Increasing Importance of NITROGEN DYNAMICS in the Lake Erie Ecosystem

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Lake Erie Paradigm . . . .

- **Phytoplankton are *P-limited***

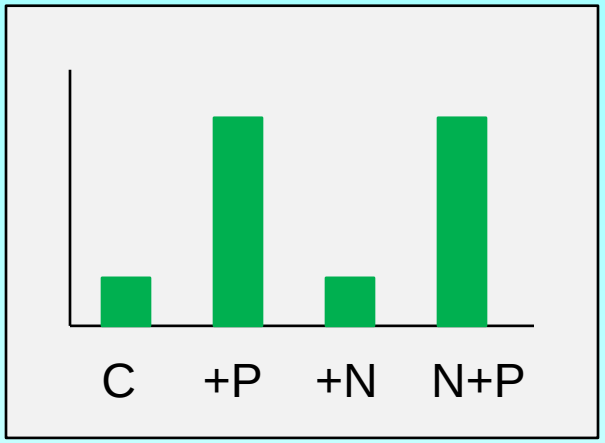
- **All P is *loaded* in water**
  - **from watershed**
  - **from sediments (only if anoxic)**

- **Management strategies have been based on reducing loadings of P**

Are Lake Erie Phytoplankton P-limited?

Nutrient amendment bioassays

+ PO_4 +NO_3 + N and P



Biochemical tests	**P-lim**	**per µg Chl *a***
Alk. Phosphatase Act.	**high**	**(>0.005 µmol P hr^{-1})**
P-Debt	**high**	**(> 0.075 µmol P)**
P Deficiency Index	**<30**	**($P_{optimum}$ / V_{max})**
SRP conc.	**< 100 nM**	**(100 nM = 3 ppb P)**
P- Turnover time	**< 20 min**	**(minutes)**

See: Guildford et al. (2005) JGLR 31: 72-88.

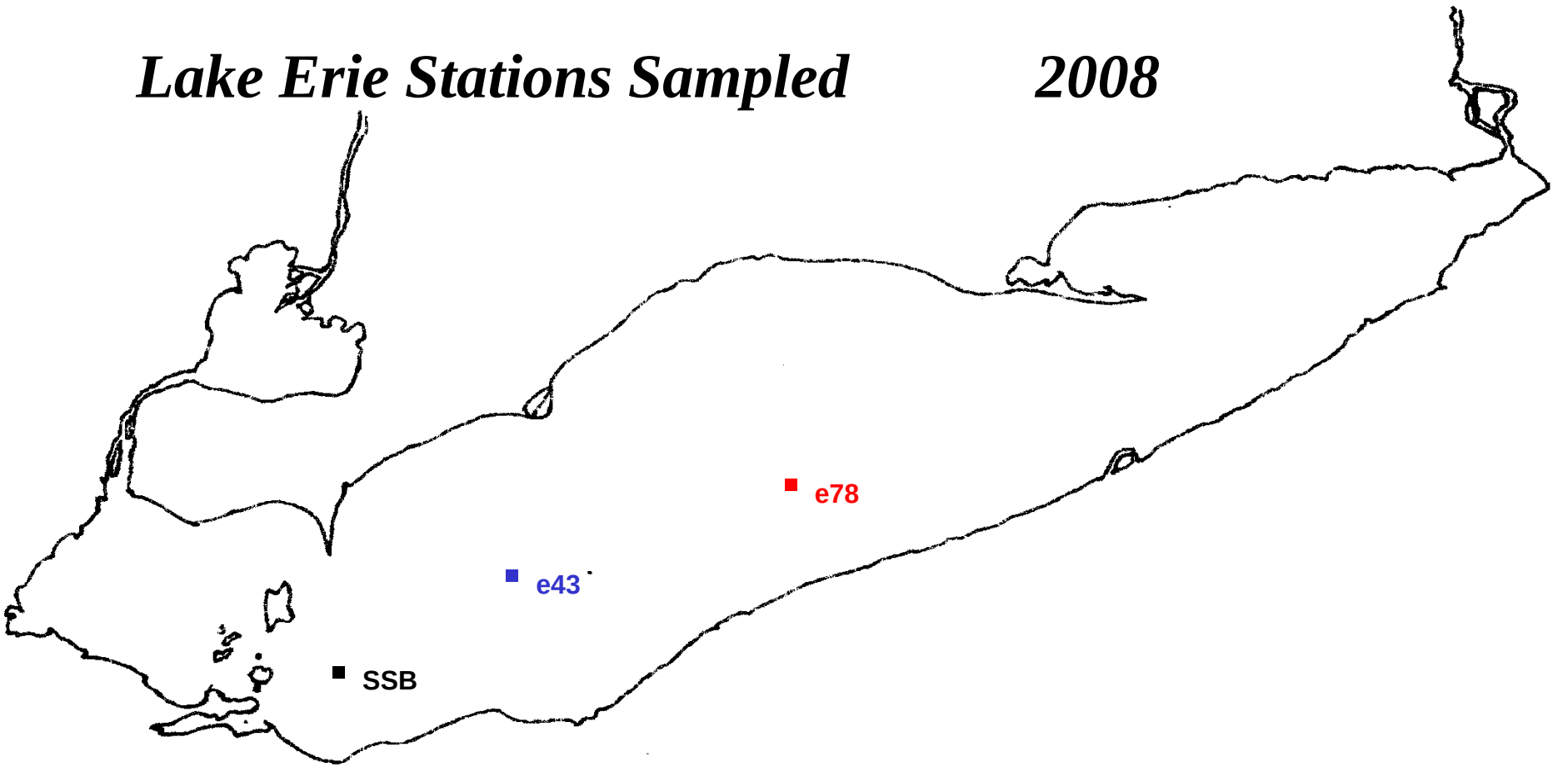
Biochemical Indicators of P-limitation . . .

In samples taken from Central Basin of Lake Erie

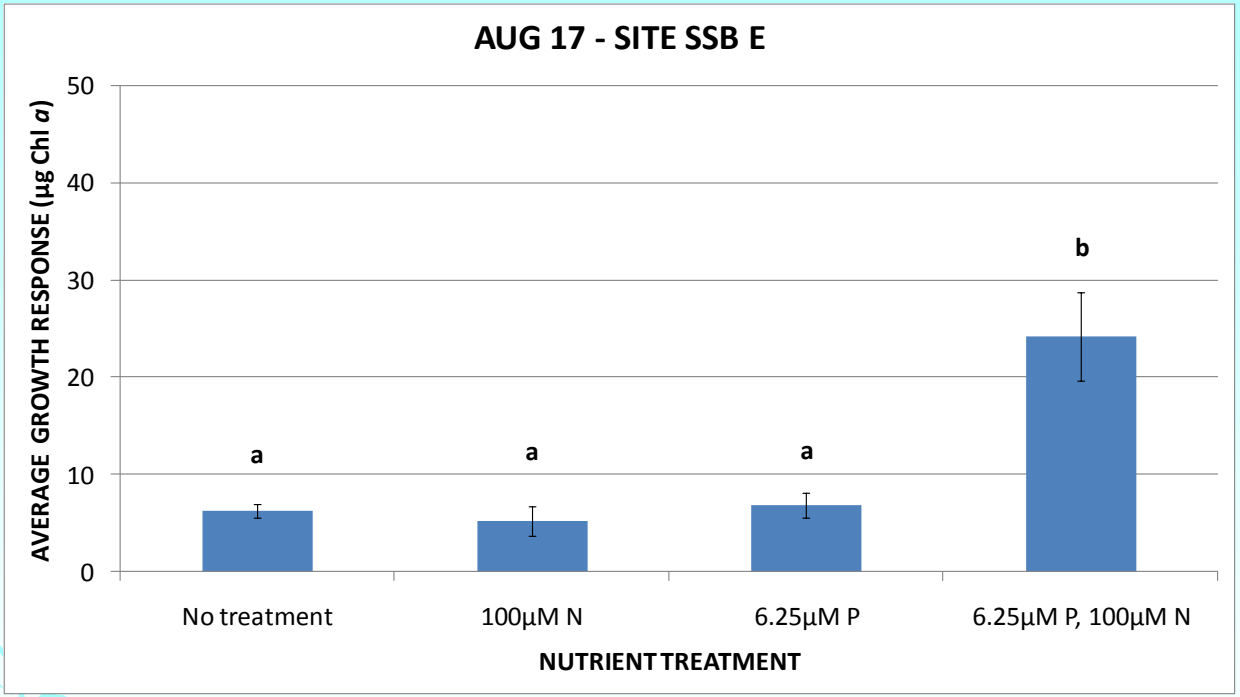
	per µg Chl *a*	**1996**	**2008**
APA	(µmol hr^{-1})	**----**	0.001_{56}
P-debt	(µmol P)	**0.36**	0.18_{4}
P D I		**14**	80
SRP	(nM)	30	**320**
P-turnover	(min)	16.1	**262**

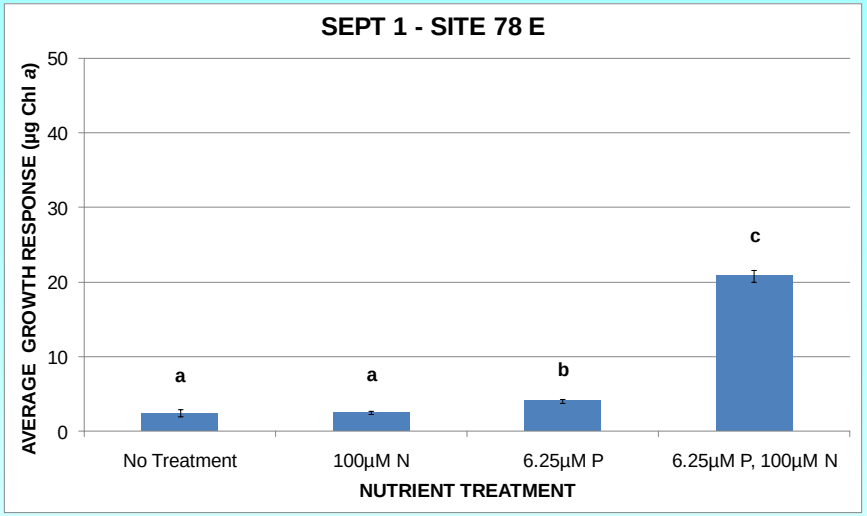
RED => P-limited

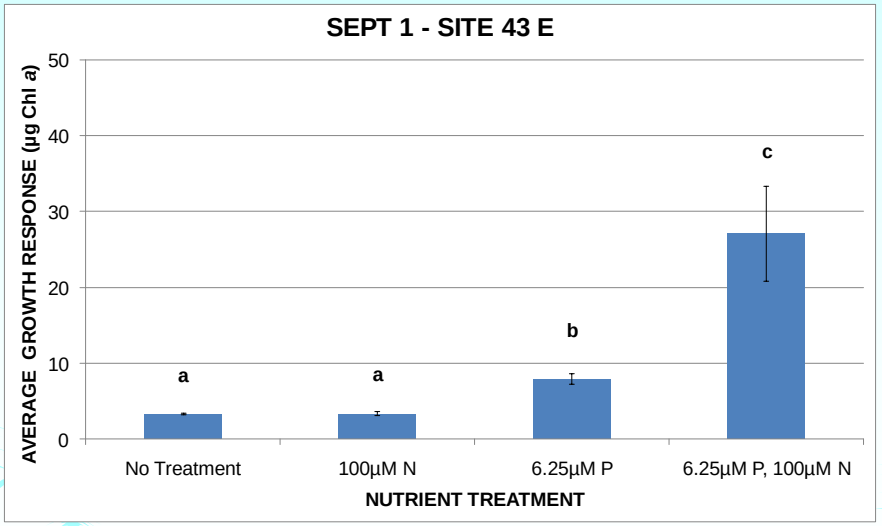
Lake Erie Stations Sampled 2008



Nutrient Amendment Bioassay . . . .



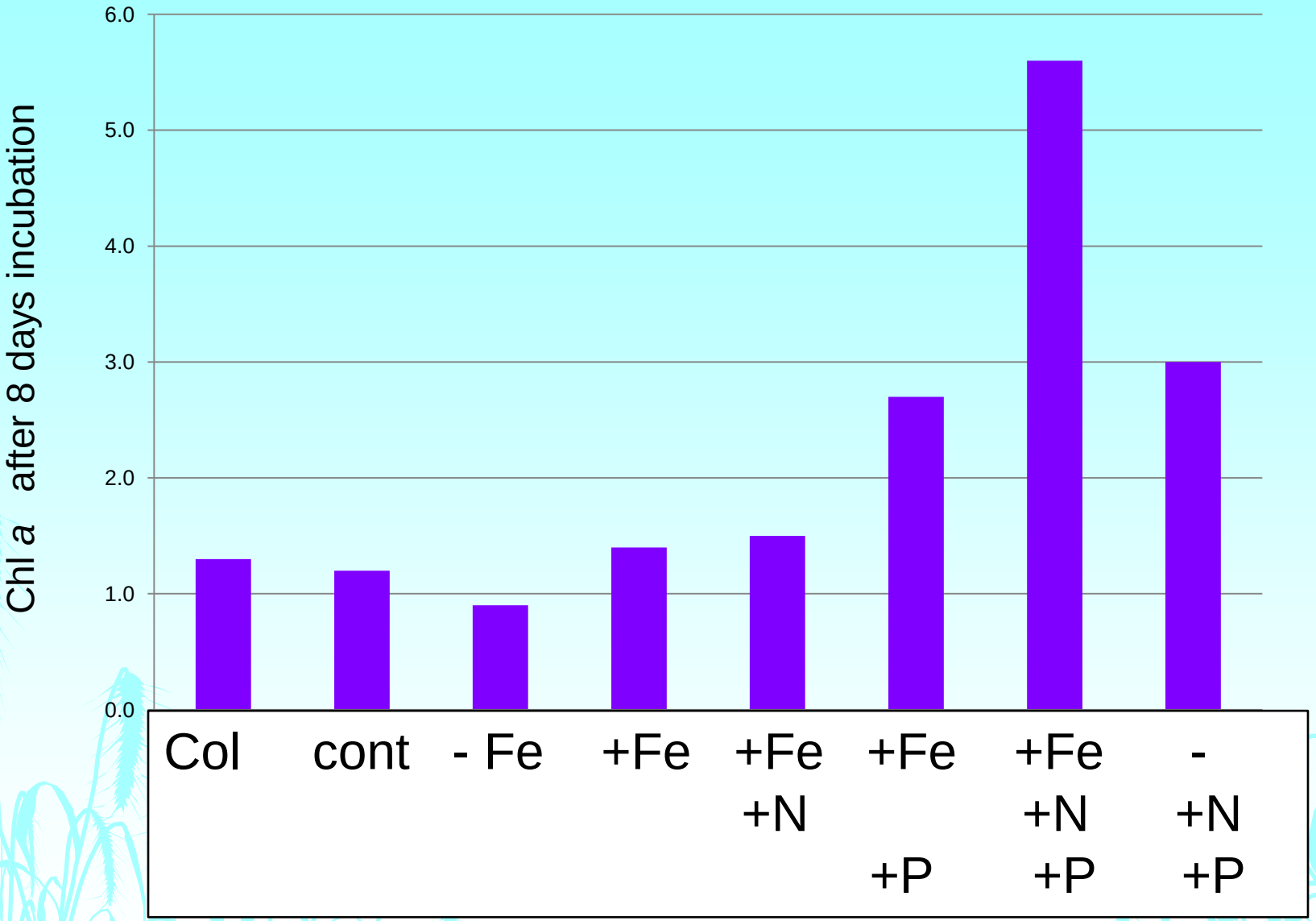

SEPT 1 - SITE 78 E
AVERAGE GROWTH RESPONSE (µg Chl a)
50
40
30
20
10
0
a
a
b
c
No Treatment
100µM N
6.25µM P
6.25µM P, 100µM N
NUTRIENT TREATMENT


SEPT 1 - SITE 43 E
AVERAGE GROWTH RESPONSE (µg Chl a)
50
40
30
20
10
0
a
a
b
c
No Treatment
100µM N
6.25µM P
6.25µM P, 100µM N
NUTRIENT TREATMENT

North, R., Guildford, S., et al. (2007)
Limnol. Oceanogr. 52: 315-328.

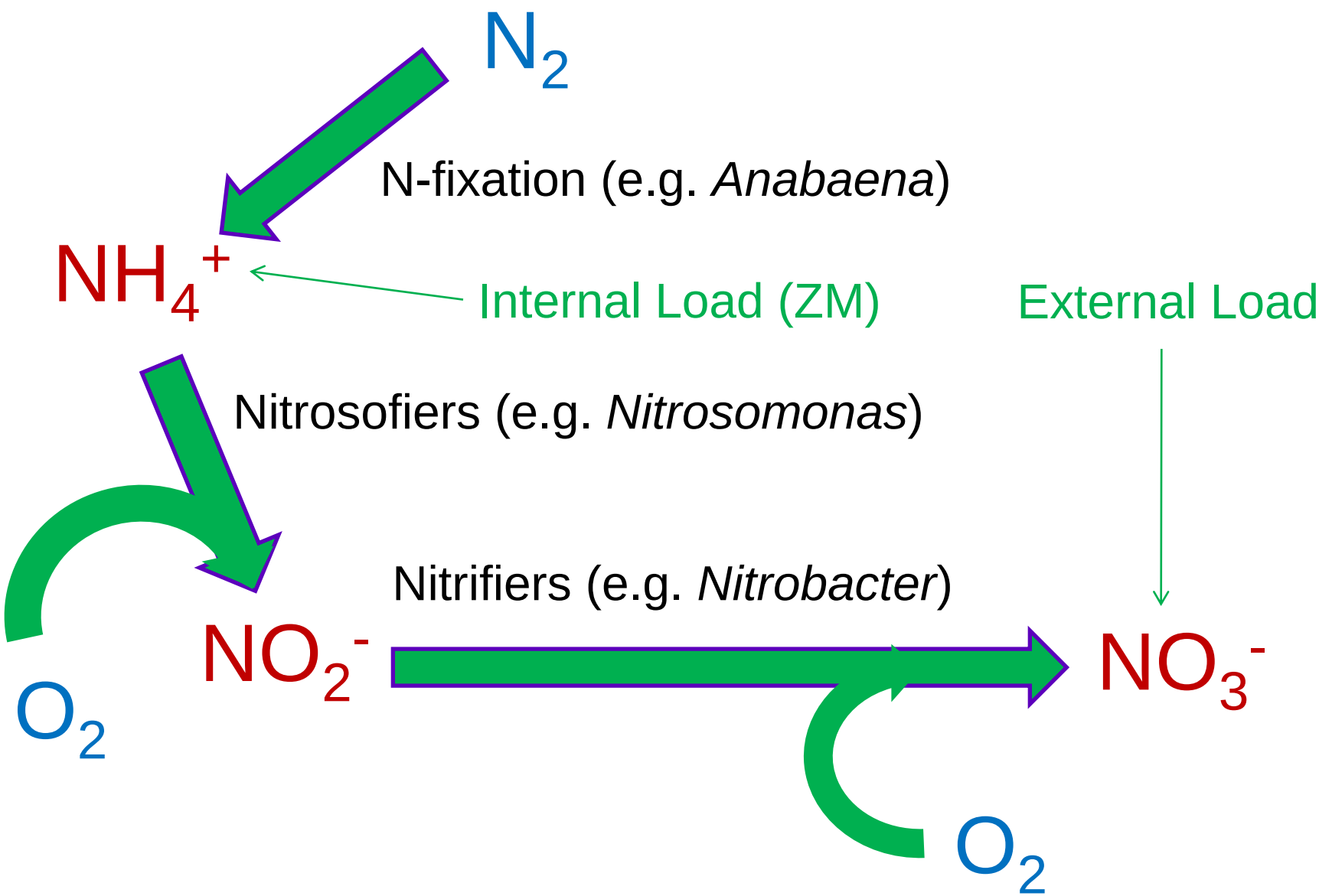
Reporting on research in 2003 in the Eastern Basin of L/E

Alk. Phos. Act.	0.002		not P-lim
P-debt	0.09	P-lim	
N:P	18.9		not P-lim
C:P	160	moderate P-lim	
C:N	8.5		slight N-lim



North, R., Guildford, S., et al. (2007) *Limnol. Oceanogr.* 52: 315-328.

N – Dynamics under AEROBIC conditions



Implications . . .

- **All roads lead to NO_3^-**

  benefit eukaryotic algae vs. cyanobacteria?

- **Nitrification (NH_4^+ → NO_3^-) is VERY Oxygen-consumptive**

  possible cause of Dead Zones ?

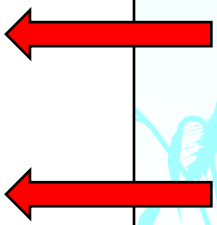
Nitrification - July 2009

EPILIMNION

Sta	Ammonium (uM)	Nitrification (uM/day)	Total O2 Uptake (uM/day)	Percent
30	0.16	8.68	11.57	**75.0**
43	0.50	10.46	13.99	**74.8**
73	0.91	7.75	11.52	**67.3**
15	0.25	2.82	8.85	**31.8**
78	0.55	2.82	8.87	**31.8**

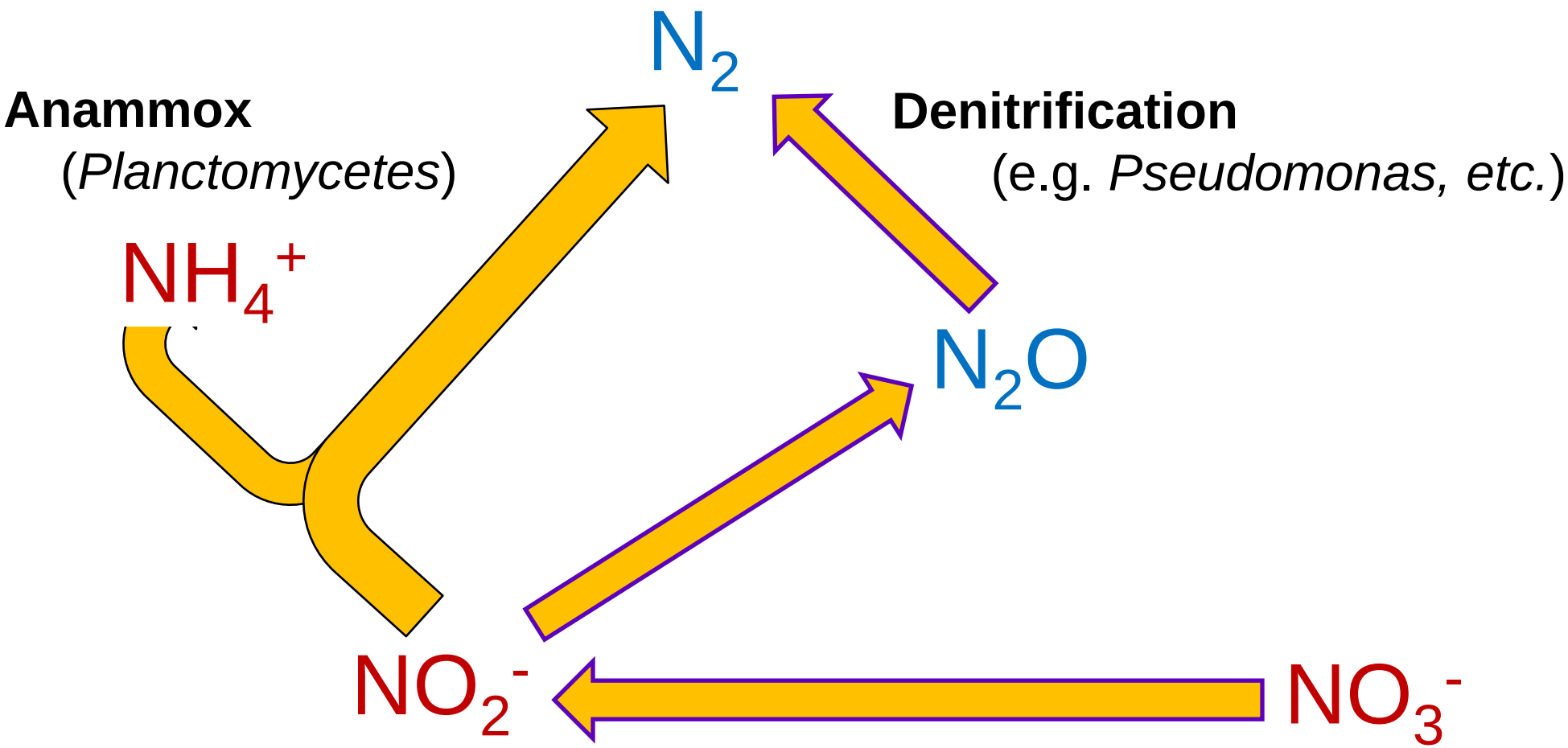
HYPOLIMNION

30	0.15	3.91	13.21	**29.6**
43	1.78	0.47	6.16	**7.7**
73	0.26	4.59	12.09	**38.0**
15	1.05	4.17	5.79	**71.9**
78	2.21	10.28	11.70	**87.9**



Clevinger, Bade, and Heath (unpub. data)

N-Dynamics under **ANAEROBIC** conditions



Implications . . . .

- **All roads lead out**

  anoxia results in **LOSS** of N from the ecosystem

- **With increased occurrence of anoxia**

  there will be increased denitrification and potentially anammox, too

  increased anoxia diminishes available N

  leading to N-limitation??

A Plausible Scenario . . . .

1. **Lower lake levels**, earlier and longer lasting stratification, warmer hypolimnion lead to increased incidence and extent of Dead Zones (hypoxia and anoxia)

2. Exacerbated by nitrification, driven by NH_4^+ released by ZM

3. Leading in turn to increased rates of denitrification (and anammox?)

4. Ultimately leading to large losses of available N and N-limitation of phytoplankton communities + Release of available P from the sediments

The Lake Erie Paradigm is Dead . . . .

Phytoplankton are now N-and-P co-limited

External P-loading no longer drives ecosystem processes

Dead Zones aren't **EFFECTS** of P-eutrophication
they are **CAUSES** of natural processes that

Lead to release of N to the atmosphere
release of P from the sediments

Research needs . . . .

- **Phytoplankton in CB and EB of Lake Erie appear to be co-limited by P & N** (and Fe ?)

  Need to study the state of N-and-P co-limitation

- **Examine implications of BOTH**

  <u>loadings</u> and <u>leavings</u>

  Need to study factors that influence N-losses

Management Implications . . .

- Management strategies designed solely around management of external P-loadings to control blooms of phytoplankton are unlikely to be successful in Lake Erie

- Management strategies need to incorporate considerations of N-cycle processes, if only to determine the limits of manageability.

Biogeochemistry