Iron regulation of cyanobacterial growth in oligotrophic lakes

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Unexplained changes

- Previous: large basins, eutrophic systems (Downing *et al*., 2001)
- Recent: small basins, oligotrophic systems (Carey *et al*., 2008)

- Increase occurrence over last decade in:
  - **Laurentian Great Lakes Basin** (Brittain *et al.*, 2000; Molot *et al.*, 2010; Watson *et al.*, 2004; Winter *et al*., 2011)
  - **Globally** (Berger *et al.*, 2008; Figueredo *et al.*, 2007)

Clear this is no longer simply a eutrophication problem

Ecosystem health implications

- Bloom forming
    - Cyanotoxins

- Microcystin (MC), anatoxin, saxitoxin, nodularin

- Laurentian Great Lakes Basin
    - *Microcystis spp*. → MC (Hotto *et al*., 2007)

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Evidence for increasing bloom events in Ontario

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Algal blooms in Ontario, Canada: Increases in reports since 1994

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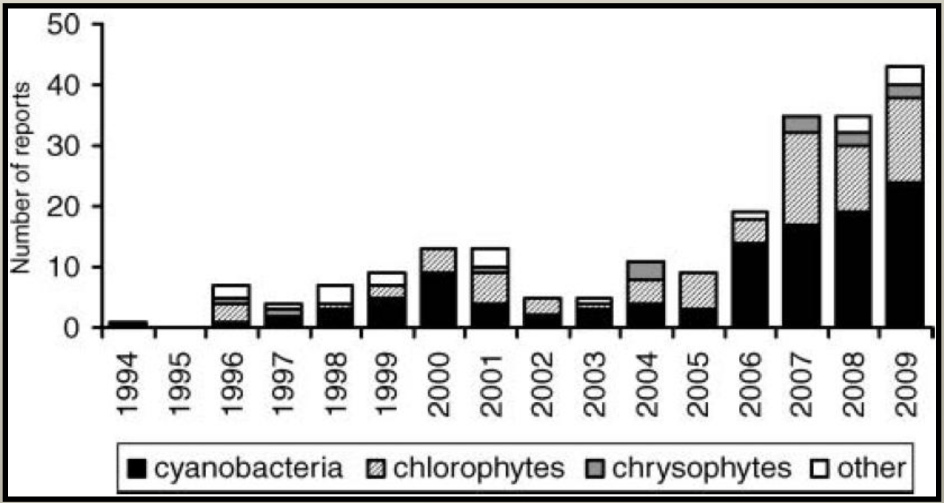
Abstract

Winter JG, DeSellas AM, Fletcher R, Heintsch L, Morley A, Nakamoto L, Utsumi K. 2011. Algal blooms in Ontario, Canada: Increases in reports since 1994. Lake Reserv Manage. 27:107–114.

The Ontario Ministry of the Environment provides an algal identification service as part of the Ministry's response to algal bloom events, and we have been tracking the reports since 1994. From 1994 through 2009, we noted a significant increase in the number of algal blooms reported each year ($P < 0.001$). There was also an increase in the number of blooms in which cyanobacteria were dominant ($P < 0.001$), with these samples making up >50% of the total during peak years. The most common taxa of cyanobacteria identified were *Anabaena*, *Aphanizomenon*, *Microcystis*, *Gloeotrichia*, and various Oscillatoriales. The remaining samples were dominated by filamentous green algae, or occasionally by chrysophytes. We also noted geographic and seasonal trends in the bloom reports. Most of the increase in the number of cyanobacterial bloom reports was accounted for from lakes on the Canadian Shield (located within the boundary of the Ministry's Northern Region). Algal blooms are now being reported later into the fall than they were during the 1990s; bloom reports have extended well into November in recent years. We attributed these trends to (1) increased nutrient inputs in some areas, which promote the growth of algae; (2) factors associated with climate warming, which may exacerbate bloom conditions; and (3) an increase in public awareness of algal issues. An increase in algal bloom reports is a management issue in Ontario, and blooms of potentially toxin-producing cyanobacteria prompted a formal response protocol to be followed.

Key words: algae, algal blooms, climate change, cyanobacteria, eutrophication, phosphorus

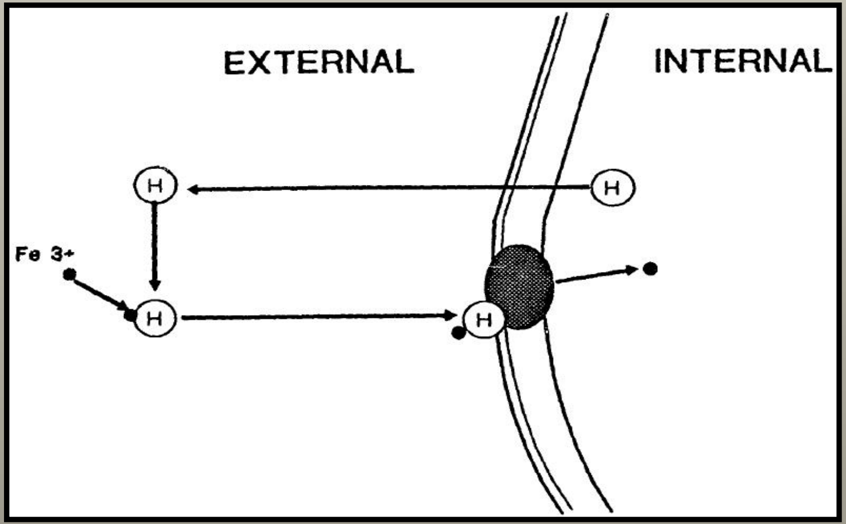


Winter *et al*. (2011)

Chemical determinants of algae

- Phosphorus → Schindler, Downing
- Nitrogen → Bergström, Berman, Herrero
- N:P → Smith, Havens

- Iron (Fe) → Trick, Wilhelm, Molot
  - Photosynthesis, Chl-α synthesis, N-fixation
  - Organic ligands (catecholate and hydroxamate)



Adapted from Wilhelm & Trick (1994)

Research objective and questions

Investigate nutrient conditions giving rise to cyanobacterial growth

Question 1: Is there a relationship between N:P and the % cyanobacteria in lakes?

H_1: Lakes with N:P <16 will experience a greater % cyanobacteria compared to lakes with N:P > 16

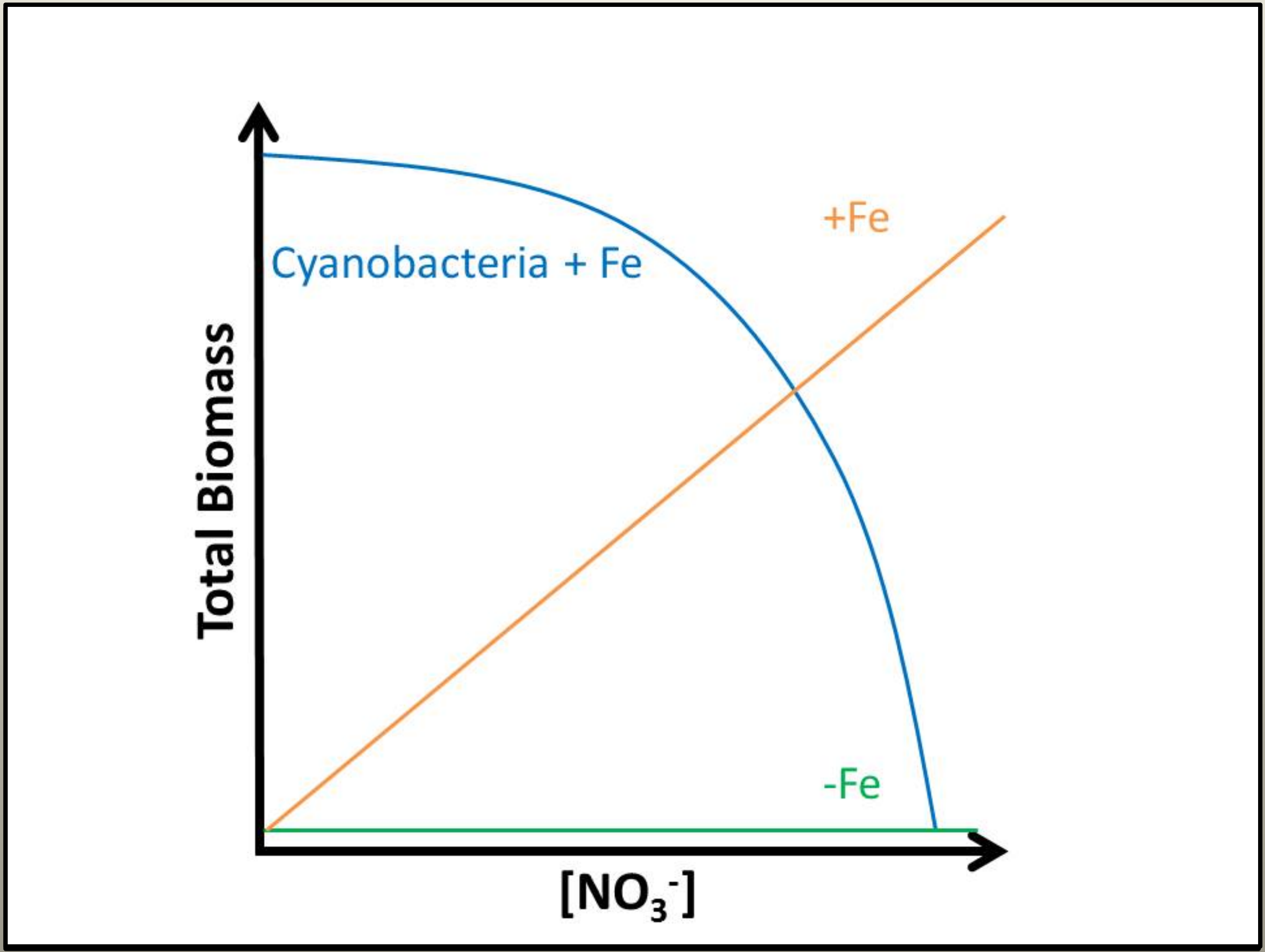
Question 2: Are there patterns that exist among lakes with respect to total algal biomass and the % cyanobacteria?

H_2: Lakes with a relatively high % cyanobacteria will have relatively lower total algal biomass compared to lakes with a relatively low % cyanobacteria, which will have relatively higher total algal biomass

Question 3: Does NO_3^- and Fe^{3+} have an influence on total algal biomass and the % cyanobacteria in the algal community?

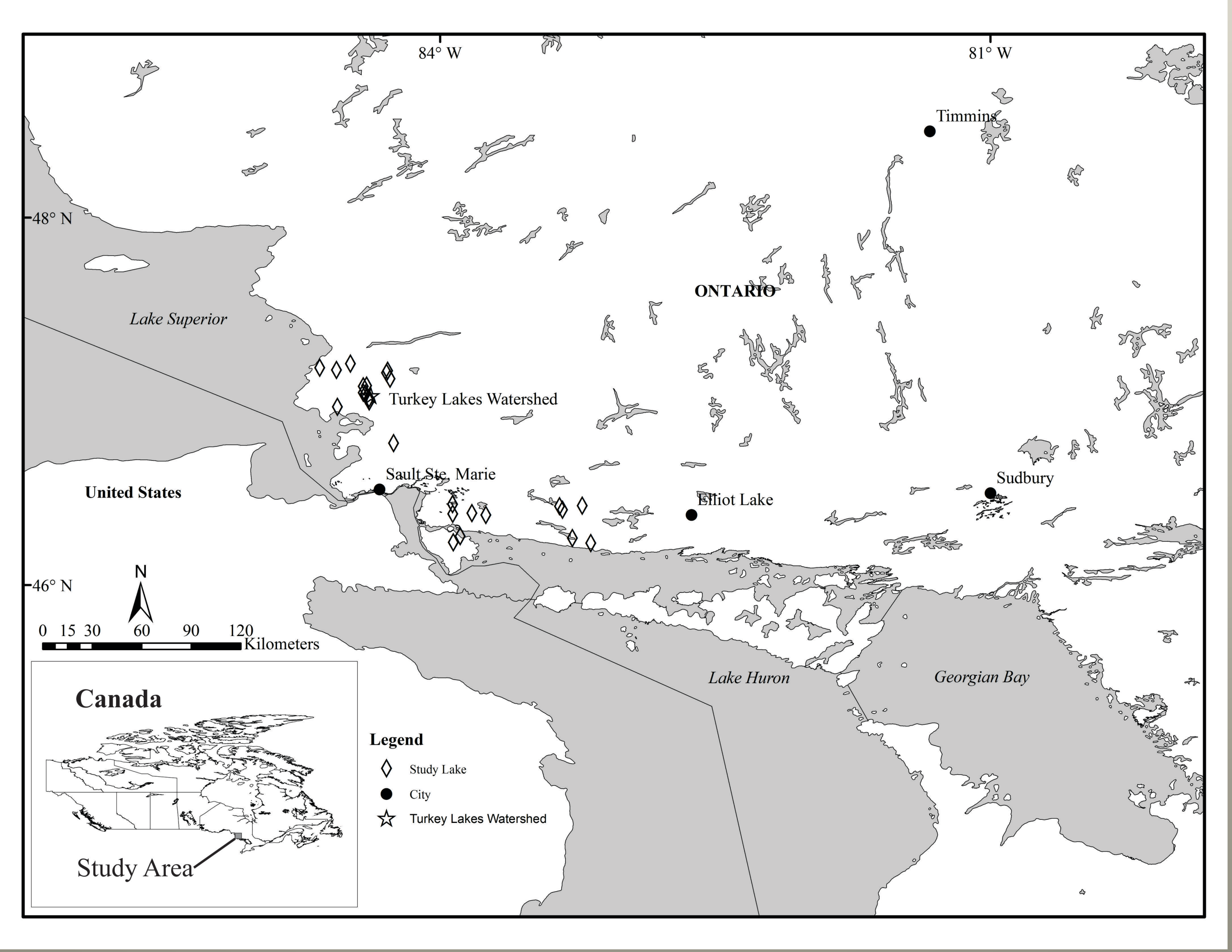
H_3: The availability of NO_3^- and Fe^{3+} will influence the % cyanobacteria and total algal biomass in lakes

Interaction of NO_3^- and Fe^{3+}



Research methods

- 25 lakes in Ontario, 2009-2011
- Water samples: pH, TP, TN, DOC, Fe, Chl-α
- Cyanobacteria density (flow cytometry)



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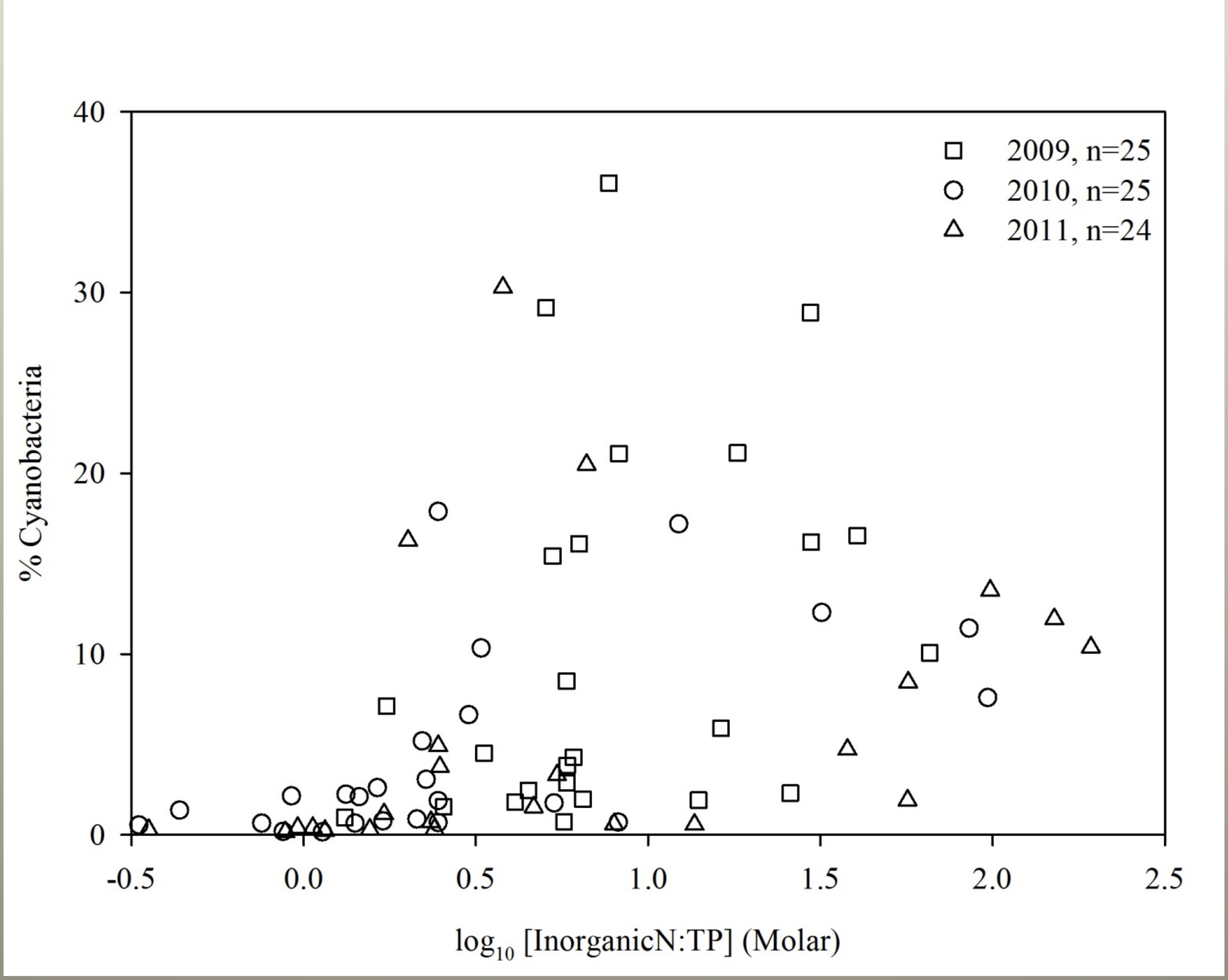

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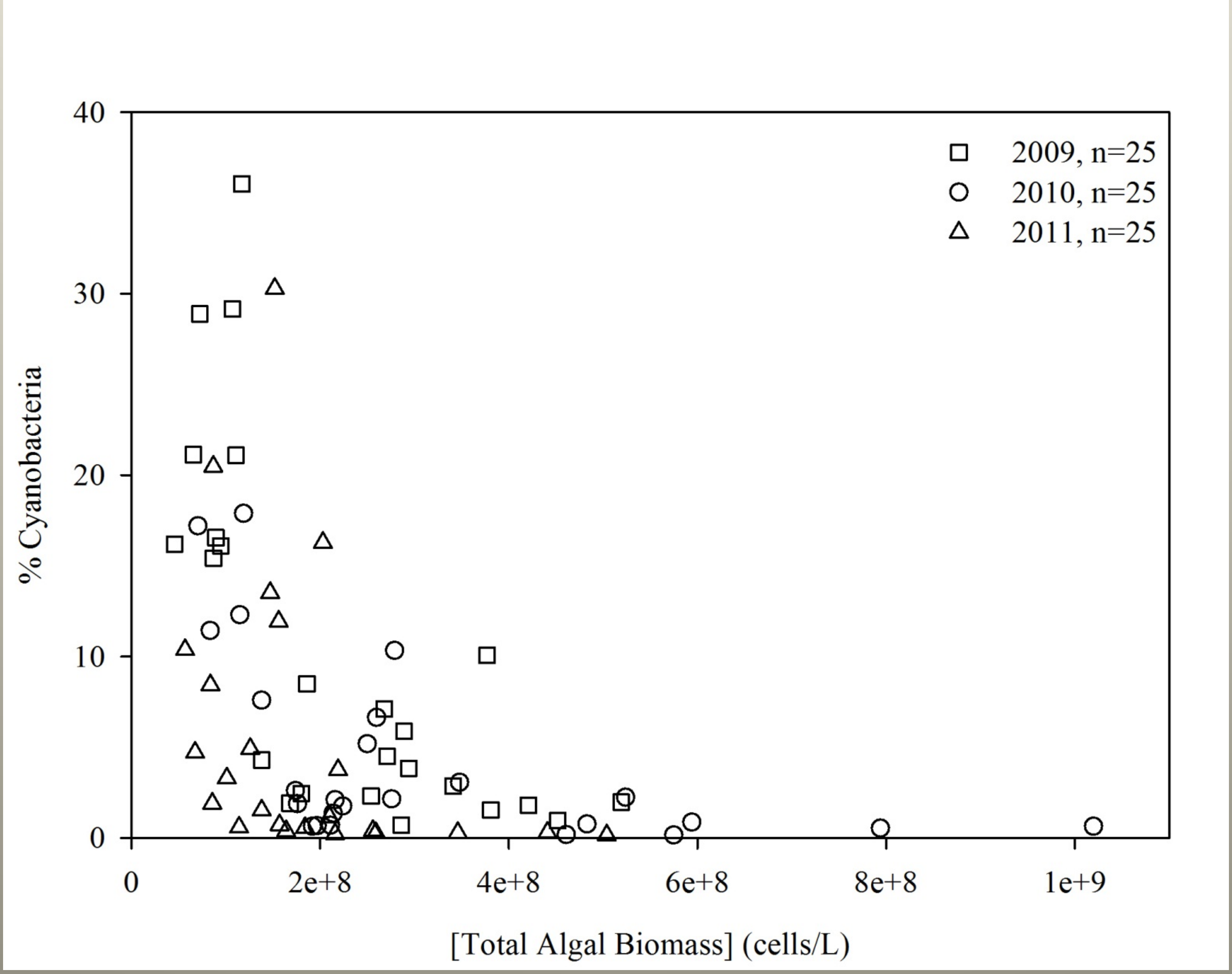
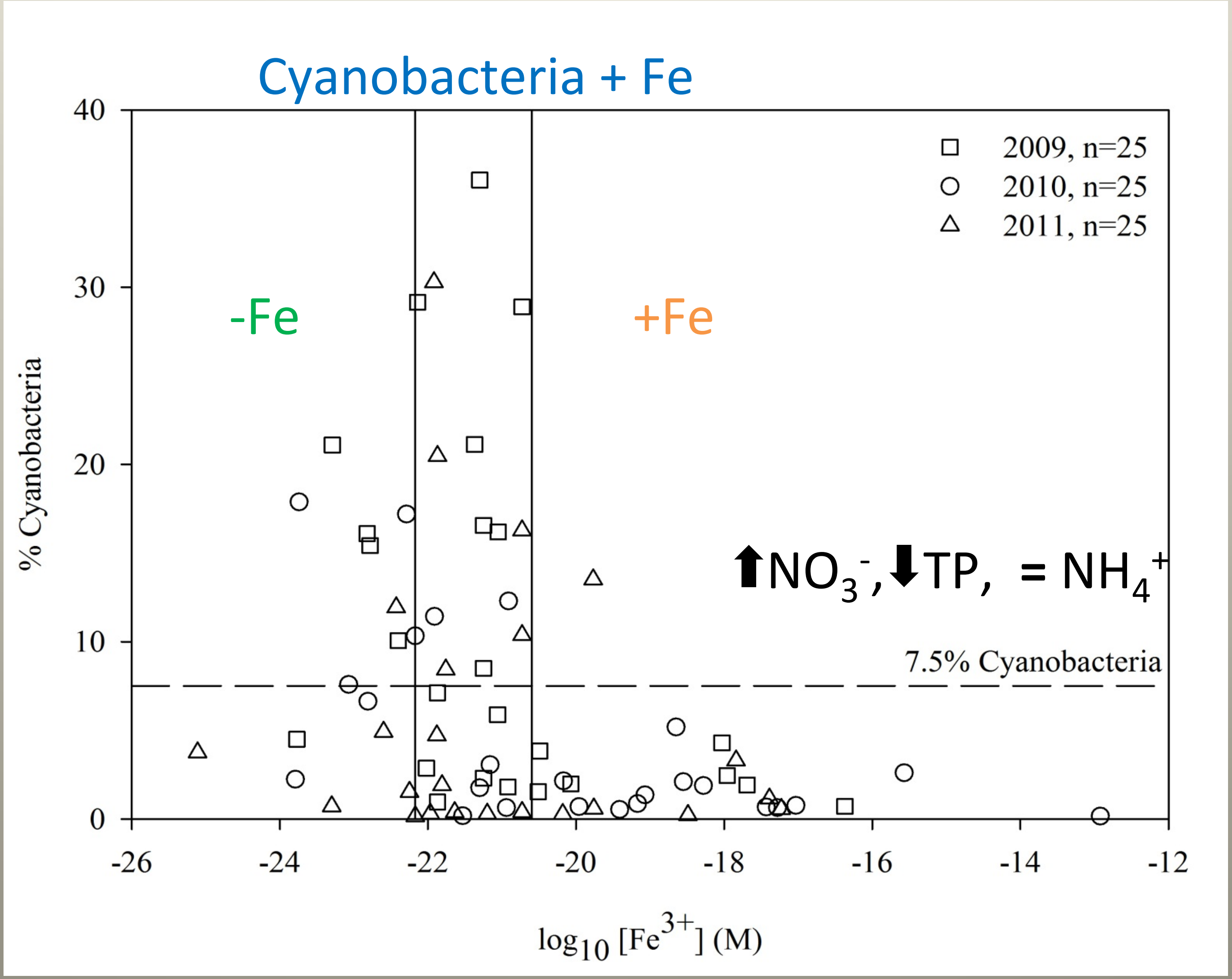


Influence of Fe^{3+} on % cyanobacteria



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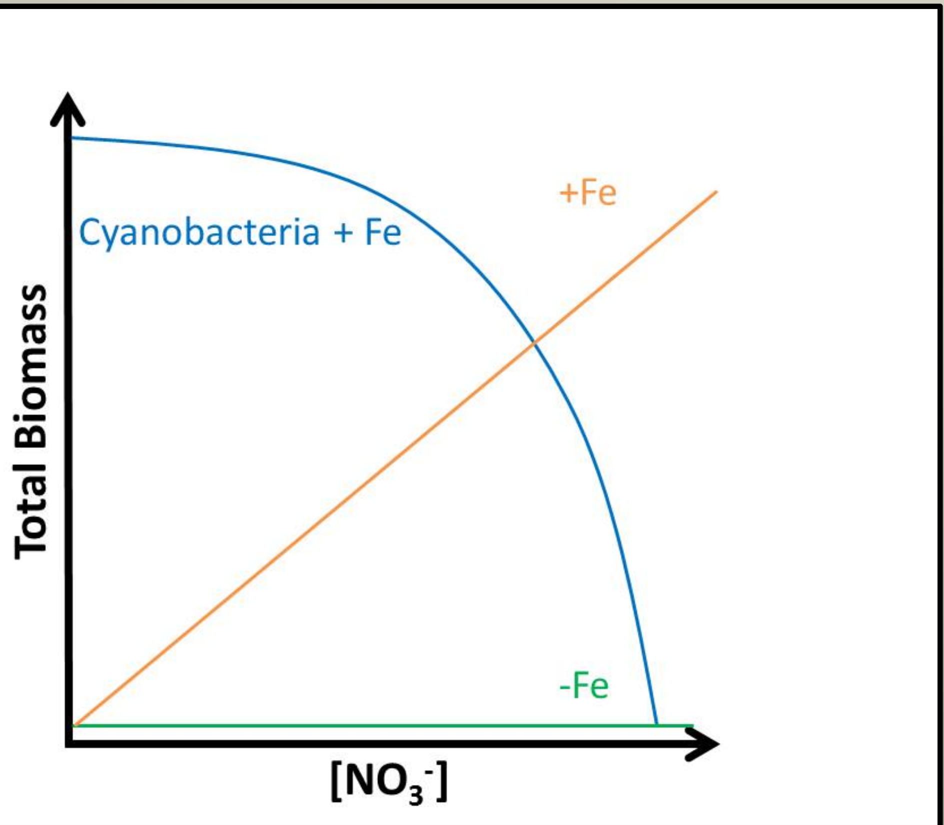

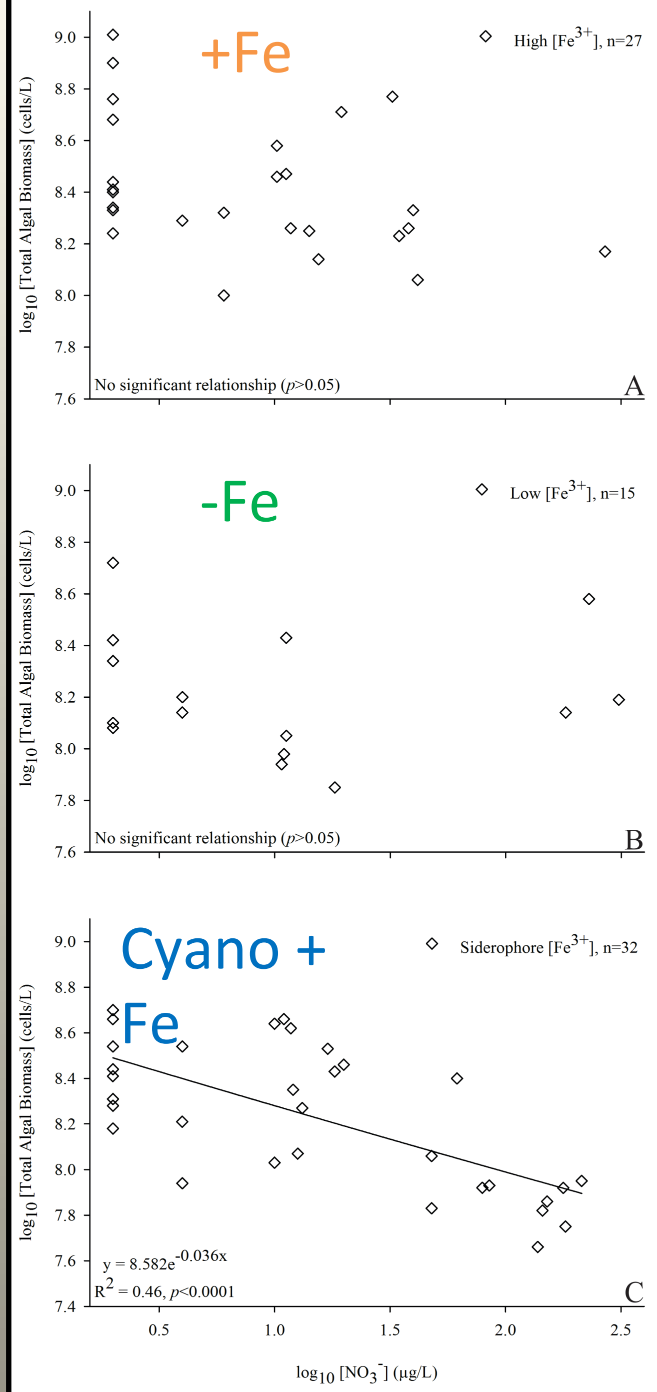

Conclusions

- Number of bloom reports increasing
- Most lakes are P-limited, some N-limited
- Lakes with high total biomass = low % cyanobacteria
- Lakes >7.5% cyanobacteria have significantly higher [NO_3^-] and lower [TP]
- % cyanobacteria increases with increasing [NO_3^-] within defined range of Fe^{3+}

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Acknowledgements

Principal Investigators:

Dr. Irena F. Creed, Dr. Charles G. Trick

Field and Laboratory Assistance:

UWO Catchment Research Facility (CRF)

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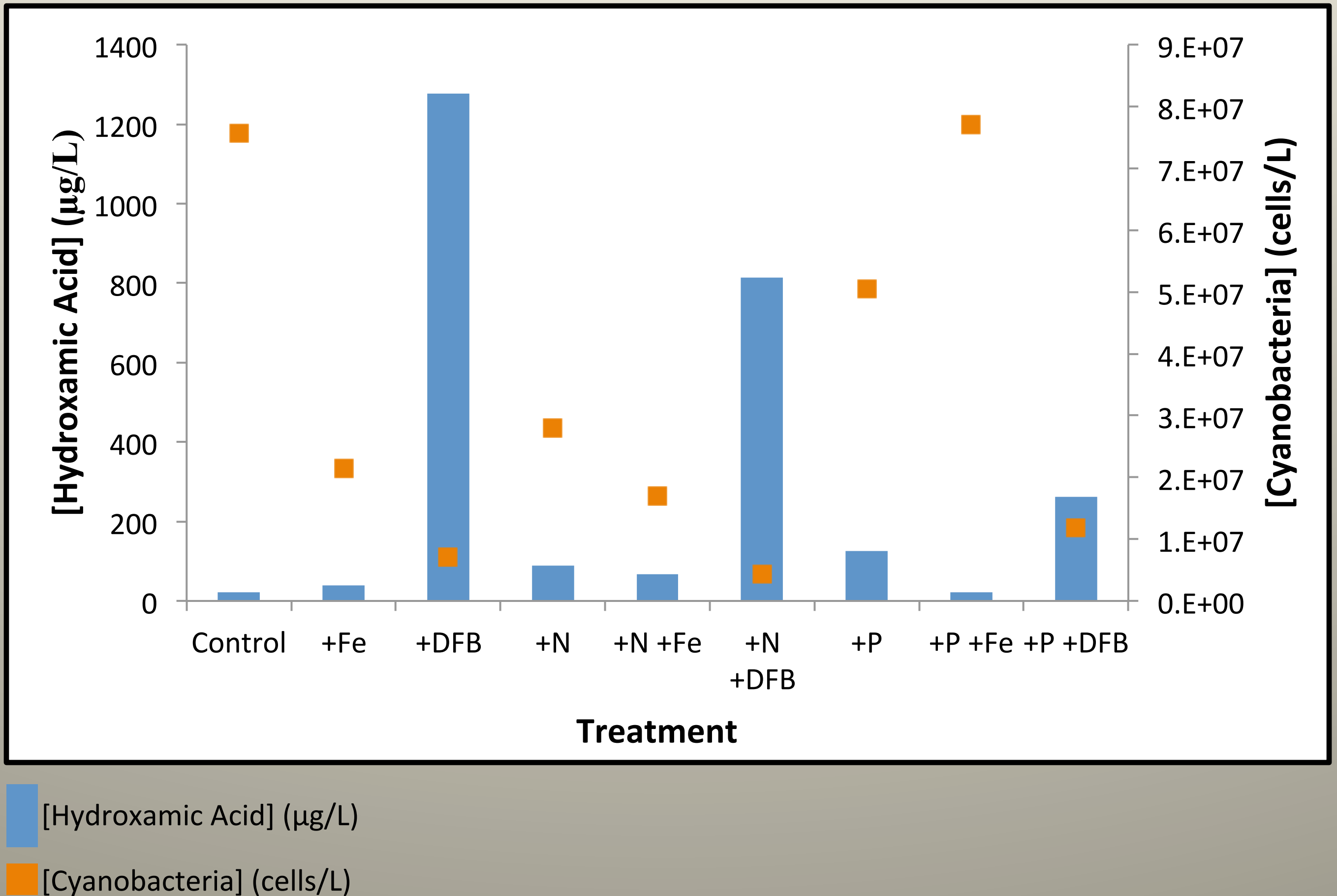
Next steps

Lower Griffin Lake



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