.0$
Low pH
$pH_T \sim 7.8$
North
Extreme Low pH
$pH_T \sim 7.2$
South
Castello Aragonese
Extreme Low pH
$pH_T \sim 6.6$
Low pH
$pH_T \sim 7.8$
Ambient pH
$pH_T \sim 8.0$
- Diversity, biomass, trophic complexity
- Calcifying organisms
- Production & resistance biomineralized structures


Jordi Boada
(CEAB-CSIC)
North
South
Castello Aragonese
Jordi
Gaia, Massimiliano

Coastal CO_2 vents occur worldwide



Tarasov et al (2005)

In situ effects of CO_2 vents on corals reefs

Decline in calcifying foundation species,
loss of diversity, and structural complexity

Ambient pH site
pH ~ 8.1

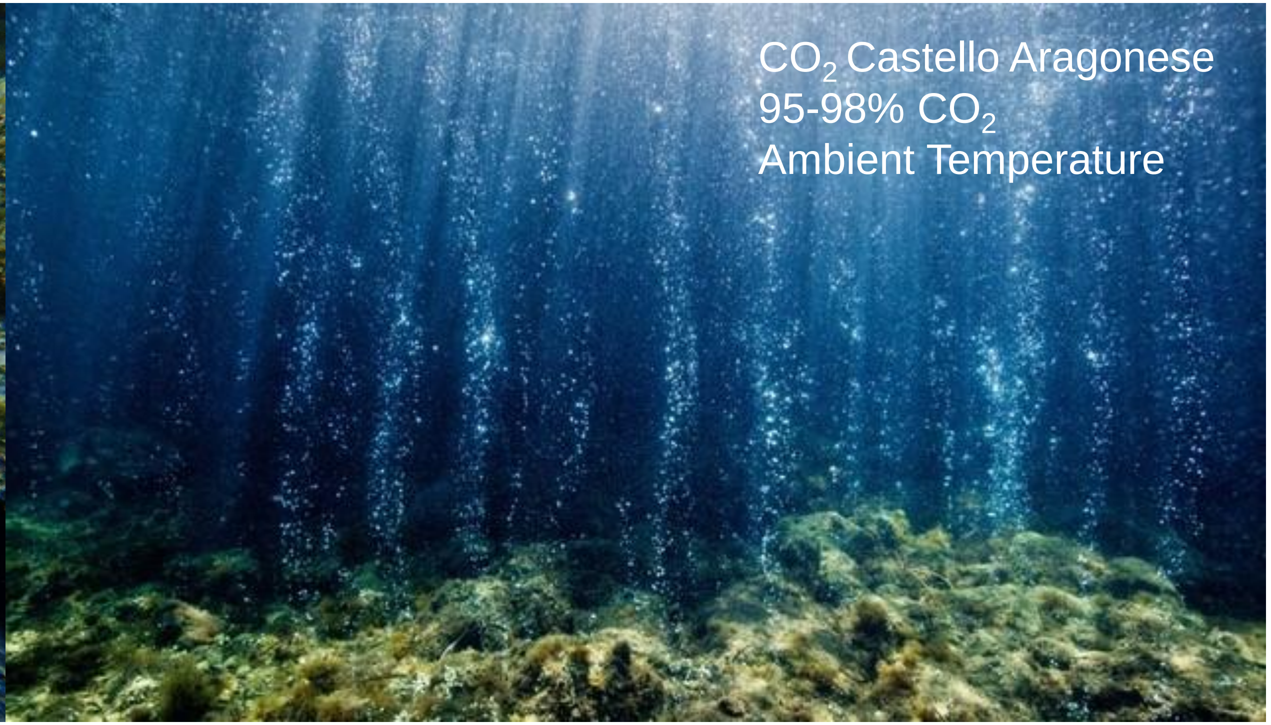
Low pH site
pH ~ 7.8

Fabricius et al (2011)

In situ effects of CO_2 vents on temperate marine communities

Decline in calcifying foundation species, loss of diversity, and structural complexity

Ambient pH site
pH ~ 8.0
pCO_2 ~ 440- 567 µatm



Low pH site
pH ~ 7.8
pCO_2 ~ 1075- 1581 µatm

Biology/Ecology

1. Abundances (flora, fauna), morphology, age, biomass, diversity

2. Manipulative experiments on recruitment, reproduction,

photosynthesis, respiration, and growth

3. Genetics/genomics/holobionts: local adaptation, gene expression,

..

Others?

Valerio, Sam, all

Research conducted over more than a decade

nature Vol 454|3 July 2008|doi:10.1038/nature07051

LETTERS

2008

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]

Journal of Experimental Marine Biology and Ecology 400 (2011) 278–287

Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

Effects of ocean acidification on macroalgal communities

Lucia Porzio [a], Maria Cristina Buia [a,*], Jason M. Hall-Spencer [b]

[a] Stazione Zoologica Anton Dohrn of Naples, Functional and Evolutionary Ecology Laboratory, Villa Dohrn, Punta San Pietro, 80077 Ischia (Naples), Italy
[b] Marine Institute, Marine Biology and Ecology Research Centre, University of Plymouth, Plymouth PL4 8AA, UK

nature climate change LETTERS

PUBLISHED ONLINE: 21 AUGUST 2011 | DOI: 10.1038/NCLIMATE1200

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 nature climate change

PUBLISHED ONLINE: 9 SEPTEMBER 2012 | DOI: 10.1038/NCLIMATE1680

Ocean acidification causes ecosystem shifts via altered competitive interactions

Kristy J. Kroeker[1★], Fiorenza Micheli[1] and Maria Cristina Gambi[2]

Biol. Mar. Mediterr. (2012), 19 (1): 49-52

E. Ricevuto, M. Lorenti, F.P. Patti, M.B. Scipione, M.C. Gambi

Stazione Zoologica Anton Dohrn, Napoli, Italy.
elena.ricevuto@szn.it

TEMPORAL TRENDS OF BENTHIC INVERTEBRATE SETTLEMENT ALONG A GRADIENT OF OCEAN ACIDIFICATION AT NATURAL CO_2 VENTS (TYRRHENIAN SEA)

PROCEEDINGS B

rspb.royalsocietypublishing.org

Coralline algae in a naturally acidified ecosystem persist by maintaining control of skeletal mineralogy and size

N. A. Kamenos[1], G. Perna[1], M. C. Gambi[2], F. Micheli[3] and K. J. Kroeker[4]

Oceanography and Marine Biology: An Annual Review, 2018, 56, 237-310
© S. J. Hawkins, A. J. Evans, A. C. Dale, L. B. Firth, and I. P. Smith, Editors
Taylor & Francis

THE CARBON DIOXIDE VENTS OF ISCHIA, ITALY, A NATURAL SYSTEM TO ASSESS IMPACTS OF OCEAN ACIDIFICATION ON MARINE ECOSYSTEMS: AN OVERVIEW OF RESEARCH AND COMPARISONS WITH OTHER VENT SYSTEMS

SHAWNA ANDREA FOO[1*], MARIA BYRNE[2], ELENA RICEVUTO[3] & MARIA CRISTINA GAMBI[3]

Journal of Experimental Marine Biology and Ecology
Volumes 530–531, September–October 2020, 151435

Ocean acidification alters the responses of invertebrates to wound-activated infochemicals produced by epiphytes of the seagrass *Posidonia oceanica*

Mirko Mutalipassi, Patrick Fink, Chingoileima Maibam, Lucia Porzio, Maria Cristina Buia, Maria Cristina Gambi, Francesco Paolo Patti, Maria Beatrice Scipione, Maurizio Lorenti, Valerio Zupo

ARTICLE

OPEN

Functional biodiversity loss along natural CO_2 gradients

Nuria Teixidó[1,2,8], Maria Cristina Gambi[1], Valeriano Parravacini[3], Kristy Kroeker[4], Fiorenza Micheli[2,5], Sebastien Villéger[6] & Enric Ballesteros[7]

nature COMMUNICATIONS

Received: 26 June 2020 | Revised: 16 May 2022 | Accepted: 20 May 2022
DOI: 10.1111/mec.16553

ORIGINAL ARTICLE

MOLECULAR ECOLOGY WILEY

Molecular response of *Sargassum vulgare* to acidification at volcanic CO_2 vents: Insights from proteomic and metabolite analyses

Amit Kumar[1] | Simona Nonnis[2,3] | Immacolata Castellano[4,5] | Hamada AbdElgawad[6,7] | Gerrit T. S. Beemster[7] | Maria Cristina Buia[1] | Elisa Maffioli[2] | Gabriella Tedeschi[2,3] | Anna Palumbo[5]

Received: 13 December 2021 | Revised: 15 March 2022 | Accepted: 22 March 2022
DOI: 10.1111/gcb.16265

RESEARCH ARTICLE

Global Change Biology WILEY

Resilient consumers accelerate the plant decomposition in a naturally acidified seagrass ecosystem

Juhyung Lee[1,2] | Maria Cristina Gambi[3] | Kristy J. Kroeker[4] | Marco Munari[5] | Kabir Peay[2] | Fiorenza Micheli[1,2,6]

Science of the Total Environment 771 (2021) 145438

Contents lists available at ScienceDirect

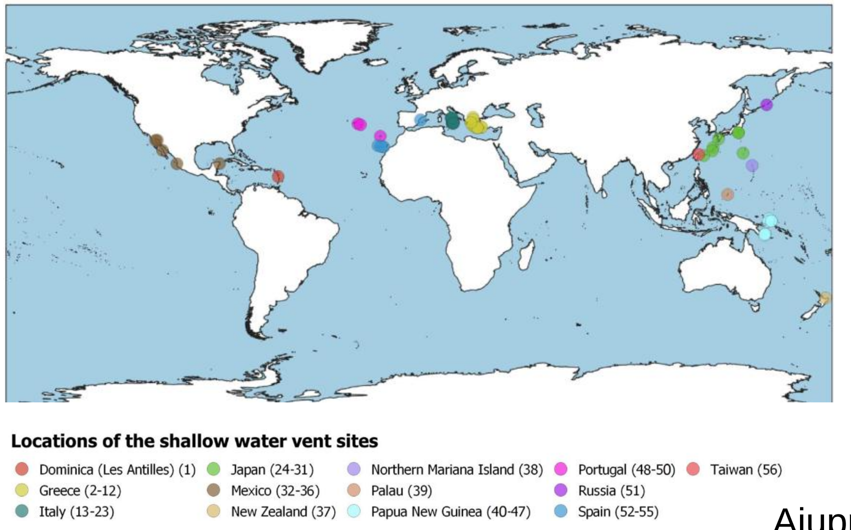
Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

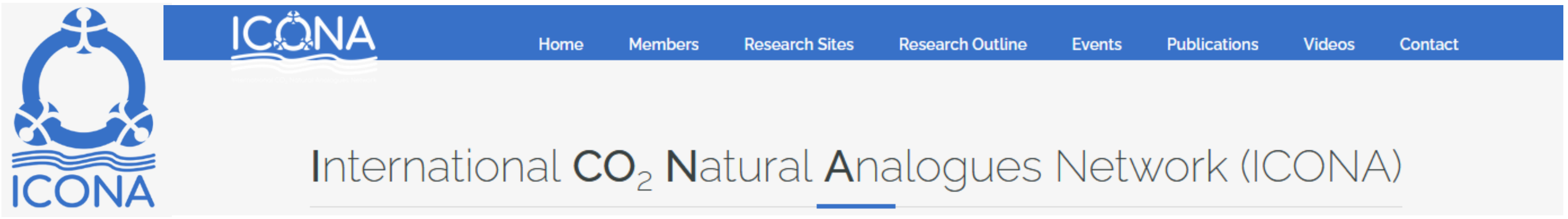
Boosted fish abundance associated with *Posidonia oceanica* meadows in temperate shallow CO_2 vents

Alice Mirasole [a,*], Fabio Badalamenti [b,c], Antonio Di Franco [c], Maria Cristina Gambi [a], Nuria Teixidó [a,d]

Research on coastal CO_2 vents following the Ischia study

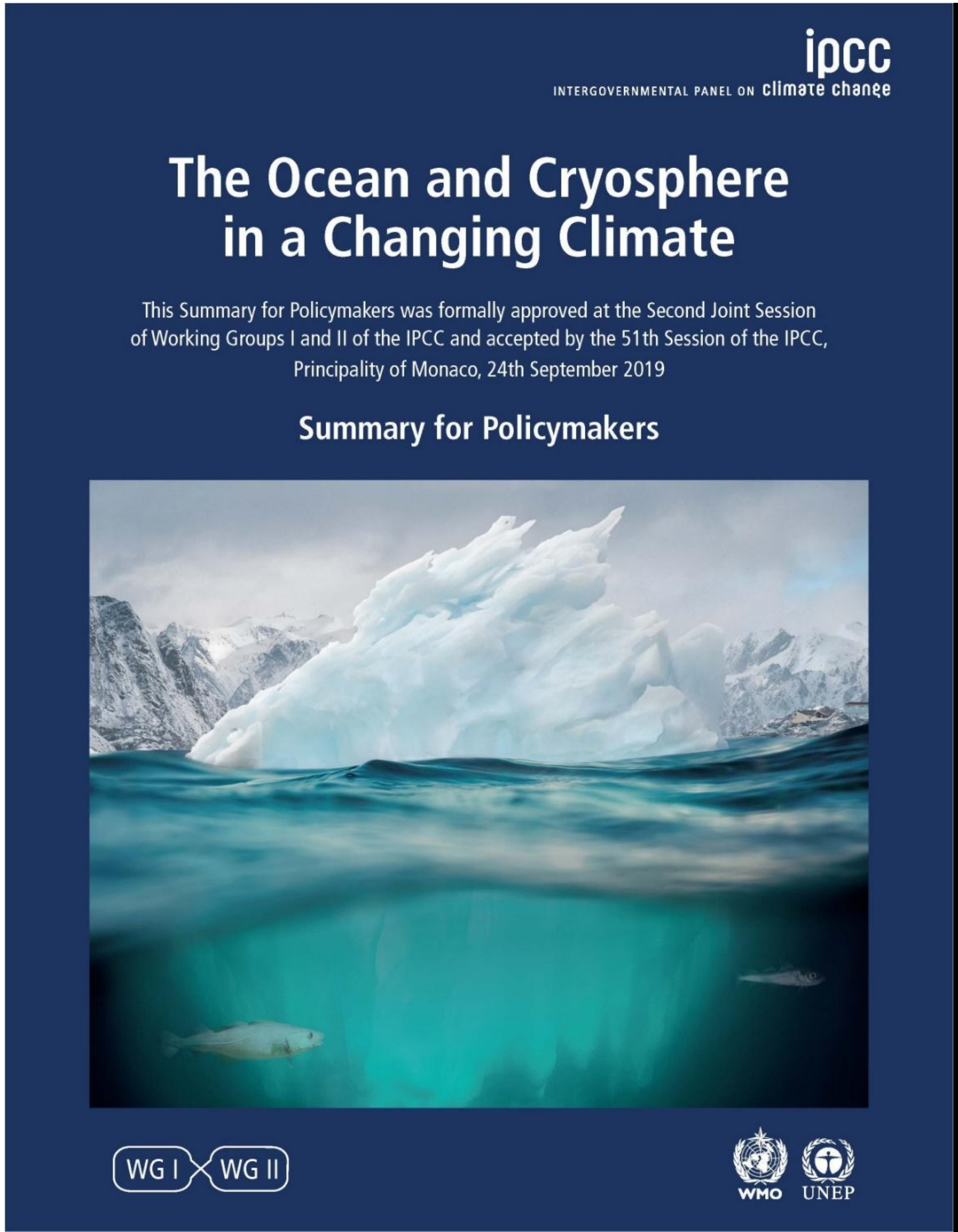


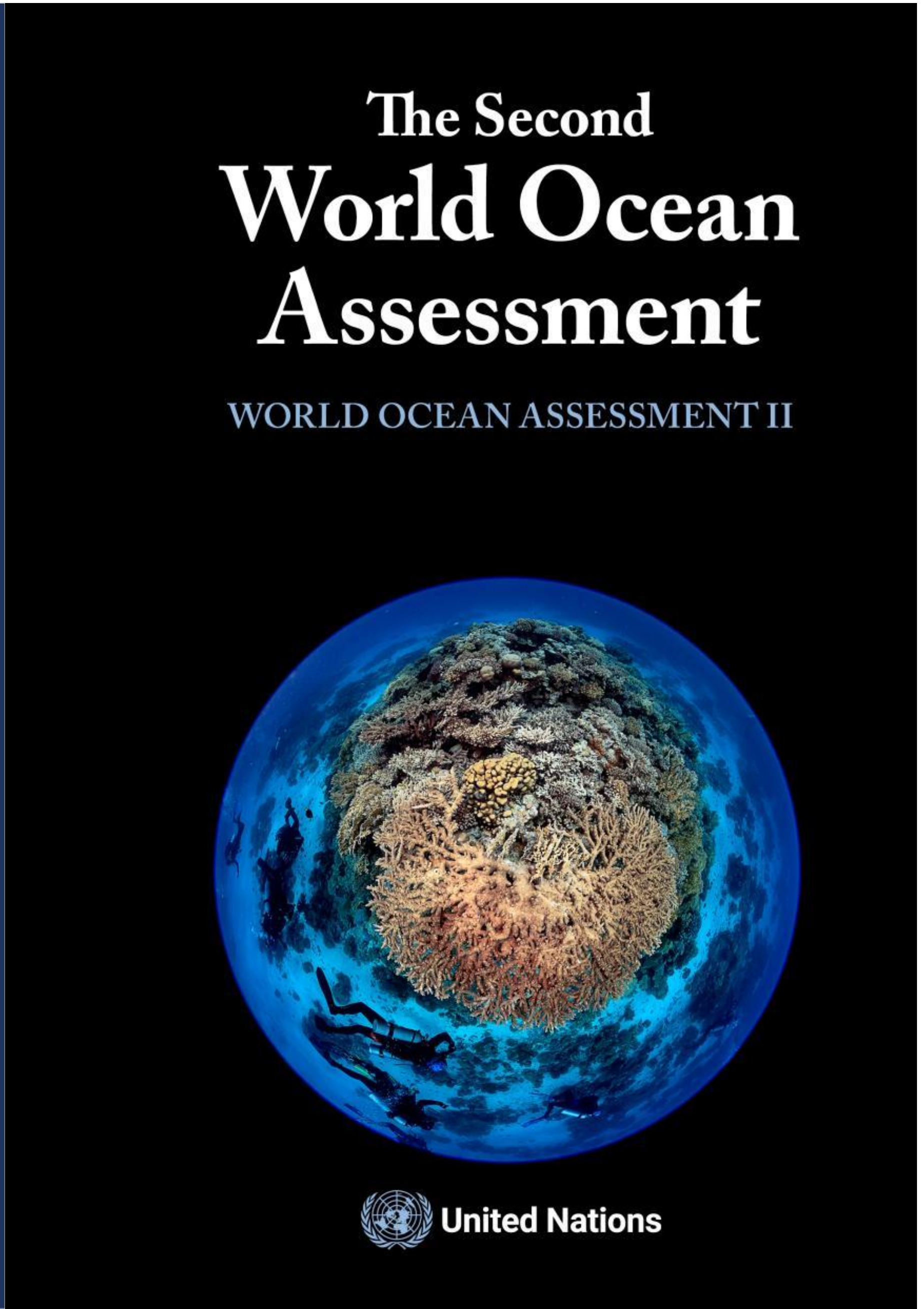
Aiuppa et al (2020) Biogeochemistry
González-Delgado (2018)



14 institutions, 5 countries

CO_2 vent research has been cited





Sam

Natural CO_2 vents

- Need to avoid confounding gradients (temperature, salinity, total alkalinity, and toxic chemicals such as H_2S, CH_4)

Panarea

Natural CO2 vents: Pros and cons

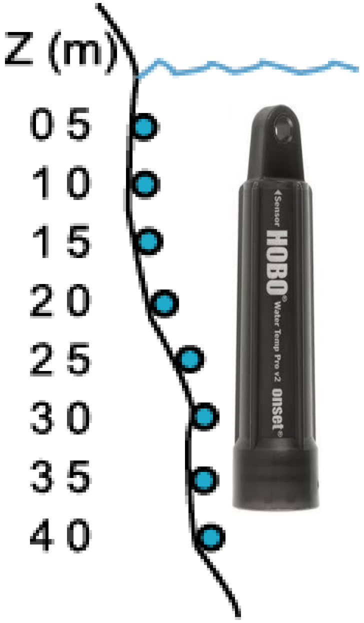
Pros	Cons

Sam

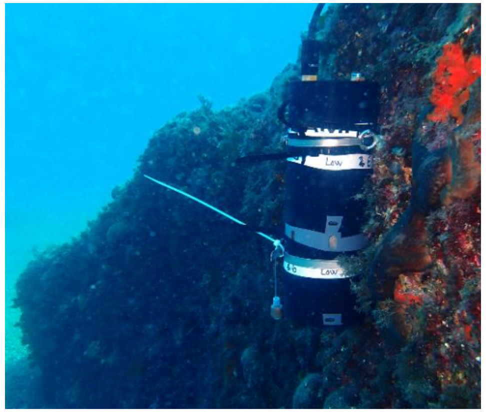
Environmental variability

Deployment of instrumentation

Temperature sensors



pH sensors



+

Discrete water samples

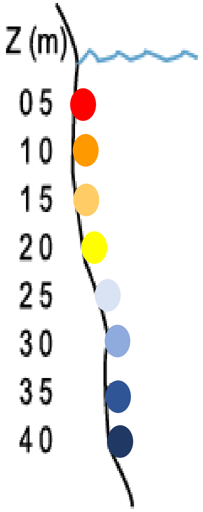
Carbonate chemistry

Light sensors (PAR)

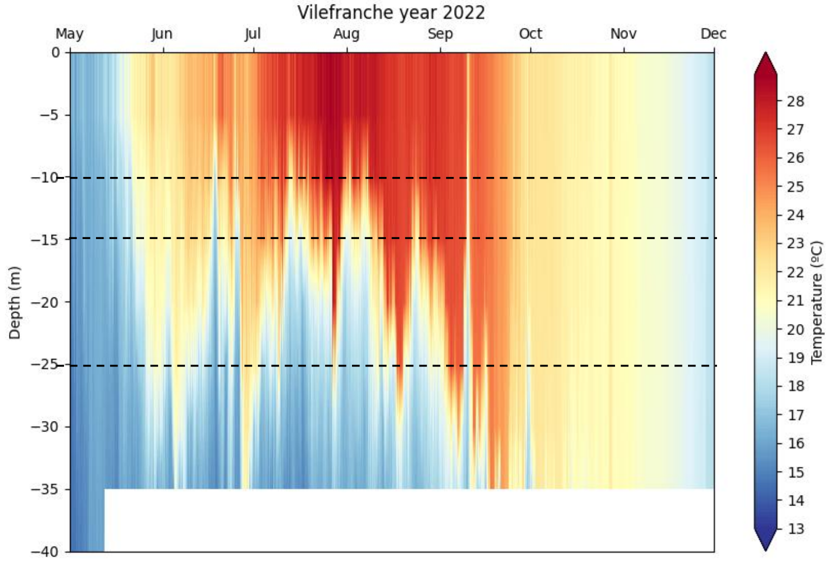
Salinity sensors

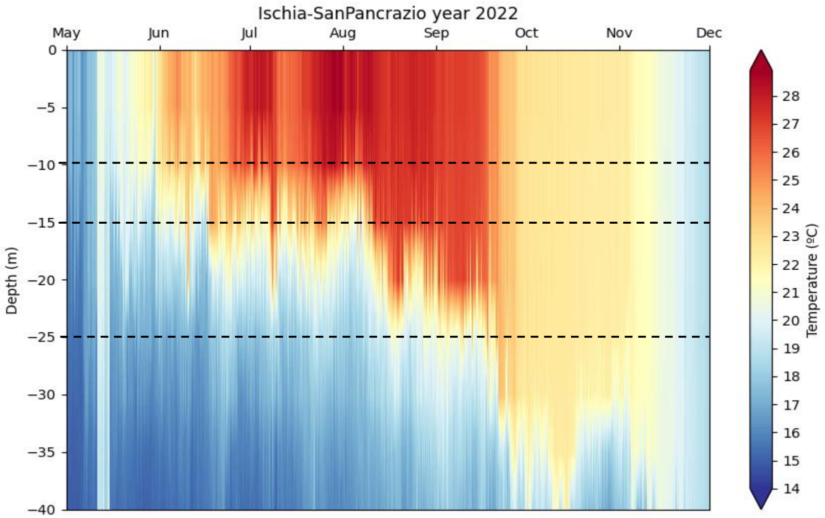
Temperature profiles to characterize Marine Heatwaves (MHWs)

Temperature sensors



Depth: 5 - 40 m, at every 5 m
Frequency: hourly





Scale: 2 sites, 1 year

Villefranche

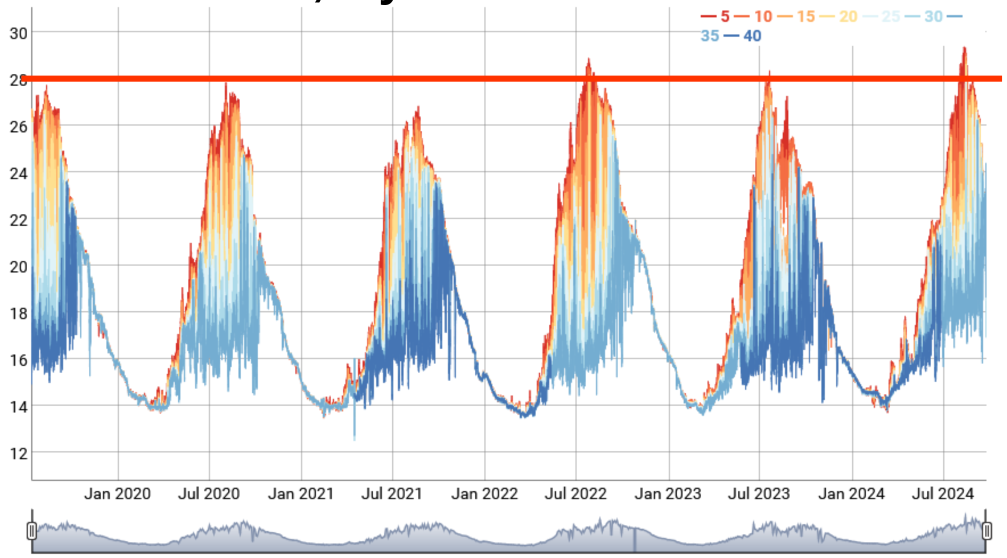
26/07/2022
28.9 °C at 5 m
17.1 °C at 25 m

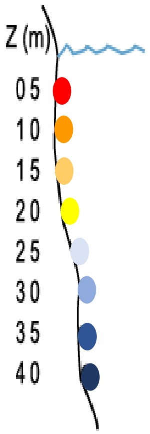
Ischia

26/07/2022
28.4 °C at 5 m
18.6 °C at 25 m

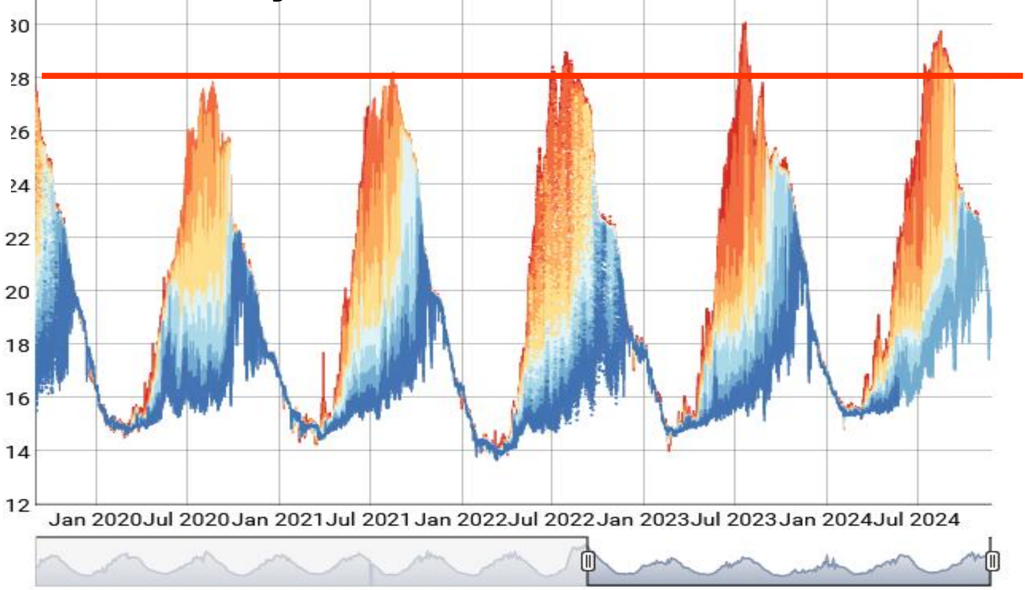
Temperature series in Villefranche and Ischia

Villefranche, 5 years





Ischia, 10 years

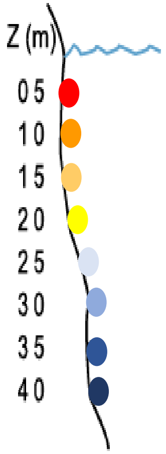


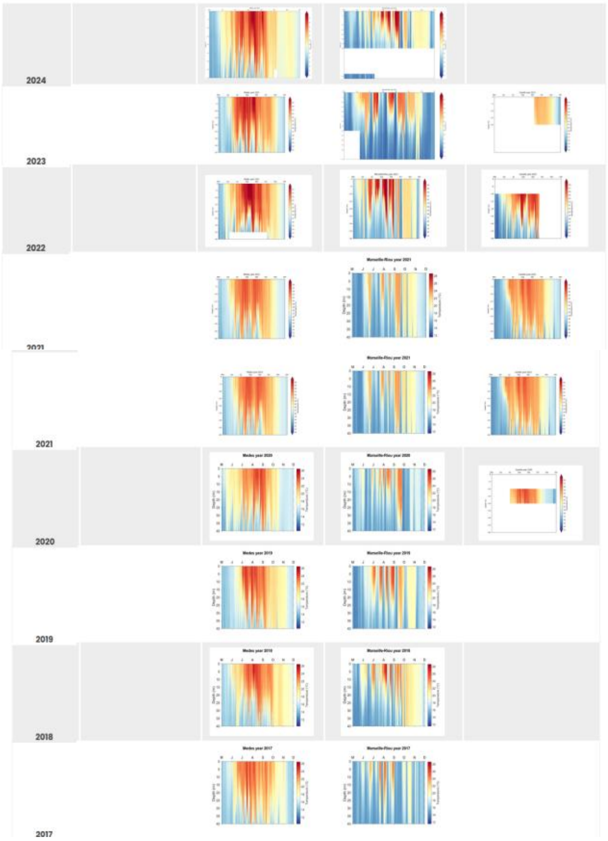
Scale: 2 sites, 5 year and 10 year data

Year	Temp (°C) Vlfr, 1-2 m	Temp (°C) Vlfr, 5m	Temp (°C) Ischia, 5m
2014	26.2		27.1
2015	28.4		28.9
2016	26.6		28.1
2017	27.7		29.0
2018	29.0		29.1
2019	28.7	27.75	28.1
2020	28.2	27.88	28.6
2021	26.9	26.87	28.3
2022	29.2	28.92	28.9
2023	28.8	28.37	30.1
2024	29.8	29.39	29.8
2025	27-28		

TMEDNet: Network of temperature and climate change effects in the Mediterranean

Pan-Mediterranean scale, decades





https://t-mednet.org/

pH sensor calibration

Data, metadata, R scripts ordered and saved

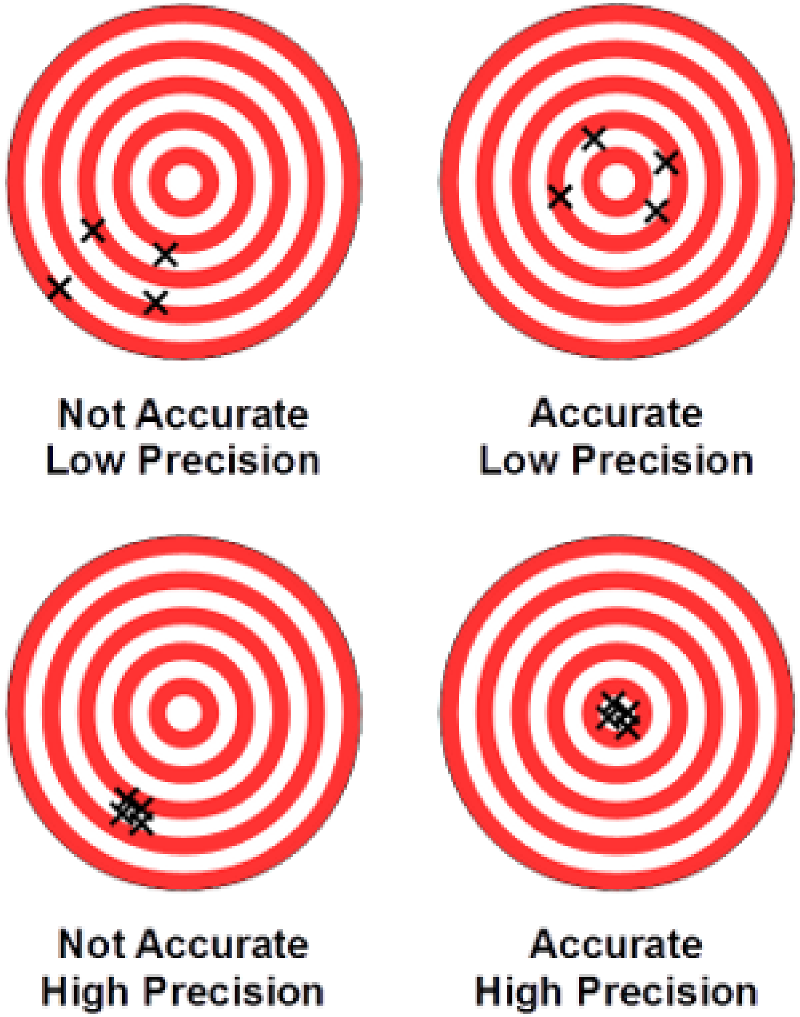
pCloud RStudio rmarkdown knitr

jpgattuso/seacarb-git

Seawater carbonate chemistry with R

Jérémy, Steeve

Measuring pH: high resolution pH sensors



Steeve

pH sensors

Accuracy, Precision

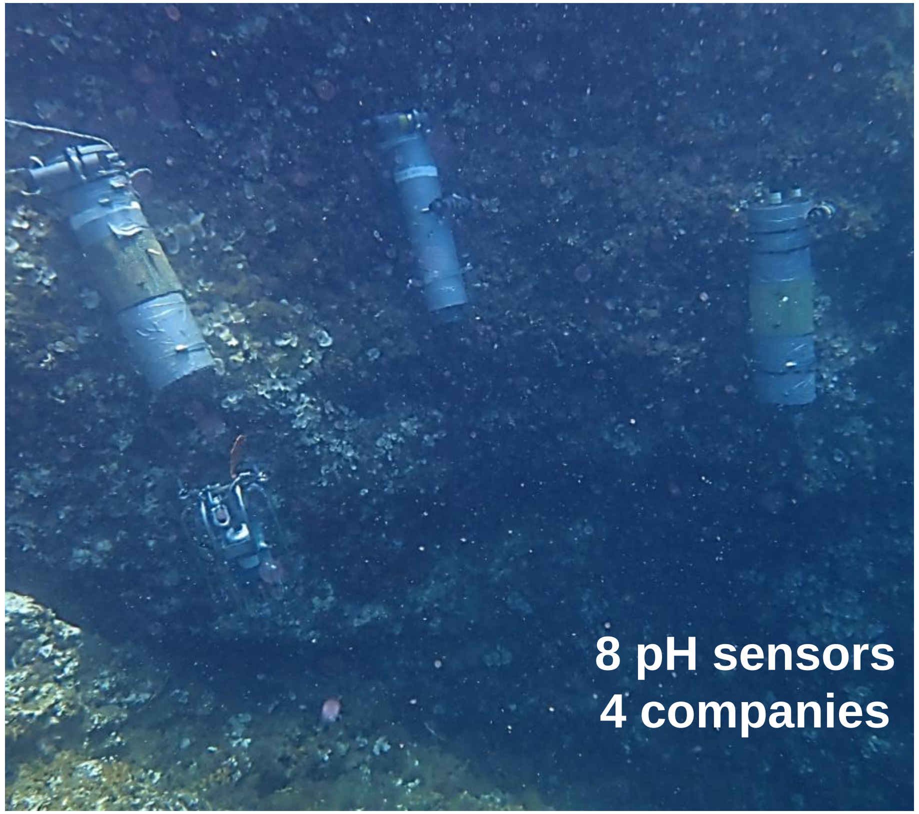
What is missing?

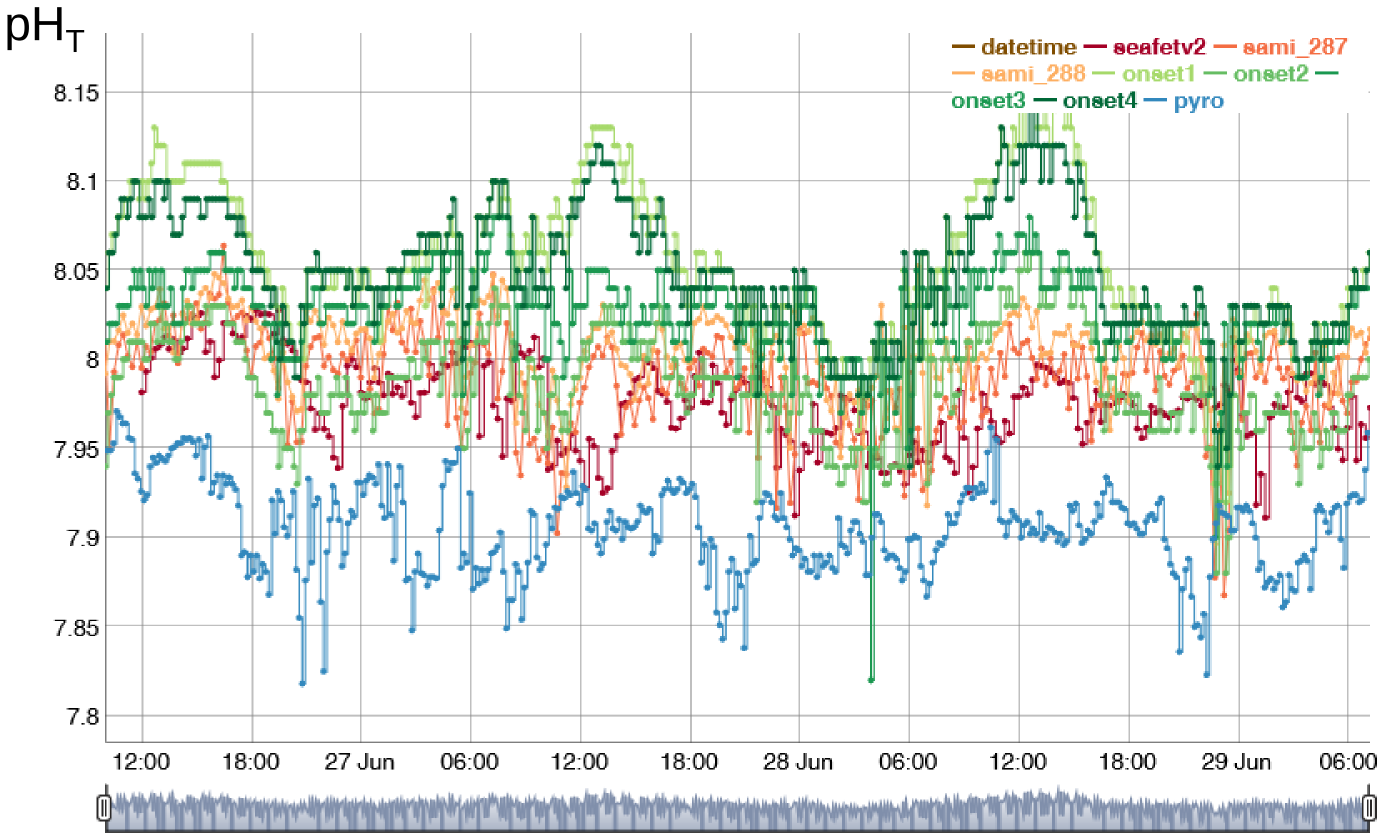
1* SeaFET v2 (Sea-Bird)

2* Sami pH (Sunburst)

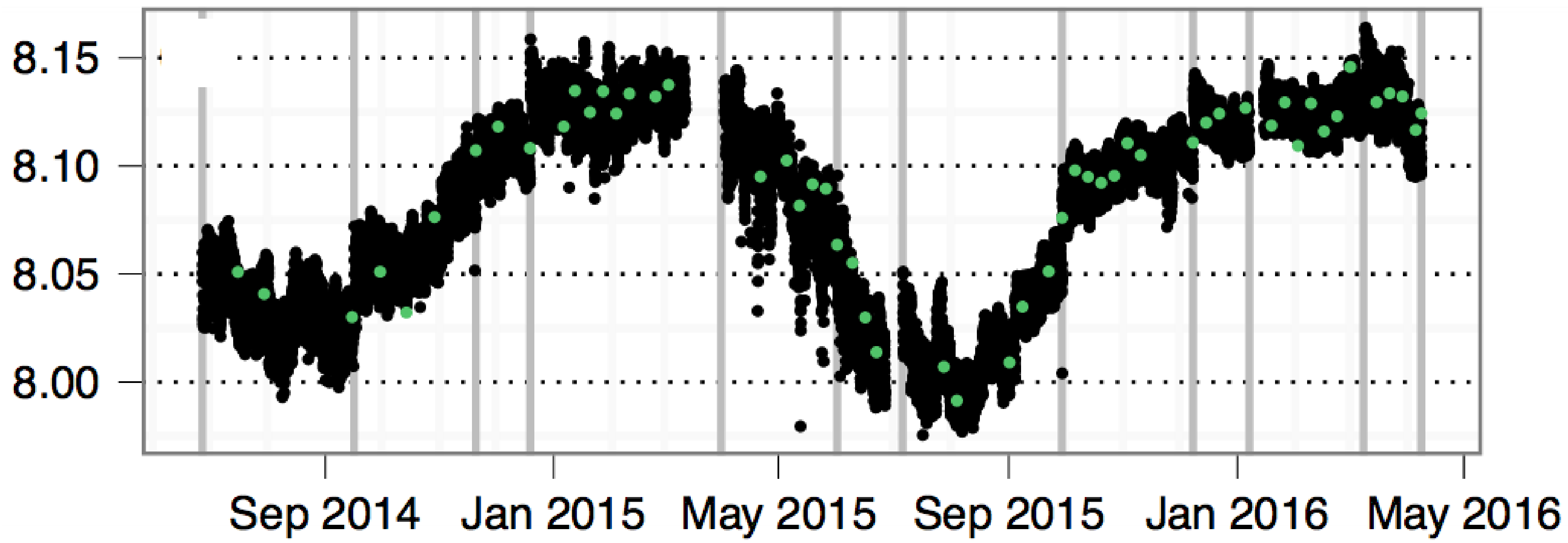
1* AquapHOx (Pyroscience)

4* Hobo pH (Onset)



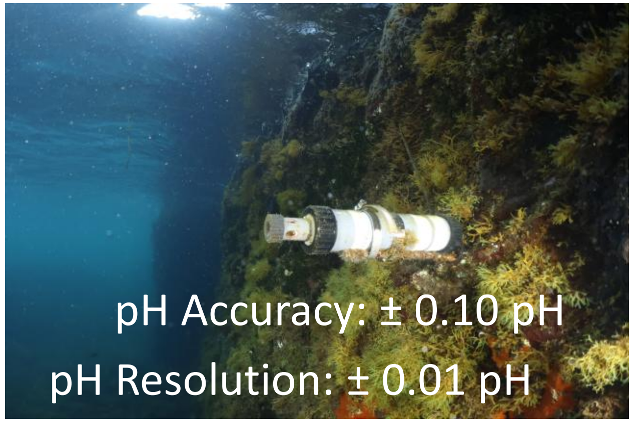


pH measurements- Spectrophotometric



Environmental variability: Carbonate chemistry

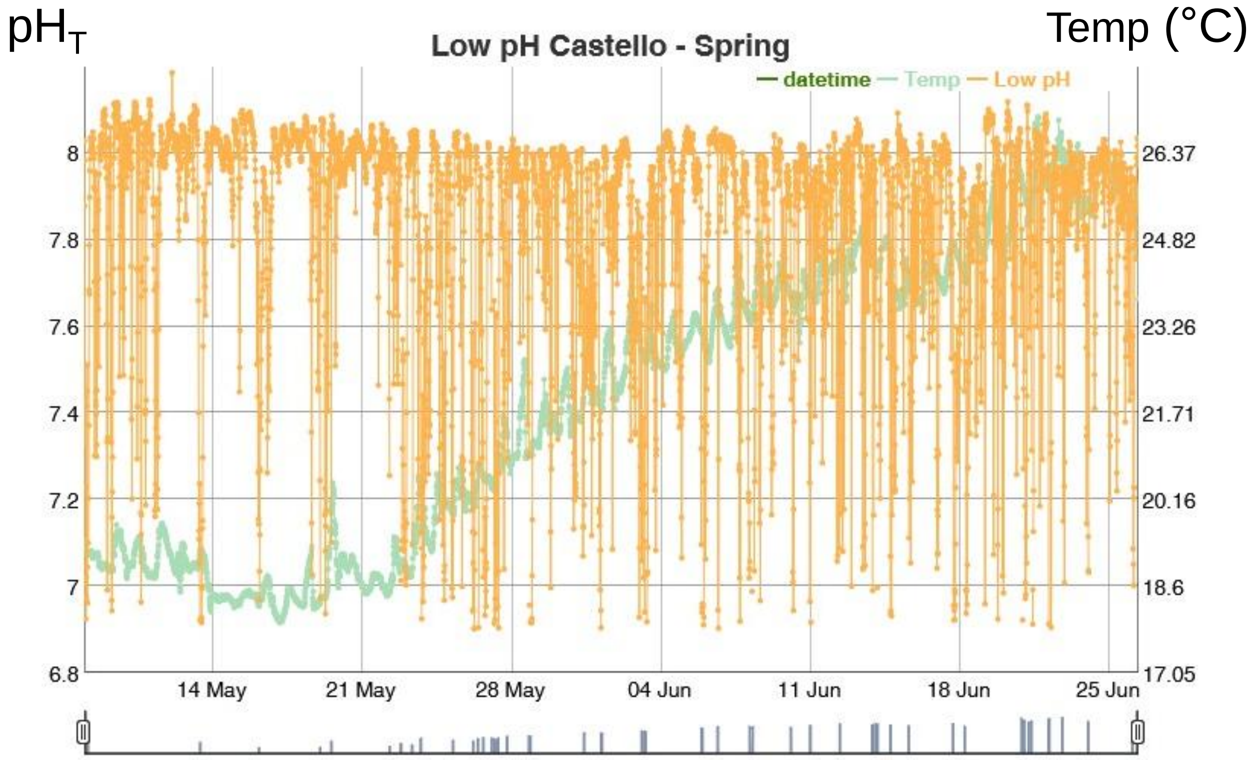
pH sensors

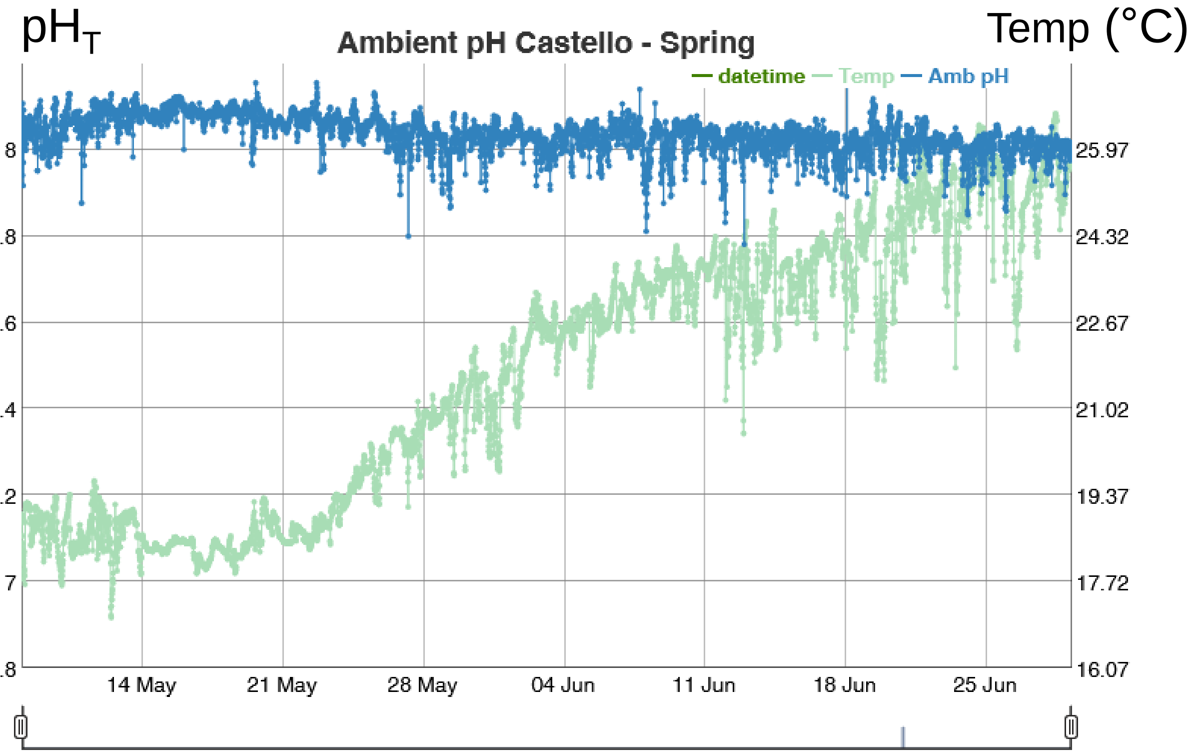


Steeve

Time series pH_T and variability

Low pH and high variability at the CO_2 vents





Mean pH_T =7.71 (25th =7.75, 75th= 8.01), n= 4738

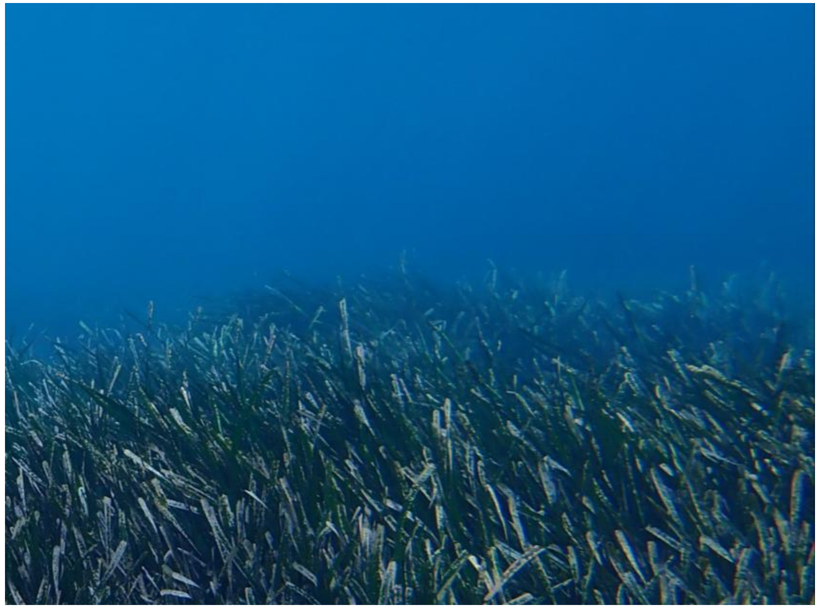
Mean pH_T =8.033 (25th =8.06, 75th =8.01), n= 5013

Measurements every 15 minutes

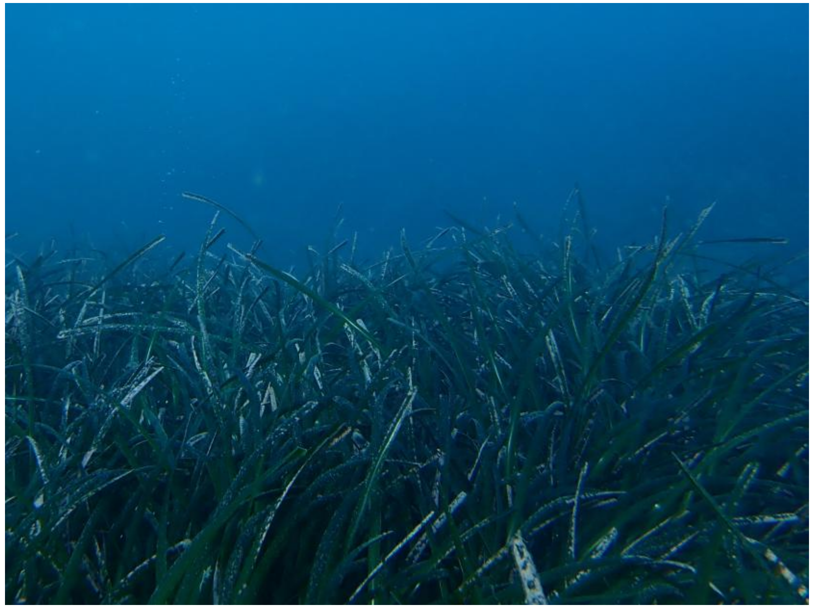
PANGAEA https://doi.org/10.1594/PANGAEA.964032

Effects of Ocean Acidification
Example on Posidonia epiphytes

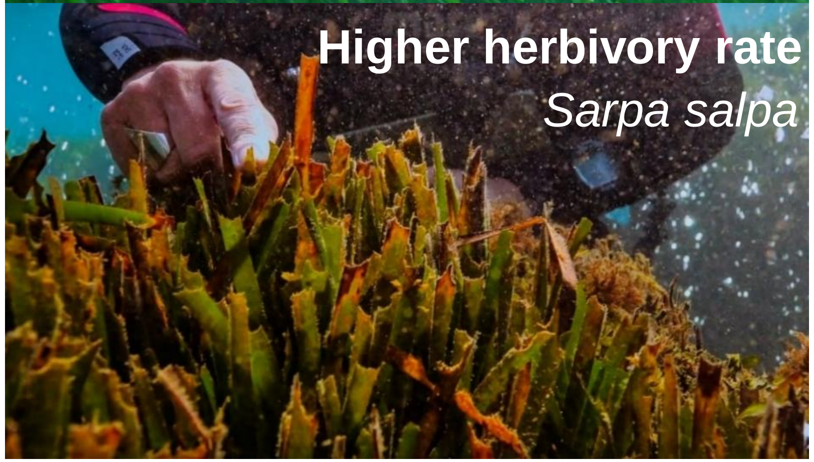
Ambient pH_T ~ 8.0
pCO_2 ~ 440-567 µatm



Low pH_T ~ 7.8 – 7.5
pCO_2 ~ 1075-1582 µatm



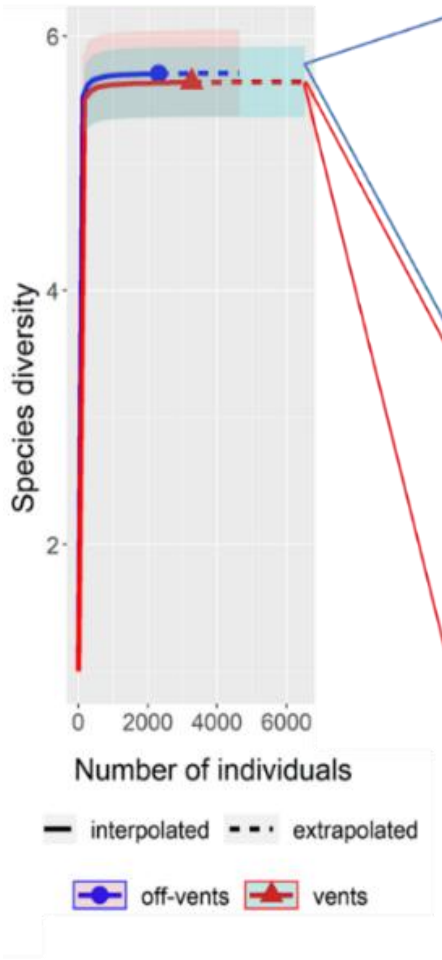
Extreme low pH_T ~ 6.6 – 7.2
pCO_2 > 6558 µatm

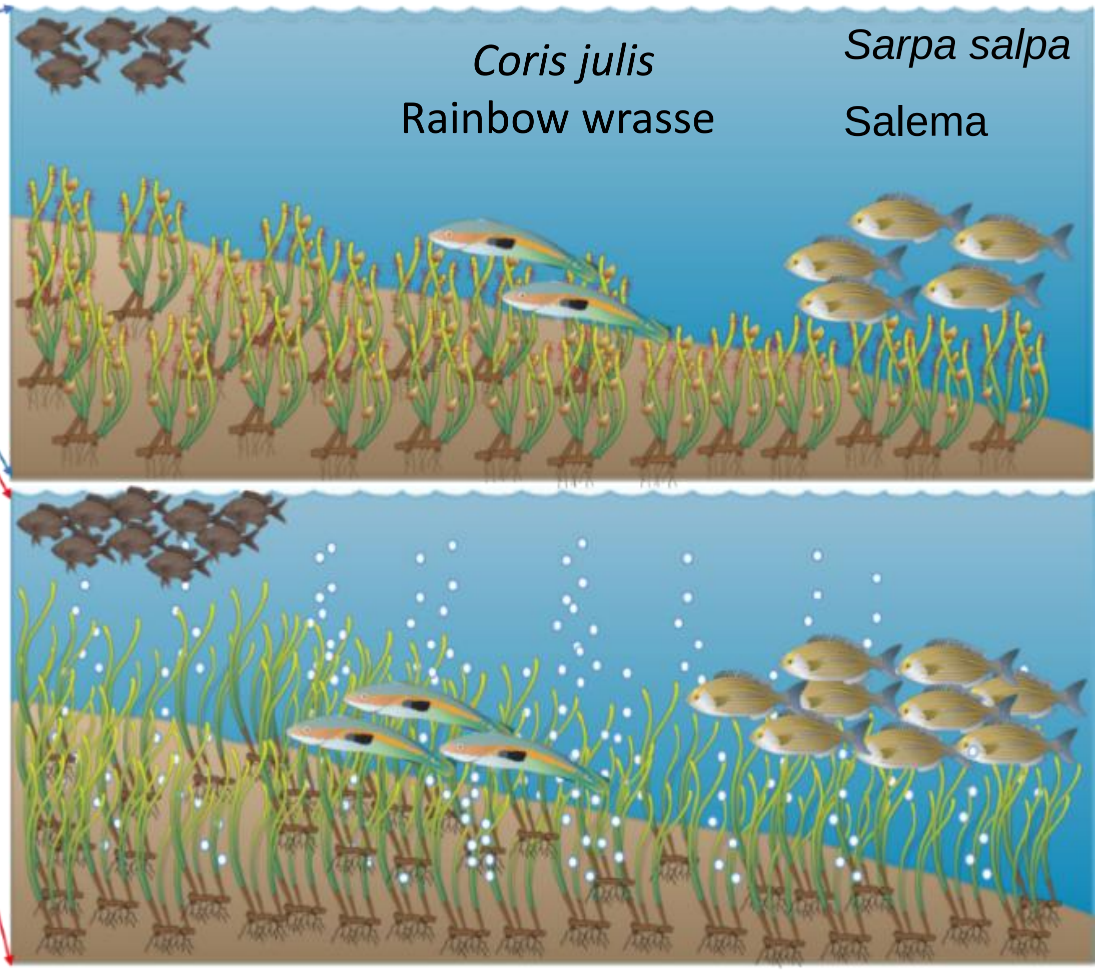


Irene, Alice

Martin et al. (2008) Biol Letters, Mecca et al. (2020) Mediterr Mar Scie, Mirasole et al. (2021) Sci Total Environ

How does exposure to high *p*CO2 alter fish abundance in *Posidonia oceanica* meadows?



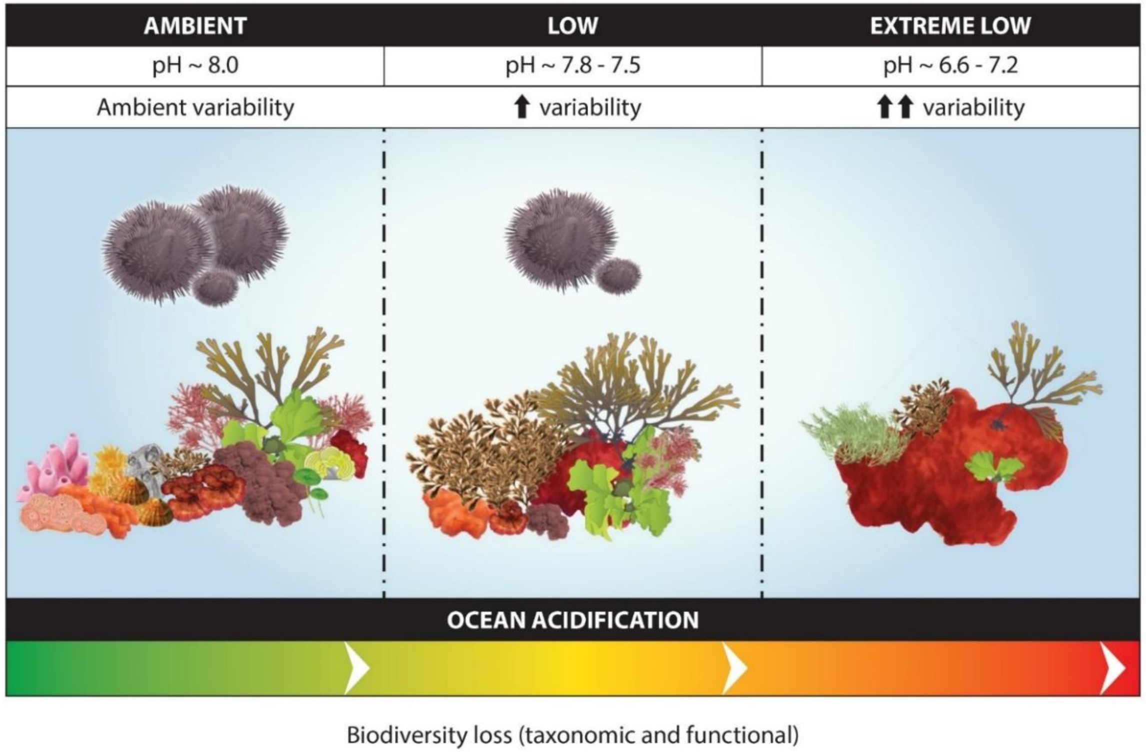


Greater palatability/nutritional value (high N on leaves)

Alice
Antonia
Valerio

Mirasole et al (2021) STOTEN

Effects of Ocean Acidification on rocky reefs



Preserved traits:

- Encrusting and filamentous forms
- Seasonal & high-growing life histories
- Photosynthetic autotrophy
- Lack of calcified structures

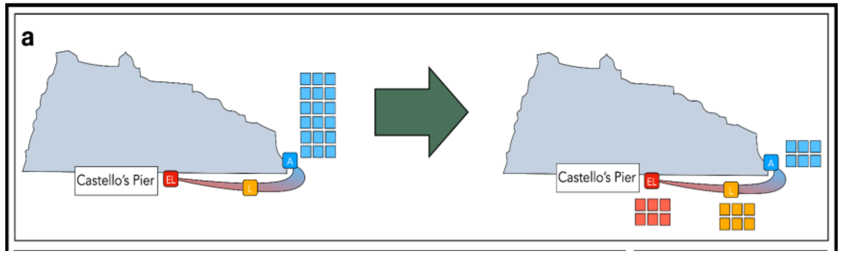
Vulnerable traits:

- Tree-like and massive forms
- Long-lived & slow-growing life histories
- Heterotrophic feeding strategies
- Calcification

Teixido et al (2018) Nature Comms

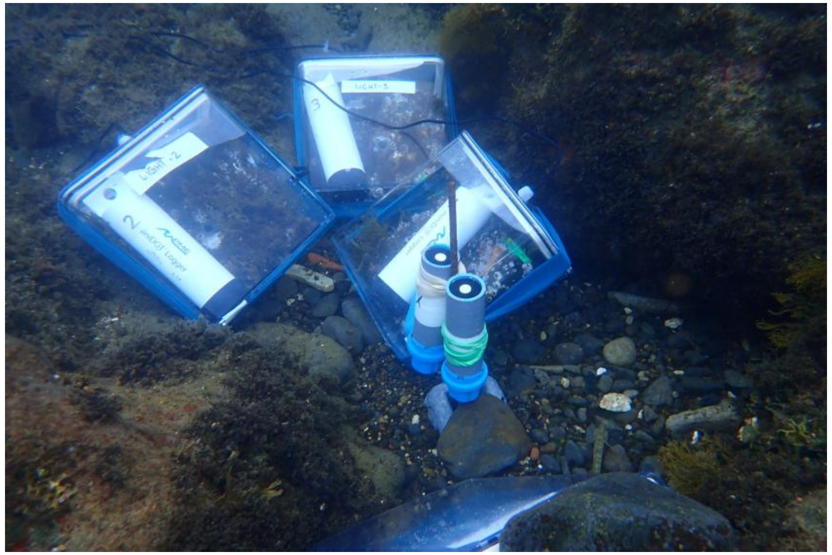
How do ecosystem processes change under OA over time?

Experiment transplants using tiles



Community: Species, cover, and biomass

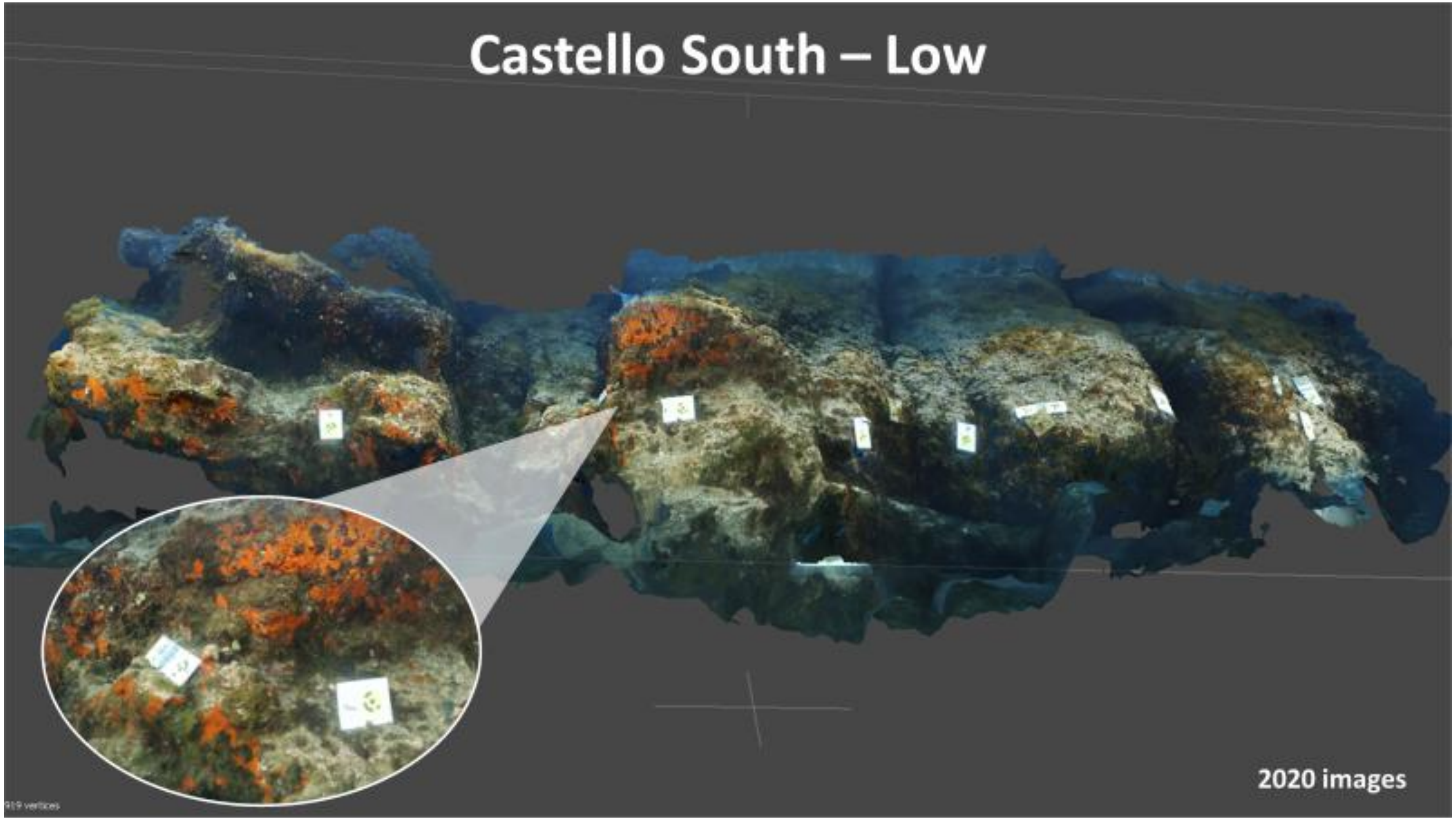
Processes:
Calcification,
Net Photosynthesis, Gross photosynthesis, Respiration
Nutrients uptake



Carlot et al. (submitted) Ecology Letters

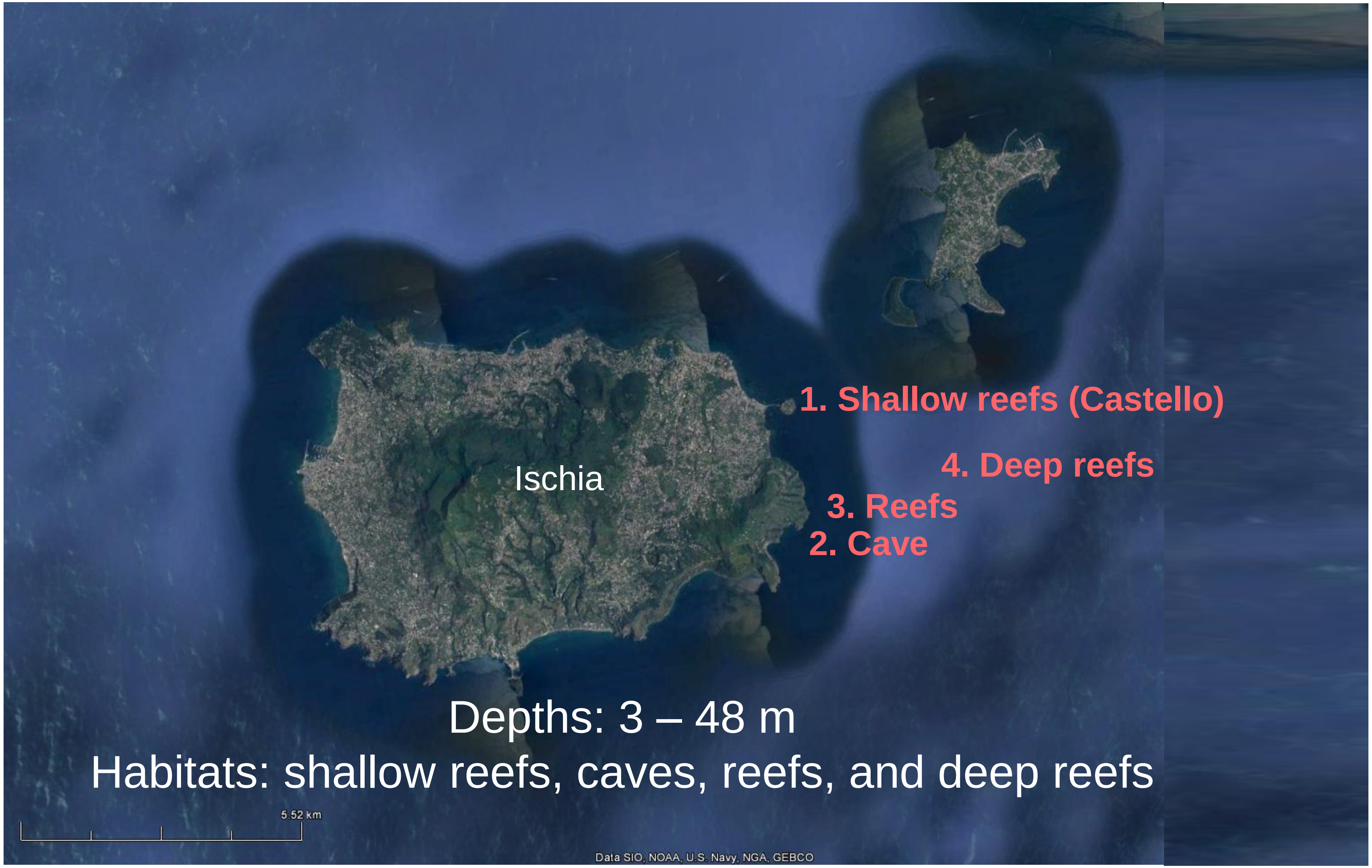
Incubations with Posidonia

New insights using 3D underwater imaging approaches



PhD: Gaia Grasso
Jordi
Gaia, Massimiliano

New CO_2 vent systems across habitats and depths

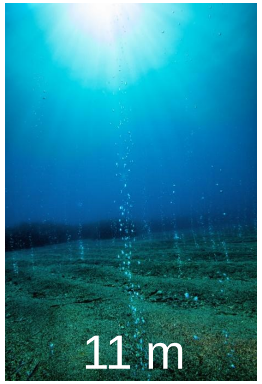


Broadening the Scope of the Ecological Effects of Ocean Acidification

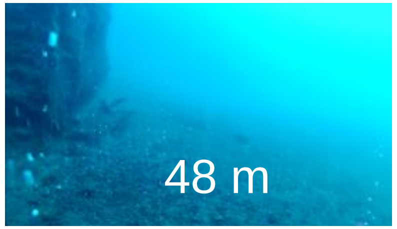
Vent 1. Shallow reef & *Posidonia oceanica*: Castello Aragonese

Vent 2. Semi-submerged cave: Grotta del Mago

Vent 3. Reef & *Posidonia oceanica*: Chiane del Lume



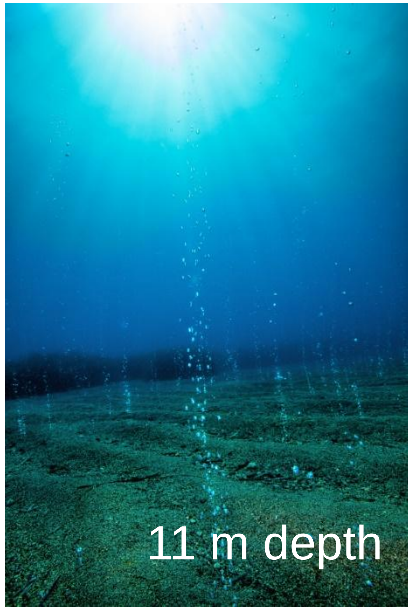
Vent 4. Deep reef (Coralligenous outcrops): Madonnina



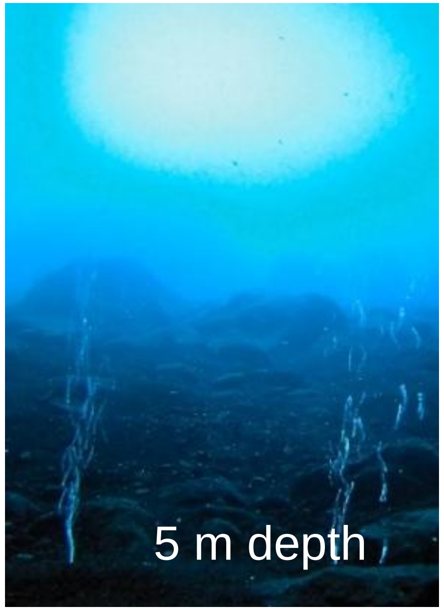
Teixidó et al (2020) Glob Change Biol
Carbonne et al (2021) Limnol & Oceangr

How natural coral populations persist under low pH environments?

Chiane del Lume



Magician’s cave



Cladocora caespitosa

Symbiotic coral

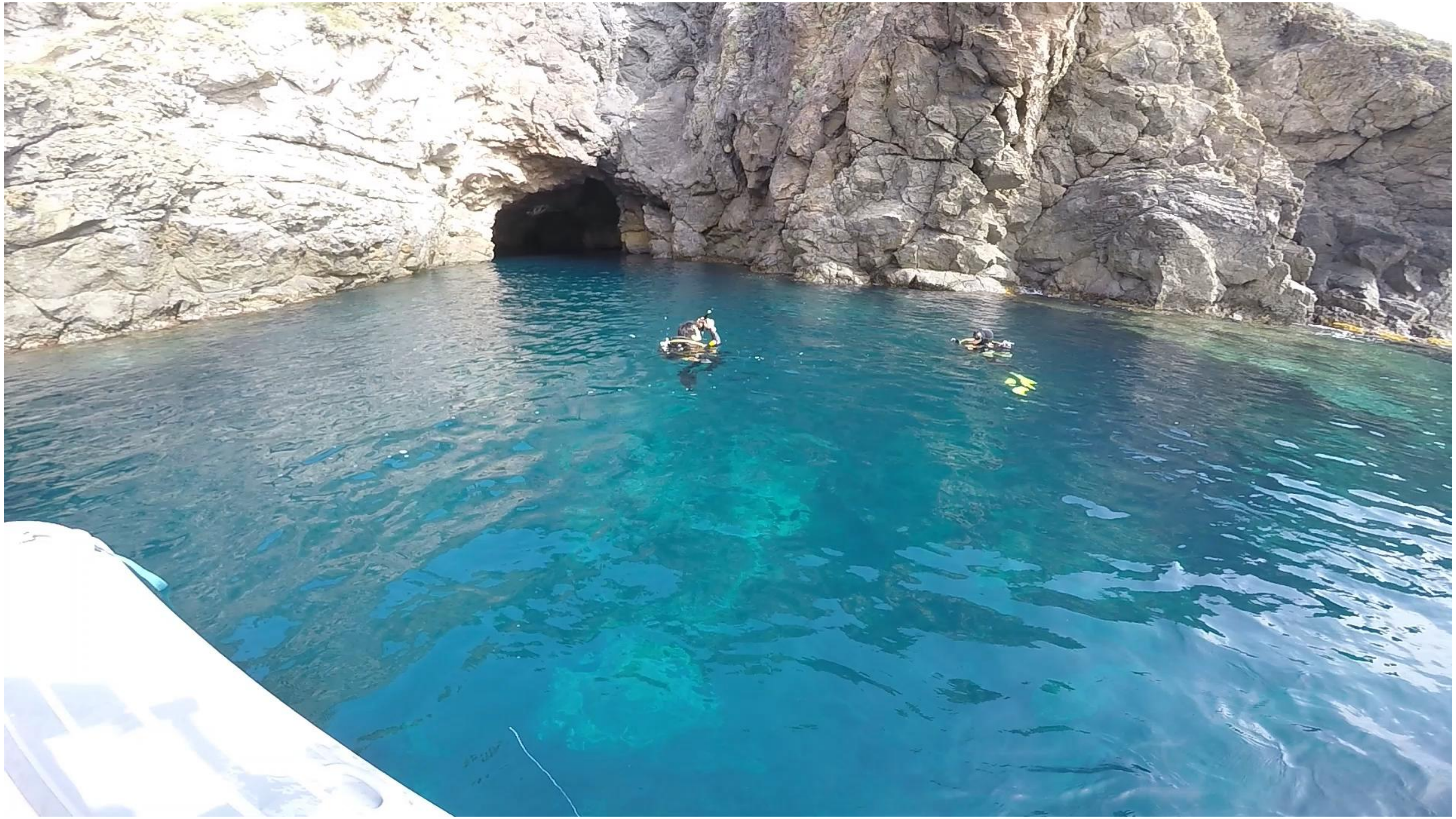
Astroides calycularis

Asymbiotic coral

Carbonne et al (2021) L&O
Teixidó et al (2020) GCB

How natural coral populations persist under low pH environments?

Grotta del Mago (Magician's Cave)



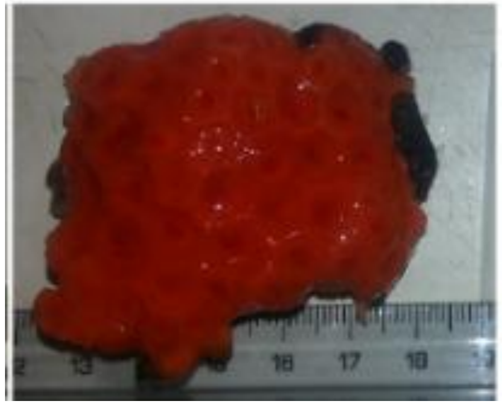
How natural coral populations persist under low pH environments?

i. Does the population at the CO_2 vent exhibit significant trait variation?:

number of polyps, size, growth, mineralogy

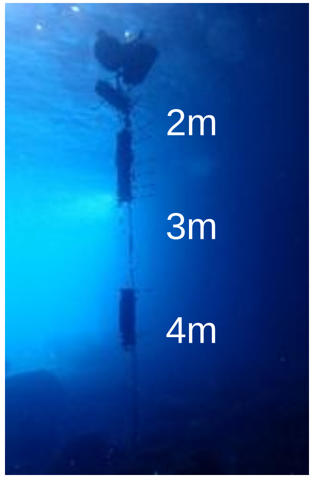
i. Do these populations display genetic differentiation?

Ambient pH

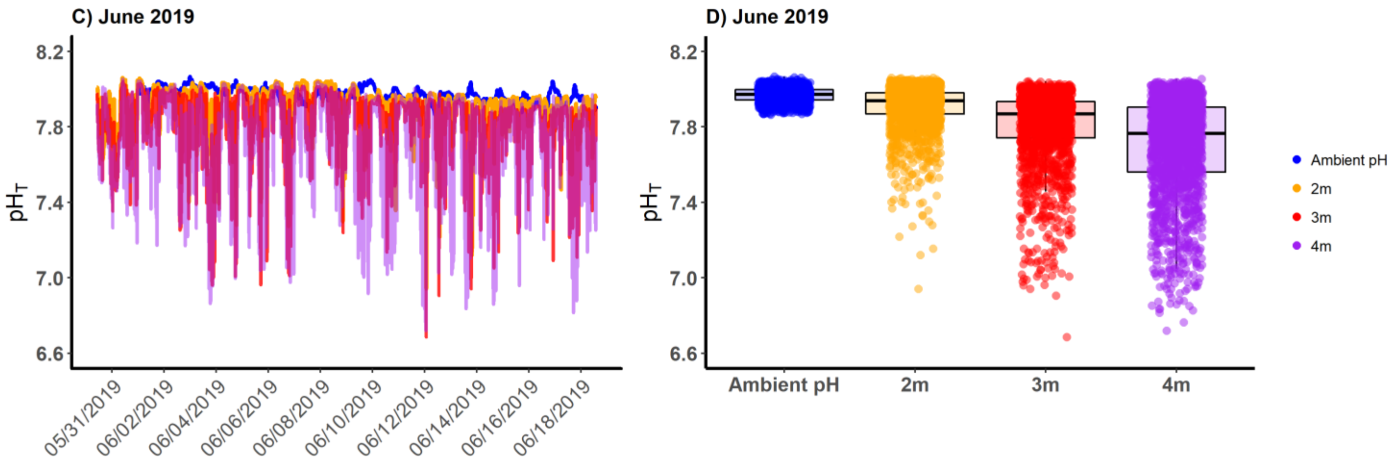


CO_2 vent

pH time series and variability



Deployment of SeaFET™ pH sensors for 20-30 days, measurements 15 minutes & discrete water samples for Total Alkalinity (TA)



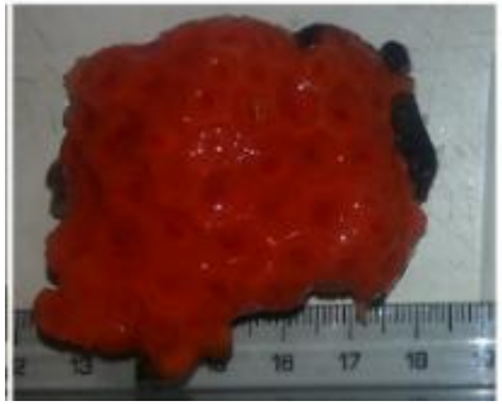
Ambient	$pH_{T=}$ 7.97 (7.94 , 7.99)	Ωa ~ 3.89
2m	pH_T= 7.88 (7.86, 7.98)	Ωa ~ 1.44
3m	$pH_{T=}$ 7.74 (7.74, 7.93)	Ωa ~ 1.23
4m	$pH_{T=}$ 7.60 (7.56, 7.90)	Ωa ~ 1.05

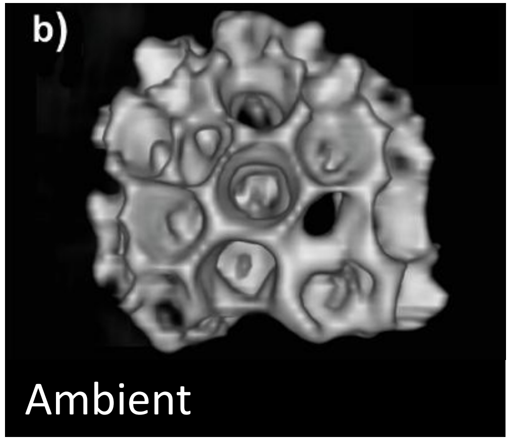
Low pH and high variability at the CO_2 vent

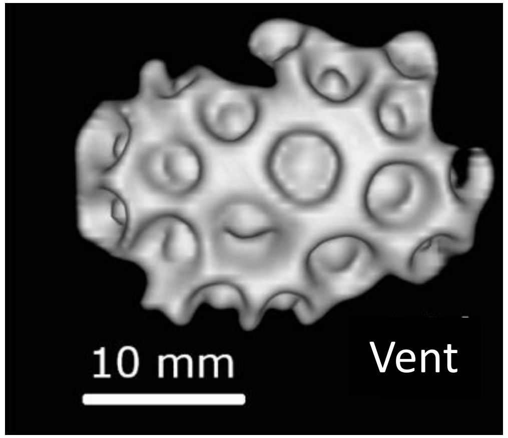
Skeletal characteristics

Colonies shifted to a skeletal phenotype characterized by:

Ambient pH	CO_2 vent







CO_2 vent :

- encrusting morphology
- smaller size
- fewer polyps

- *less porous*
- *denser skeletons*

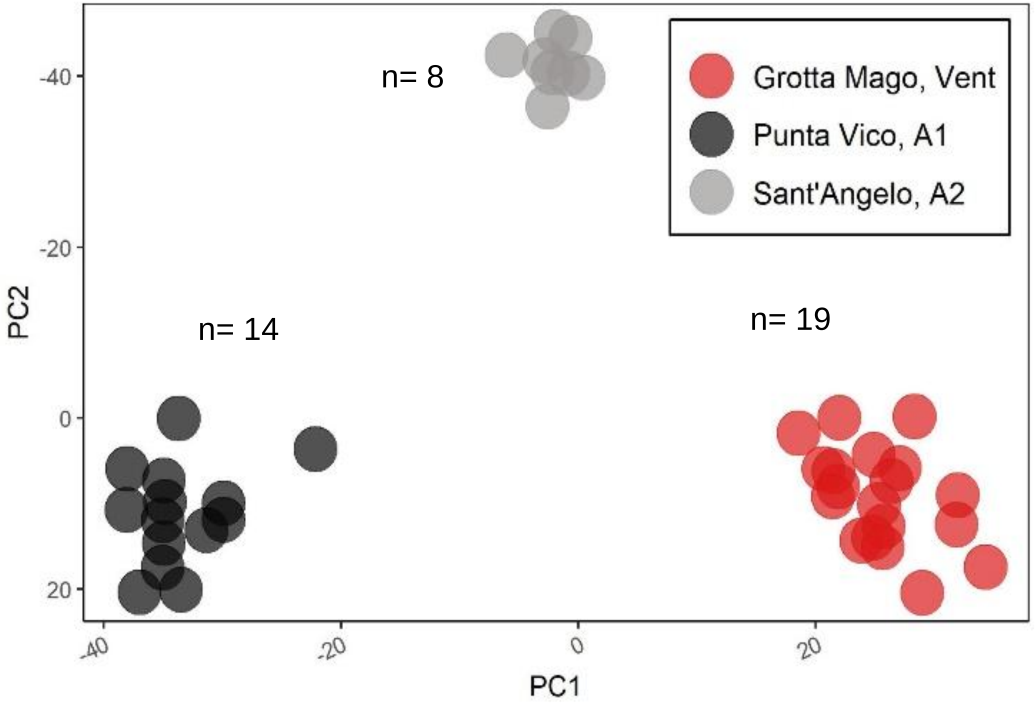
that same calcification is allocated to a minor number of polyps, and these few polyps result in having a more dense skeleton

Teixidó et al (2020) GCB

Population genetic structure

Strong population genetic structure

(distinct populations)



Teixidó et al (2020) GCB

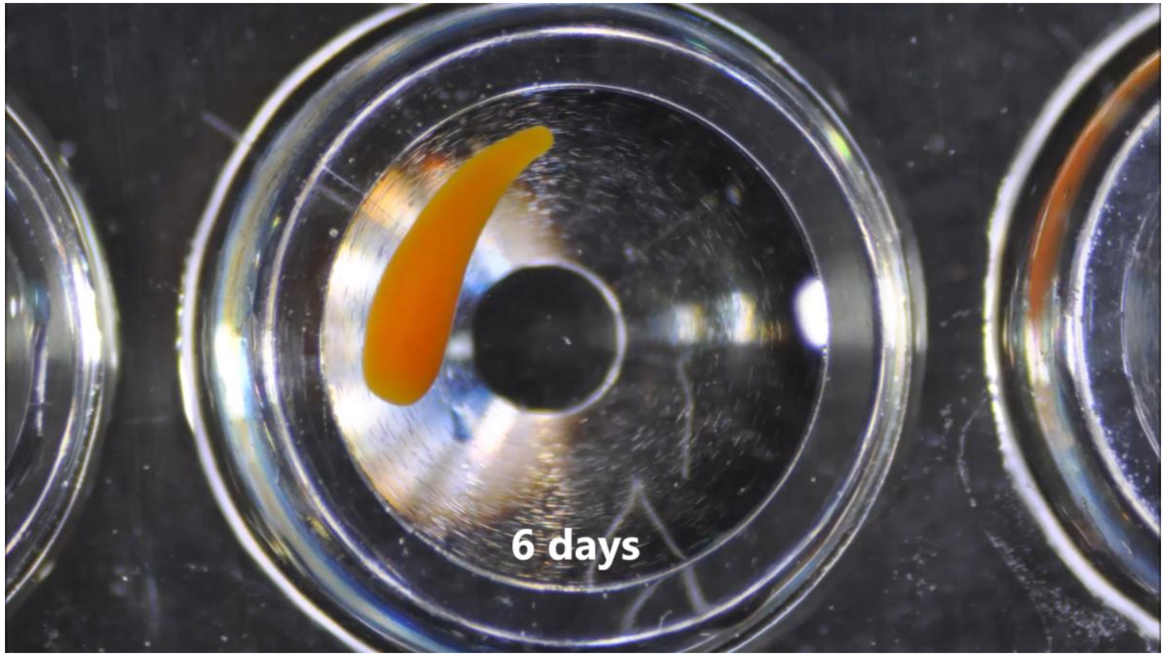
Coupling *in situ* measurements and laboratory experiments

Laboratory experiments of 5 to 9 months with controlled temperature and pH.

PhD Chloé Carbonne (2022)

Unexpected finding:
larvae release from the mothers

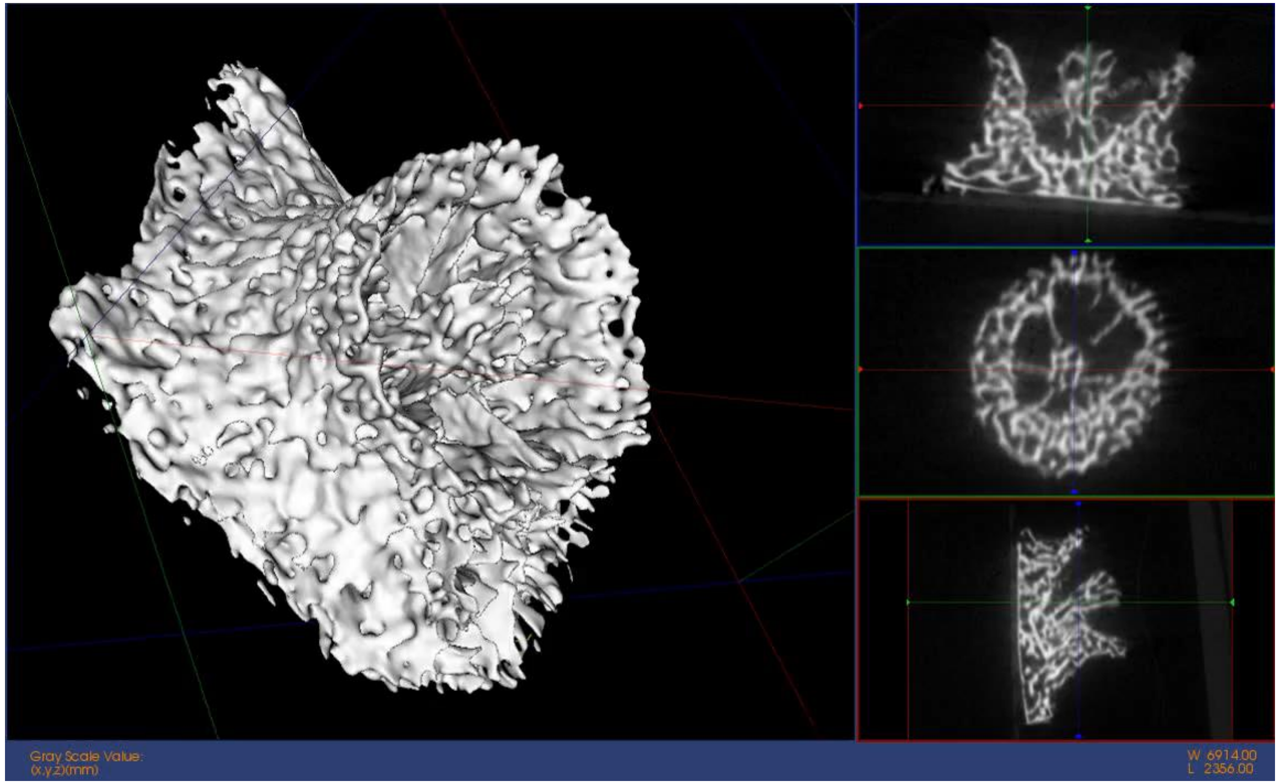
larvae → polyp



Carbonne et al (2022) Biogeosciences

3D Reconstruction of coral polyp density using micro-Computed Tomography

Gene expression larvae and juvenile corals



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