UK Ocean Acidification Research Programme
Benthic Acidification

UKOA Benthic Consortium - Aims 1

credits:

Burdett
Burrows
Calosi
Findlay
Godbold
Hauton
Hawkins
Hennige
Kamenos
Mieszkowska
Queiros
Rastrick
Roberts
Solan
Spicer
Whiteley
Wicks
Widdicombe

Steve Widdicombe & Piero Calosi

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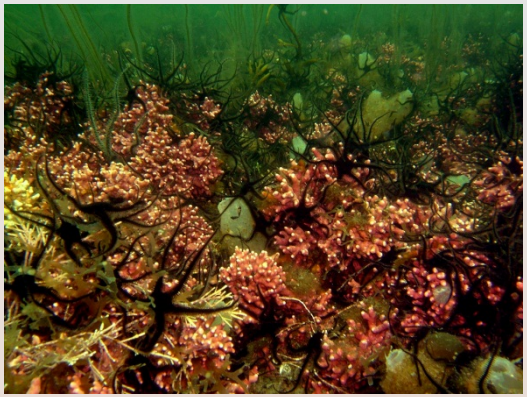
Benthic Acidification

Our Promise as Consortium

The ultimate aim of the Consortium was that to help predicting the impact of acidification and warming on the biodiversity and function of three key UK habitats:

- Sediment habitats
- Calcifying / biogenic habitats
- Rocky intertidal habitats



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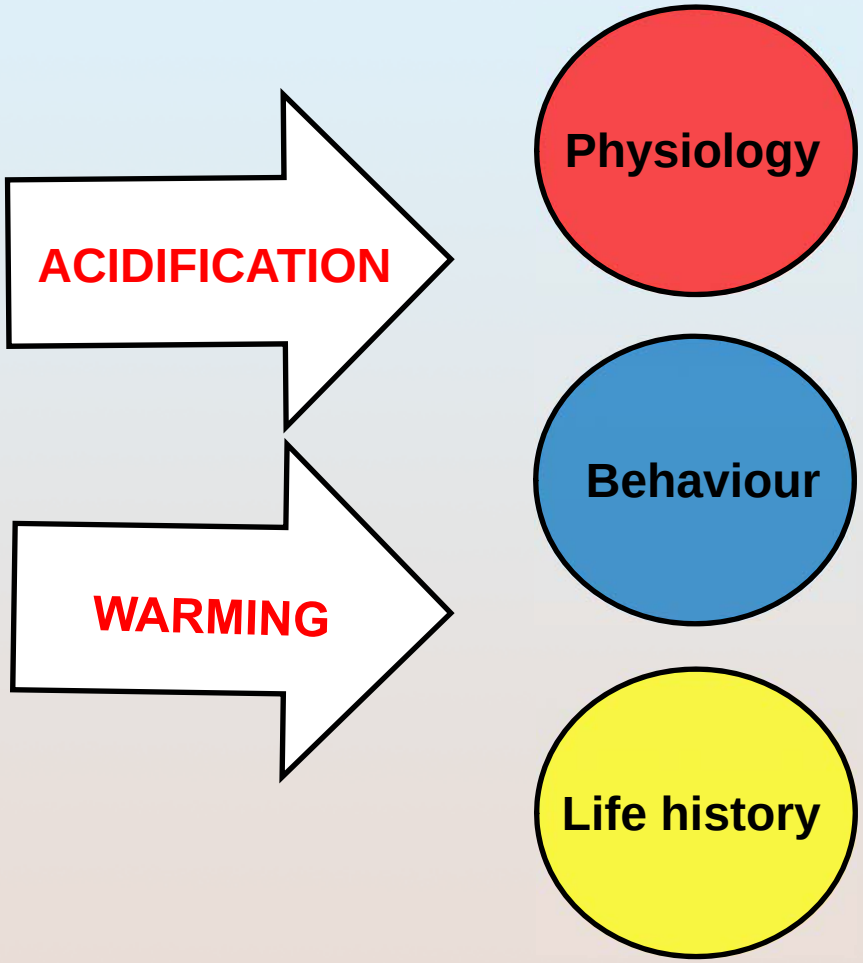
Environmental Drivers Targeted at Traits



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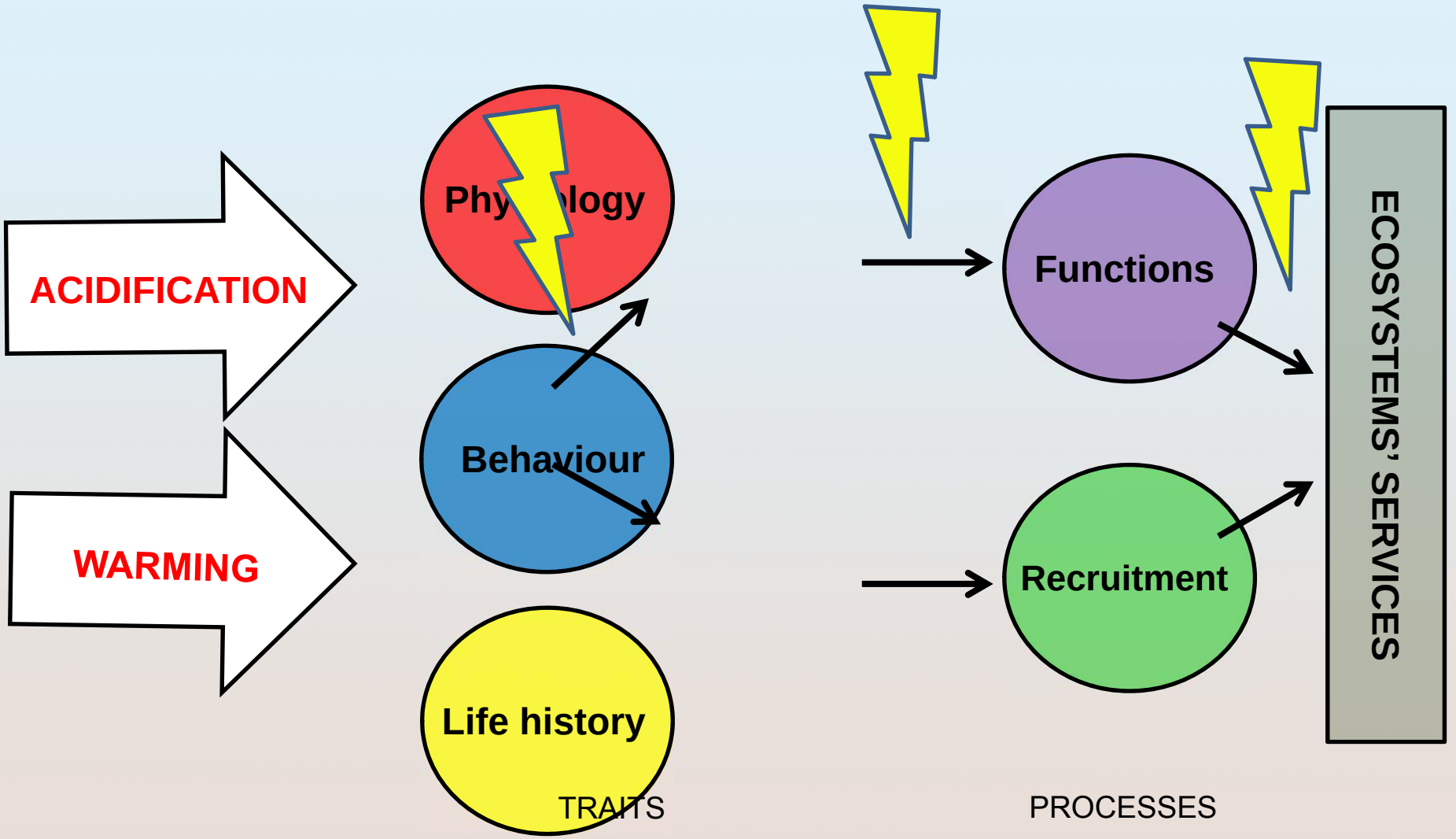
Targeted Processes

Aim 1



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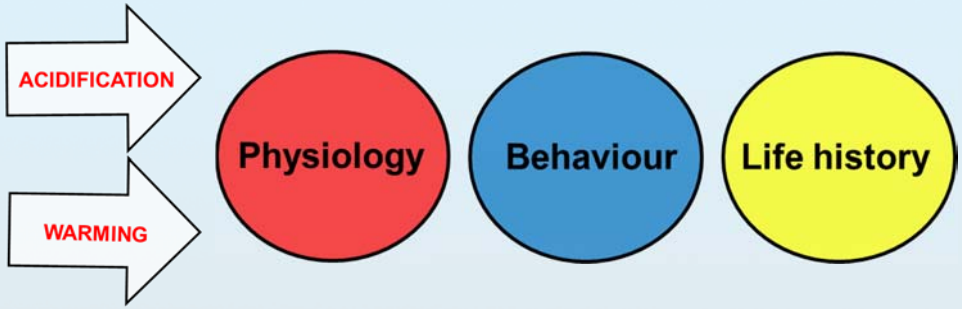
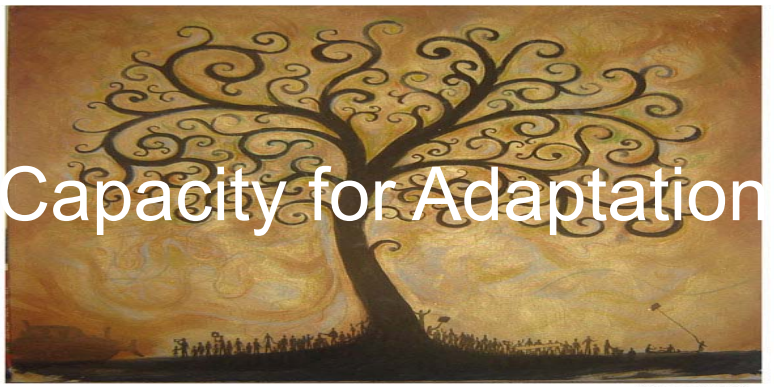
Biogeography & Adaptation

Aim 1



Sensitivity of different life stages



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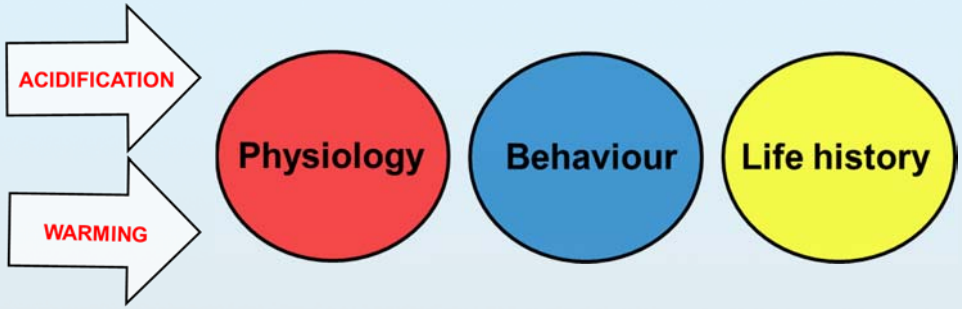
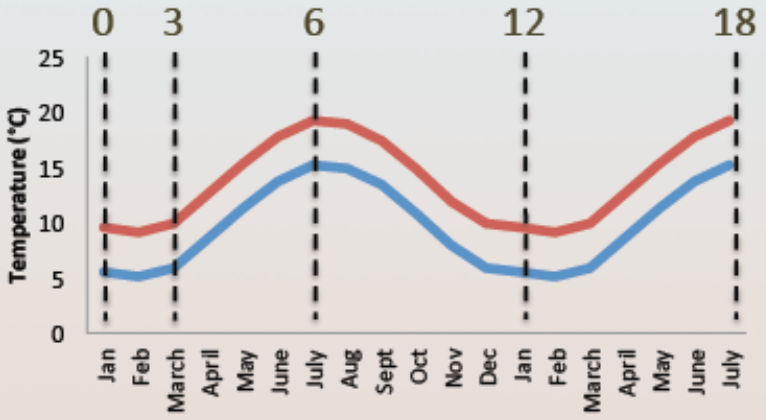
Seasonal Fluctuations

Aim 1



1) Ambient temperature, 380 µatm pCO_2
2) Ambient temperature, 750 µatm pCO_2
3) Ambient temperature, 1000 µatm pCO_2
4) +4 °C Ambient temperature, 380 µatm pCO_2
5) +4 °C Ambient temperature, 750 µatm pCO_2



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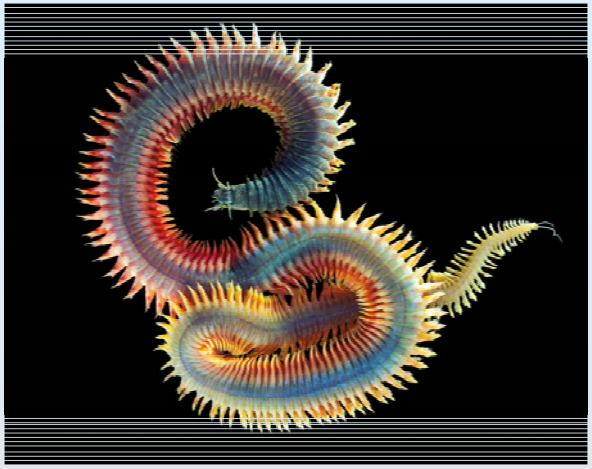
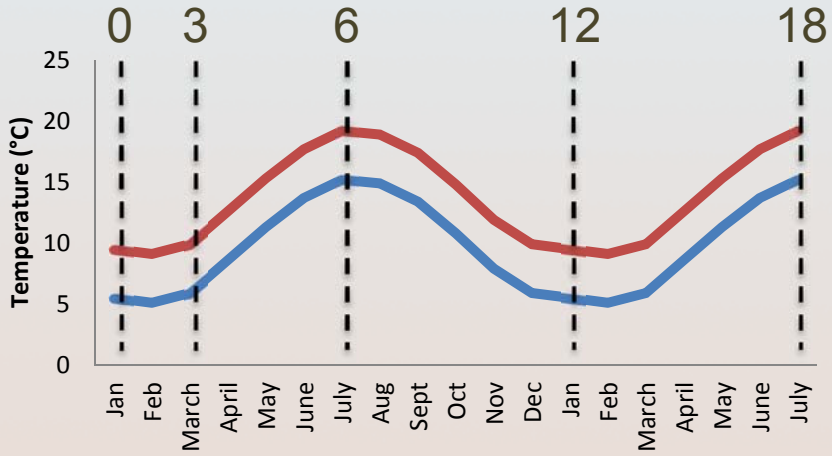
A Fluctuating Environment



Alitta virens

- **Time**: 3, 6, 12, 18 months
- **Temp. regime**: Const, Amb, Amb + 4°C
- **CO_2** (ppm) 380 750 1000 380 750
- **$pH_{(NBS)}$** 8.1 7.9 7.7 8.1 7.9



Godbold & Solan 2013 *Phil. Trans. Roy. Soc B* in press

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Response ~ f(Season x CO_2 x Temp. regime)	**Response ~ f(Season x CO_2)**
Growth ~ f(Season + CO_2 + Temp regime)	Growth ~ f(Season + CO_2)
Bioturbation ~ f(Season x Temp regime)	Bioturbation ~ f(Season)
Bioirrigation~ f(Season x Temp regime + Temp regime x CO_2)	Bioirrigation~ f(Season x CO_2)
NH_4~ f(Season x CO_2)	NH_4~ f(Season)
NO_x~ f(Season x Temp regime + Temp regime x CO_2)	NO_x~ f(Season)
PO_4~ f(Season x Temp regime)	PO_4~ f(Season)

➔ **Temporal expression of complex system dynamics vital for predicting ecological consequences of climatic forcing**

Godbold & Solan 2013 *Phil. Trans. Roy. Soc B* in press

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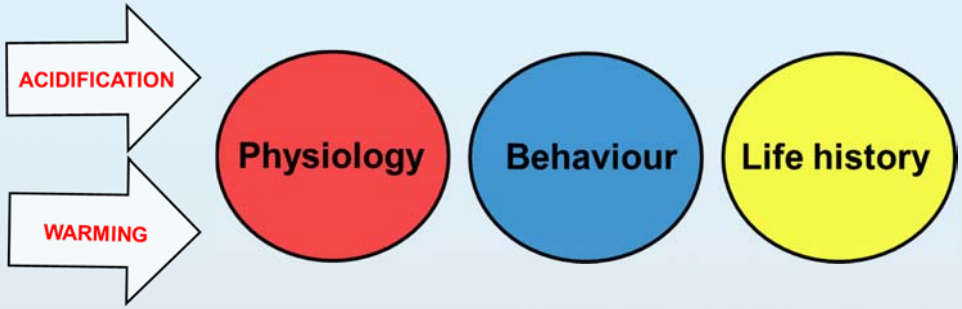
Sediment Habitat

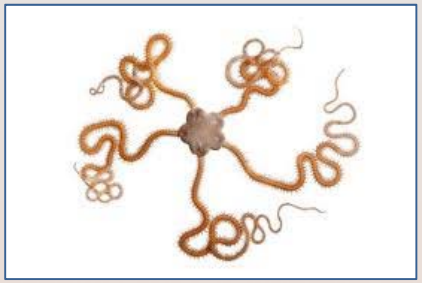
Aim 1



Cerastoderma edulis

Hedistes diversicolor

Amphiura filiformis



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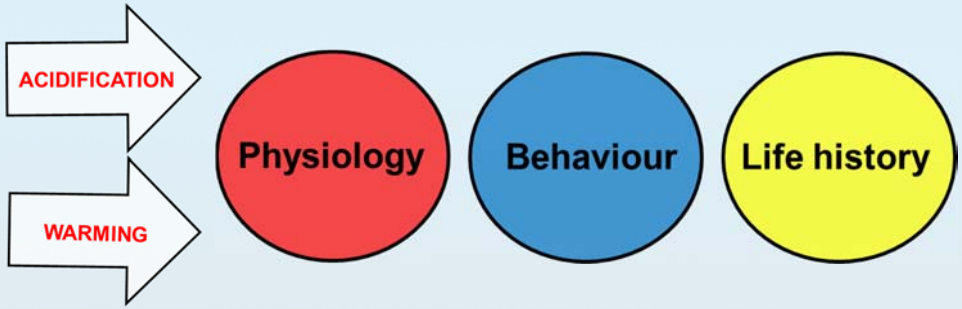
Rocky Intertidal Habitat

Aim 1



Nucella lapillus

Osilinius lineatus

Paracentrotus lividus

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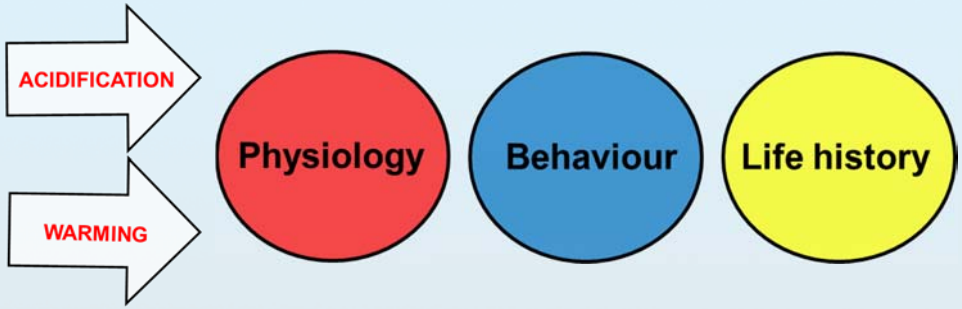
Biogenic Habitat

Aim 1



Lophelia pertusa

Hennige, Murray, Wicks in progr.

Lithothamnion glaciale

Burdett et al. 2012 *Marine Biology Research* 8 pp756-763

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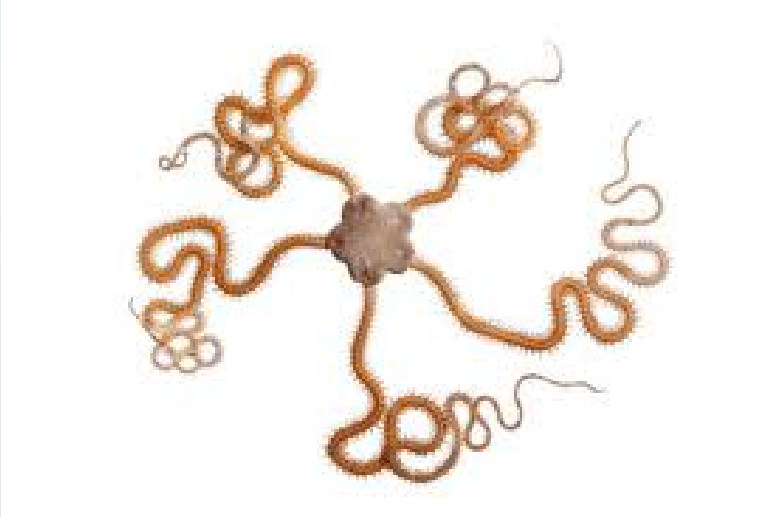
Brittlestars

Aim 1



Amphiura filiformis

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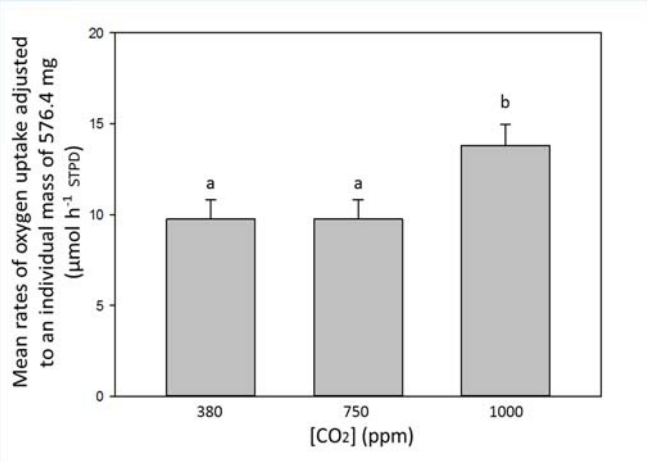

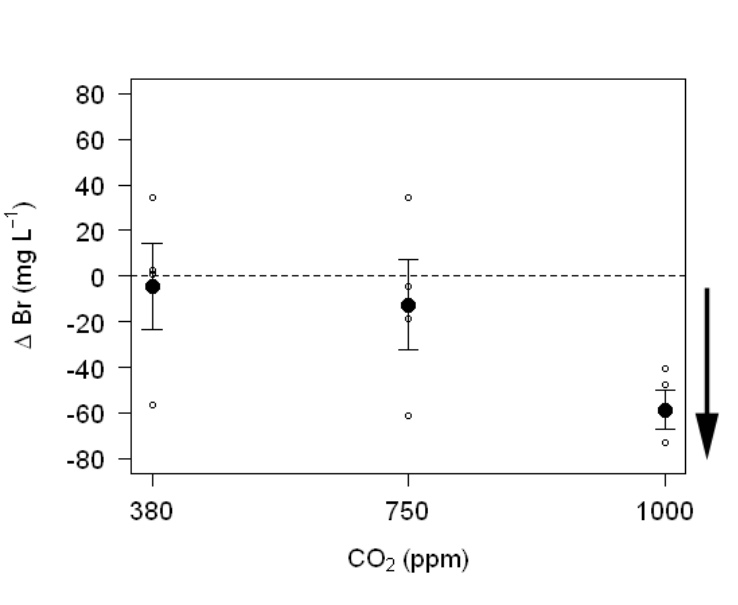

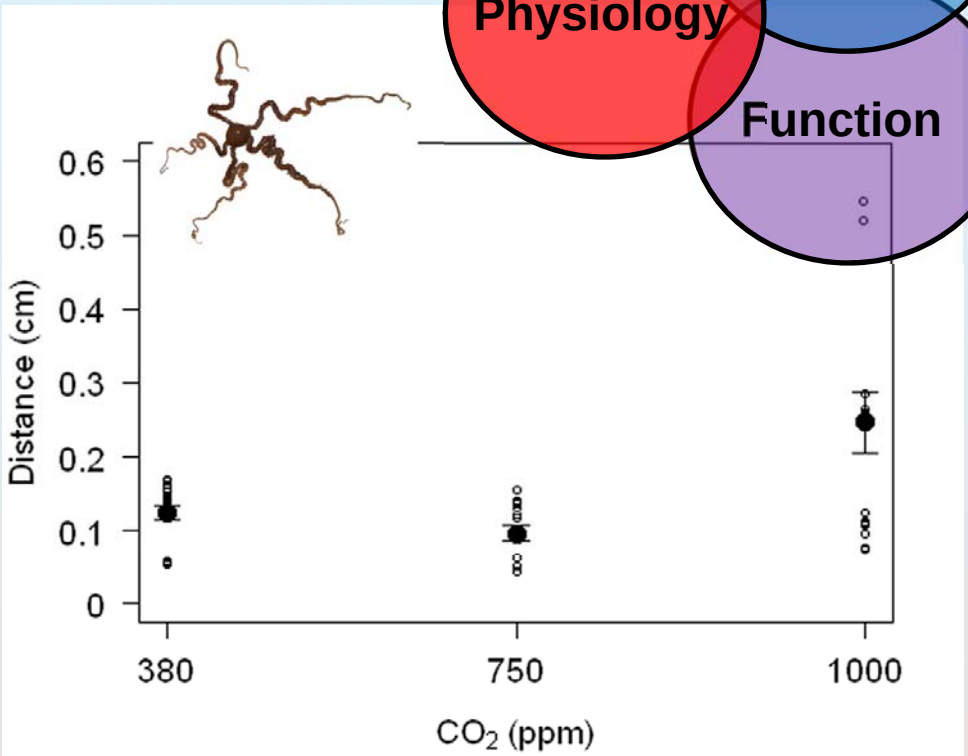

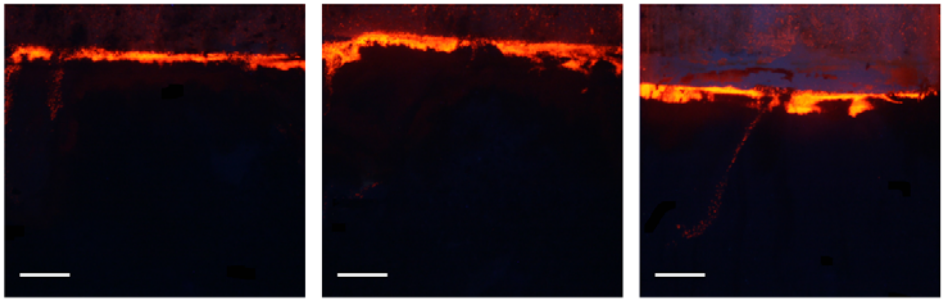

Behaviour

Physiology

Function

Godbold et al. in prep.

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6 months exposure

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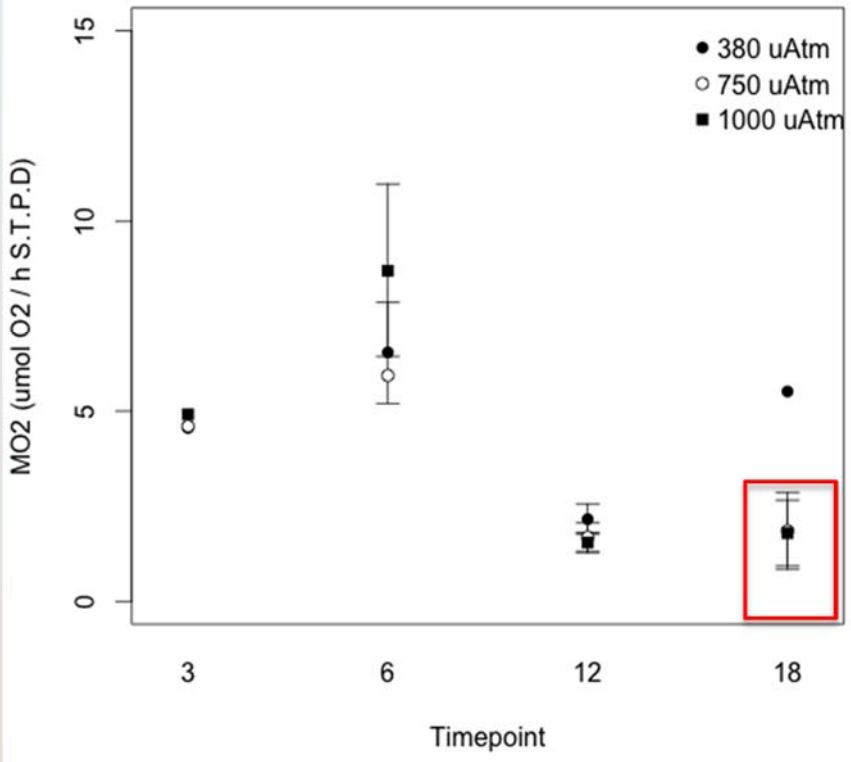
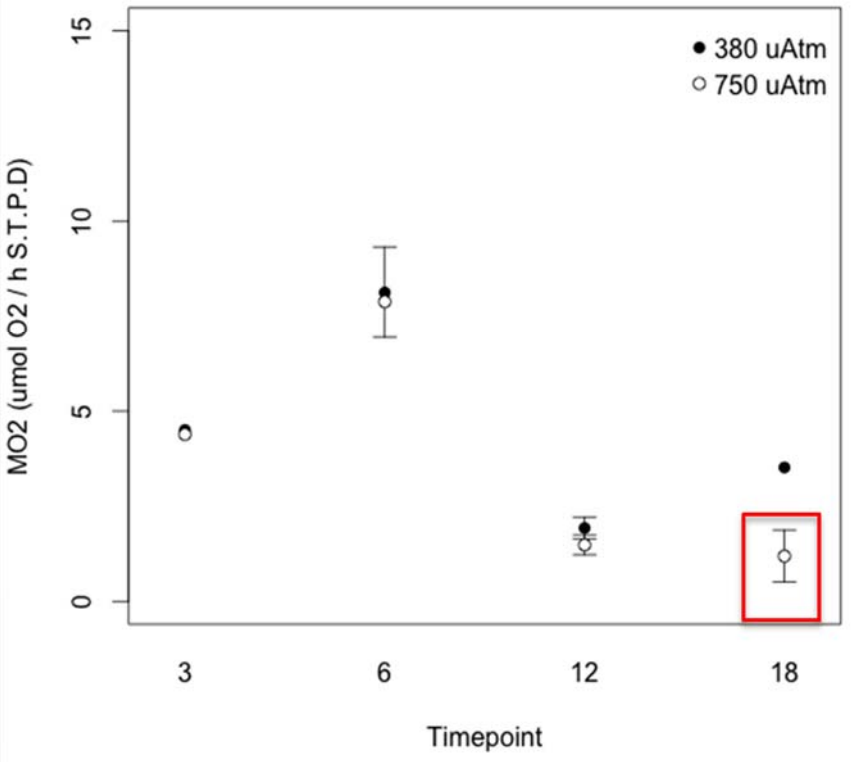
Physiology

Ambient



Ambient + 4°C



Godbold et al. in prep.

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Aim 1

Responses to long-term exposure to elevated CO_2 and temperature in rocky intertidal habitat

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Purple Sea Urchins

Aim 1

- **Sea urchins are ecologically important in coastal habitats worldwide** (Lawrence, 1975; Harrold & Pearse, 1987; Dayton, 1992; Elner & Vadas, 1990; Estes & Duggins, 1995; Shears & Babcock 2002).
- ***Paracentrotus lividus* is the 'most significant' invertebrate herbivore in the Mediterranean'** (Boudouresque & Verlaque, 2001)
- **Economically important**

Paracentrotus lividus

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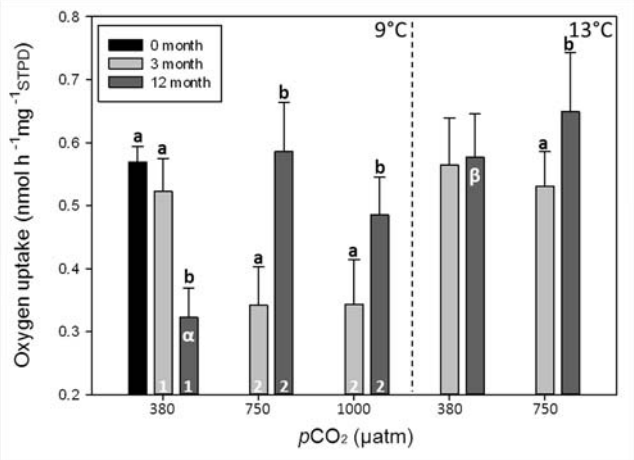
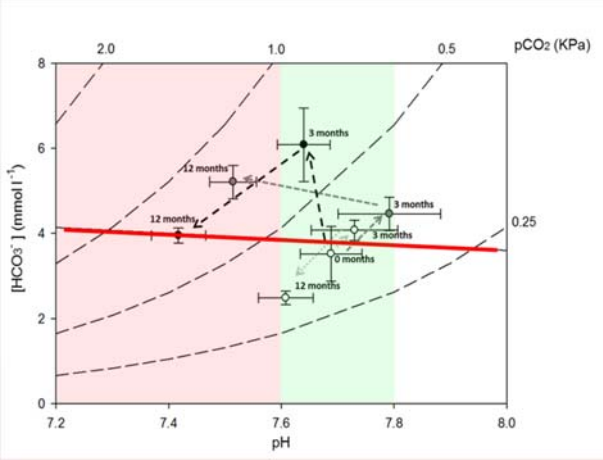
Energy Trade-Offs

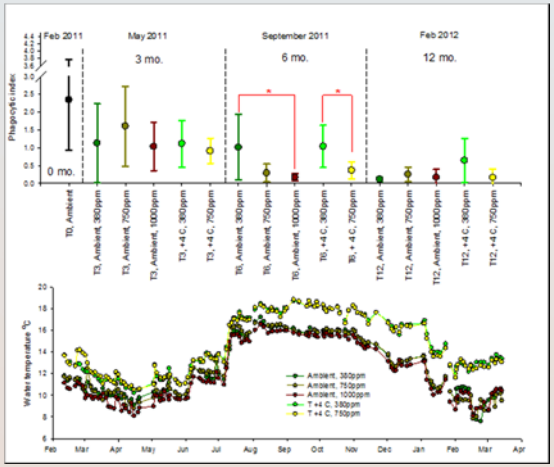
Physiology

Paracentrotus lividus

Linking physiological costs to recruitment







Rastrick et al. in prep

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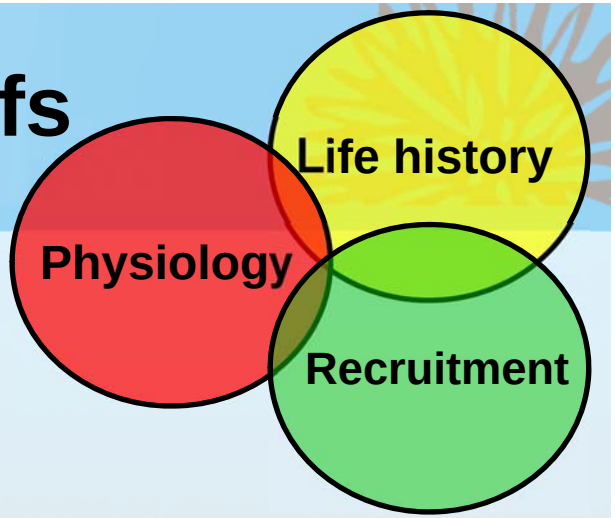
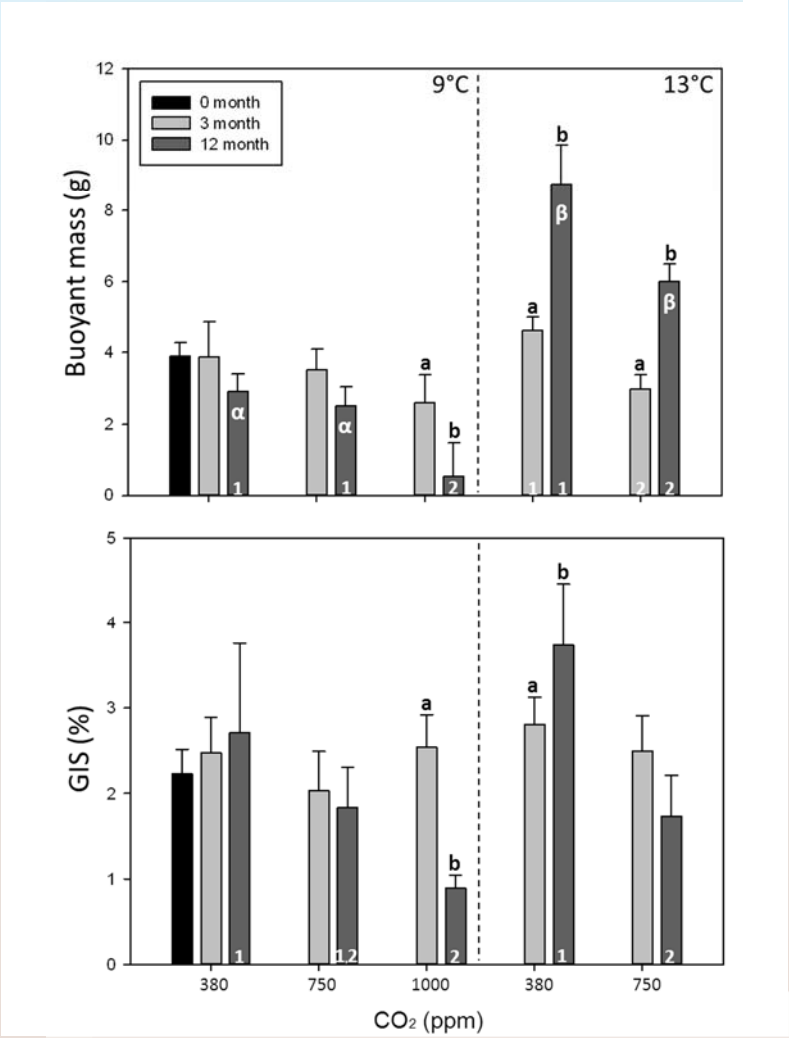
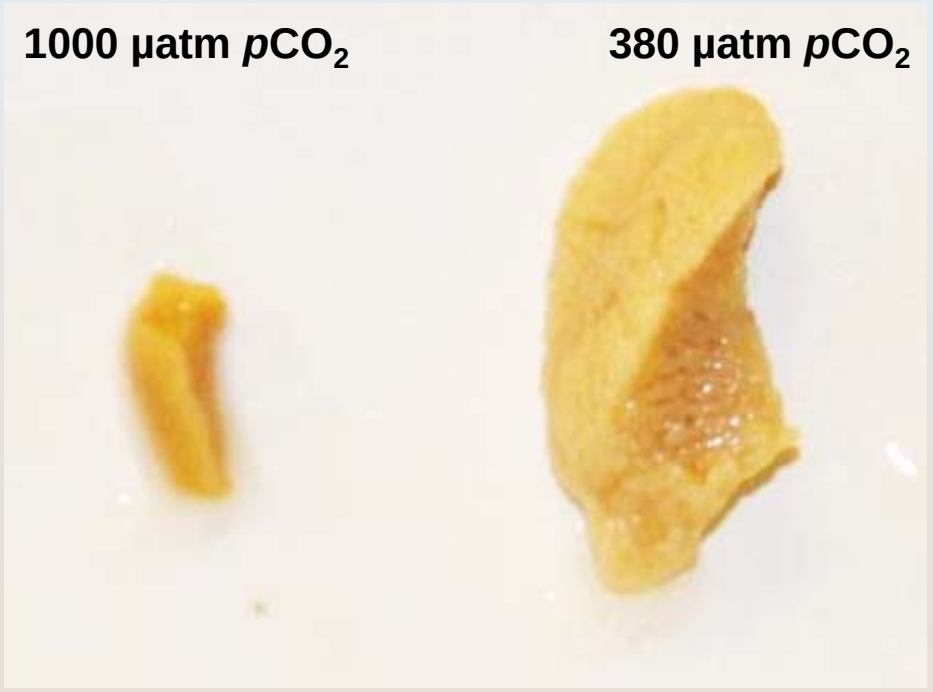
Energy Trade-Offs







Rastrick et al. in prep

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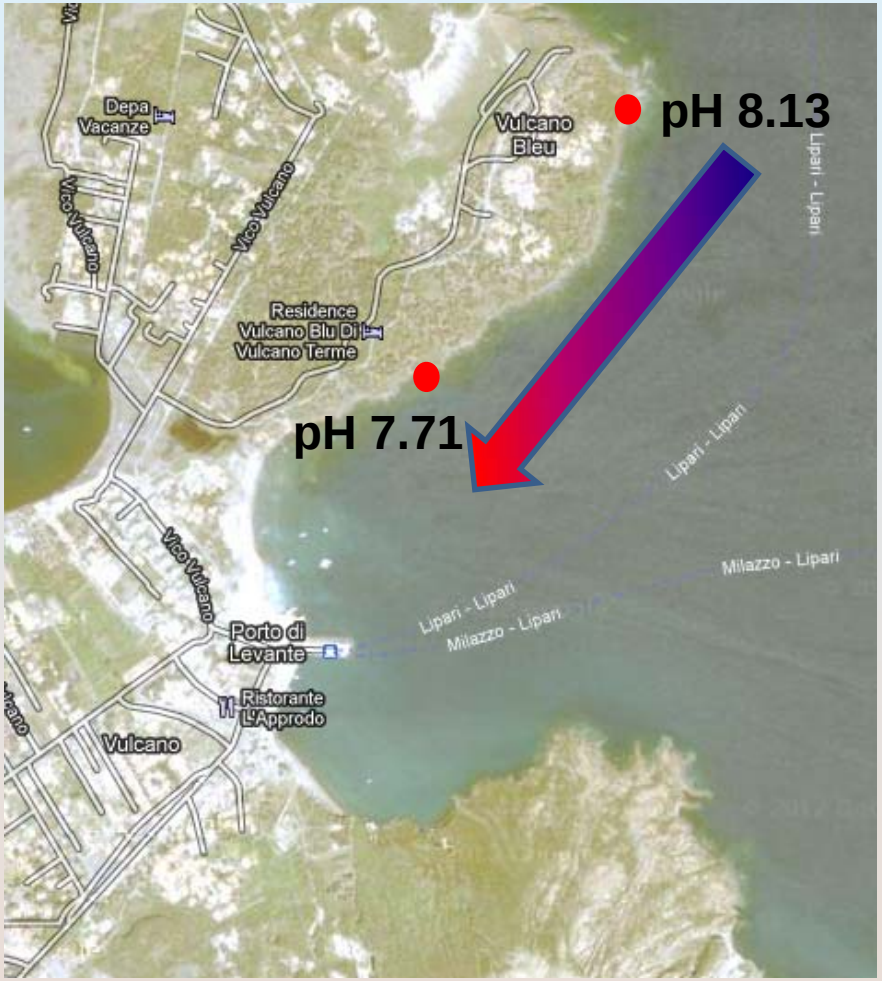
Field Validation

Calosi P. et al. 2013 *Mar. Poll. Bull.* in press



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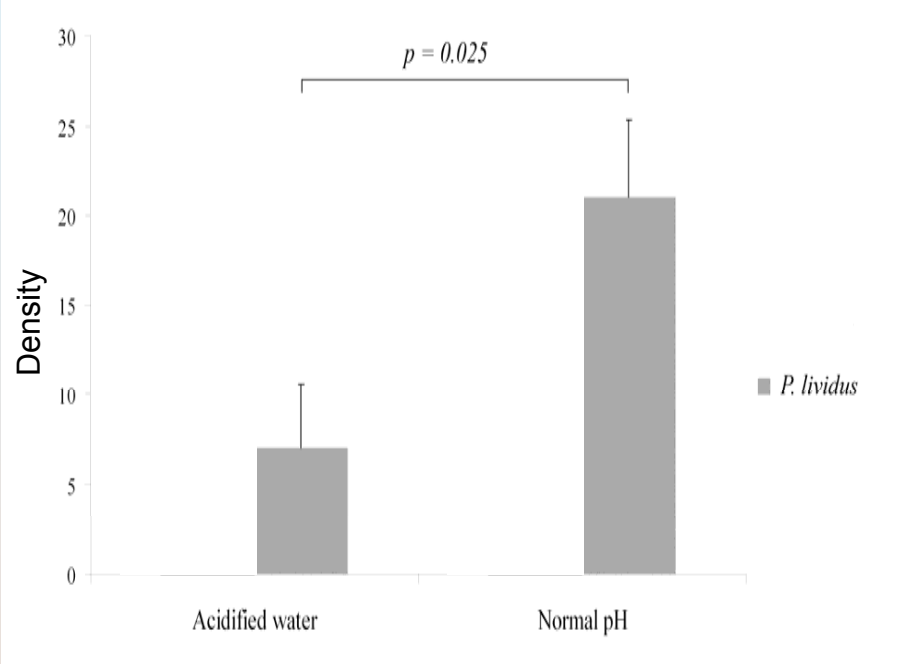
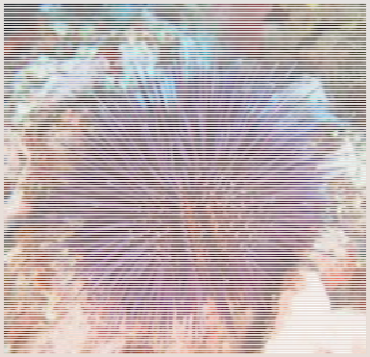
Field Validation

Life history

Recruitment

MedSeA
MEDITERRANEAN SEA ACIDIFICATION IN A CHANGING CLIMATE





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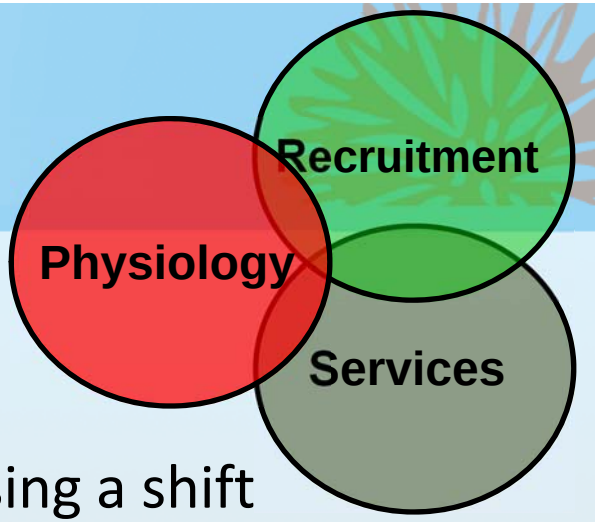

Changes in energy budget may cause a reallocation in the amount of energy sea urchins Invest on growth and reproduction, possibly causing a shift in recruitment potential, ultimately affecting ecosystem dynamics.

Summary of the long-term studies:

- marine invertebrates are physiologically challenged by the combined exposure to elevated CO_2 and temperature (differently during different seasons).
- different traits are differently affected, although over the long-term some traits may show the capacity to 'recover'.
- there is a strong link between physiological costs, changes in behaviour and life history and ultimately ecosystems' functions (mechanistic underpinning)
- the combination of long-term laboratory studies with field validation allow for more solid predictions on how marine life will respond to the ongoing environmental change.

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Sensitivity of life stages

Aim 1

Experimental manipulations CO_2 and temperature

Combined with published data

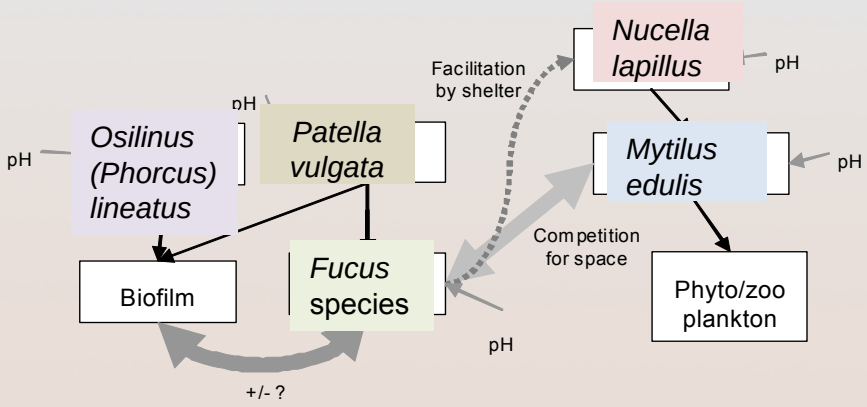
Construct age based population models
→ population effects

Experiments

18 month microcosm exposure experiment at the MBA, CO_2 (380, 750, 1000ppm × temperature (L4 monthly SST, SST +4°C)

Osilinus lineatus, Nucella lapillus;

survival, growth, gonad development, reproduction



Mieszkowska & Burrows in progr.

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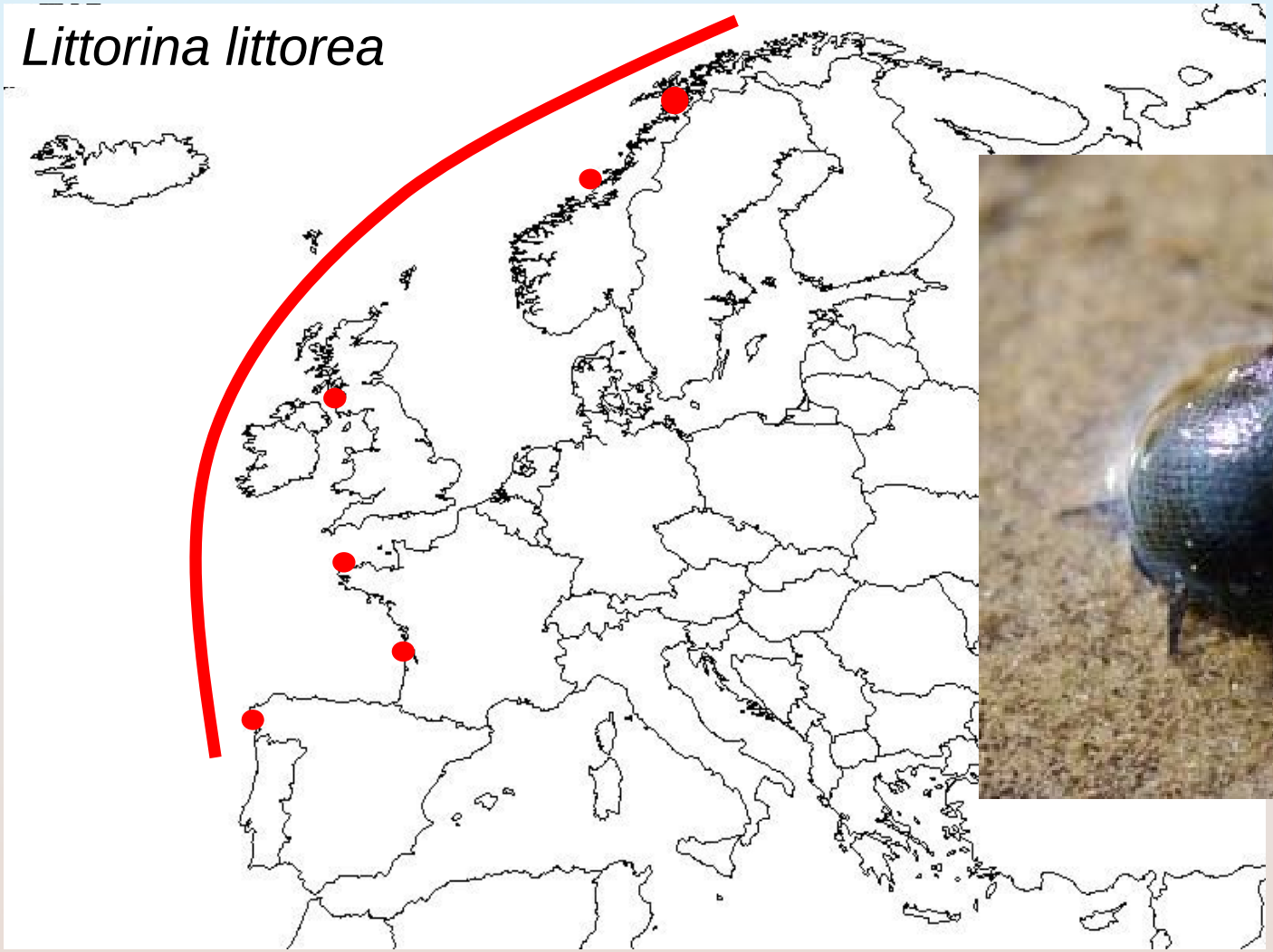
Populations Sensitivity

Aim 1

Littorina littorea



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Melatunan et al. in prep

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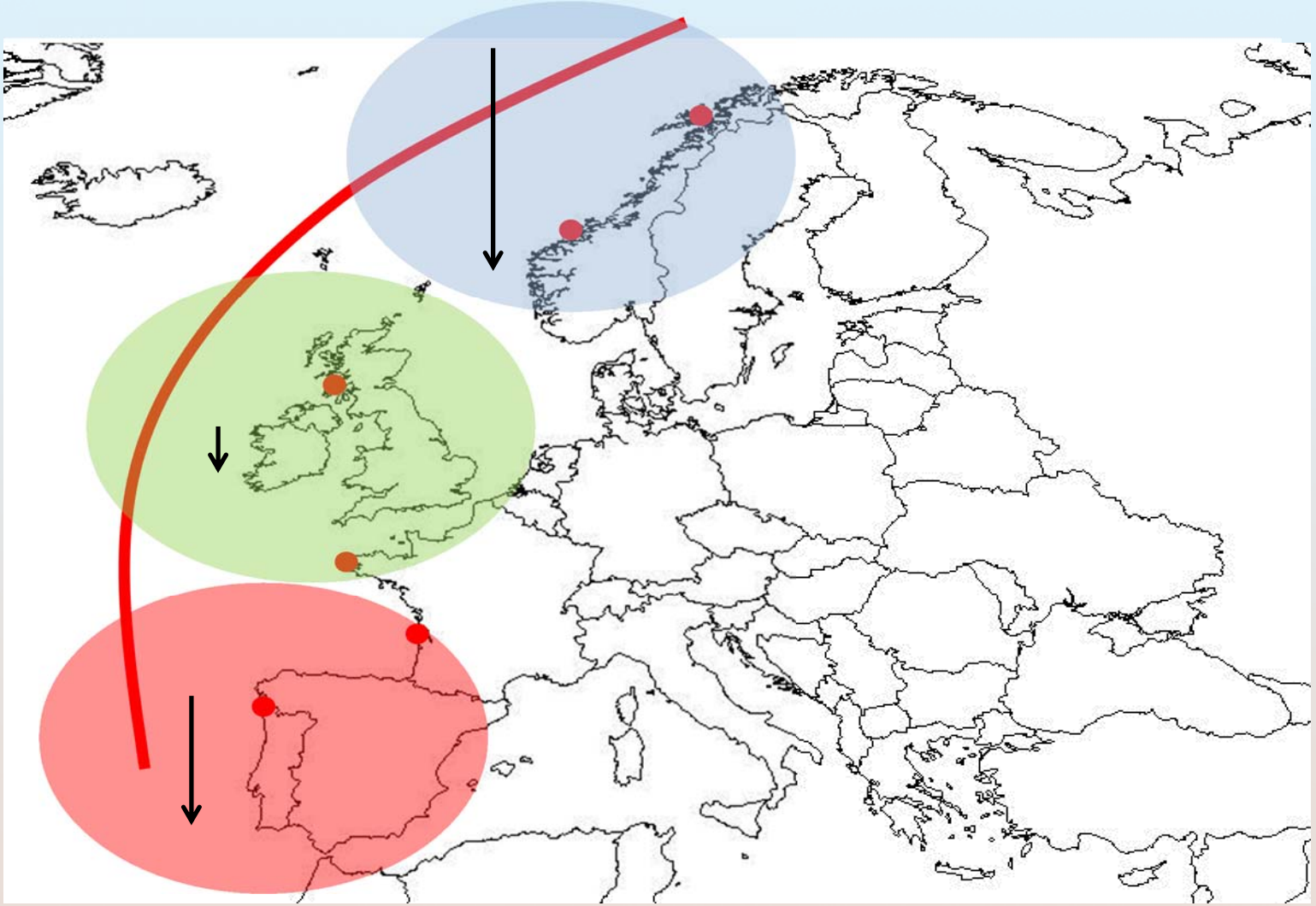
Aim 1



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Melatunan et al. in prep

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DYNAMIC BIOCLIMATIC ENVELOPE MODEL

Aim 1

distributional data

+

geochemical simulation

DBEM

responses to pH, T (O_2)

+

(larval dispersal)

parameters of the length-weight relationship
von Bertalanffy growth parameters
larval survival
larval diffusion (NA)
adult movement
adult mortality
Activation Energy

UKOA experimental data

FISH and FISHERIES

FISH and FISHERIES, 2009, **10**, 235–251

Projecting global marine biodiversity impacts under climate change scenarios

William W.L. Cheung[1], Vicky W.Y. Lam[1], Jorge L. Sarmiento[2], Kelly Kearney[2], Reg Watson[1] & Daniel Pauly[1]

ICES Journal of Marine Science (2011), 68(6), 1008–1018. doi:10.1093/icesjms/fsr012

Integrating ecophysiology and plankton dynamics into projected maximum fisheries catch potential under climate change in the Northeast Atlantic

William W. L. Cheung[1,2*], John Dunne[3], Jorge L. Sarmiento[4], and Daniel Pauly[5]

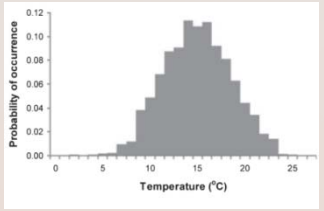
nature climate change

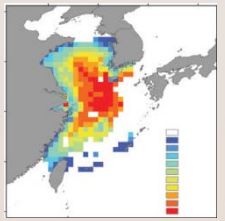
LETTERS

PUBLISHED ONLINE: 30 SEPTEMBER 2012 | DOI: 10.1038/NCLIMATE1691

Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems

William W. L. Cheung[1]*, Jorge L. Sarmiento[2], John Dunne[3], Thomas L. Frölicher[2], Vicky W. Y. Lam[1], M. L. Deng Palomares[1], Reg Watson[1] and Daniel Pauly[1]





Queiros, Fernandes et al. in progr.

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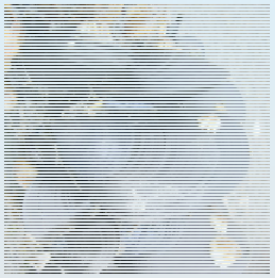
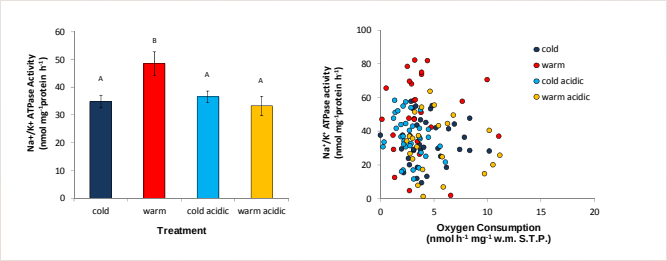
Potential for adaptation?

Aim 1

Examples on metazoans



Chan et al. 2011 *JEB*
Pistevos et al. 2011 Oikos
Sunday et al. 2011 *PLoS ONE*
Foo et al. 2012 *PLoS ONE*
Miller et al. 2012 *NNC*
Parker et al. 2012 *GCB*
Schlegel et al. 2012 *PLoS ONE*
Calosi et al. 2013 *Int. Comp. Biol.*
Carter et al. 2013 *JEB*
Pespeni et al. 2013 *PNAS*



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Echinogammarus marinus

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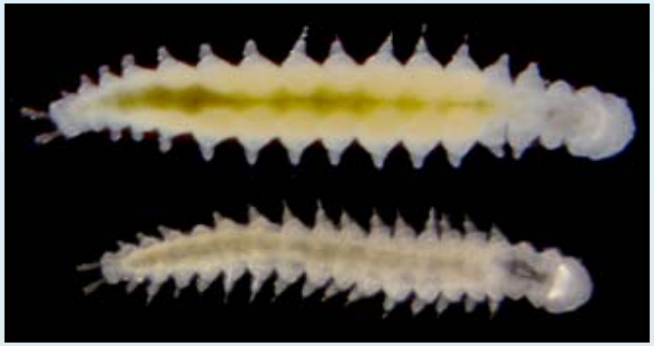
Experimental Evolution

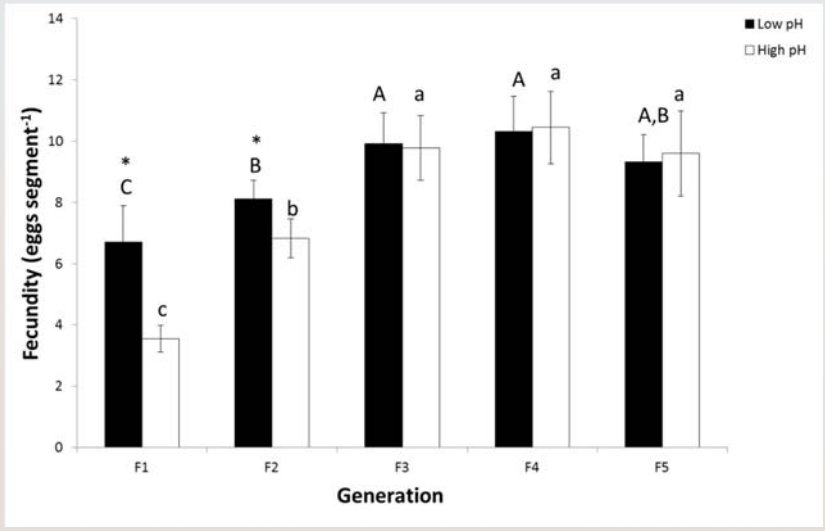
Aim 1



Ophryotrocha labronica
8 generations

Laboratory Natural Selection Experiments

Echinogammarus marinus
3 generations



Rodriguez et al. in prep.

Jarrold et al. in prep.

UK Ocean Acidification Research Programme
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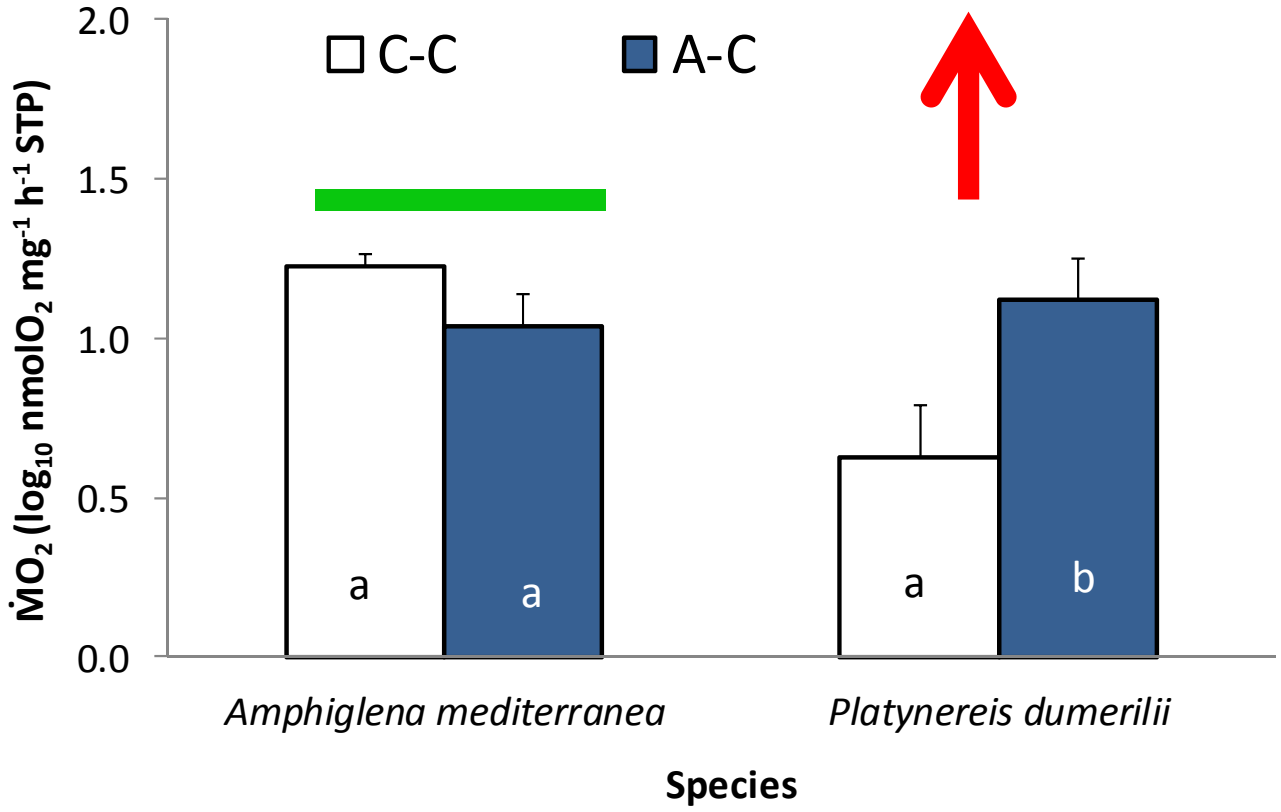
Field Validation



Calosi et al. 2013 *Phil. Trans. Roy. Soc B* in press

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Tools for the Future

Aim 1

A fundamental understanding of the mechanisms of action of complex climate changes on biological systems will help us predicting changes in population and community structure and dynamics. From here we can attempt explaining the consequences to the ecosystem level.

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Thanks

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