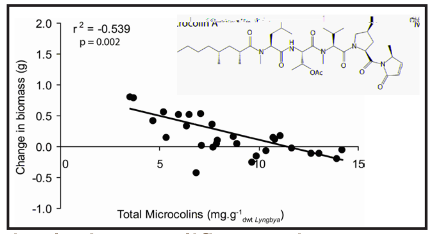
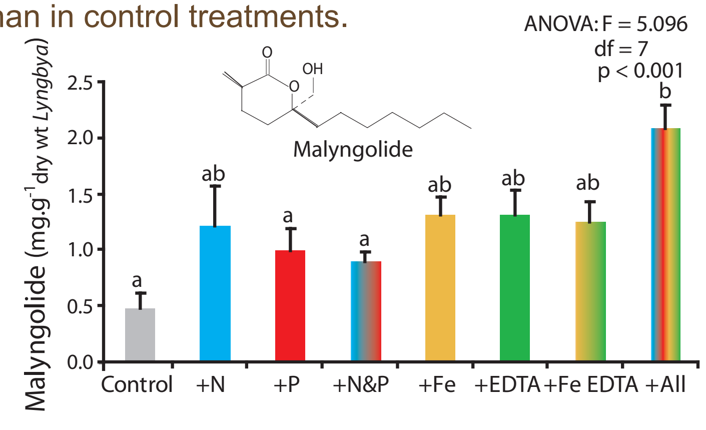
Lyngbya Toxicology



The genus *Lyngbya* includes prolific producers of secondary metabolites, with over 200 compounds isolated from these cyanobacteria worldwide. Because these compounds often make cyanobacteria unpalatable to consumers, they are able to bloom under conditions of appropriate temperature, light, and nutrient availability. *L. polychroa* strains produce microcolins a and b, and when nutrients are replete, *L. polychroa* demonstrates a trade-off between secondary metabolite production and growth. At Sanibel, *L. majuscula* contained malyngolide- the first report of this toxic compound in Florida waters. When N, P, and chelated iron were added to growth chambers, *L. majuscula* was found to produce more malyngolide than in control treatments.



Malyngolide concentrations in treatment groups at the end of the 2007 5-day bioassay from L. majuscula*, showing the cumulative effects of N, P, Fe, and EDTA.*

Management

Enrichment of nitrogen, phosphorus, and iron can lead to increased growth, productivity, and changes in secondary metabolite concentration among different *Lyngbya* species. Since many of the secondary metabolites produced by *Lyngbya* can act as feeding deterrents to generalist grazers, these compounds may give *Lyngbya* a competitive advantage over other benthic algae. Subsequent blooms may inhibit the feeding of benthic grazers.

The present study confirms and extends the results from other coastal studies, which indicate that both N and P inputs need to be controlled when non-N-fixing HABs co-occur (such as the red tide organism *Karenia*) with N-fixing cyanobacterial species. Therefore, we can conclude that single nutrient input controls are ineffective in addressing HAB ramifications. A larger-scale vision of both the ecosystems and the ecophysiology of these HABs is essential for setting thresholds for nutrient management strategies. Additionally, these results add to the growing body of knowledge that indicates the introduction of nutrients into the marine environment can not only increase the prevalence of HABs, but may also facilitate greater secondary metabolite production.

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Continued development along both sides of Florida's coast continues to present nutrient management issues, which will affect future Lyngbya *blooms.*

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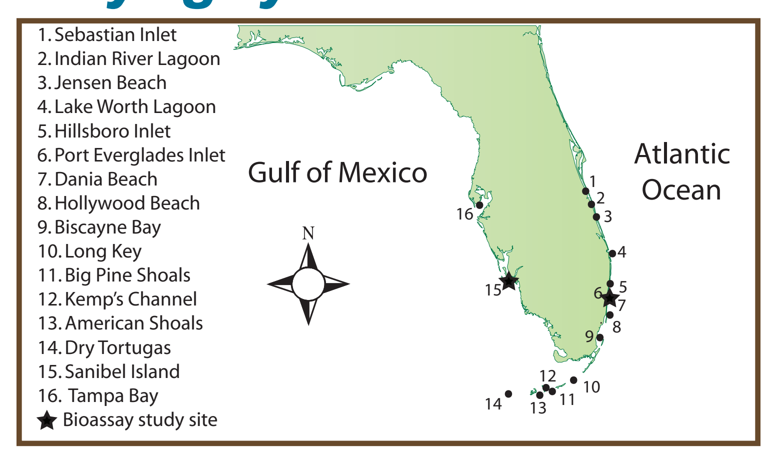
Toxic Cyanobacteria Blooms Degrade Ecosystems in Coastal Florida

Harmful algal blooms (HABs) have increased in abundance and severity around the world in recent decades. Among coastal HABs, benthic cyanobacteria (blue green algae) blooms, particularly Lyngbya spp., are becoming more numerous and persistent in tropical and subtropical marine embayments, estuaries, and reef environments. These species have become increasingly problematic in the near-shore waters of Florida, and it has been suggested that this may be in part caused by nutrient enrichment resulting from highly developed coastal habitats. Both climate change and anthropogenically derived nutrients provide the potential for increases in these nuisance blooms.

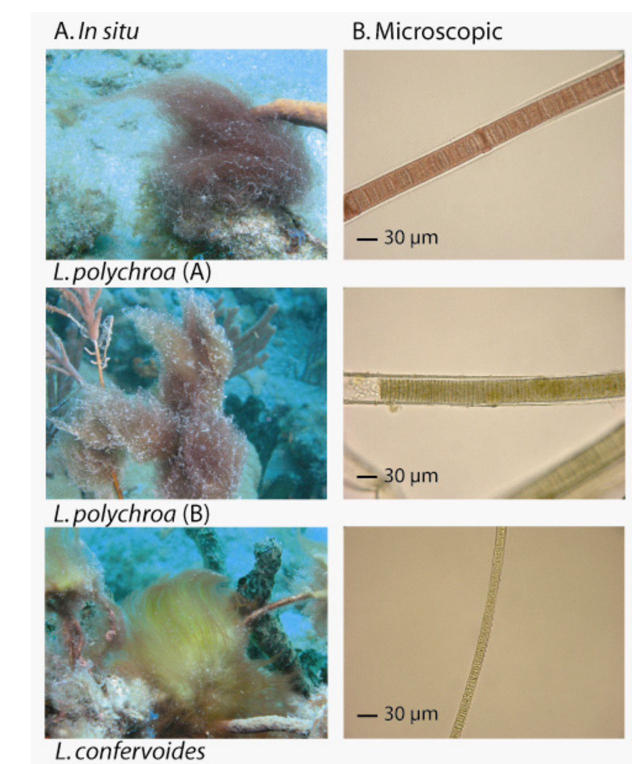
Globally, blooms of Lyngbya have been linked to ecosystem and human health issues, including smothered corals and seagrass, reduced grazing by fish and invertebrates, and dermatitis and respiratory symptoms in humans. In a three-year study funded by the National Oceanographic and Atmospheric Administration's Ecology of Harmful Algae Bloom Program (NOAA-ECOHAB), we examined the diversity, distribution, and abundance of Lyngbya in nearshore waters of southern Florida. Additionally, blooms on coral reefs off of Broward County and on seagrass and sediments near Sanibel-Captiva Island were investigated using an *in situ* nutrient bioassay approach that examined the effects of nitrate (N), phosphate (P), and biologically-available iron (Fe) on growth, carbon, nitrogen fixation, and secondary metabolite production in multiple Lyngbya spp. found in southern Florida, USA.

Lyngbya Distribution



Observations (168) of *Lyngbya spp.* were made throughout Florida. They were common in inshore habitats, particularly in the time period April-August. *Lyngbya* was observed as persistent blooms in the Indian River Lagoon, Broward County reefs, and Sanibel Island. At least four different species were identified in Floridian waters based on morphological characteristics: *L. majuscula, L. confervoides*, and two morphotypes of *L. polychroa*.

Macro and microscopic morphology of Lyngbya spp. *observed during summer months on Broward County reefs.*

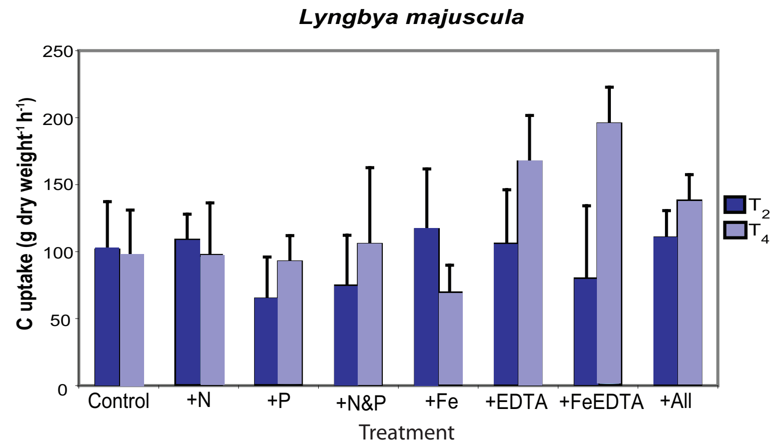


Sanibel Island: *Lyngbya* on Seagrasses

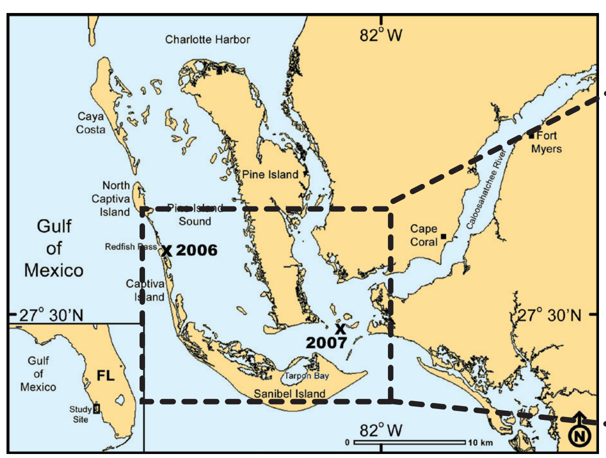
Blooms of the species *Lyngbya majuscula* have been occurring on the seagrass beds and sediments of Florida's Gulf Coastal region of Sanibel Island. These blooms can overgrow seagrass, potentially smothering other benthic organisms. Mangroves in this region are also adversely affected by *Lyngbya*. Results of the bioassay conducted in this study showed increased primary production with additions of N and P. Although *L. majuscula* is primarily a benthic species, the oxygen it produces by rapid photosynthesis can get trapped in the filaments, causing tufts to become buoyant. The tufts can dislodge from the bottom, float up to the surface of the water, and form rafts of material that washes up on beaches. This material-in addition to being unsightly-is malodorous as it rots and can maintain toxic properties deleterious to humans and animals even after drying.

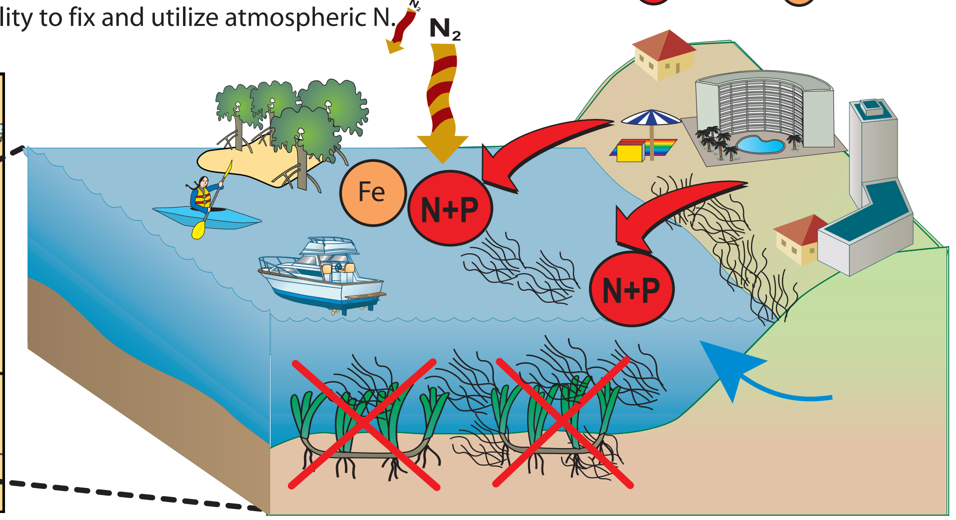
Right: Lyngbya overgrowing seagrass.

Below: Primary productivity represented as C uptake in L. majuscula *bioassay at T_0, T_2, and T_4 (96 h incubation) after daily additions of N, P, Fe, EDTA and combinations of nutrients. Error bars represent + 1 SE (n = 5)*

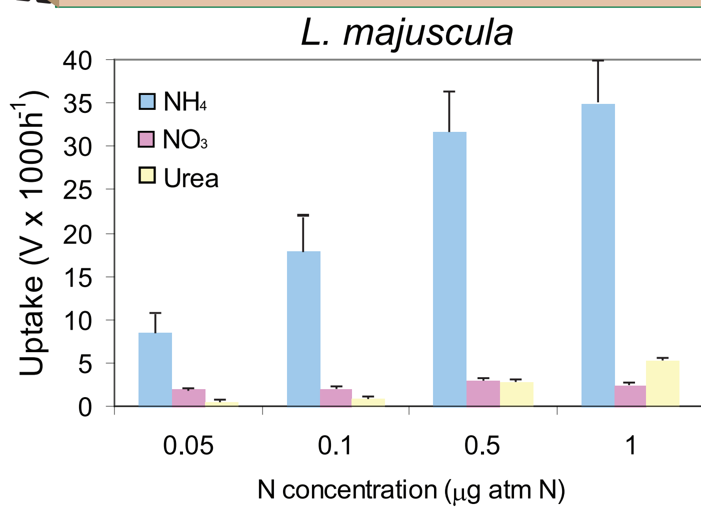


Florida's Gulf Coastal region of Sanibel Island is being affected by blooms of the cyanobacteria *Lyngbya majuscula* which fouls beaches and cause the death of seagrasses. These blooms are most likely due to nutrient inputs from development, recreational activities, and groundwater. Study sites in 2006 and in 2007 revealed that both N and P and iron are essential in bloom formation, due to this species' ability to fix and utilize atmospheric N.





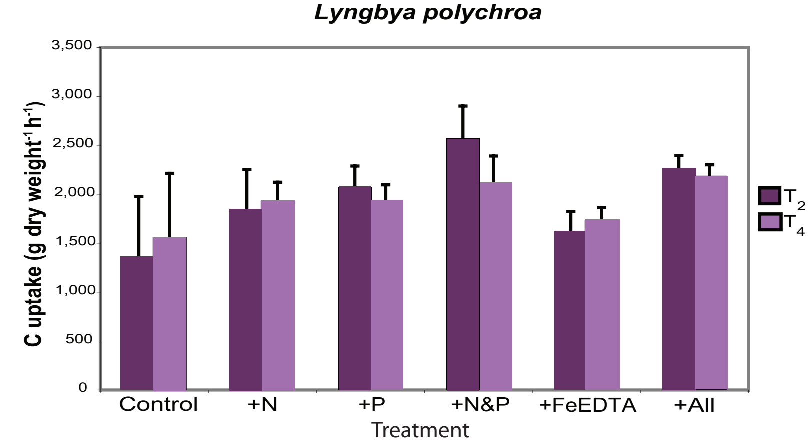
Lyngbya has the ability to use atmospheric nitrogen (N_2) for its cellular needs through the process of N-fixation, an energetically demanding process that requires high amounts of iron for the enzyme nitrogenase that mediates the process. Experiments from Sanibel indicate that bioavailable iron stimulates *L. majuscula* productivity and N-fixation. In addition to N-fixation, *L. majuscula* can also take up inorganic forms of nitrogen, such as ammonium, nitrate, and the organic form urea.



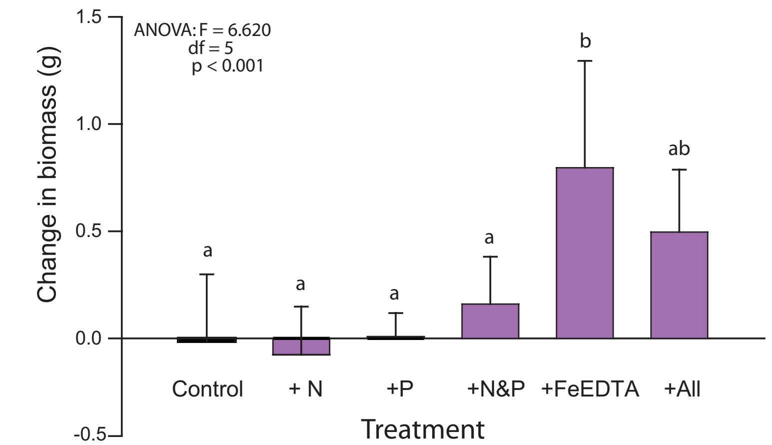
Fort Lauderdale: *Lyngbya* on Corals

Bioassay results from *Lyngbya* (*L. polychroa*, shown here) from Fort Lauderdale showed increased primary productivity with additions of nitrogen and phosphorus together. Growth of the *L. polychroa* was significantly stimulated by additions of bioavailable iron. This may be due to increased N-fixation at this site, which is also supported by lower $\delta^{15}N$ (an indicator of atmospheric N_2) values.

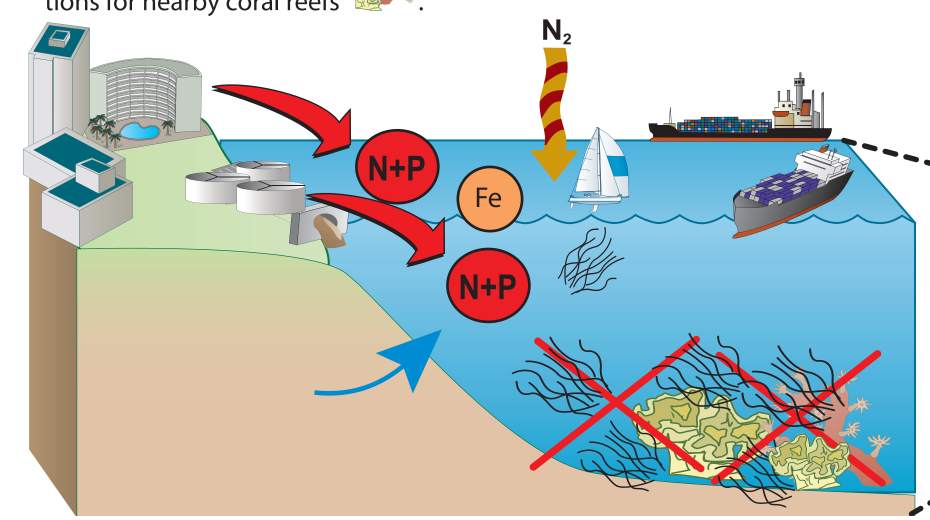
Primary productivity represented as C uptake in L. polychroa *bioassay at T_0, T_2, and T_4 after daily additions of N, P, Fe, and EDTA. Error bars represent + 1 SE (n = 5)*

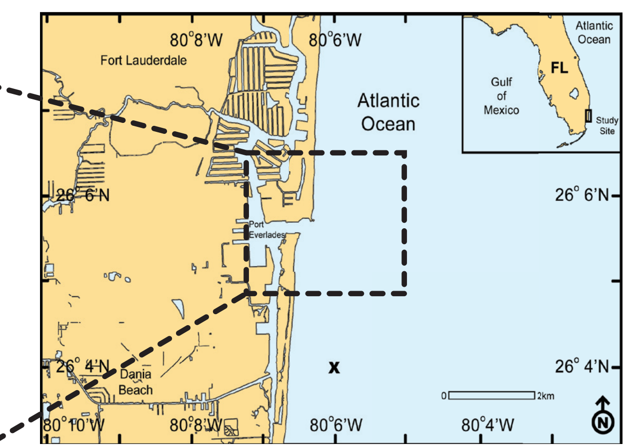


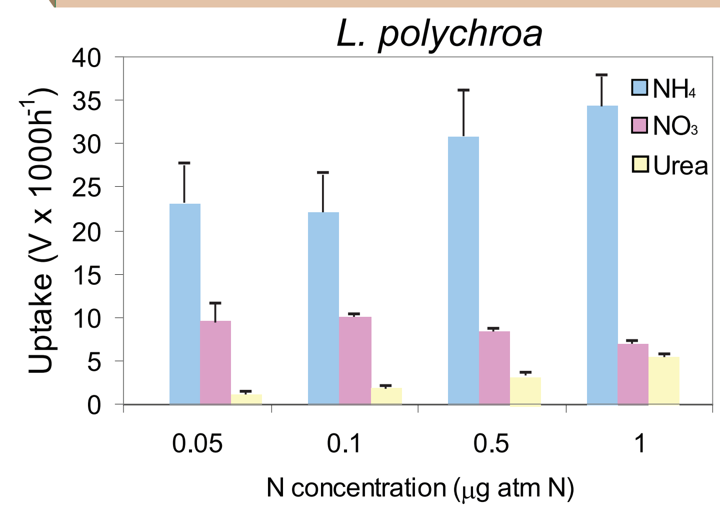
Change in biomass from control, N, P, Fe, and EDTA samples from May 2006 bioassay for L. polychroa *from Fort Lauderdale reefs. Error bars are + 1 SE (n = 5)*



The coastal environments adjacent to Fort Lauderdale and Dania Beach, Florida, are also experiencing intense blooms of *Lyngbya polychroa*. This N-fixing cyanobacteria is responding to coastal inputs of iron, N, and P from sewage outfalls wastewater, development, and groundwater. In addition to their toxicity, these blooms are causing adverse conditions for nearby coral reefs.







Lyngbya at both Sanibel and Fort Lauderdale appears to prefer ammonium, which requires the least amount of energy for uptake. However, the ability of both species (*L. majuscula* and *L. polychroa*) to use all forms of nitrogen, as well as its ability to fix nitrogen, gives these cyanobacteria a competitive advantage over algae species that do not fix nitrogen.