

Response of Coral Reef to Ocean Acidification

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NDSU Geochemistry 428

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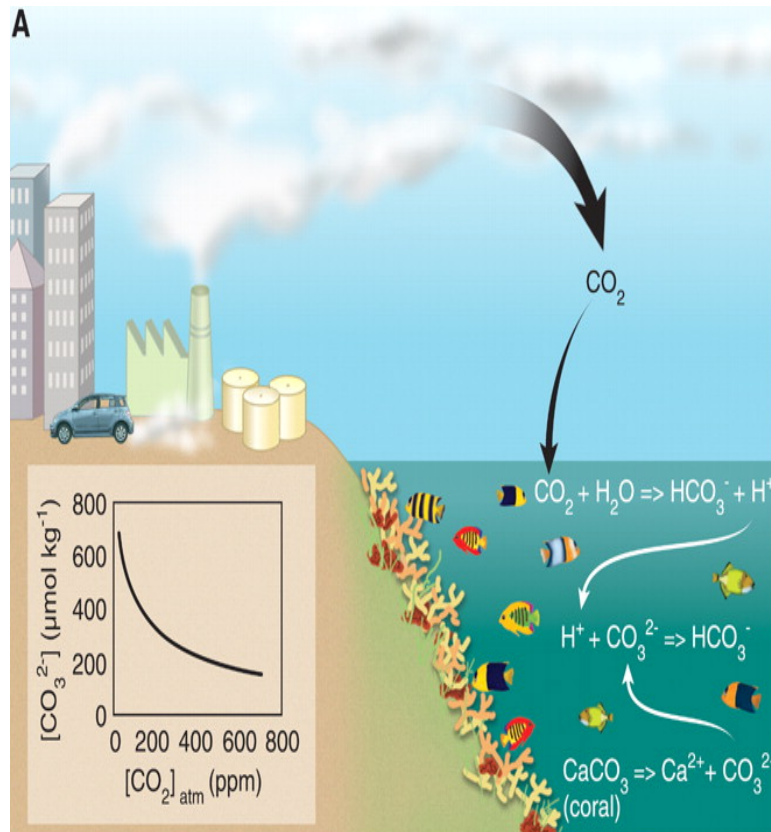
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Back Ground

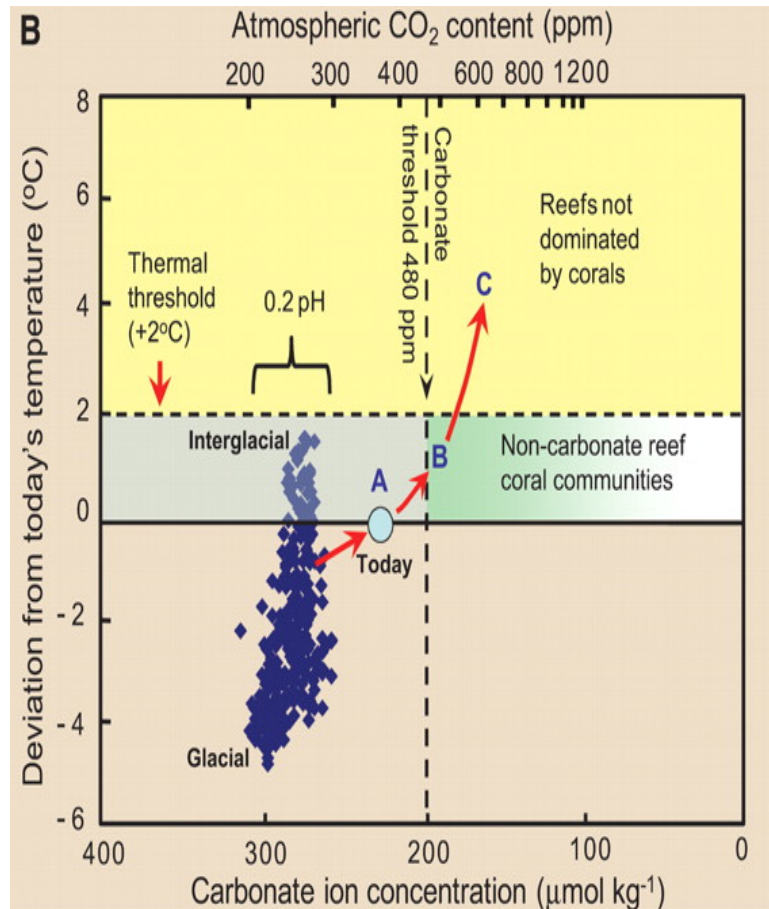
- Atmospheric carbon dioxide concentration is expected to exceed 500ppm and global temperature is expected to rise by at least 2°C by 2050 to 2100.
- Under conditions expected in the 21st century, global warming and ocean acidification will compromise carbonate accretion, with corals becoming increasingly rare on reef systems.

Warming and Acidifying Seas



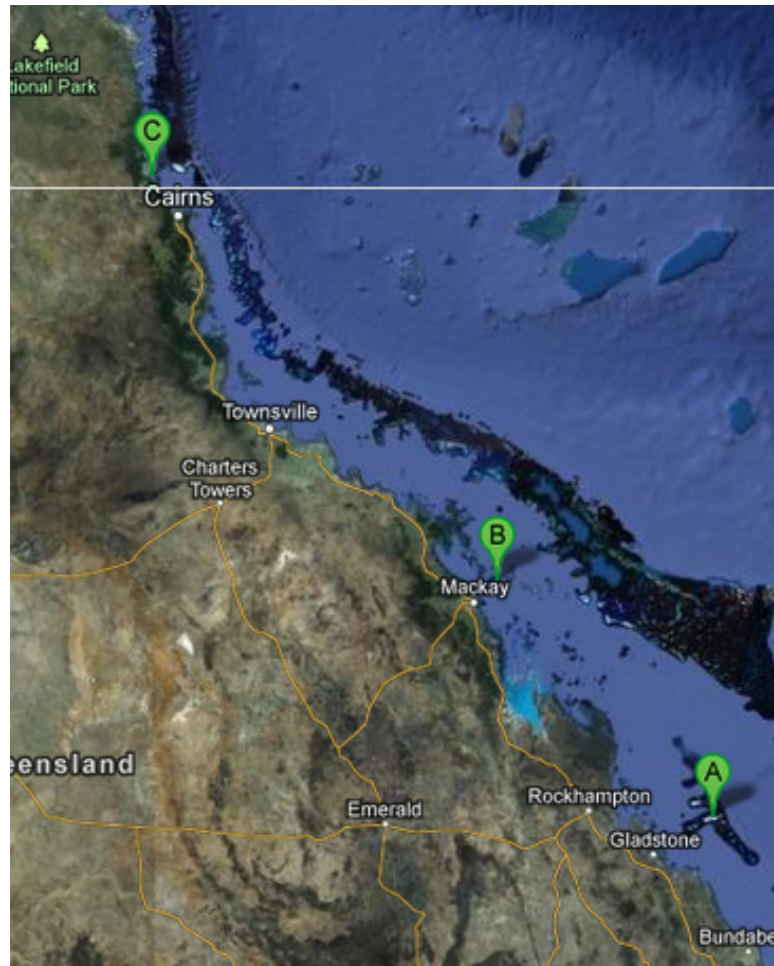
- Linkage between buildup of atmospheric carbon dioxide and the slowing of coral calcification due to ocean acidification
- Increasing atmospheric carbon dioxide concentration, and hydrogen concentration also increase (ocean acidification), and decrease of concentration of carbonate
- Making it unavailable to marine corals

Warming and Acidifying Seas



- Relation between temperature, [CO₂]_{atm}, and carbonate-ion concentrations
- The thresholds for major changes to coral communities are indicated for thermal stress(+2°C) and carbonate-ion concentrations.
- The arrows pointing progressively toward the right hand top square

Example of Response to Ocean Acidification



- Great Barrier Reef
- A : reef slope at Heron Island
- B : coral communities associated with inshore reefs around St. Bees Island
- C : reef slope around Port Douglas
- Not in same place, but

How to use 'CO₂Calc'

The screenshot displays the 'CO₂calc' application window in 'Single-Point Mode'. The interface is organized into several sections for data entry:

- Sample Information:** Includes fields for Name (Port Douglas), Date (2012.12.2), Latitude, Longitude, Time (7:04:14), and a checkbox for 'Record calculation'.
- Physical Data:** Contains Salinity, temperature (°C), and Pressure (dbars), each with a 'required' label and a red underline.
- Adjusted Conditions:** Includes temperature (°C) and Pressure (dbars) with 'optional' labels.
- Carbonate Data:** Includes TA, TCO₂, pH, fCO₂ water, and pCO₂ water, each with a 'choose 2 of 5*' label and a red underline.
- Nutrient Data:** Includes Total P and Total Si, both with 'optional' labels.
- Air-sea CO₂ Flux:** Includes pCO₂ Air and Windspeed* in m/s, both with 'optional' labels.

At the bottom, there is a section for constants and scales, including 'CO₂ Constants: Millero, 2010', 'KHSO₄: Khoo et al. (1977)', 'pH Scale: Seawater scale (mol/kgSW)', and 'Air-Sea Flux: Ho et al., 2006'. A 'Process' button is located at the bottom right.

- 'CO₂Calc'
- Application for the calculation of carbonate system
- developed by finding Ecosystems Response to Climate Change Project in response to its Ocean Acidification Task
- Fill out required data and then get the value that we want

How to use 'CO₂Calc'

CO2calc

Single-Point Mode Batch Processing

Sample Information

Name: Port Douglas Date: 2012 .12 . 2 Latitude in decimal degrees: optional New File... Open File... ☐ Record calculation

Comment: optional Time: 오후 7:04:14 Longitude in decimal degrees: optional

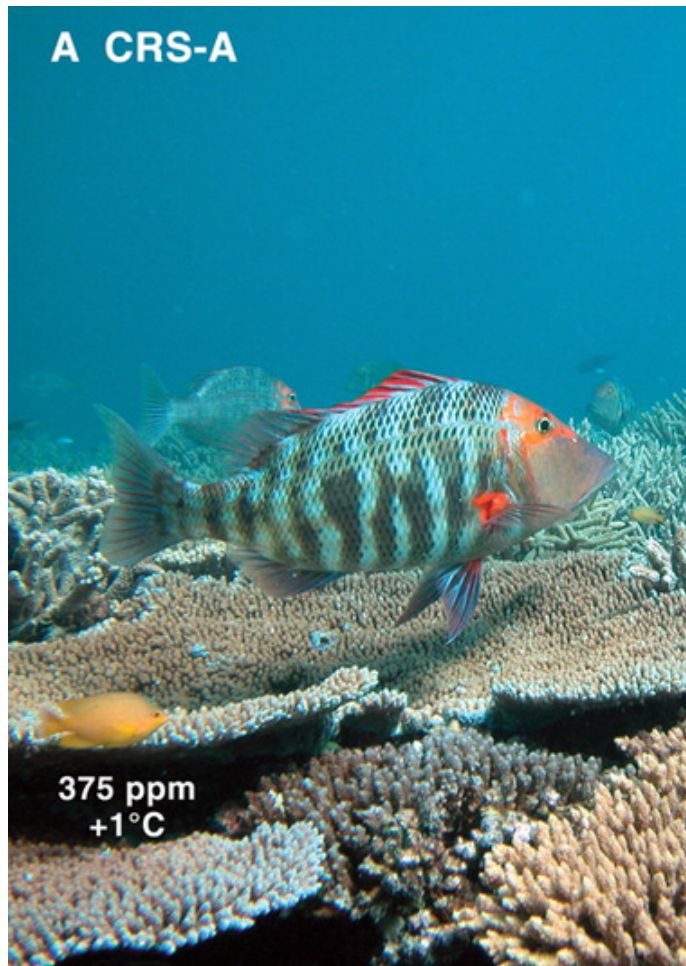
Input Results

Results at input conditions Results at adjusted conditions

Physical Data (adjusted)	Carbonate Results (adj.)	Auxiliary Results (adjusted)	
Salinity: 34.000	TA (μmol/kgSW): 2500.000	HCO ₃ (μmol/kgSW): 1764.465	Si Alk (μmol/kgSW): 0.000
temperature (°C): 25.000	TCO ₂ (μmol/kgSW): 2078.350	CO ₃ (μmol/kgSW): 305.919	Revelle: 8.489
Pressure (dbars): 0.000	pH (chosen scale): 8.190	CO ₂ (μmol/kgSW): 7.966	Ω Ca: 7.425
	fCO ₂ water (μatm): 279.107	B Alk (μmol/kgSW): 114.328	Ω Ar: 4.885
Nutrient Data	pCO ₂ water (μatm): 280.000	OH (μmol/kgSW): 9.374	CO ₂ (dry at 1 atm): 288.860
Total P (μmol/kgSW): 0.000	Air-sea CO ₂ Flux (adj.): 0.000	P Alk (μmol/kgSW): 0.000	
Total Si (μmol/kgSW): 0.000	Air-Sea Flux (mmol/m ² /day): 0.000		

CO₂ Constants: [Millero, 2010](#)
KHSO₄: [Khoo et al. \(1977\)](#)
pH Scale: [Seawater scale \(mol/kgSW\)](#) Air-Sea Flux: [Ho et al., 2006](#)

Result



Sample Information

Name: Heron Island Date: 2012.12.2. Latitude in decimal degrees: optional
Comment: optional Time: 오후 5:31:35 Longitude in decimal degrees: optional
Record calculation: ☐

Input Results

Results at input conditions Results at adjusted conditions

Physical Data (adjusted)	Carbonate Results (adj.)	Auxiliary Results (adjusted)	
Salinity: 34.700	TA (μmol/kgSW): 2408.726	HCO ₃ (μmol/kgSW): 1770.617	Si Alk (μmol/kgSW): 0.000
temperature (°C): 28.000	TCO ₂ (μmol/kgSW): 2044.049	CO ₃ (μmol/kgSW): 263.556	Revelle: 8.872
Pressure (dbars): 0.000	pH (chosen scale): 8.070	CO ₂ (μmol/kgSW): 9.876	Ω Ca: 2.006
	fCO ₂ water (μatm): 373.847	B Alk (μmol/kgSW): 101.636	Ω Ar: 4.253
Nutrient Data	pCO ₂ water (μatm): 375.000	OH (μmol/kgSW): 9.371	xCO ₂ (dry at 1 atm): 0.000
Total P (μmol/kgSW): 0.000		P Alk (μmol/kgSW): 0.000	
Total Si (μmol/kgSW): 0.000	Air-sea CO ₂ Flux (adj.): 0.000		
	Air-Sea Flux (mmol/m ² /day): 0.000		

A little bit changed but remain coral dominated and carbonate accreting

Result



Sample Information

Name	Date	get	Latitude in decimal degrees	New File...
St. Bees Island	2012 .12 . 2.		optional	Open File...
Comment	Time	get	Longitude in decimal degrees	
optional	오후 5:36:37		optional	☐ Record calculation

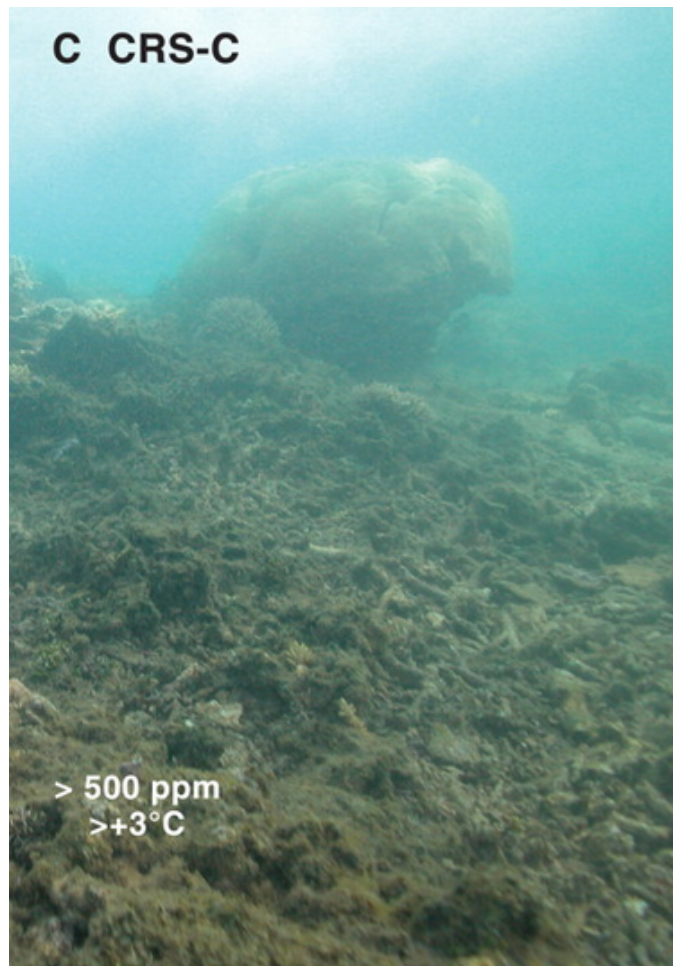
Input Results

Results at input conditions Results at adjusted conditions

Physical Data (adjusted)	Carbonate Results (adj.)	Auxiliary Results (adjusted)	
Salinity	TA (μmol/kgSW)	HCO ₃ (μmol/kgSW)	Si Alk (μmol/kgSW)
34.700	2123.875	1655.447	0.000
temperature (°C)	TCO ₂ (μmol/kgSW)	CO ₃ (μmol/kgSW)	Revelle
29.000	1856.996	189.331	9.629
Pressure (dbars)	pH (chosen scale)	CO ₂ (μmol/kgSW)	Ω Ca
0.000	7.940	12.218	
	fCO ₂ water (μatm)	B Alk (μmol/kgSW)	Ω Ar
	473.556	82.204	3.072
Nutrient Data	pCO ₂ water (μatm)	OH (μmol/kgSW)	xCO ₂ (dry at 1 atm)
Total P (μmol/kgSW)	475.000	7.575	
0.000	Air-sea CO ₂ Flux (adj.)	P Alk (μmol/kgSW)	494.162
Total Si (μmol/kgSW)	Air-Sea Flux	0.000	
0.000	(mmol/m ² /day)		
	0.000		

Higher CO₂, some areas becoming dominated by more thermally tolerant corals

Result



Sample Information

Name: Port Douglas Date: 2012 .12 . 2. Latitude in decimal degrees: optional

Comment: optional Time: 오후 5:43:46 Longitude in decimal degrees: optional

☐ Record calculation

Results at input conditions Results at adjusted conditions

Physical Data (adjusted)	Carbonate Results (adj.)	Auxiliary Results (adjusted)	
Salinity: 34.700	TA ($\mu\text{mol/kgSW}$): 2179.254	HCO ₃ ($\mu\text{mol/kgSW}$): 1738.116	Si Alk ($\mu\text{mol/kgSW}$): 0.000
temperature (°C): 30.000	TCO ₂ ($\mu\text{mol/kgSW}$): 1931.998	CO ₃ ($\mu\text{mol/kgSW}$): 179.430	Revelle: 10.157
Pressure (dbars): 0.000	pH (chosen scale): 7.880	CO ₂ ($\mu\text{mol/kgSW}$): 14.452	Ω Ca: 0.000
	fCO ₂ water (μatm): 573.273	B Alk ($\mu\text{mol/kgSW}$): 75.102	Ω Ar: 2.928
Nutrient Data	pCO ₂ water (μatm): 575.000	OH ($\mu\text{mol/kgSW}$): 7.189	xCO ₂ (dry at 1 atm): 0.000
Total P ($\mu\text{mol/kgSW}$): 0.000	Air-sea CO ₂ Flux (adj.): 0.000	P Alk ($\mu\text{mol/kgSW}$): 0.000	
Total Si ($\mu\text{mol/kgSW}$): 0.000	Air-Sea Flux (mmol/m ² /day): 0.000		

Density and diversity of corals on reefs decline, including losses of coral associated fish

Result

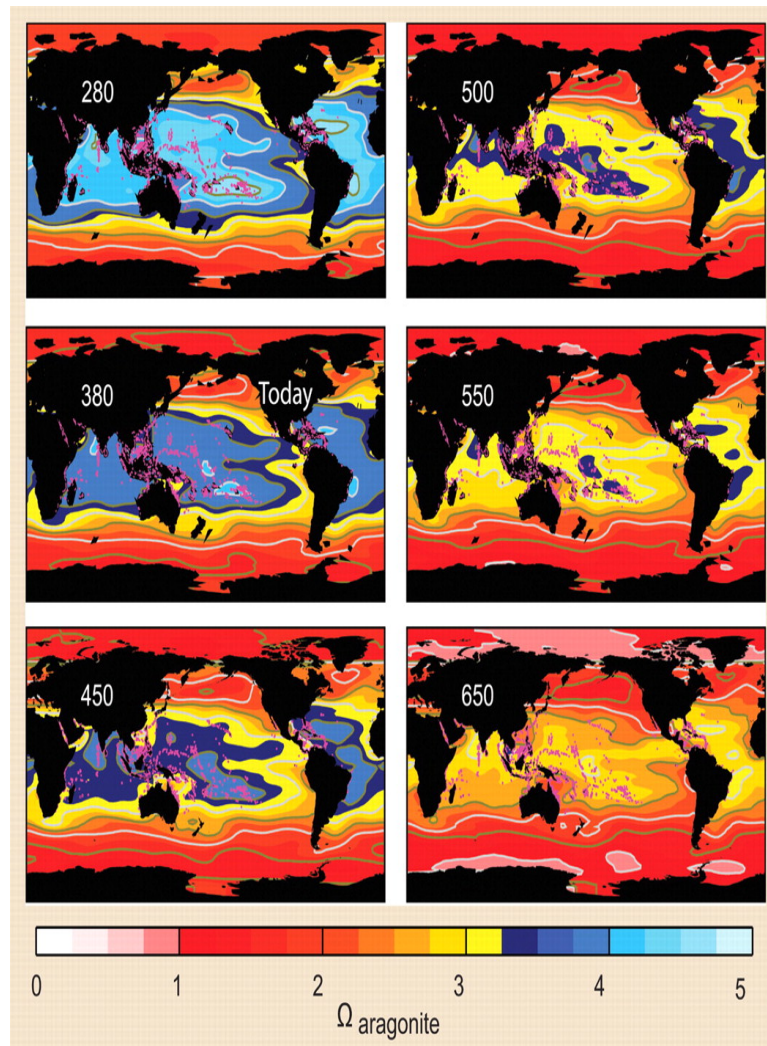
	A		B		C	
Condition	28°C	375ppm	29°C	475ppm	30°C	575ppm
Ω Aragonite	4.253		3.072		2.928	

- Change in aragonite saturation
 - Changes in aragonite saturation occur as atmospheric CO₂ concentrations increase
 - Changes in aragonite saturation occur as temperature increase

Result

- Formula of aragonite saturation
 - $\Omega \text{ aragonite} = [\text{Ca}^{2+}] * [\text{CO}_3^{2-}] / K_{\text{sp}} \text{ aragonite}$
- Meaning of Change in aragonite saturation
 - Under acidified conditions, the oceans become less saturated in respect to aragonite, meaning that aragonite does not precipitate from seawater as readily. So it means the density and diversity of corals on reefs are likely to decline.

Conclusion



- Before the industrial revolution, nearly all shallow-water coral reefs had $\Omega_{\text{aragonite}} > 3.25$ (when [CO₂] lower than 280ppm), there is a lot of corals on reefs.
- The number of existing coral reefs with aragonite saturation decreases rapidly as [CO₂] increase

Conclusion



- Decreased linear extension rate and skeletal density of coral colonies
- Reducing habitat quality and diversity
- Corals may maintain both growth and density under reduced carbonate saturation, so side effect is the diversion of resources from other essential processes(reproduction)

Reference

- <http://www.sciencemag.org/content/318/5857/1737.full>



Thank you