The impact of high pCO_2, both static and fluctuating, on whole-organism thermal tolerance.

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Aim: To investigate whether magnitude or variability of seawater pCO_2 has the greatest impact on thermal tolerance of marine ragworms

Background:

- One of the earliest effects of climate change has been a shift in species distribution
- Thermal tolerance is a key predictor of changes in species distribution
- However, climate change involves increasing pCO_2 as well as temperature
- Coastal pCO_2 is highly dynamic, varying temporally and spatially
- The impact of pCO_2 (magnitude or variability) on organismal thermal tolerance is poorly understood

Hypotheses:

1. The metabolic rate of the ragworm would be affected by either pCO_2 magnitude or regime

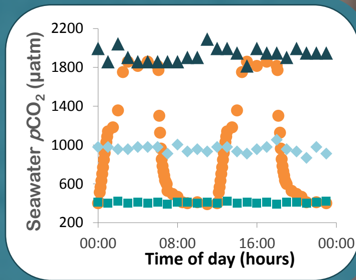
Fig 1: *Hediste diversicolor*

2. If metabolic rate differs between treatments, metabolic scope and thus thermal tolerance should also be affected.

Methods:

Ragworms were acclimated to one of four pCO_2 regimes prior to monitoring metabolic rate (closed respirometry), upper thermal tolerance (CT_{max}) and lower thermal tolerance (CT_{min}) (0.5 ˚C min^{-1}). Treatments represent current (400 µatm static), 2100 RCP 8.5 (950 µatm static) and 2300 A2 (1900 µatm static) emissions scenarios. We also included a fluctuating treatment representing a semi-diurnal tidal cycle (cycling between 400 µatm and 1900 µatm) (Fig. 2).

Fig 2: Daily regime of seawater pCO_2. Static 400 µatm (blue squares), static 950 µatm (light blue diamonds), static pH 1900 µatm (dark blue triangles) and fluctuating 400-1900 µatm (orange circles)



Results :

Metabolic rate

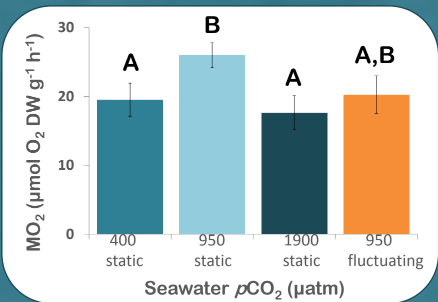


Fig 3: Metabolic rate of *H. diversicolor* chronically exposed to elevated seawater pCO_2. Blue bars (static pCO_2 exposure), Orange bars (fluctuating pCO_2 exposure). Significant differences ($p < 0.05$) indicated by different letters.

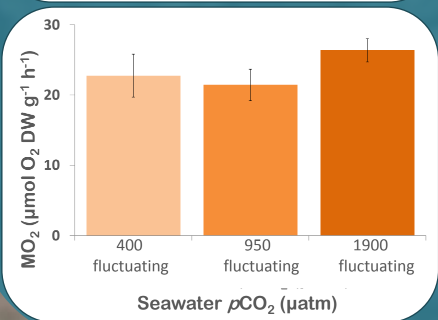


Fig 4: Metabolic rate of *H. diversicolor* during chronic exposure to fluctuating seawater pCO_2 measured at three points of the fluctuating cycle (400µatm, 950µatm and 1900µatm). Significant differences ($p < 0.05$) indicated by different letters.

Thermal tolerance

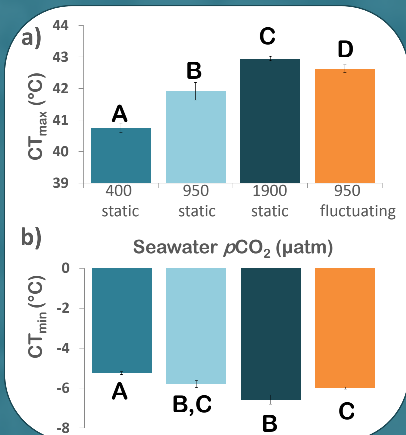


Fig 5: Thermal limits of *H. diversicolor*: a) CT_{max} and b) CT_{min} after chronic exposure to elevated seawater pCO_2. Blue bars (static pCO_2 exposure), Orange bars (fluctuating pCO_2 exposure). Significant differences ($p < 0.05$) indicated by different letters.

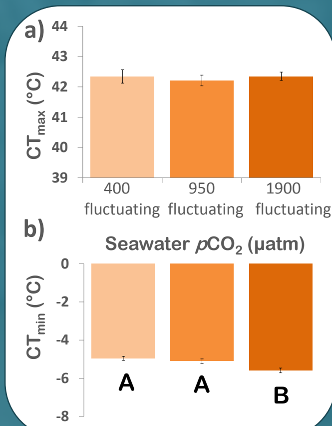


Fig 6: Thermal limits of *H. diversicolor* a) CT_{max} and b) CT_{min} measured at three points of the fluctuating pCO_2 cycle (400µatm, 950µatm and 1900µatm). Significant differences ($p < 0.05$) indicated by different letters

Summary:

- Understanding the influence of pCO_2 on thermal tolerance is key to accurately project/model species distribution shifts in a changing ocean.
- There was a bimodal effect of static pCO_2 exposure on metabolic rate, being highest at 950 µatm. There was no effect on metabolic rate across the range pCO_2 values measured in the fluctuating treatment.
- Unlike metabolic rate, thermal tolerance increased in proportion to the elevation of pCO_2 during static exposures, i.e. increasing CT_{max} and decreasing CT_{min}. Fluctuating pCO_2 also increased thermal tolerance, similar to the effect of the highest static pCO_2, and this was largely unaffected by the point in the fluctuating pCO_2 cycle it was measured at.

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