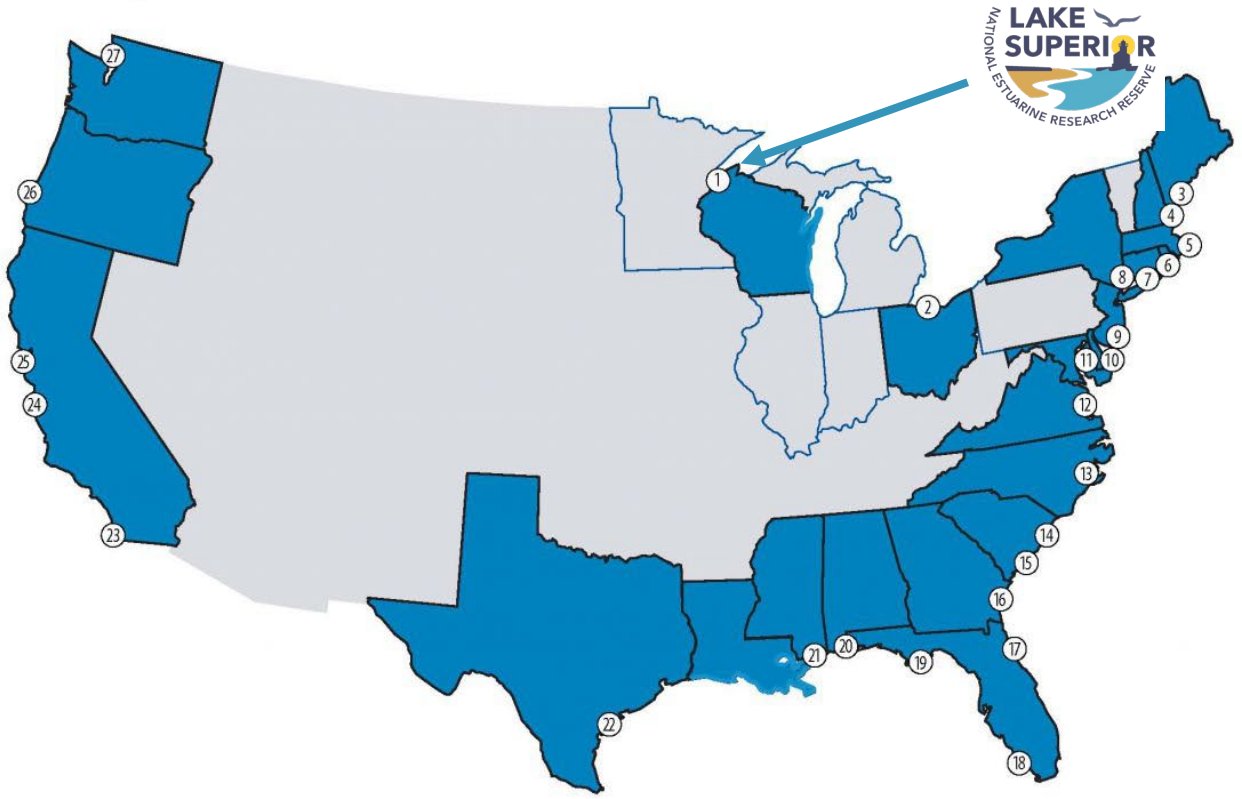
Blooms in unexpected places

Dr. Kait Reinl, Research Coordinator

Lake Superior National Estuarine Research Reserve

Cold-water bloom on November 1, 2018 on West Campus Pond, Lawrence KS. Photo Credit: Ted Harris, Kansas Biological Survey.

NATIONAL ESTUARINE RESEARCH RESERVES



Great Lakes
1. Lake Superior, Wisconsin
2. Old Woman Creek, Ohio

Northeast
3. Wells, Maine
4. Great Bay, New Hampshire
5. Waquoit Bay, Massachusetts
6. Narragansett Bay, Rhode Island
7. Connecticut

Mid-Atlantic
8. Hudson River, New York
9. Jacques Cousteau, New Jersey
10. Delaware
11. Chesapeake Bay, Maryland
12. Chesapeake Bay, Virginia

Southeast
13. North Carolina
14. North Inlet-Winyah Bay, South Carolina
15. ACE Basin, South Carolina
16. Sapelo Island, Georgia
17. Guana Tolomato Matanzas, Florida

Gulf of Mexico
18. Rookery Bay, Florida
19. Apalachicola, Florida
20. Weeks Bay, Alabama
21. Grand Bay, Mississippi
22. Mission-Aransas, Texas

West
23. Tijuana River, California
24. Elkhorn Slough, California
25. San Francisco Bay, California
26. South Slough, Oregon
27. Padilla Bay, Washington
28. Kachemak Bay, Alaska

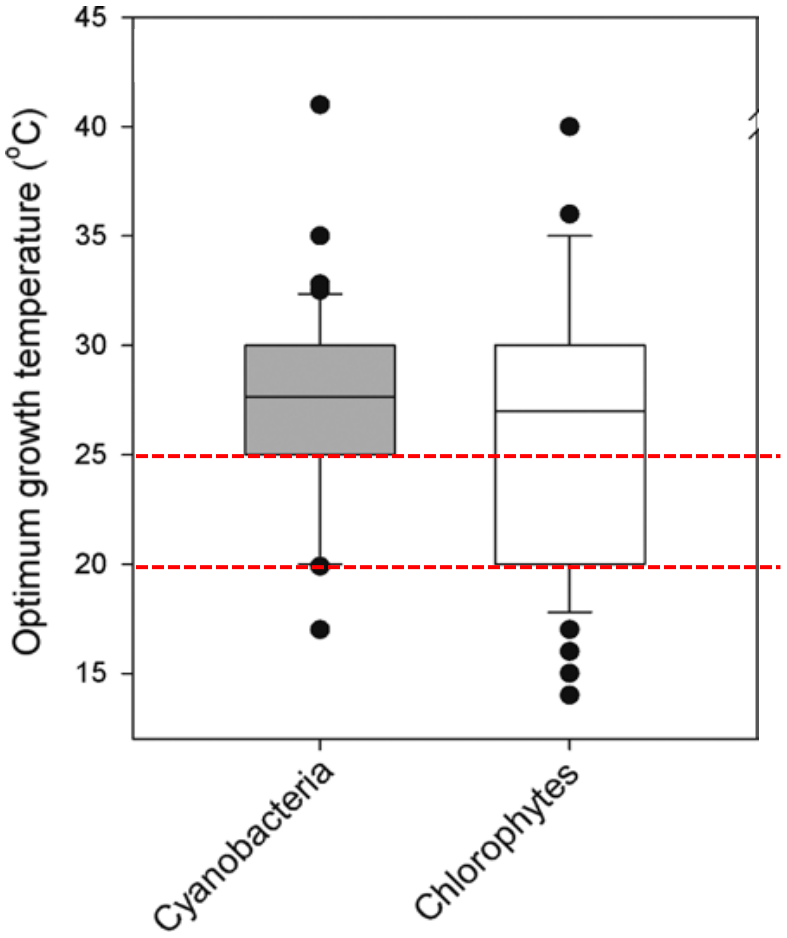
Pacific
29. He'eia, Hawai'i

Caribbean
30. Jobos Bay, Puerto Rico

PROPOSED
Bay of Green Bay, Wisconsin
Louisiana

Research Education Outreach Stewardship

The Current Paradigm

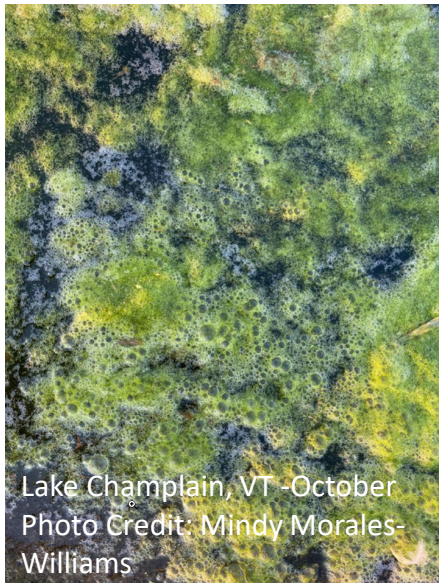


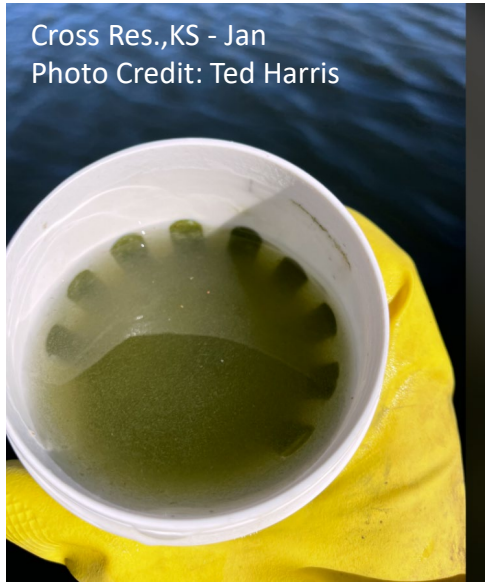
Lürling et al. (2013)

A boat pushes its way through a pea soup-like toxic algae outbreak on Lake Erie in late summer 2011. The bloom was the largest in the lake's history and spanned nearly 2,000 square miles.
Photo Credit: Peter Essick

2018 Cyanobacterial Bloom in Lake Superior near the Apostle Islands, Photo Credit: Brenda Lafrancois, National Park Service

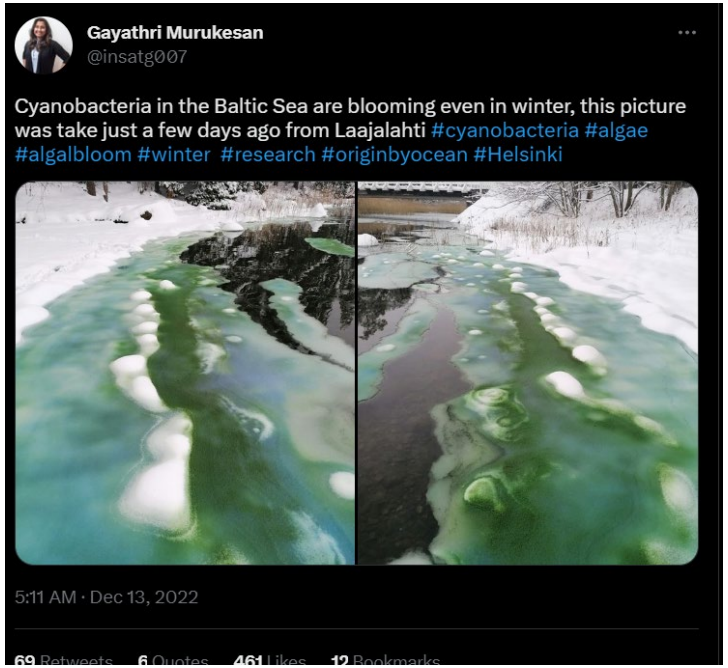

Lake Champlain, VT - February
Photo Credit: Mindy Morales-Williams


Lake Champlain, VT -October
Photo Credit: Mindy Morales-Williams


Cross Res.,KS - Jan
Photo Credit: Ted Harris


Cross Res., KS -Jan
Photo Credit: Ted Harris


Lake Champlain, VT - October
Photo Credit: Mindy Morales-Williams



LIMNOLOGY AND OCEANOGRAPHY LETTERS
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Blooms also like it cold

Kaitlin L. Reinl, Ted D. Harris, Rebecca L. North, Pablo Almela, Stella A. Berger, Mina Bizic, Sarah H. Burnet, Hans-Peter Grossart, Bastiaan W Ibelings, Ellinor Jakobsson, Lesley B. Knoll, Brenda M. Lafrancois, Yvonne McElarney, Ana M. Morales-Williams, Ulrike Obertegger, Igor Ogashawara, Ma Cristina Paule-Mercado, Benjamin L. Peierls, James A. Rusak, Siddhartha Sarkar, Sapna Sharma, Jessica V. Trout-Haney, Pablo Urrutia-Cordero, Jason J. Venkiteswaran, Danielle J. Wain, Katelynn Warner, Gesa A. Weyhenmeyer, Kiyoko Yokota

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Freshwater Biology

OPINION | Open Access

Cyanobacterial blooms in oligotrophic lakes: Shifting the high-nutrient paradigm

Kaitlin L. Reinl, Justin D. Brookes, Cayelan C. Carey, Ted D. Harris, Bas W. Ibelings, Ana M. Morales-Williams, Lisette N. De Senerpont Domis, Karen S. Atkins, Peter D. F. Isles, Jorrit P. Mesman, Rebecca L. North, Lars G. Rudstam, Julio A. A. Stelzer, Jason J. Venkiteswaran, Kiyoko Yokota, Qing Zhan

Bloom Definition

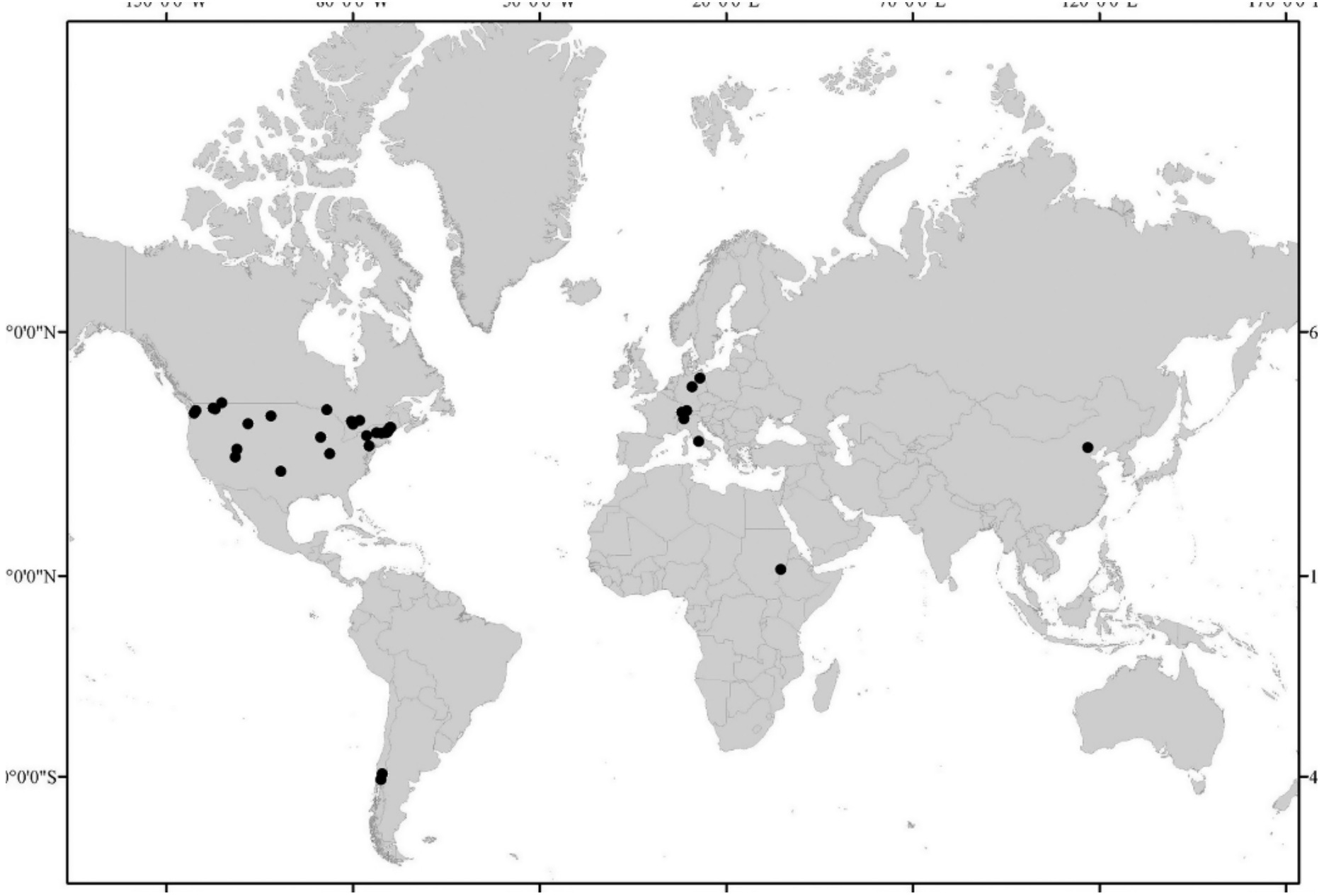
An **accumulation of phytoplankton biomass** in the water column or littoral regions, which may lead to **strong discoloration of the water**, the occurrence of **aggregations (scums)** on the surface or edge of the lake, or **chlorophyll maxima in the metalimnion** (Giling et al. 2017; Leach et al. 2018; Reinl et al. 2020, 2021).

Cold-water bloom on November 1, 2018 on West Campus Pond, Lawrence KS. Photo Credit: Ted Harris, Kansas Biological Survey.

Cold-water Cyanobacterial Bloom Definition

We define a "**cold-water cyanobacterial bloom**" as a cyanobacterial bloom that is observed when the **water temperature is <15 °C**, well below typical growth optima for cyanobacteria (>25 °C, Paerl and Huisman 2008; Lürling et al. 2013).

A December 1st algae bloom in the chilly waters of Devils Lake, WI. Photo: Richard Lathrop.

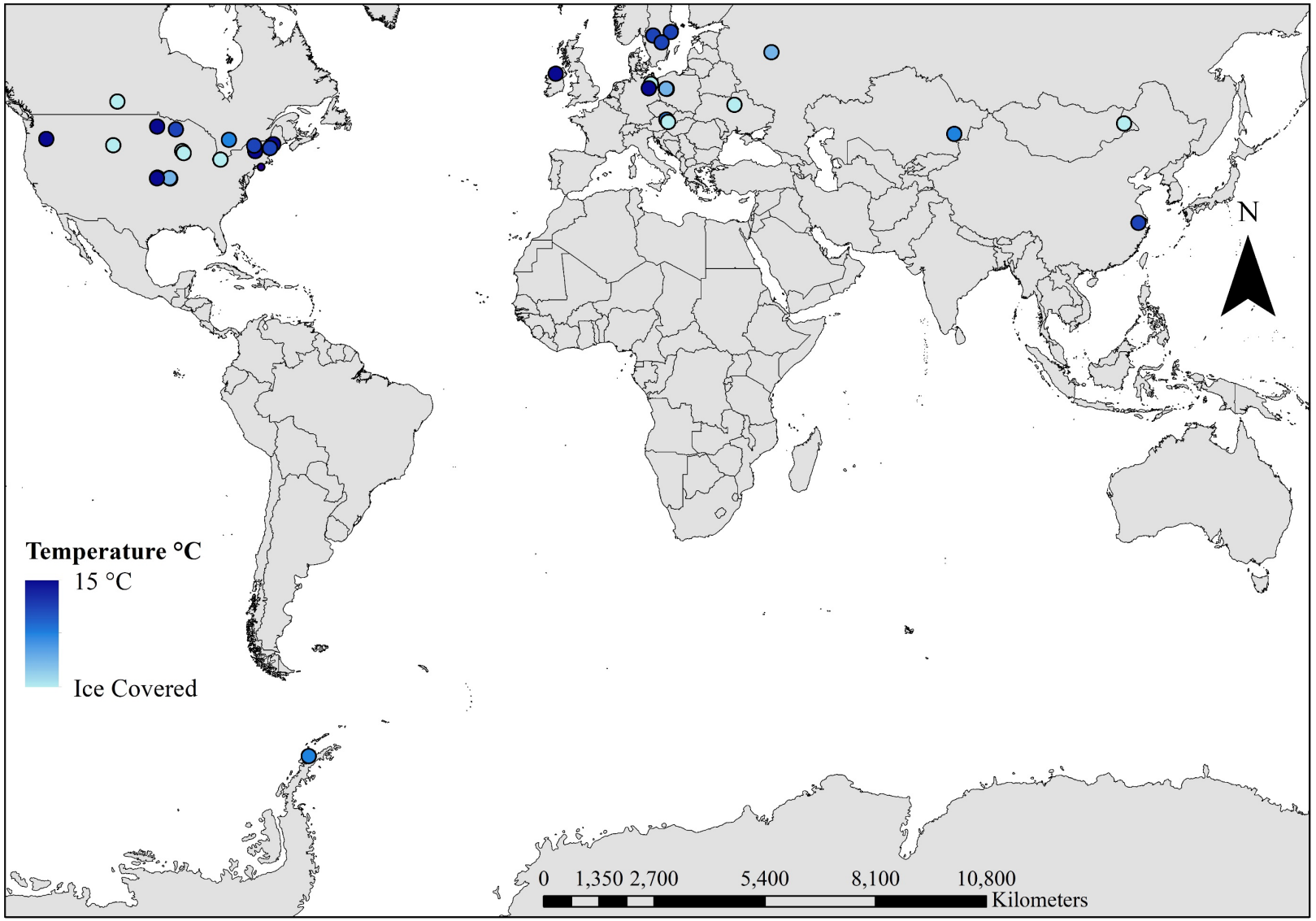


Oligotrophic Blooms

46 Blooms identified from various outlets

~12 genera of cyanobacteria from the orders
Chroococcales
Nostocales
Oscillatoriales
Synechococcales

Carlson's Trophic State Indices (TSI) for oligotrophic trophic state classification: total phosphorus (TP) ≤12 µgL-1, chlorophyll a (chl-a) ≤ 2.6 µg L-1, or Secchi depth >4 m

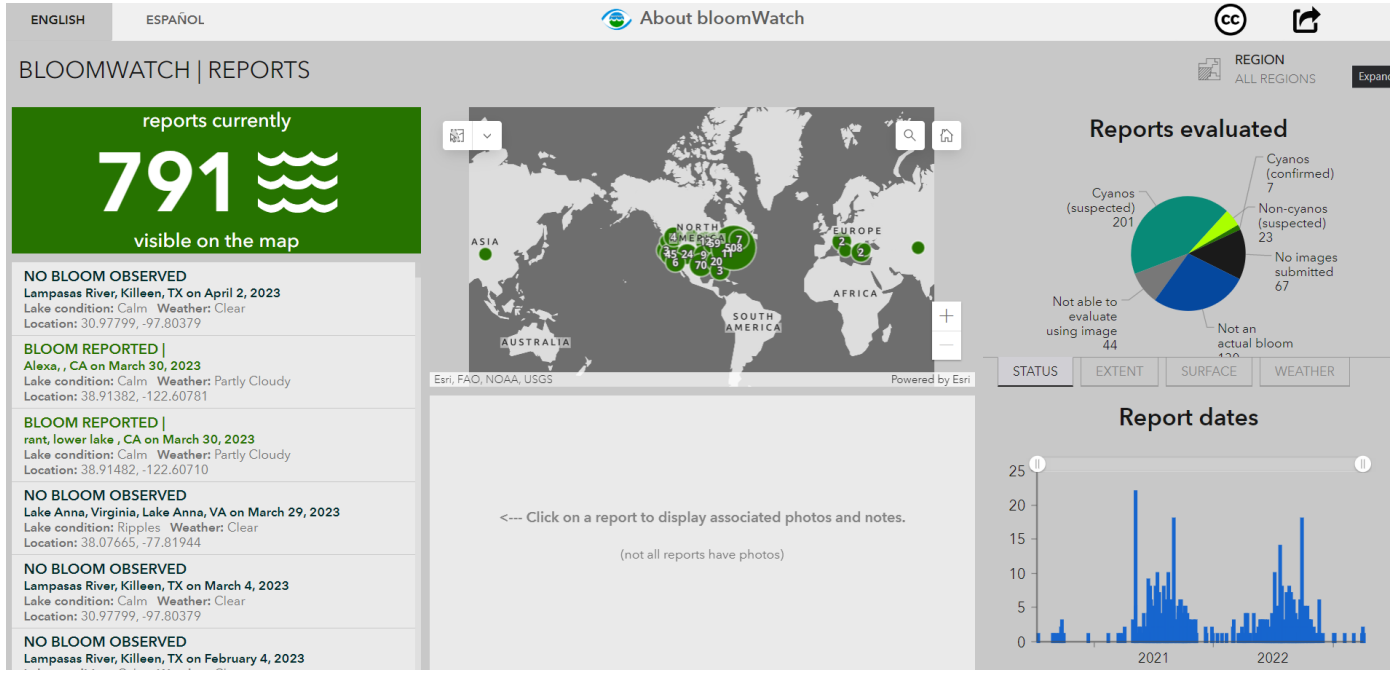


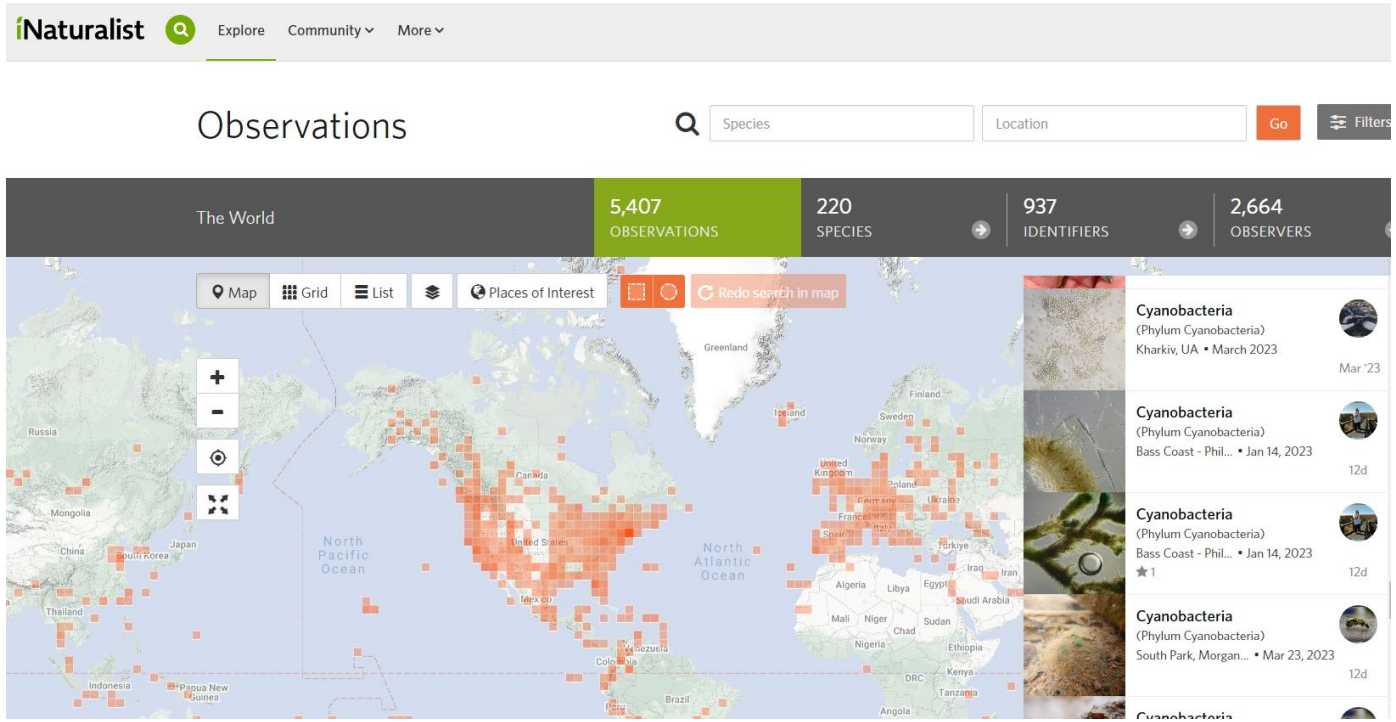
Cold-water blooms

37 cold-water cyanobacterial blooms

Surface water conditions at the time of observation ranged from ice-covered to 15 °C

19 blooms occurring during ice-covered conditions





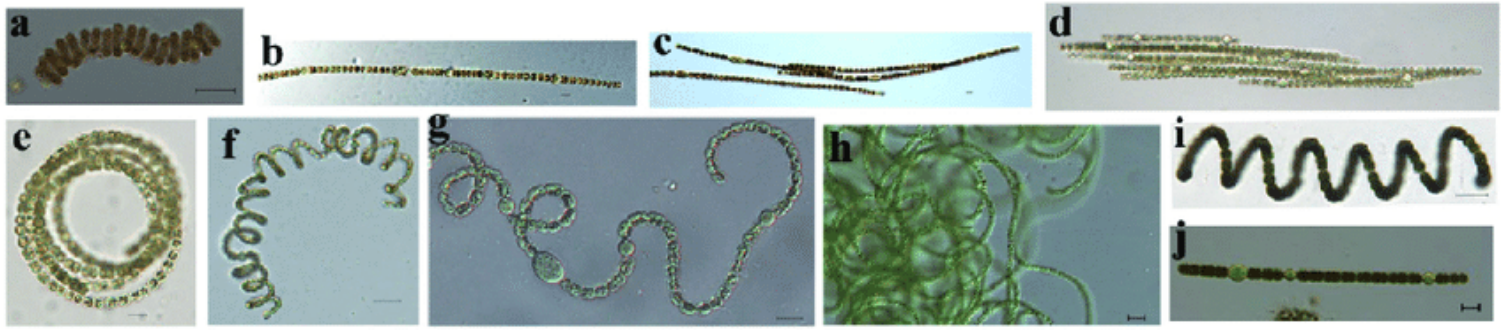
Searched US Sates for reports in November through April above the 40°N latitude line

Average air temperature during this period is typically below 15 °C

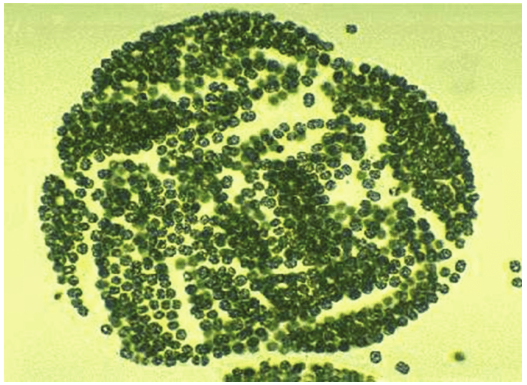
Bloomwatch: 3 reports

Cyanoscope: 50 reports

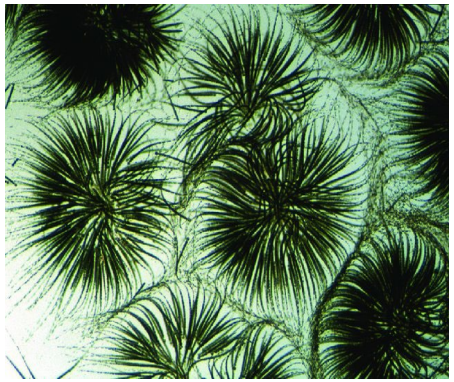
Cyanobacteria Species



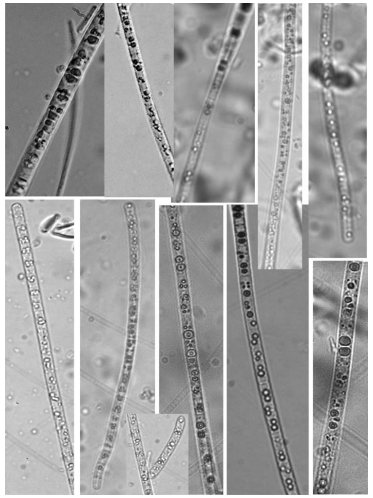
Dolichospermum spp. Li et al. (2016)



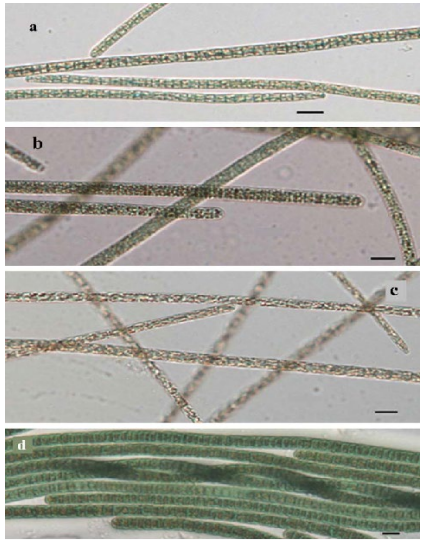
Microcystis spp.
Backer and McGillicuddy (2015)



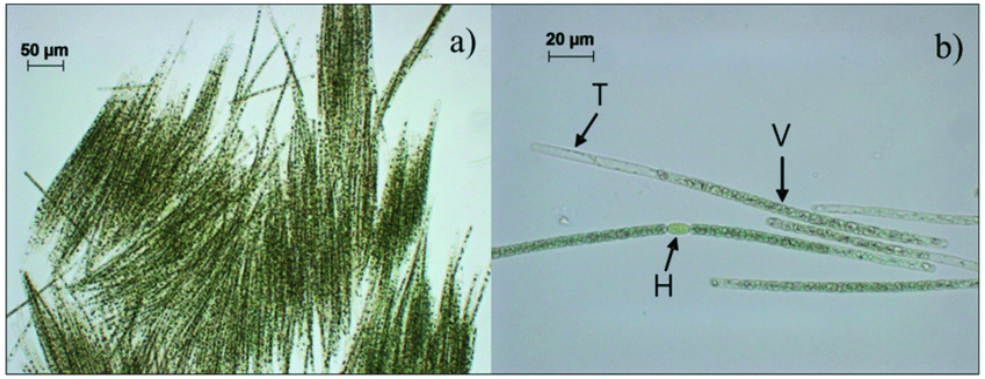
Gleotrichia spp.
Whitton and Mateo (2012)



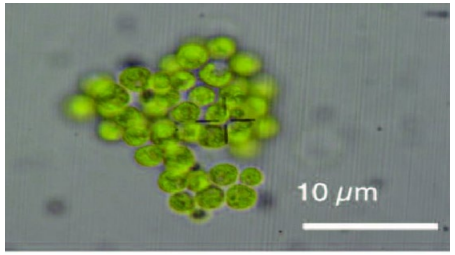
Limnothrix spp.
Matula et al. (2007)



Planktothrix spp.
Lin et al. (2010)



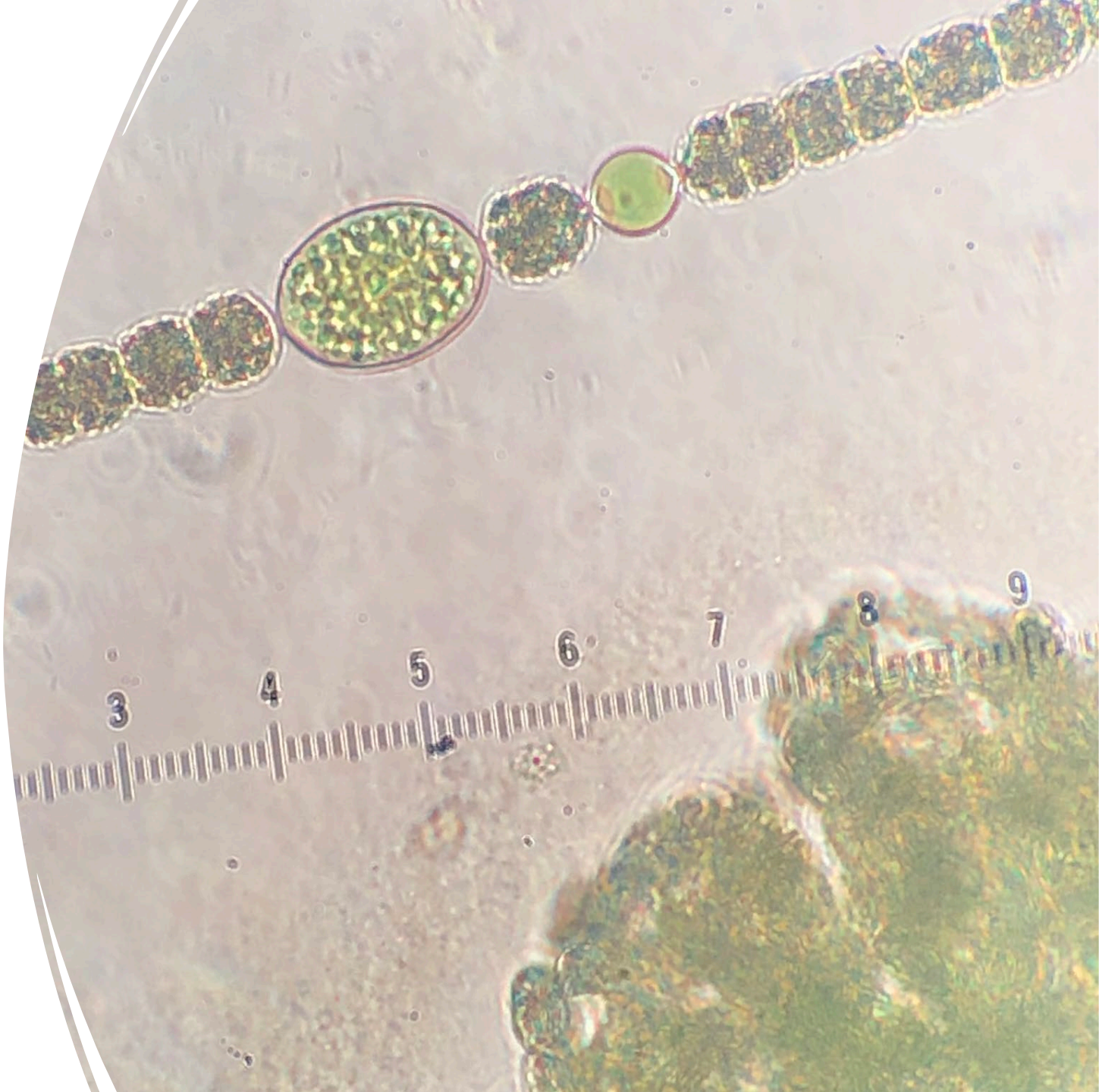
Aphanizomenon spp. Park et al. (2018)



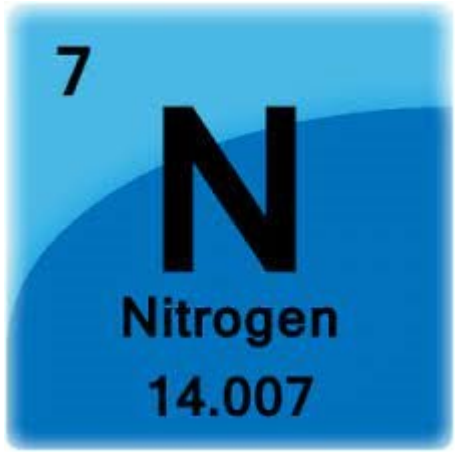
Synechococcus spp.
Ariztegui et al. (2012)

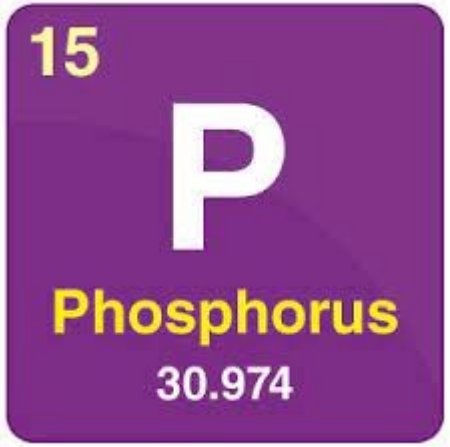
Raphidiopsis raciborskii
Aguilera et al 2018

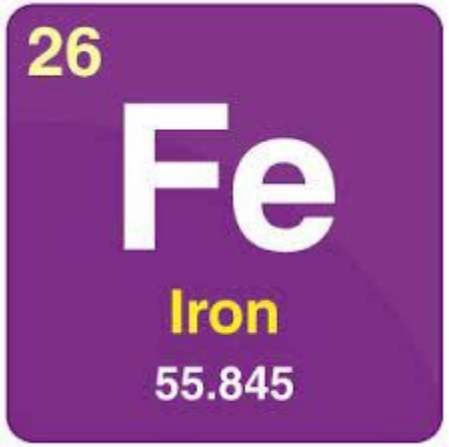
Adaptations

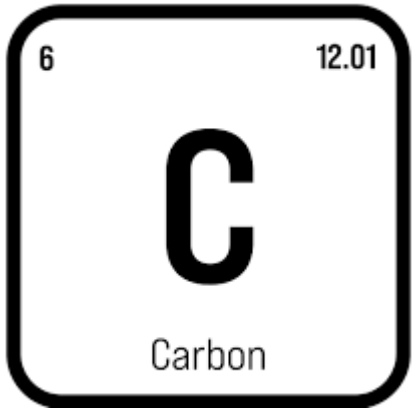


Nutrient Uptake and Storage – (Oligo Blooms)

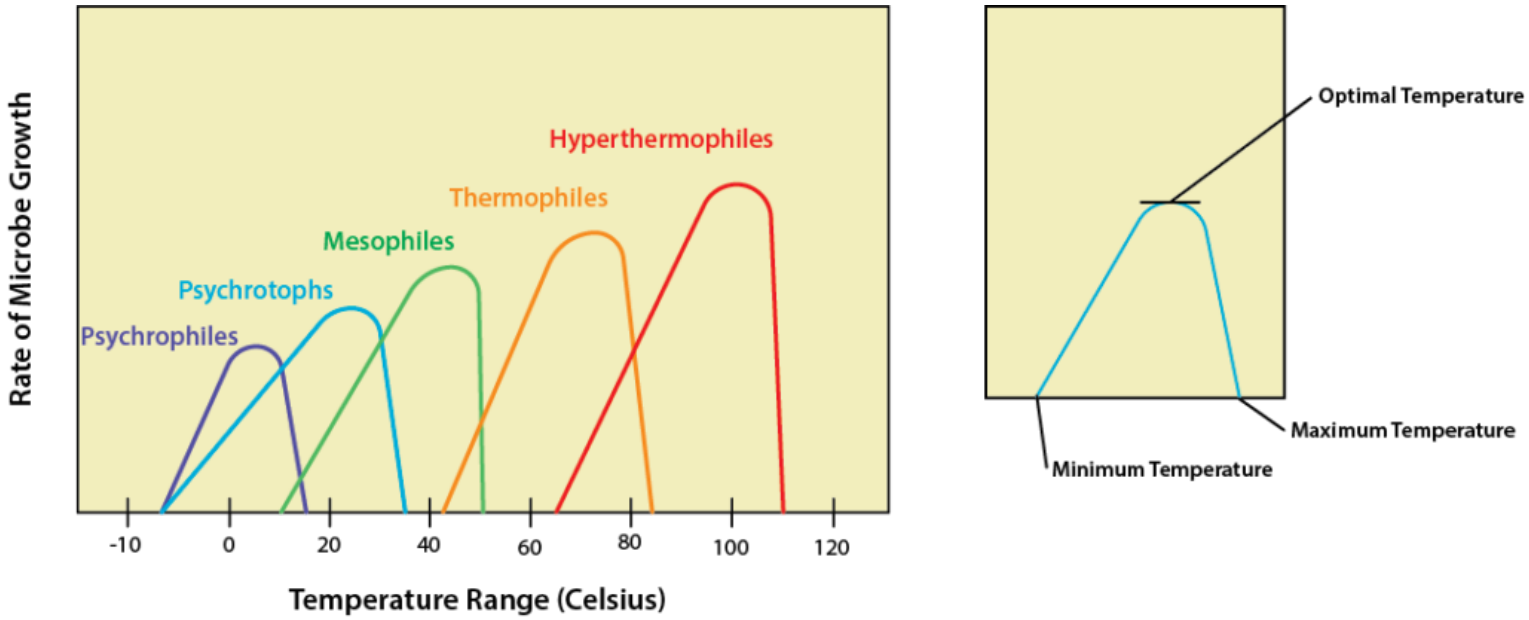








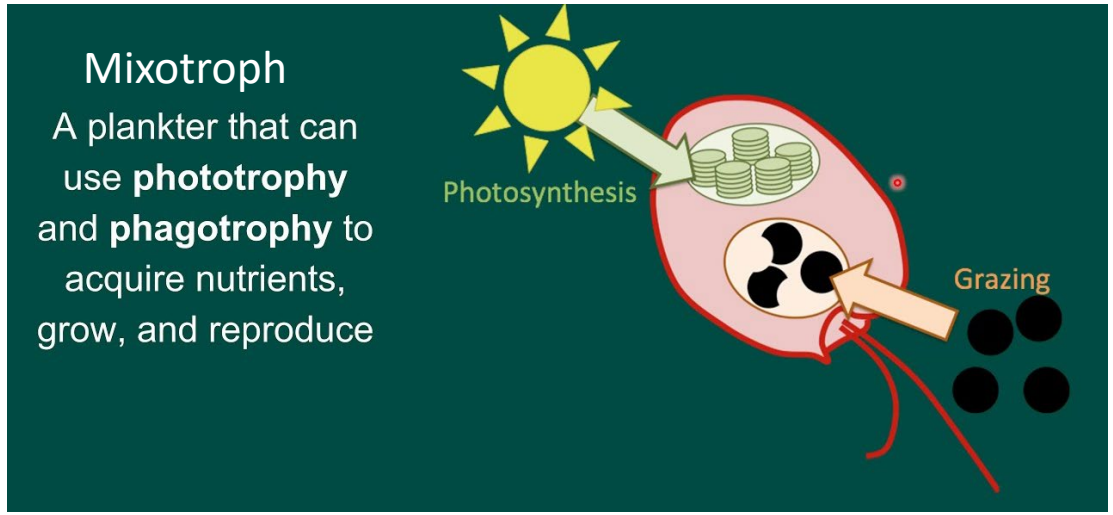
Adaptations for cold temperatures – (Cold Blooms)



Graph of bacterial growth rate as a function of temperature. Microbiology: Canadian Edition, 9.6 Temperature and Microbial Growth

- Psychrophilic vs Psychrotolerant
- Summer vs winter strains
- Accumulation of polyunsaturated fatty acids acyl chains
- Evolution of cold shock and antifreeze proteins
- Modulation of the kinetics of key enzymes

Adaptations for low light



OCB2021 Overview of OCB Mixotrophy & Mixotrophy working group: Nicole Millette (Virginia Inst. Marine Science)

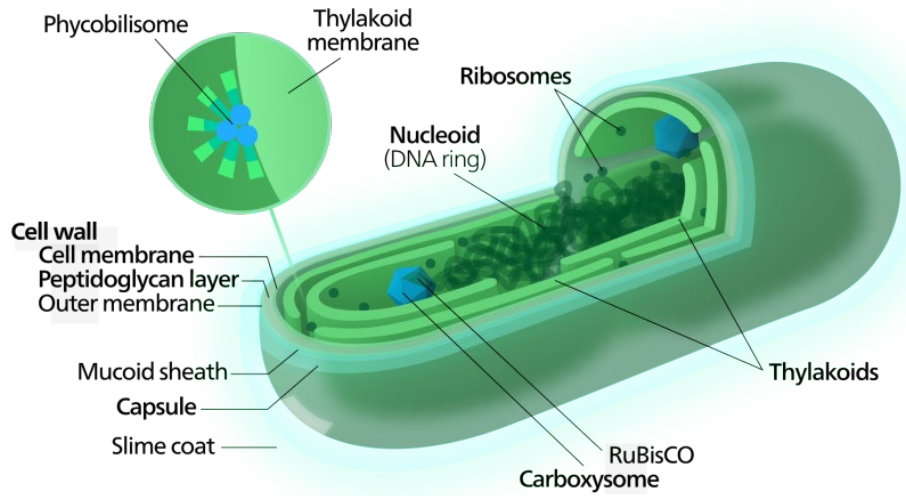
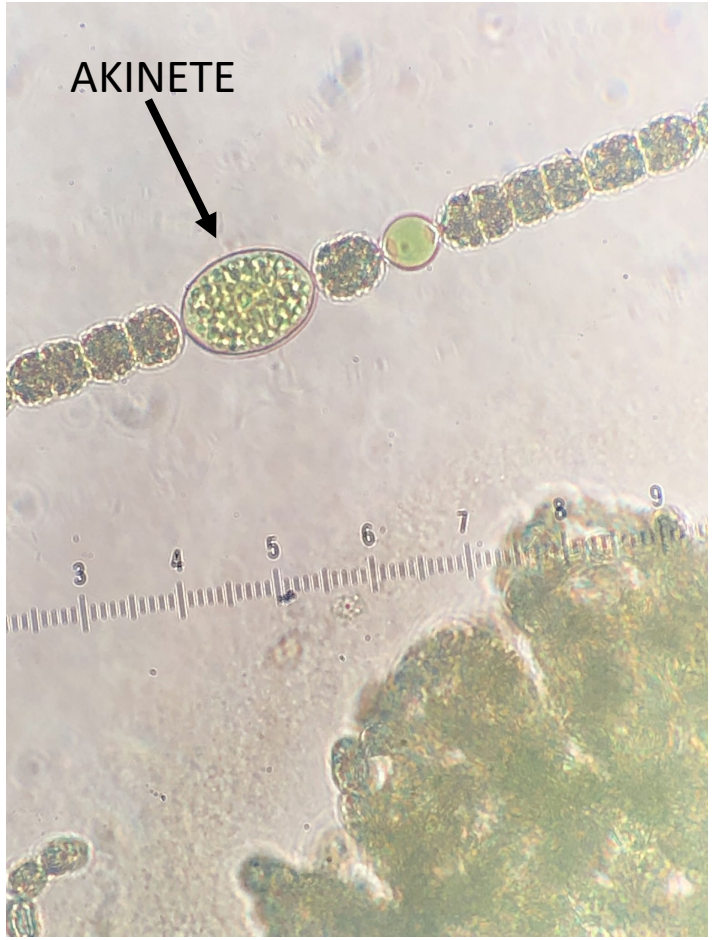
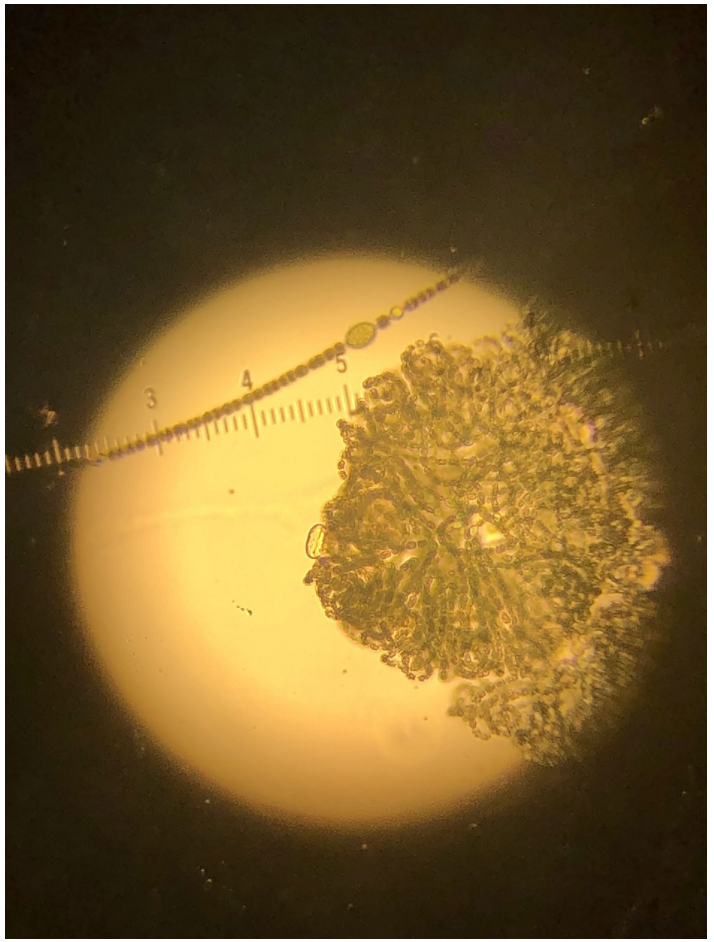
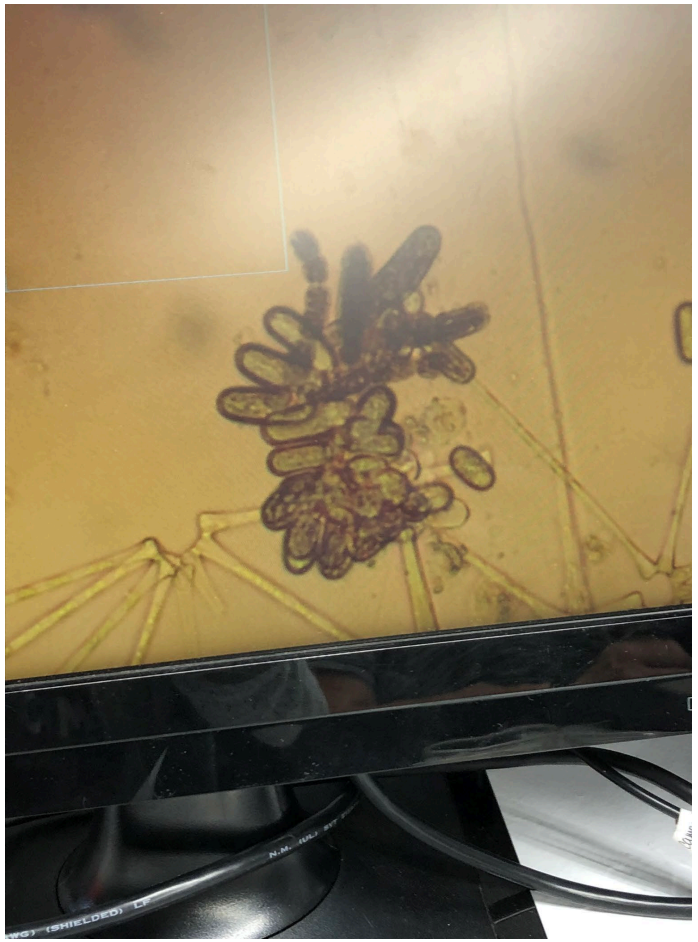


Illustration of Cyanobacterium Cell Structure by Kelven Song

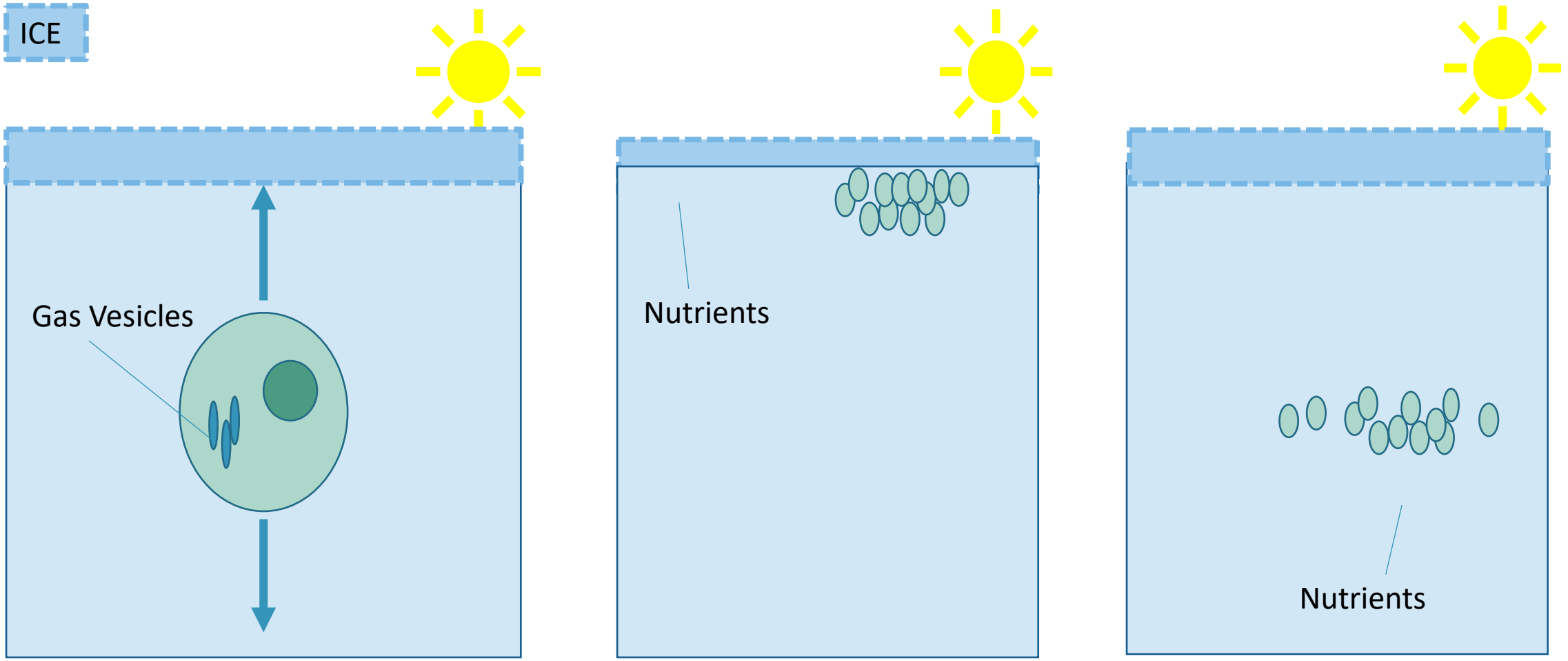
Resting stages cells

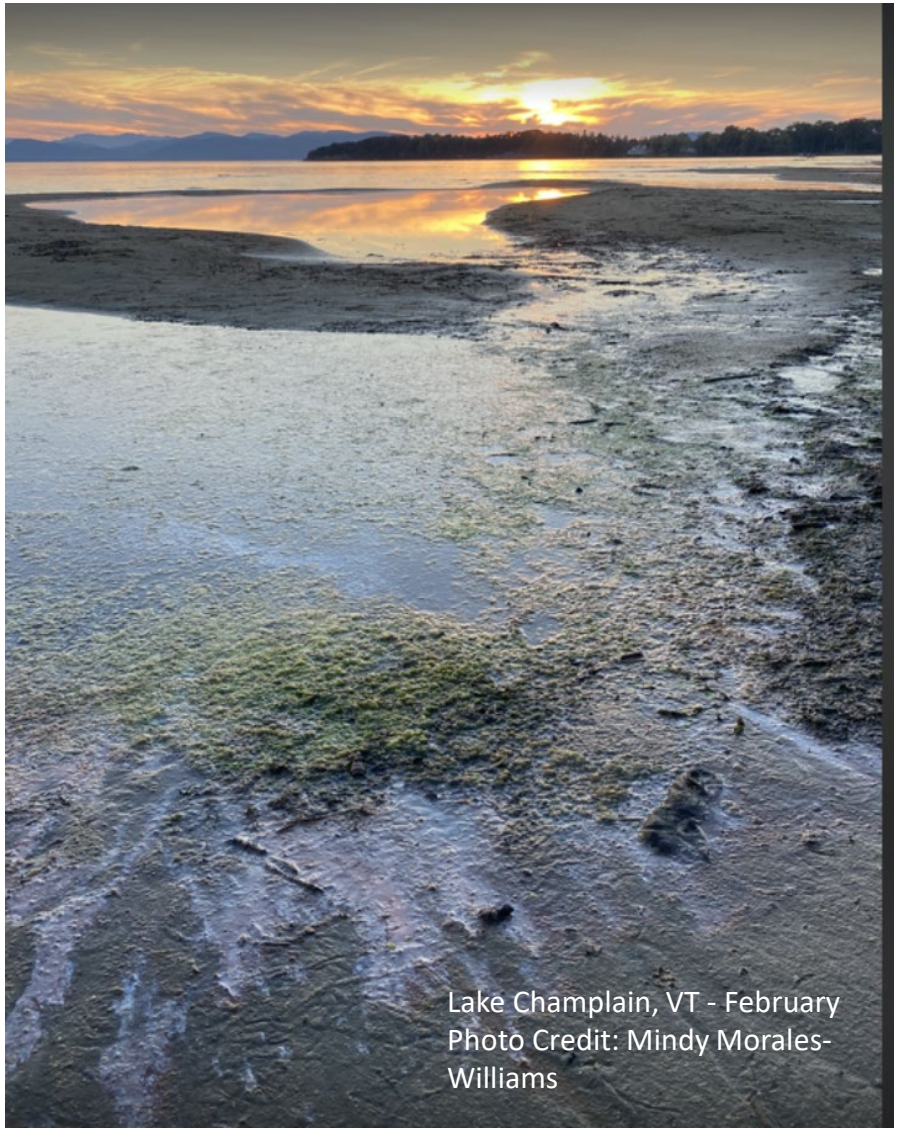






Buoyancy Regulation

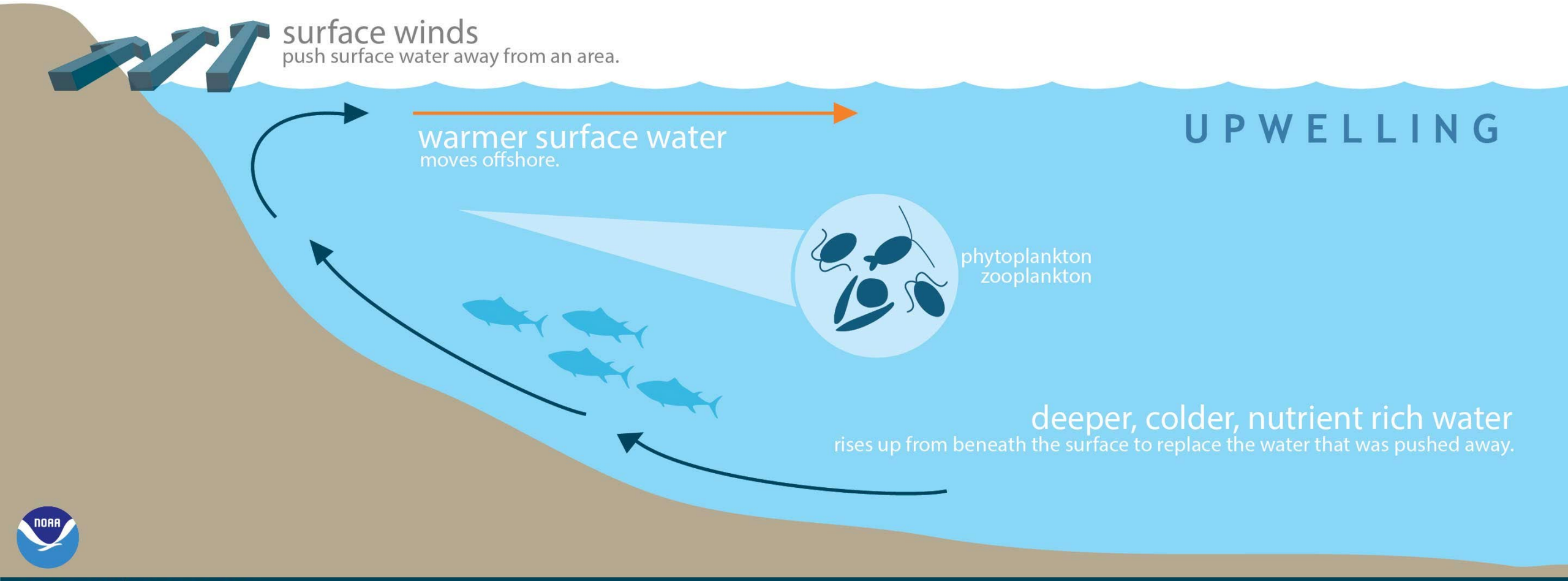




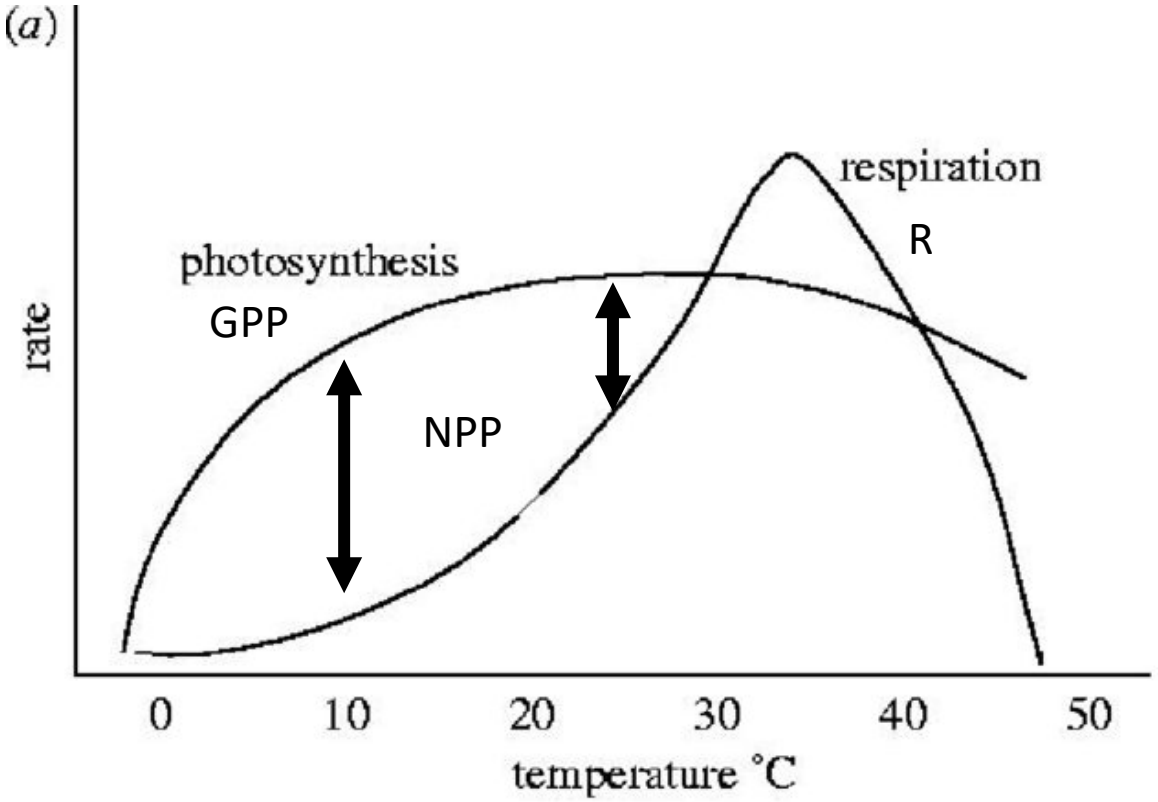
Lake Champlain, VT - February
Photo Credit: Mindy Morales-Williams

Other factors contributing to oligotrophic and cold-water cyanobacterial blooms

Upwelling and Wind Mixing - Nutrients



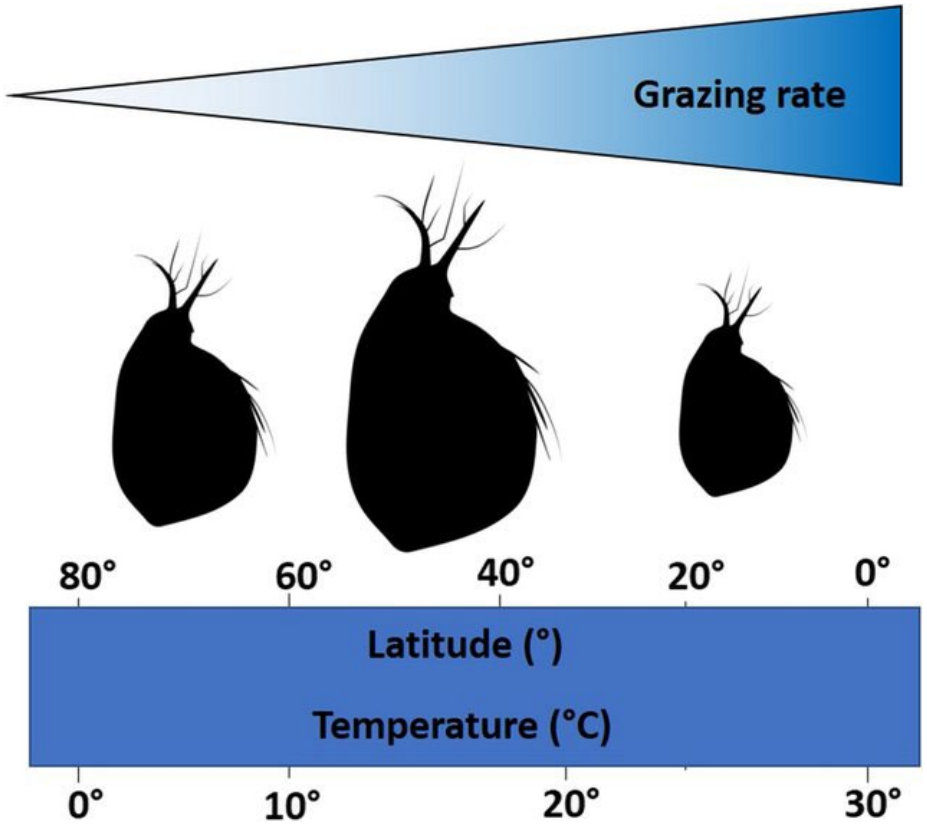
Net Primary Production (NPP) is higher at low temperatures



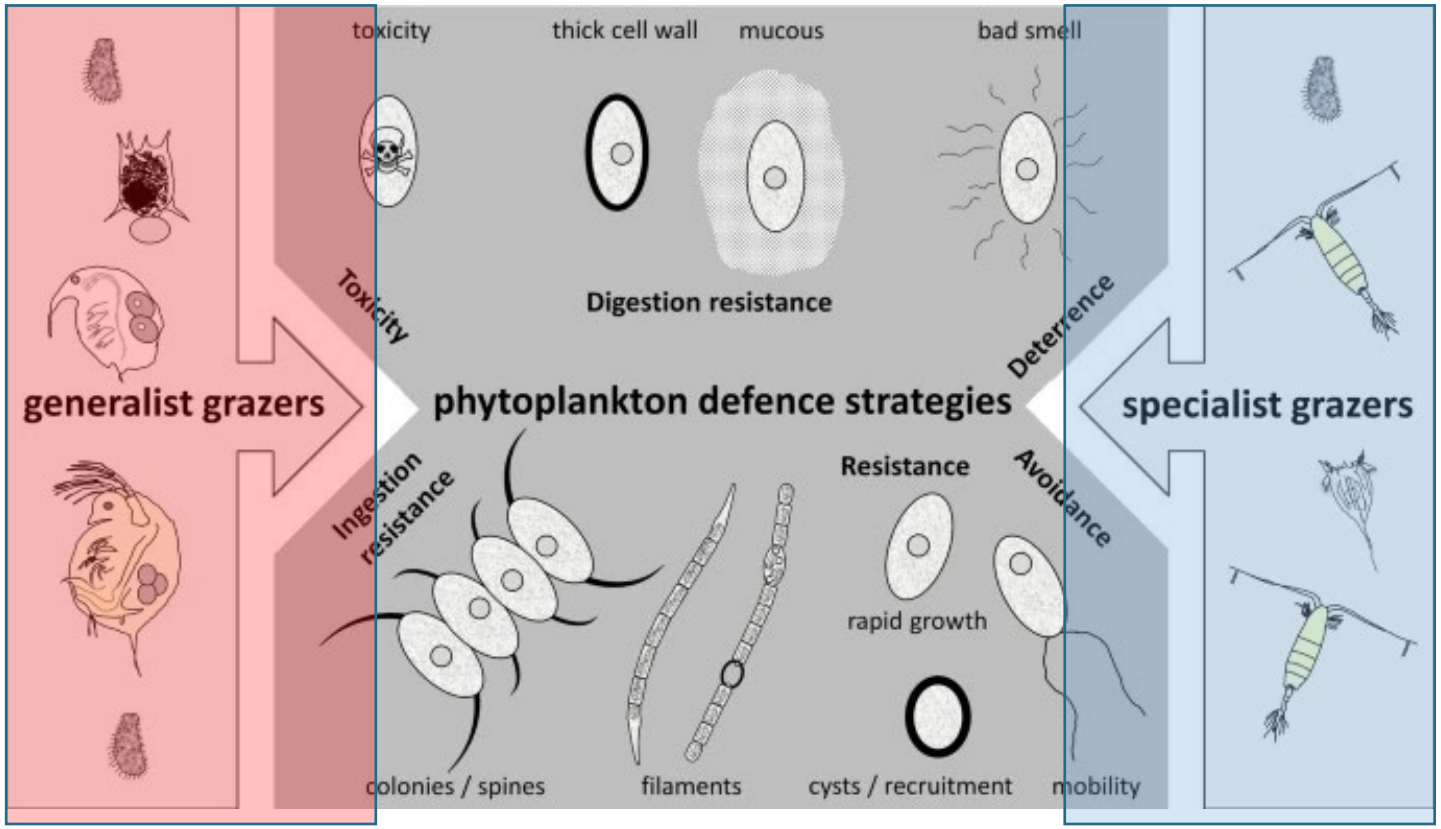
NPP (energy stored as biomass) = GPP (energy store during photosynthesis) – R (energy used for cellular work)

Porter and Semenov 2005

Zooplankton grazing is lower at cold temperatures

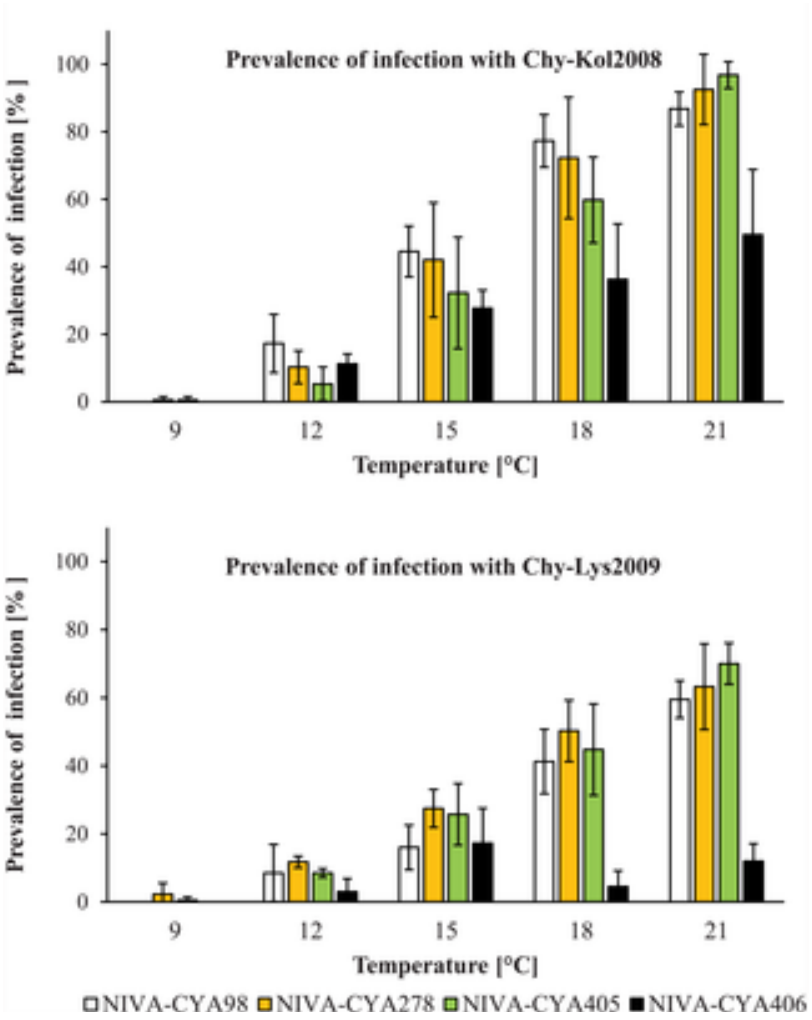


Frau 2021

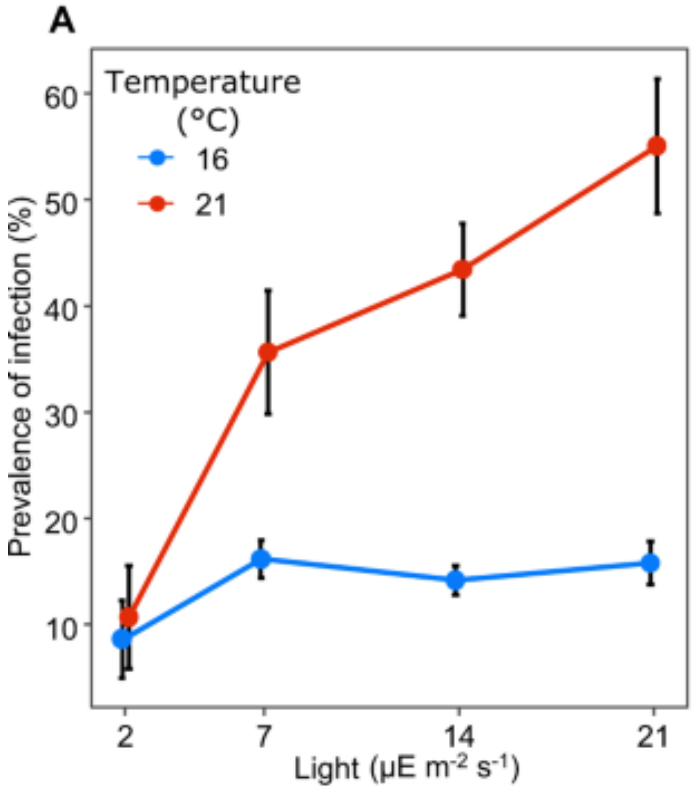


Lürling 2020

Overall infections are reduced, and mortality is limited

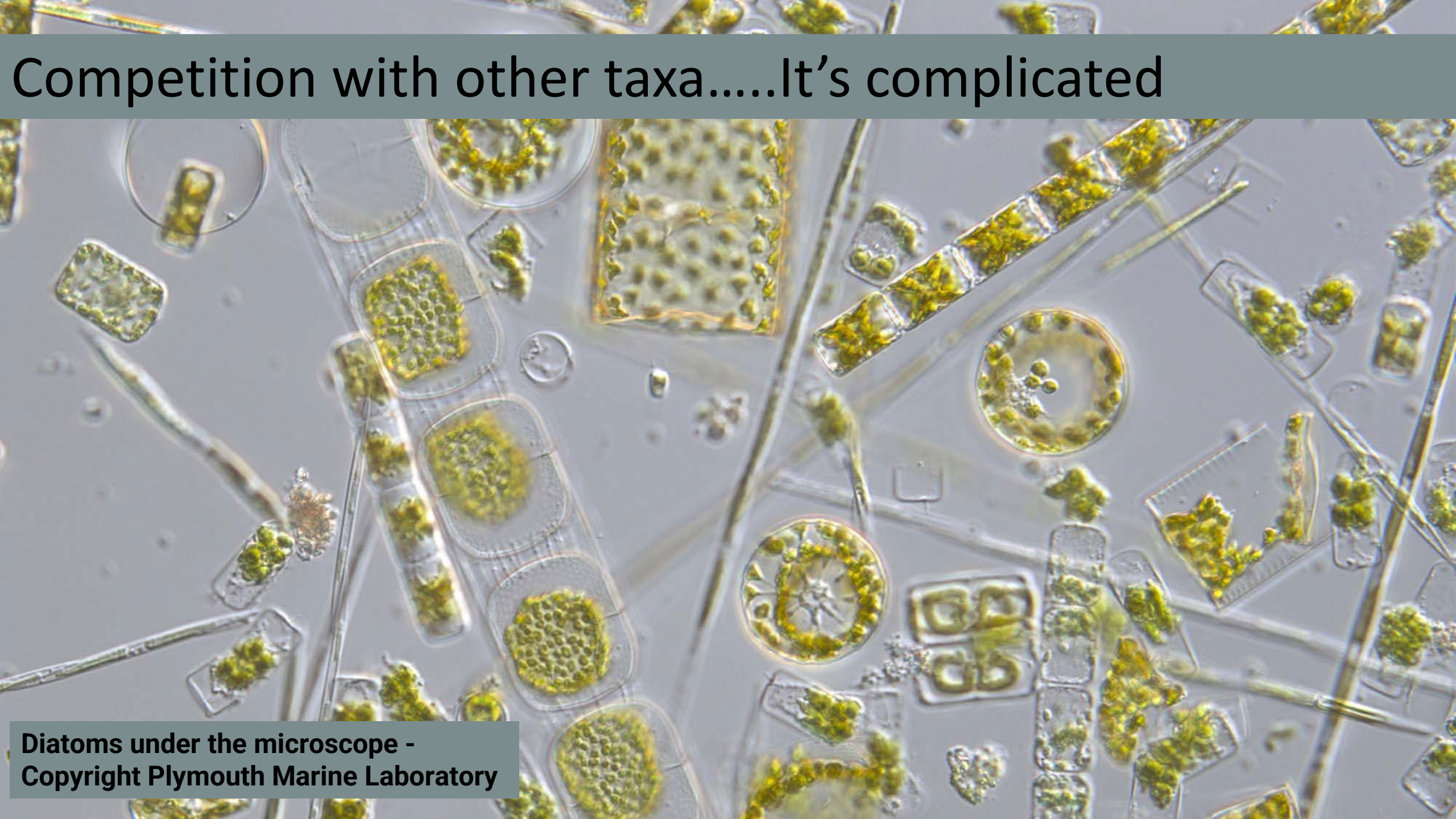


Effect of temperature on growth and chytrid infectivity in Planktothrix. Rohrlack et al (2015)



P. rubescens is affected more strongly by the chytrid parasite at 21 °C, especially at high light. Wierenga et al (2022)

Competition with other taxa…..It’s complicated



Diatoms under the microscope - Copyright Plymouth Marine Laboratory

Key Takeaways

- Blind spot regarding temperature and nutrients for bloom ecology
- Many species of cyanobacteria have a wide range of temperature optimums and adaptations allow for phytoplankton to thrive in low nutrient and cold-water conditions
- Suboptimal temperatures ≠ No cyano growth
- Future work documenting and understanding cold-water blooms is needed

Lake Champlain, VT -October ; Photo Credit: Mindy Morales-Williams

Feel free to add questions to the chat or email me!

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global lake ecological observatory network

Extension
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LAKE SUPERIOR
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