A literature review of ocean acidification's effect on coral calcification rates and skeletal growth

BROWARD COLLEGE

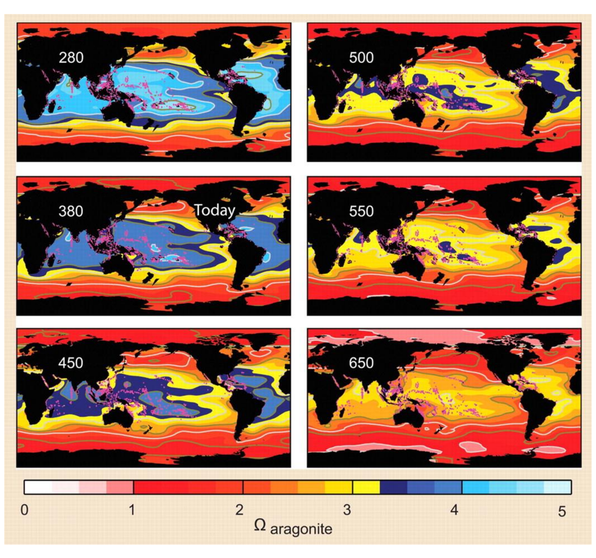
Lauren Camden | Broward College | camdl@mail.broward.edu

Research Question

How will ocean acidification affect the calcification rates, and therefore the growth and development, of coral in the coming years worldwide?

Introduction

- Ocean acidification is a result of increased anthropogenic atmospheric carbon dioxide being absorbed by the world's oceans
- About 25% of all carbon dioxide emitted from human activities into the atmosphere is absorbed by the ocean
- Carbon dioxide levels are currently increasing at a rate of approximately 2.2 parts per million annually
- CO2 reacts with sea water to produce two positively charged ions, causing a lowered pH, or a more acidic ocean
- These positive ions react with negative bases in the water such as CaCO3- carbonate ions
- Hydrogen saturation and carbonate saturation have an inverse relationship
- This chemical reaction means less carbonate ions being available for calcifying marine organisms to build their skeletons
- As calcification rate slows, coral are unable to maintain
  - Skeletal density
  - Linear expansion rate
  - Reproduction rate



(Heogh-Guldberg et al, 2007)

Aragonite is a mineral form of calcium carbonate. This figure shows the changes in ocean water aragonite saturation predicted to occur with increasing levels of ppm of atmospheric CO2 saturation exhibited in white at the top left of each panel. Coral reef locations are shown as pink dots.

Methods

Langdon & Atkinson, 2005

- Coral specimens were collected off the coast of Hawaii and placed in an offshore experimental flume
- A series of incubations of the samples were performed in Summer 1999 and Winter 2000
- 18 summer incubations were performed with ambient (natural) pCO2 conditions and 9 were performed with elevated pCO2 levels of 1.7x
- 15 winter incubations were performed with 6 at ambient conditions, 2 at 1.4x, and 6 at 2.0x
- Calcification rates were determined through statistical analysis

Okazaki et al, 2013

- 20 coral samples were collected at 4 sites near Peterson Key in the Florida Bay
- Samples were epoxied to plastic tiles which were then attached to cinder blocks
- A random subset of samples were incubated in a chamber in situ simulated to represent an increase of 500-800 ppm of CO2
- NaHCO3 and HCl were injected into chambers to elevate pCO2
- Calcification rates were calculated using statistical analysis from April 2007- November 2010

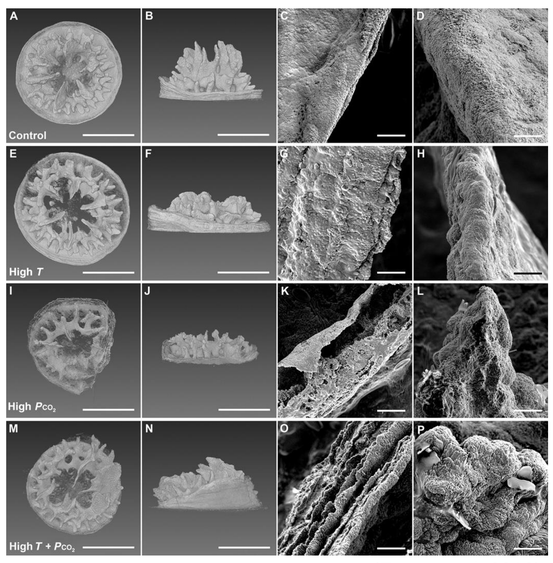
Foster et al, 2016

- Fertilized coral samples were collected during the 2013 mass spawning event off the coast of Australia
- Larvae were transferred to an offshore outdoor aquarium and allowed to reach the juvenile stage
- They were then grown for 1 month under four different regimes: control, elevated temperature, elevated pCO2, elevated temperature and pCO2
- Skeletons were analyzed using 3D x-ray microscopy and scanning electron microscopy

Results

X-ray microscopy and scanning electron microscopy images of the coral skeletons under the four temperature-pCO2 treatment regimes

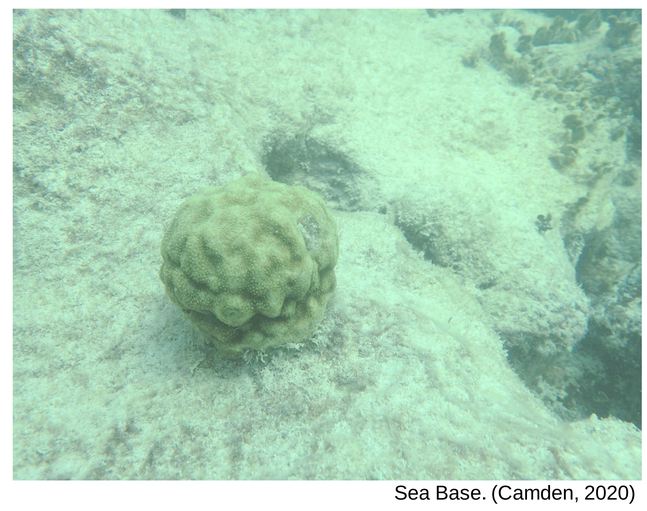
- Control- 24 degrees C, pH 8.2
- Elevated Temperature- 27 degrees C, pH 8.2
- Elevated pCO2- 24 degrees C, pH7.7
- Elevated temperature and pCO2- 27 degrees C, pH 7.7



(Foster et al, 2016)

- Langdon & Atkinson, 2005
  - Calcification regularly decreased when pCO2 was adjusted from ambient conditions
  - In August 1999, calcification rates decreased around 44% with a 1.7x increase
  - In January 2000, calcification rates decreased 26% with a 1.4x increase and 80% with a 2.0x increase
- Okazaki et al, 2013
  - Calcification rates decreased 52% with a pCO2 elevated to simulate a drop in pH of 0.2 units over a 2-year period
  - Calcification rates decreased 50% with a pCO2 elevated to simulate a drop in pH of 0.1 units over a 2-year period
- Foster et al, 2016
  - Corals exposed to high pCO2 had an array of deformities such as lowered density, missing portions of skeleton, reduced linear expansion
  - Fractures were observed in 50% of corals grown at high pCO2

Sea Base. (Camden, 2020)



Sea Base. (Camden, 2020)

Recommendations & Conclusion

- Calcification rates and acidification levels (increased pCO2 and decreased pH units) are directly related in reefs observed worldwide
- As a result, structural deformities in coral skeletons are observed with increasing severity, leading to fractures, decreased density, and reduced linear expansion
- Future reefs will move towards net carbonate dissolution and be unable to build their skeletons as atmospheric CO2 levels continue to rise
- Further research is needed regarding the influence of various environmental factors such as light exposure, pollution, and nutrient levels when paired with increased pCO2 on calcification levels
- Further research is needed regarding stress and acidic environment resistant and resilient coral species

References

- Camden, L. (2020, March). *Sea base* [Photograph]. JPEG file.
- Foster, T., Falter, J., McCulloch, M., & Clode, P. (2016). Ocean acidification causes structural deformities in juvenile coral skeletons. *Science Advances, 2*(2), 1-7. https://doi.org/10.1126/sciadv.1501130
- Hoegh-Guldberg, O., Mumby, P., Hooten, A., Steneck, R., Greenfield, P., Gomez, E., Harvell, C., Sale, P., Edwards, A., Caldeira K., Knowlton N., Eakin, E., Iglesias-Prieto, R., Muthiga, N., Bradbury R., Dubi, A., & Hatziolos, M. (2007, December 14). Coral reefs under rapid climate change and ocean acidification. *Science, 318*(5858), 1731-1742. https://doi.org/10.1126/science.1152509
- Langdon, C., & Atkinson, M. (2005, September 7). Effect of elevated pCO2 on photosynthesis and calcification of corals and interaction with seasonal change in temperature/irradiance and nutrient enrichment. *Journal of Geophysical Research, 110*, 1-16. https://doi.org/10.1029/2004JC002576
- Okazaki, R. R., Swart, P. K., & Langdon, C. (2013). Stress-tolerant corals of Florida Bay are vulnerable to ocean acidification. *Coral Reefs, 32*(3), 671-683. https://doi.org/10.1007/s00338-013-1015-3
- Mathis, J. T. (2019, March). *Ocean acidification*. Access Science. https://doi.org/10.1036/1097-8542.463750