# Ecology of the benthic cyanobacteria *Lyngbya* spp. What do we know?

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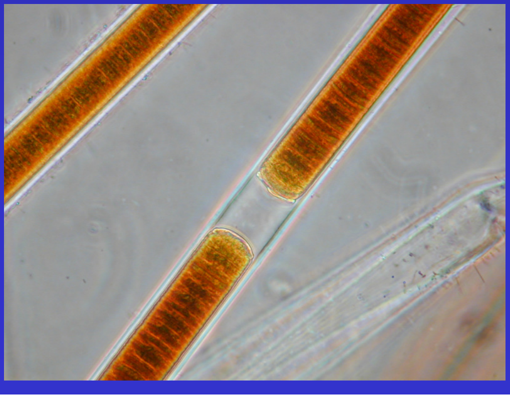


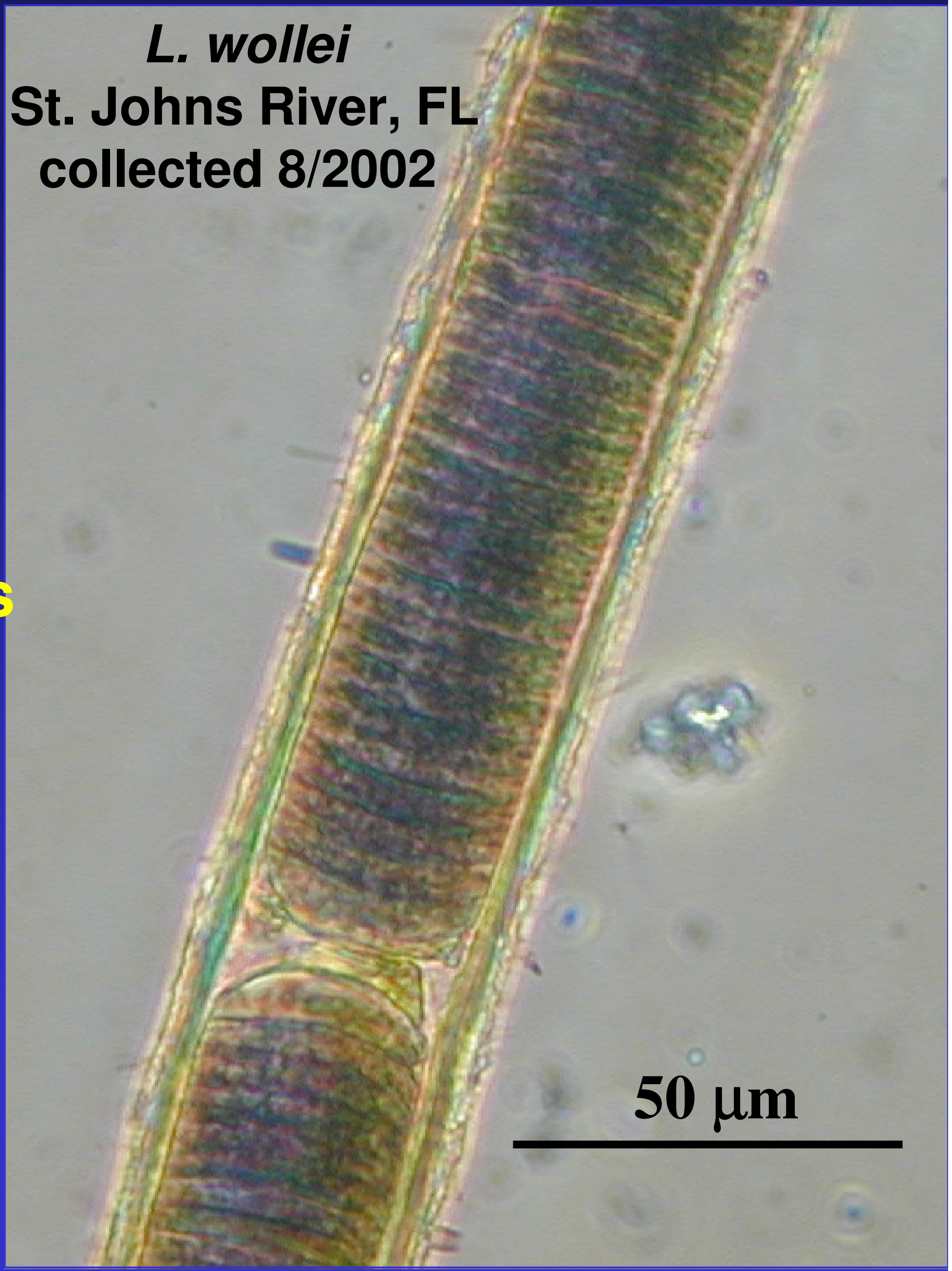
# Key Questions

- What are characteristics of *Lyngbya majuscula* and *Lyngbya wollei*?
  - Morphology and physiology
  - Occurrence
  - Bloom dynamics
  - Toxicity of *L. majuscula* and *L. wollei*
  - Nitrogen fixation in *L. majuscula* and *L. wollei*
- Why is *L. wollei* proliferating in inland waters?
  - A look at the Florida Aquifer
  - Nutrient effects on growth rates of *L. wollei*
  - Changes in water residence time (impoundments, droughts)
- Why is *L. majuscula* proliferating in coastal waters?
  - A look at the Florida Reef and Seagrass habitats
  - Nutrient uptake of *L. majuscula*

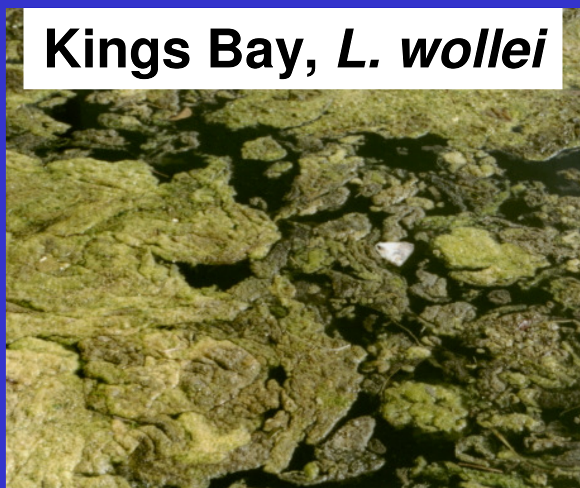
# *L. majuscula* and *L. wollei*

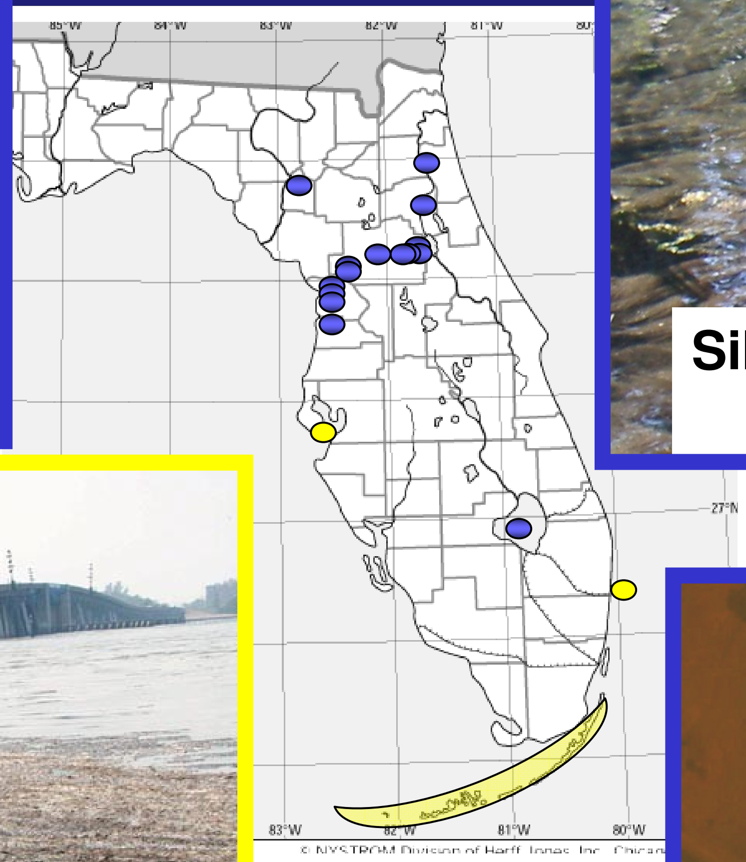
Cosmopolitan benthic cyanobacteria

- Recent proliferation in marine & freshwater systems
- $N_2$ fixation:
  - could provide a large amount of N into system
  - advantage in N-limited waters
- Harmful Algal Bloom (HAB) species



# Distribution of *L. majuscula* and *L. wollei* in Florida

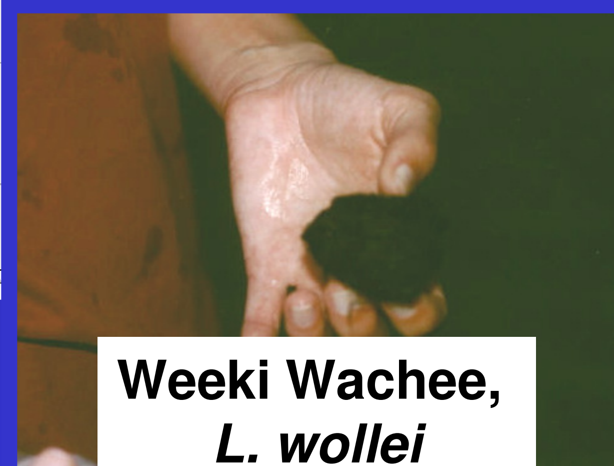

Kings Bay, *L. wollei*



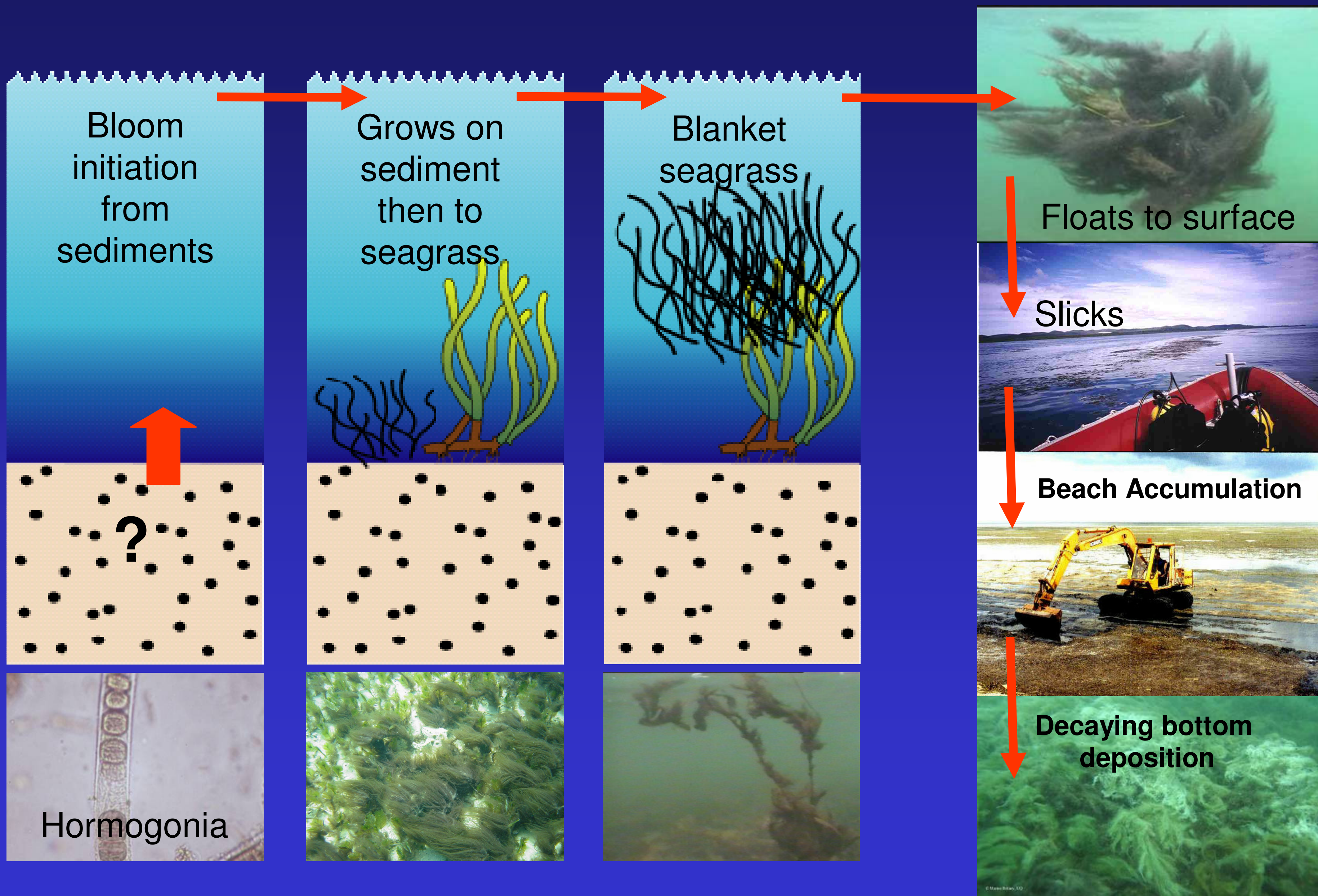


Silver Glen Springs, *L. wollei*

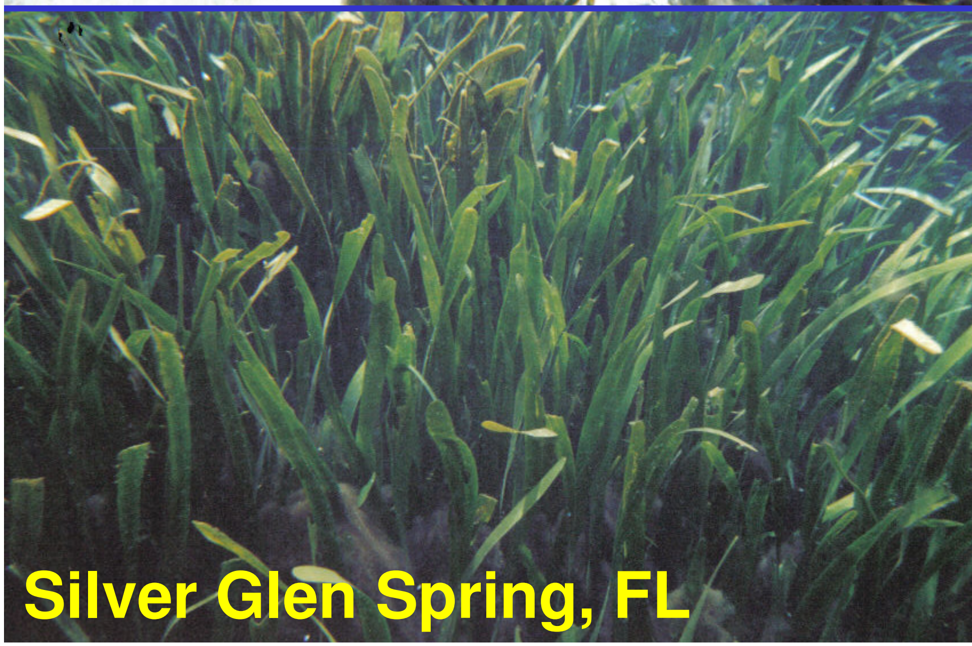

Tampa Bay, *L. majuscula*

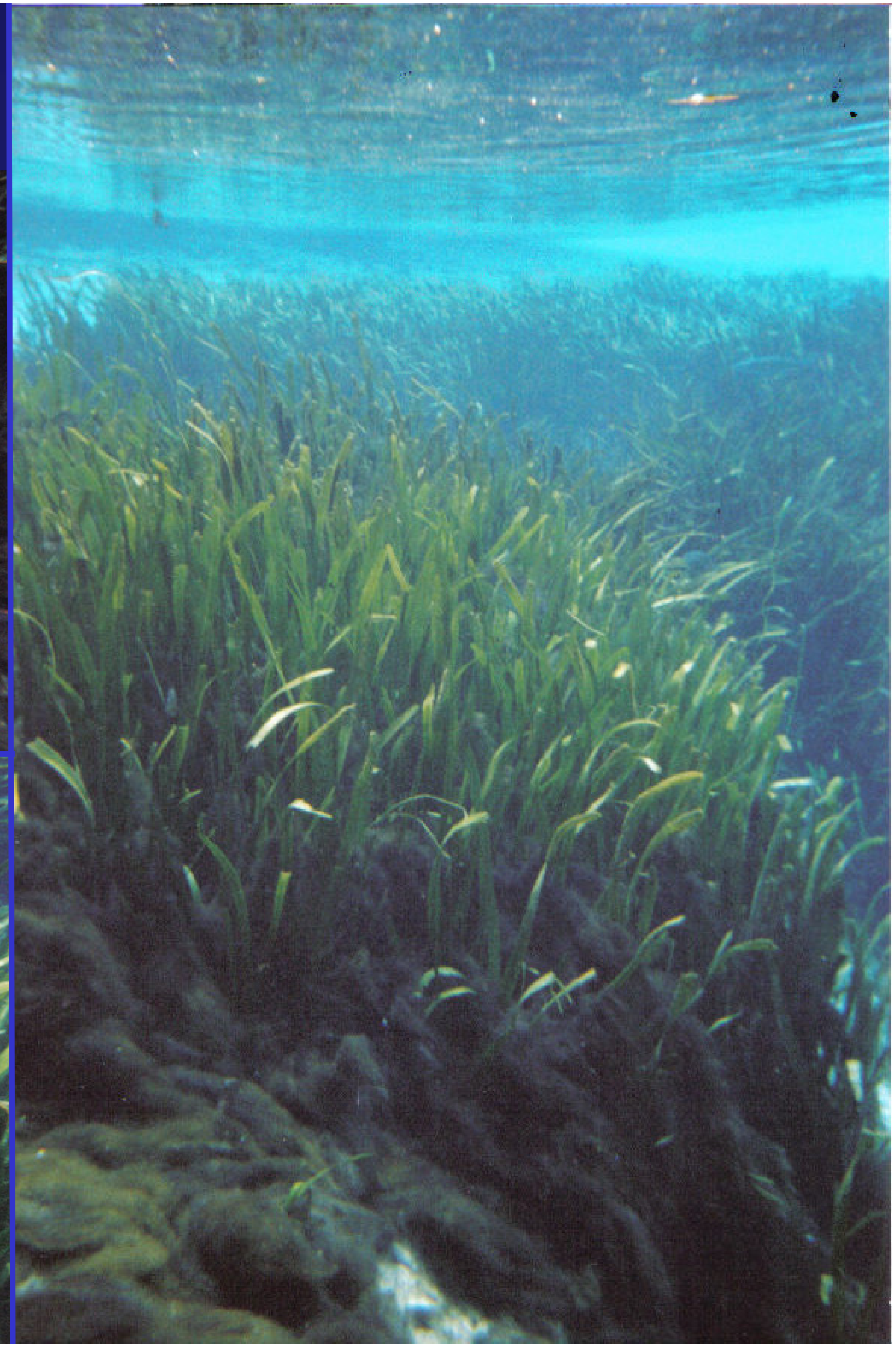

Weeki Wachee, *L. wollei*

# *L. majuscula* Bloom Cycle → Bloom Fate



# *L. wollei*



# *L. wollei*



Littoral Zone:

- Surface mat
- Streamers
- Benthic mat

(Speziale 1988)

# Bioactive Compounds

***L. majuscula***

**Dermatotoxic Alkaloids**

- **lyngbyatoxin-a** (Cardellina et al. 1979)
- **aplysiatoxin** (Mynderse et al. 1977)
- **debromoaplysiatoxin** (Mynderse et al. 1977)

***L. wollei***

**Neurotoxin**

- **saxitoxin** (Carmichael et al. 1997, Onodera et al. 1997)
- **PSP analog?**

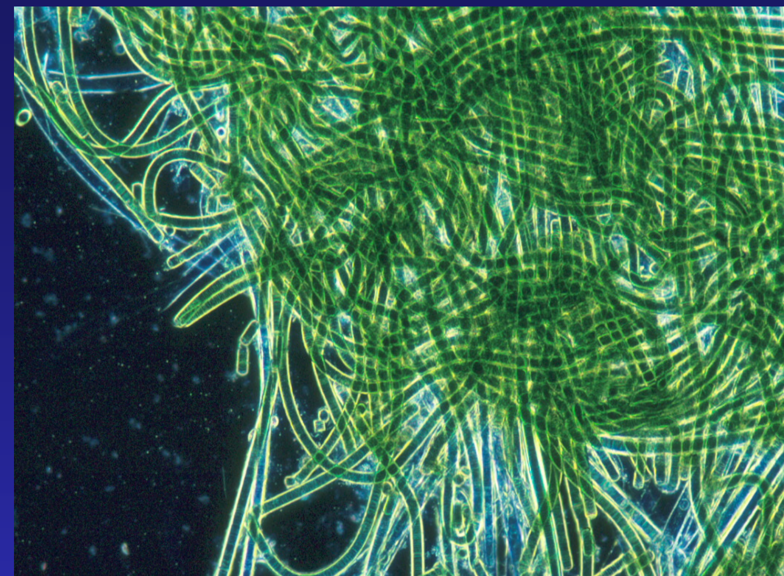
# Lyngbya Blooms & Adverse Health Effects

Notable occurrences of skin, eye, and respiratory irritation by *Lyngbya*

| | | | |
|---|---|---|---|
| 1958 | Laie | Hawaii | 123 cases |
| 1968 | Okinawa | Japan | 242 cases |
| 1980 | Kailua, Oahu | Hawaii | 86 cases |
| 1983 | Maui | Hawaii | 31 cases |
| 1986 | Oahu | Hawaii | |
| 1996-present | Moreton Bay | Australia | 120 cases |
| 1980s-present | Florida, Alabama, North Carolina | USA | >200 cases |

# Nitrogen Fixation

*Anabaena* spp.

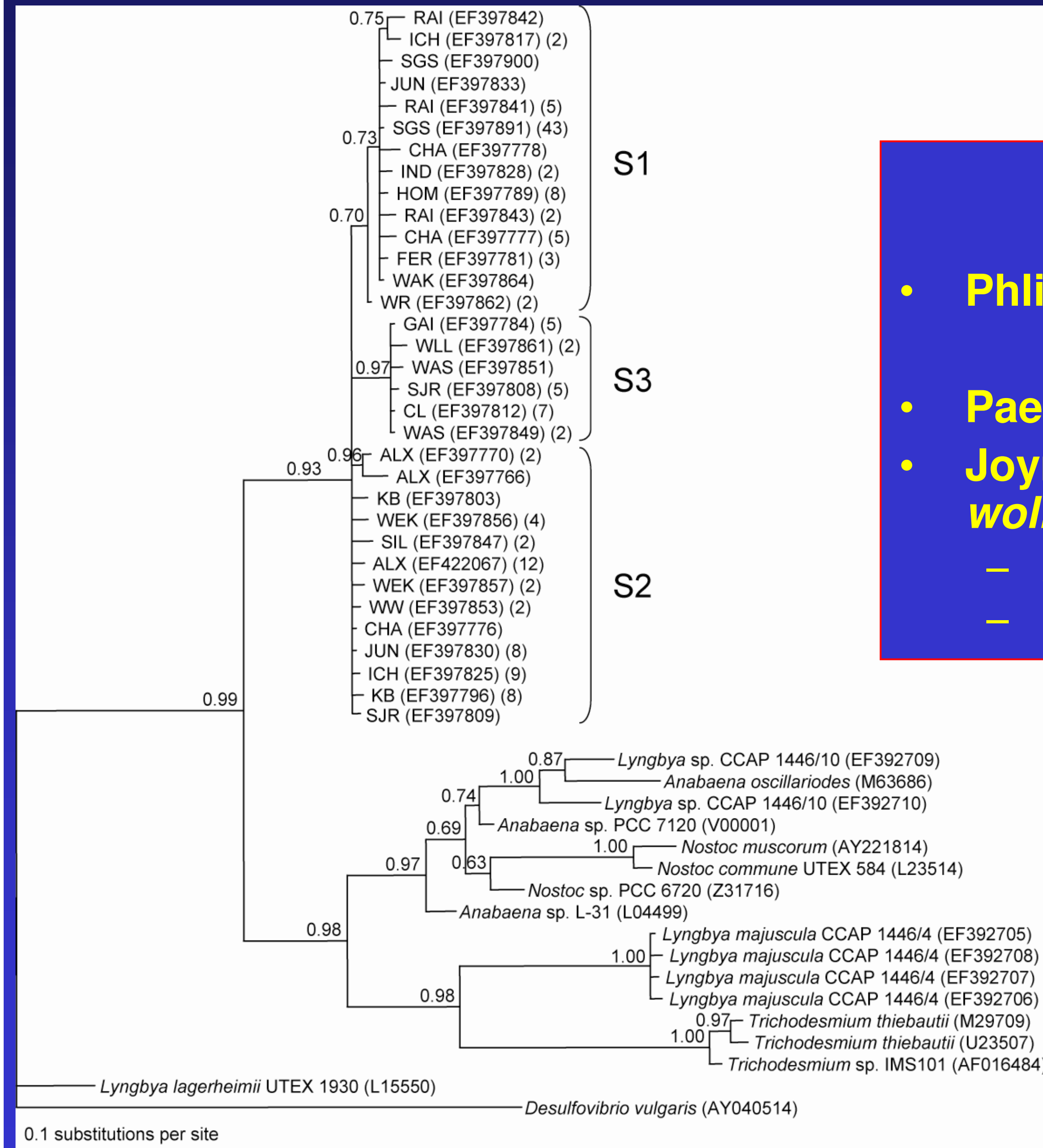


*Lyngbya* sp.

$$N_2 + 16\ ATP \xrightarrow{\text{nitrogenase}} 2NH_3$$

- Provides biologically available source of N for supporting *Lyngbya*
- Can be important input of "new" N in affected waters
- On ecosystem scale, can stimulate eutrophication & WQ declines

# Nitrogen Fixation in *L. wollei*: *NifH* phylogeny



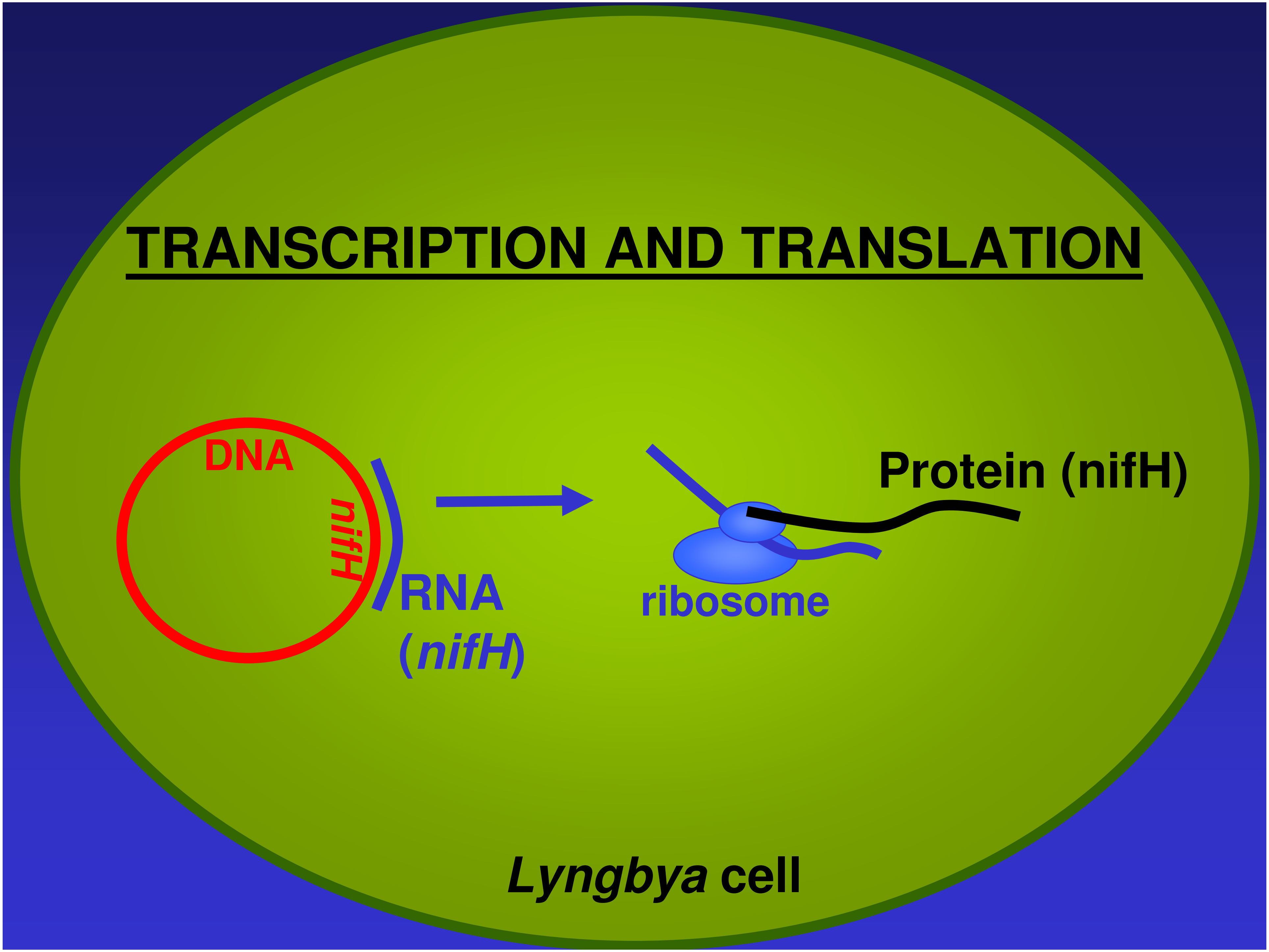

**Evidence**

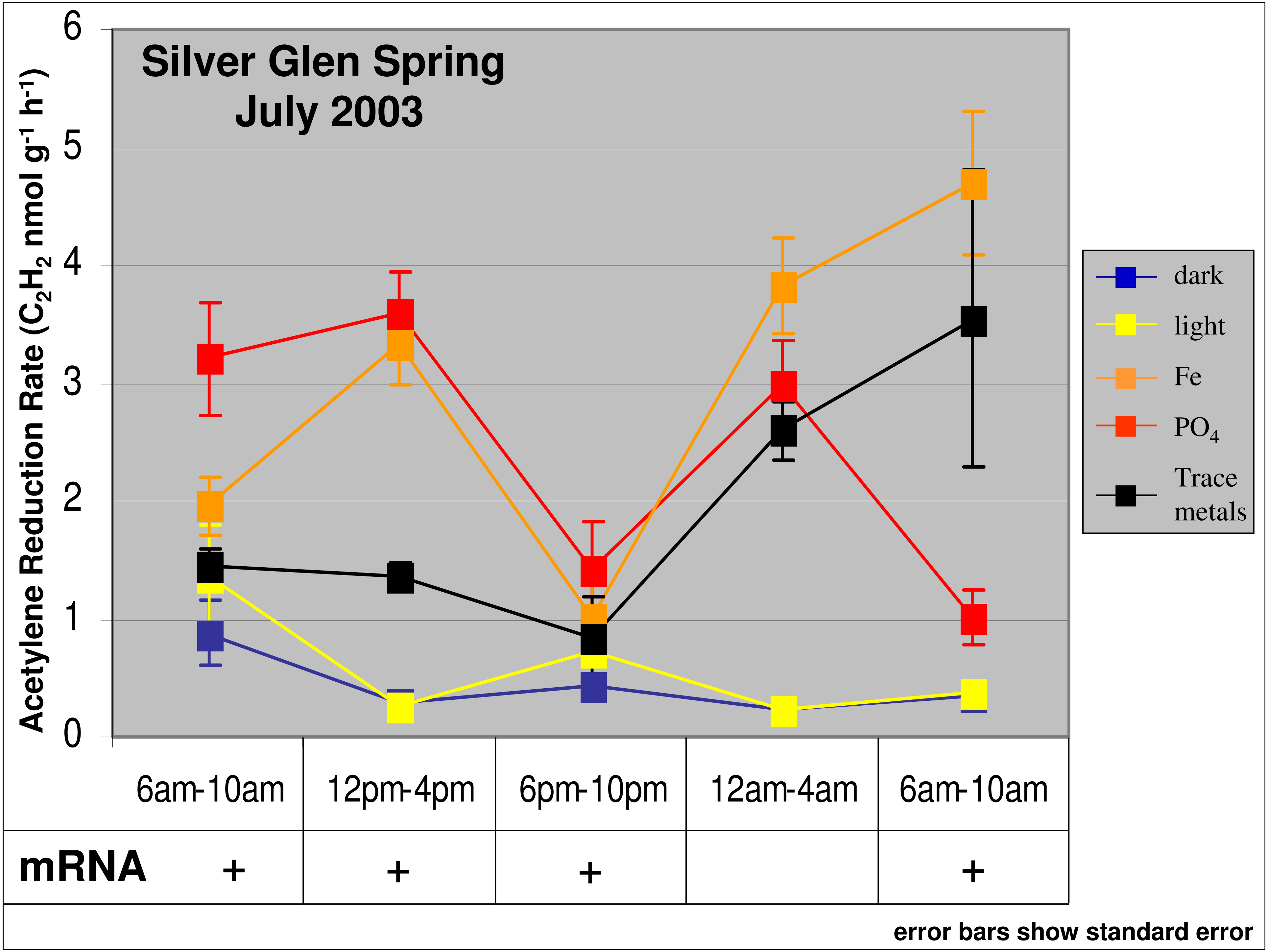
- **Phlips et al. 1991, *Lyngbya* culture from Lake Okeechobee, FL**
- **Paerl et al. 1991, *Lyngbya aestuarii***
- **Joyner et al. (in press) *Lyngbya wollei***
  - **Acetylene reduction assay**
  - **DNA/RNA evidence**

# Nitrogen Fixation in *L. majuscula*

| Study Site | Nitrogenase Activity ($nm\ C_2H_2 g^{-1} h^{-1}$) |
|---|---|
| Deception Bay, Australia | 0.1-1.2 |
| Wellington Point, Australia | 1.0-5.9 |
| Diabla Passage, Australia | 2.47-4.85 |
| Tampa Bay, Florida | 2.2-6.4 |
| Hawaii | 0.7 |

- Highly variable control rates ($p < 0.01$)


TRANSCRIPTION AND TRANSLATION
DNA
nifH
RNA
(nifH)
ribosome
Protein (nifH)
Lyngbya cell


Silver Glen Spring
July 2003
Acetylene Reduction Rate ($C_2H_2$ nmol $g^{-1}$ $h^{-1}$)
0
1
2
3
4
5
6
dark
light
Fe
$PO_4$
Trace metals
6am-10am
12pm-4pm
6pm-10pm
12am-4am
6am-10am
mRNA
+
+
+
+
error bars show standard error

# CONCLUSIONS

***Lyngbya wollei*** **is capable of nitrogen-fixation**

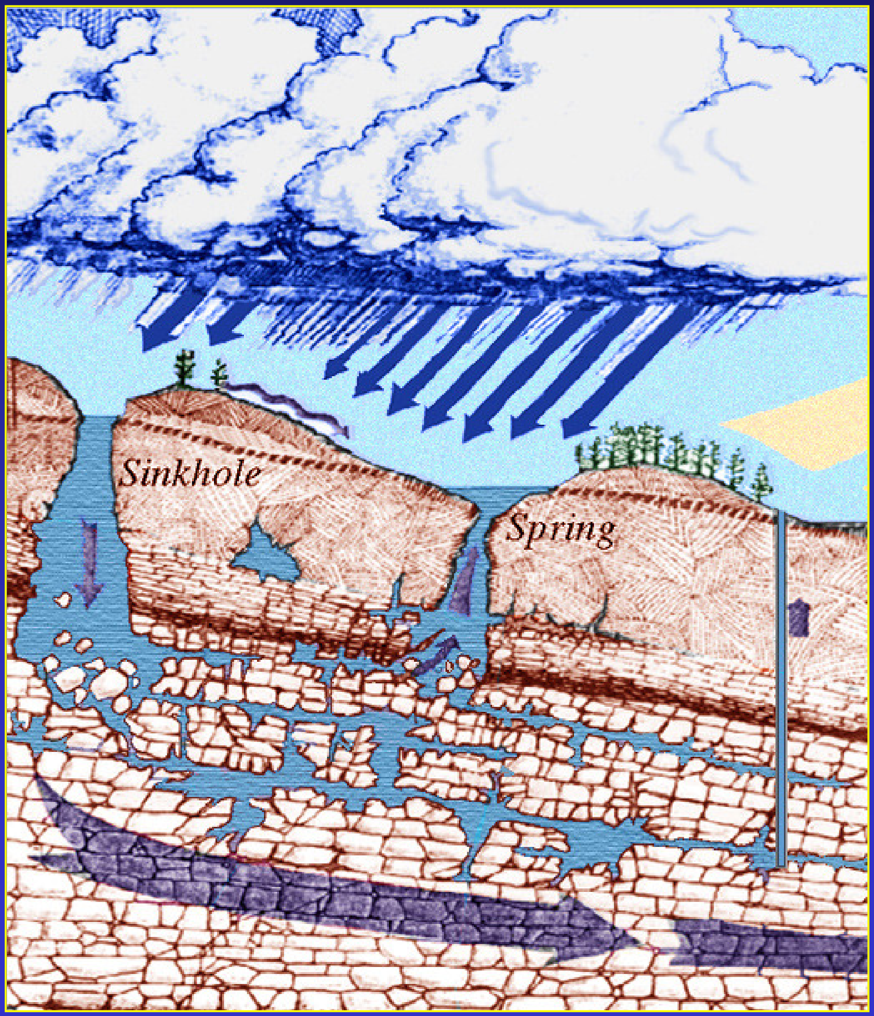
- **Nitrogen fixation (acetylene reduction) detected in a *Lyngbya wollei* mat**

- **RNA evidence that *Lyngbya wollei* was the dominant contributer to cyanobacterial fixed N**

# OUTLINE

- What are characteristic traits of *Lyngbya majuscula* and *Lyngbya wollei*?
  - Microscopic traits
  - Bloom dynamics
  - Locations within Florida
  - Toxicity of *L. majuscula* and *L. wollei*
  - Nitrogen fixation in *L. majuscula* and *L. wollei*
- **Why is *L. wollei* proliferating in Florida?**
  - **A look at the Florida Aquifer**
  - **Nutrient effects on growth rates of *L. wollei***
- Why is *L. majuscula* proliferating in Florida?
  - A look at the Florida Aquifer
  - Nutrient uptake of *L. majuscula*
- Future Research

# Why is *Lyngbya* proliferating in Florida Springs?

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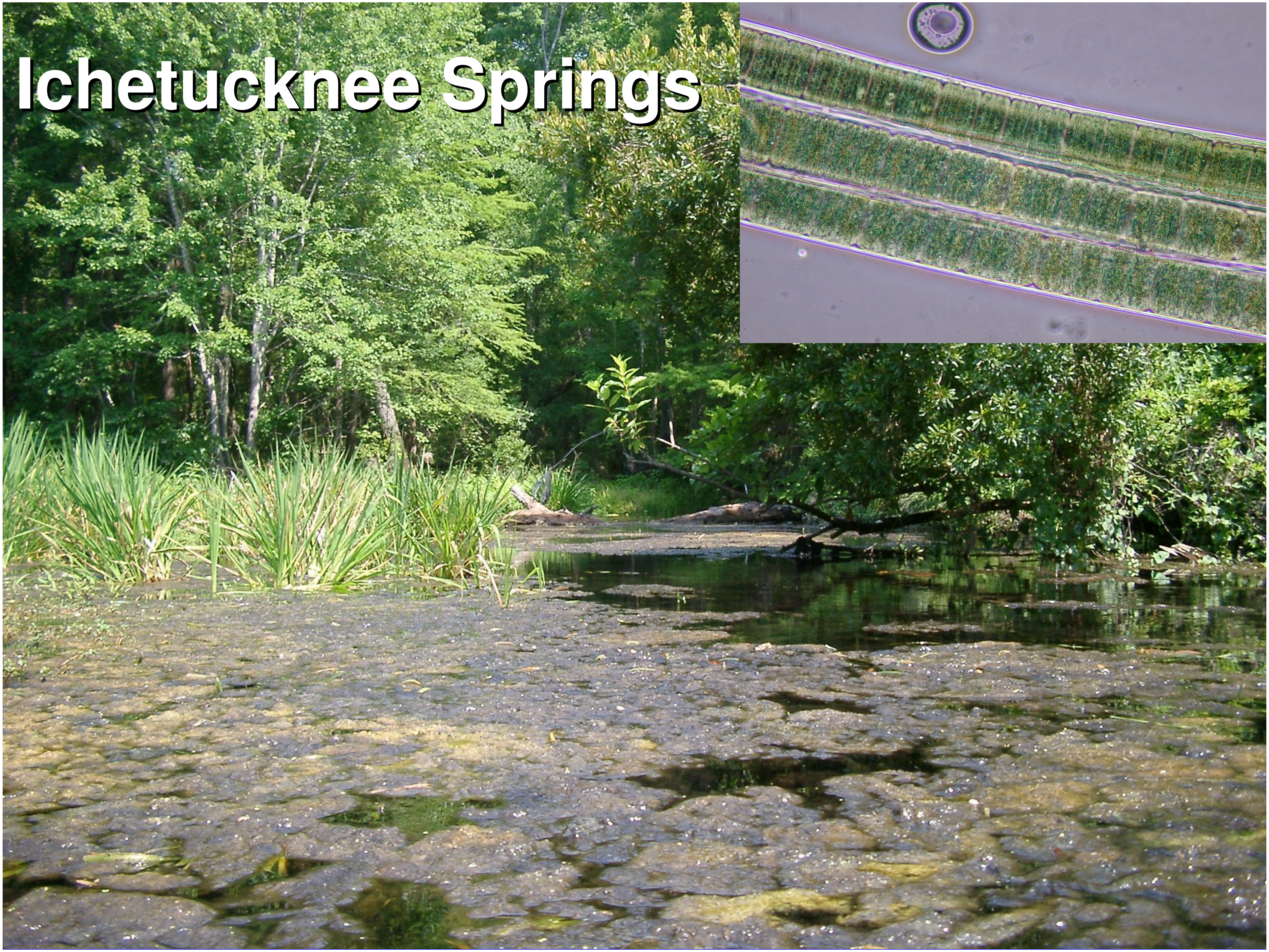
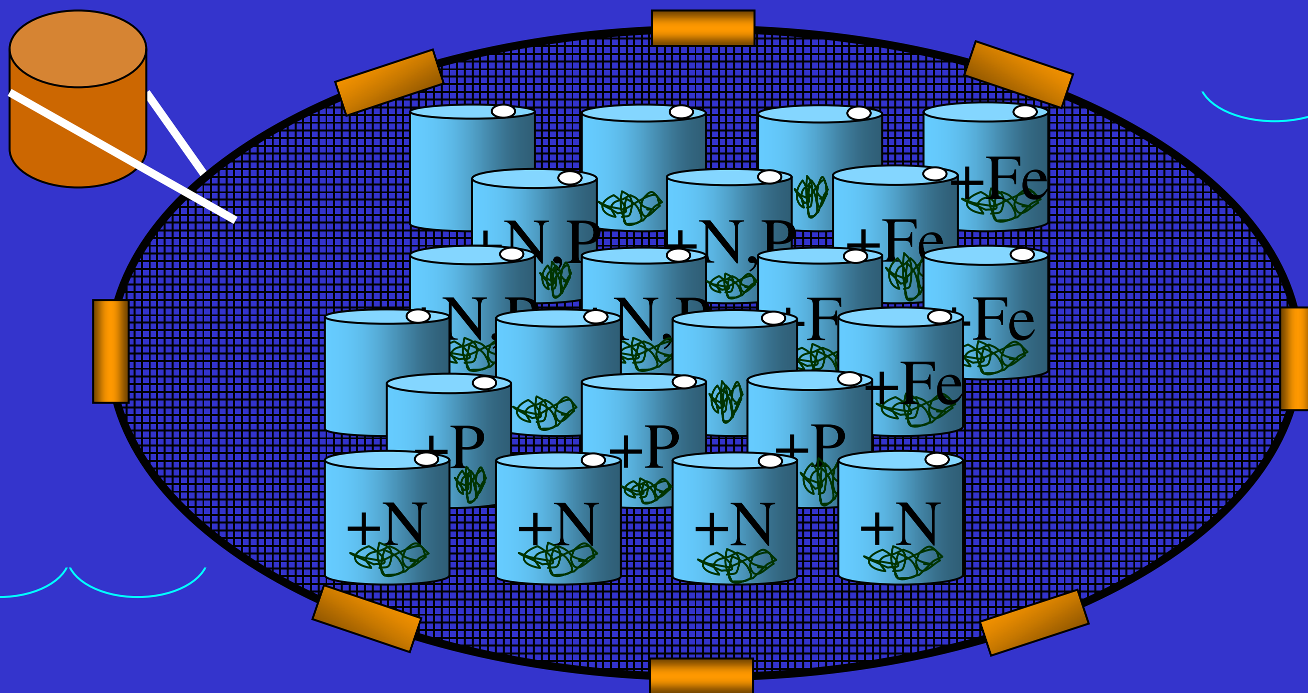
**Florida Aquifer**

- Changes in groundwater and surface water chemistry
- Increased runoff of nutrients into springs or into sinks

# Ichetucknee Springs



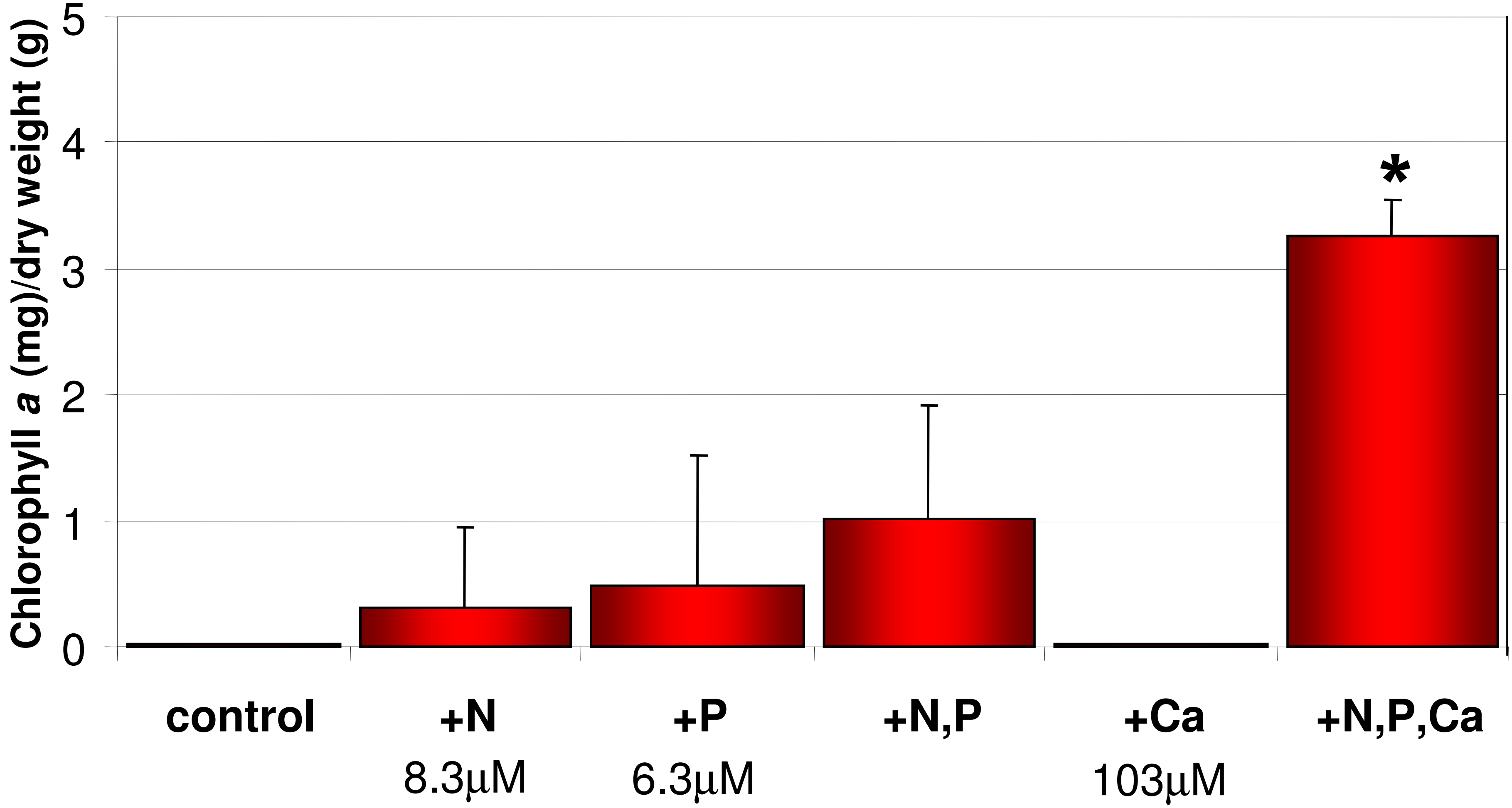
# *Lyngbya* bioassays



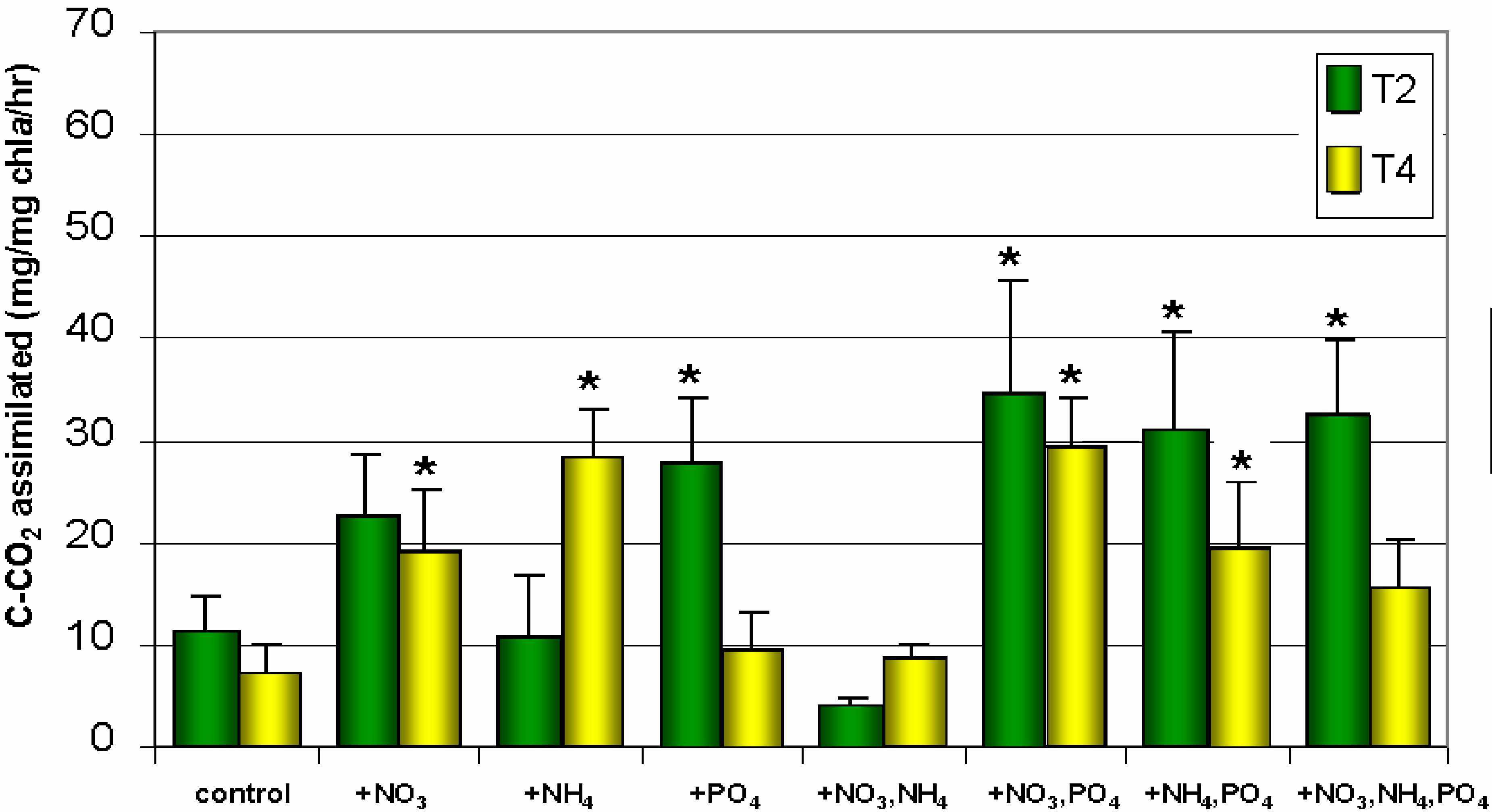

- bioassays *in situ* indicate which nutrient limits growth in the organism's natural environment
- important for management decisions/strategies
- potential limiting nutrients tested: N, P, Fe

# *Lyngbya* bioassays

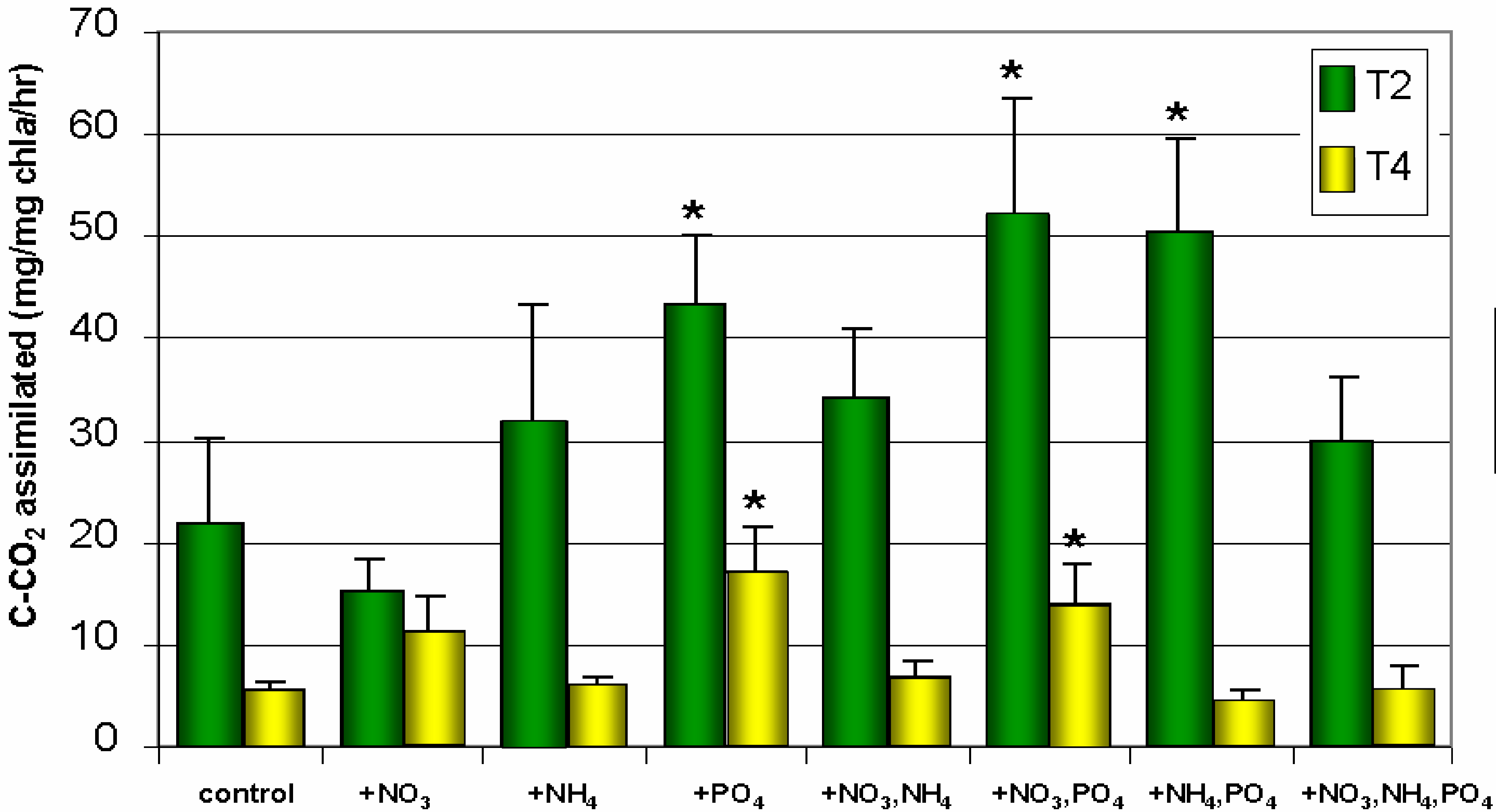
# City Lake, High Point, NC; June 2002
# Chlorophyll *a* T5



# Alexander Spring; July 2004
# Primary Productivity



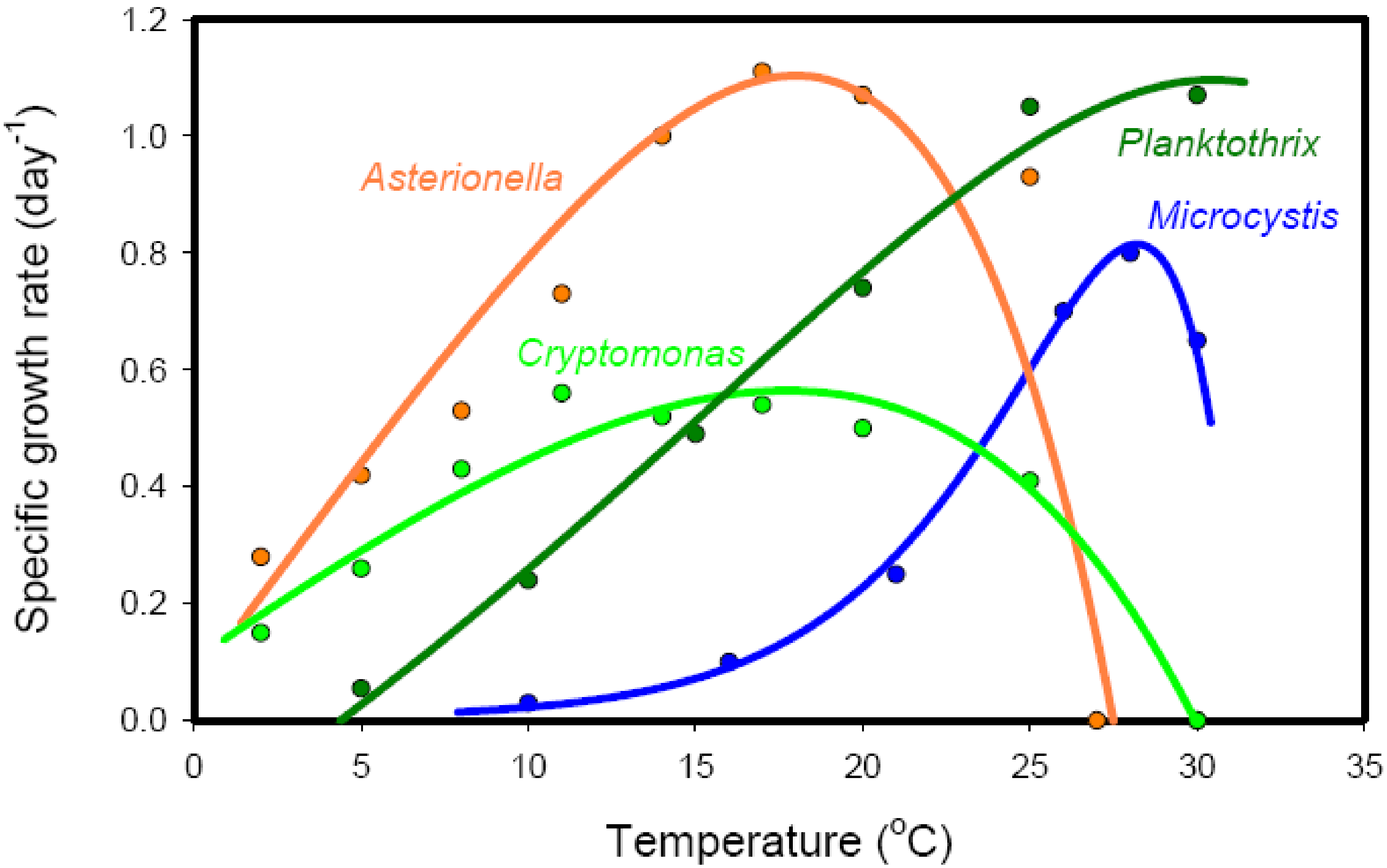
# Alexander Spring; October 2004
# Primary Productivity



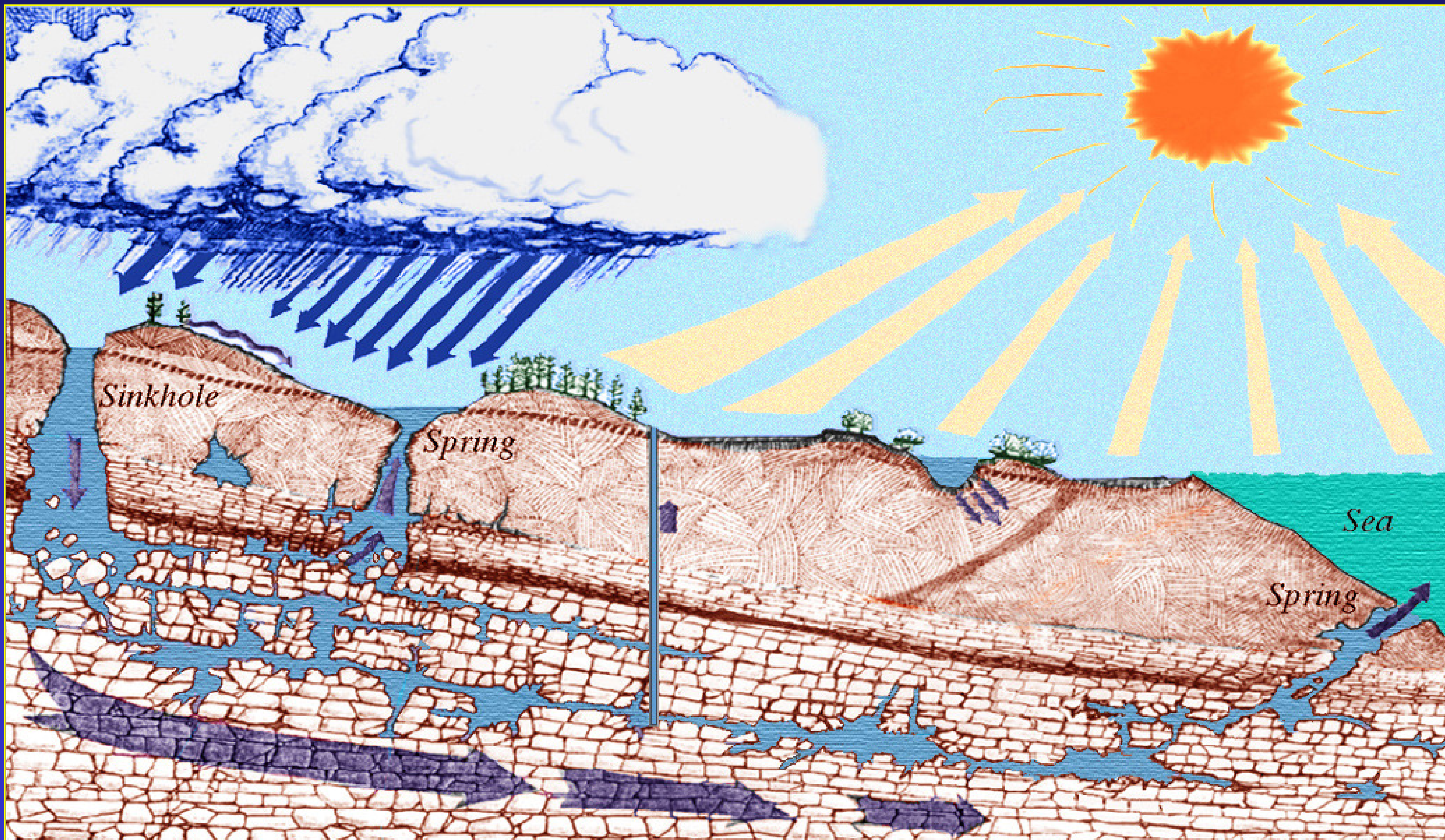
**Another factor……impound water (i.e. marinas/lagoons) + nutrients = Cyanobloom!**
**Examples: St. Lucie, West Palm Beach, Caloosahatchee River**

# St. Johns R., FL:  Nutrients + drought (low flow, stagnant conditions)

# One more Factor: Increasing temperatures (i.e. global warming) favors cyanos



# Why is *Lyngbya* proliferating in Florida's coastal zone?




**Florida Aquifer**

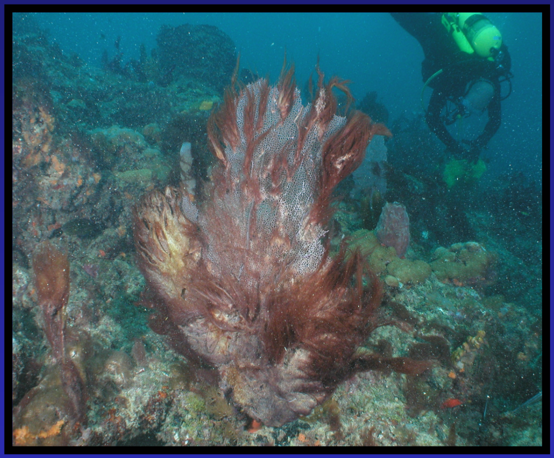
Hazlett-Kincaid, Inc.

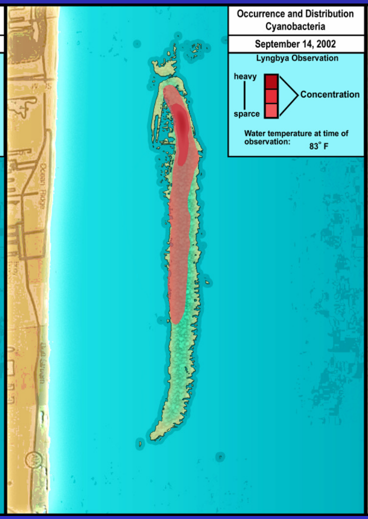
# Marine Lyngbya

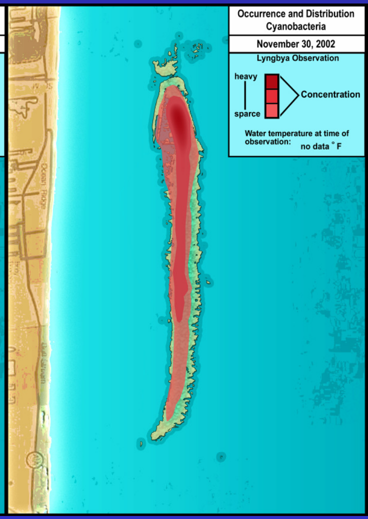
# *Lyngbya*: Reports From Florida Marine Environments

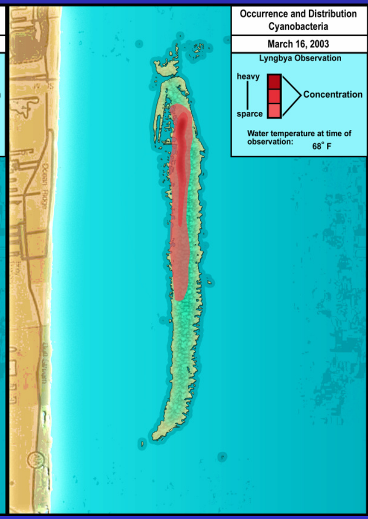
- Sarasota Bay, Tampa Bay, Terra Ceia Bay, Palma Sola, Charlotte Harbor, Cedar Key, Sebastian Inlet, mouth of Manatee River (1999, 2000, 2002)
- East coast on reefs off Broward Co.,Florida Keys, Indian River Lagoon

# Lyngbya - Broward County Reef

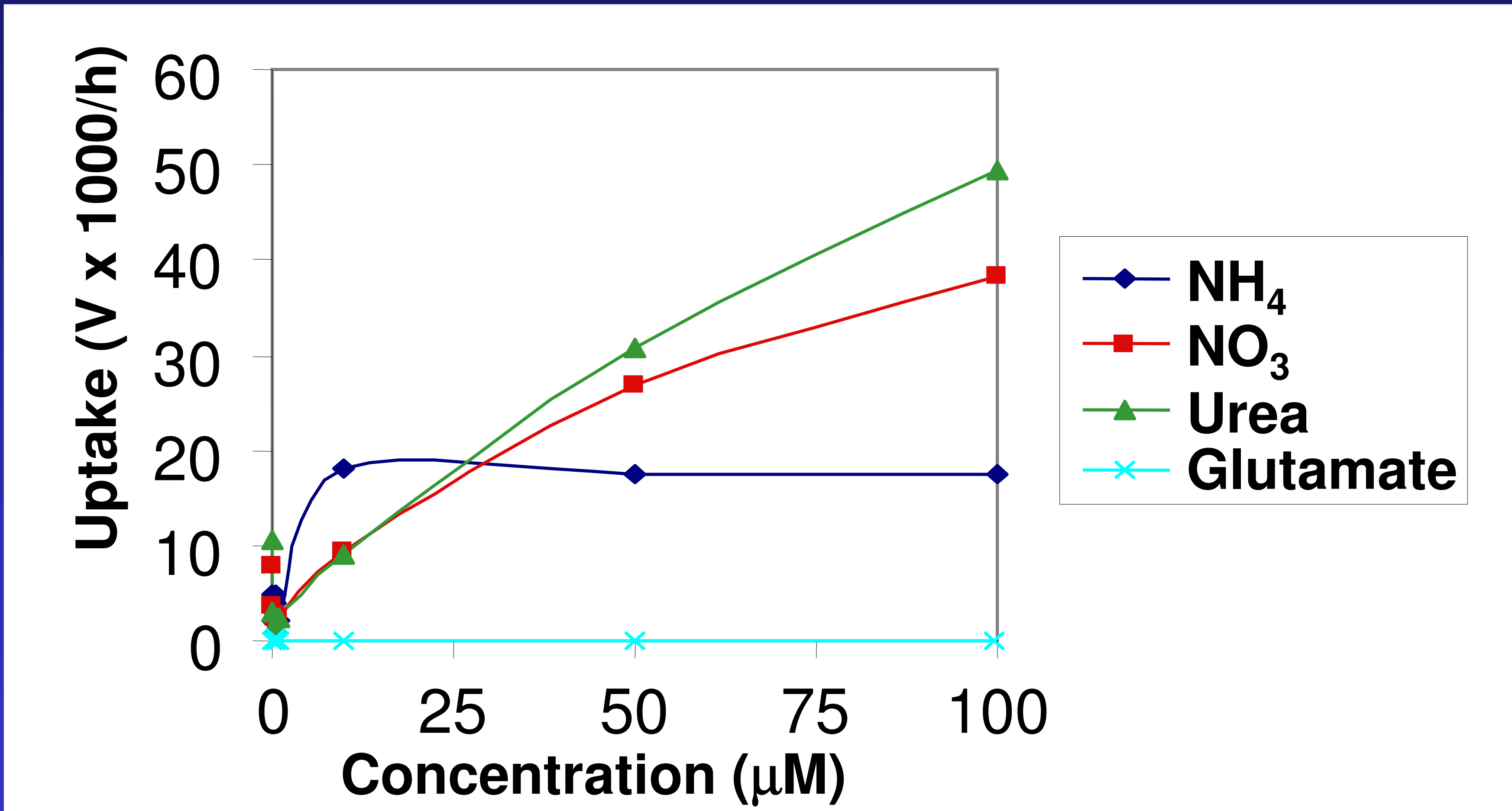



# Uptake of $^{15}N$ substrates by *L. majuscula* in Tampa Bay



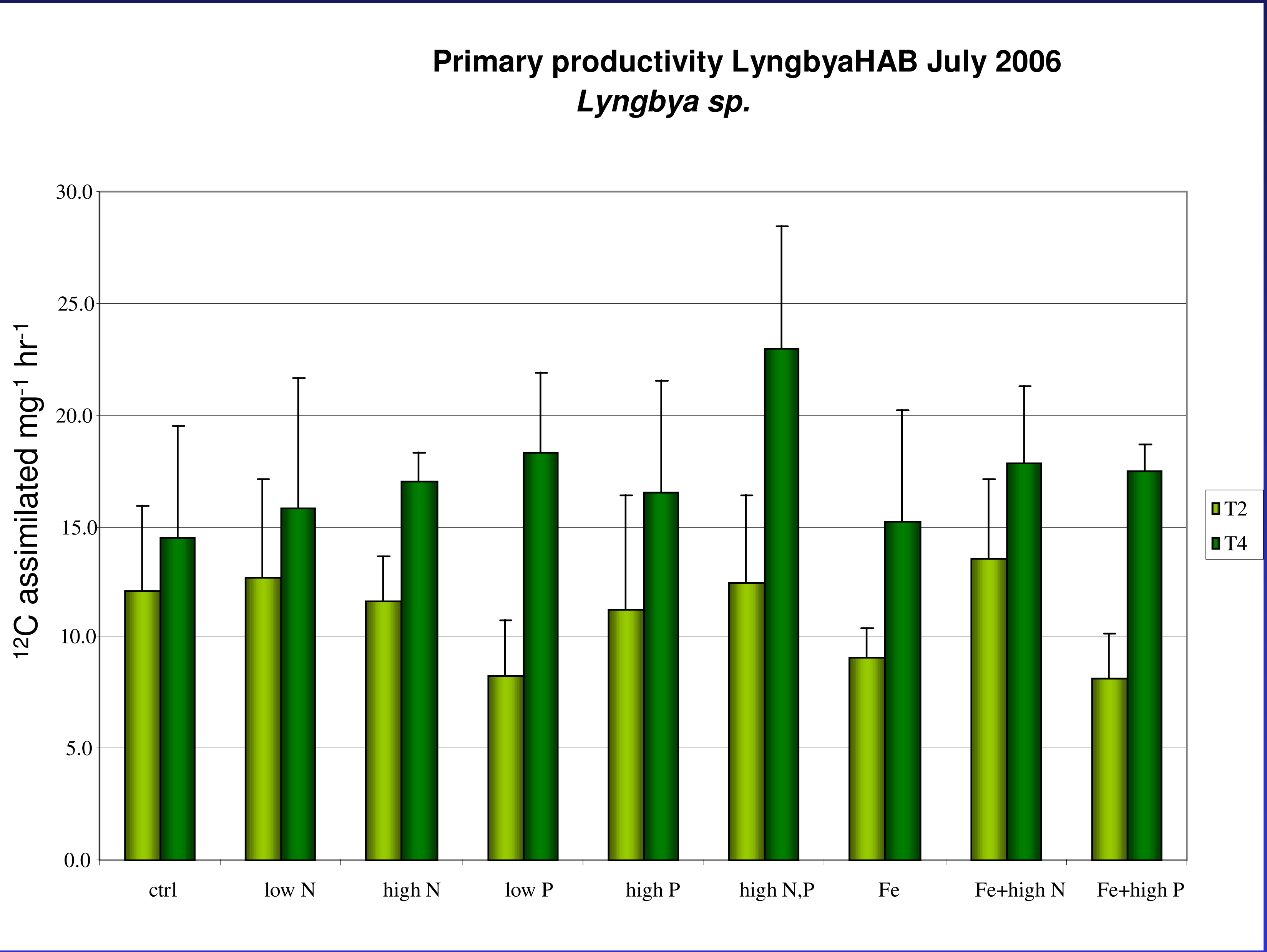

Low $K_s$ for $NH_4^+$ → utilize episodic nutrient pulses

But can also utilize $NO_3$ and urea if available

# Lyngbya majuscula on seagrass beds: Sanibel-Captiva, FL '07

# *Lyngbya* spp. nutrient bioassays: Florida




Primary productivity LyngbyaHAB July 2006
Lyngbya sp.
12C assimilated mg-1 hr-1
30.0
25.0
20.0
15.0
10.0
5.0
0.0
ctrl
low N
high N
low P
high P
high N,P
Fe
Fe+high N
Fe+high P
T2
T4

# Conclusions

Both N and P enrichment are involved in *Lyngbya* expansion

Most *Lyngbya* strains can fix $N_2$

*Lyngbya* is also a good competitor for N compounds

N or P input controls alone will not likely do the job
Hence both must be controlled

Hydrologic modifications (increased residence time)
plays a role: Should be minimized

This also applies for *Microcystis*, so a the management
strategy will be similar

# Future Research:

- Use *in situ* bioassays and N/P uptake experiments to develop bloom thresholds

- Use molecular and conventional microscopic techniques to identify and characterize (toxins, $N_2$ fixation and bloom potentials, controls) various *Lyngbya* strains/species

- Based on above, develop long-term control and mitigation strategies

# Acknowledgments

**Jennifer & Alan Joyner, Mike Piehler, Bonnie Chang, Melissa Leonard, Jeremy Braddy, Bill Frazier, John Burns, Juli Dyble, Val Paul, Judy O'Neil, Karen Arthur**

**Funding:**

**St. Johns River Water Management District**

**Florida Department of Health**

**NOAA-EPA/ECOHAB**

**NSF**

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# Background-Springs

- Florida contains 27 of the 78  1st Order Magnitude springs in the USA, high recreational use
- Provide base flow for many streams and rivers
- 320 known springs discharge ~12,300 ft3 sec-1 or 8 billion gal day-1
- 15 submarine springs documented off of Florida coasts
- Specific conductance generally <500 microsiemens cm-1
- Chloride <12 mg L-1 and Sulfate <60 mg L-1