Ecological Implications of Sponge Nutrient Cycling on the Florida Keys Reef Ecosystem

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**Linking Science to Management
on the Florida Keys Marine Ecosystem
Duck Key, FL
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Collaborators

- **Chris Martens, Niels Lindquist, Brian Popp**

- **Rich Camilli, Bob Byrne, Jim Hench,** Johanna Rosman, Howard Mendlovitz, Dan Hoer, Meredith Kintzing, Nyssa Silbiger, Melissa Southwell, Jeremy Weisz, Sherwood Liu, Lori Adornato, Pam Hallock-Muller, Ute Hentschel, Bonnie Chang, Carol Arnosti, Joe Boyer, Brian White, many, many others.

- **Funding Sources**
  NSF, NOAA, NURC/ARB,
  PADI Foundation
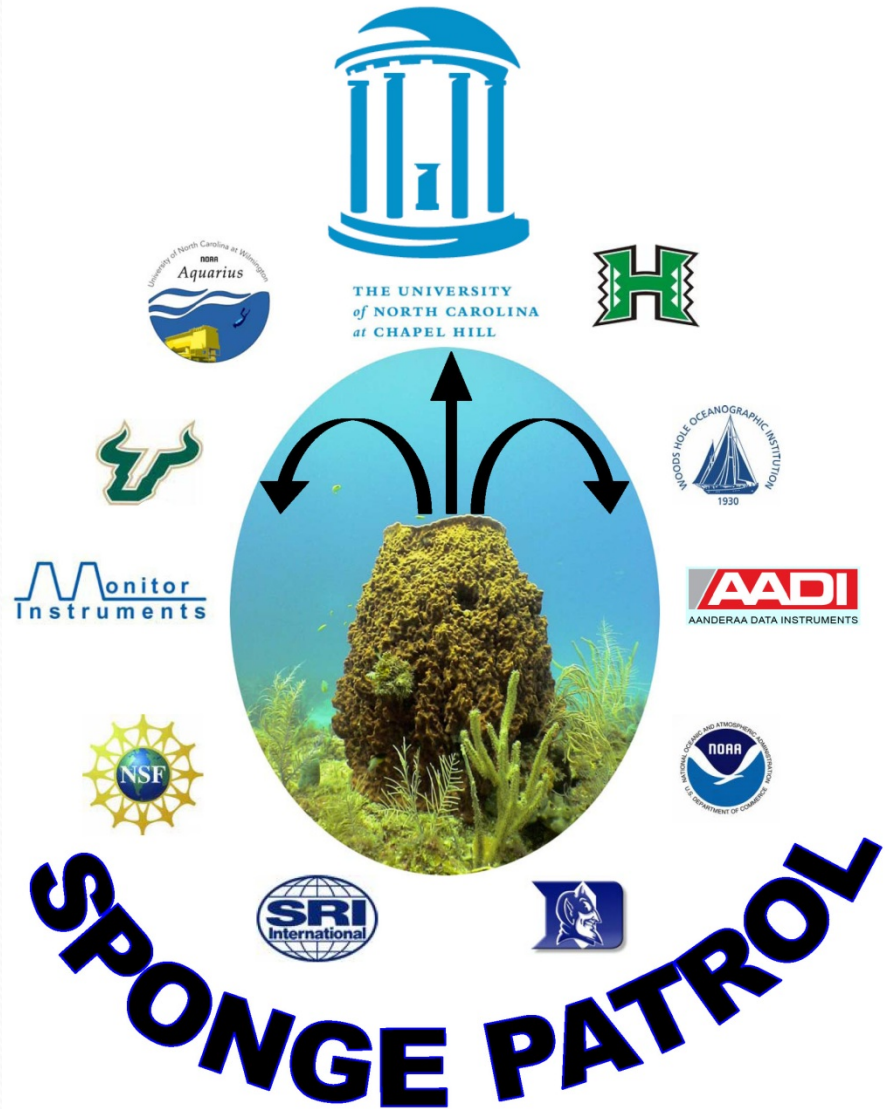
Coral Reef Decline

Insert Your Favorite Coral Cover Plot Here

Why Sponges? (Sponge 101)

- Massive Pumping: over 50,000 times their volume/day.

- Host diverse microbial communities.

- Aerobic and anaerobic tissue environments.

- Dominant reef animal: >20 times live coral biomass.

- "Passive" alteration of water chemistry.

- "Active" alteration of reef structure through bioerosion.

Sponge Nutrient Cycling - Discoveries:

1. Sponges with large associated microbial communities use primarily DOM as a C source.

2. Sponge respiration drives localized acidification.

3. Sponges host coupled nitrification-denitrification.

4. Coral reef sponge and algae populations create a positive feedback loop that encourages their proliferation at the expense of hard corals.

In situ Instrumentation – A Cabled Observatory

- *Aquarius Reef Base* infrastructure facilitates a unique system for *in situ* real time reef observation and experimentation

- The underwater lab:

  - TETHYS Membrane Inlet Mass Spectrometer (O_2, N_2, Ar, CO_2)

  - SEAS Spectrophotometric Auto Analyzers (pH, NO_x)

  - AADI String Optode System (10 O_2, C, T, P, Turbidity, Current)

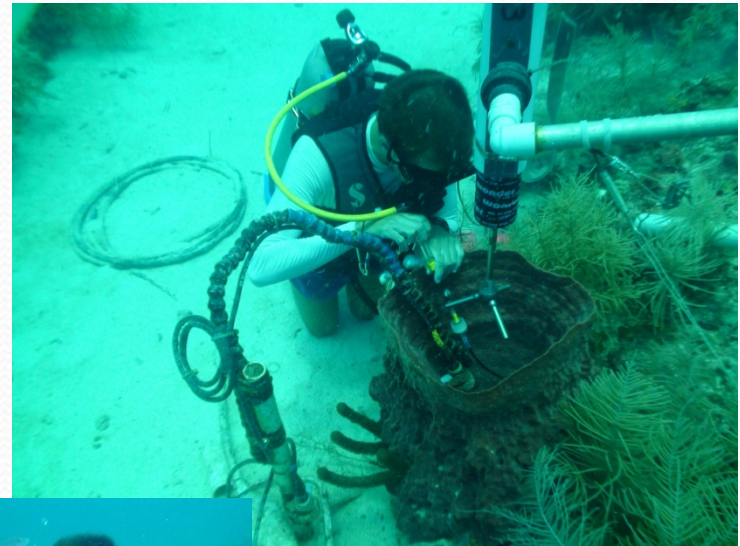 - Nortek ACDPs and ADVs.
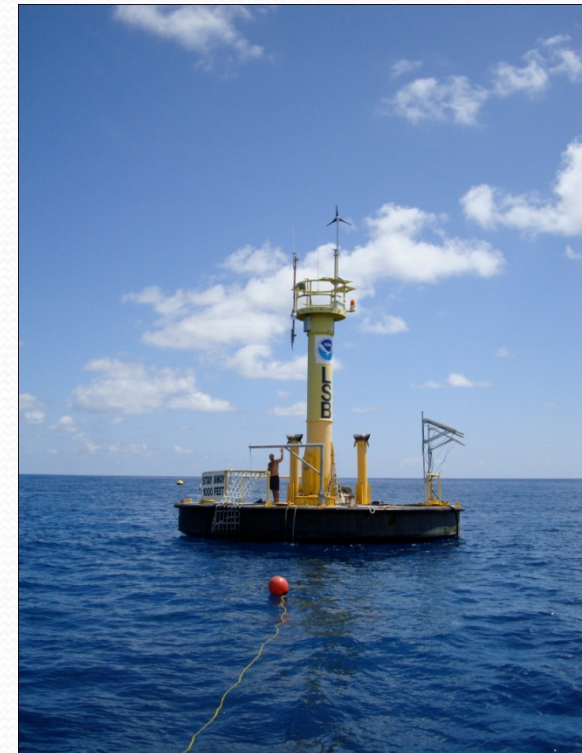
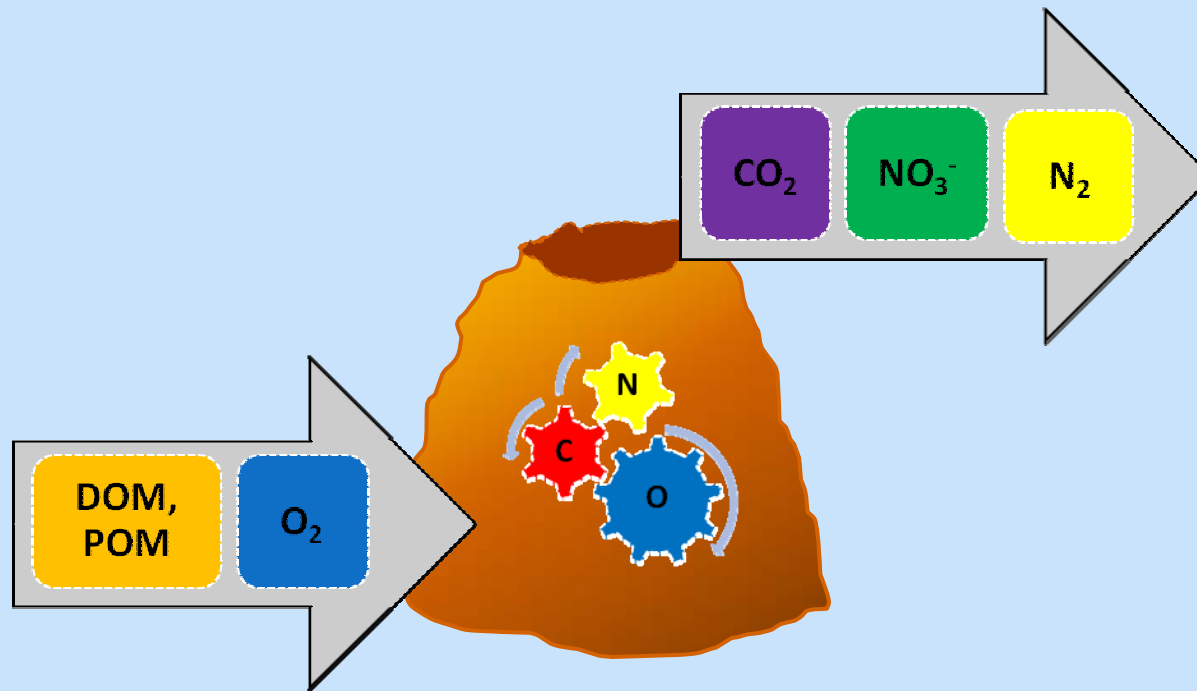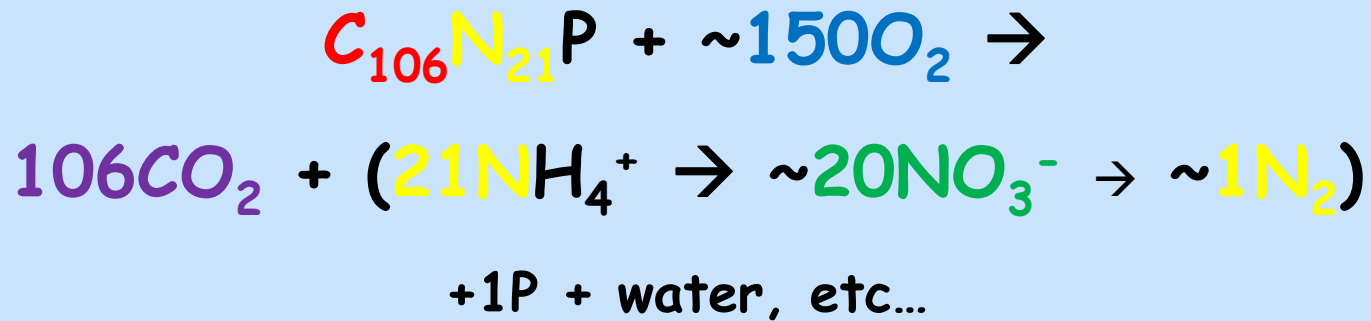# The Underwater Lab
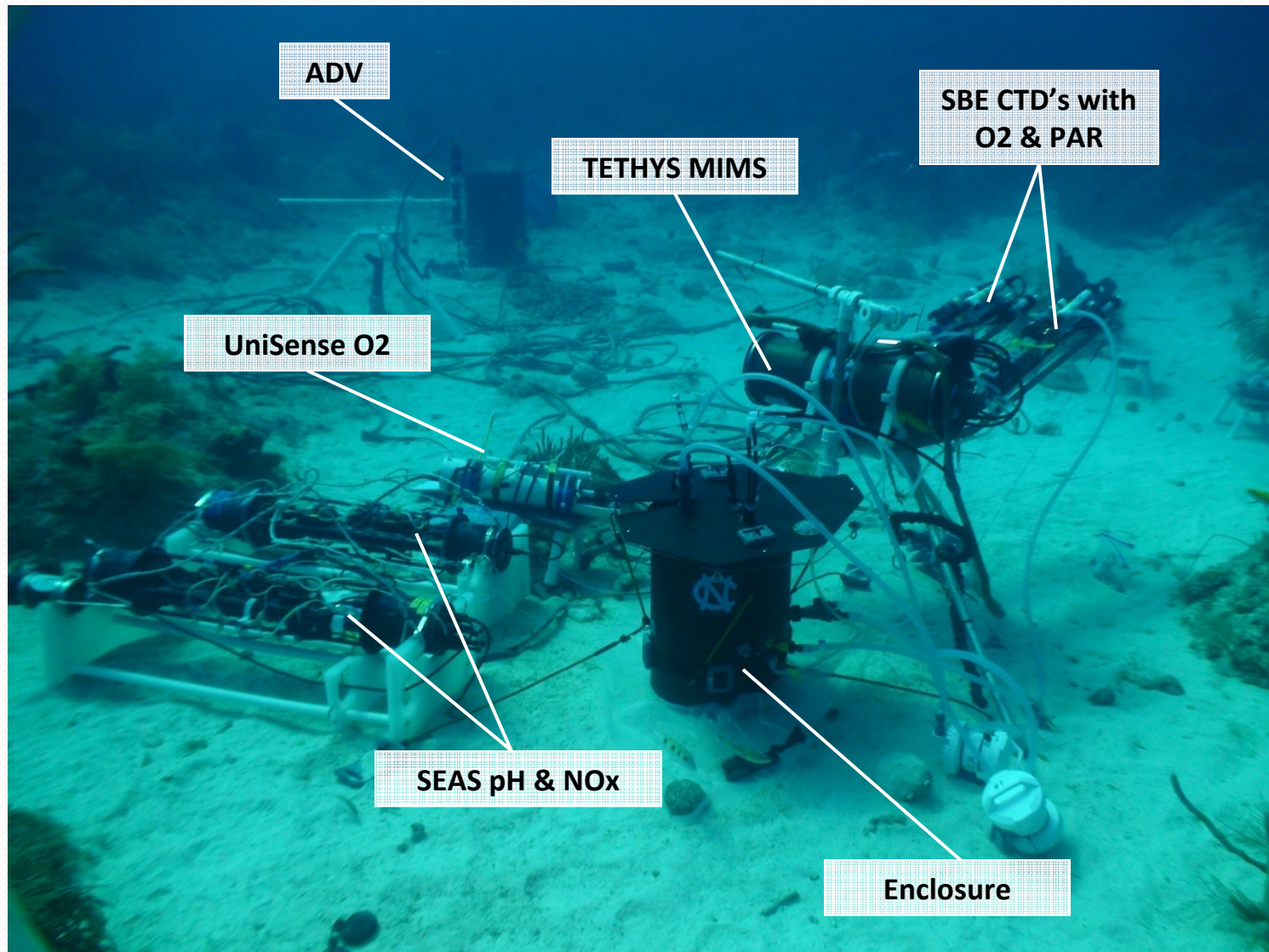
Realtime Data Flow

Continuous, realtime data monitoring with instrument control from the ARB habitat or base.

Diver Collections, Field and Lab Experiments
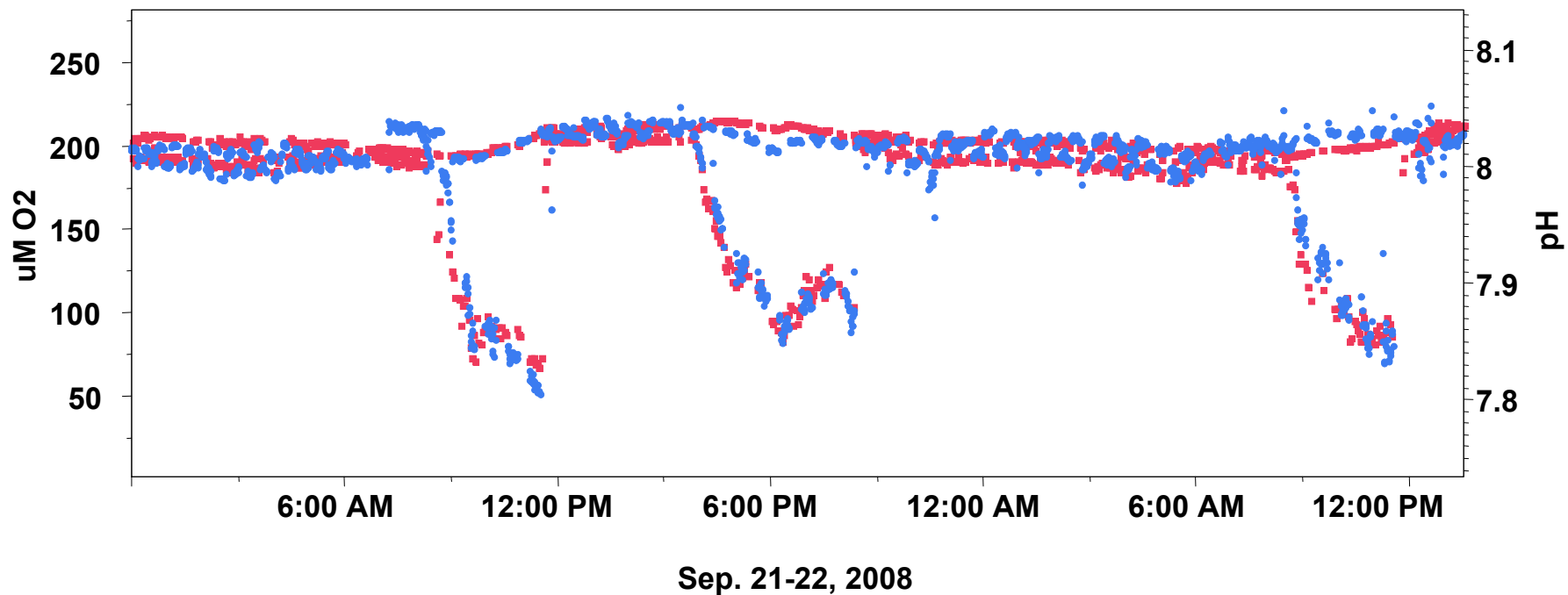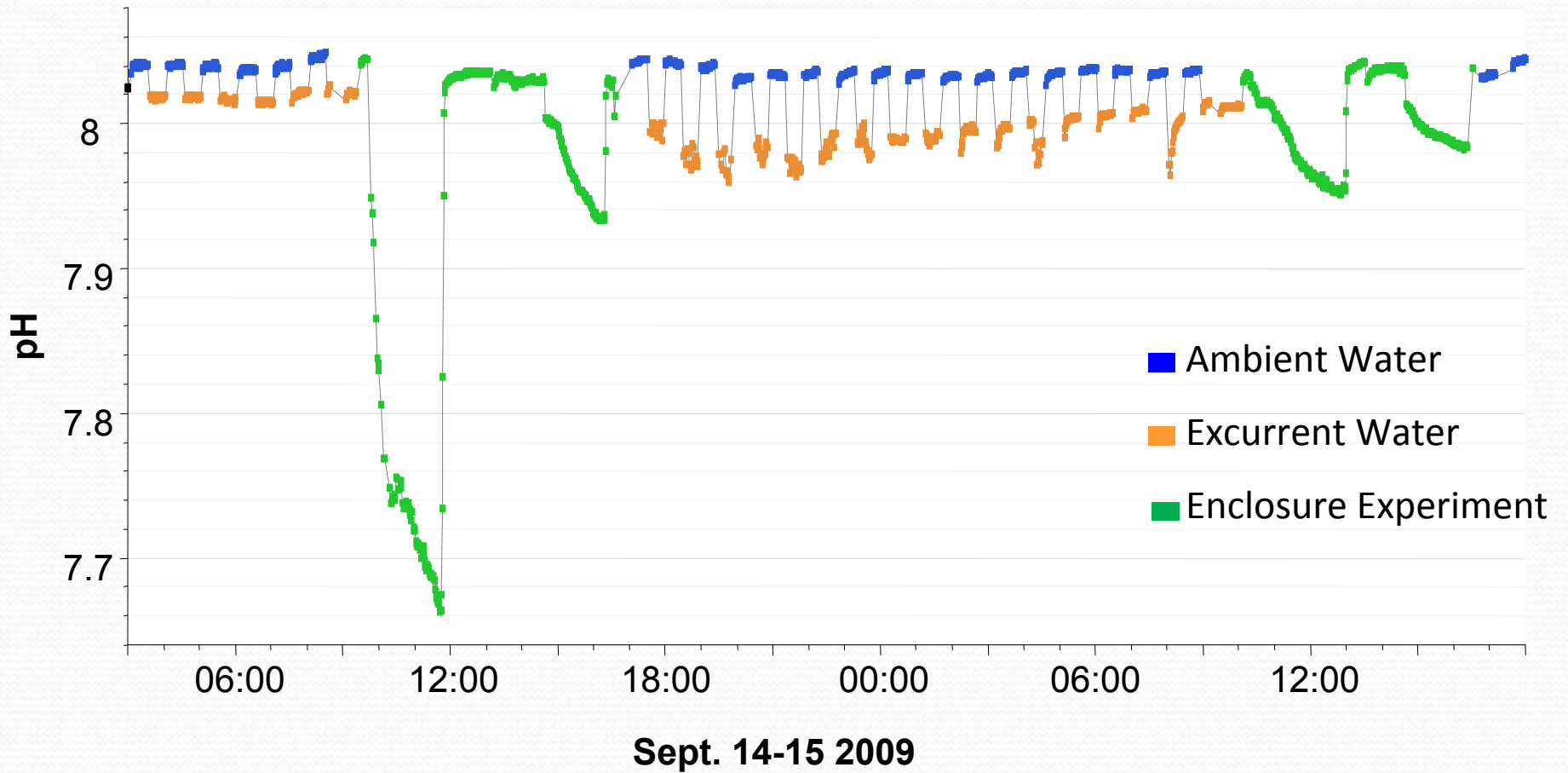
Sponge Stoichiometry

$$C_{106}N_{21}P + \sim 150 O_2 \rightarrow$$

$$106 CO_2 + (21 NH_4^+ \rightarrow \sim 20 NO_3^- \rightarrow \sim 1 N_2)$$

+1P + water, etc…

DOC Uptake

DOC difference between paired ambient and excurrent water.
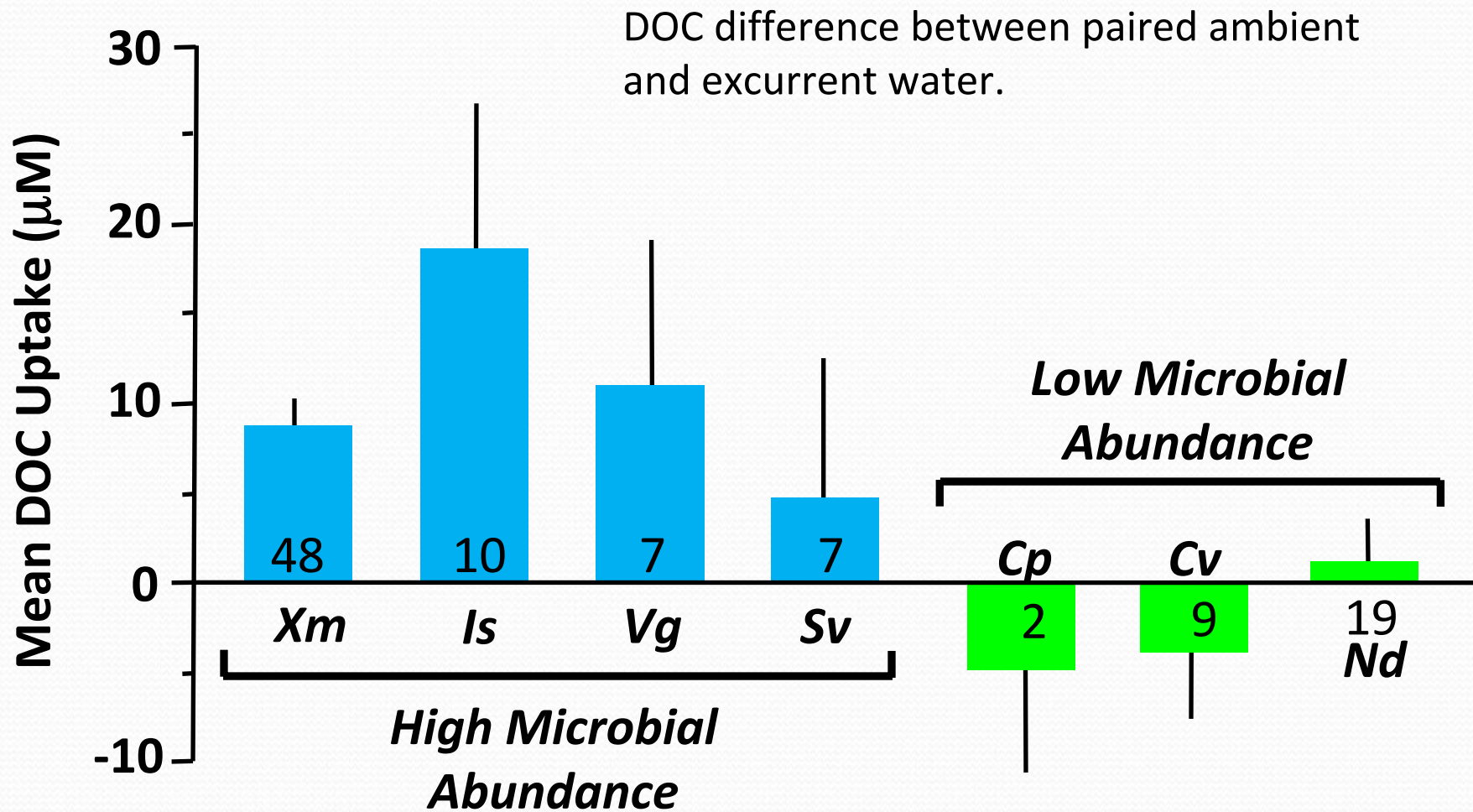
Respiration and pH

Sep. 21-22, 2008

Left Scale: ■ uM O2
Right Scale: ● pH

Localized Acidification

Y-axis: pH (8, 7.9, 7.8, 7.7)

X-axis: 06:00, 12:00, 18:00, 00:00, 06:00, 12:00

Sept. 14-15 2009

Legend:
- Ambient Water
- Excurrent Water
- Enclosure Experiment

Aragonite Saturation

sampling height above bottom = ▬ 5 m   ▬ 0.05 m

$CO_3 (\mu M) = 270; \Omega\text{-arag} = 4.2$

$CO_3 (\mu M) = 175; \Omega\text{-arag} = 2.6$

pH axis: 8.15, 8.10, 8.05, 8.00, 7.95, 7.90, 7.85

Time axis: 16:00, 18:00, 20:00, 22:00, 00:00, 02:00, 04:00, 06:00, 08:00

July 13-14, 2010
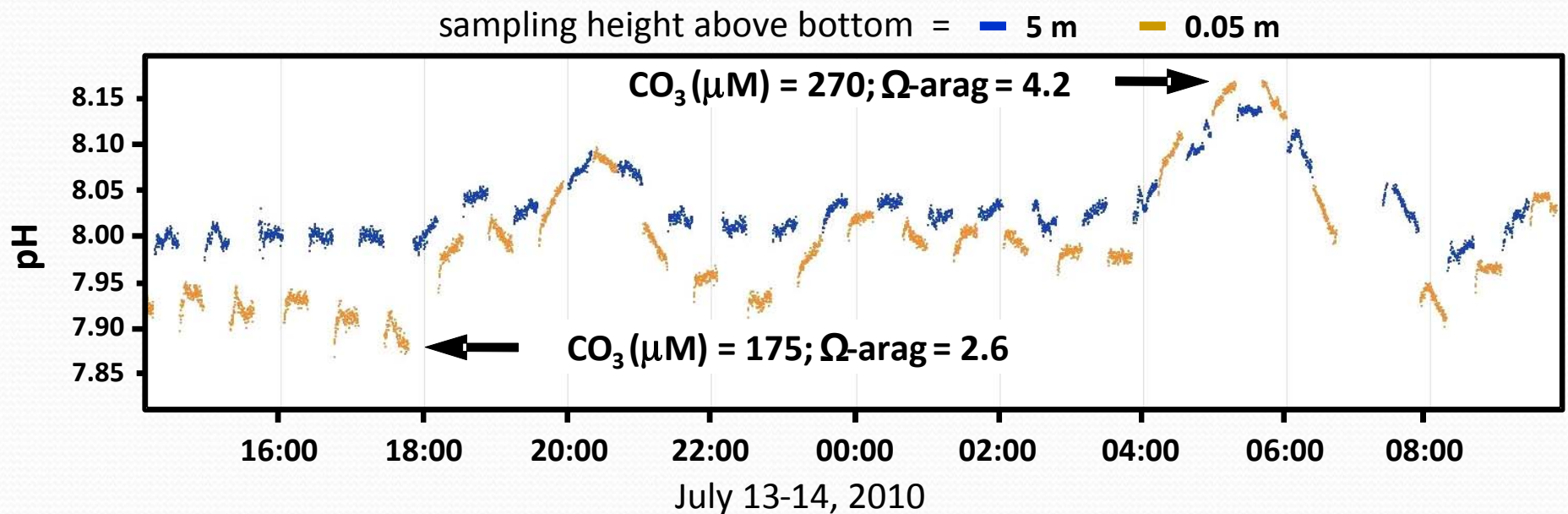
- Comparison of pH 0.05 m above boring sponges vs. 5 m above in water column.

- High rates of sponge respiration diminish reef calcification.

- Carbonate accretion stops at Ω-arag <3.3.

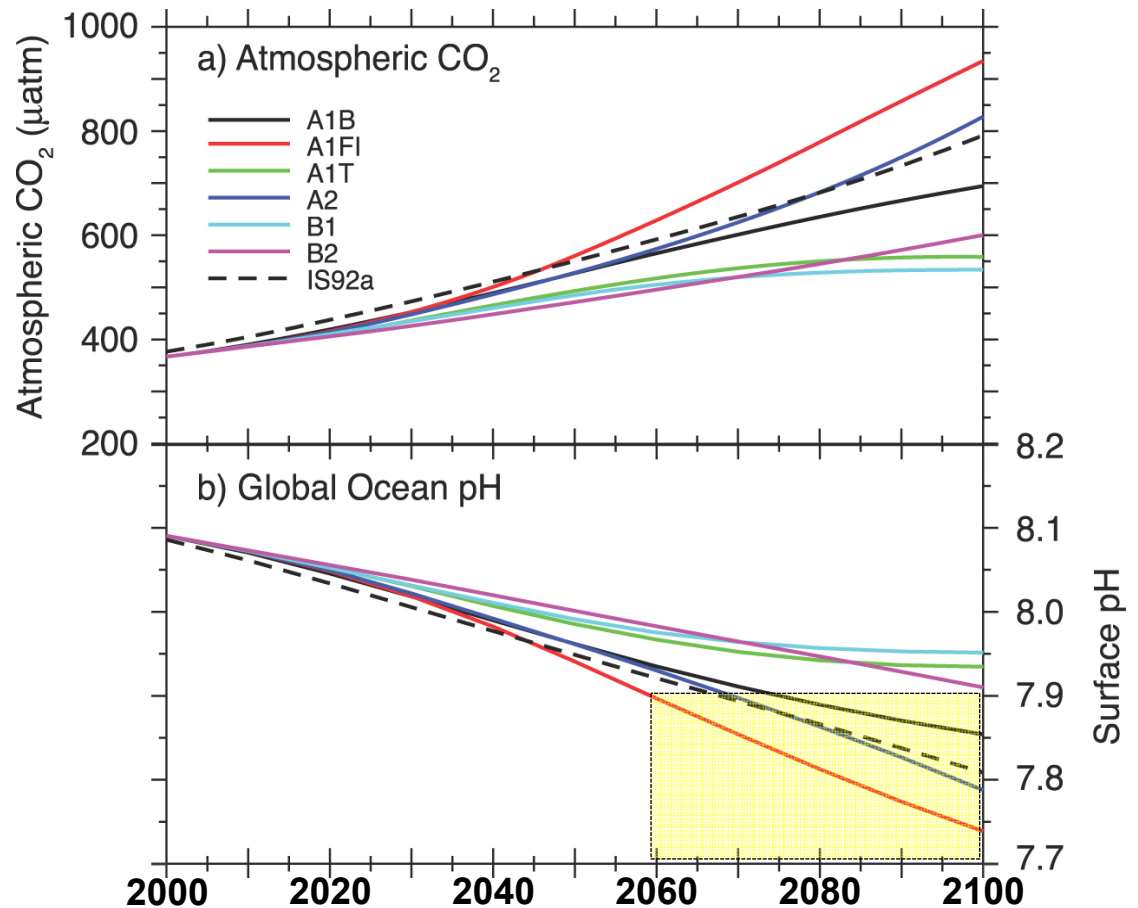   *(Kleypas et al. 1999, Kleypas & Langdon 2006, Hoegh-Goldberg et al. 2007)*

Local vs. Global Change

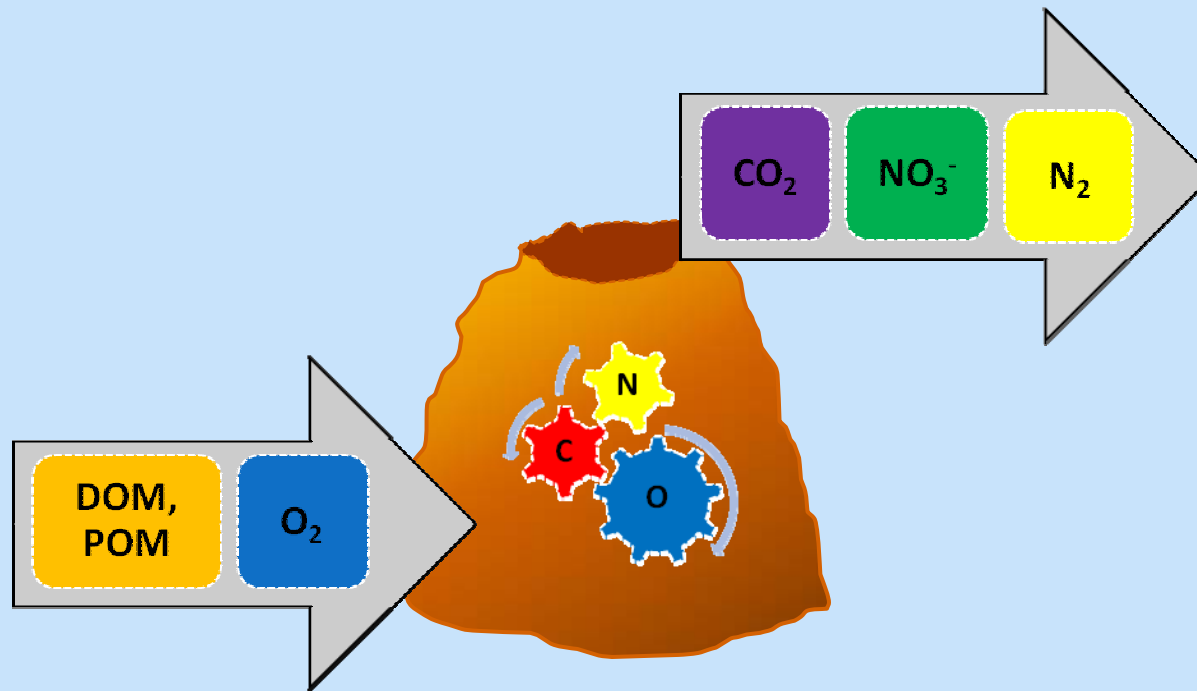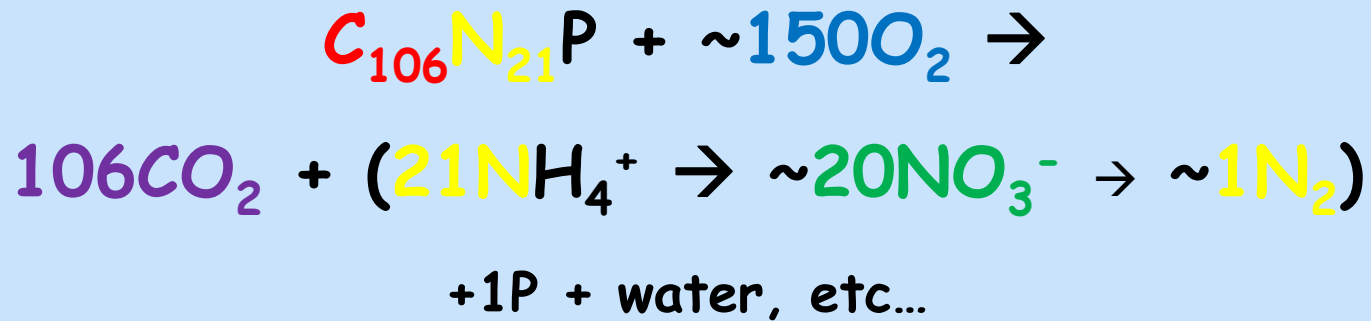Conch Reef BBL experiences localized minima in carbonate system parameters:

pH < 7.9
Ω-arag < 2.6

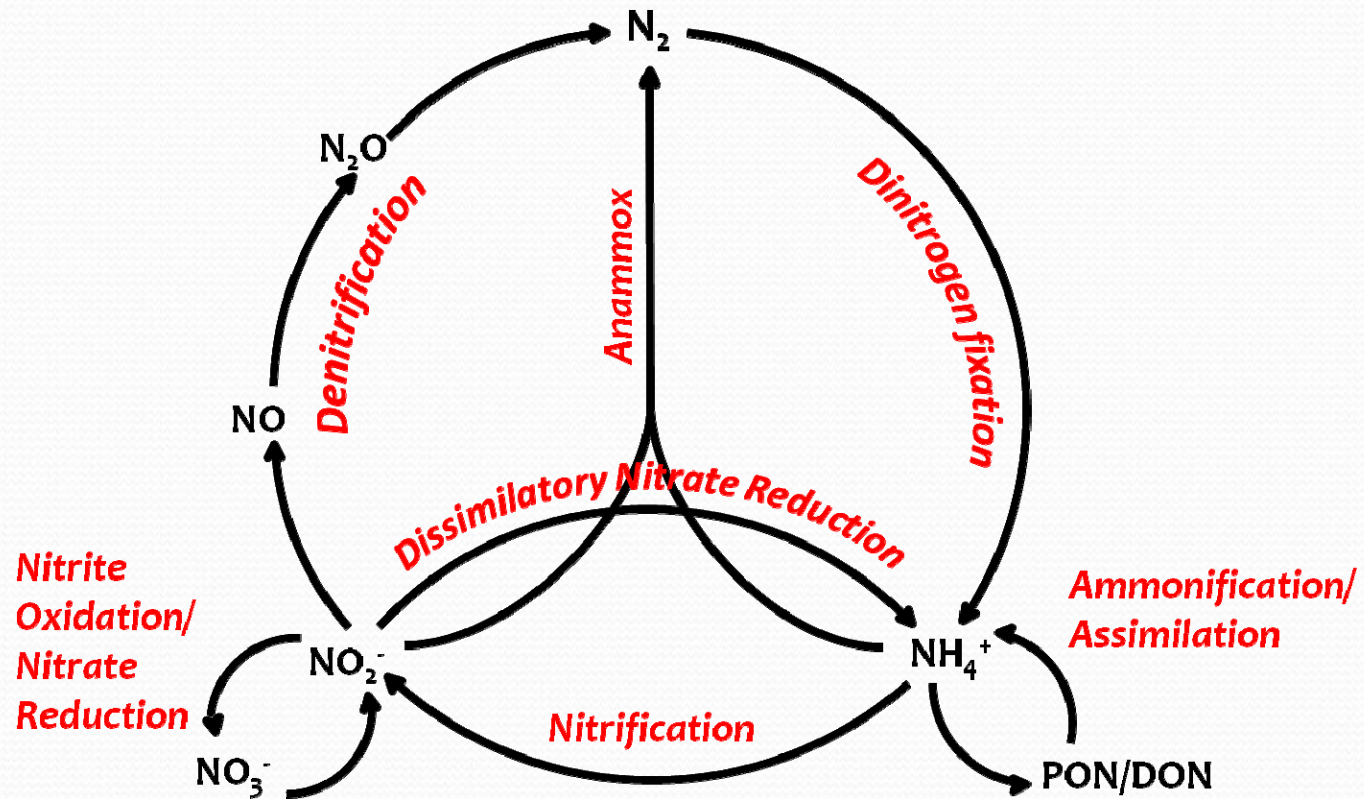Equivalent to IPCC Global Ocean pH projections beyond 2060.

Is Conch Reef 50 years ahead of schedule?

IPCC 2007

Sponge Stoichiometry

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$$106CO_2 + (21NH_4^+ \rightarrow \sim20NO_3^- \rightarrow \sim1N_2)$$

$$+1P + water, etc\ldots$$

The Nitrogen Cycle

Nitrification

July 10-12, 2010
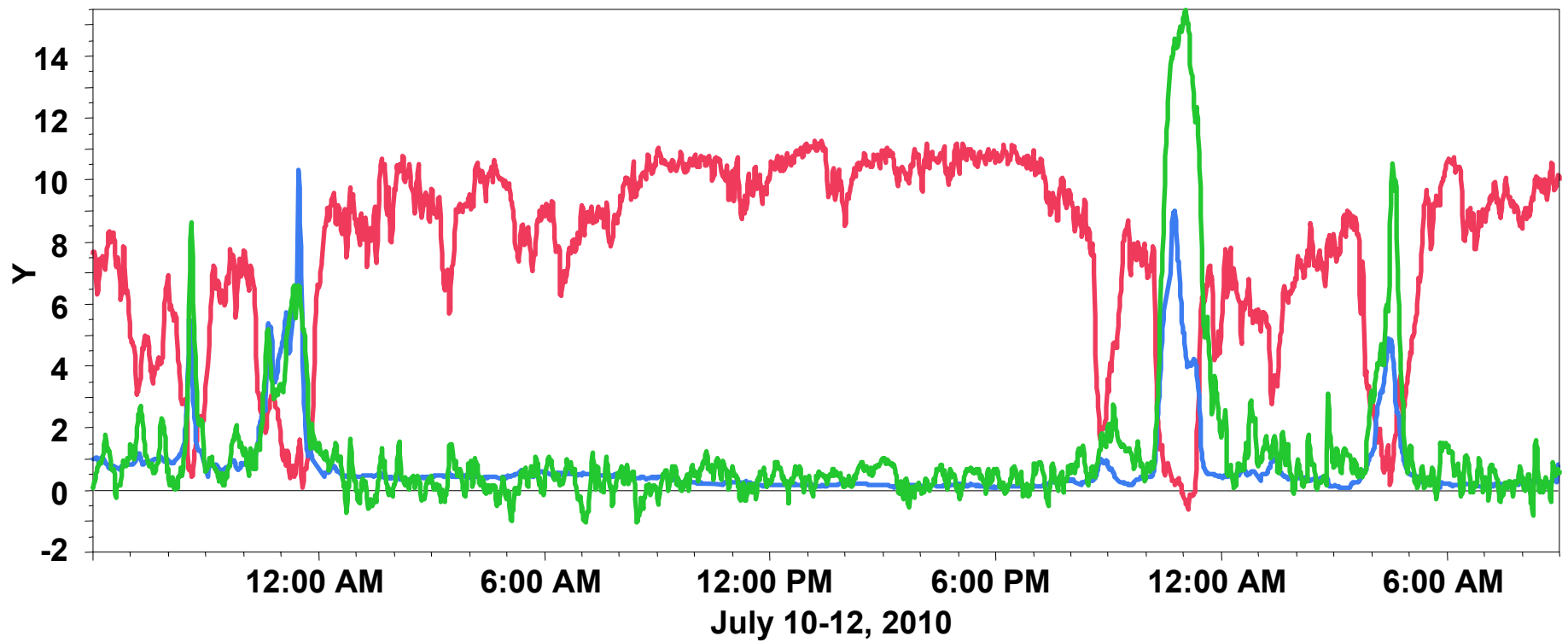
Y — **Pumping Rate (cm s^{-1})** — **NOx (uM)** — **O2 Demand (10uM)**

Reef N Flux Budget- *X. muta only*

- Estimated 0.925 mmol NO_X L_{sponge}^{-1} day^{-1}
- 2.6 L X.muta m^{-2} of reef

- **2.4 mmol NO_X m^{-2} day^{-1}**

- Reef Sediment Flux = 0.41 ($\pm$0.22) mmol N m^{-2} day^{-1}

Ecosystem Interactions

- Space (hard substrate) is a limiting resource of reef ecosystems.

- Degraded reef ecosystems feature reduced hard coral populations which create this resource.

- Positive and negative feedbacks exist which compound the effects of resource limitation.

Sponge-Algal Feedbacks

Grow *Dictyota* macroalgae in seawater labeled with $H^{13}CO_3$ and $^{15}NH_4$.

↓

Add algae to aquarium with HMA sponge.

→ Sample aquarium water for $DI^{13}C$ as evidence of DOM respiration.

↓

Remove labeled algae and add fresh unlabelled algae & allow to grow.

→ Sample algae for ^{15}N label as evidence of uptake of sponge derived $^{15}NO_3^-$.

DOM → 13CO2 / 15NO3-
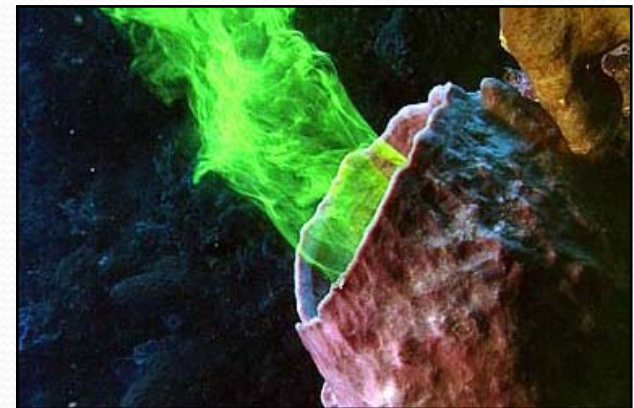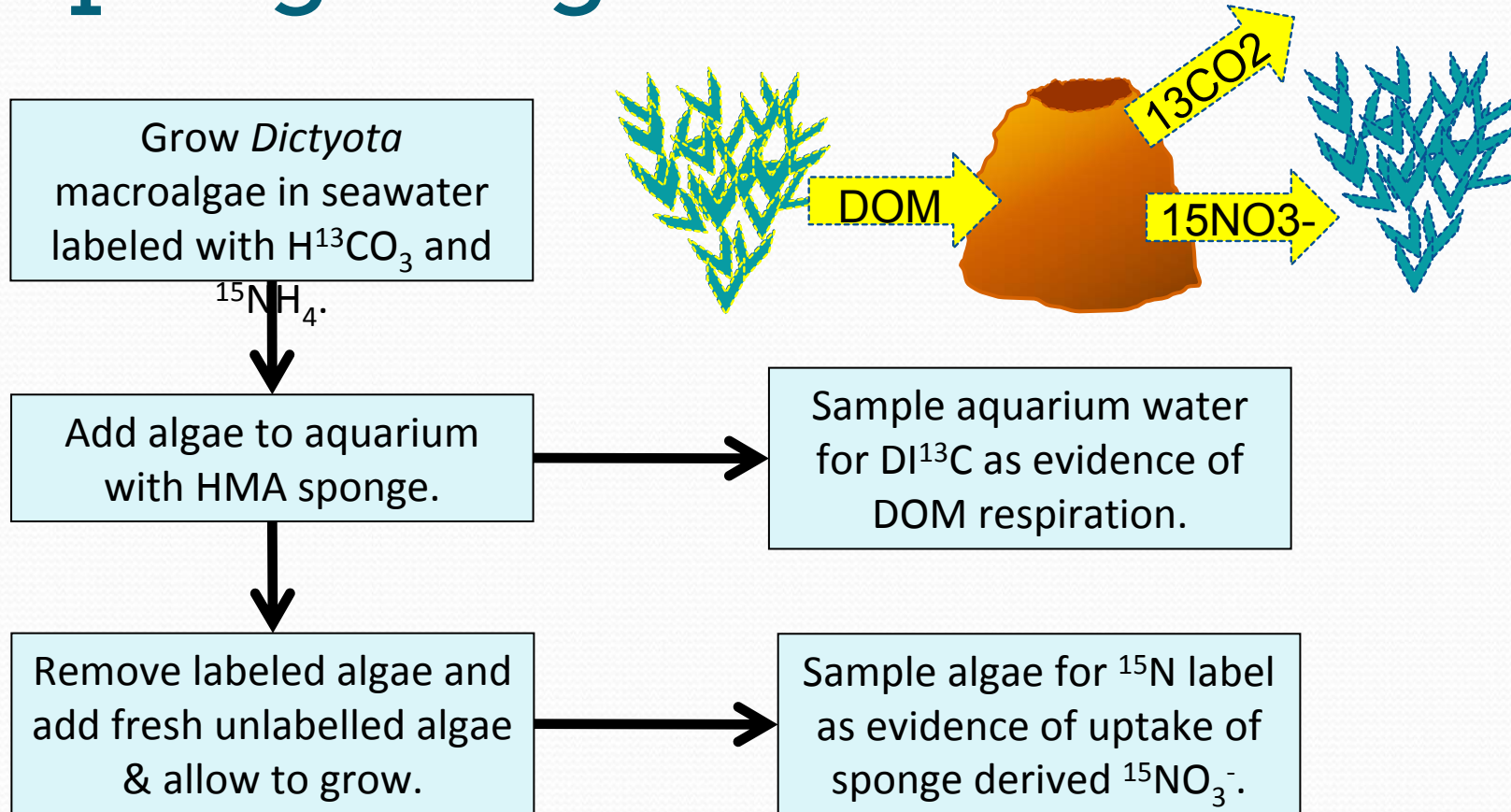
Run controls for algal respiration, microbial respiration, treatment effects.
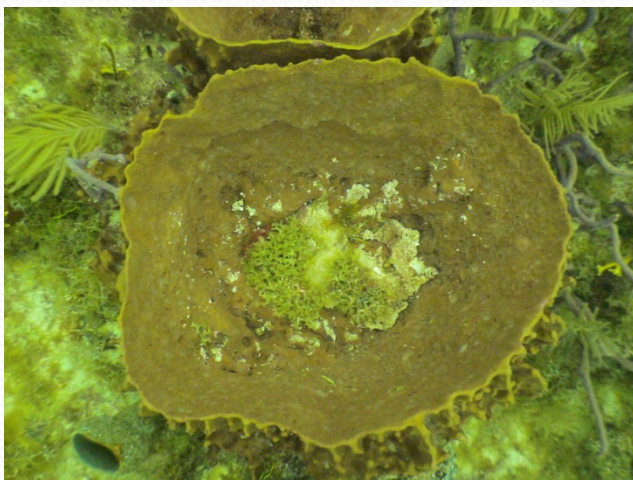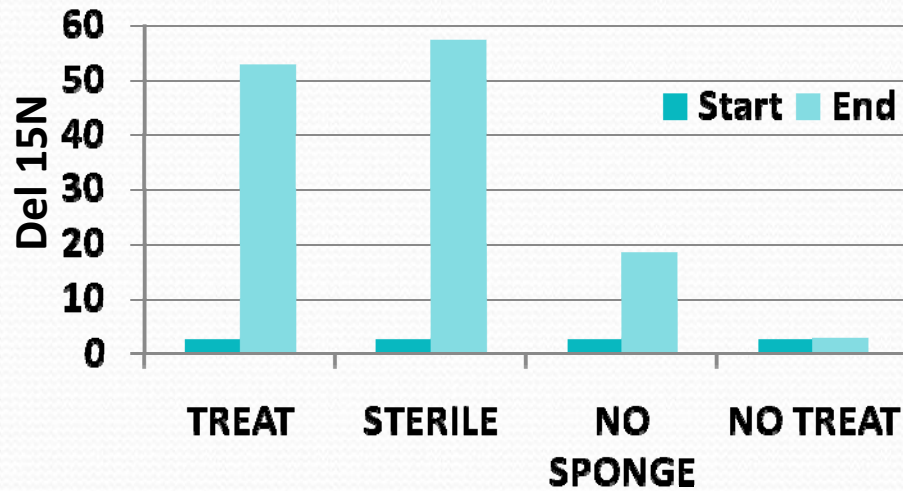
Sponge Respiration of Algal DOC
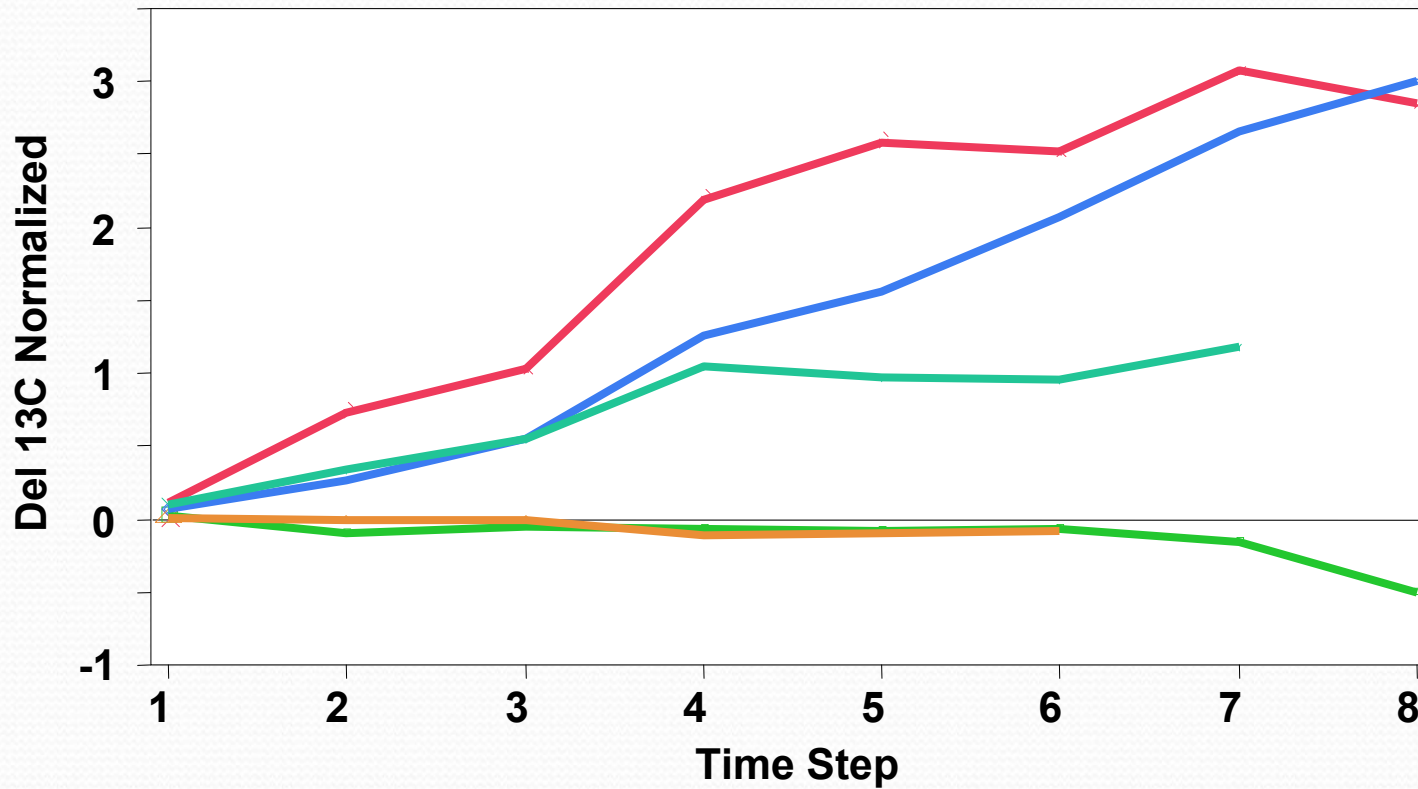
Algal Uptake of Sponge DIN

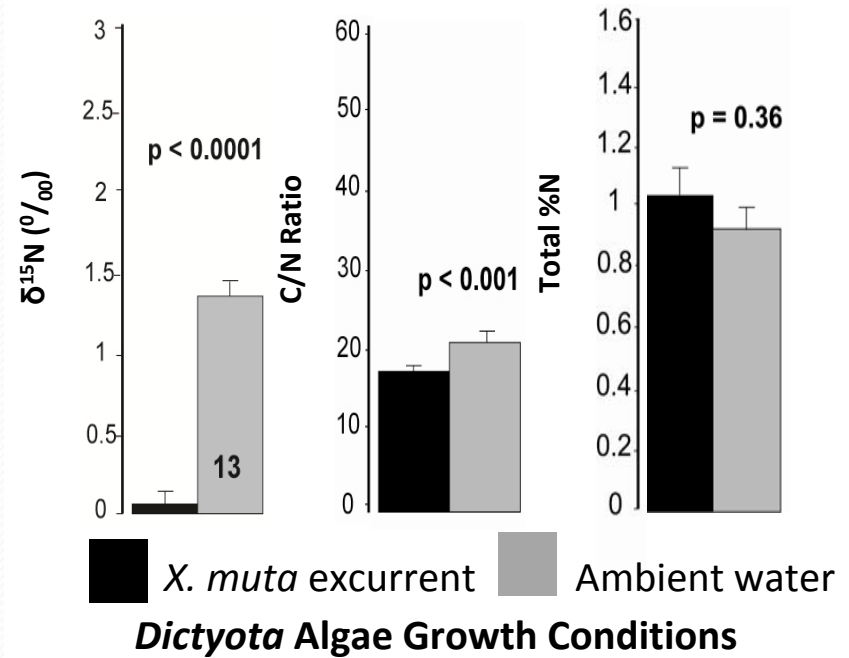N. Silbiger unpublished

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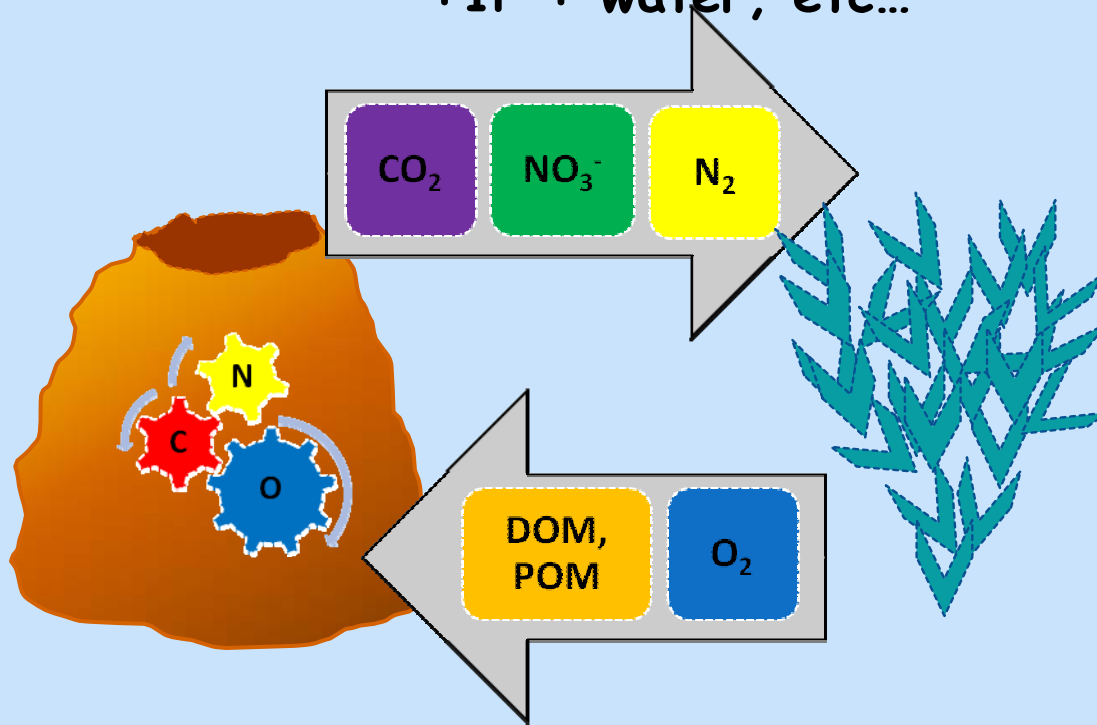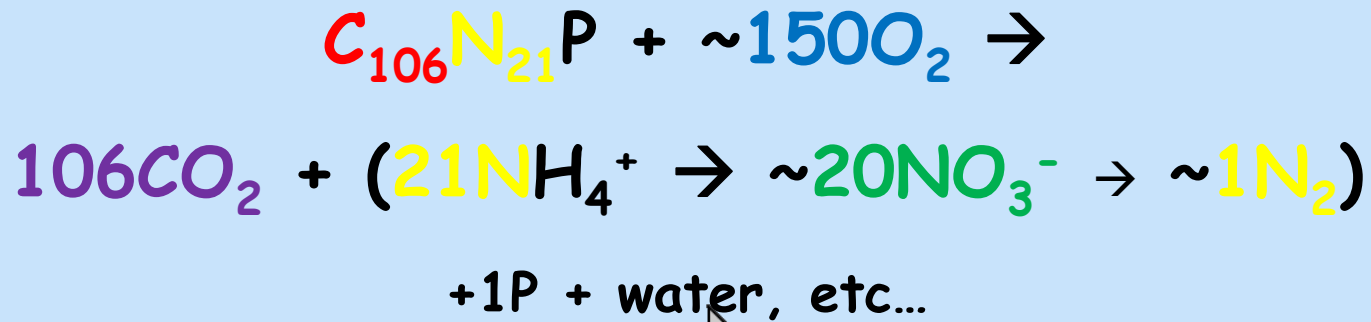
Reef Ecosystem Feedback
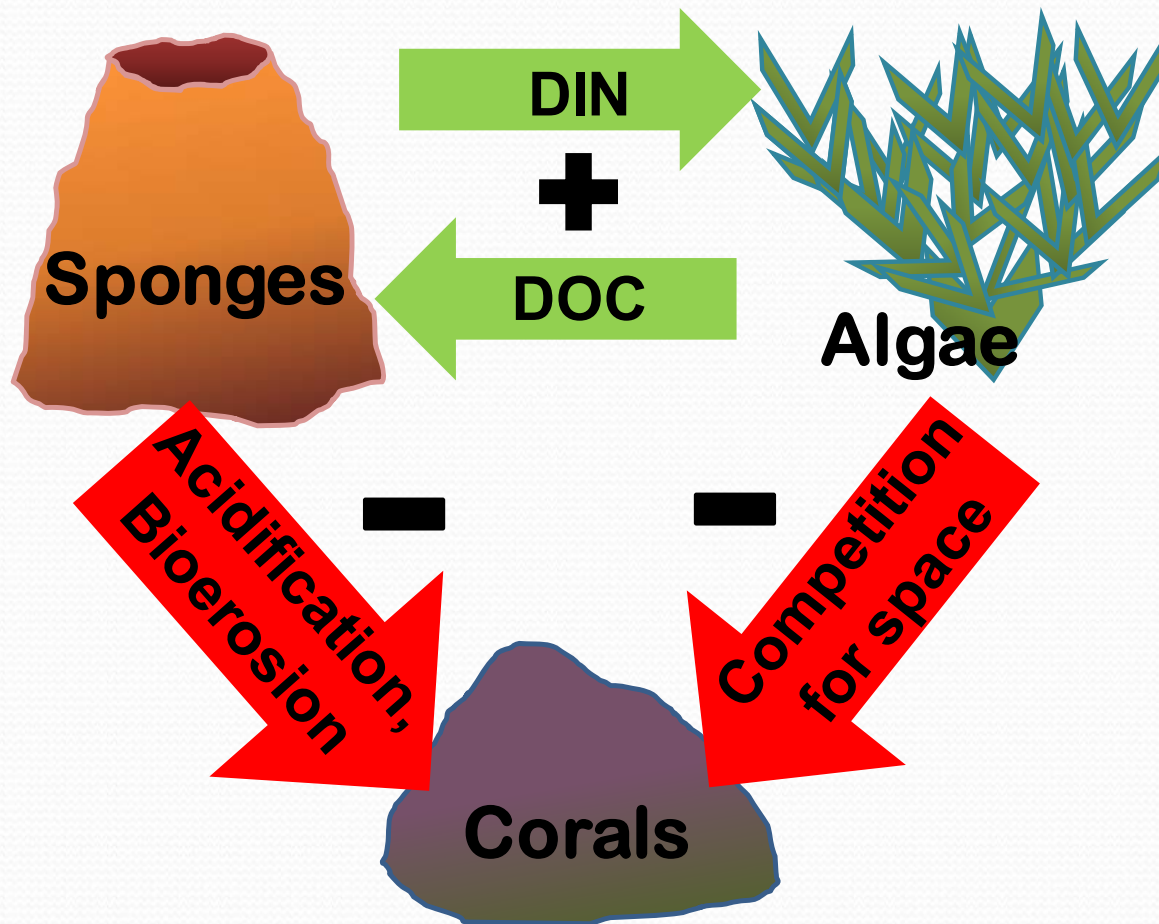
Take-Home Messages

- Sponges dominate much of the Keys reef ecosystem.

- Rapid metabolic processes can alter reef water quality.

- Feedbacks between reef ecosystem components may be accelerating system change.

- More attention should be paid to the functional role of sponge populations on the reef.

Thank You!