Ocean Acidification Risks to Corals and Coral Reefs

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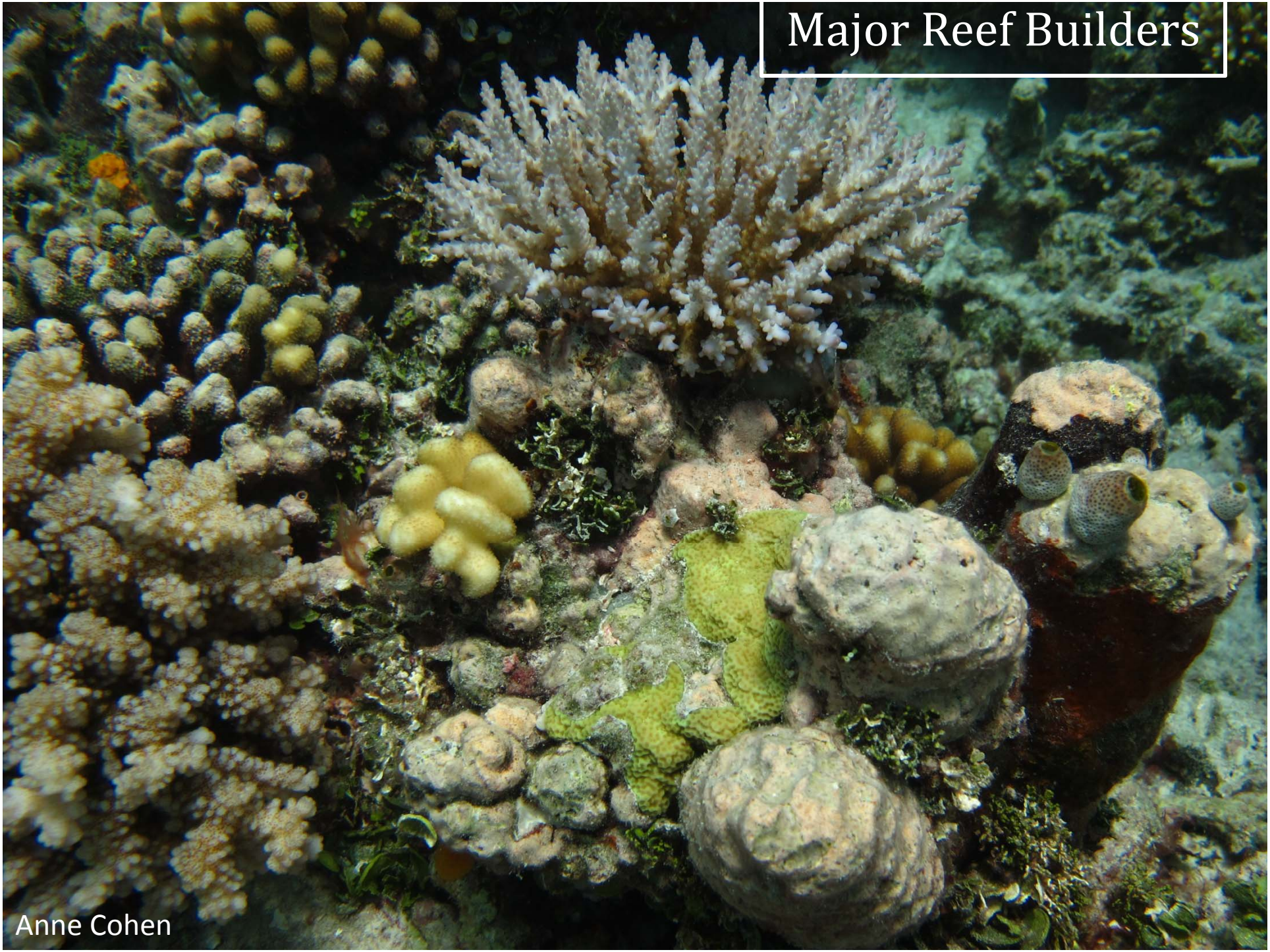
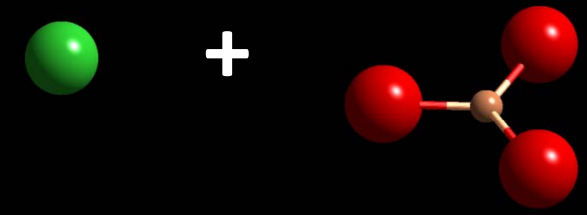
1000’s of years of $CaCO_3$ accumulation

Major Reef Builders

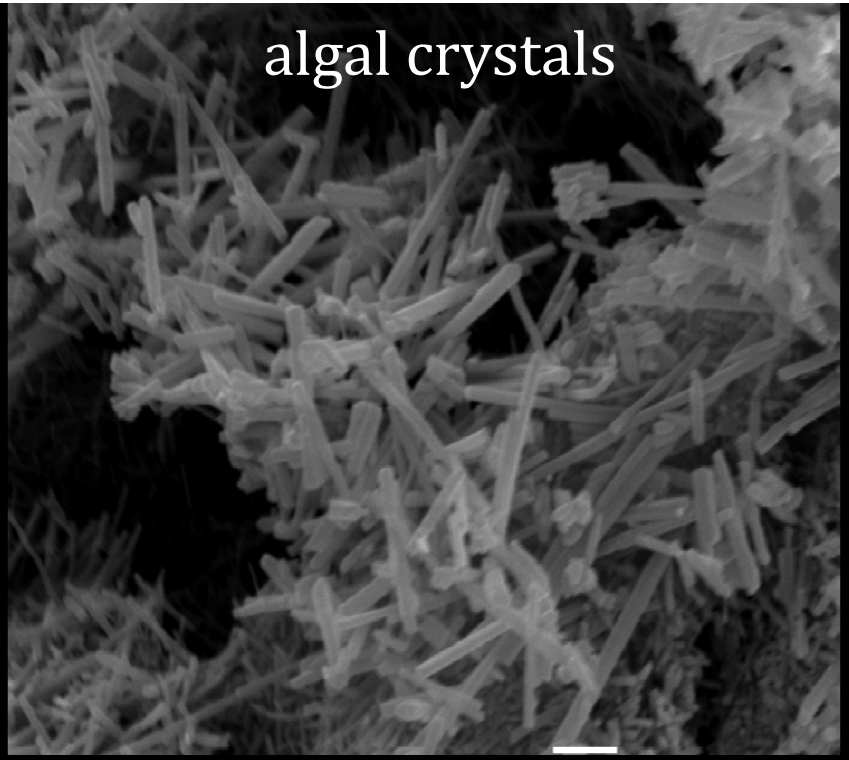


Anne Cohen

calcium carbonate

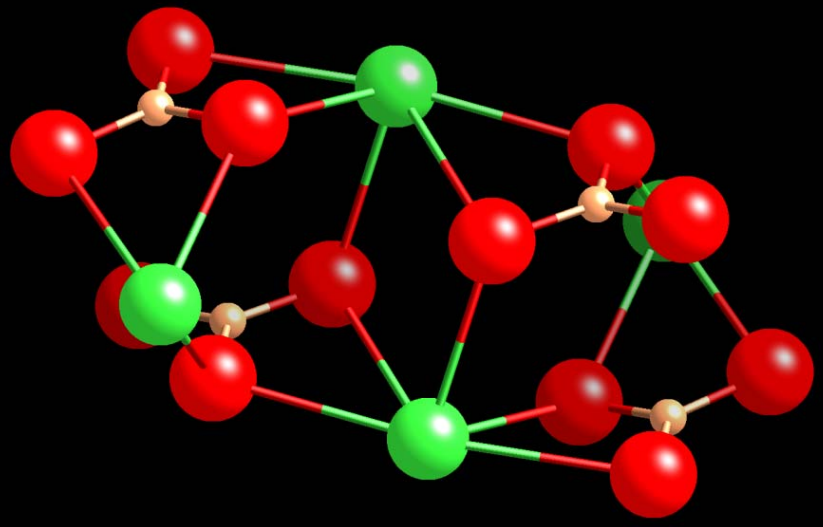


algal crystals

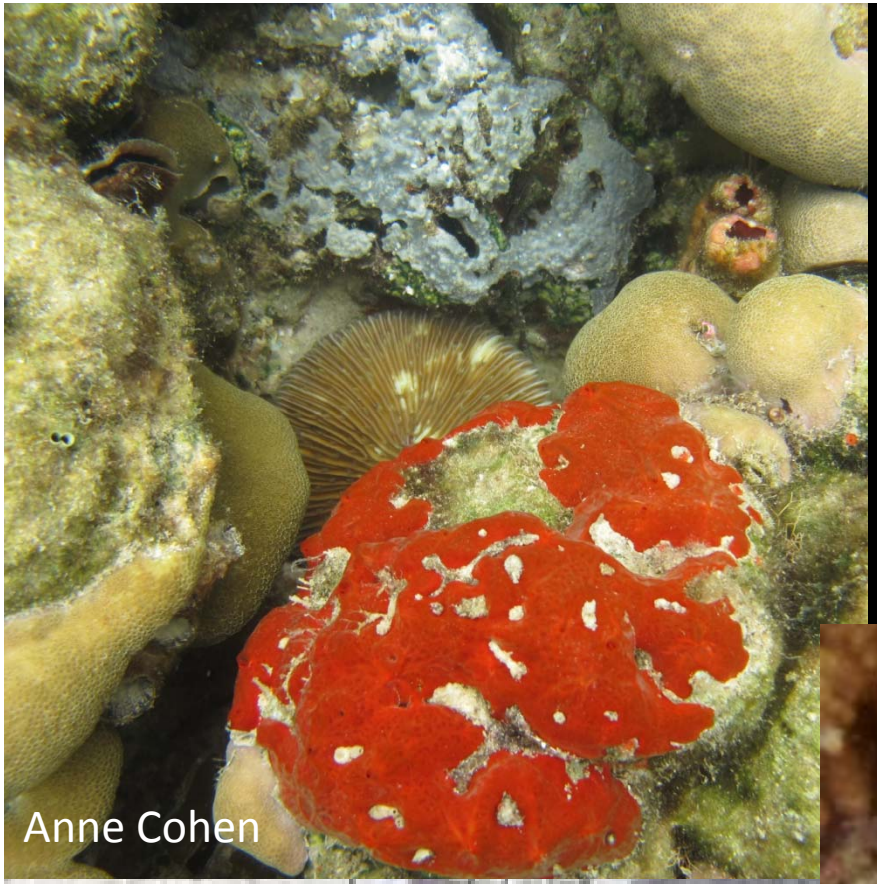


coral crystals

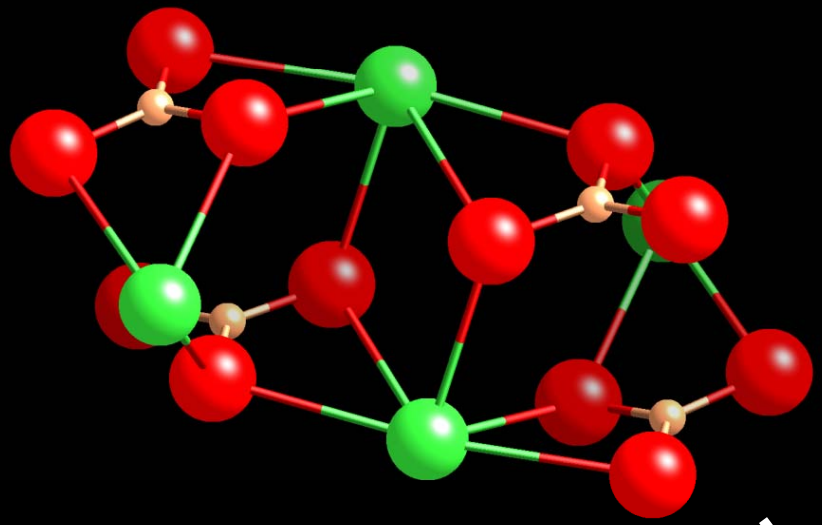
calcium carbonate



Major Reef Eroders

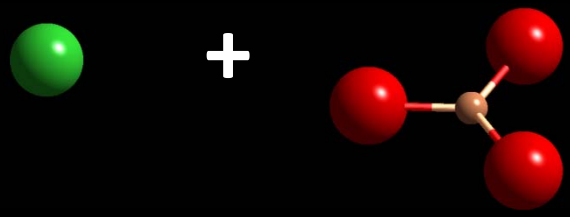


calcium carbonate

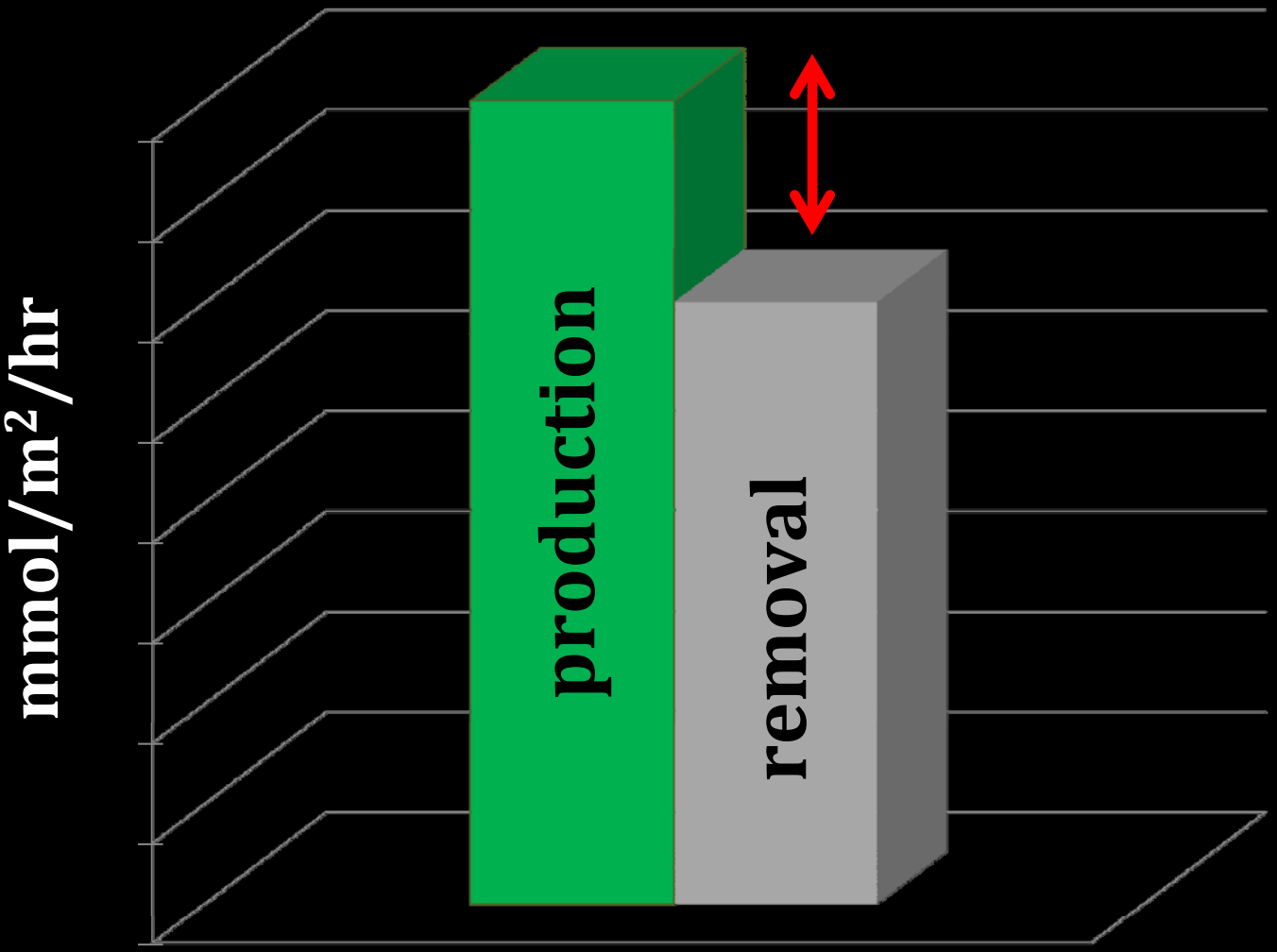


Science Photo Library

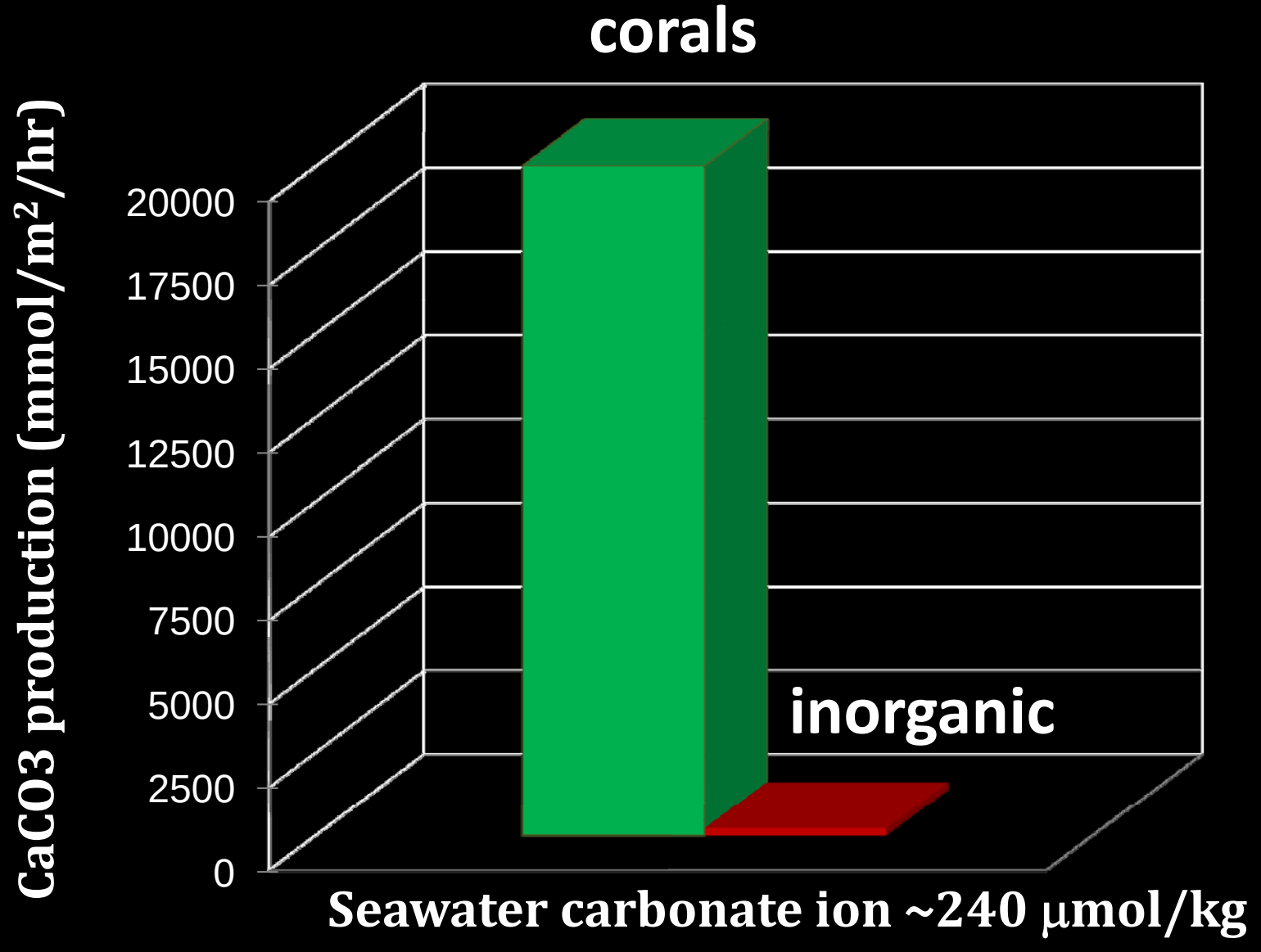
calcium carbonate



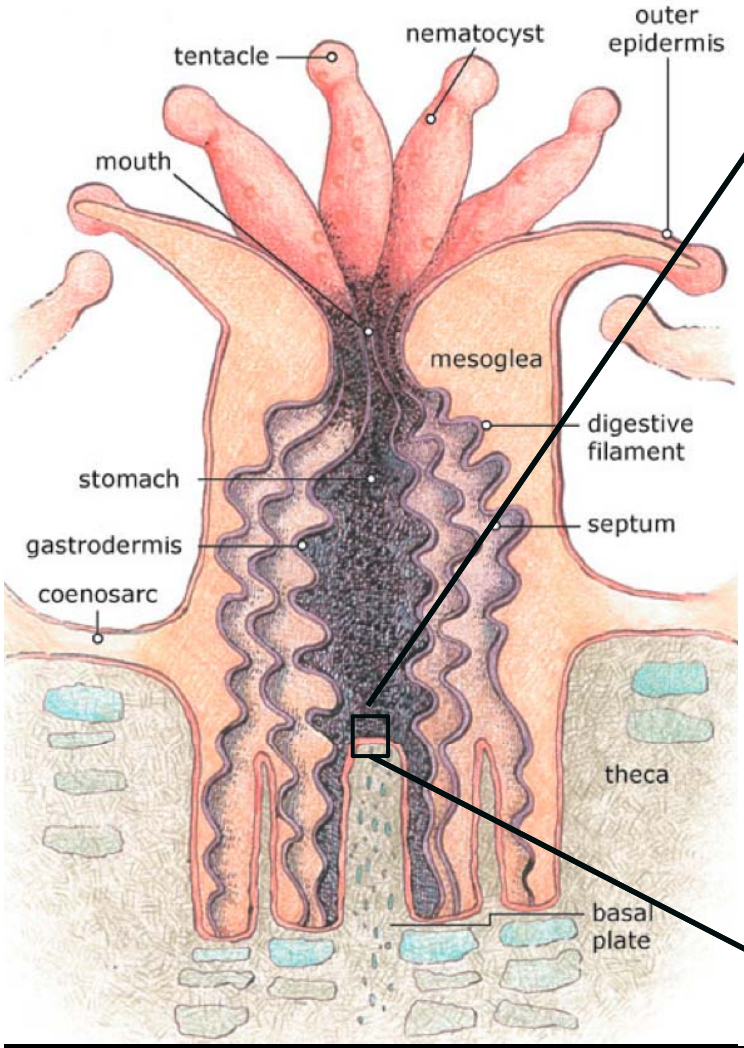
$CaCO_3$ production slightly exceeds $CaCO_3$ removal

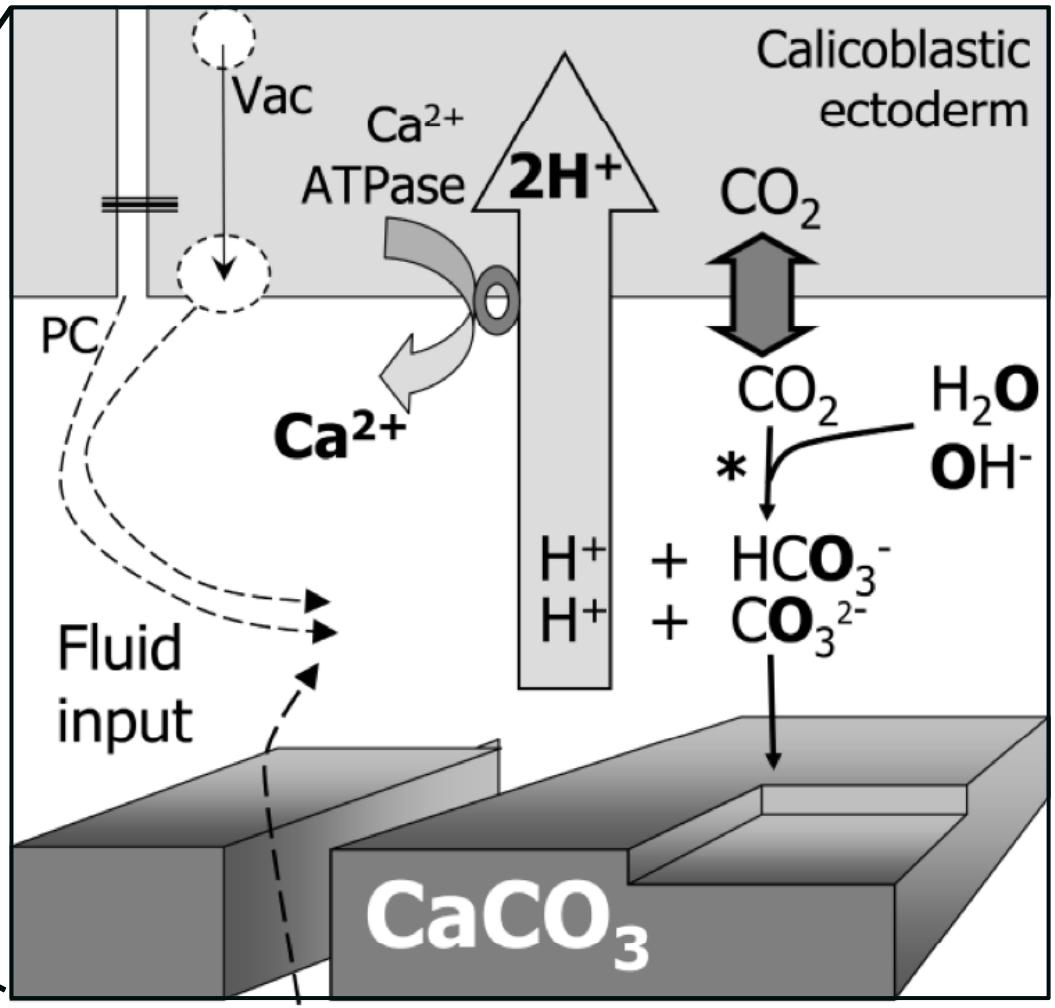


Production by corals 1000X faster than inorganic rates



Corals calcify rapidly by elevating the concentration of calcium and carbonate ions (Ω) at the calcification site

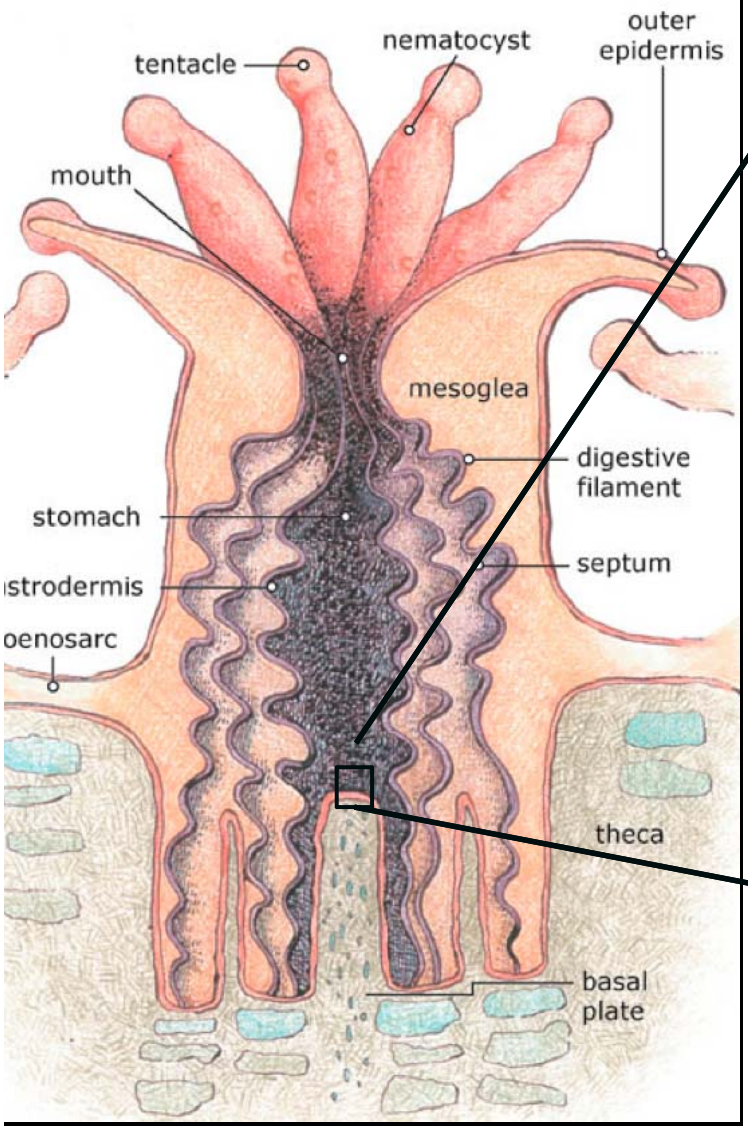


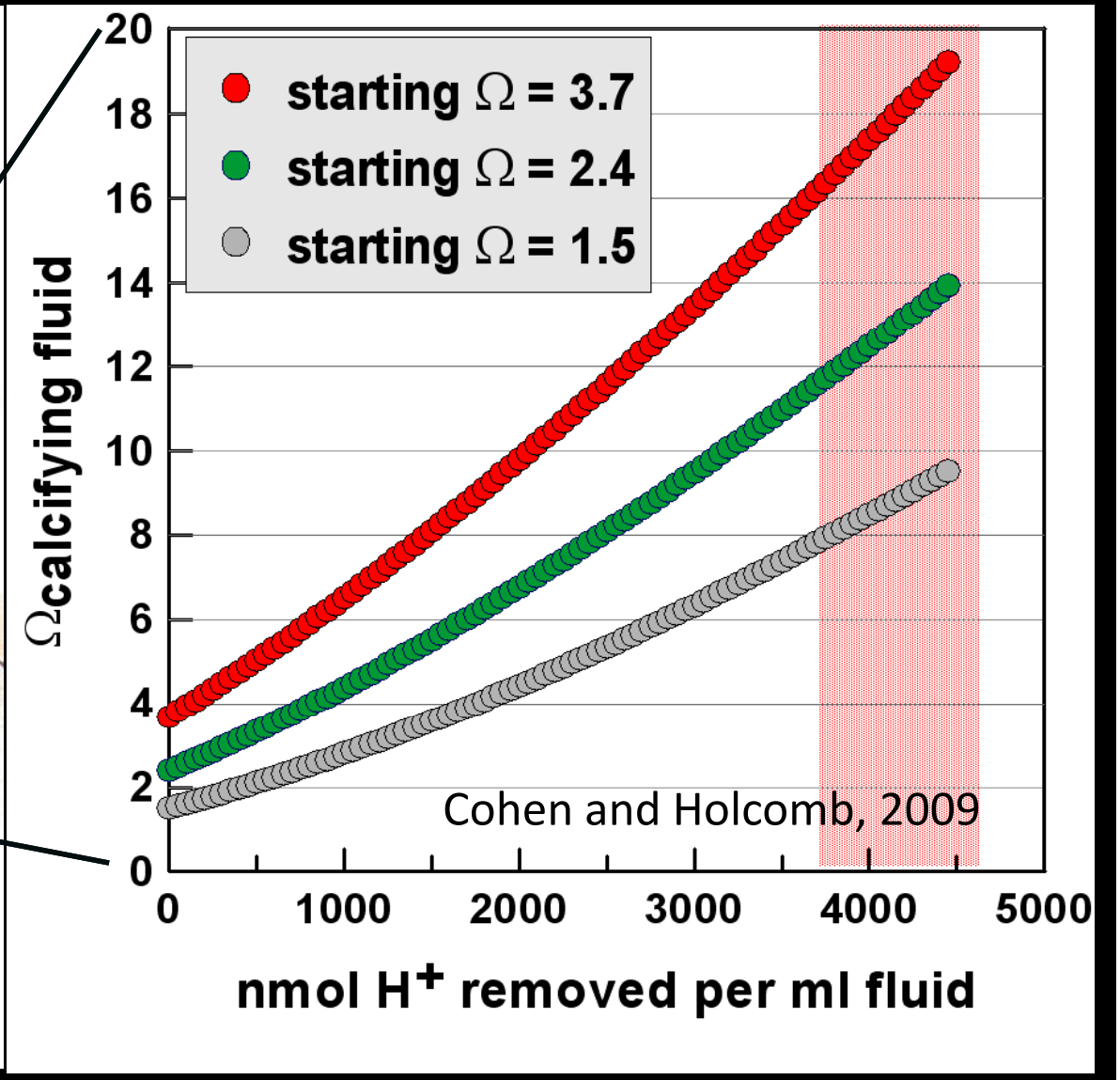


NOAA/ Gini Kennedy

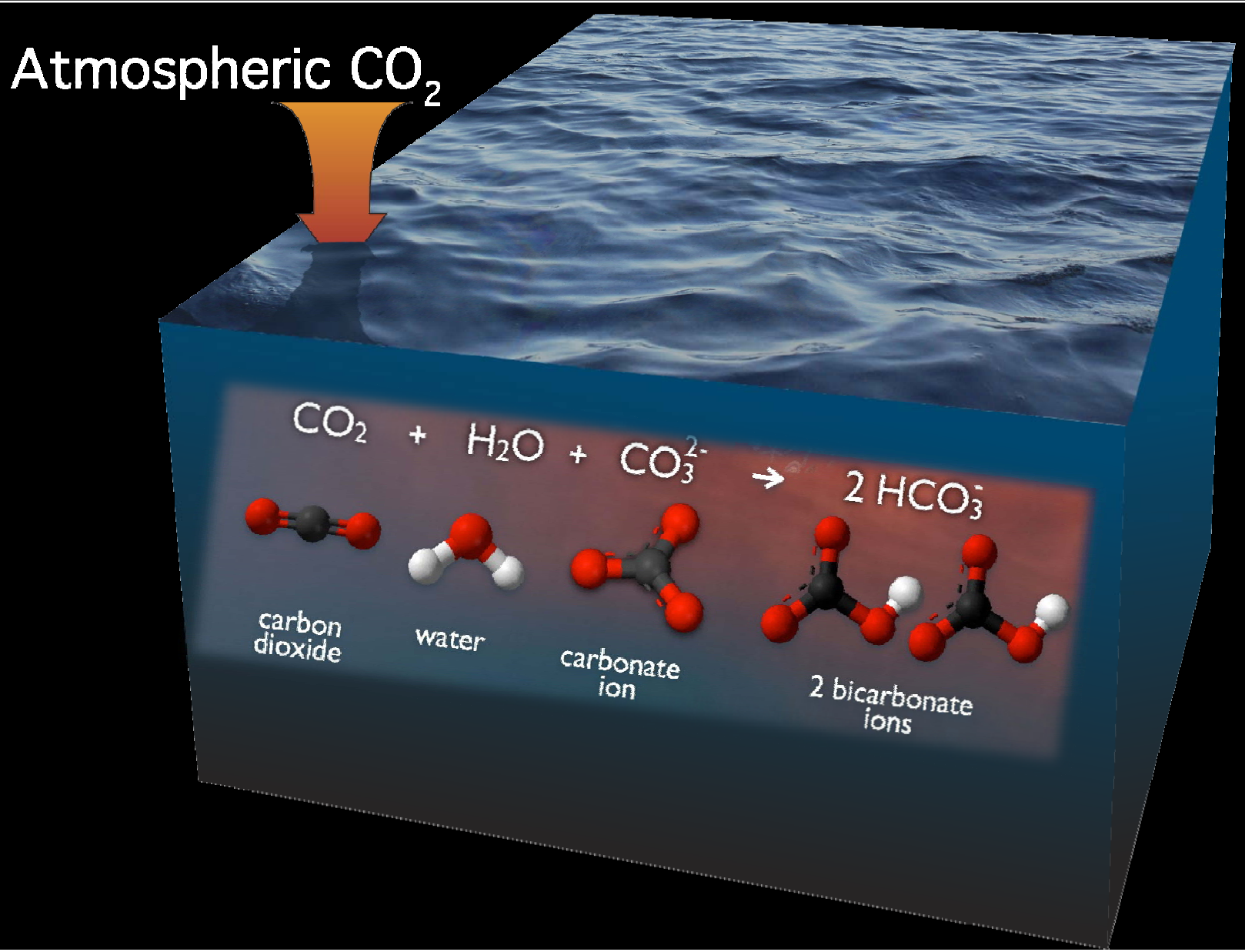
Cohen and McConnaughey, 2003

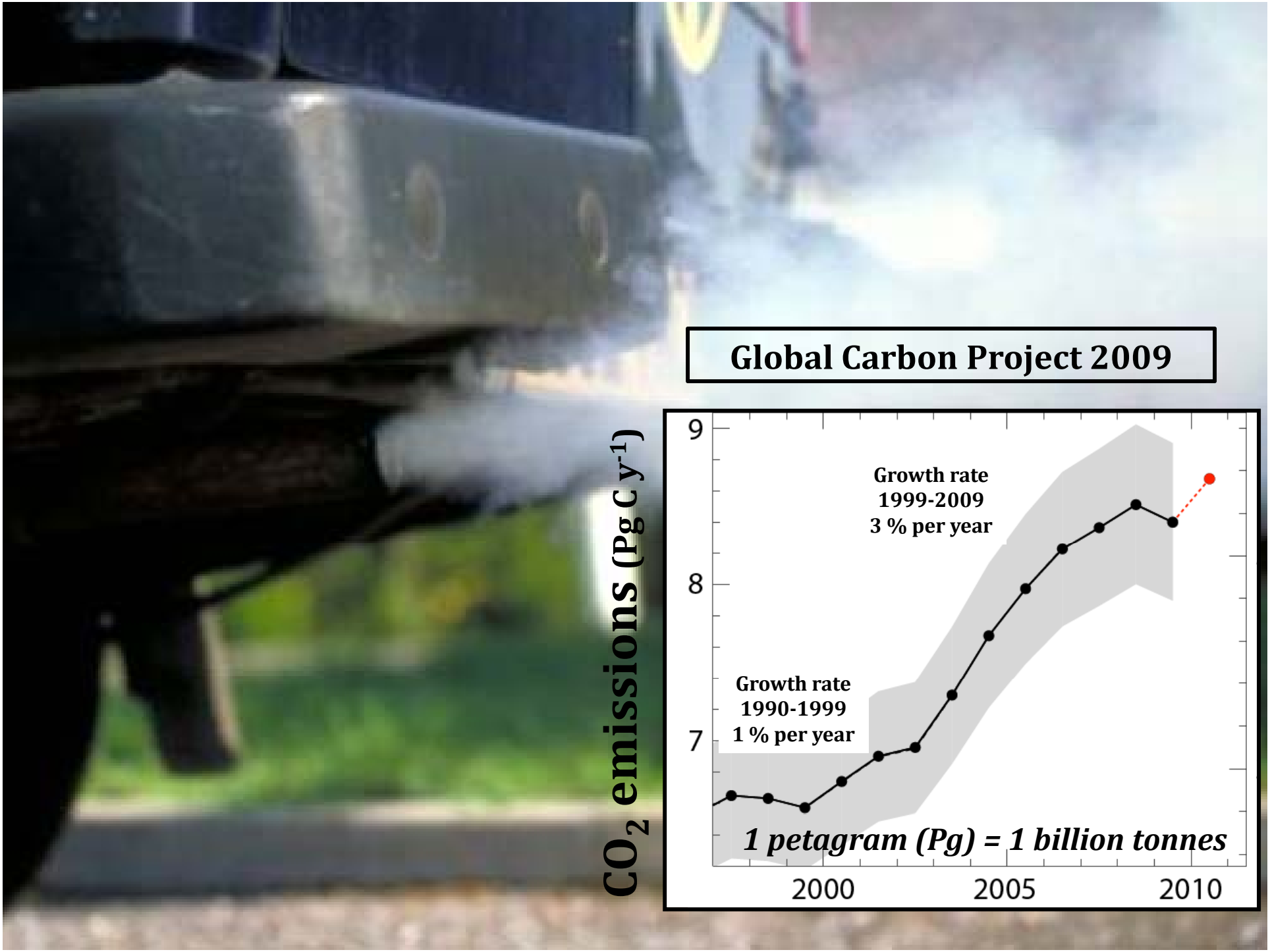
Concentration of calcium and carbonate ions (Ω) at calcification site depends on Ω of starting fluid (seawater)





When carbon dioxide dissolves in seawater, carbonate ion concentration decreases




Global Carbon Project 2009
CO_2 emissions (Pg C y^{-1})
9
8
7
Growth rate
1999-2009
3 % per year
Growth rate
1990-1999
1 % per year
1 petagram (Pg) = 1 billion tonnes
2000
2005
2010

Where does all that carbon dioxide go?

1.5 Pg C y^{-1}

+

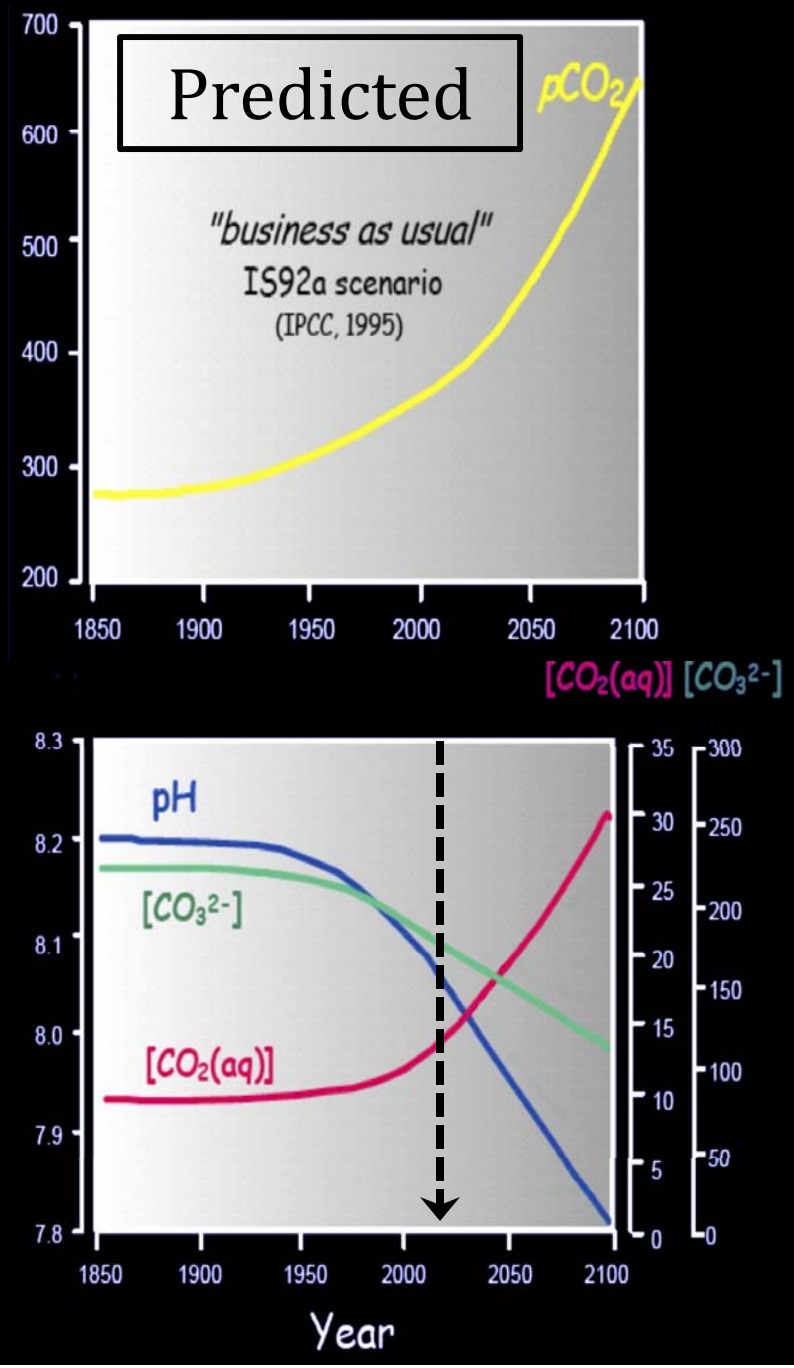
7.6 Pg C y^{-1}

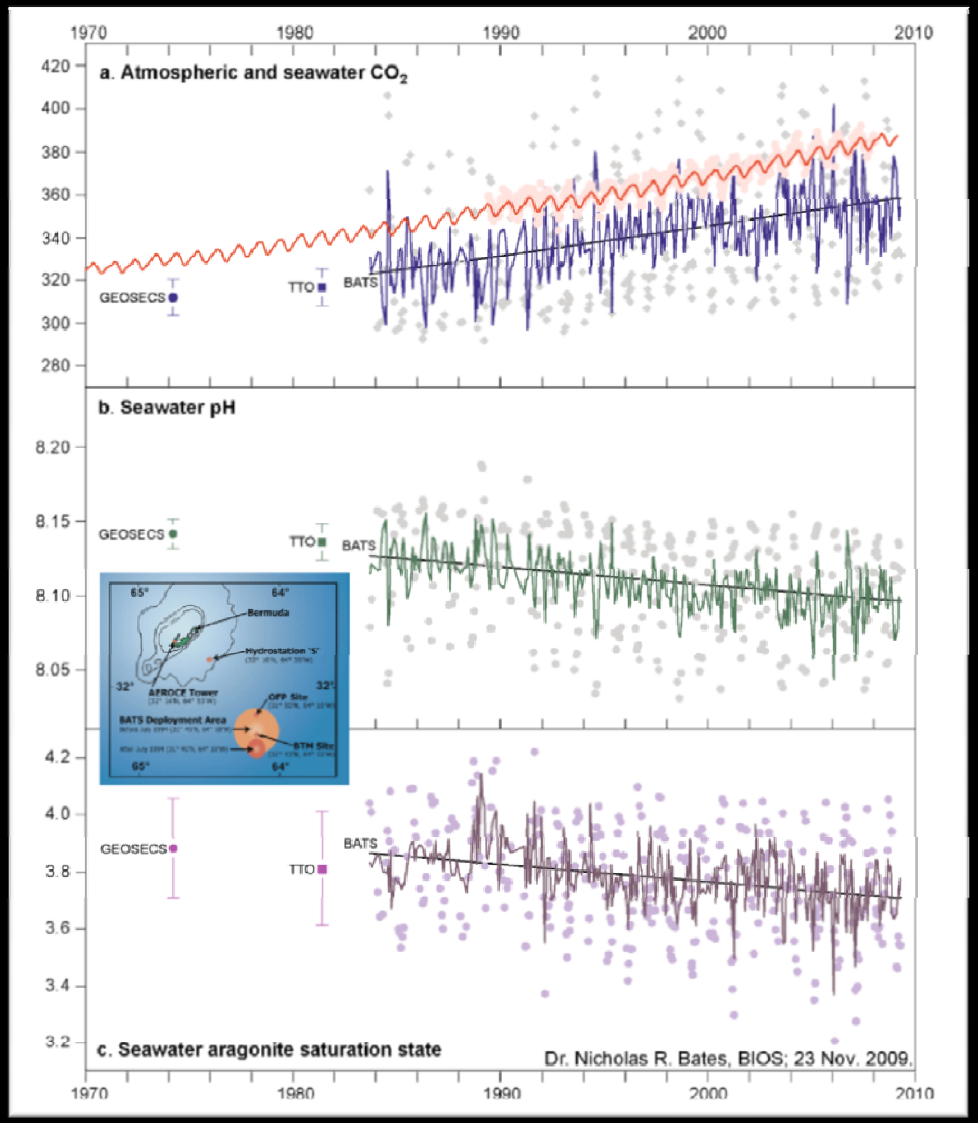
4.1 Pg y^{-1}
Atmosphere
45%

2.8 Pg y^{-1}
Land
30%

2.2 Pg y^{-1}
Oceans
25%

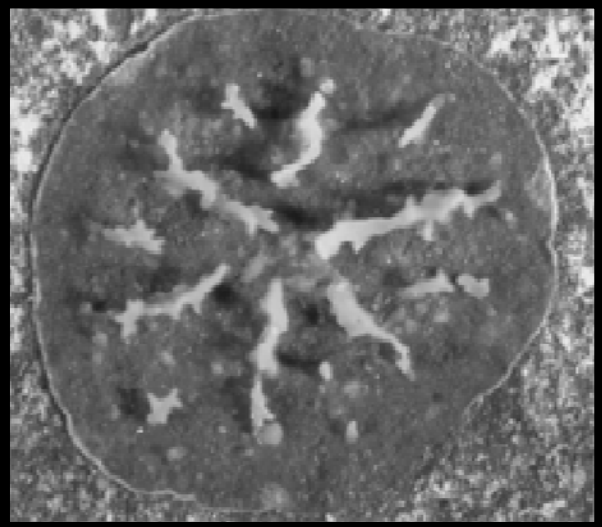
Observed: Ocean Acidification





Coral growth under reduced carbonate ion concentrations

246 μmol/kg

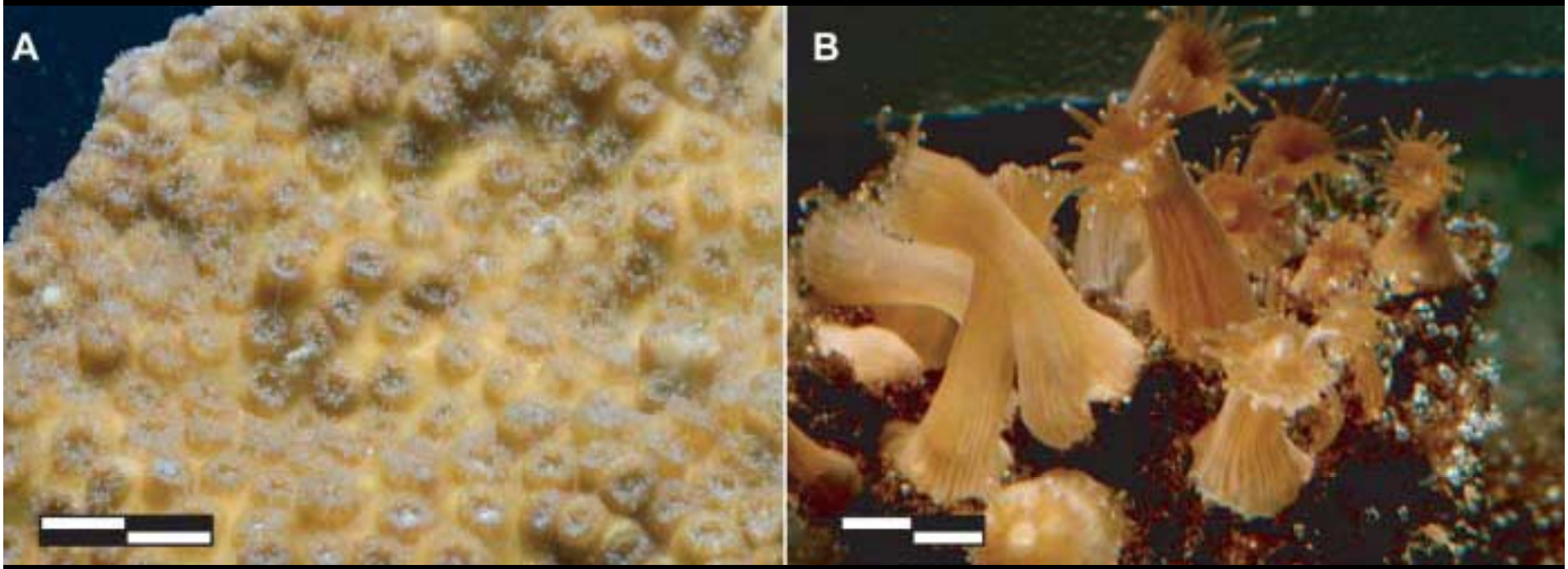


160 μmol/kg (2040 AD)

<100 μmol/kg (2100 AD)

Cohen et al., 2009

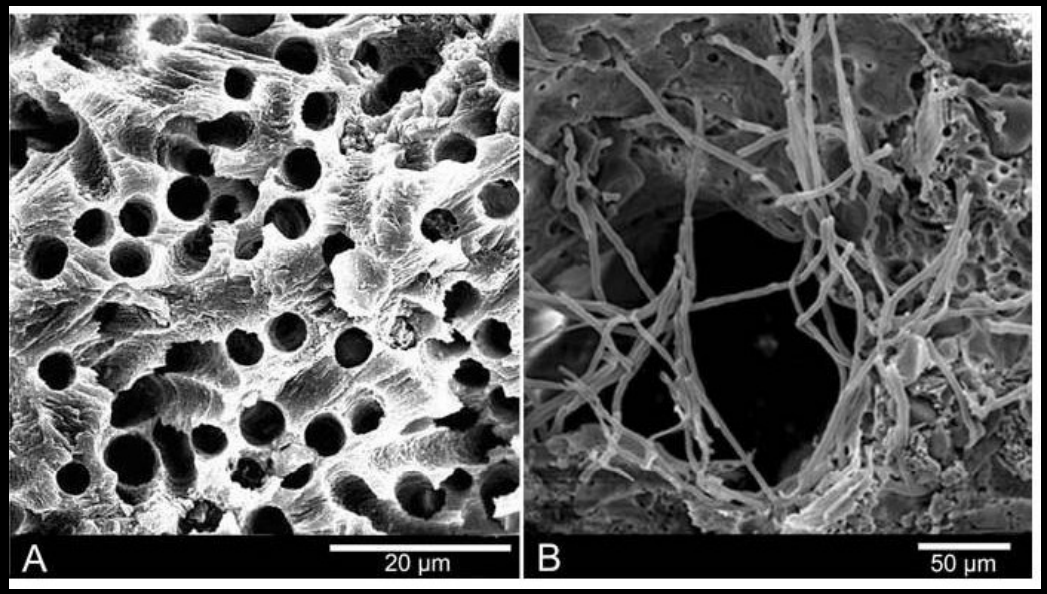
At very low carbonate ion concentrations, dissolution of skeleton occurs



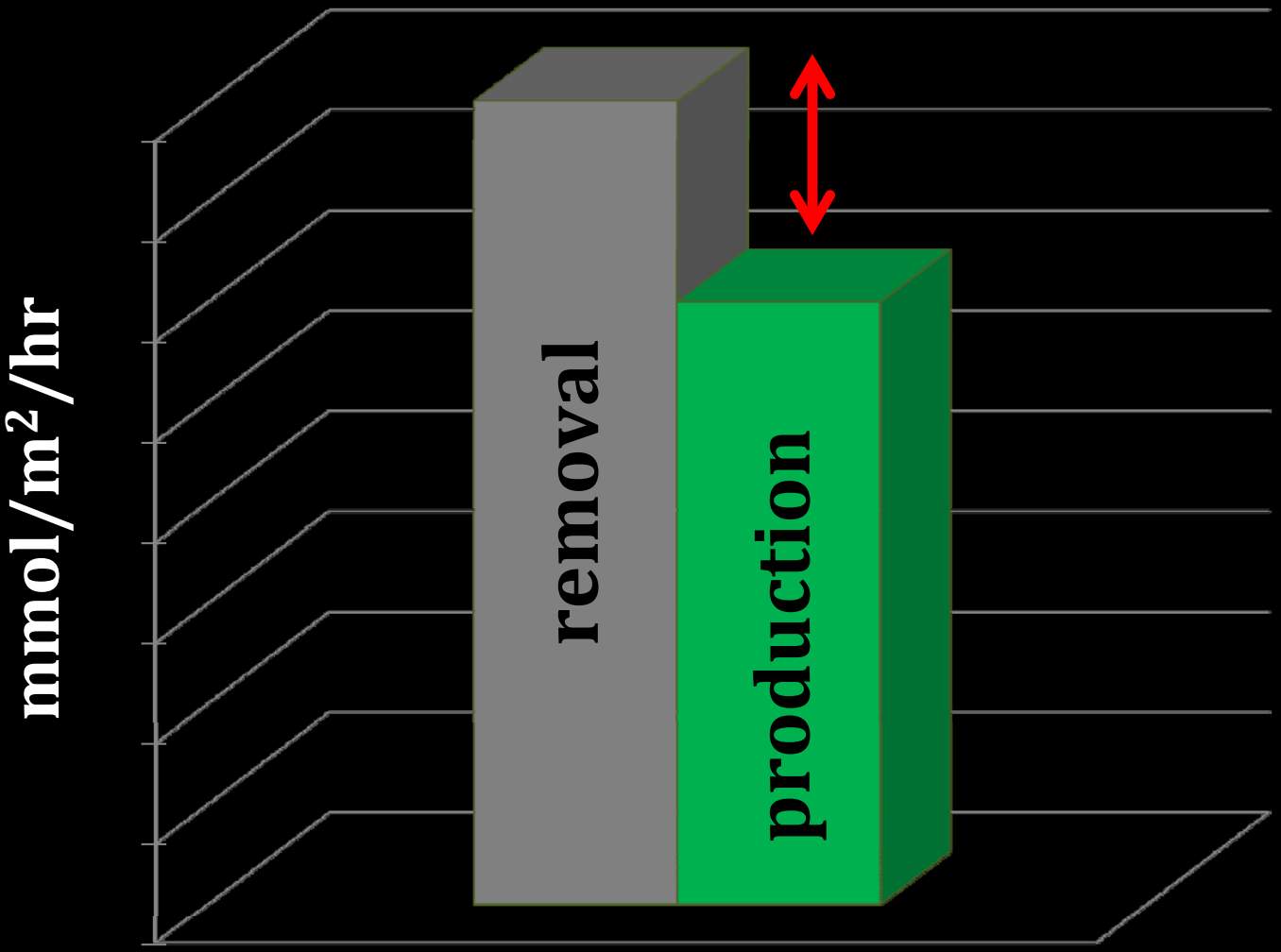
Maoz and Fine, 2007

Experimental evidence for increased bioerosion under elevated CO_2

"The depth of penetration of [algal] filaments was significantly higher under 750 ppmv (1.4 mm) than under 400 ppmv (1 mm). Consequently, rates of carbonate dissolution measured under elevated pCO_2 were 48% higher than under ambient pCO_2"
Tribolet et al., GBC 2009

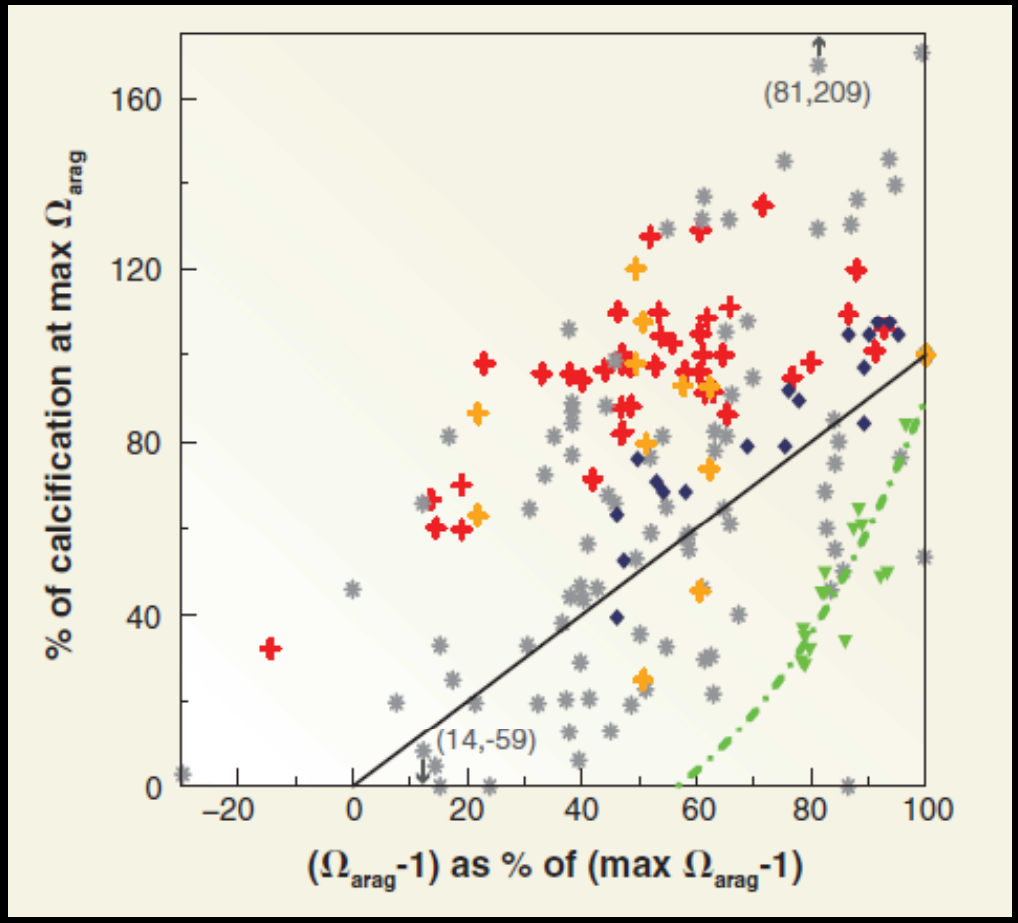


$CaCO_3$ removal will exceed $CaCO_3$ production



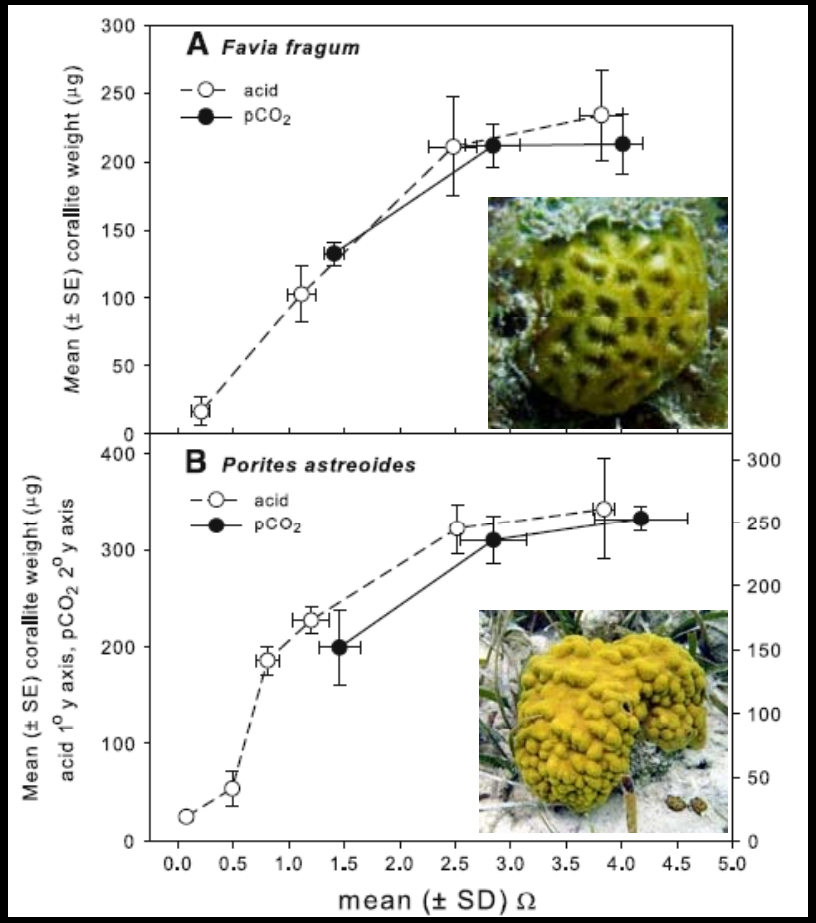
Are some species more sensitive than others?

Different species, different experiments



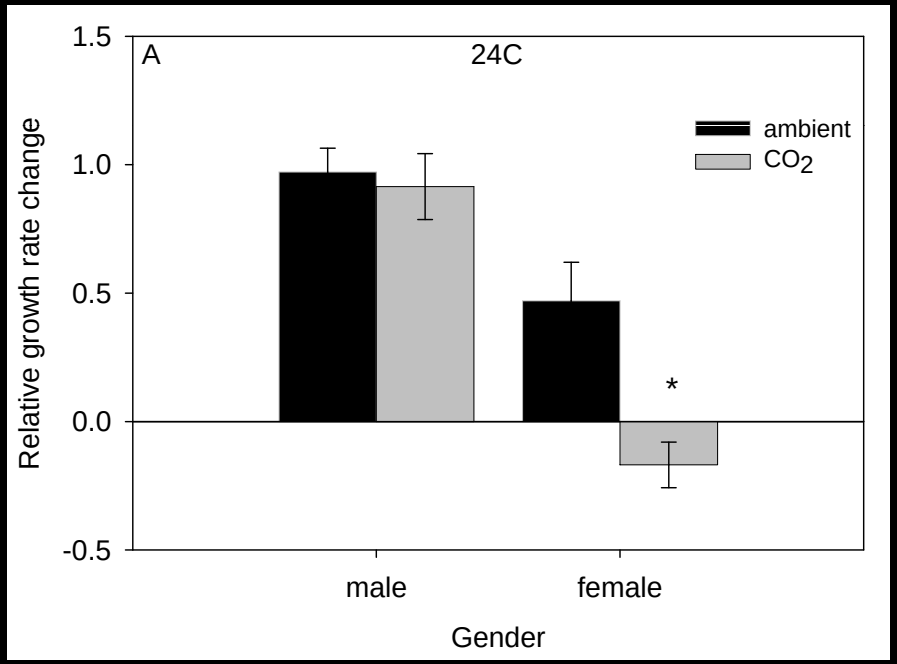
Pandolfi et al., 2011

Different species, same experiment



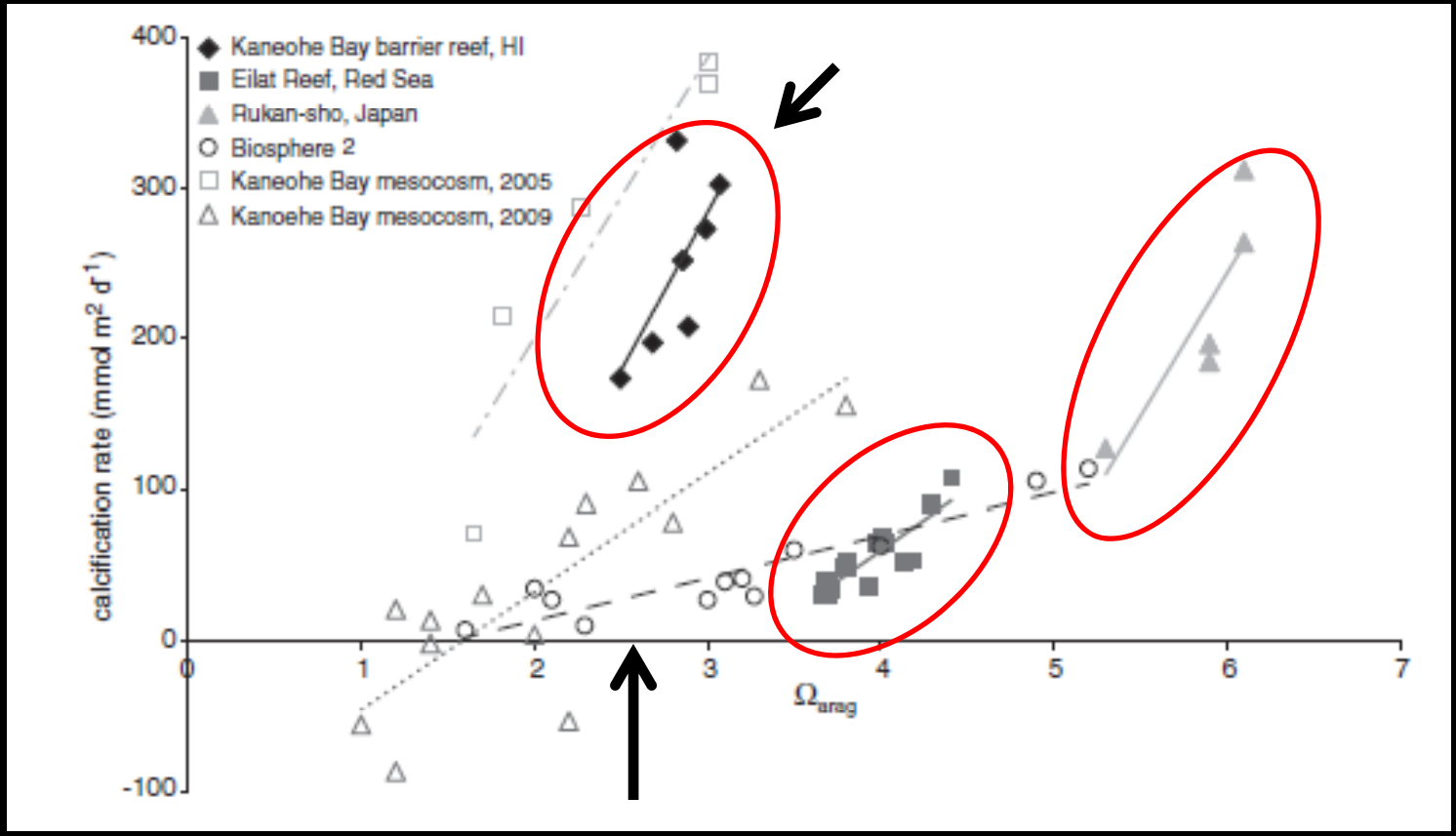
De Putron et al., 2011

Spawning female corals are more sensitive than male corals and non-spawning females



Holcomb et al., 2012

Are some reefs more sensitive than others?



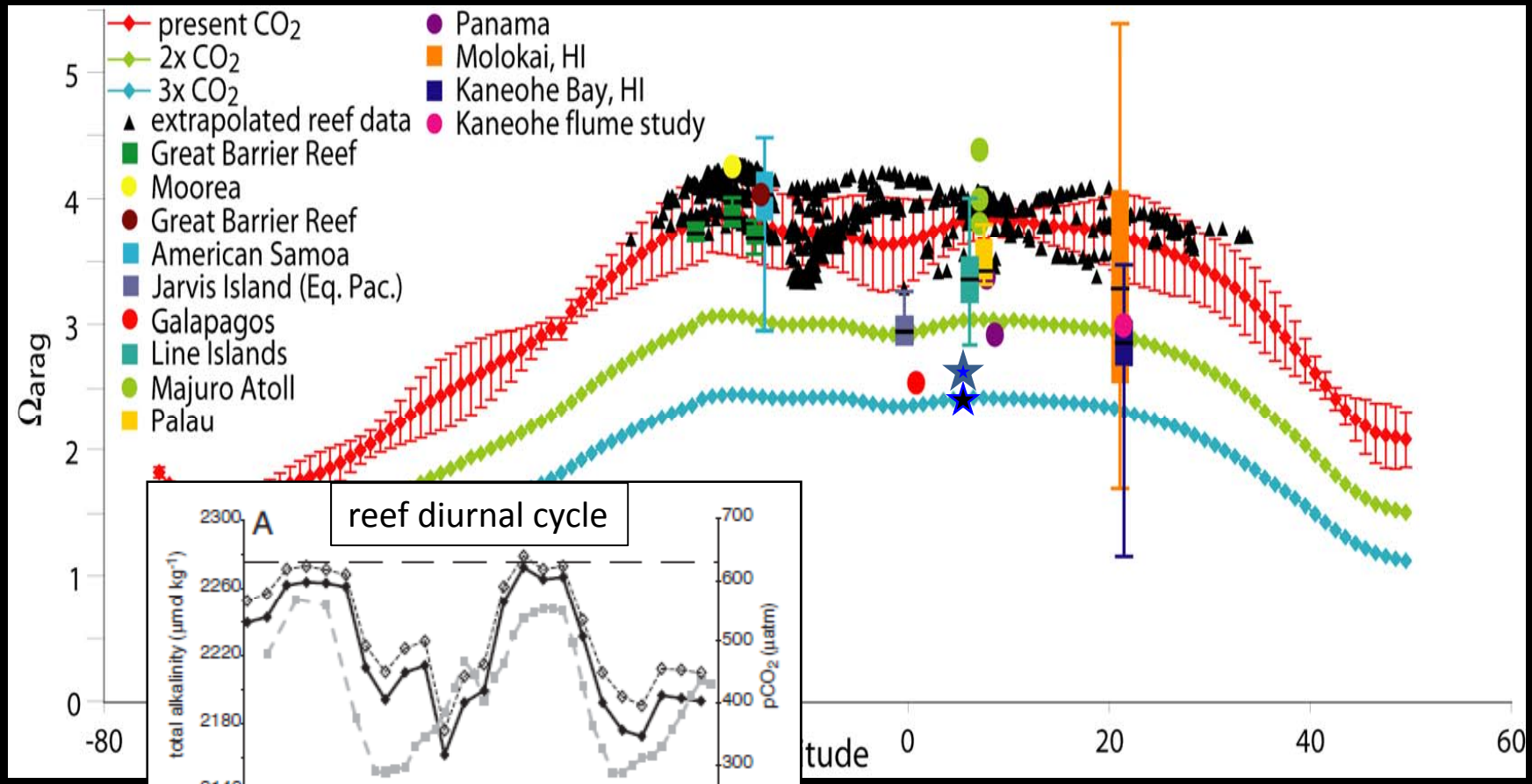
Shamberger et al., 2011

Decreased cover and diversity with increased CO_2 at vent sites

Increasing pCO_2, decreasing carbonate ion and pH

Fabricius et al., 2011

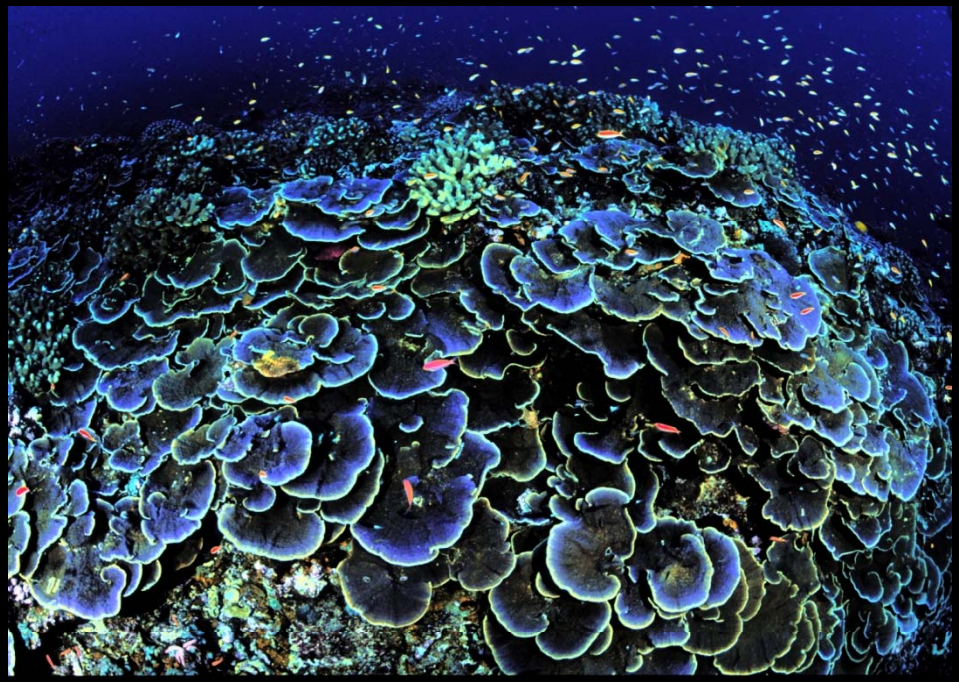
Carbonate system chemistry of reef systems is variable in space and time



Shamberger et al., 2011; and in press 2012

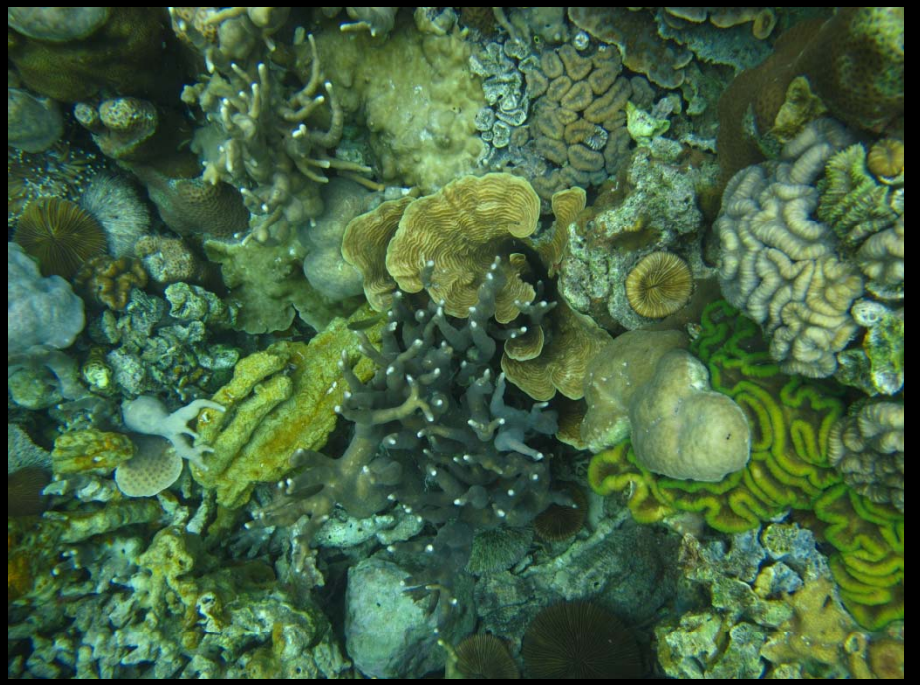
Amongst today's "acidic" reefs: variable coral cover, coral diversity and coral growth rates

East & Central Equ. Pacific: UPWELLING
low diversity, high cover, high growth rates



Ω_{ar} = 2.7-2.9

Western Tropical Pacific: non-UPWELLING
high diversity, high cover, low growth rates



Ω_{ar} = 2.4-2.6

Ocean Acidification Risks to Coral Reefs:

1. Persistence of coral reefs requires that rates of $CaCO_3$ production exceed rates of dissolution.
2. Ocean acidification slows coral calcification via fundamental laws of physical chemistry (inescapable)
3. Slowed rates of $CaCO_3$ production coupled with (possible) enhanced rates of $CaCO_3$ dissolution will (even in the absence of additional "stressors") shift coral reefs from net accreting to net dissolving structures
4. Emerging evidence of healthy coral reefs in seawater with low mean pH and carbonate ion concentration; *however, these reefs retain sensitivity to increased* CO_2
5. Due to (4), the trajectory of reef decline and the threshold Ω value at which dissolution exceeds accretion will *vary widely* across different systems
6. Because slowed calcification is an inevitable and inescapable consequence of lower carbonate ion concentrations, ocean acidification poses an extinction threat to all modern coral reef structures.

Ocean Acidification Risks to Corals:

1. Ocean acidification (OA) slows coral calcification; evidence for impacts on other physiological processes is limited.
2. Evidence for species-specific impacts is limited: few experiments conducted with different species, identical conditions.
3. Some evidence for *enhanced impact on reproductively active females*; but reproduction not affected by slowed calcification.
4. Limited evidence for impact on fertilization success and settlement.
5. Emerging evidence for exacerbation and modulation of OA effects due to other environmental factors.
6. Slowed calcification, on its own, is unlikely to pose an extinction threat to mature individuals and colonies
7. However, experimental data implies that slowed calcification will affect recruitment success.
8. If shown to be true, the ocean acidification could drive coral species extinction via its impact on recruitment success.