

Disentangling the effects of local and global stressors on urbanized corals in a changing ocean

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Wendy Heiger-Bernays³, Randi Rotjan¹

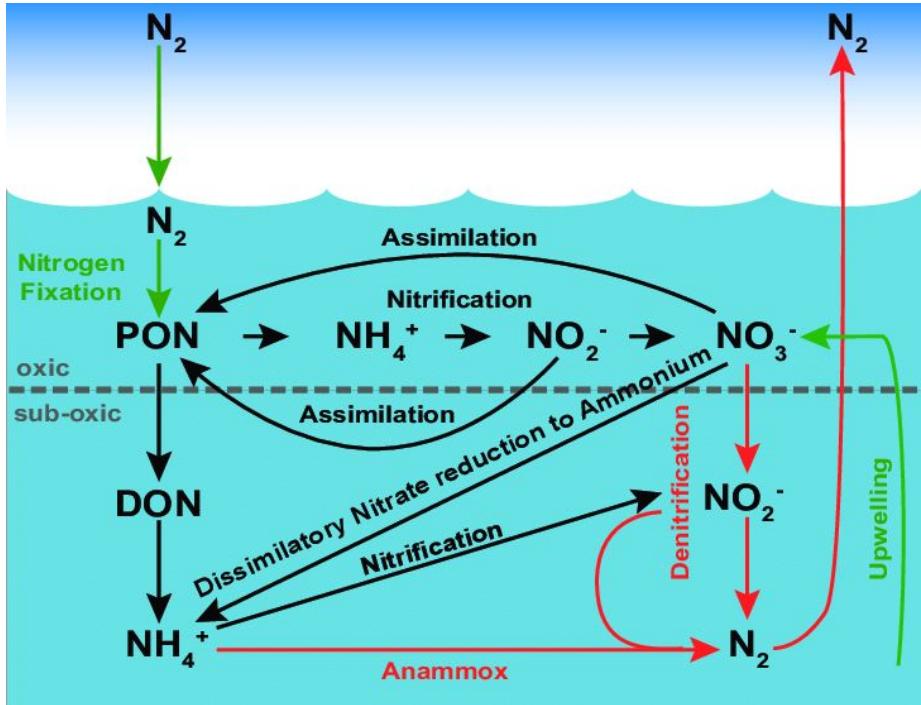
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University, Boston, Massachusetts

Nitrogen is essential to all life!

- Amino acids (proteins)
- DNA
- Energy storage
- Structure
- In corals...
 - Assimilation of photosynthates into workable energy



The problem: nitrogen pollution & corals

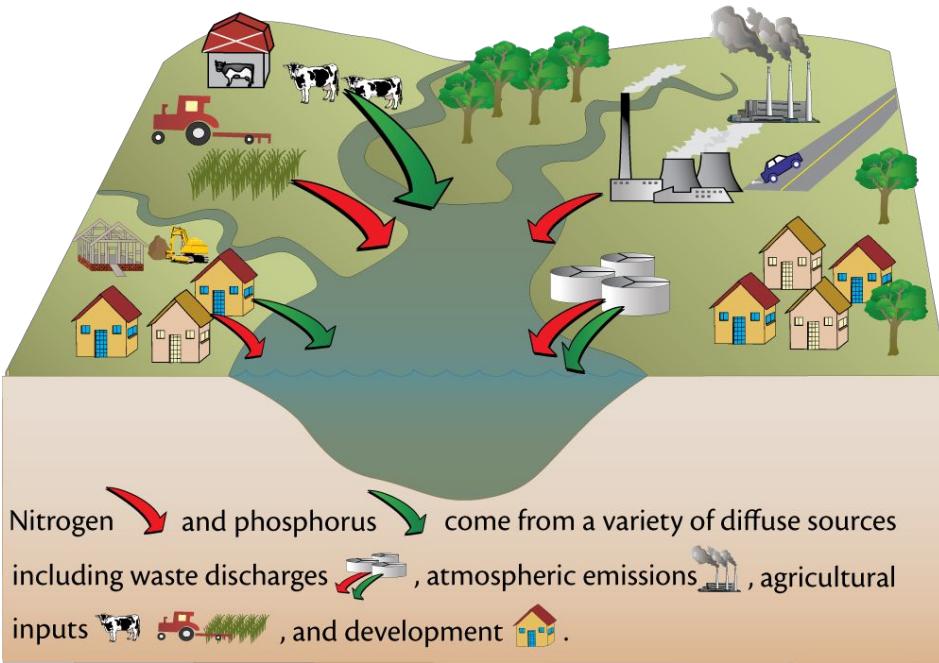
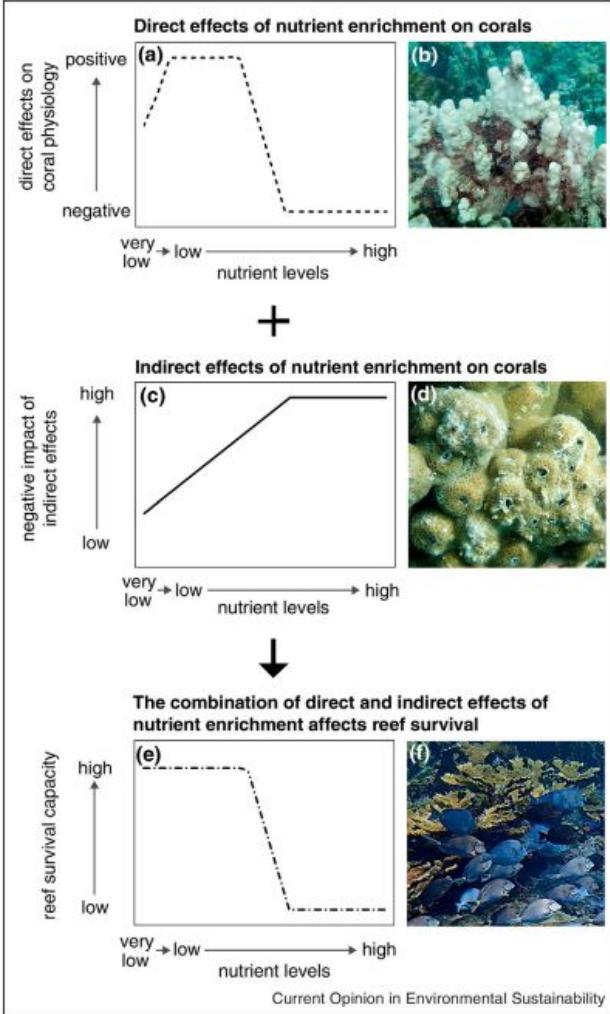


Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Lane, H., J.L. Woerner, W.C. Dennison, C. Neill, C. Wilson, M. Elliott, M. Shively, J. Graine, and R. Jeavons. 2007. Defending our National Treasure: Department of Defense Chesapeake Bay Restoration Partnership 1998-2004. Integration and Application Network, University of Maryland Center for Environmental Science, Cambridge: MD.



Astrangia poculata

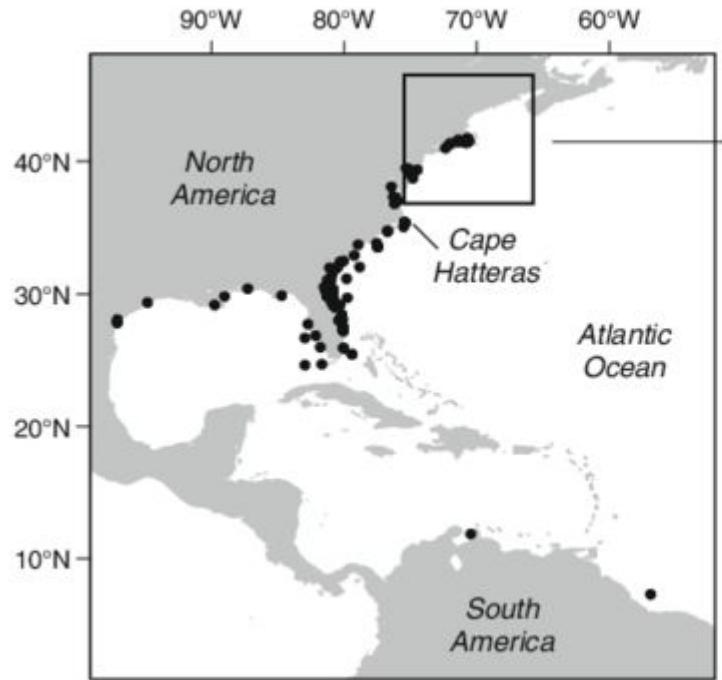


Credit: J. Dimond

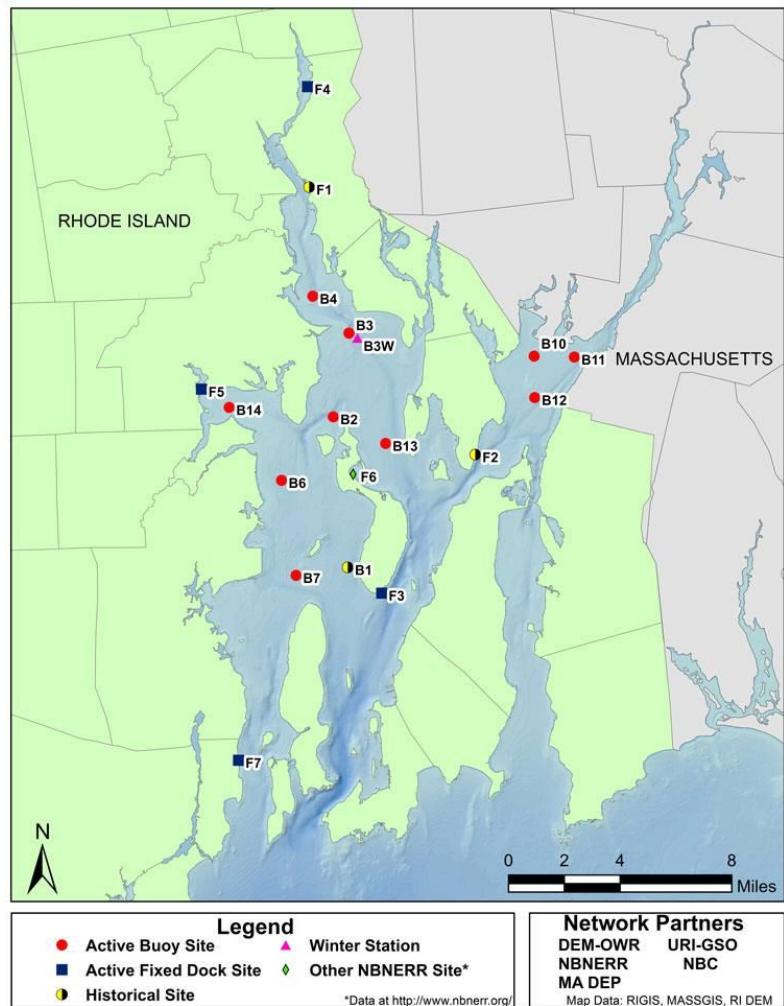
The northern star coral



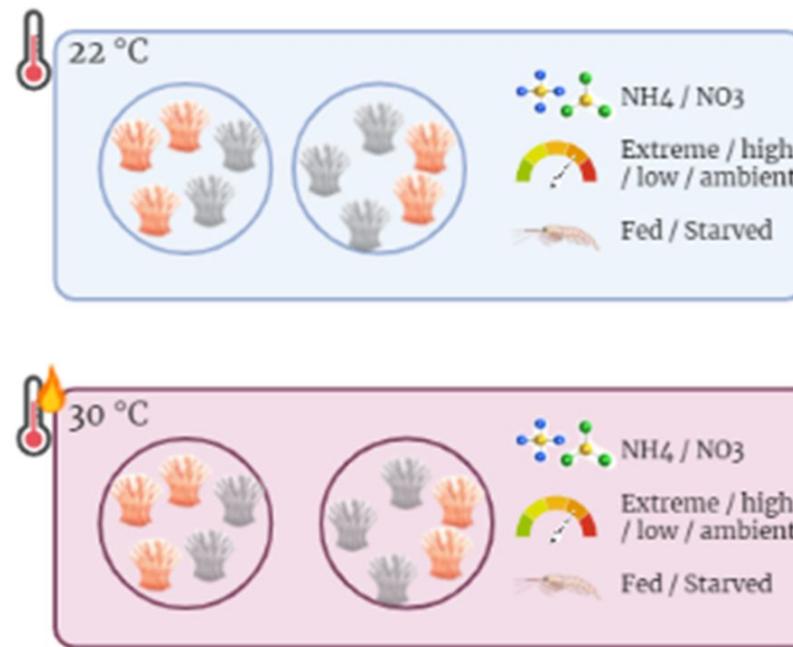
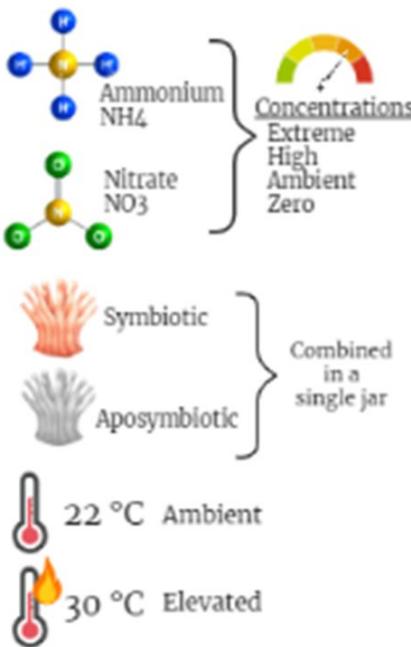
Astrangia's urban habitat



Narragansett Bay Fixed-Site Water Quality Monitoring Network Locations



TREATMENTS



METHODS



Schedule



Treatment summary:

2 N species x
4 N levels x
2 temperatures x
2 feeding regimes
= 32 treatment combinations

Diving and coral collection



Coral fragmentation & assigning

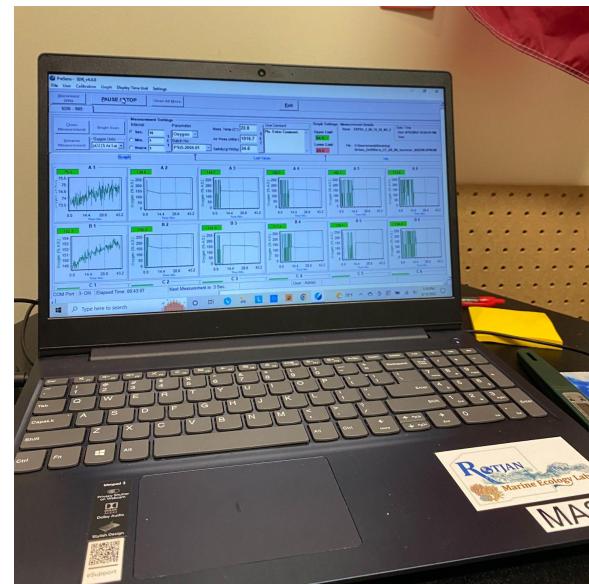




Photosynthetic efficiency



Respirometry





Respirometry



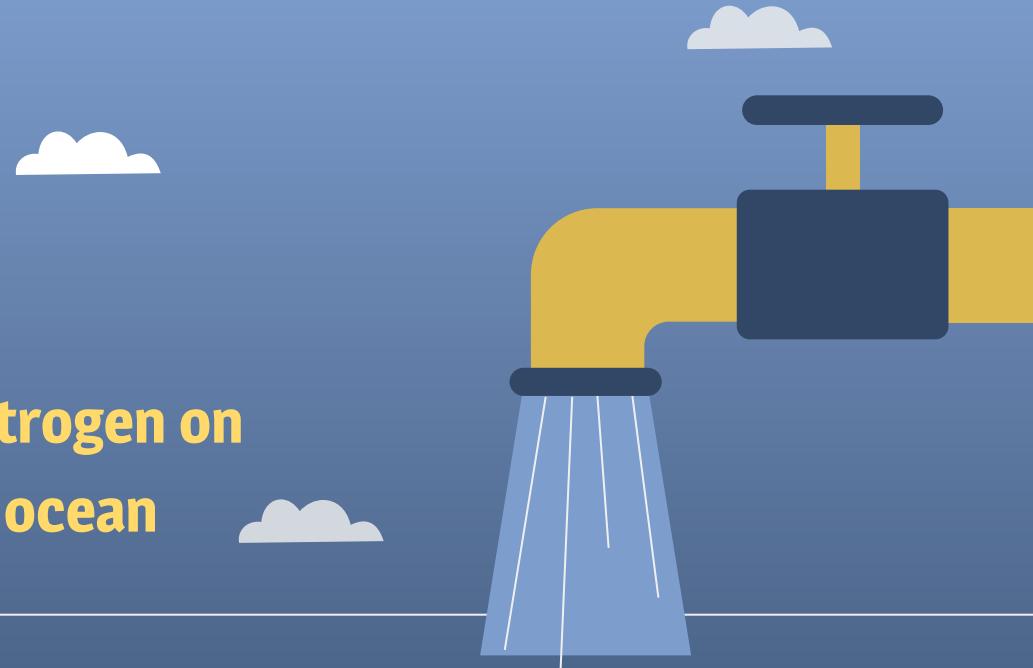
Photosynthetic efficiency

Nutrient or pollutant?

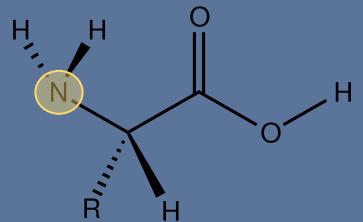
Disentangling the effects of nitrogen on
urbanized corals in a changing ocean



Caroline Fleming
Spring 2023 Chalk Talk



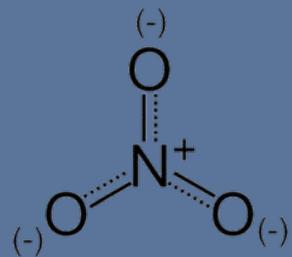
Nitrogen is essential to all life...



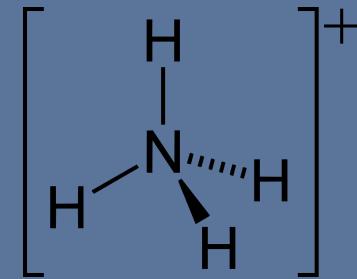
Amino acids



DNA

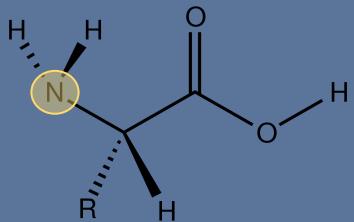


Nitrate

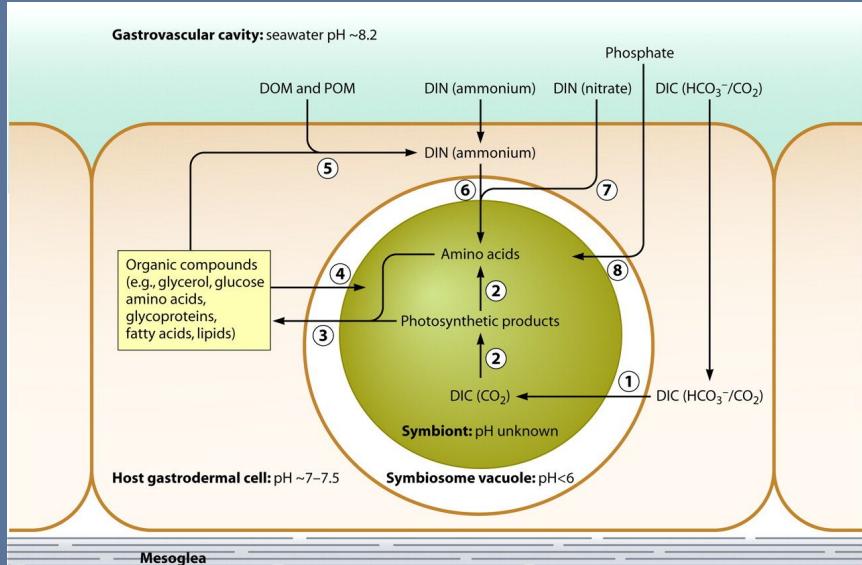


Ammonium

Nitrogen is essential to all life...



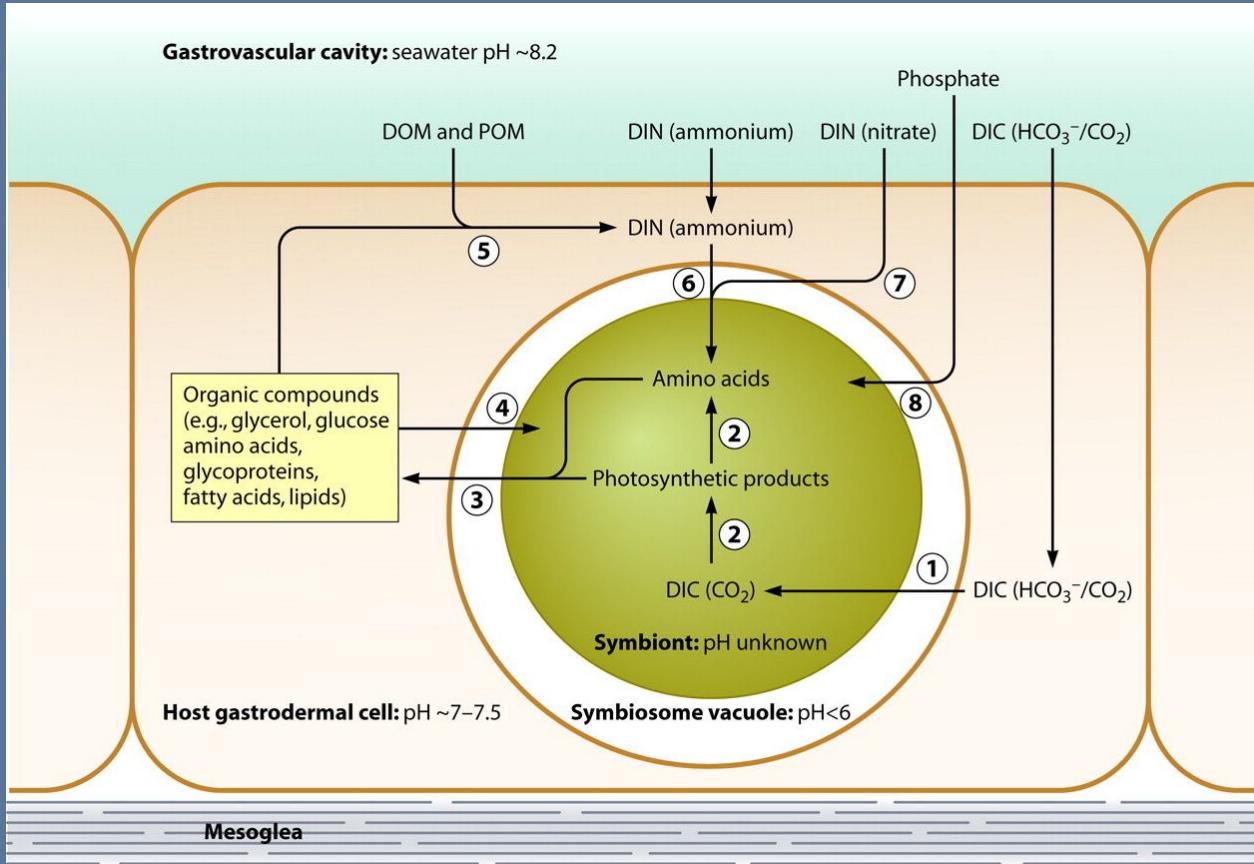
Amino acids



Davy et al. 2012

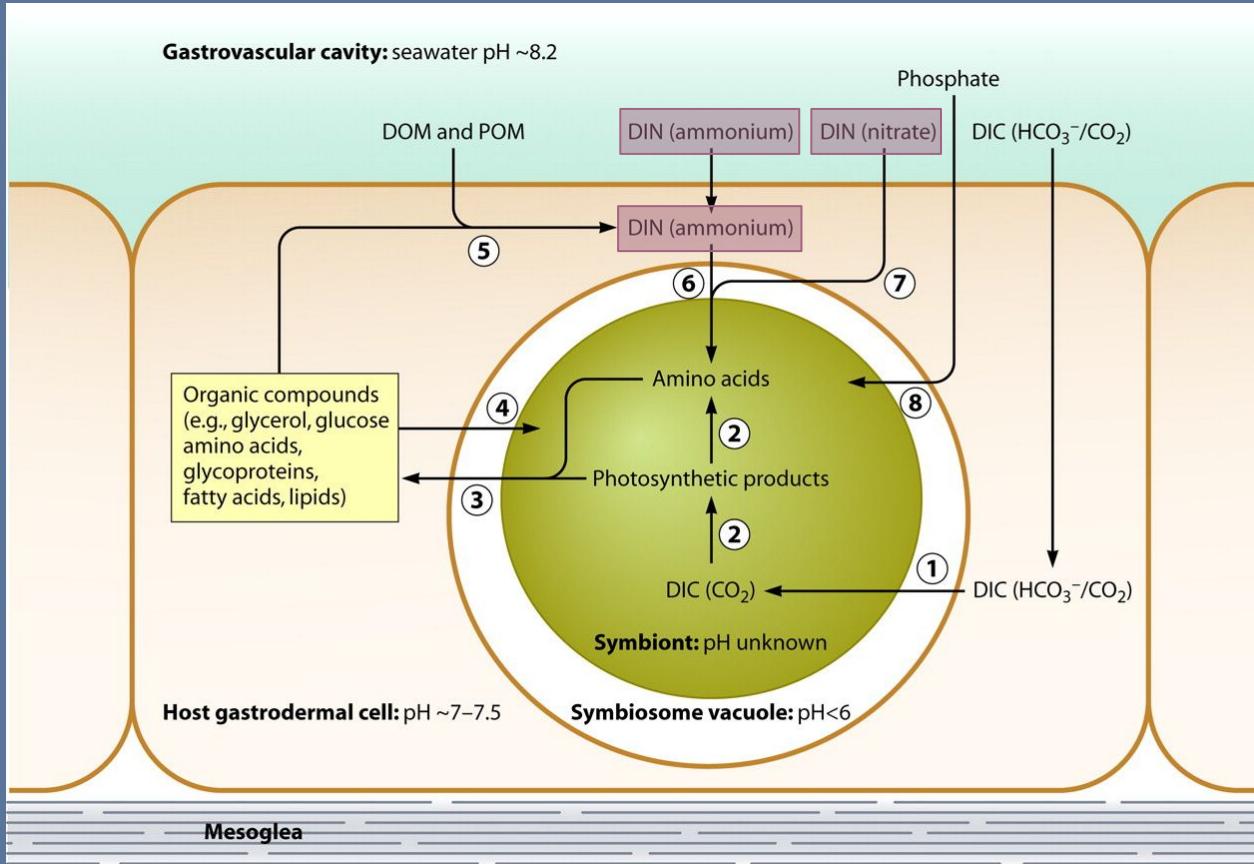
...but particularly important in coral symbiosis

N is particularly important in coral symbiosis...



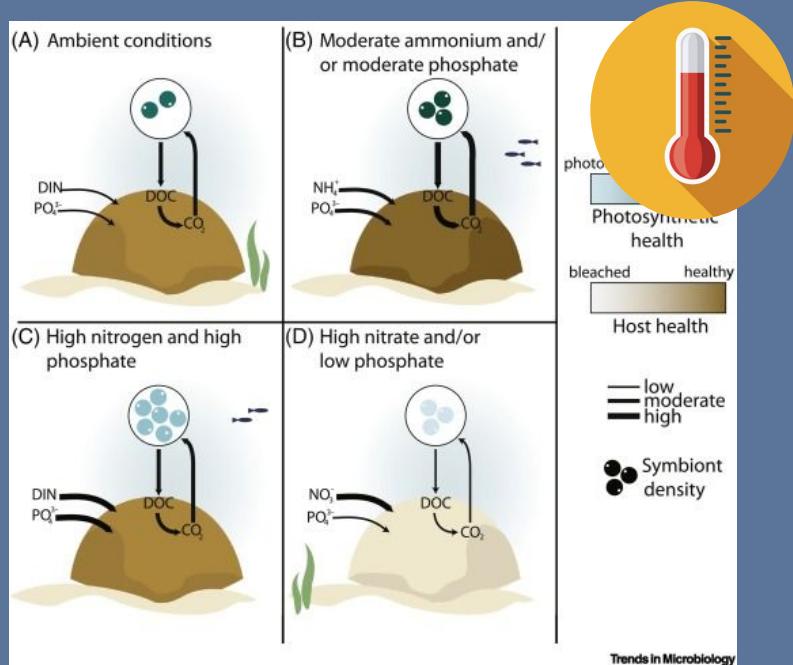
- Ammonium is bioavailable
 - Nitrate needs to be reduced into ammonium - ATP!
 - Burkepile et al. 2020
- Symbiont is more effective at taking up ammonium vs. host
 - Radecker et al. 2015

N is particularly important in coral symbiosis...

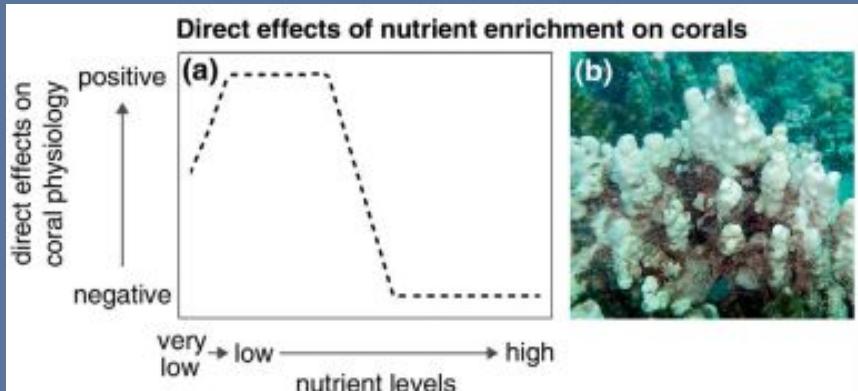


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Too much of a good thing in tropical corals



Morris et al. 2019



D'Angelo and Wiedenmann 2014

High levels of NH₄ and NO₃ can cause ROS, potentially lower bleaching threshold
(DeCarlo et al. 2020)

Nitrogen pollution occurs in urban areas

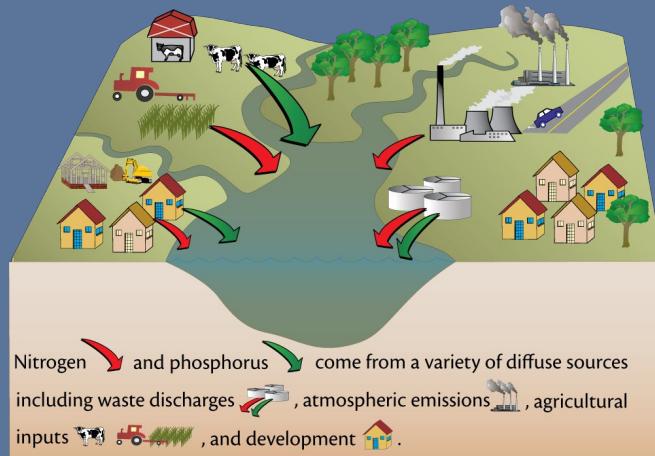


Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Lane, H., J.L. Woerner, W.C. Dennison, C. Neill, C. Wilson, M. Elliott, M. Shively, J. Graine, and R. Jeavons. 2007. Defending our National Treasure: Department of Defense Chesapeake Bay Restoration Partnership 1998-2004. Integration and Application Network, University of Maryland Center for Environmental Science, Cambridge, MD.



Kyiv, Ukraine

Residential x Agricultural x Industrial



Corals live in urban areas

Northeastern USA

- NYC
- Providence
- New Bedford

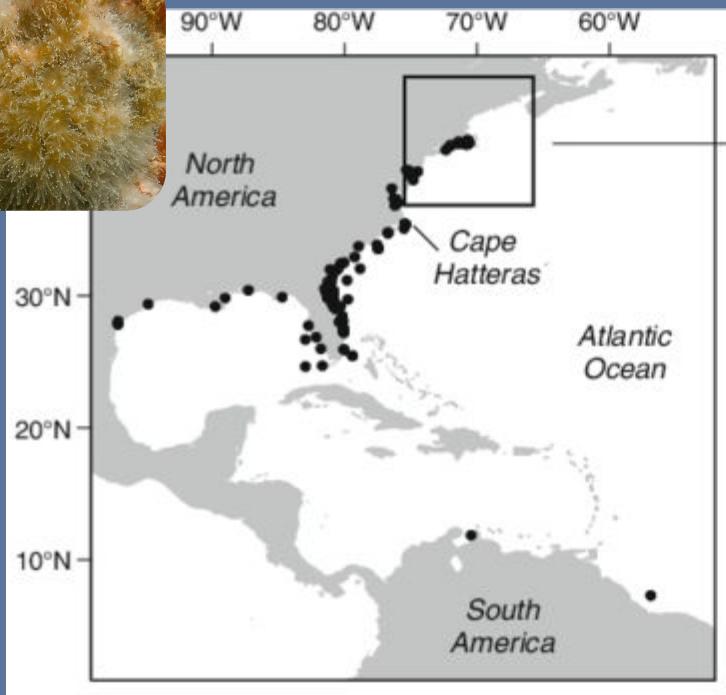
Miami, Florida

Caribbean

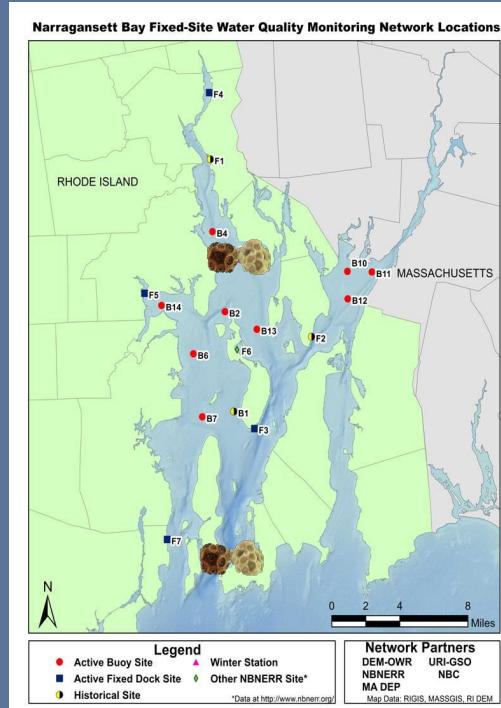
- Kingston, Jamaica
- Port-au-Prince, Haiti
- Santo Domingo, Dominican Republic
- San Juan, Puerto Rico
- Cancun, Mexico
- Havana, Cuba
- Barranquilla, Colombia
- Cartagena, Colombia



Astrangia poculata: an urban coral



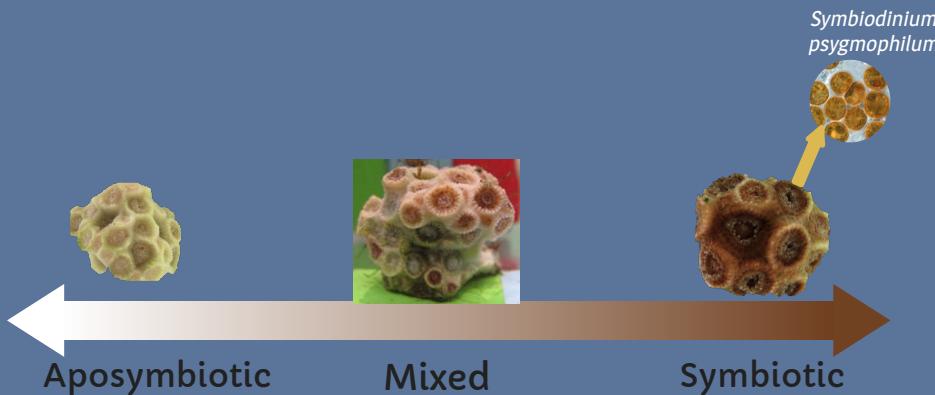
Narragansett Bay, RI



- Established history of nutrient and bacterial pollution
 - Balint et al. 2021, Tyrell et al. 1995
- Large population of *A. poculata*

Astrangia's facultative symbiosis

Interacting species are **NOT** fully dependent on each other to survive



Here's what we know...

- Nitrate and ammonium can act as a nutrient OR pollutant in tropical corals, depending on:
 - Dose (Morris et al. 2019)
 - Environmental conditions (e.g. temperature, Fernandes de Barros Marangoni et al. 2020)
- Temperate corals exists in areas with elevated levels of nitrate and ammonium (Balint et al. 2021) & of SST concern (Saba et al. 2016)
 - They readily take NO₃ and NH₄ up (DiRoberts et al. 2021)
 - They have the machinery to process & regulate these nutrients (Rivera and Davies 2022)

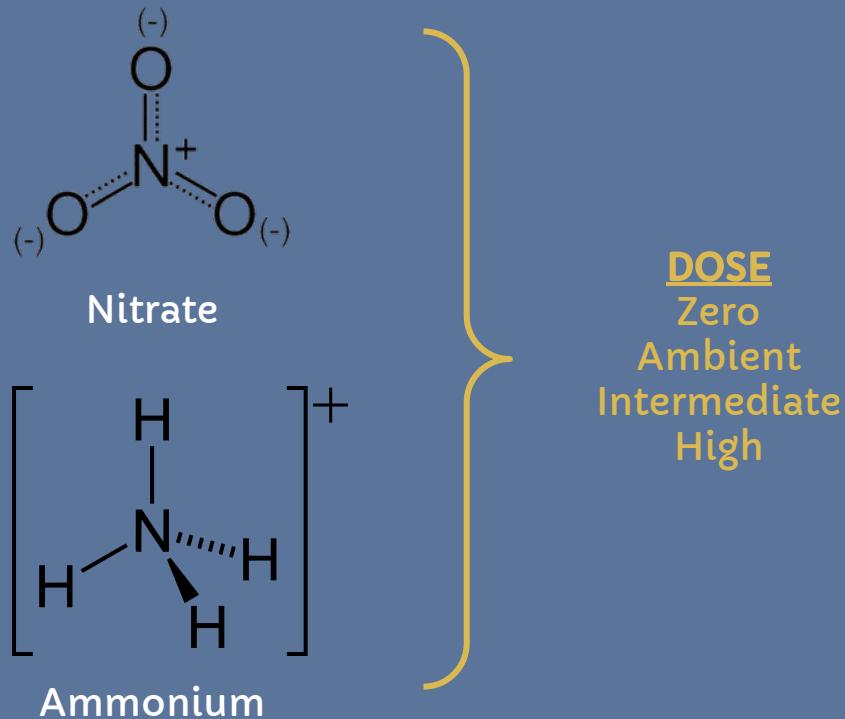
Here's what we DON'T know...

- How will *A. poculata* react to varying levels of nitrate or ammonium?
- How will these responses be modulated by local and global stressors?

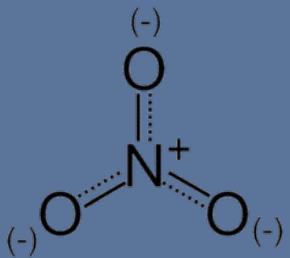
Local urban stressor : nutrient pollution

What is the effect of different ammonium and nitrate doses on coral symbiont & holobiont physiology?

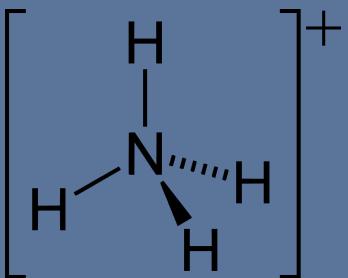
Local urban stressor : nutrient pollution



Local urban stressor : nutrient pollution



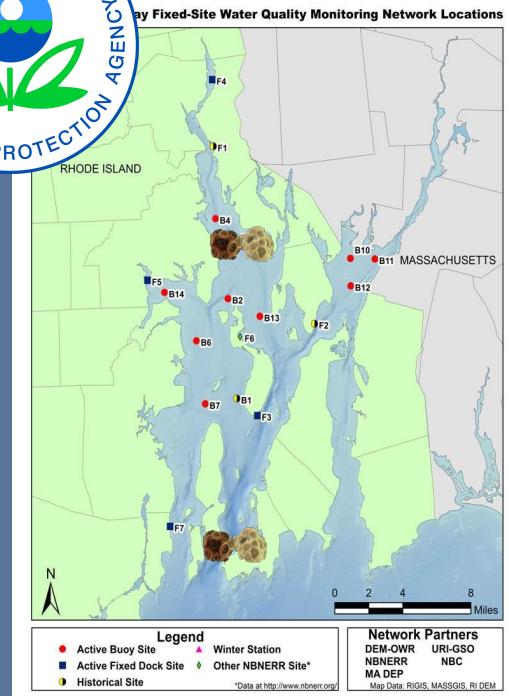
Nitrate



Ammonium



DOSE
Zero
Ambient
Intermediate
High



Coral collection

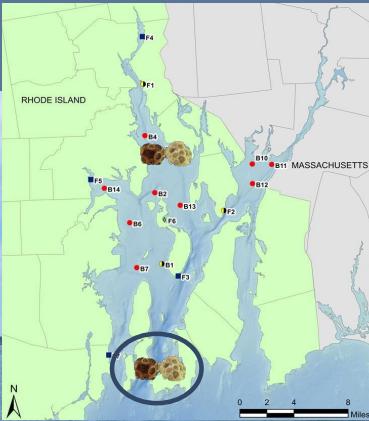


Ft. Wetherill, Rhode Island

Coral collection



Ft. Wetherill, Rhode Island



Grace
Comrade in science



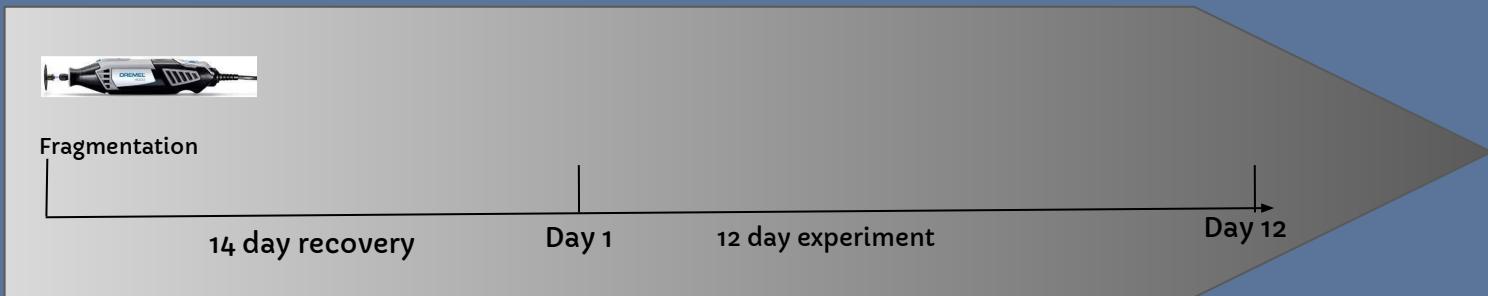
Lil' friends in the wild



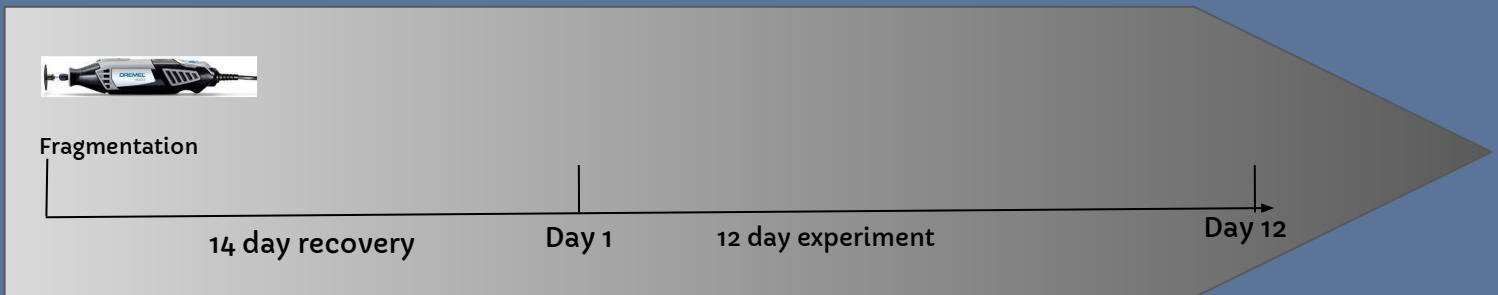
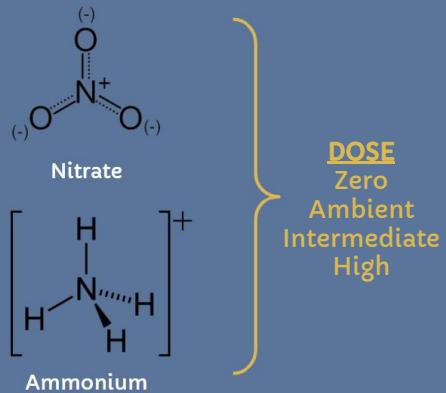
Jacob, Randi & Narineh
Divers Extraordinaire



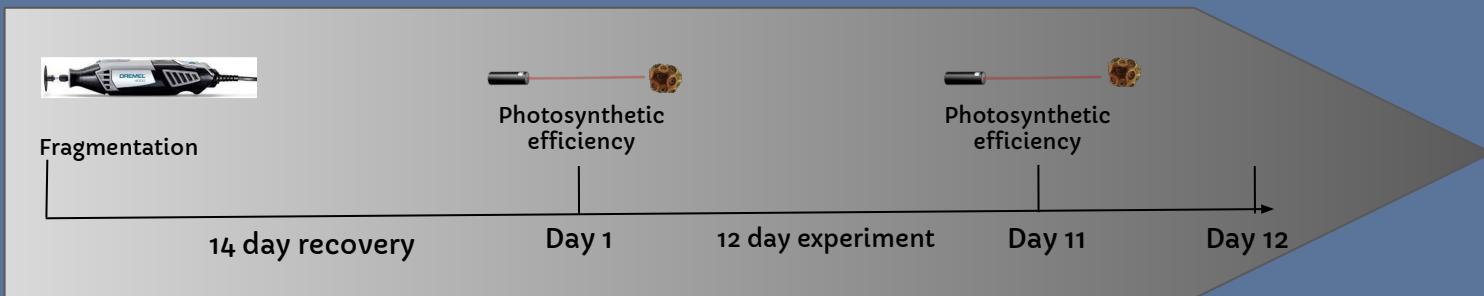
Coral fragmentation



Experimental setup



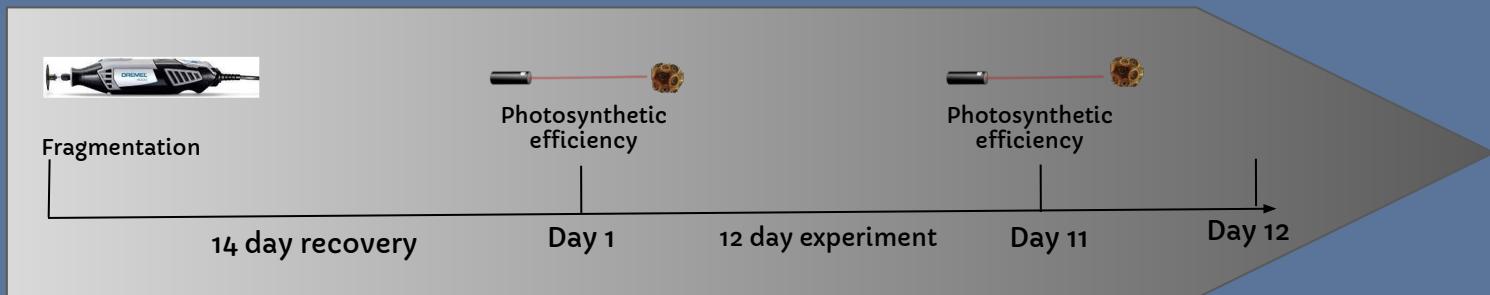
Metric #1: Photosynthetic efficiency as a measure of symbiont physiology



Change in photosynthetic efficiency

$$\Delta Fv/Fm =$$

$$Fv/Fm_{Day\ 11} - Fv/Fm_{Day\ 1}$$



Change in photosynthetic efficiency

$$\Delta Fv/Fm = \\ Fv/Fm_{Day\ 11} - Fv/Fm_{Day\ 1}$$

+ $\Delta Fv/Fm$ = increase in photosynthetic efficiency (BETTER)

- $\Delta Fv/Fm$ = decrease in photosynthetic efficiency (WORSE)



Previous work on Photosynthetic Efficiency (PAM)

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<https://doi.org/10.3354/meps13731> | Published: June 2021

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Testing assumptions of nitrogen cycling between a temperate, model coral host and its facultative symbiont: symbiotic contributions to dissolved inorganic nitrogen assimilation

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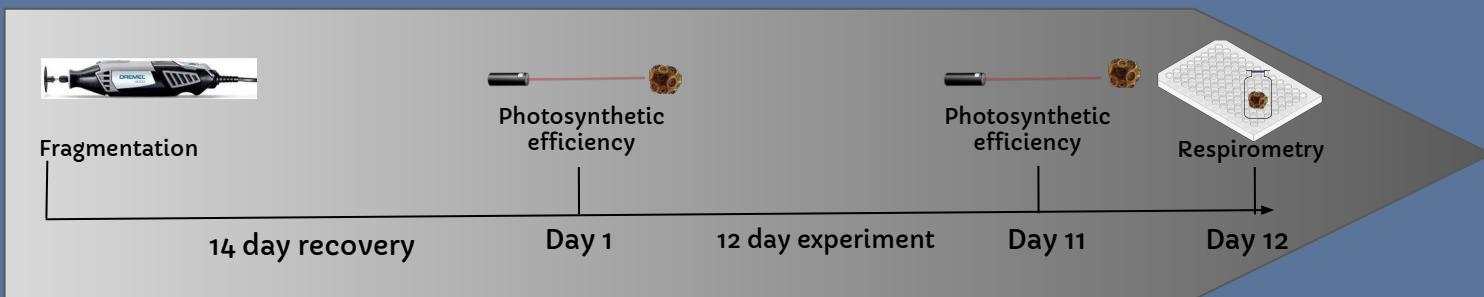
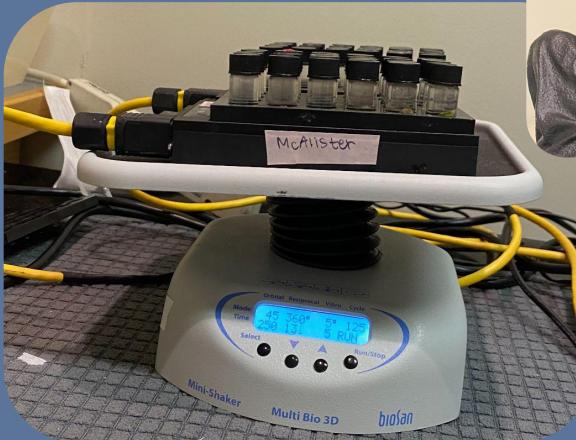


Photosynthetic efficiency increased with the addition of ammonium and decreased with nitrate, but only under certain symbiotic and feeding conditions.

Local urban stressor : nutrient pollution

What is the effect of different ammonium and nitrate doses on coral energetic physiology?

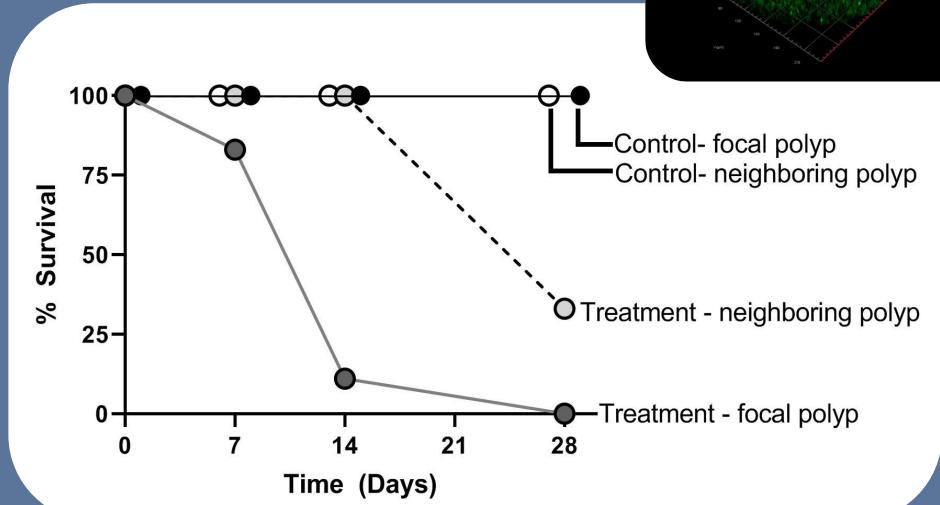
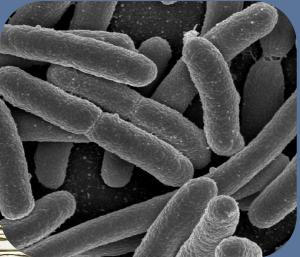
Metric #2: Dark respiration as a measure of holobiont physiology



Wastewater bacteria is also an urban input; how does it interact with N?

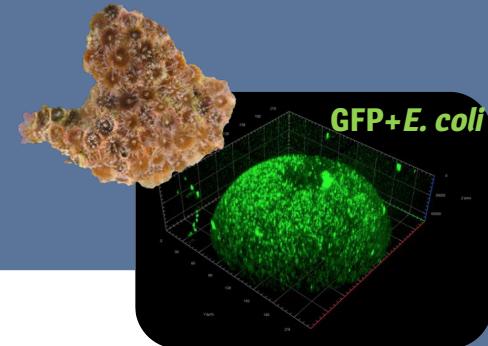


Escherichia coli



Elmund et al. 1999

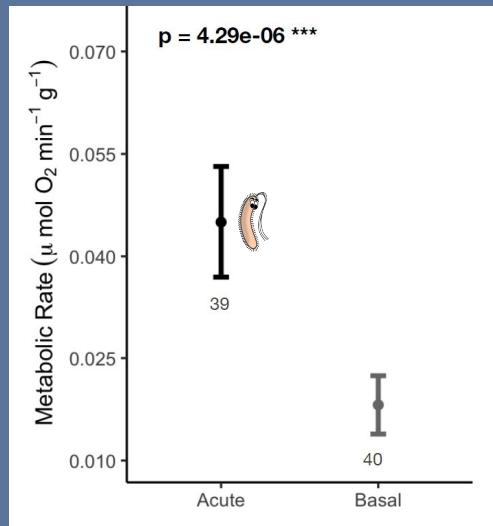
Rotjan et al. 2019



Metric #3: Dark respiration + *E. coli* as an indicator of holobiont immune response

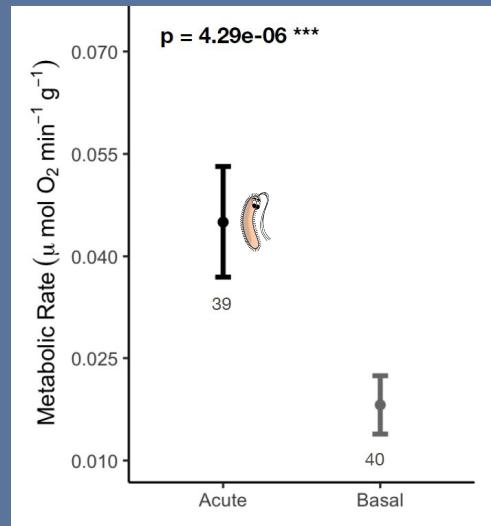


Previous study: *A. poculata* O₂ consumption amplifies in the presence of *E. coli*:



Speroff et al. *in prep*

Previous study: *A. poculata* O₂ consumption amplifies in the presence of *E. coli*:



Speroff et al. *in prep*

Does the presence of N modify this response?

Global stressor : temperature

What is the effect of temperature on *A. poculata*'s physiology, particularly in addition to local (*E. coli*, nutrients) stressors?

(Saba et al. 2016)



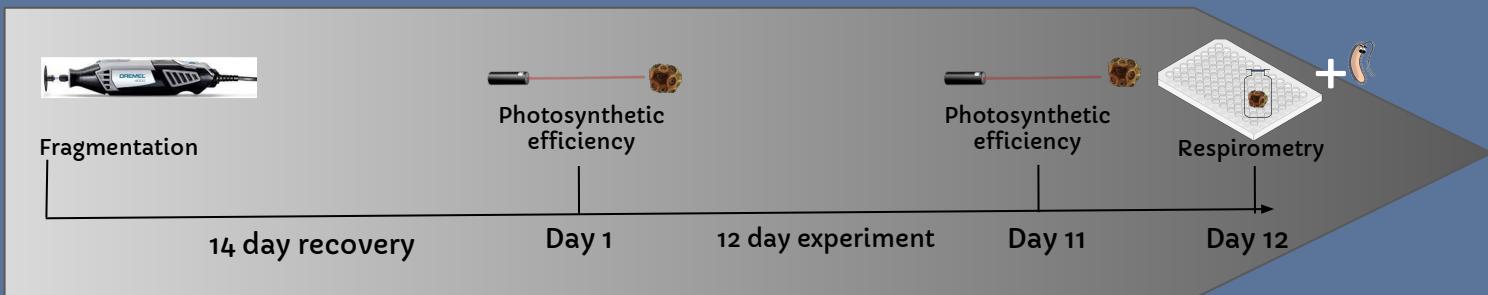
Introducing temperature stress...



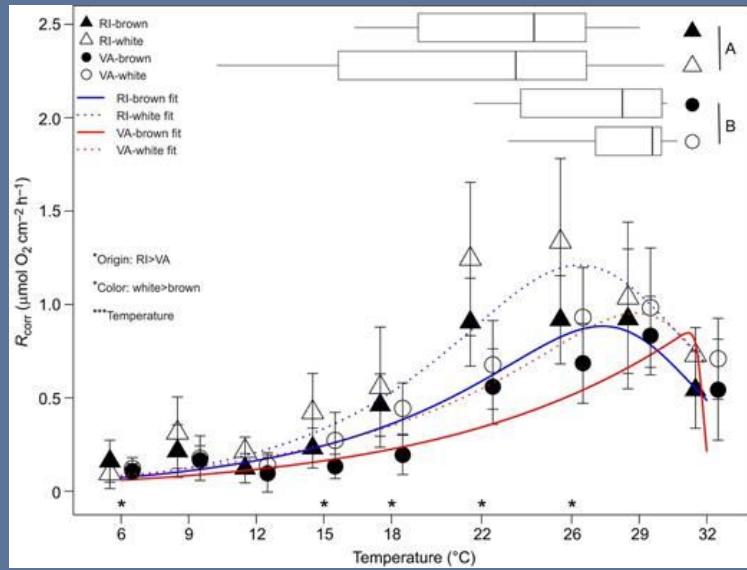
20°C



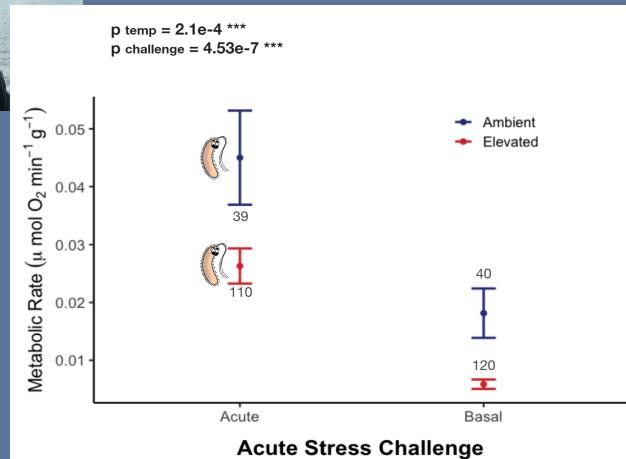
30°C



Previous work: *Astrangia* corals under thermal stress exhibit **metabolic depression**, indicative of physiological stress.



Aichelman et al. 2019



Speroff et al. *in prep*