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

Patrick J. Gibson
Chris Martens, Niels Lindquist, Brian Popp, Nyssa Silbiger, Dan Hoer

Linking Science to Management on the Florida Keys Marine Ecosystem
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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.

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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 (O₂, N₂, Ar, CO₂)
  - SEAS Spectrophotometric Auto Analyzers (pH, NOₓ)
  - AADI String Optode System (10 O₂, C, T, P, Turbidity, Current)
  - Nortek ACDPs and ADVs.
The Underwater Lab

- ADV
- TETHYS MIMS
- UniSense O2
- SEAS pH & NOx
- SBE CTD's with O2 & PAR
- Enclosure
Realtime Data Flow

Continuous, realtime data monitoring with instrument control from the ARB habitat or base.
Diver Collections, Field and Lab Experiments
Sponge Stoichiometry

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

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

\[ +1P + \text{water, etc…} \]
DOC difference between paired ambient and excurrent water.
Respiration and pH

Sep. 21-22, 2008

Left Scale: uM O2
Right Scale: pH
Localized Acidification

Ambient Water
Excurrent Water
Enclosure Experiment

Sept. 14-15 2009
Aragonite Saturation

- 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 $\Omega$-arag <3.3.

(Kleypas et al. 1999, Kleypas & Langdon 2006, Hoegh-Goldberg et al. 2007)
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?
Sponge Stoichiometry

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+1P + water, etc...
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 (±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.
Grow *Dictyota* macroalgae in seawater labeled with $H^{13}CO_3$ and $^{15}NH_4$.

Add algae to aquarium with HMA sponge.

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

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

Sample algae for $^{15}$N label as evidence of uptake of sponge derived $^{15}$NO$_3$.

Run controls for algal respiration, microbial respiration, treatment effects.
Sponge Respiration of Algal DOC

![Graph showing Del 13C Normalized over Time Step](image)

- **TREAT**
- **NO ALGAE**
- **NO SPONGE**
- **NO TREAT**
- **STERILE**
Algal Uptake of Sponge DIN

Del 15N

Start  End
TREAT  STERILE  NO SPONGE  NO TREAT

Algal Uptake of Sponge DIN

X. muta excurrent Ambient water

Dictyota Algae Growth Conditions

N. Silbiger unpublished
Sponge Stoichiometry

$$C_{106}N_{21}P + \sim150O_2 \rightarrow$$

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

$$+1P + \text{water, etc...}$$
Reef Ecosystem Feedback

Sponges

Corals

Algae

DIN

DOC

Acidification, Bioerosion

Competition for space

Competition for space
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!

Sponges

DIN

DOC

Algae

Corals

Acidification, Bioerosion

Competition for space