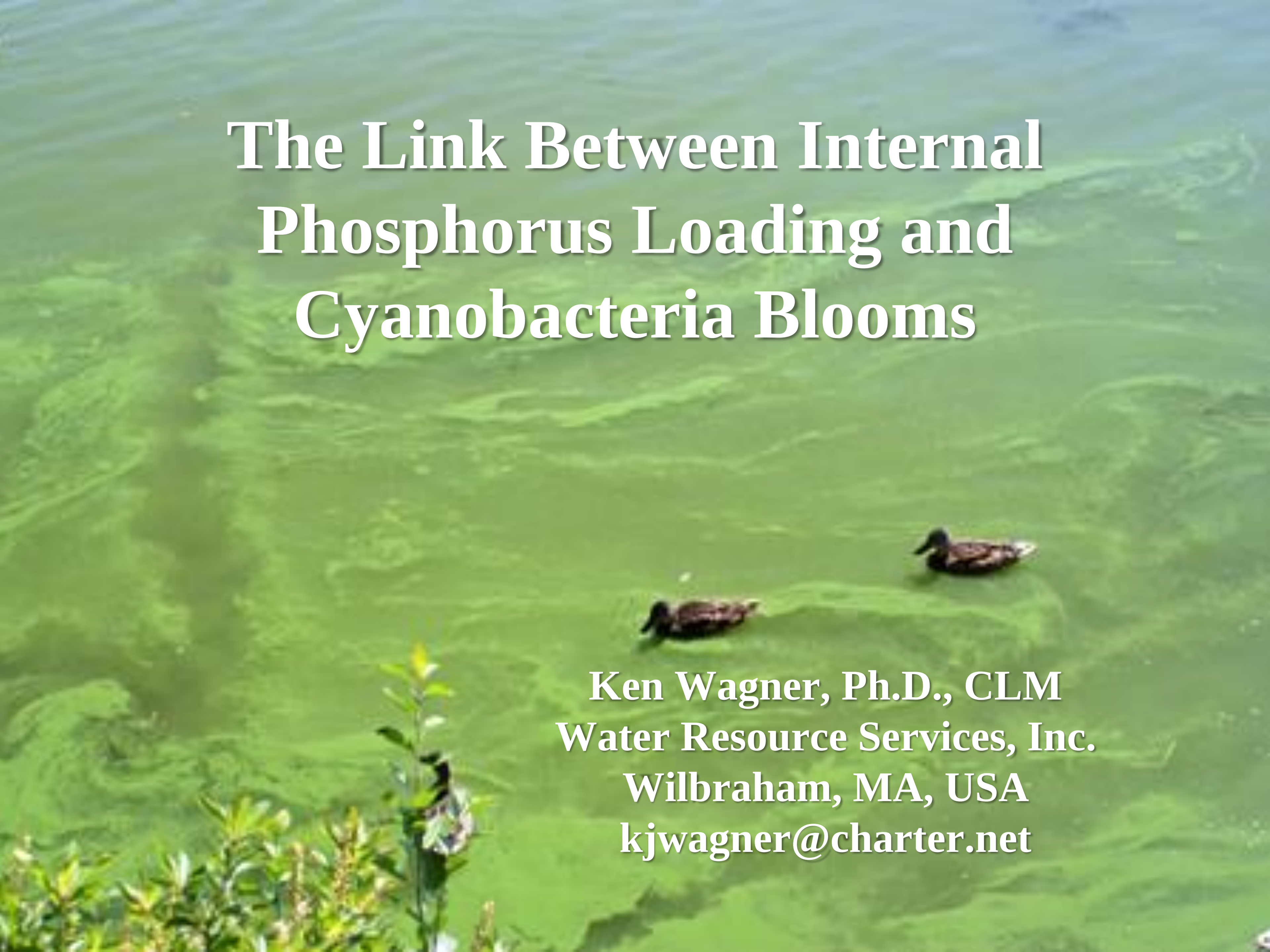
The Link Between Internal Phosphorus Loading and Cyanobacteria Blooms



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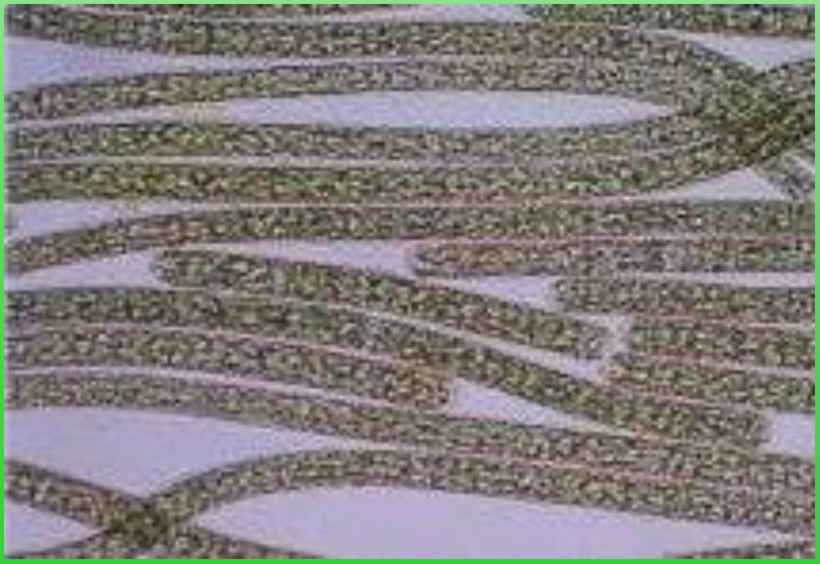
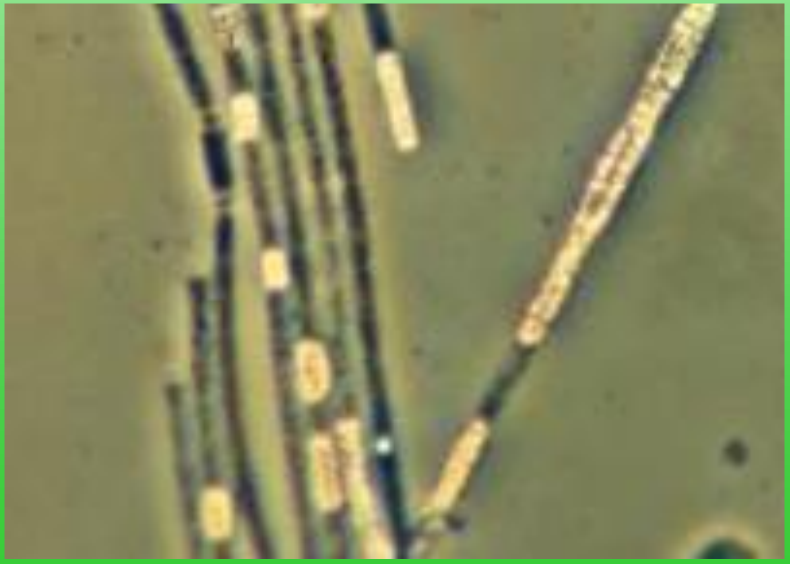
What are cyanobacteria (blue-green algae)?

- Photosynthetic bacteria, 2 billion year old group
- Native, natural, part of functioning aquatic system
- Mostly small cells in large aggregations
- Prefer warmer water, elevated phosphorus concentrations, more reduced iron, higher pH

What are cyanobacteria (blue-green algae)?

- Pigments allow photosynthesis under low light
- Many have heterocytes that allow N fixation
- Many can control buoyancy, form surface scums
- Resting stages fall to sediment, germinate later
- Most are capable of producing toxins
- Diverse group, extensive taxonomic revision



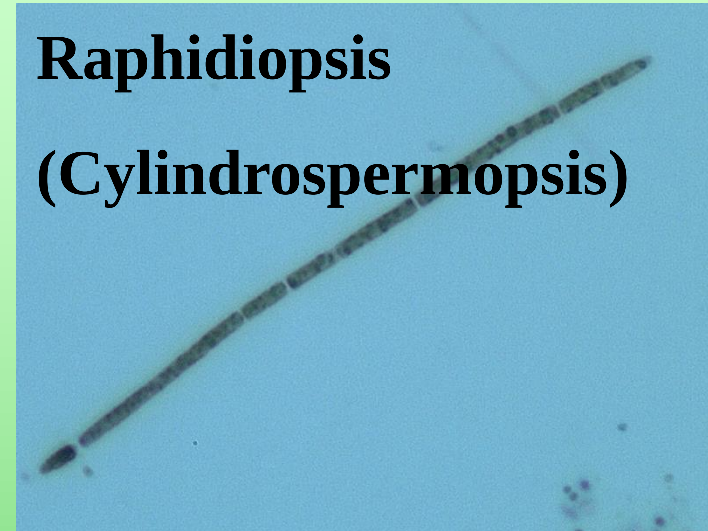


Common planktonic cyanobacteria

Common planktonic cyanobacteria

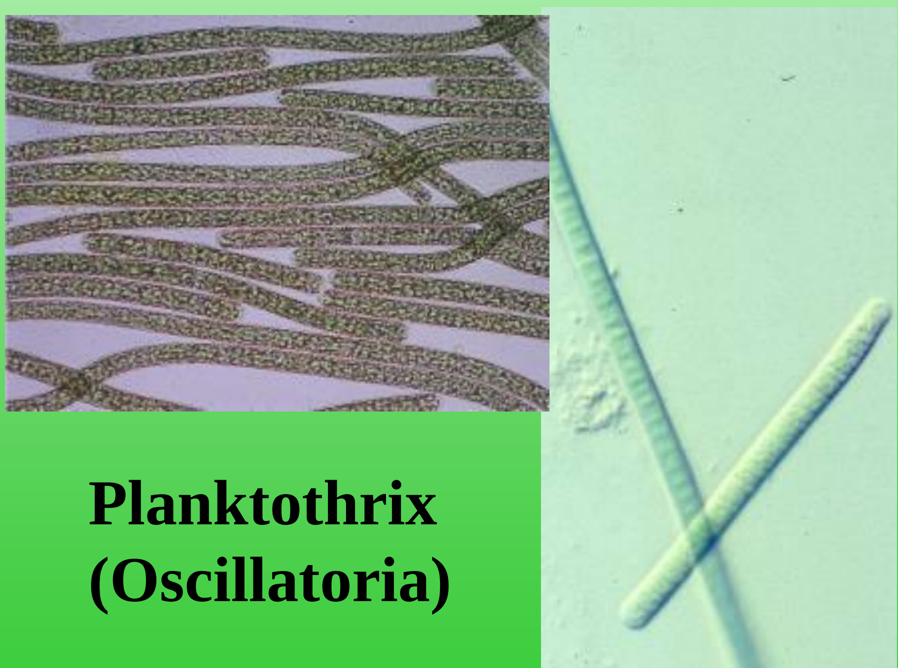
Planktolyngbya

(Lyngbya)



Raphidiopsis

(Cylindrospermopsis)



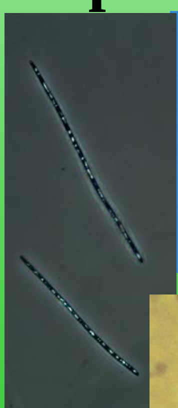
Planktothrix
(Oscillatoria)

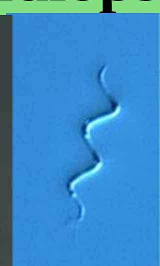
Gloeotrichia

Modes of bloom formation

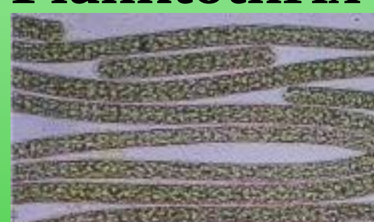
1. Entry from upstream source in large quantity
2. Organic growth in upper water layer
3. Formation at mid-depth with movement into upper water layer
4. Benthic growth of planktonic forms followed by synchronized rise into the upper water layer

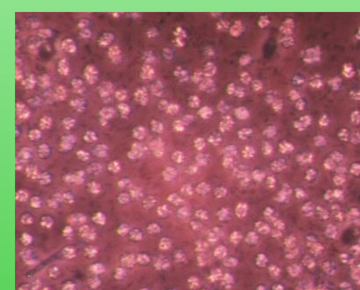
Raphidiopsis





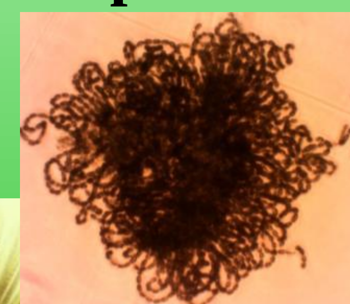
Planktothrix

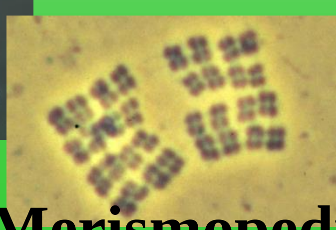




Microcystis

Dolichospermum





Merismopedia

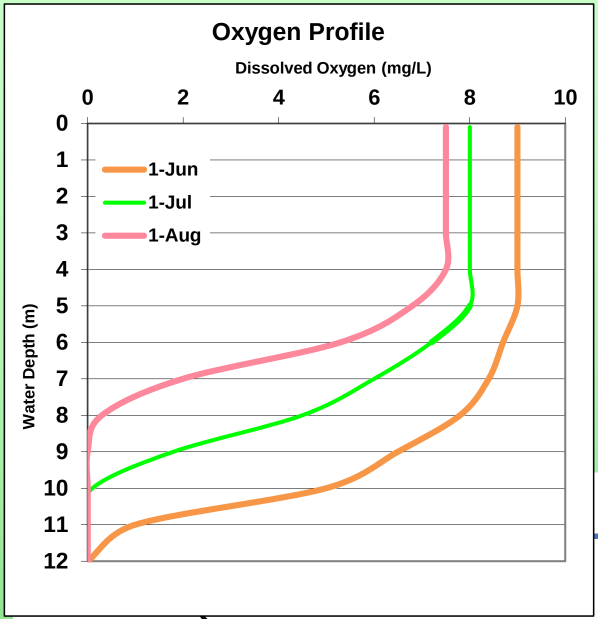
Pseudanabaena

Gloeotrichia

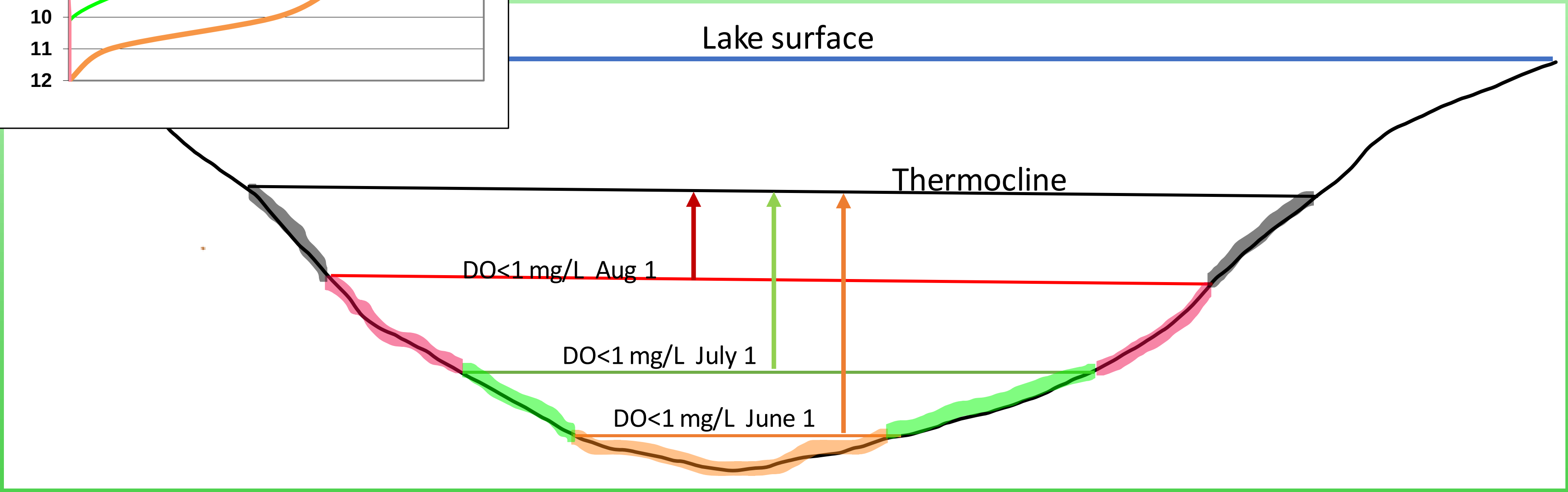
Factors that support cyanoblooms

- **Increased temperature – faster growth rates, cyanobacteria metabolically favored**
- **Increased nutrient inputs – more fertile water**
- **Internal recycling – legacy inputs can become main source of phosphorus**

Oxygen, internal loading and cyanobacteria



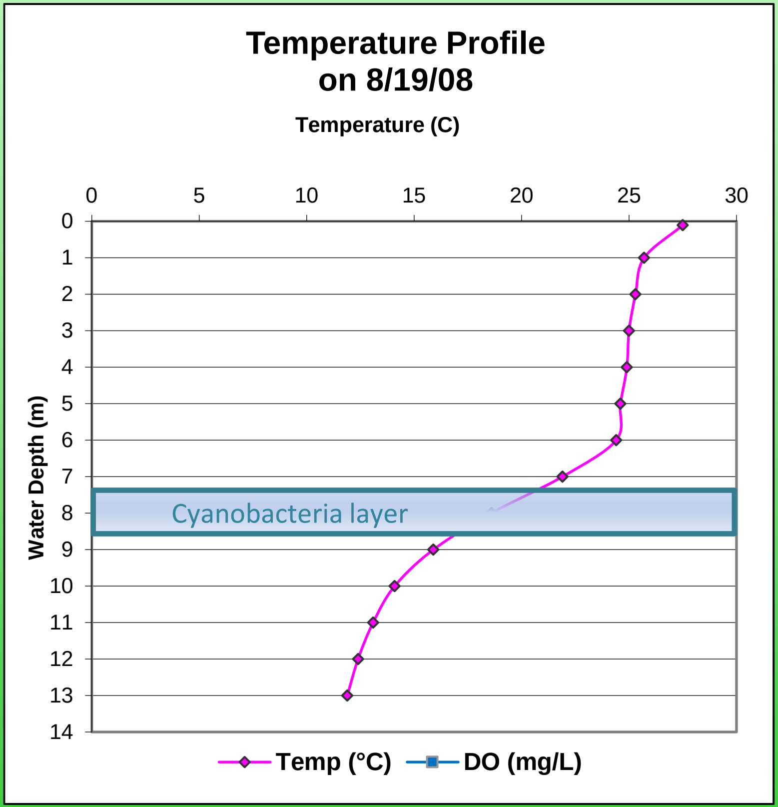
Where the thermocline sets up and how fast oxygen is lost below it can have huge impacts on internal loading and cyanoblooms

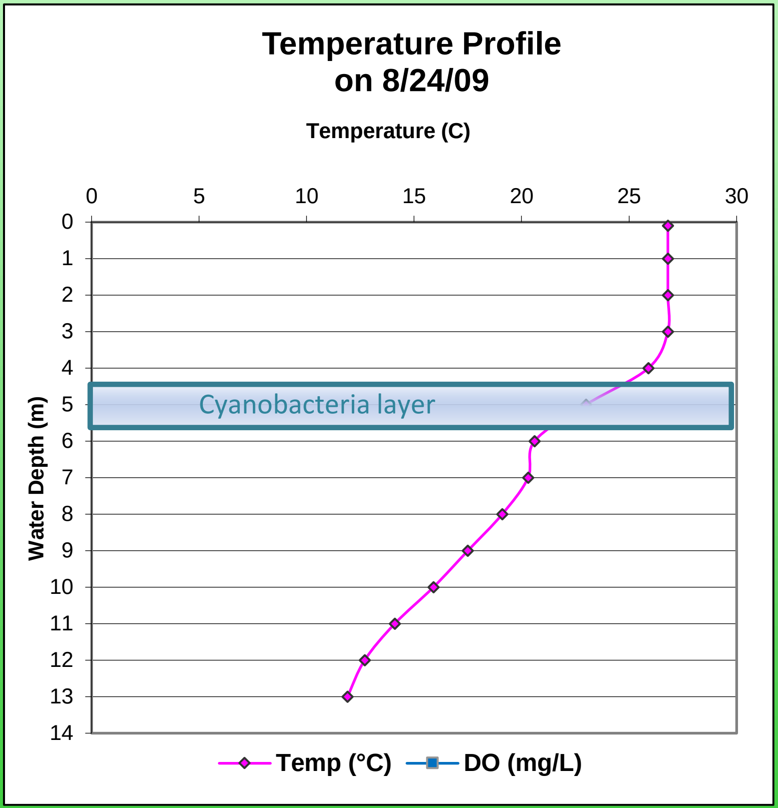


As the top of the anoxic zone rises in the water column, the portion of the lake bottom exposed to anoxia increases and the distance to the thermocline (where light is available) gets shorter.

Metalimnetic cyanobloom

Depth at which thermocline forms will vary with spring weather and could have major consequences for algae impacts

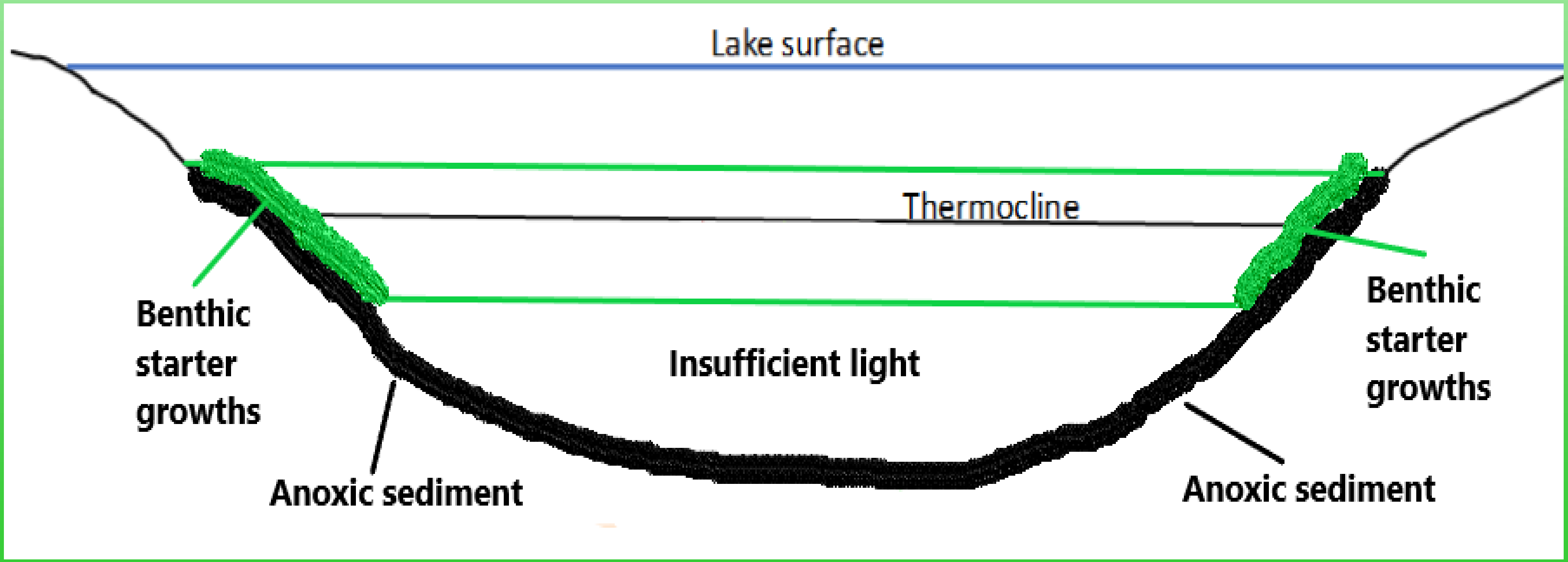




Two successive years in a stratified Cape Cod lake. The bloom came to the surface in 2009 and killed 2 million mussels

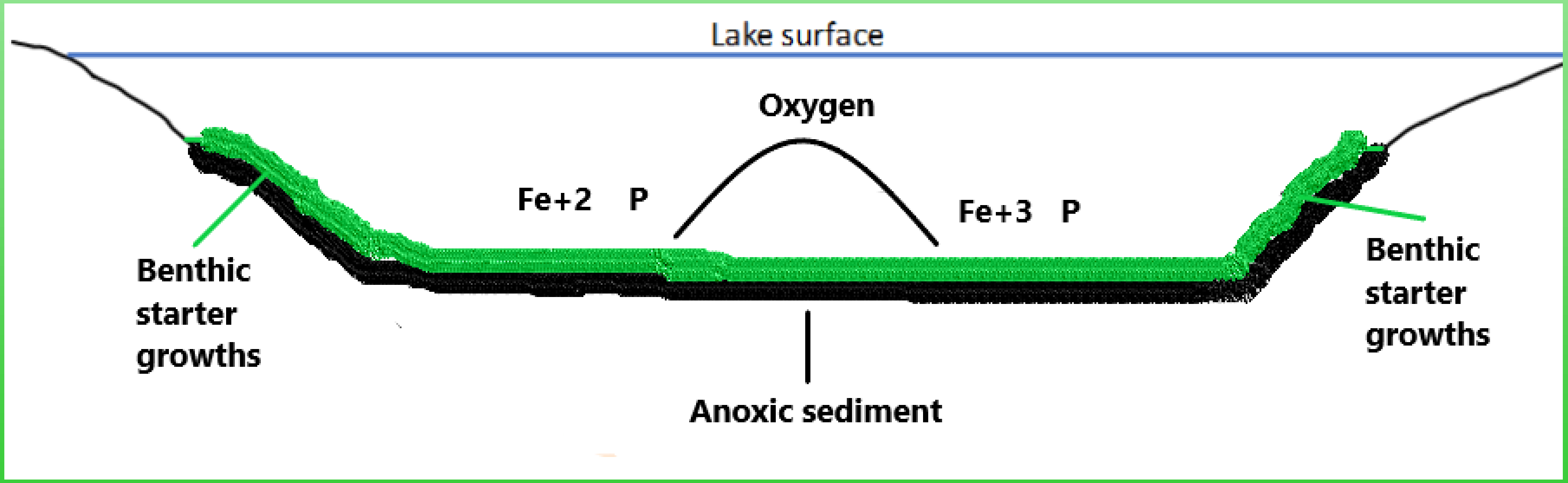
Cyanobacteria blooms with a benthic origin

- Cyanobacteria can grow at the sediment-water interface where P (and Fe) can be released and light is adequate
- P (and Fe) released from sediment by redox reactions (or decomposition) is utilized before it gets into the oxic overlying water and is inactivated
- Cyanobacteria can then rise into upper waters for more light (and sink again to get more nutrients)



Cyanobacteria blooms with a benthic origin

- **A lake does not have to be stratified to support blooms of benthic origin**
- **P and Fe that would not make it far into the water column without being inactivated is still available at sediment-water interface with adequate light**
- **Cyanobacteria grow then rise into water column**

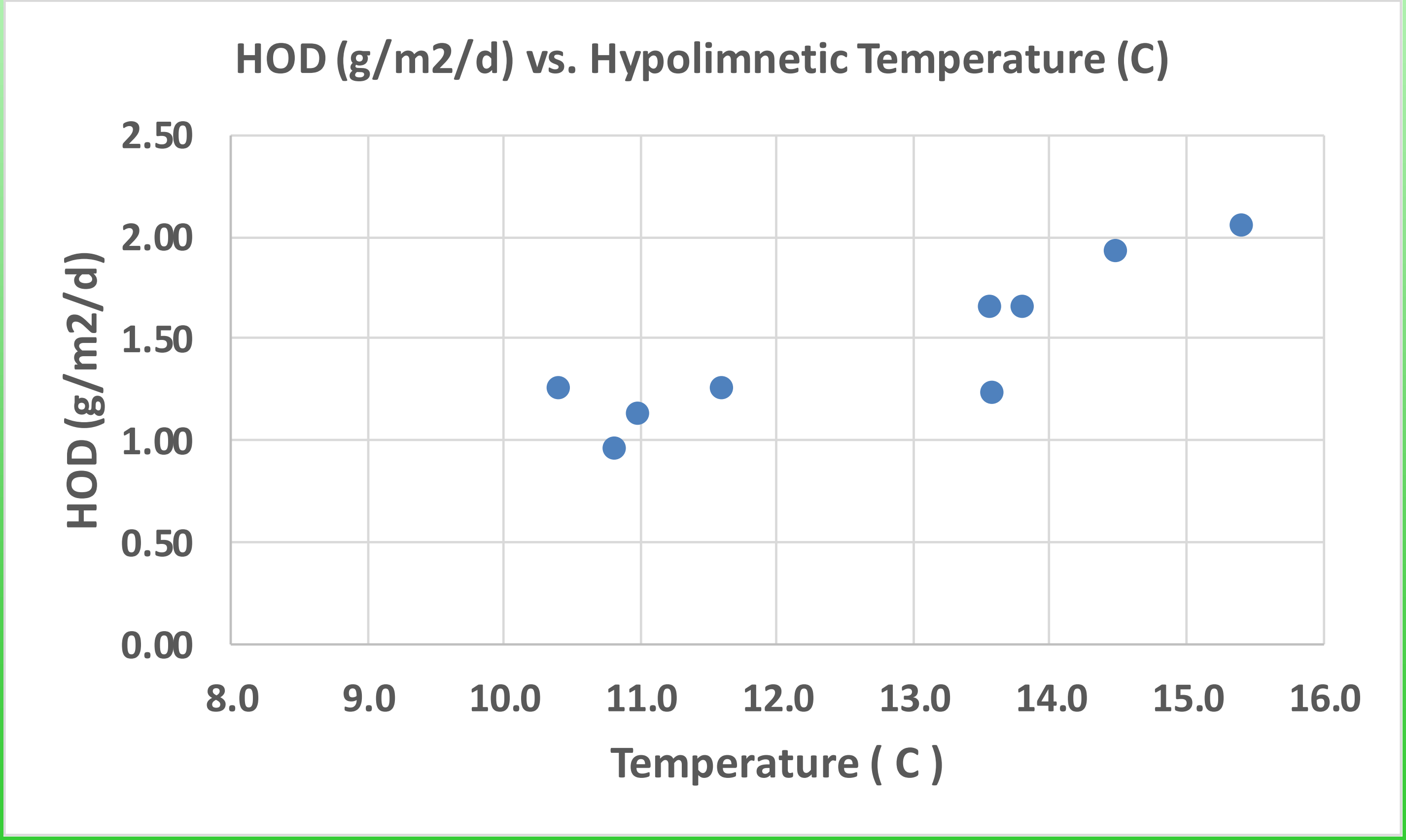


Why cyanobacteria are more linked to internal loading than other algae

- Other algae can utilize the same approach (e.g., filamentous green algae in shallower areas of many lakes, golden algae in metalimnion), just not as well overall
- Many cyanobacteria are adapted to low light, can grow deeper
- Many cyanobacteria have a buoyancy mechanism to allow movement into the upper water
- Internal nutrient release under anoxia has a low N:P ratio and higher Fe^{+2} content that favors cyanobacteria that can fix N_2 gas

Temperature, oxygen demand, internal load

- **Increased temperature leads to increased metabolism, faster decay, more oxygen demand**
- **Low oxygen can lead to greater P release from sediment**
- **Small changes in temperature could have big consequences**



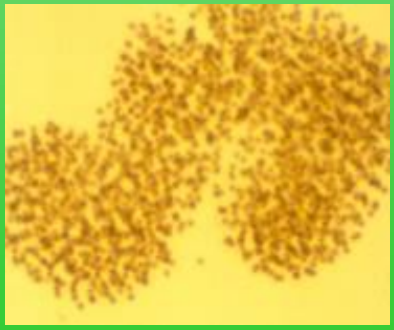
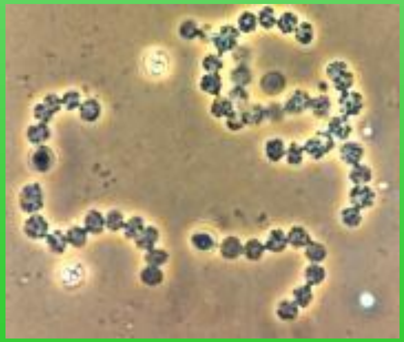
Cyanobacteria bloom trends

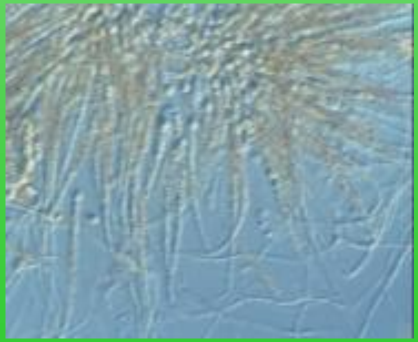
Cyano blooms are increasing:

- Phosphorus rising; decreased N:P ratios favor cyanos
- Temperatures rising; more oxygen demand, more internal loading, plus warmer water favors cyanos

Bottom growth/quick rise blooms seem to be increasing in particular:

- Long-term accumulation of nutrients in sediment fosters such growths; loss of oxygen over larger areas is a big influence
- Light and low oxygen in sediment are key triggers; intermediate depth zone implicated as biggest contributor



Some relevant references

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Questions and Comments