UK Ocean Acidification
Research Programme
Benthic Acidification

Physiological adaptation of marine invertebrates to high CO_2/low pH and hypoxia - paradigms and pitfalls

UK OA Research Programme
Benthic Consortium – Task 1.4
Identify the potential for organism resistance and adaptation to prolonged CO_2 exposure

Piero Calosi, Marie Hawkins, Lucy M. Turner, Manuela Truebano, John I. Spicer

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Evolutionary approaches . . . . .

- quantifying existing physiological diversity
- comparing species and populations responses

  (also along environmental and geographical gradient/transplantations)
- inferring paleophysiology
- conducting laboratory selection experiments

  (natural and artificial)

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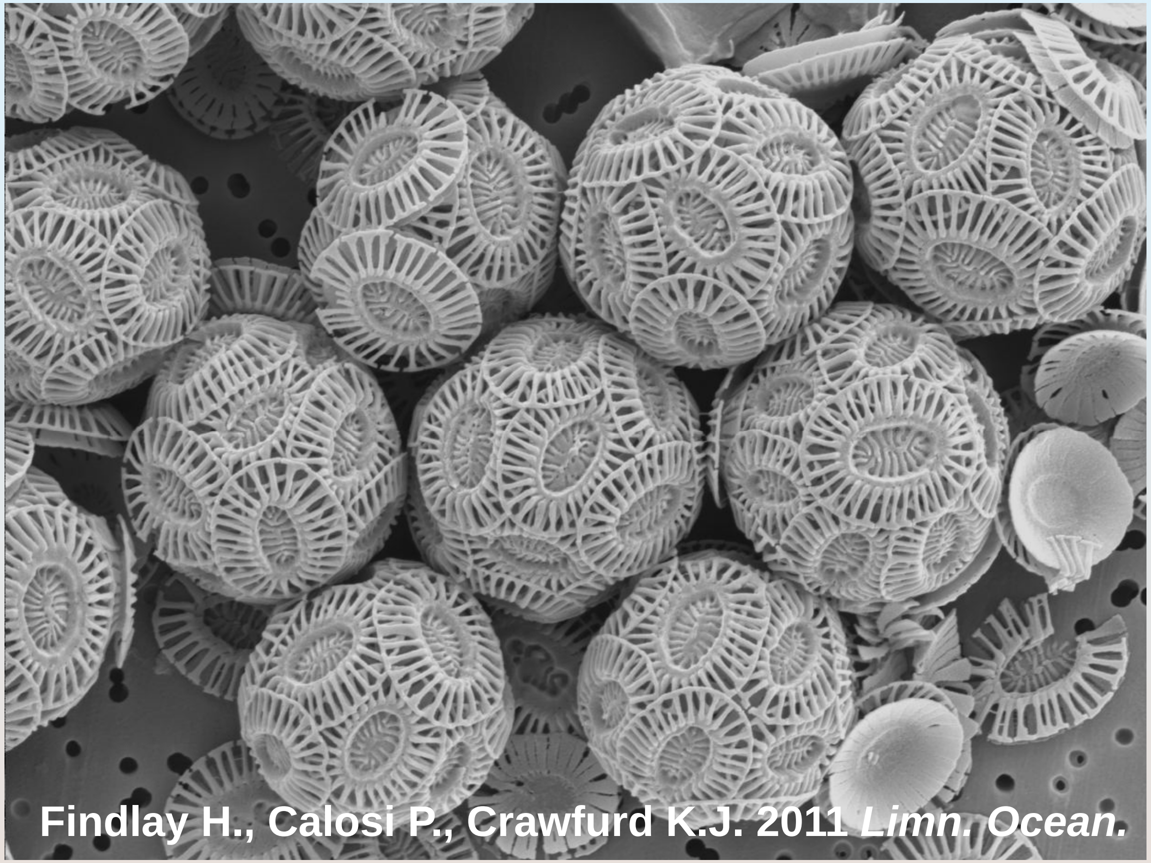
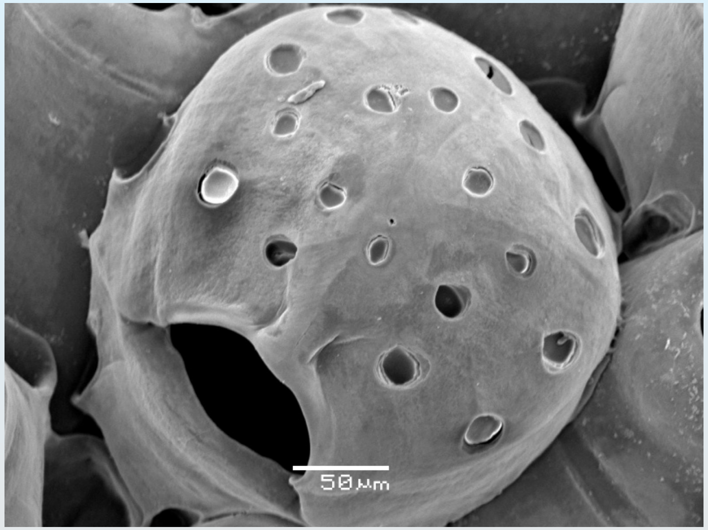


Findlay H., Calosi P., Crawfurd K.J. 2011 *Limn. Ocean.*



Pistevos J., Calosi P., Widdicombe S., Bishop J. 2011 *Oikos*

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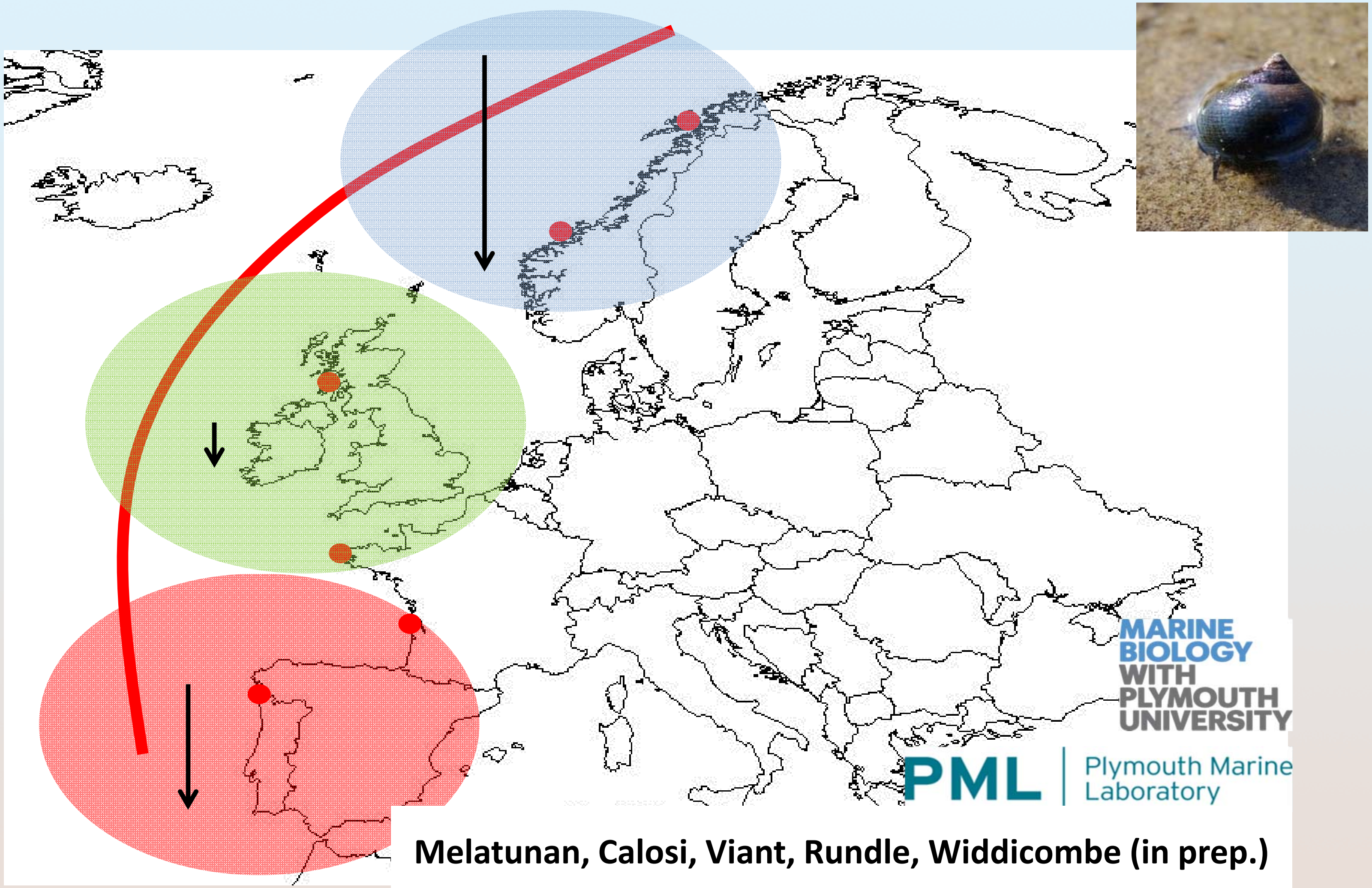

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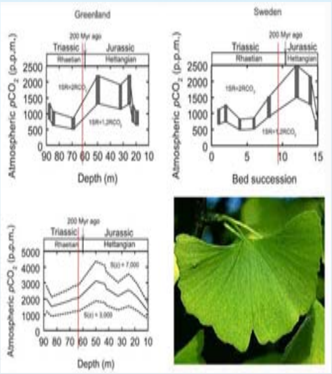
PML | Plymouth Marine Laboratory

Melatunan, Calosi, Viant, Rundle, Widdicombe (in prep.)

Evolutionary approaches . . . . .



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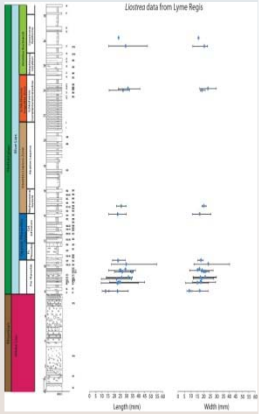

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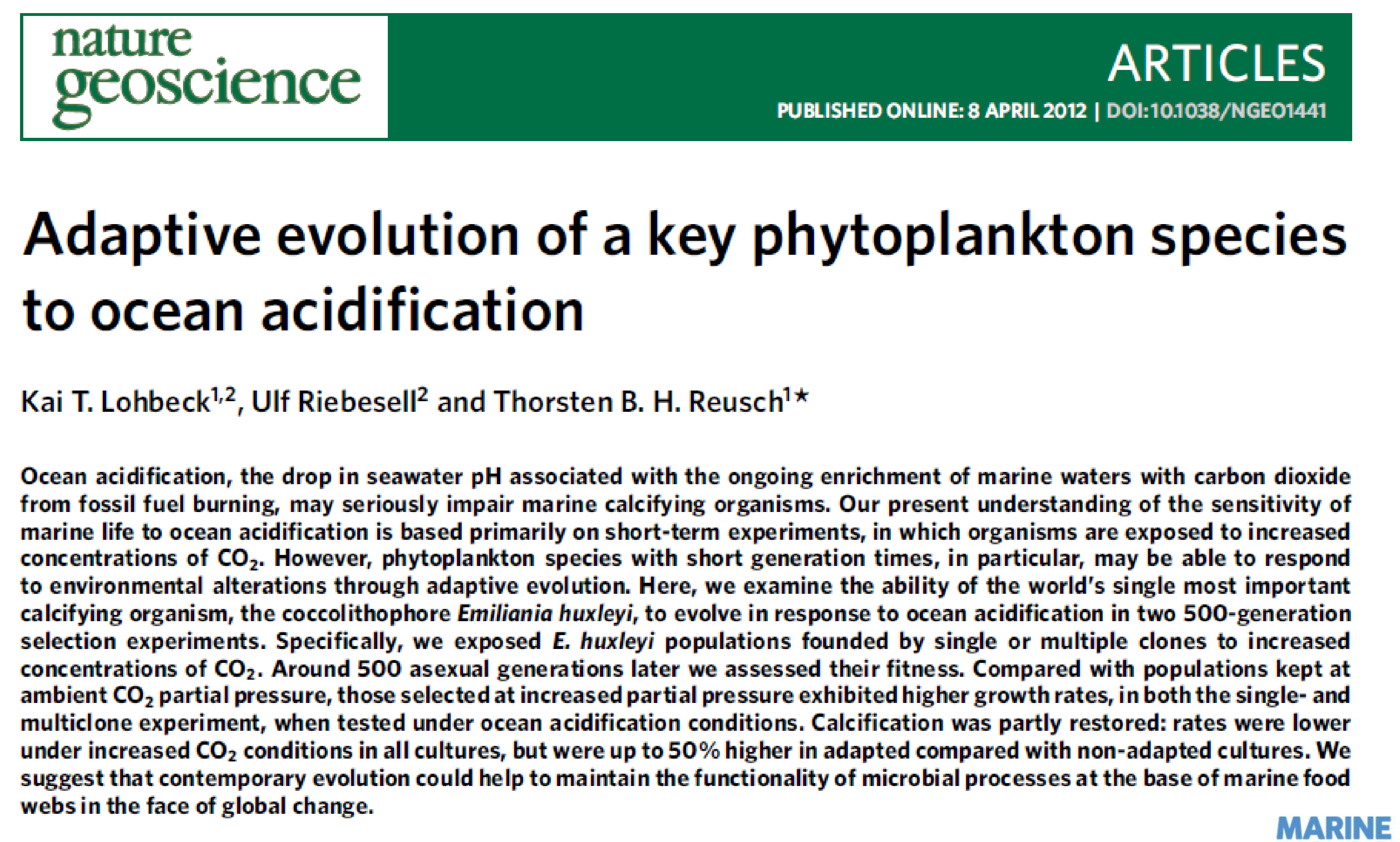
Do species possess the ability to adapt physiologically to rapid climatic changes?

Laboratory Natural Selection - *Experimental Evolution*



nature geoscience

ARTICLES

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Adaptive evolution of a key phytoplankton species to ocean acidification

Kai T. Lohbeck[1,2], Ulf Riebesell[2] and Thorsten B. H. Reusch[1]*

Ocean acidification, the drop in seawater pH associated with the ongoing enrichment of marine waters with carbon dioxide from fossil fuel burning, may seriously impair marine calcifying organisms. Our present understanding of the sensitivity of marine life to ocean acidification is based primarily on short-term experiments, in which organisms are exposed to increased concentrations of CO_2. However, phytoplankton species with short generation times, in particular, may be able to respond to environmental alterations through adaptive evolution. Here, we examine the ability of the world's single most important calcifying organism, the coccolithophore *Emiliania huxleyi*, to evolve in response to ocean acidification in two 500-generation selection experiments. Specifically, we exposed *E. huxleyi* populations founded by single or multiple clones to increased concentrations of CO_2. Around 500 asexual generations later we assessed their fitness. Compared with populations kept at ambient CO_2 partial pressure, those selected at increased partial pressure exhibited higher growth rates, in both the single- and multiclone experiment, when tested under ocean acidification conditions. Calcification was partly restored: rates were lower under increased CO_2 conditions in all cultures, but were up to 50% higher in adapted compared with non-adapted cultures. We suggest that contemporary evolution could help to maintain the functionality of microbial processes at the base of marine food webs in the face of global change.

Task 1.4 Identify the potential for organism resistance and adaptation to prolonged CO_2 exposure

H_0 Marine organisms will not have the potential to adapt to rapidly changing levels of CO_2 x temperature.

The extent to which marine biodiversity and ecosystem functioning will be impacted by elevated CO_2 x temperature in large part will be determined by the **potential of eco-physiological adaptation of marine organisms** to these stressors. Unfortunately, our knowledge on rates of eco-physiological adaptation in marine animals can, at present, only be inferred from either limited paleontological studies or laboratory studies of experimental evolution using model species . . . . . . In Task 1.4 we will **identify the potential for adaptation in 2 marine invertebrate species** . . . . . **in laboratory-based natural selection (LNS) experiments** . . . . .

Gammarus chevreuxi

Gammarus marinus

Gammarus duebeni

Experimental Apparatus and Design

Founders: large outbred population of the selected species, 5 independent lab lines for each treatment combination of CO_2 and temperature (as Task 1.1 & 1.2) and hypoxia established and maintained across several generations.

Assessment of key functions within and between generations:

- **metabolic rates**, **thermal limits,**
- **Na^+/K^+ ATPase activity/gene expression**, **carbonic anhydrase activity/gene expression,**
- **life history / reproduction**

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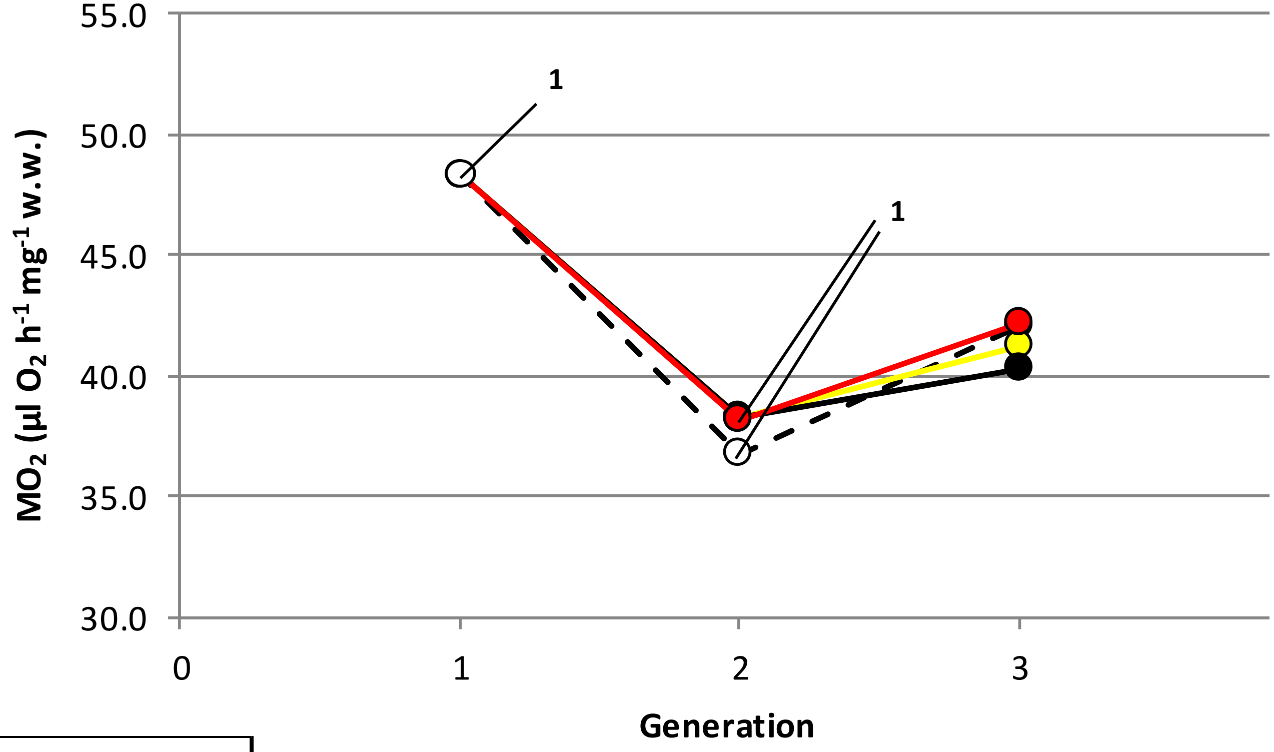
Metabolic rates



☐ control

🟨 CO_2

⬛ hypoxia

🟥 CO_2 * hypoxia

Gammarus marinus

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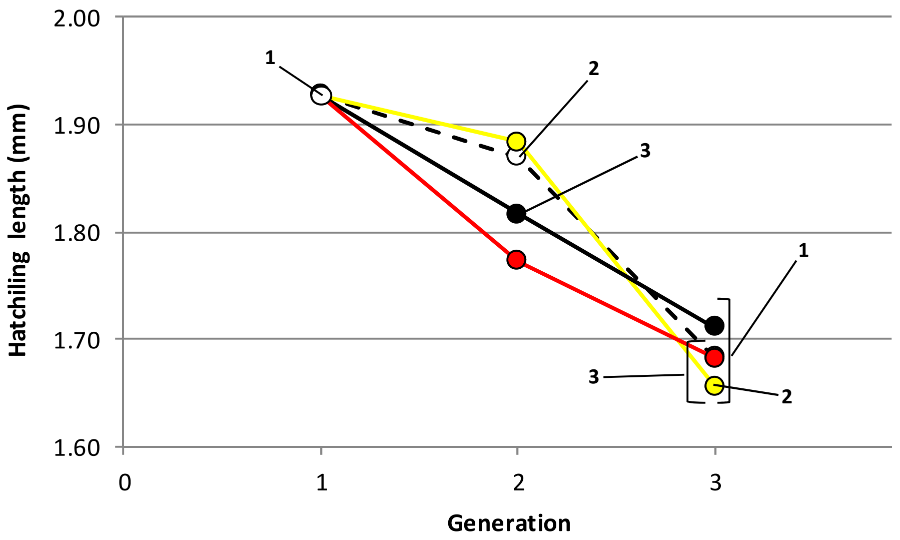
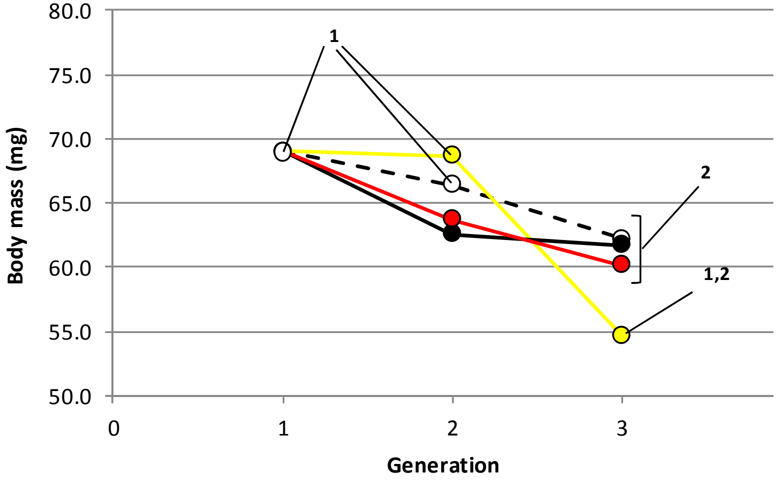
Life-history

Gammarus marinus





□ control

🟨 CO_2

⬛ hypoxia

🟥 CO_2 * hypoxia

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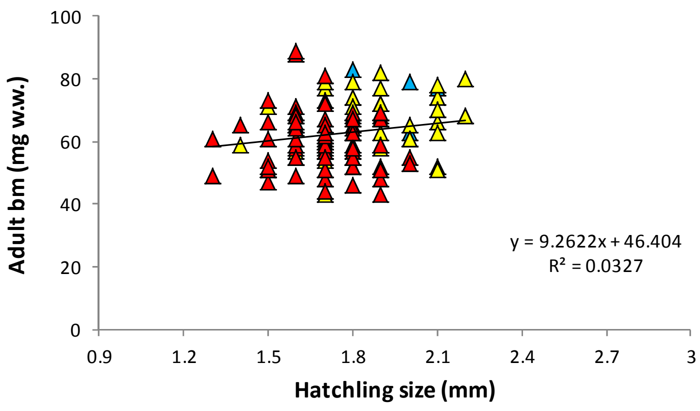
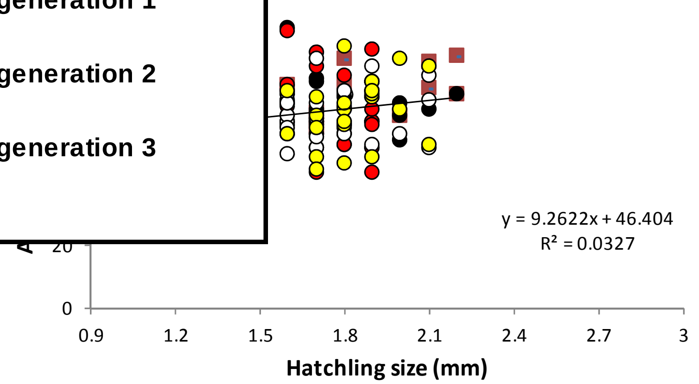
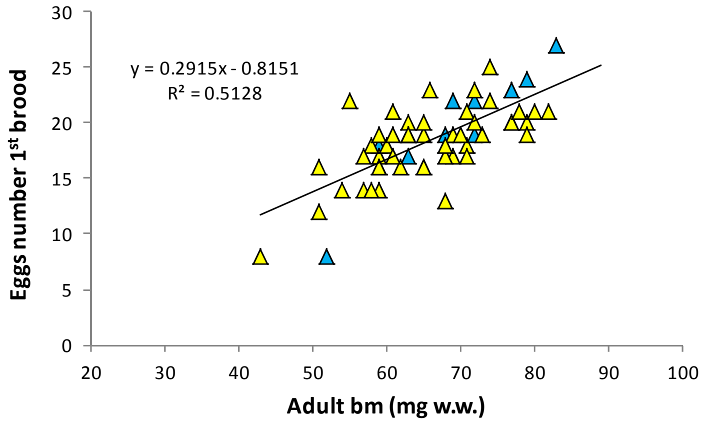
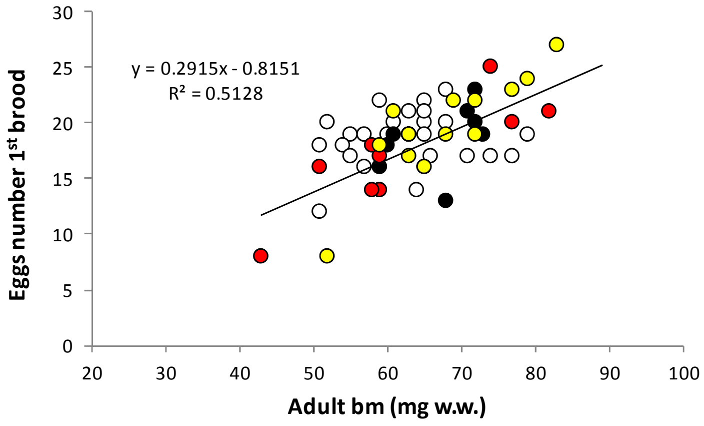
Relationships among traits

🟦	generation 1
🟨	generation 2
🟥	generation 3









Gammarus marinus

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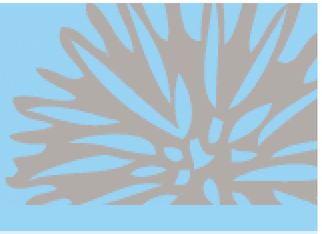


Remarks

- There might be preliminary indications that rapid adaptation may occur in gammarid amphipods, however relationships among traits do not seem to change across different generations or treatments.

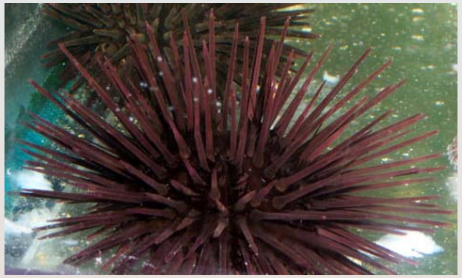
- Need to use an ‘*individual approach’* and conduct *‘cross over experiments’ and field verification*.

‘To validate the results generated in this task, we will measure a number of the same physiological functions in animals occurring naturally (and transplanted) in localities with natural CO_2 vents and in contiguous areas not affected by such vents’.

Sea Urchins

Acid-base-dependent distribution around a CO_2 vent

Characterisation of density and haemolymph acid-based and ionic status responses in sea urchins exposed *in-situ* to elevated pCO_2/low pH conditions (transplantation experiments).



Arbacia lixula

Paracentrotus lividus

Marine
Pollution
Bulletin
in review

Calosi P., Rastrick S.P.S., Graziano M., Hall-Spencer J., Milazzo M., Spicer J.I.

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Polychaetes

Metabolic adaptation in populations living around a CO_2 vent

STAZIONE ZOOLOGICA ANTON DOHRN • Napoli •

ENEA

Calosi P., Rastrick S.P.S., Lombardi C., Spicer J.I., Gambi M.C.

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MedSeA
MEDITERRANEAN SEA ACIDIFICATION IN A CHANGING CLIMATE

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