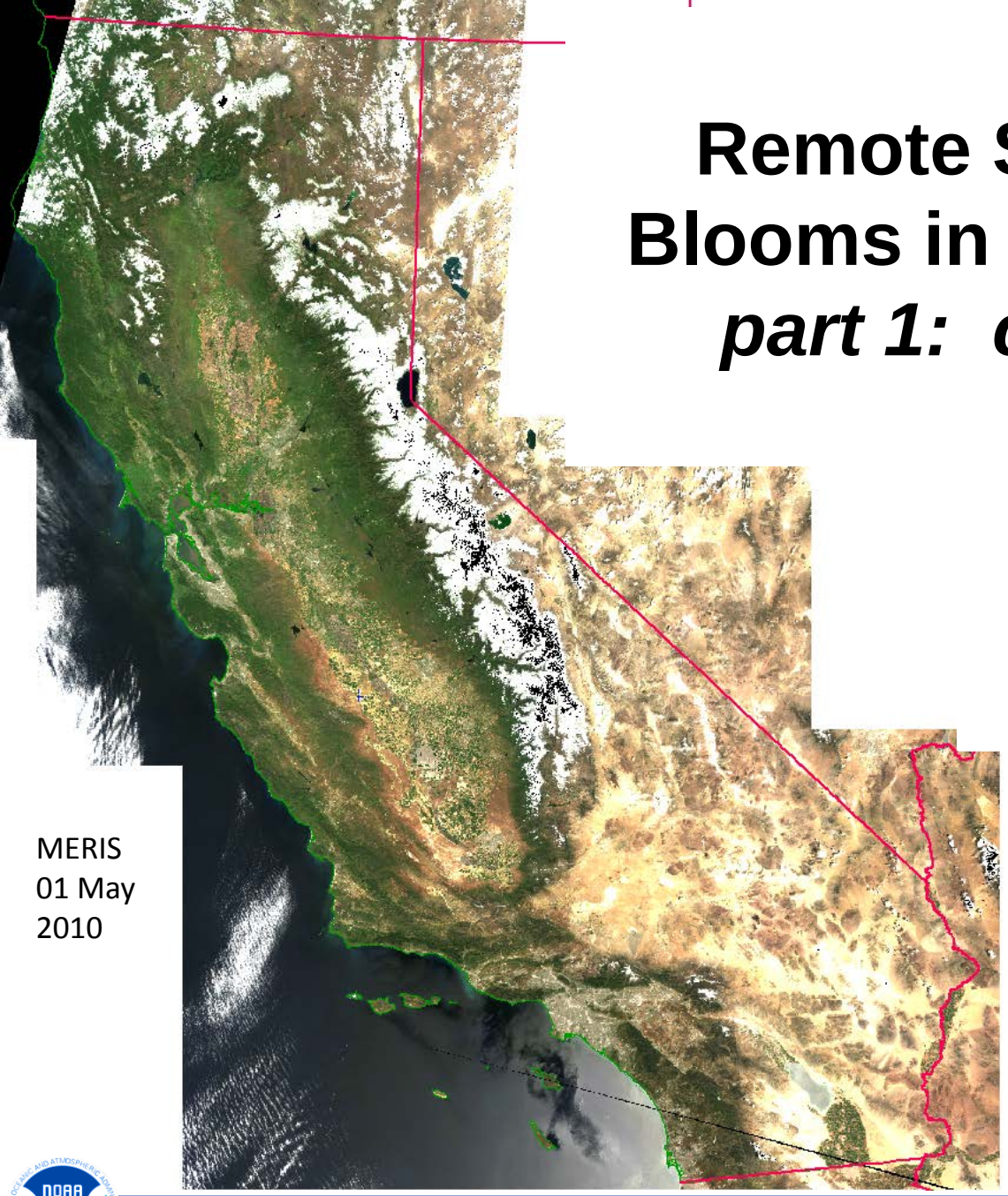


MERIS
01 May
2010

Remote Sensing for Algal Blooms in California Lakes
part 1: cyanobacteria

Rick Stumpf
Andrew Meredith
Shelly Tomlinson

NOAA
National Centers for
Coastal Ocean Science

Algal Concerns

- Toxins
- Taste & Odors
- Filter clogging
- DBP precursors
- pH changes
- Oxygen deficiencies
- Light limiting
- Decreased recreational use
- Decreased property values
- Economy

Risks to pets and animals

http://www.oda.state.ok.us/ais/bluegreenalgae.pdf

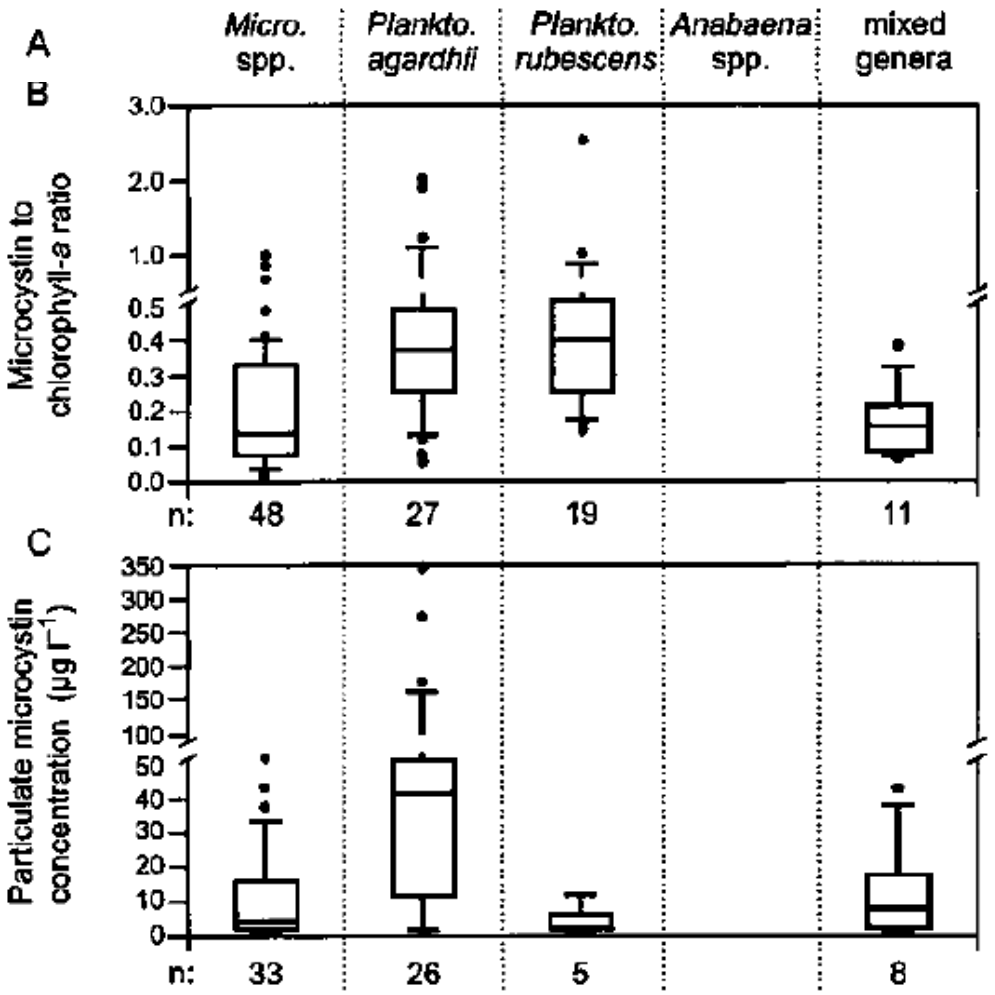
Dog deaths in Humboldt County.

Evidence for a Novel Marine Harmful Algal Bloom: Cyanotoxin (Microcystin) Transfer from Land to Sea Otters.

Miller et al., PLoSONE.

World Health Organization Alert levels

- Relatively low 2-4 µg/L microcystin
  20,000 cells/mL (10 µg/L chl-a)
- Moderate 20 µg/L microcystin,
  100,000 cells/mL (50 µg/L chl-a)
- High extremely high
  scum formation



Amount of microcystin (and microcystin to chl-a biomas for different species

Major Groups of Algae

Common Name	Phylum
Green Algae	Chlorophyta
Diatoms	Bacillariophyta
Blue-Green “Algae” (cyanobacteria)	Cyanophyta
Golden (Chrysophytes)	Chrysophyta
Dinoflagellates	Pyrrhophyta
Euglenoids	Euglenophyta
Cryptomonads	Cryptophyta
Red Algae	Phaeophyta
Brown Algae	Rhodophyta
Stoneworts	Charophyta

Content courtesy of Richard Lorenz
City of Westerville

Cyanobacteria vs Algae

Prokaryotes

- No nucleus
- No internal organelles
- Photosynthesis – plasma membrane
- Photosynthesis process, less chl*a* fluorescence
- Phycobilins present
  - Phycocyanin, phycoerythrin
- Heterocysts, some sp. Fix N

Eukaryotes

- Nucleus
- Internal organelles
- Photosynthesis – chloroplast
- Chl*a* fluorescence
- No Phycobilins
-
- No heterocysts

Harmful Algal Blooms (HAB's)

- Bloom – increase in concentration & mass development of algal & cyanobacterial cells
- Some blooms can rise to surface (cyanos need vacuoles)
- Typical conditions:
  - Warm temperature
  - Sunlight
  - Nutrients – phosphorus
  - Calm lake conditions
- Last day to several months
- Not necessarily single species, typically multiple strains

Algae of Concern

- ***Microcystis***
  - Colony, no heterocysts, gas vac., T&O, toxins
- ***Aphanizomenon***
  - Filament, heterocysts (N-fixer), gas vac., T&O, toxins
- ***Anabaena***
  - Filament, heterocysts, gas vac., T&O, toxins
- ***Planktothrix* (Oscillatoria)**
  - Filament, no heterocysts, gas vac. ?, T&O, toxins
- ***Cylindrospermopsis***
  - Filament, heterocysts, no gas vac.?, no T&O, toxins
- ***Lyngbya***
  - Filament, no heterocysts, no gas vac., no T&O, toxins

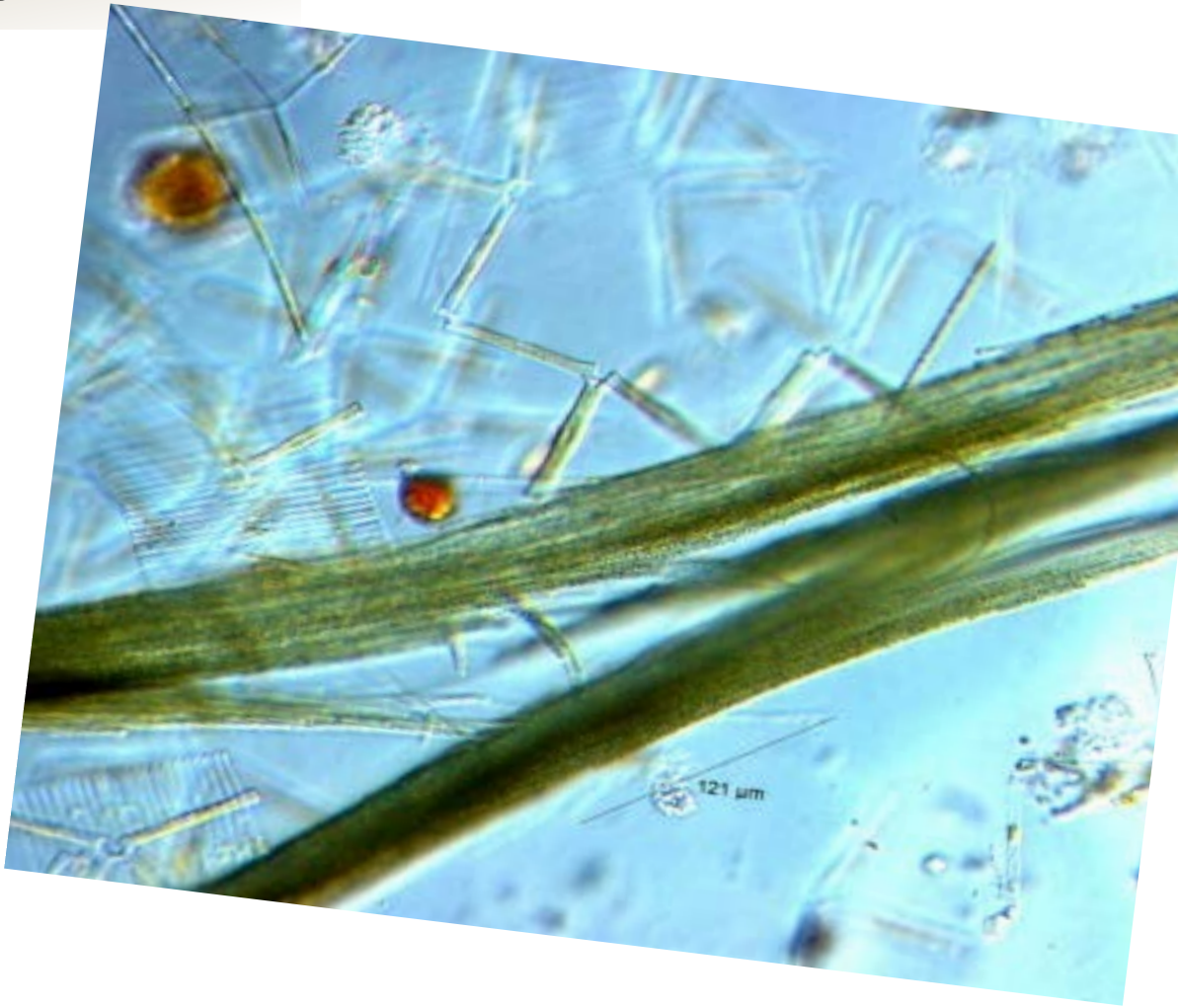
Heterocysts: **nitrogen fixing**; Gas vacuoles: **flotation**

Microcystis

- Colonies spherical or irregular sometimes holes in the colonies, very polymorphic
- Spherical shaped cells often densely irregularly arranged in mucilage, blue-green, grayish to yellow
- Cells contain gas vacuoles
- No heterocysts
- Blooms start as bright blue-green clumps through the water column and develop large surface scums
- 50+ species
- Musty odor several strains can produce Toxin – Microcystins

Aphanizomenon

- Filamentous, planktonic trichomes straight to curved solitary or in parallel bundles without sheaths
- Cells mostly cylindrical, end cells elongated with tapered tips
- Trichomes can include heterocysts (barrel shaped) near middle and akinetes (oval to long) located close to the heterocysts, contains gas vacuoles
- Blooms consist of bright blue-green threads
- 5+ species
- Produces musty odor and Toxins – Anatoxin-a, Cylindrospermopsin, Saxitoxin

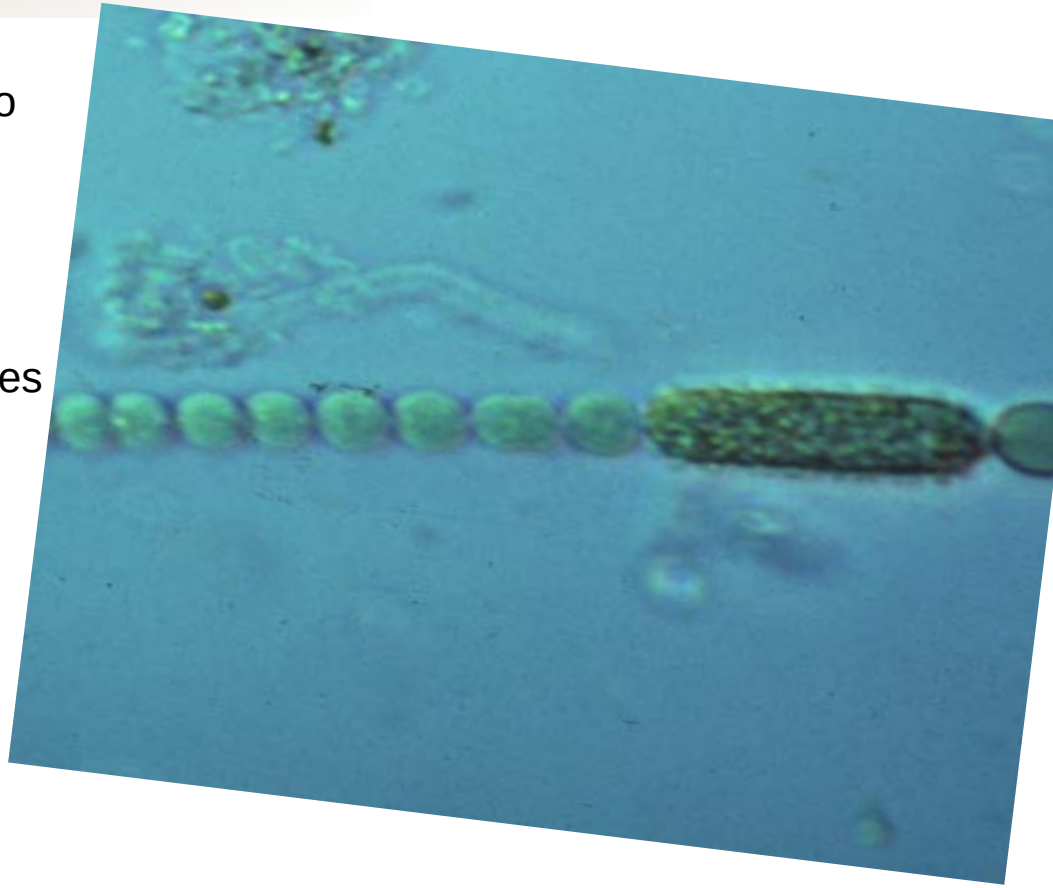


Anabaena

- Filamentous, trichomes straight to coiled, solitary or clumped
- Cells mostly spherical – barrel shaped, often resembling strings of beads
- Trichomes often include heterocysts and akinetes (round) developing close to heterocysts and with gas vacuoles
- Blooms form bright blue-green surface scums
- 100+ species
- Produces musty smell and Toxins – Anatoxin –a, Anatoxin a(s), Microcystin and Saxitoxin

Cylindrospermopsis

- Filamentous, trichomes straight, curved to spiral and solitary.
- Cells cylindrical with end cell attenuated
- Trichomes contains terminal heterocysts (often teardrop shaped) akinetes form adjacent or close to heterocysts sometimes in pairs, gas vacuoles may be present
- Blooms can appear dark green to light yellow-green to reddish-brown generally distribute through upper water column
- No odor associated with blooms
- Produces Toxins - Anatoxin-a, Cylindrospermopsin, Saxitoxin

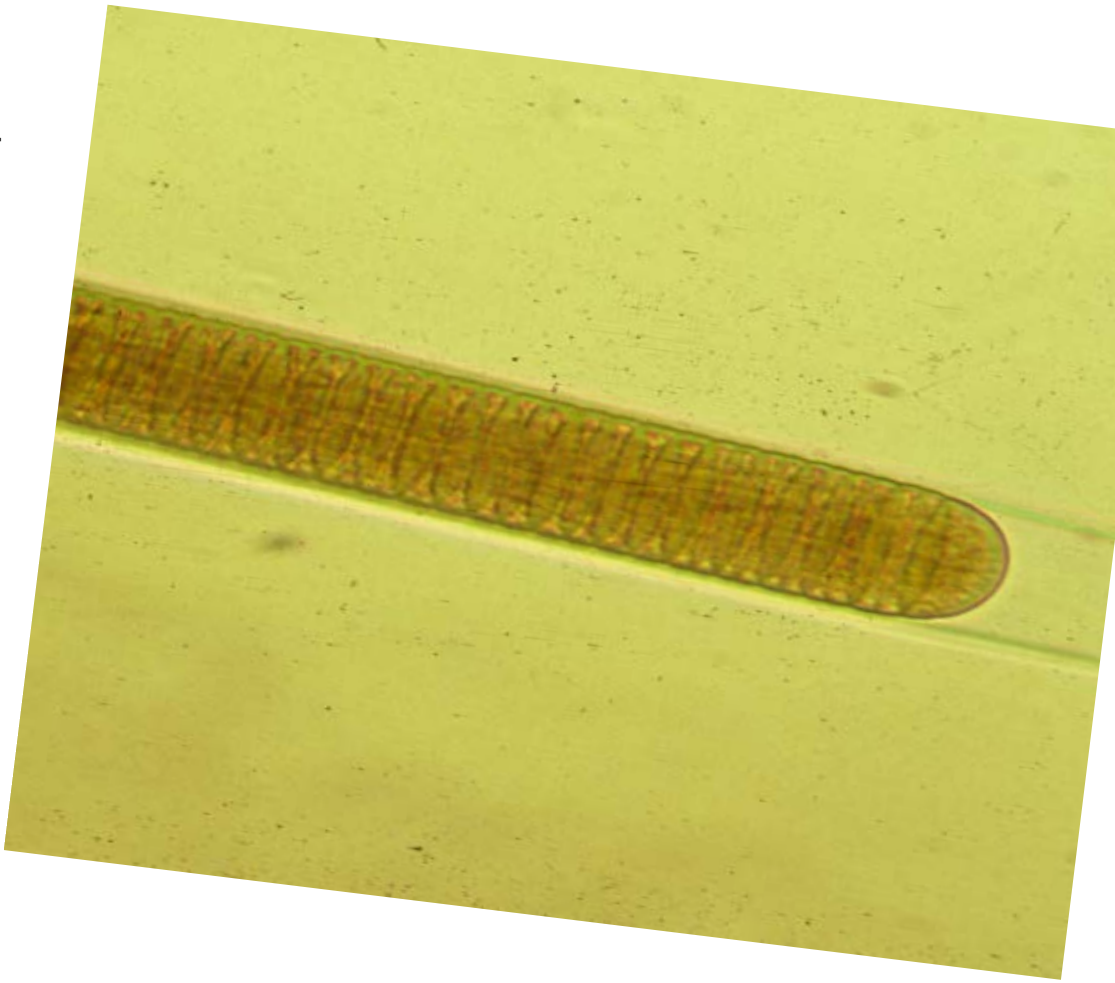


Planktothrix

- Filamentous, trichomes straight or waved, solitary or can form clumps of layered mats
- Cells cylindrical, slightly wider than long, end cells attenuated often rounded, sheaths not present
- Trichomes slightly tapered at the ends sometimes capitate, do not contain heterocysts or akinetes, gas vacuoles throughout the planktonic cells and can be motile by oscillating/gliding
- Blooms can be reddish to purple in color
- 30+ species
- Some species produce geosmin and Toxins – Anatoxin-a, Homoanatoxin-a and Microcystin

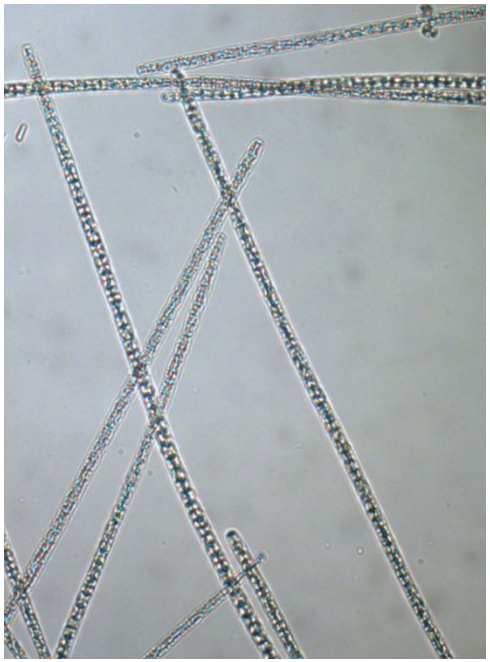
Lyngbya

- Filamentous, many species benthic or associated with other plants forming wooly clumps, planktonic species solitary straight to curved wide trichomes.
- Cells large and wider than long with thick sheaths extending past rounded end cells.
- Trichomes do not contain heterocysts or akinetes, gas vacuoles not present in cells.
- Blooms do not form surface scums, often scattered among other bloom formers.
- No odor associated with blooms
- Produces Toxins – Debromoaplysiatoxin, Lyngbyatoxin-a and Saxitoxin.

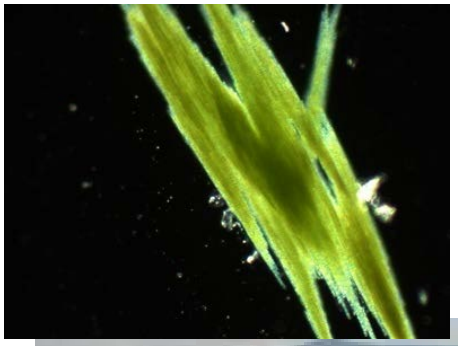


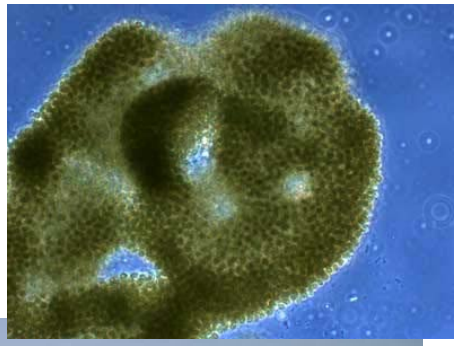
Planktothrix example

- Sandusky Bay, dispersed



Examples from California





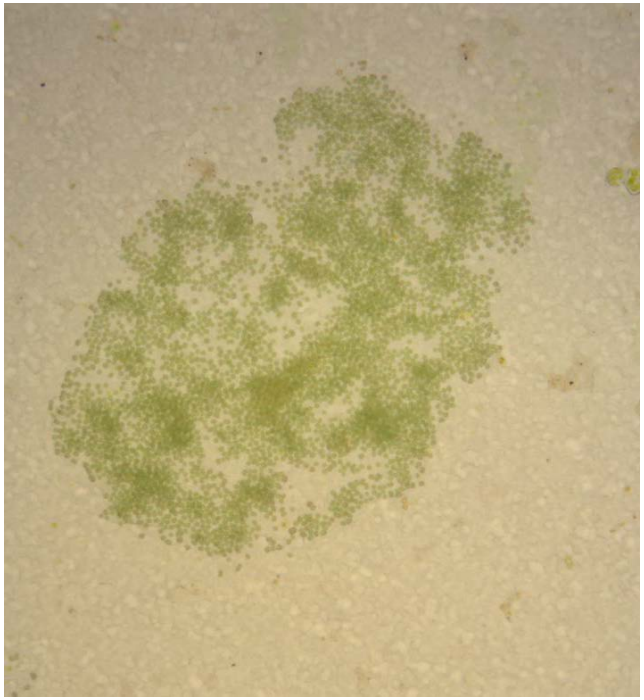
Photos from R. Kudela, UCSC

Aphanizomenon flos-aquae

Microcystis spp.

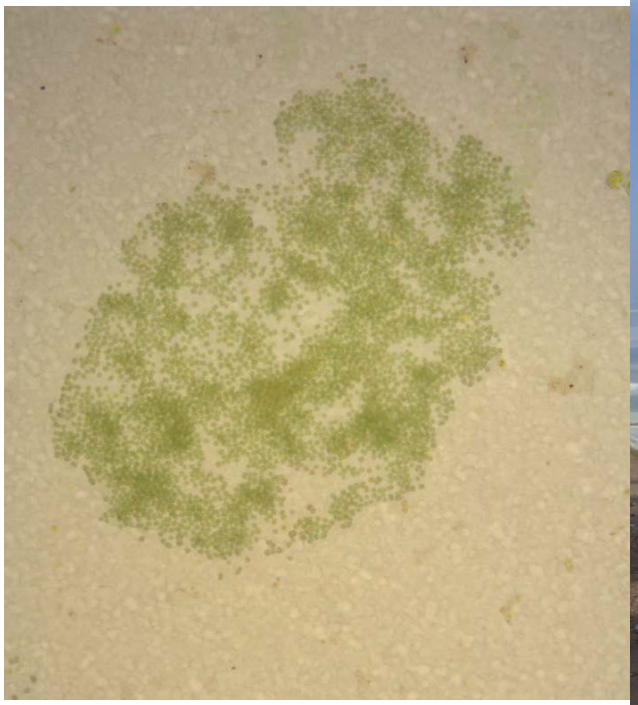
Microcystis example

- Aug 2010, Lake Erie



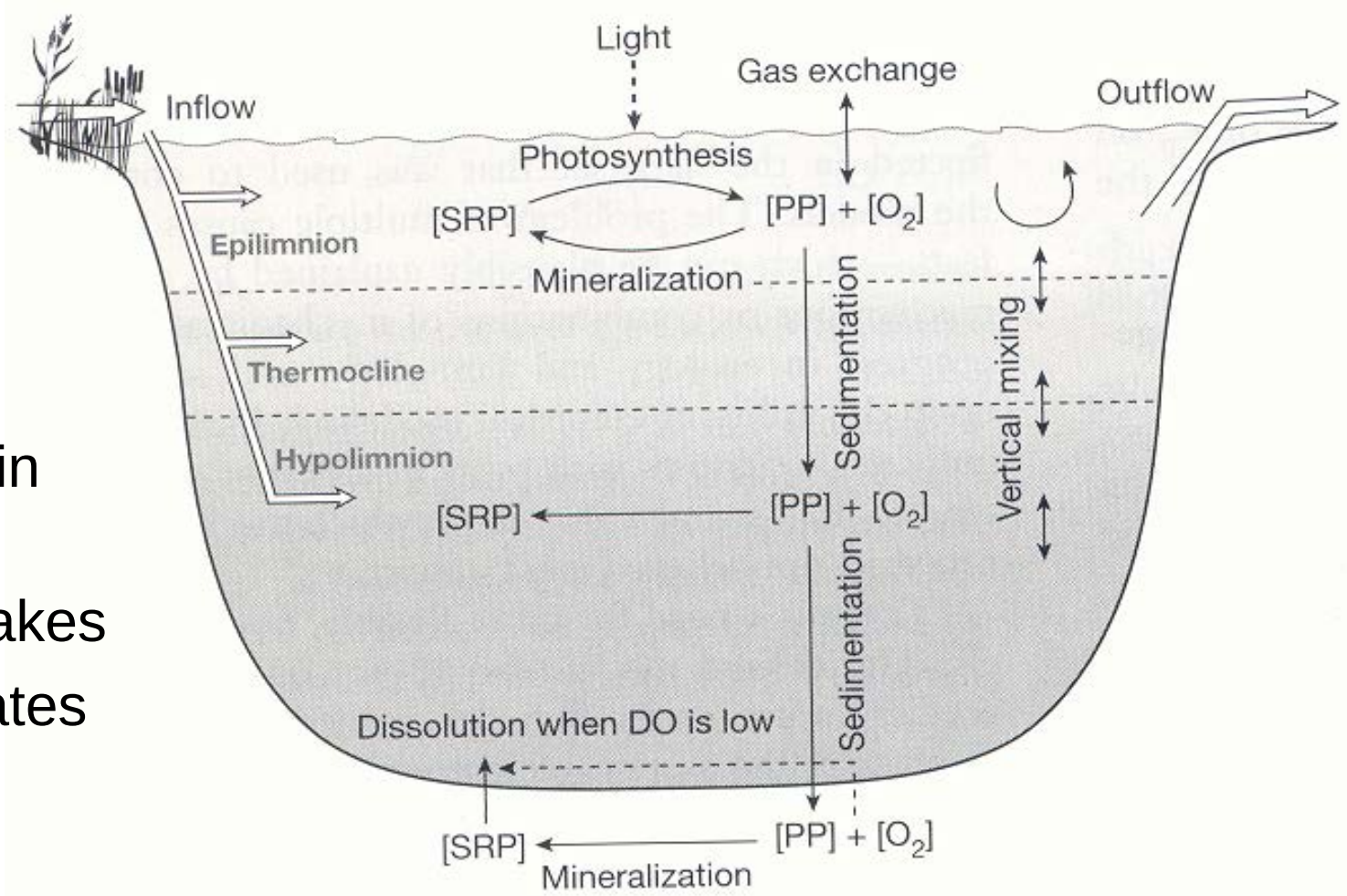
Microcystis scum example

- Aug 2009, Lake Erie

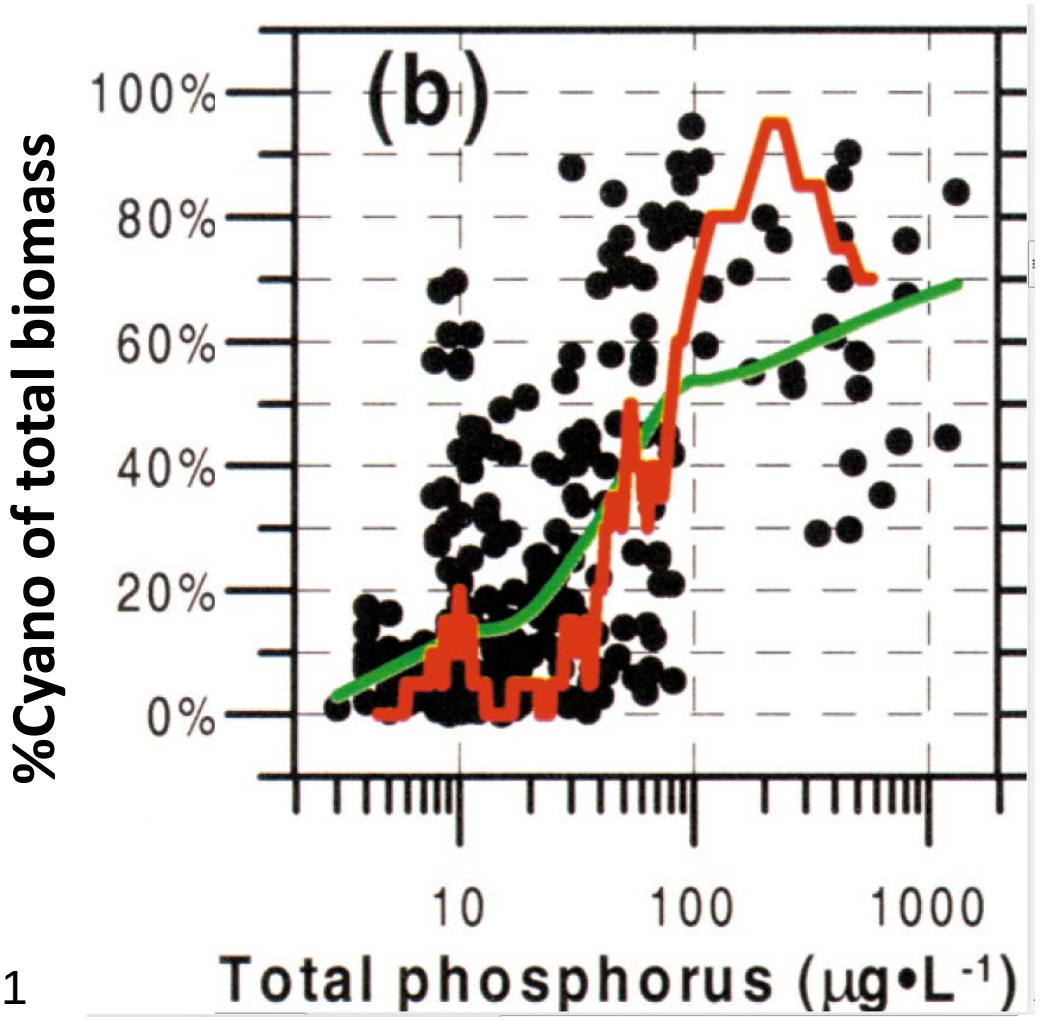


Lake Chemistry - Phosphorus

- P limits biological production in lakes
- P cycle in lakes
- P accumulates in the sediments

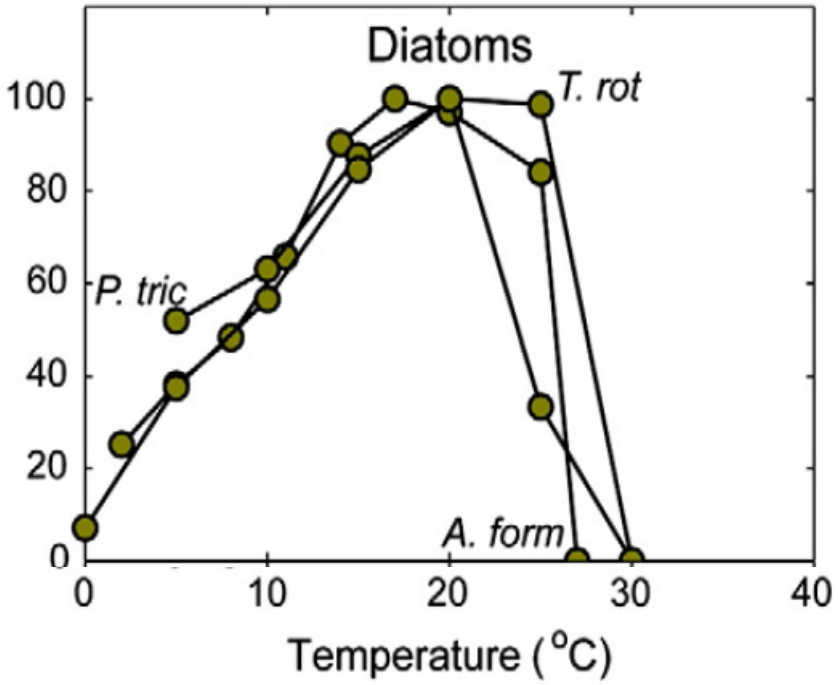


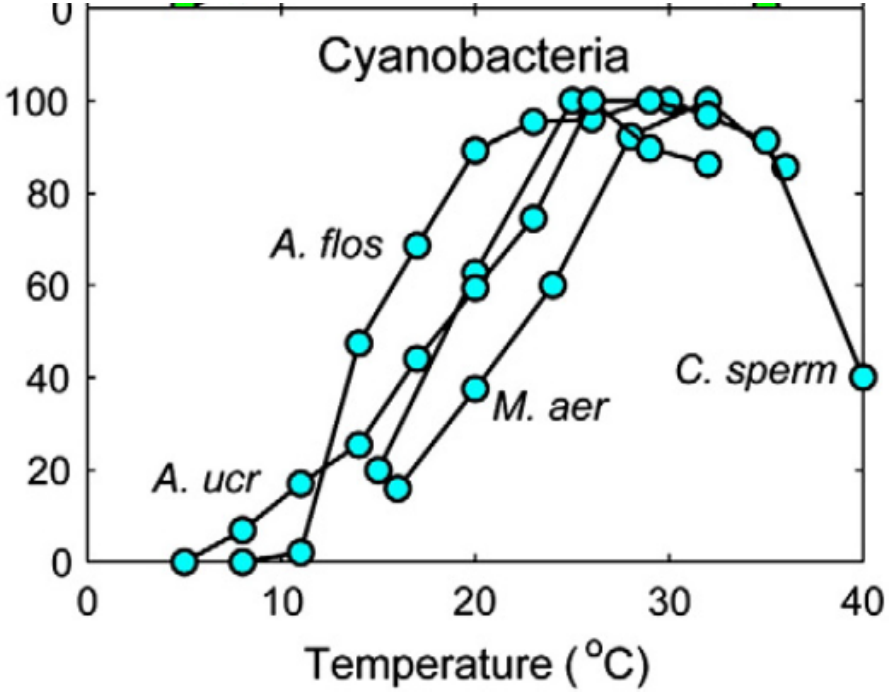
Nutrients, especially phosphorus



Downing et al. 2001

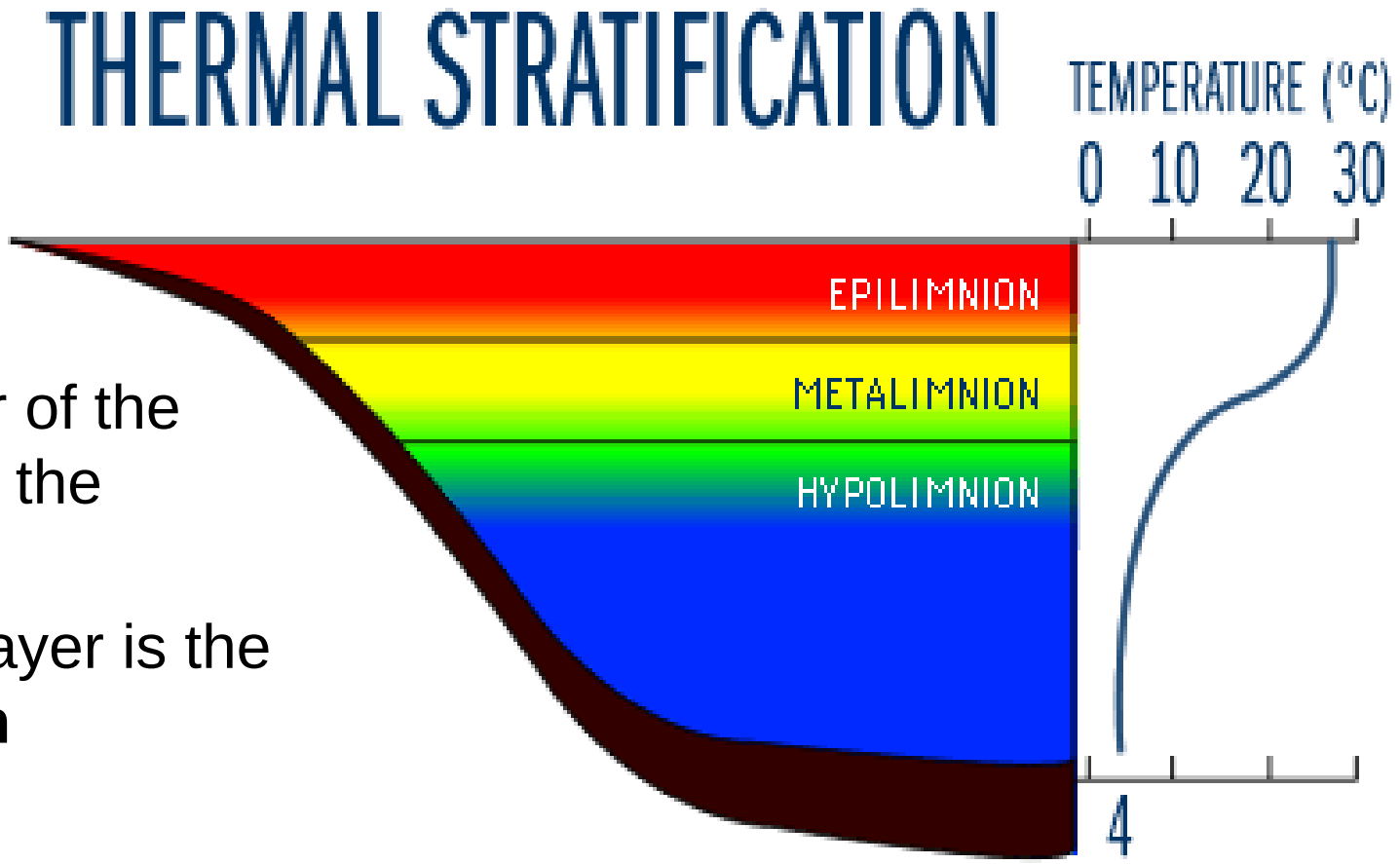
Cyanobacteria like warm water; strong growth > 20ºC; minimal growth < 15ºC





- Paerl et al., 2011 (Science of the Total Environment)

Lake Layers During Stratification



The upper layer of the lake is called the **epilimnion**

And the lower layer is the **hypolimnion**

Verh. Internat. Verein. Limnol.	19	784 – 791	Stuttgart, Oktober 1975

The studies reported here present the biological and physical aspects of blue-green algal movements in relation to prevailing winds over a summer in Clear Lake (39 °N, 123 °W).

The use of remote sensing to detect how wind influences planktonic blue-green algal distribution

A. J. Horne and R. C. Wrigley

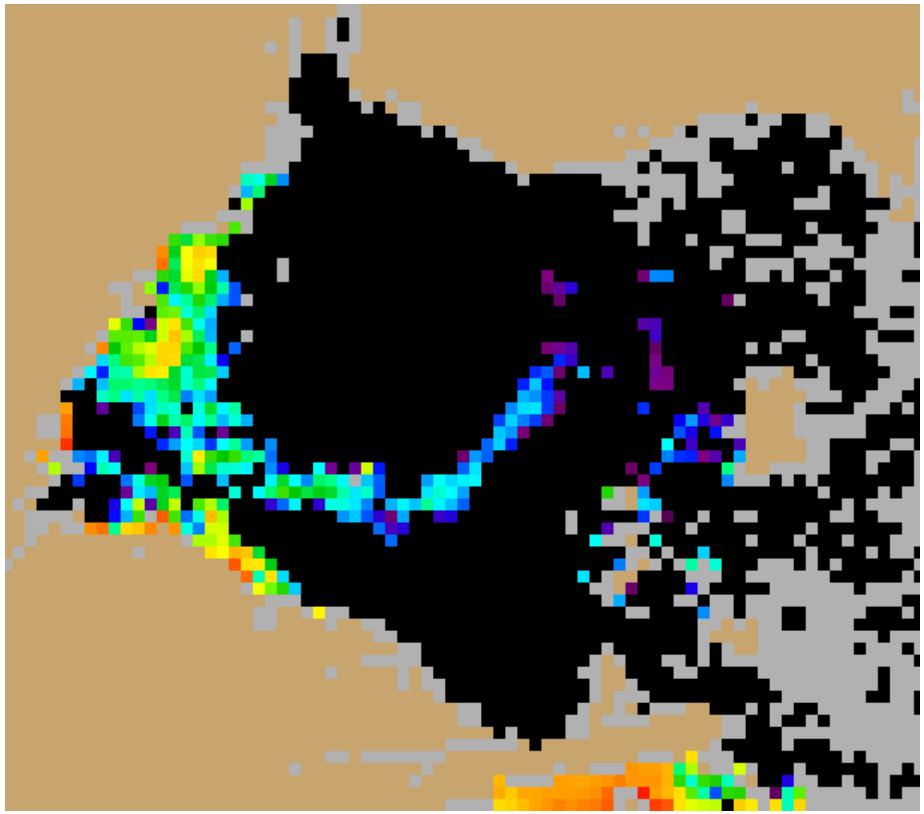
With 4 figures in the text

- Wind matters for buoyant blooms (which are common in CA)

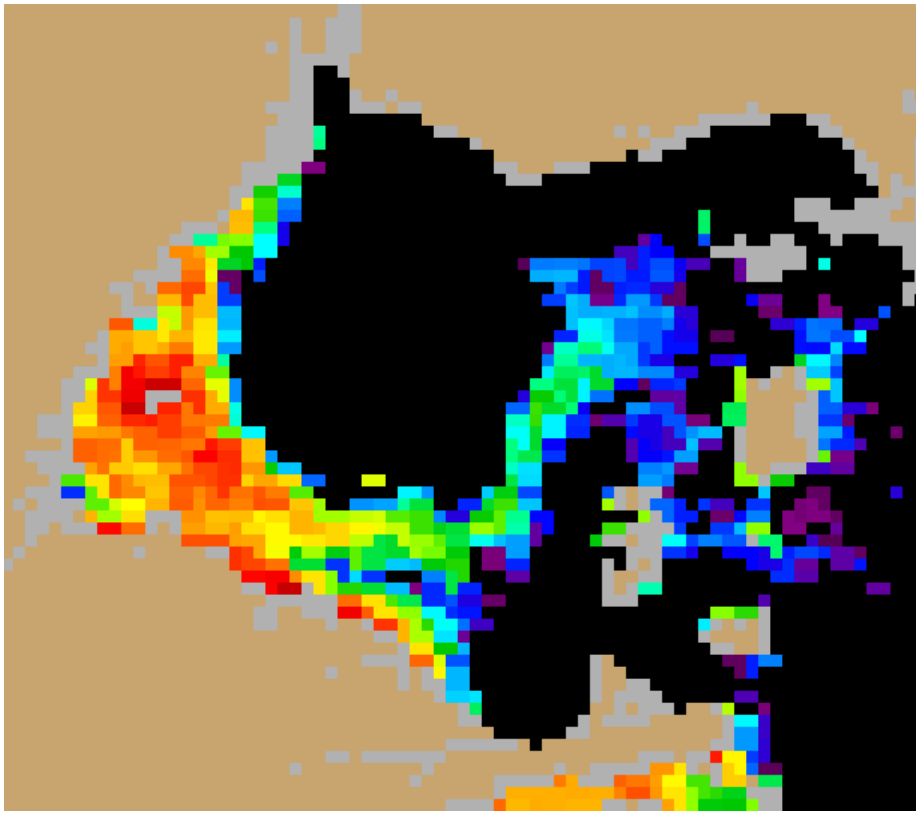
Surface concentration depends on wind

Lake Erie data

Sep 22 10-20 knot winds



Sep 23 calm, 2-8 knot winds



Where Are We With Satellite

- We can find algal blooms
- Cyano blooms are detectable,
  but usable method currently produces many false positives
    - We are examining strategies to reduce these
    - We bias against false negatives
- All sensors can find scum
- Most sensors have limitations
  – Resolution trade-offs: spatial, spectral, temporal
- We are also examining portable radiometers for small lakes