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Effects of elevated pCO_2 levels on the response of *Acropora cervicornis* to heat stress

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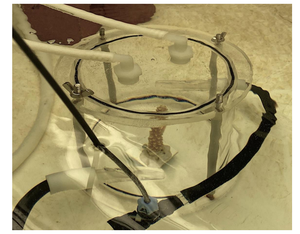

Abstract

Previous studies on the impact of ocean acidification on scleractinian corals have largely focused on impairment of calcification. More recent studies suggest that decreased calcification rates may not be the primary effect of acidification but rather an indication of inhibition of cellular metabolic processes. I investigated the effect of pH on the growth, photophysiology, and survivorship of *Acropora cervicornis* by exposing fragments to two different levels of pCO_2: ambient (400ppm) and elevated (1000ppm, projected to occur in the next 40-50 years[1]. Tanks were maintained at 30˚C and then ramped 0.3˚C every day until they reached 32˚C. Corals (n=10) in the CO_2-enriched treatment exhibited significant reductions in calcification, linear extension, and net photosynthetic rates even before ramping began (i.e, while at 30˚C). Furthermore, fragments in the high CO_2 treatment were only able to withstand half as many days at 32˚C as those in the low CO_2 treatment (7.5 and 14.0 days respectively) before perishing (as defined as tissue sloughing). Consequently, *A. cervicornis* is predicted to experience significant reductions in its growth and overall survival in the coming decades as temperature and CO_2 emissions continue to increase.

Introduction

- Elevated temperatures damage the photosystem and incite coral bleaching (i.e. breakdown of coral/algal symbiosis)
- Previous ocean acidification studies largely investigate impacts on calcification and growth
  - Not much is known about symbiosis interactions under pH stress
- In order to calcify, corals must upregulate their internal pH at extracellular calcifying matrix
  - While they try to hold this constant, internal pH falls as seawater increases in acidity[2]
- Results in acidosis and metabolic suppression
  - Short term: adaptive response
  - Long term: leaves corals highly susceptible to other environmental stressors
    - Corals may be unable to appropriately respond to thermal stress in lower pH

Aim

To investigate the effects of heat stress on *Acropora cervicornis* after eight months of pre-exposure to 1000 ppm CO_2 (the level of CO_2 that corals may begin to experience year-round in 40-50 years)[1]

Methods

- Two tanks at 30˚C, each with fragments (n=10) from five different genotypic families were maintained at two different treatment pCO_2 levels: ambient/low (400 ppm) and high (1000 ppm) for 8 months.
- Data collection began 30 days before the tanks were ramped up 0.3˚C/day until they reached 32˚C
- Buoyant weight & linear extension were measured during acclimation (1x week) & experimentation (3x week)
- Respiration & net photosynthesis (NP) were observed as O_2 output using intermittent flow respirometers
  - Individual fragments were placed in airtight chambers and NP was normalized to coral surface area

Results

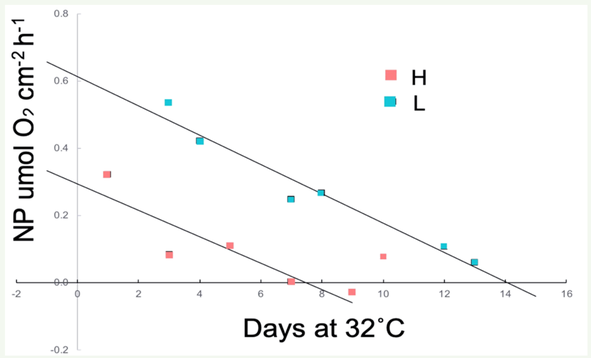

Fig. 1 Averaged net photosynthetic rates (umol O_2/cm^2h) for fragments with best-fit linear regression lines for high (H) and low (L) CO_2 treatments

- No fragments (n=20) were able to handle sustained temperatures of 32˚C for more than 18 days in ambient CO_2 (L) and 12 days in elevated CO_2 (H) treatment
- Corals reached negative or zero net photosynthesis (NP) rates on day 7.5 in H and on day 14 in L
- All exhibited steady linear decrease of NP rates as duration of thermal stress increased

- Significantly higher net photosynthesis ($p<1e-9$), calcification ($p<0.0001$), and linear extension ($p<0.001$) rates in the low CO_2 treatment even before ramping of tanks (i.e. at 30˚C)
- Calcification and linear extension rates were significantly impaired by pCO_2 levels at 32˚C
- Parents exhibited slight genotypic variability in ability to maintain NP rates, calcification rates, and linear extension rates

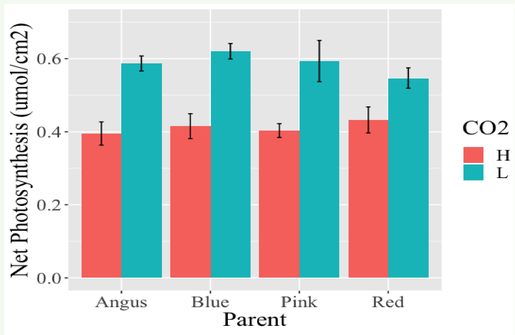

Fig. 2. Average net photosynthetic rates (umol/cm^2) ± SE by parent genotype during the 30-day acclimation period at 30˚C before thermal stress was introduced

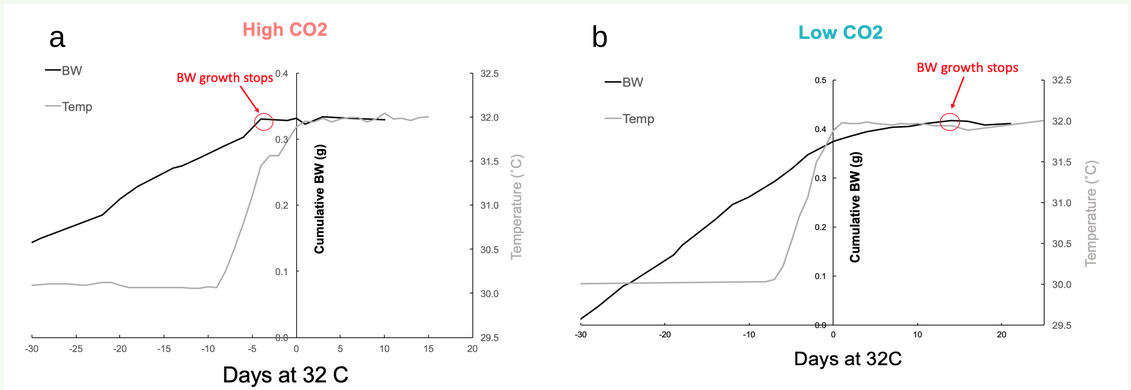

Fig. 3. Cumulative change in buoyant weight of corals (black) overlaid with the temperature of the tank (grey). At Day -7, ramping of 0.3˚C began until it reached 32˚C at Day 0. Indicated in red is the day in which progressive buoyant weight (BW) calcification stopped. **3a.** BW growth stopped at day -5 in high CO_2 treatment **3b.** BW growth stopped on day 14 in the low CO_2 treatment

Discussion

- Survivorship of fragments in H treatment decreased significantly
- No fragments were able to withstand more than 19 days at 32˚C regardless of pCO_2 treatment

Fig. 4a. *Acropora cervicornis* fragments in the low treatment on Day 4 at 32˚C. Corals are paired by genotype with families from left to right being Bernadette, Blue, Angus, Pink, and Red

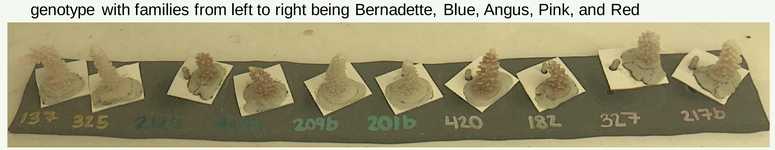

Fig. 4b. The same fragments 14 days later on Day 18 at 32˚C. At this time, genotypes Bernadette (far left), Angus (middle), and Red (far right) were already declared dead (as indicated by tissue sloughing)

- Progressive calcification rates stopped before linear extension rates ceased
- Corals in H treatment likely had reduced skeletal integrity
- pCO_2 significantly impaired photosynthetic capability
- Fragments in the low CO_2 treatments were able to maintain positive net photosynthetic rates for twice as long
- H treatment corals were unable to maintain internal pH and entered metabolic suppression, increasing susceptibility to thermal stress

Conclusions

- **Pre-exposure of *Acropora cervicornis* to elevated pCO_2 levels of 1000 ppm reduced its survival time at 32˚C by nearly half when compared to those in ambient (400 ppm) pCO_2 levels**
- In the next 40-50 years, projected pCO_2 levels of 1000 ppm[1] will significantly impair the growth & survival of *A. cervicornis*
- Potential adaptations to thermal stress be offset or overweighed by ocean acidification
- Ability of *A. cervicornis* to respond to thermal stress is impaired by cellular acidosis

References/Acknowledgements

1. Langdon, C., R. Albright, A. C. Baker, and P. Jones. 2018. Two threatened Caribbean coral species have contrasting responses to combined temperature and acidification stress. Limnology and Oceanography **63**:2450-2464
2. Venn, A. E. Tambutté, M. Holcomb, D. Allemand, and S. Tambutté. 2011. Live tissue imaging shows reef corals elevate pH under their calcifying tissue relative to seawater. PloS one **6**:e20013-e20013

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