UF IFAS
UNIVERSITY of FLORIDA

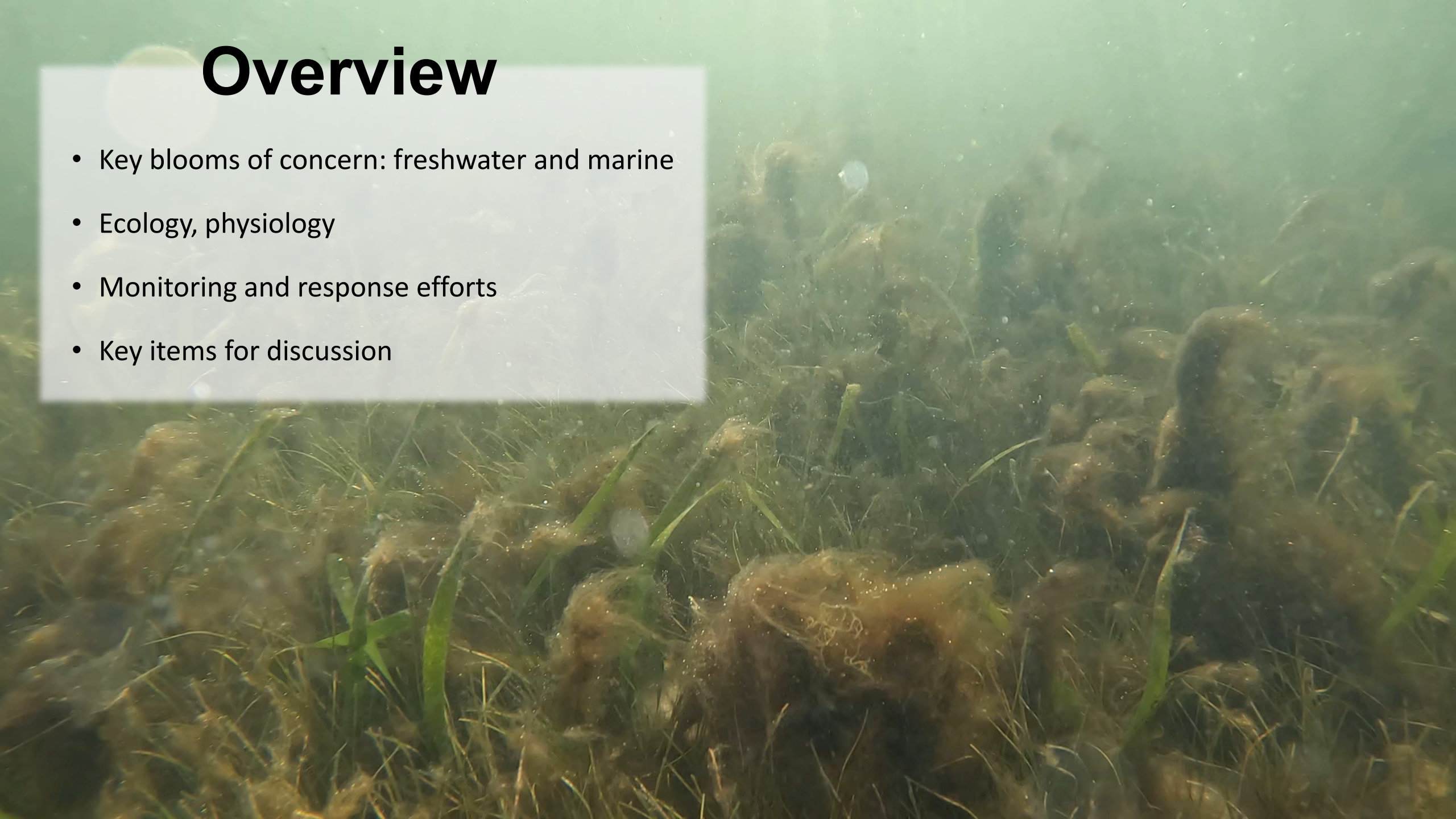
Marine and Freshwater Benthic CyanoHABs

David E. Berthold, Ph.D.

FLORIDA BLUE-GREEN ALGAE
STATE OF THE SCIENCE
Symposium II

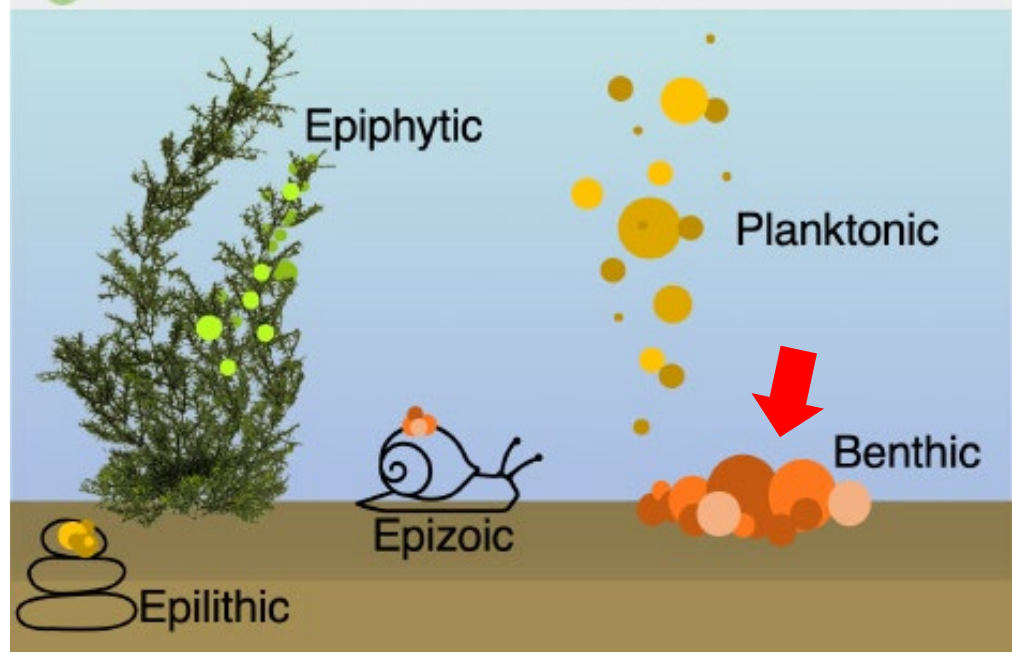
Overview

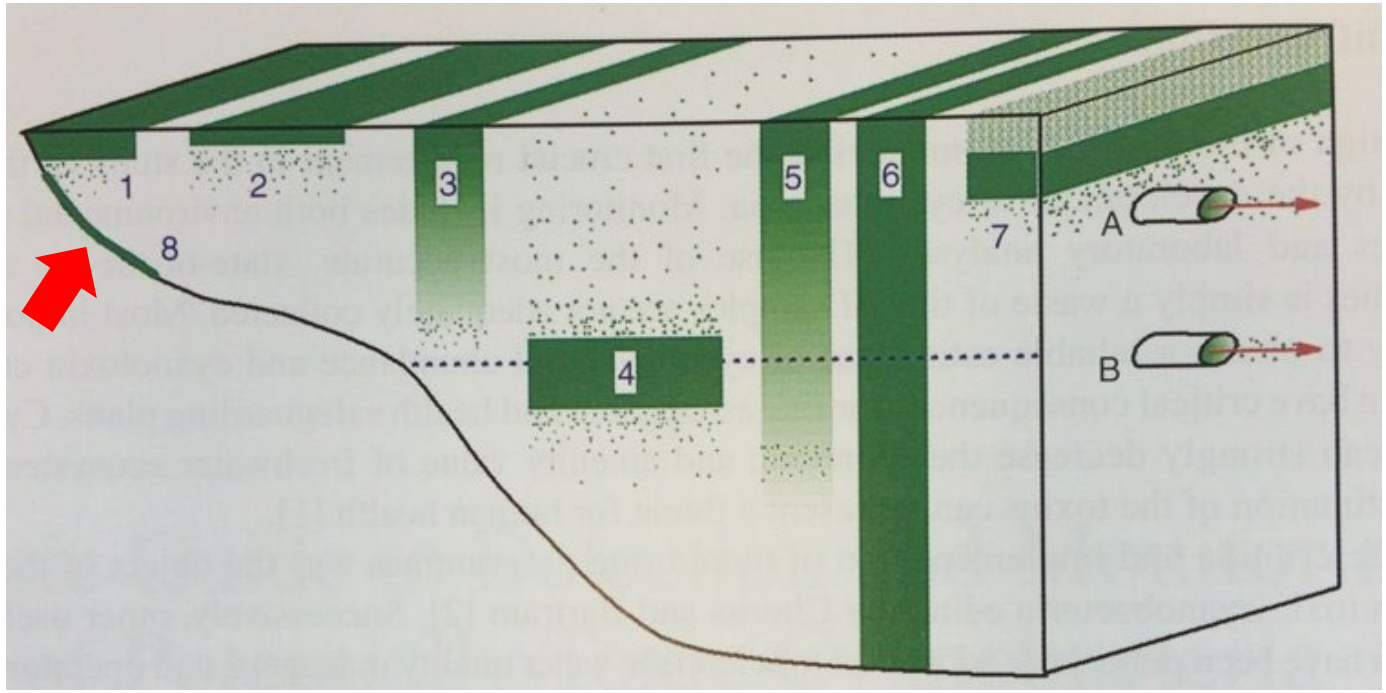
- Key blooms of concern: freshwater and marine
- Ecology, physiology
- Monitoring and response efforts
- Key items for discussion



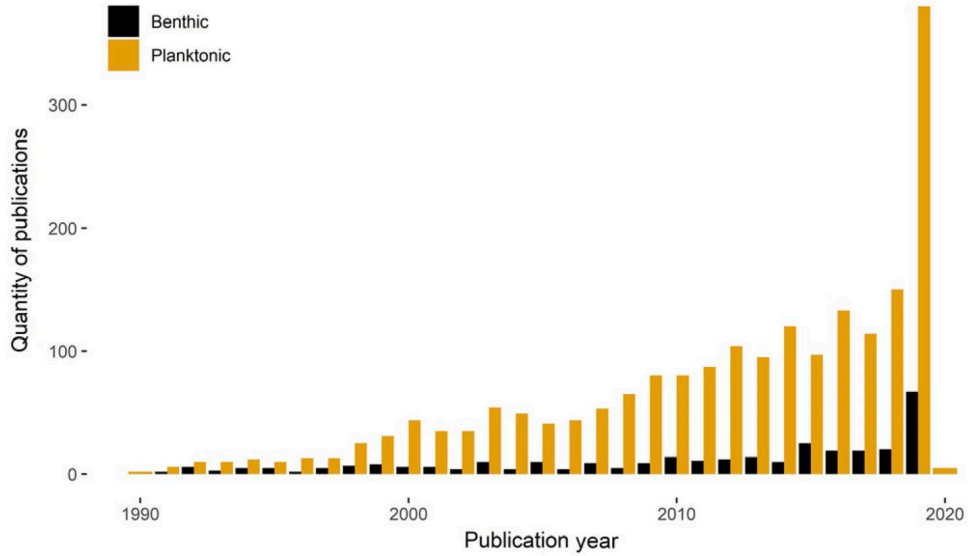
What are Benthic Blooms?

- Cyanobacteria have many habits
- Focus on benthic
- Freshwater-Marine continuum





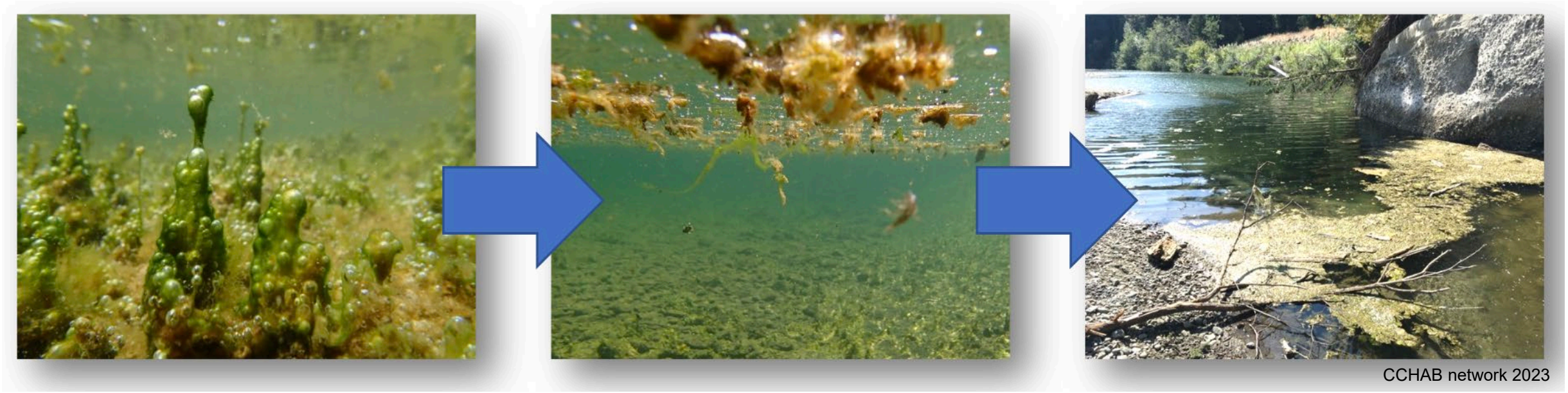
Humbert et al. 2017



Wood et al. 2020

Freshwater Benthic CyanoHABs

- Benthic growth and detachment
- Poses risks to recreational activity
  - Children and animals most susceptible



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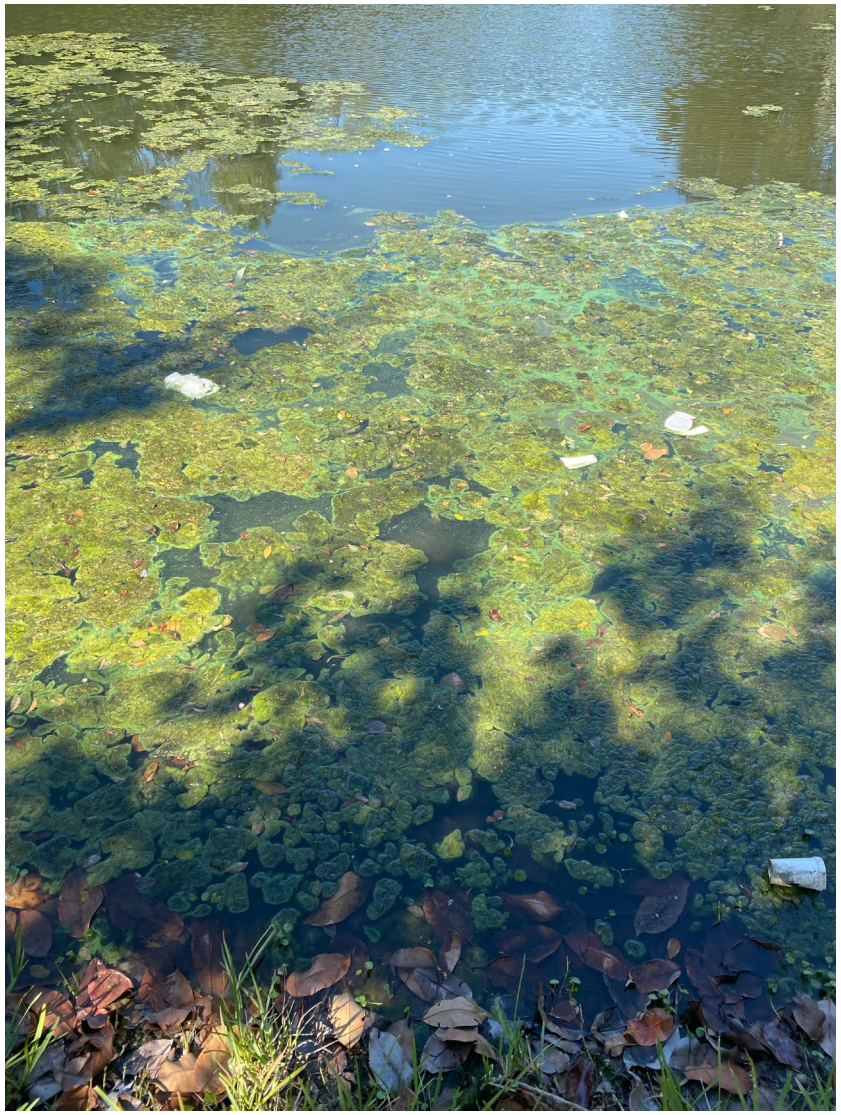
Freshwater Benthic CyanoHABs

- Called “*Lyngbya*” blooms
  - Not *Lyngbya*
- Prevalent in lakes, canals, streams, springs, rivers and STPs
- Can accumulate on littoral zone

Freshwater Benthic CyanoHABs

- Harbor pathogenic microorganisms
- Feed other blooms through decay
- Decomposition, Low DO
- Effects on flora/fauna



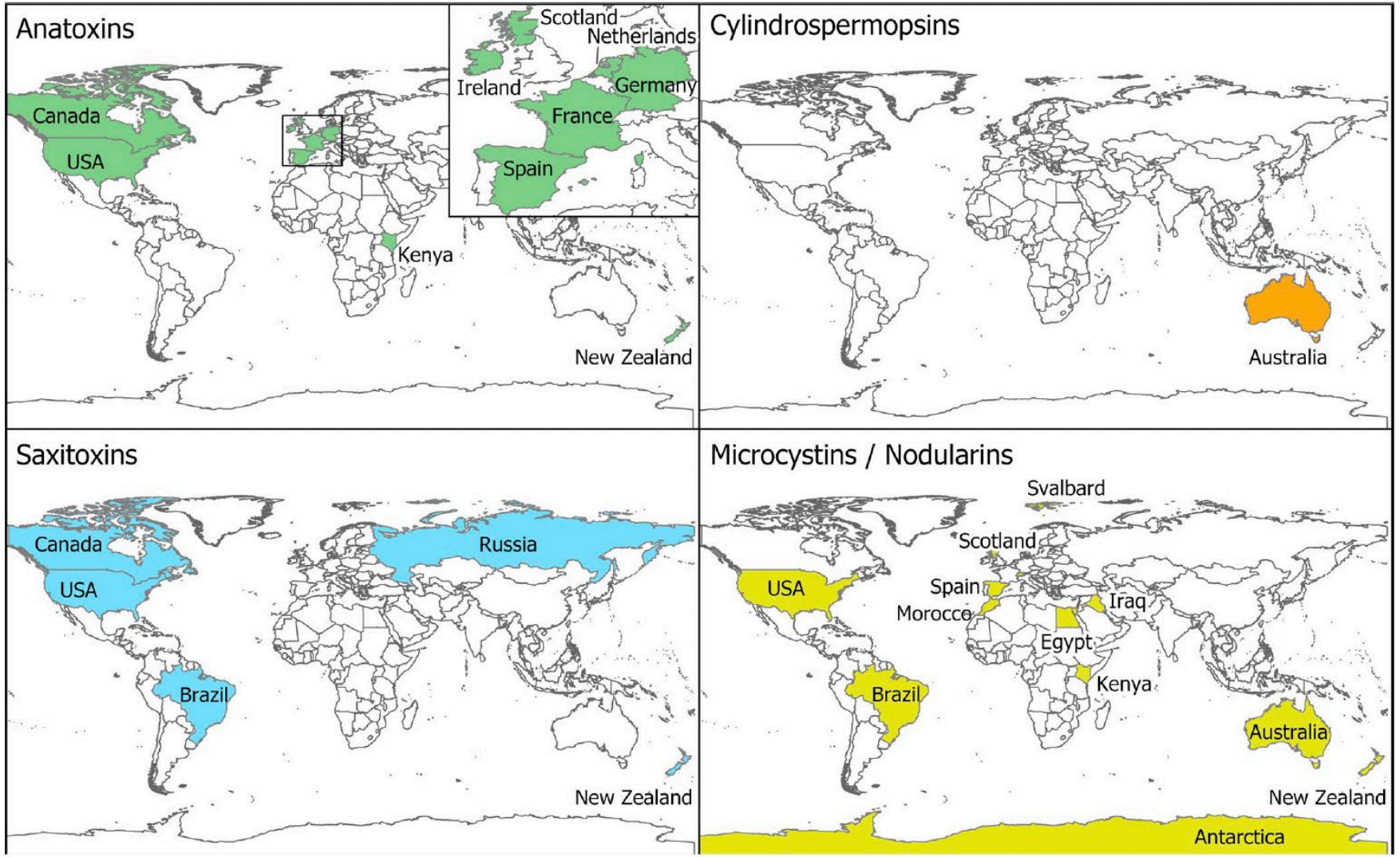
Freshwater Benthic CyanoHABs

Quiblier et al. 2013

Table 2 – Benthic cyanobacterial species in which toxin production has been confirmed through uni-cyanobacterial strain isolation, culturing and toxin testing. NA, not available.

Toxin	Species (culture code)	Reference
Microcystin	*Planktothrix* sp. (CYN60,61)	Wood et al., 2010a
	Anabaena subcylindrica (NA)	Mohamed et al., 2006
	Anabaena variables (NA)	Mohamed et al., 2006
	Nostoc spongiforme (NA)	Mohamed et al., 2006
	Plectonema boryanum (NA)	Mohamed et al., 2006
	Phormidium corium (NA)	Mohamed et al., 2006
	Rivularia biasolettiana (NA)	Aboal et al., 2005
	Rivularia haematites (NA)	Aboal et al., 2005
	Phormidium splendidum (NA)	Aboal et al., 2005
	Tolypothrix distorta (NA)	Aboal et al., 2005
	Phormidium sp. (11 strains)	Izaguirre et al., 2007
Cylindrospermopsin	*Lyngbya wollei* (NA)	Seifert et al., 2007
	Oscillatoria sp. (PCC 6506)[a]	Mazmouz et al., 2010
Saxitoxins	*Lyngbya wollei* (NA)	Yin et al., 1997
	Scytonema cf. *crispum* (UNFS10)	Smith et al., 2011, 2012
Homo/anatoxin-a	*Oscillatoria* sp. (PCC6506,6407, 6412, 9029, 9240)[a]	Aráoz et al., 2005
	O. formosa (PCC10111)[a]	
	Oscillatoria sp. (PCC 10601,10702,10608)	Cadel-Six et al., 2007
	Oscillatoria sp. (NA)	Edwards et al., 1992
	Phormidium autumnale (many strains)	Wood et al., 2012b
		Heath et al., 2010
	Phormidium favosum (PMC240.04)	Gugger et al., 2005
Unknown	*Limnothrix* (AC0243)	Humpage et al., 2012a

Toxic Freshwater Benthic CyanoHABs: Toxin Distribution



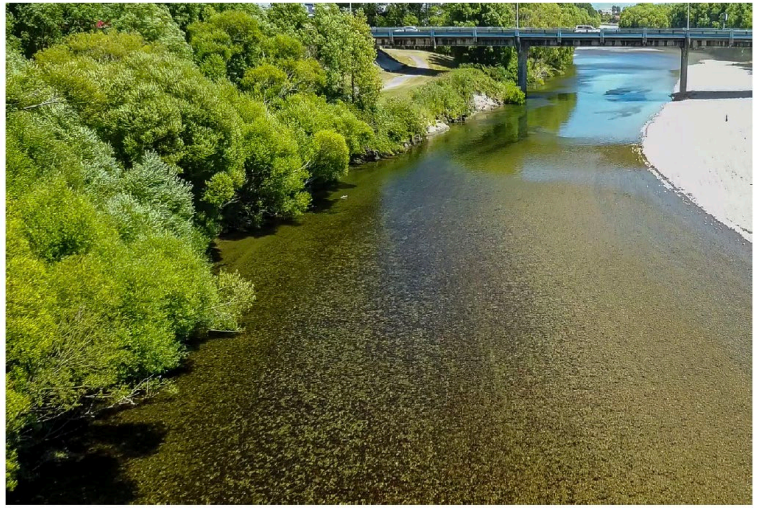
Wood et al. 2020

FIGURE 2 Global distribution of reported cyanotoxin detections from benthic cyanobacteria [Colour figure can be viewed at wileyonlinelibrary.com]

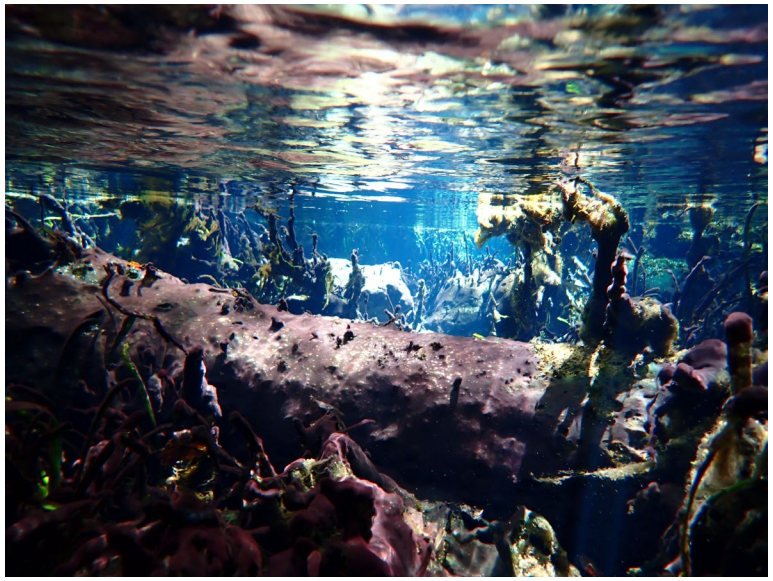
Freshwater Benthic CyanoHABs

- Key bloom formers

Wood et al. 2020

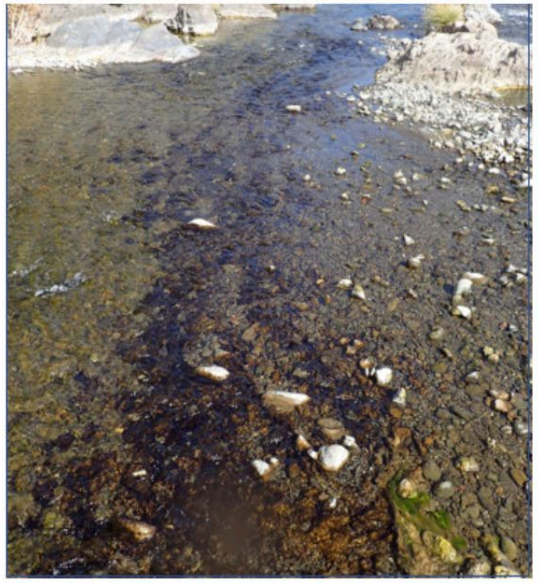


Richard Owen

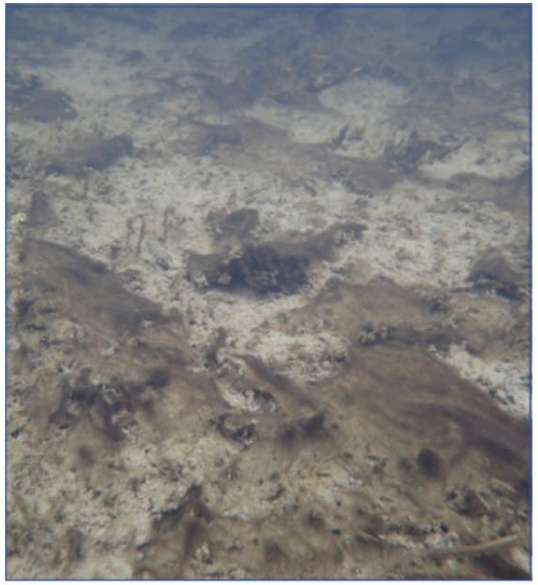


Anabaena

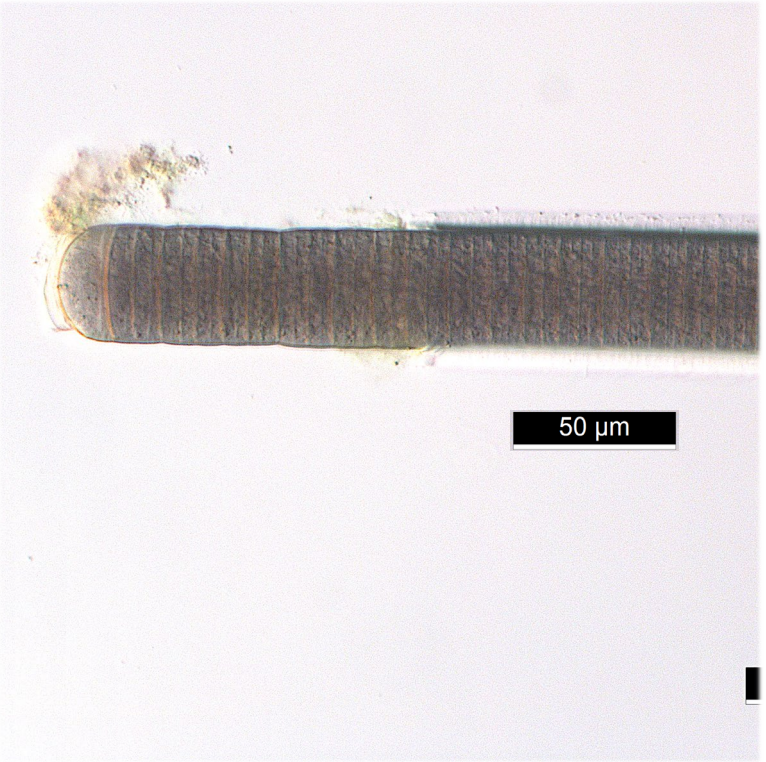
Microcoleus/Phormidium



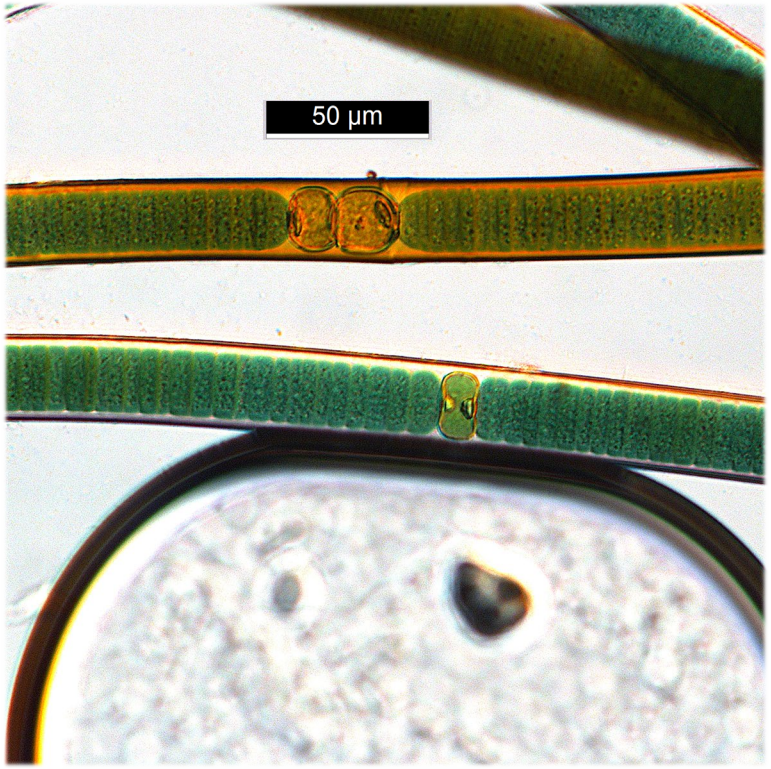
Oscillatoria



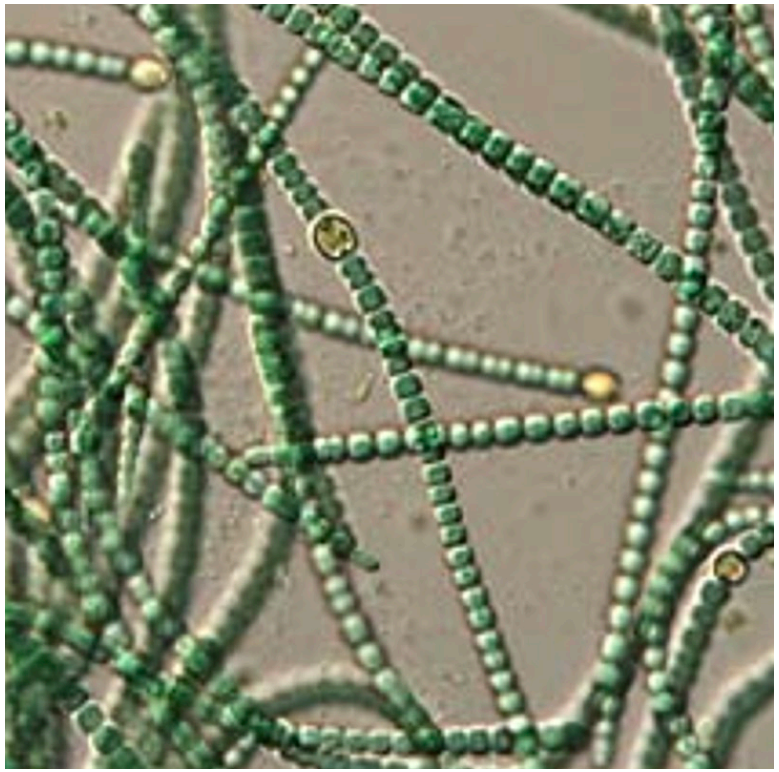
Key **Freshwater** Benthic Genera



Microseira wollei
(= *Lyngbya wollei*)
ATX, CYN

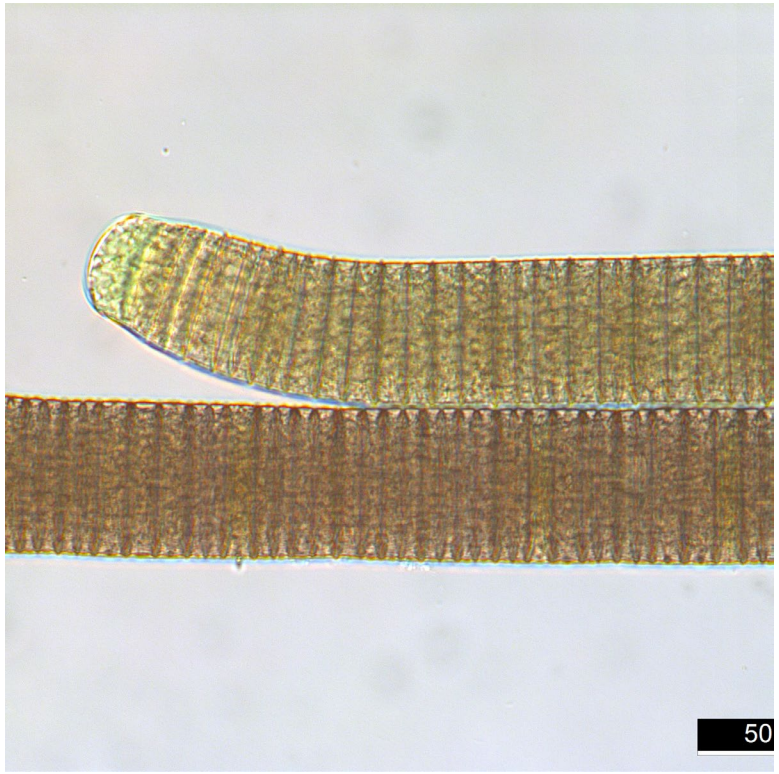


Heteroscytonema
(=*Scytonema*)
STX



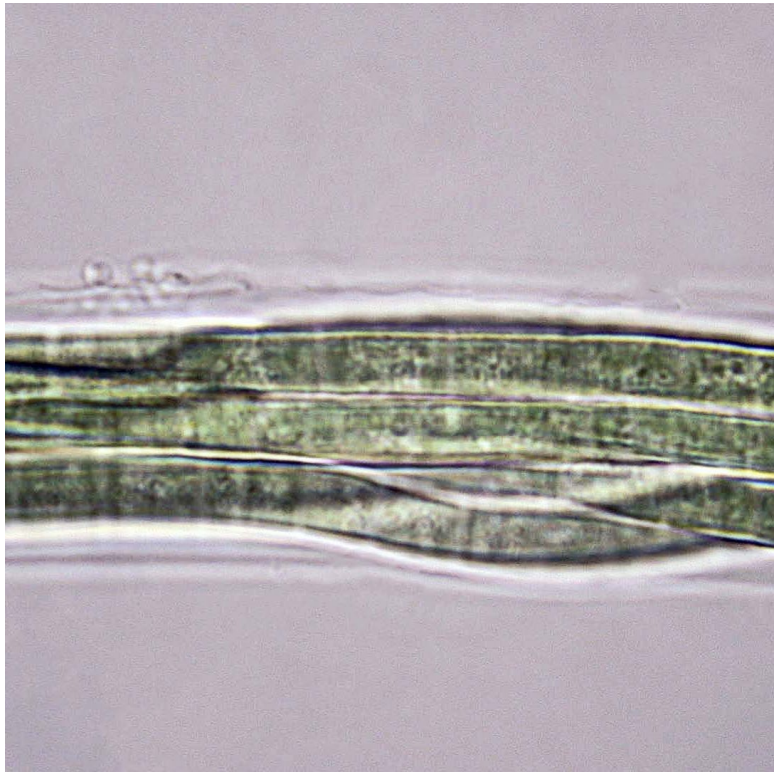
Wollea
(=*Anabaena*)
MCs

Key **Freshwater** Benthic Genera



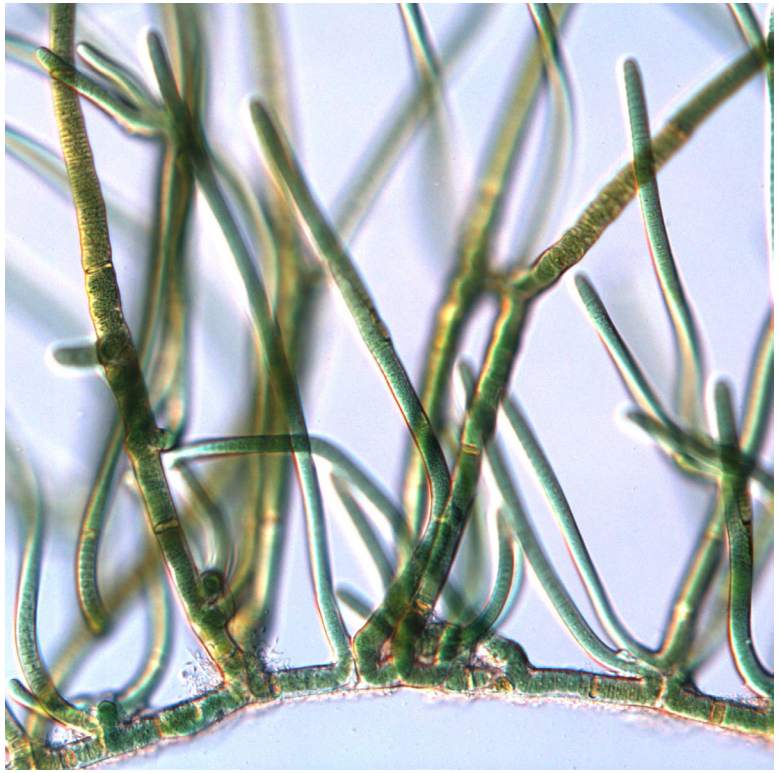
Oscillatoria

ATX, STX



Microcoleus
(= *Phormidium*)

ATX



Iningainema

NOD, MC

Sendall and McGregor 2018

Monitoring and Response: **Freshwater** Benthic CyanoHABs

Field methods:

1. Coverage/visual assessment
2. Collection of mat material
3. Water column sample
4. Deployment of SPATTs

1

2

3

4

CCHAB network 2023

Marine Benthic CyanoHABs

What are marine benthic cyanoHABs?

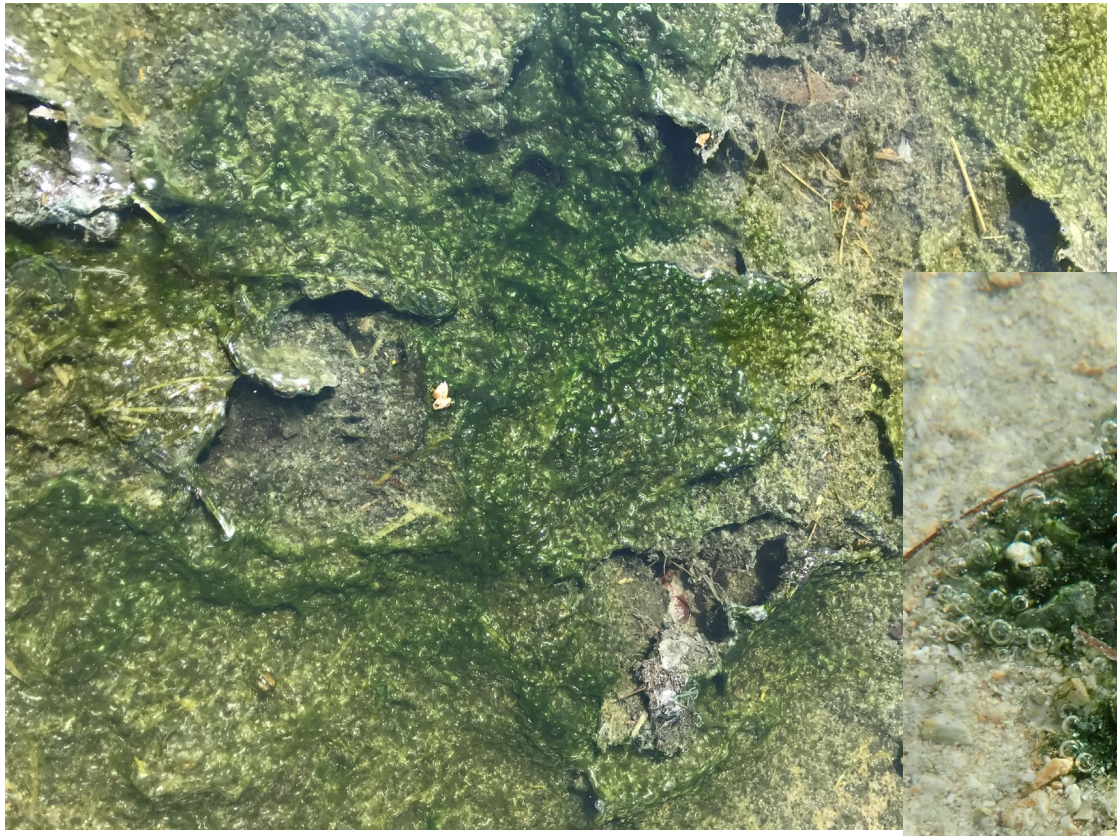
- BCMs, benthicHABs, '*Lyngbya'* blooms, cyanoHABs, cHABs,
- Benthic cyanobacterial growth
- Widespread issue for Florida
  - brackish to marine

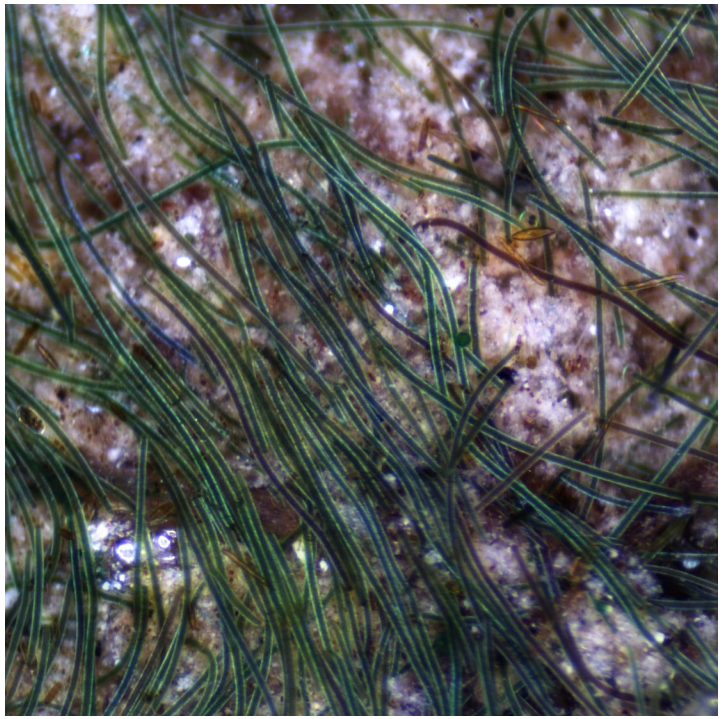
Marine Benthic CyanoHABs

Occurrences and reports :

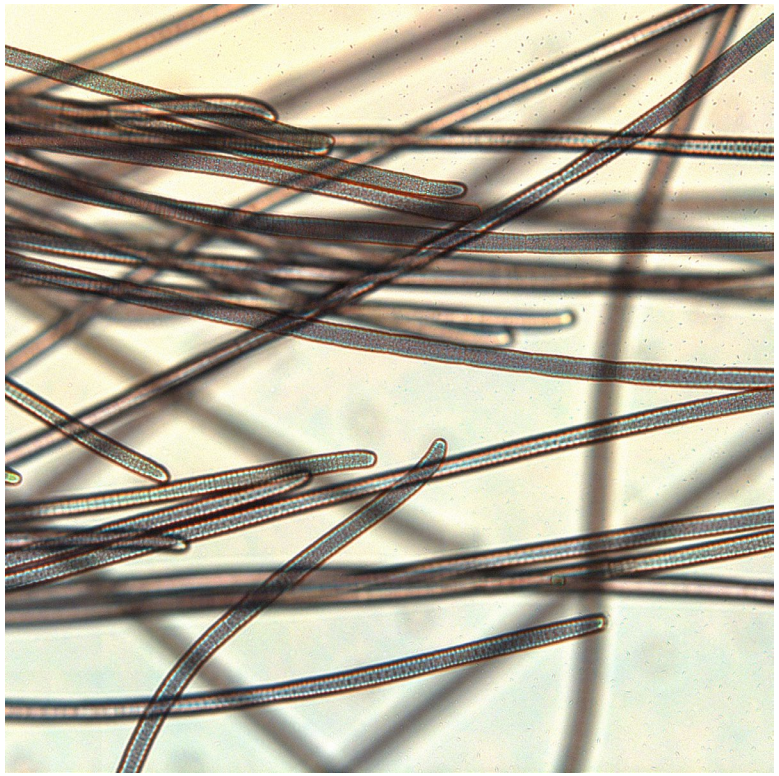
- Shoreline
- Marinas
- Mangroves
- Seagrasses
- Sandy dunes
- Corals
- Deep (60-90m) (van Heuzen et al. 2015)

Marine Benthic CyanoHABs: **Mangroves/Marinas**

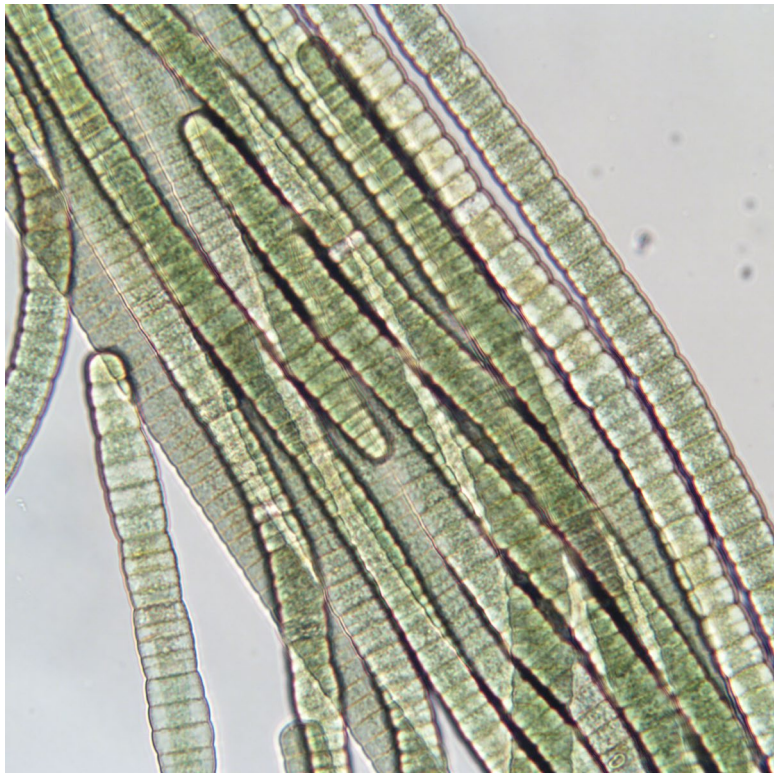




Key **Marine** Benthic Genera

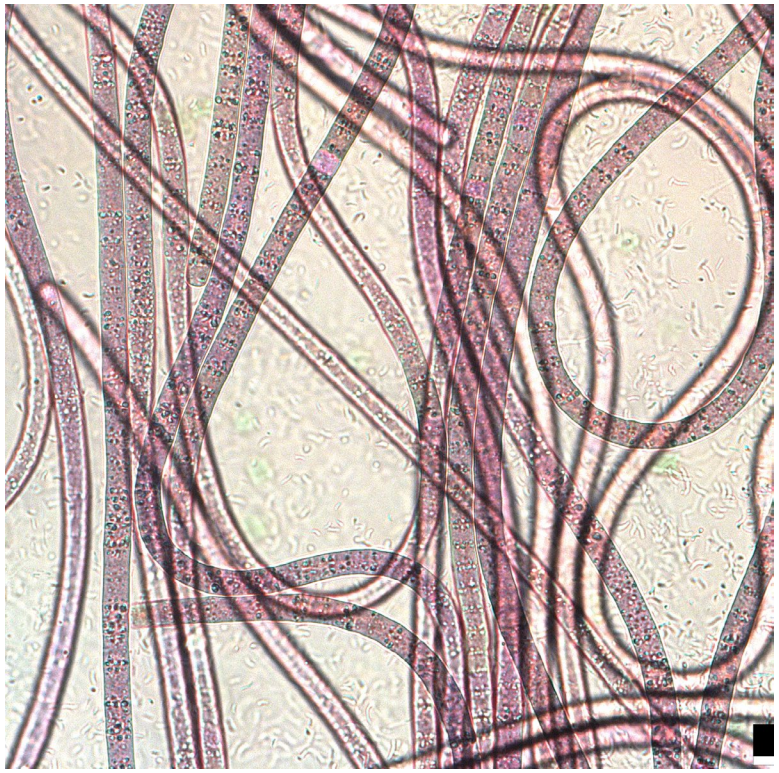


Vermifilum



Ophiophycus

Berthold et al. 2021



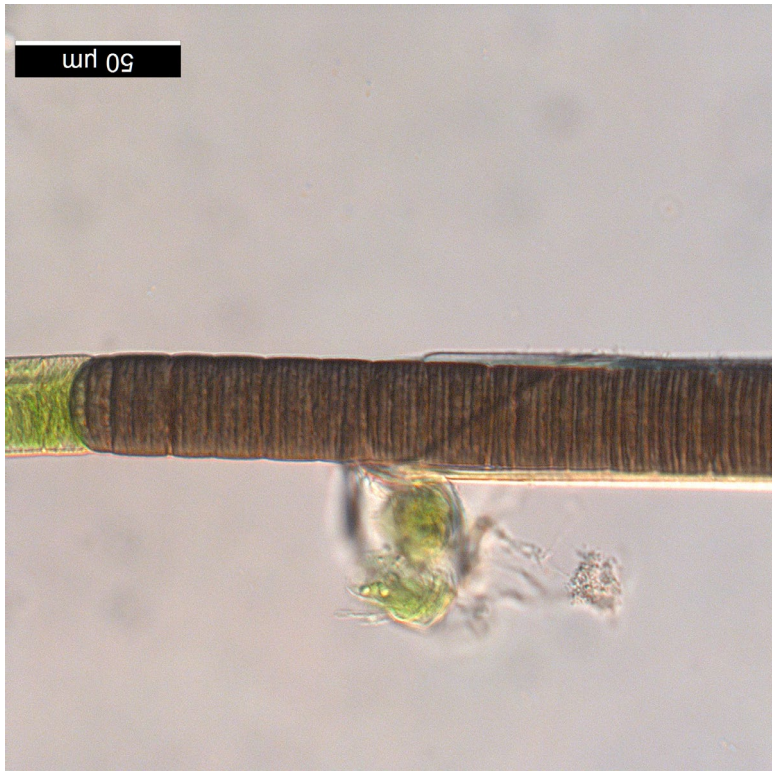
Leptochromothrix

Seagrasses

Marine Benthic CyanoHABs

Key **Marine** Benthic Genera

Dapis
Engene et al. 2018



Okeania
Engene et al. 2013

Sirenicapilllaria
Berthold et al. 2022

Genomic Insights: Genetic potential

Function role	Gene Count	subsystem name	subsystem class
Sirenicapillaria/ Dapis /Okeania			
4Fe-4S ferredoxin, nitrogenase-associated	2		
Ammonium transporter	4	Nitrogen regulation orphans	Nitrogen Metabolism
Distantly related to nitrogen regulatory protein P-II	2		
Global nitrogen regulatory protein, CRP family of transcriptional regulators	2		
Iron-sulfur cluster assembly scaffold protein NifU	2	Fe-S cluster assembly	Cofactors, Vitamins, Prosthetic Groups
		Nitrogen fixation	Nitrogen Metabolism
Mo-dependent nitrogenase-like protein	4		
NifT protein	2	Nitrogen fixation	Nitrogen Metabolism
NifX-associated protein	4	Nitrogen fixation	Nitrogen Metabolism
NifZ protein	2	Nitrogen fixation	Nitrogen Metabolism
Nitrogen assimilation transcriptional activator NtcB	2		
Nitrogen regulatory protein P-II	4	Nitrogen regulation orphans	Nitrogen Metabolism
Nitrogen-responsive response regulator NrrA	2	Heterocyst formation in cyanobacteria	Prokaryotic cell type differentiation
Nitrogenase (molybdenum-iron) alpha chain (EC 1.18.6.1)	2		
Nitrogenase (molybdenum-iron) beta chain (EC 1.18.6.1)	2		
Nitrogenase (molybdenum-iron) reductase and maturation protein NifH	2		
Nitrogenase FeMo-cofactor carrier protein NifX	2	Nitrogen fixation	Nitrogen Metabolism
Nitrogenase FeMo-cofactor scaffold and assembly protein NifE	2	Nitrogen fixation	Nitrogen Metabolism
Nitrogenase FeMo-cofactor scaffold and assembly protein NifN	2	Nitrogen fixation	Nitrogen Metabolism
Nitrogenase FeMo-cofactor synthesis FeS core scaffold and assembly protein NifB	2	Nitrogen fixation	Nitrogen Metabolism
Nitrogenase stabilizing/protective protein NifW	2	Nitrogen fixation	Nitrogen Metabolism

Key **Marine** Benthic Genera

cf. Hormothamnion

Neolyngbya

Caires et al. 2018

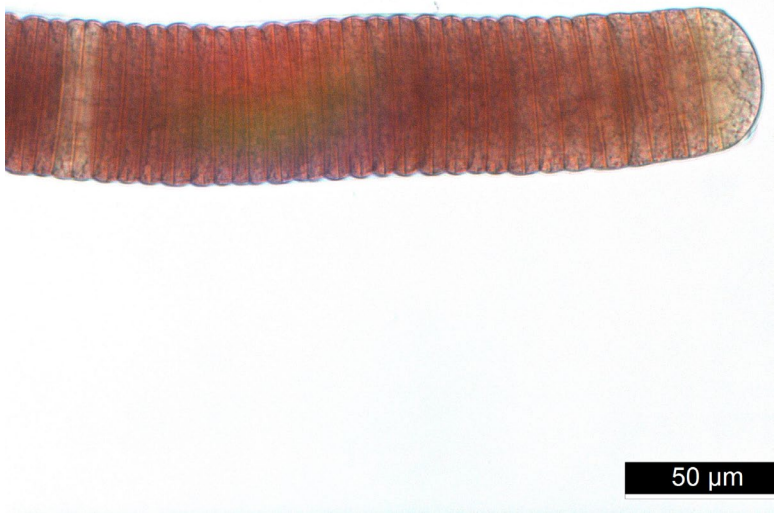
Nunduva

González-Resendiz et al. 2018

Stanieria

Affixifilum

Lefler et al. 2021



Capilliphycus

Caires et al. 2018

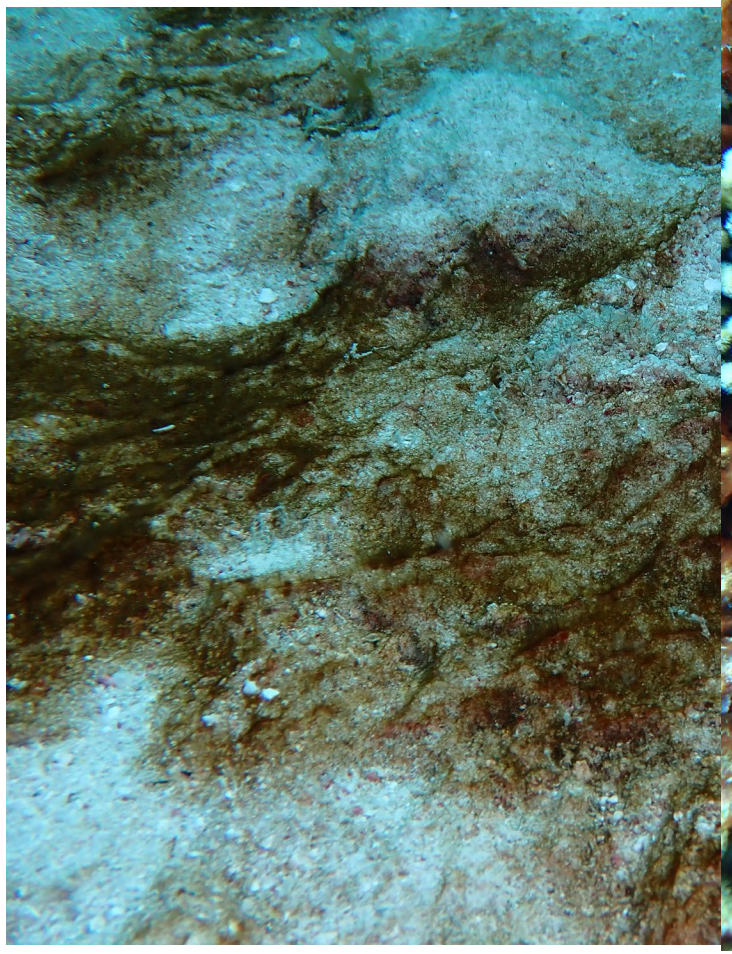
Caldora

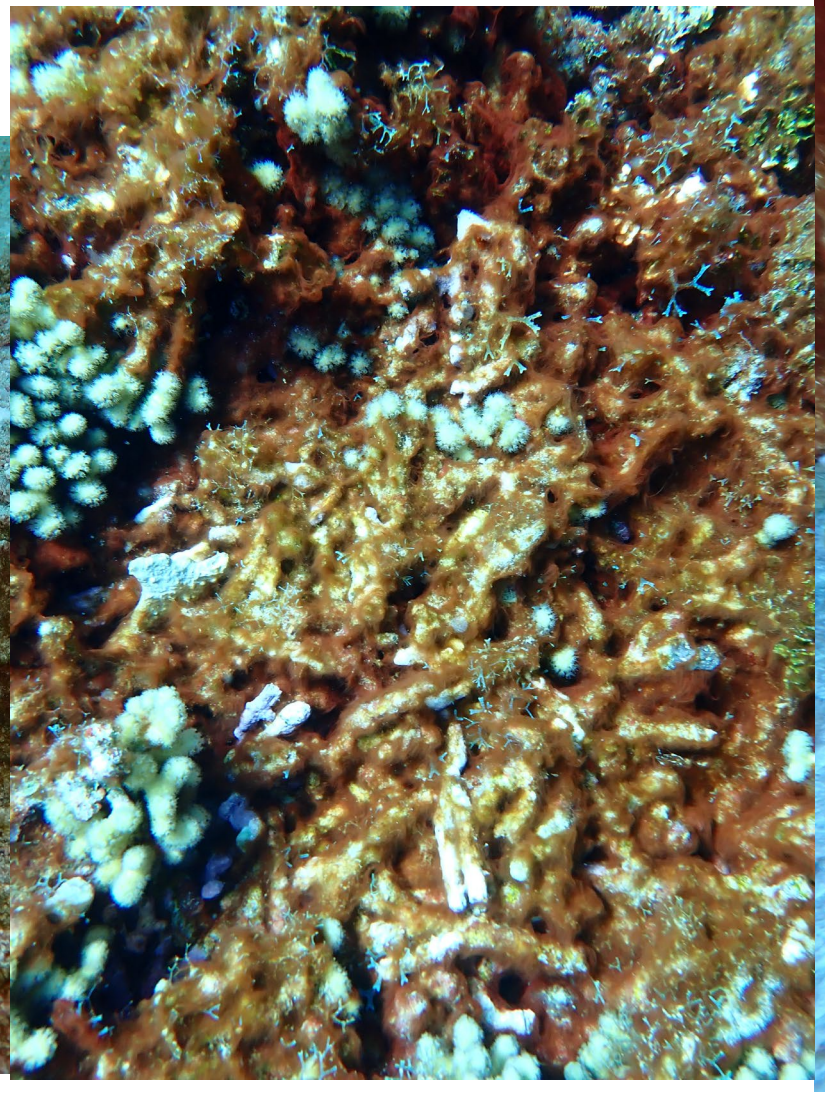
Moorena

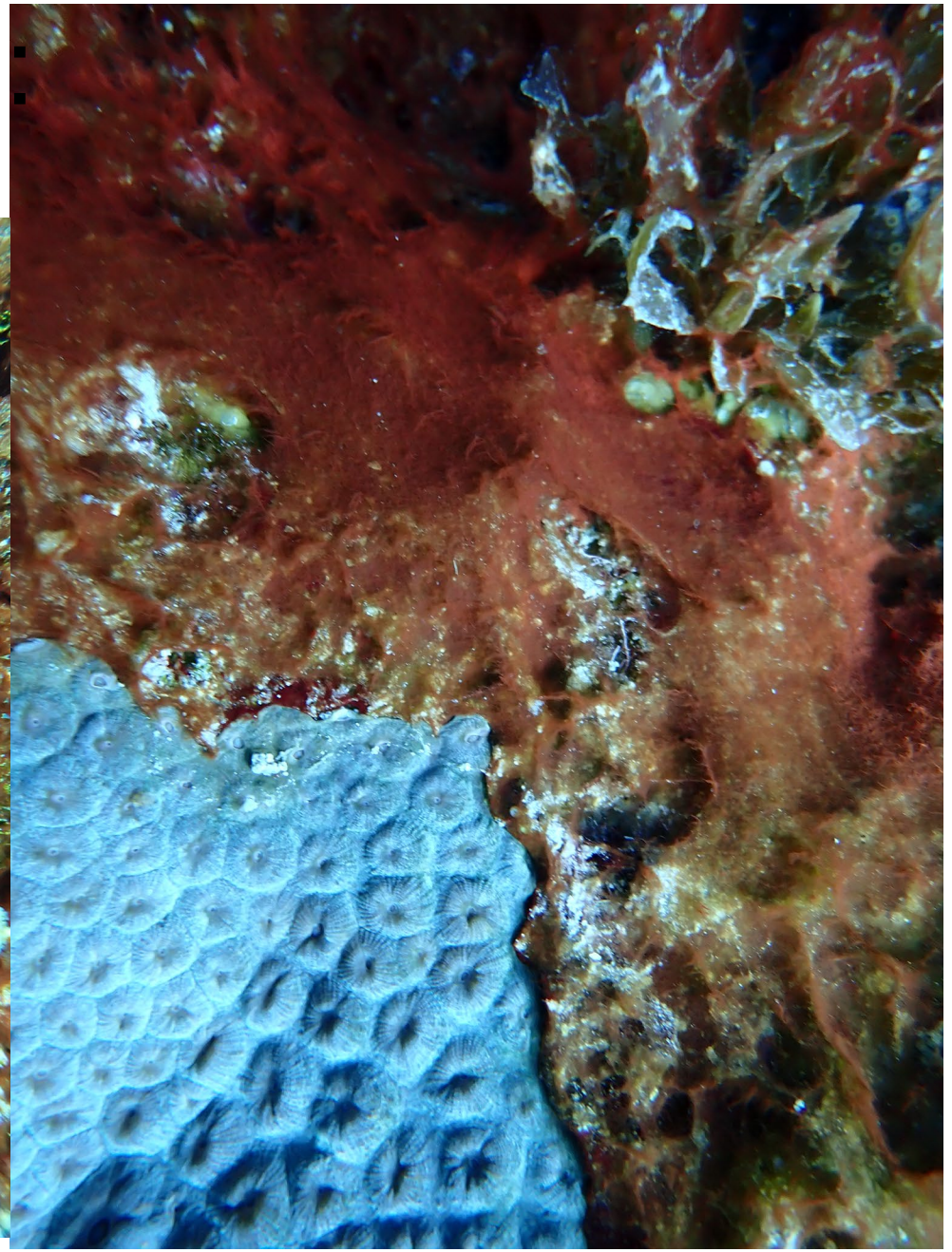
Rivularia

Spirulina

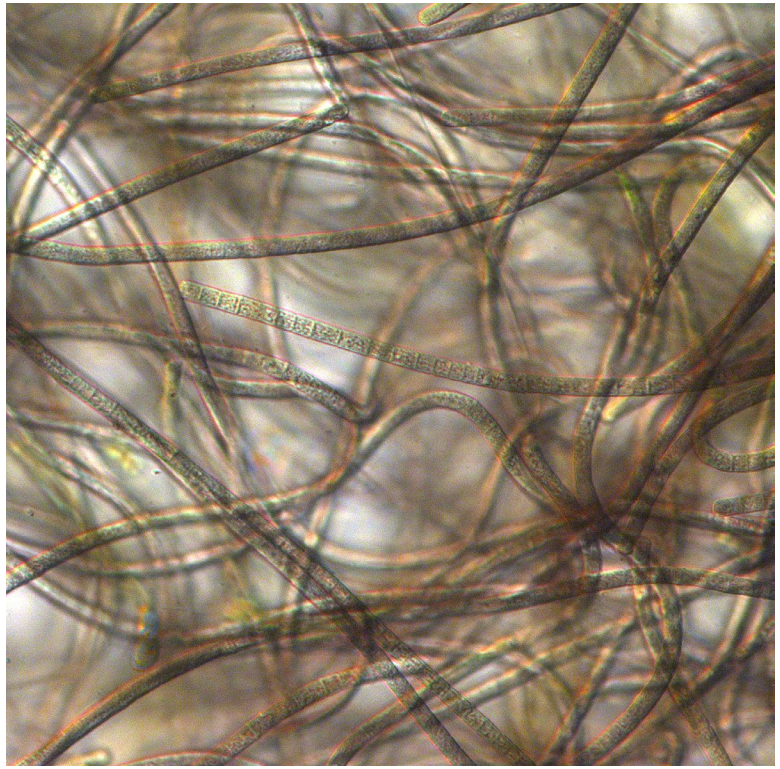
Marine Benthic CyanoHABs: Corals



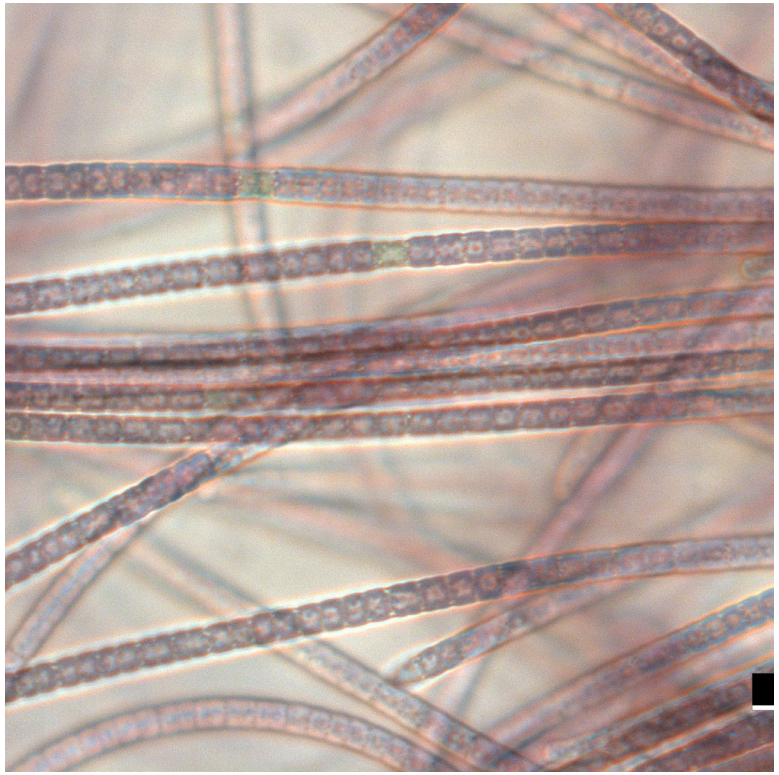




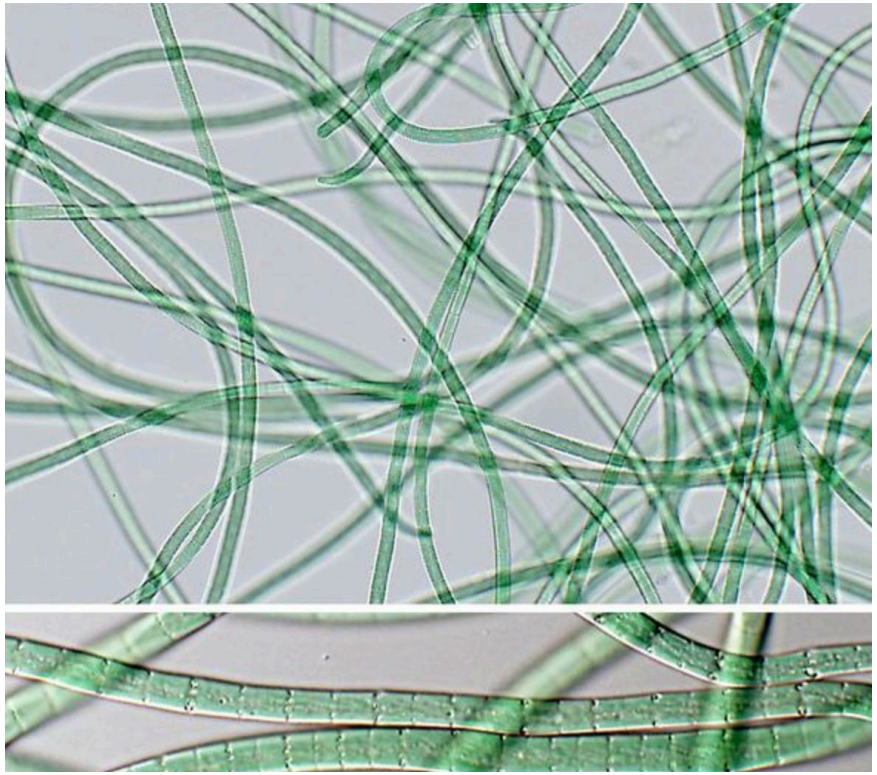
Key **Marine** Benthic Genera



Symploca



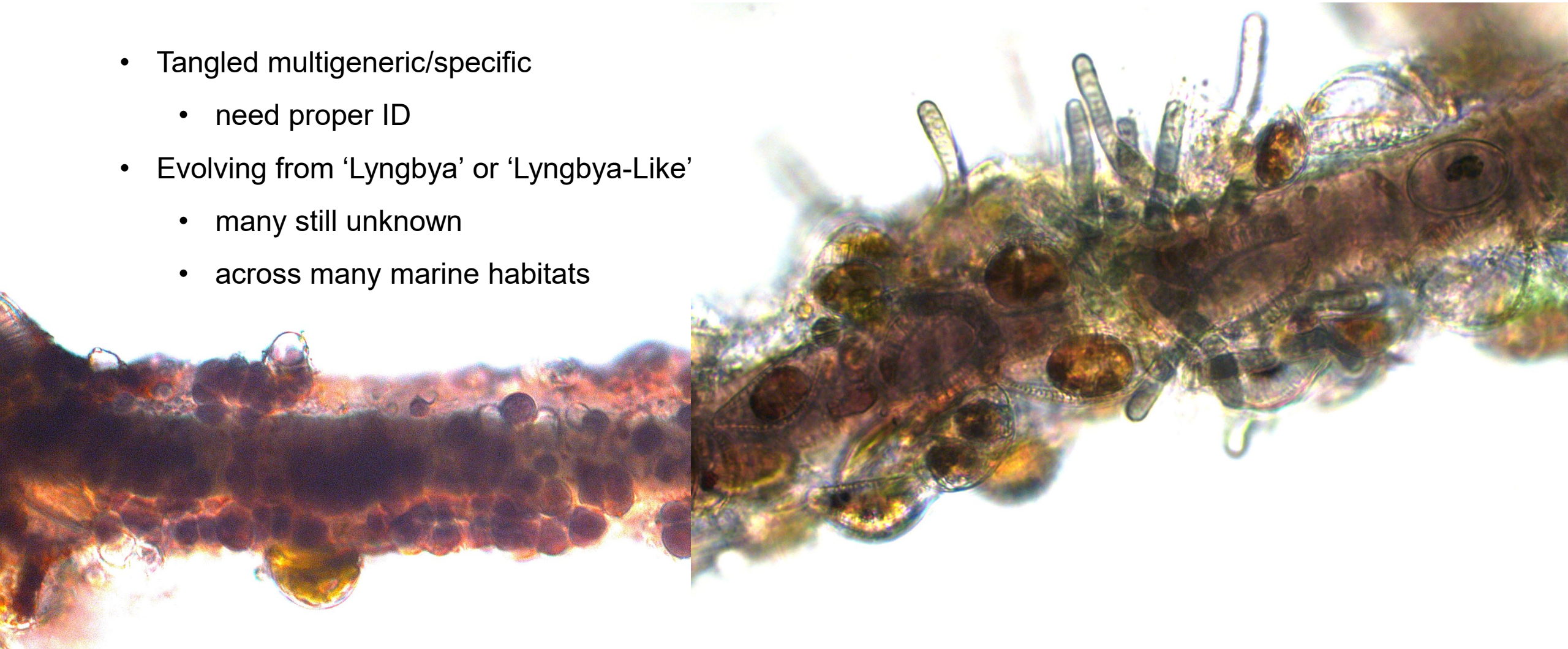
Roseofilum



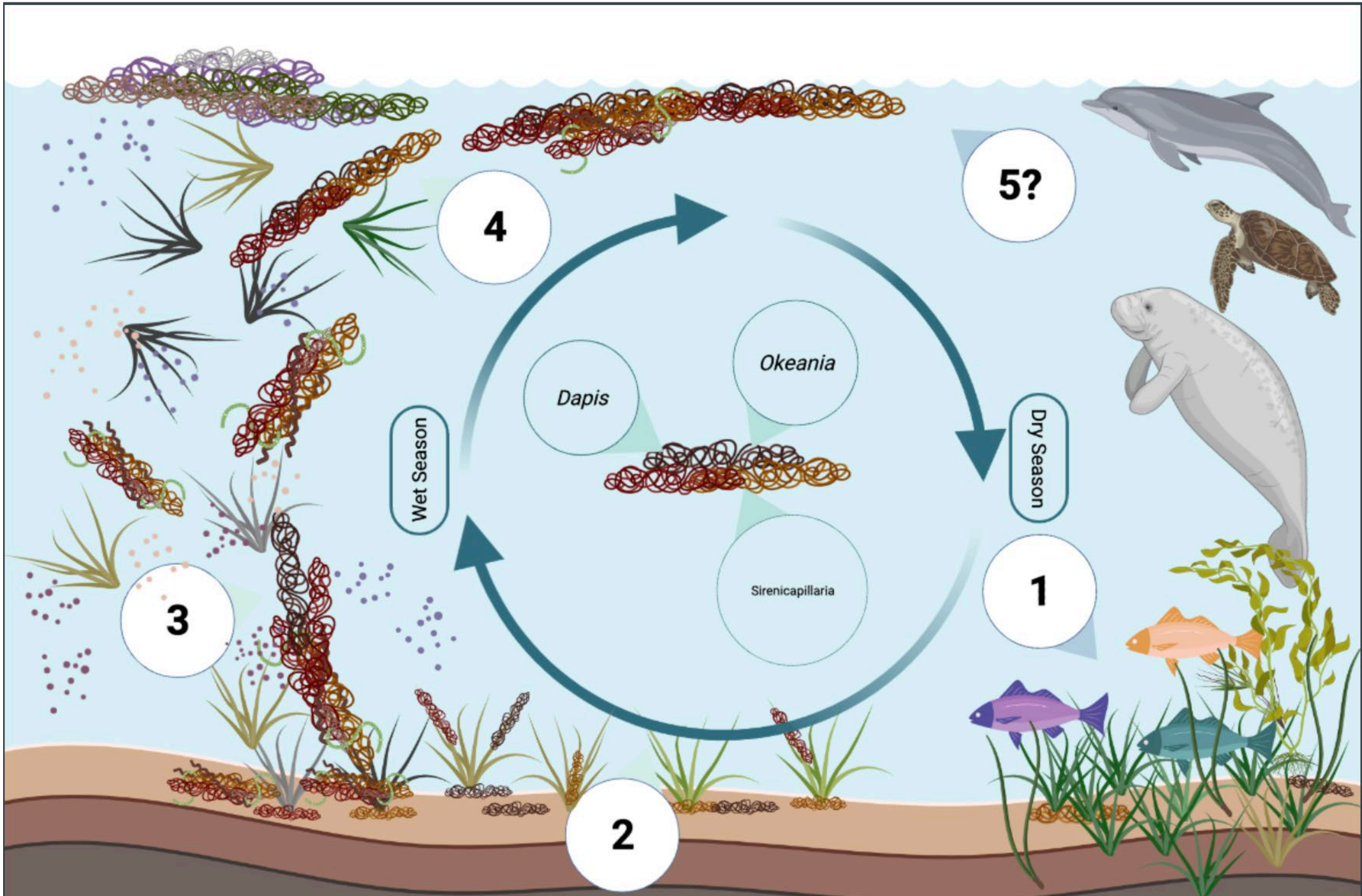
Geitlerinema

Marine Benthic CyanoHABs

- Tangled multigeneric/specific
  - need proper ID
- Evolving from ‘Lyngbya’ or ‘Lyngbya-Like’
  - many still unknown
  - across many marine habitats



Marine BCM Life Cycle

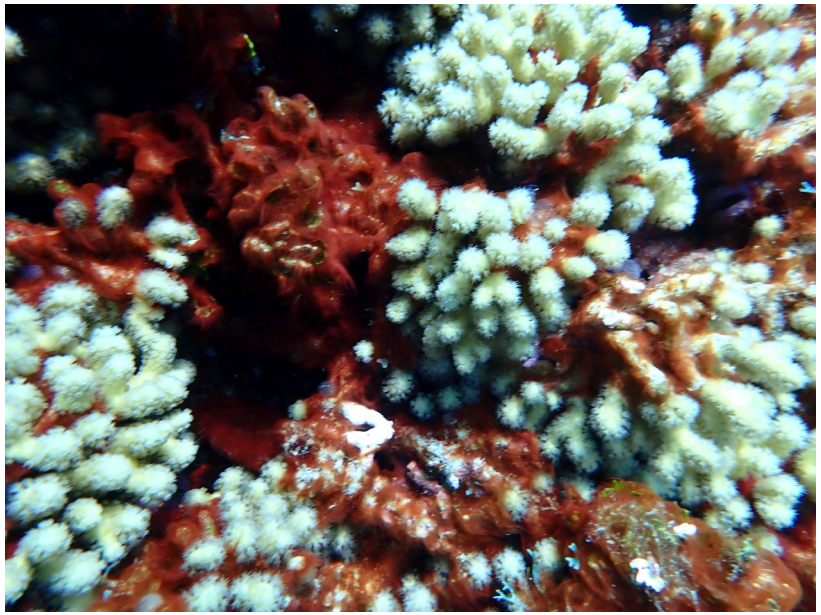


Marine mat properties

- Contain toxins
  - Anatoxin (ATX)
  - Saxitoxins (SXT)
  - Microcystins (MCs)
  - Lyngbyatoxins
- Co-occurring organisms
  - Pathogenic bacteria
  - Micro Euks
- Decomposition
  - Low DO, noxious odors, toxin release

Marine mat properties

- Secondary compounds
- Many unknown
  - Identity and function
- Just beginning to discover



1-heptadecene
Aeruginoside
Aeruginosin
Anabaenopeptin
Anaclyclamide A
Curacin A
Cyanopeptolin
Erdasporine
Geosmin
Hapalosin
Hexose-shinorine
Malyngamide
Meroclyclophane
Micropeptin
Microviridin
Nocuolin A
Nostophycin
Piriclyclamide
Pseudospumigins
Puwainaphycin
Staurosporine
Xenotetrapeptin

Roseofilum
BBD

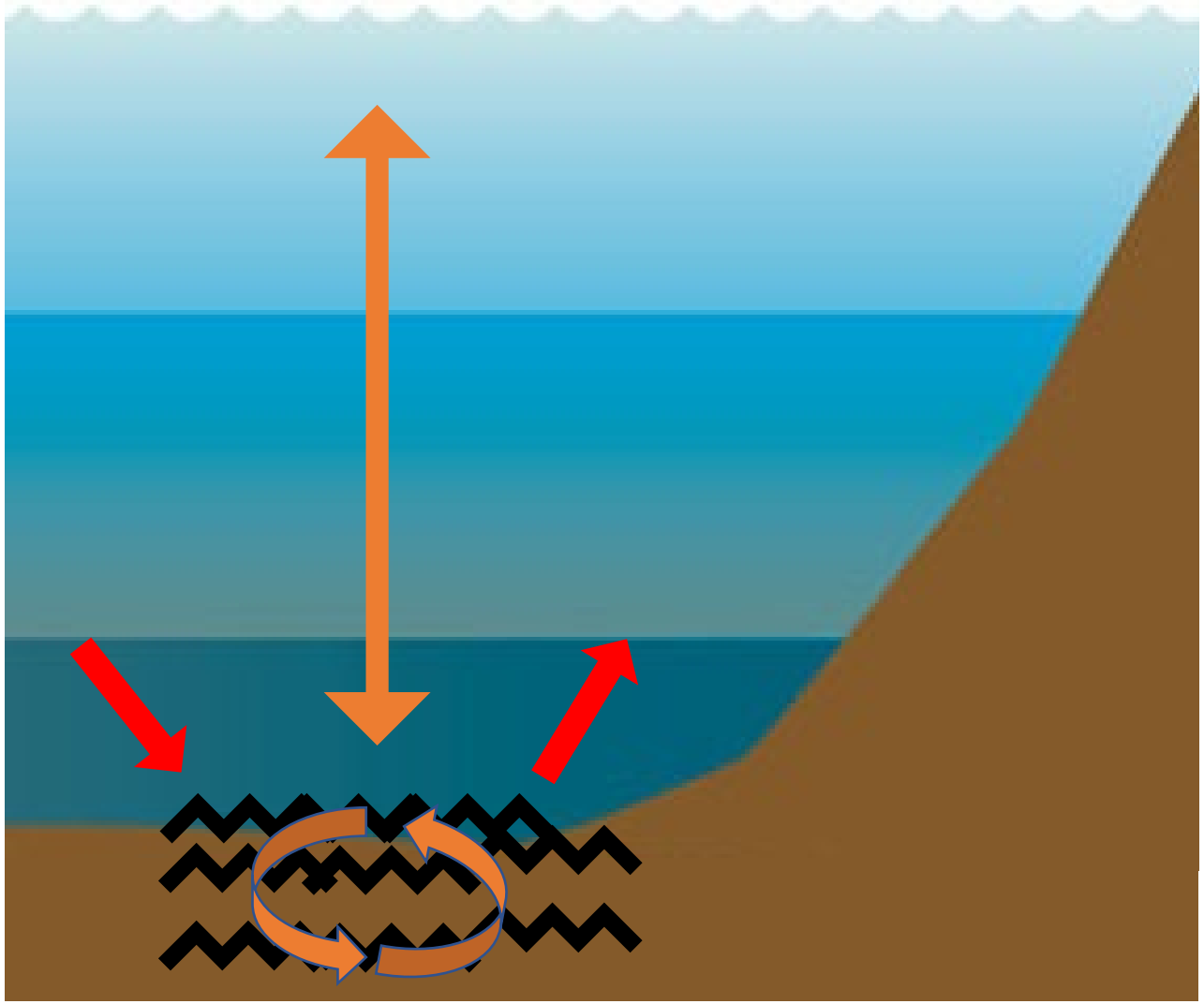
Meyer et al.
2023

Marine mat properties

- Difference between water column and benthic sampling
- Bloom microhabitat
- Productivity
- Relationship with nutrients
  - source and sink, fate

Cyanotoxins	Anatoxins	Microcystins
Water Grab Samples	4%	22%
Benthic Mat Samples	85%	68%
SPATT Samples	58%	74%

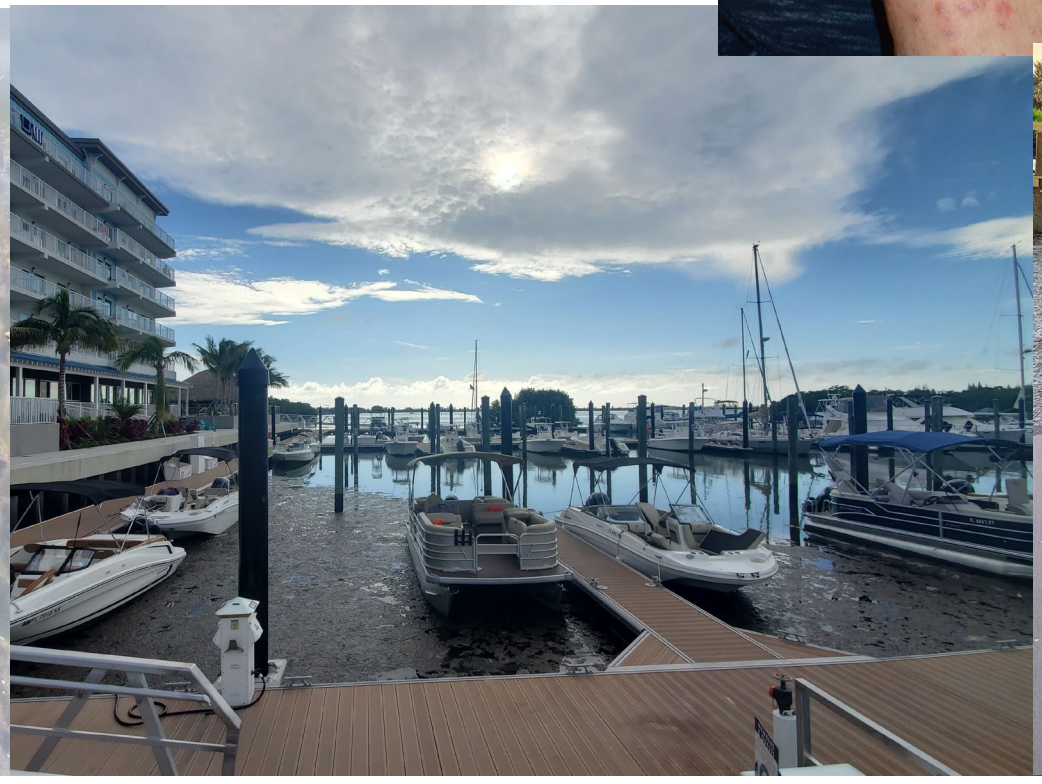
CCHAB network 2023



Issues

- Environment and human health
- Marine flora/fauna (seagrasses/manatees)
- Residences, tourism, local economies

Angela Collins



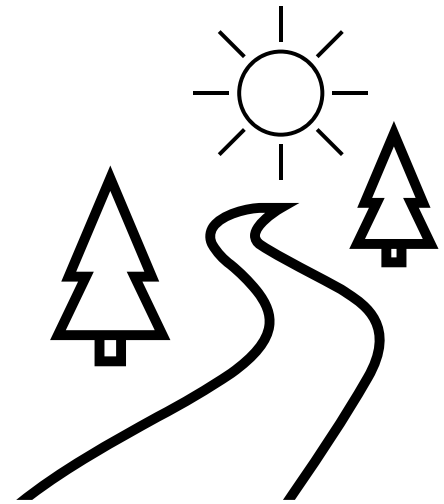
Monitoring and Response: **Marine** Benthic CyanoHABs

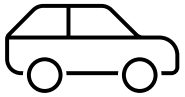
Field methods:

1. Coverage/ visual assessment
2. ***Collection*** of mat material
3. Clean mat material
4. Water column sample
5. Application of SPATTs

Monitoring and Response: Benthic CyanoHABs

- Roadmap to battling benthics
  - Freshwater and Marine
  - A lot more to discover





Who is there → What toxins → Toxin source → Spatiotemporal sampling → Drivers

Drivers
Monitoring
Mitigation
Forecasting

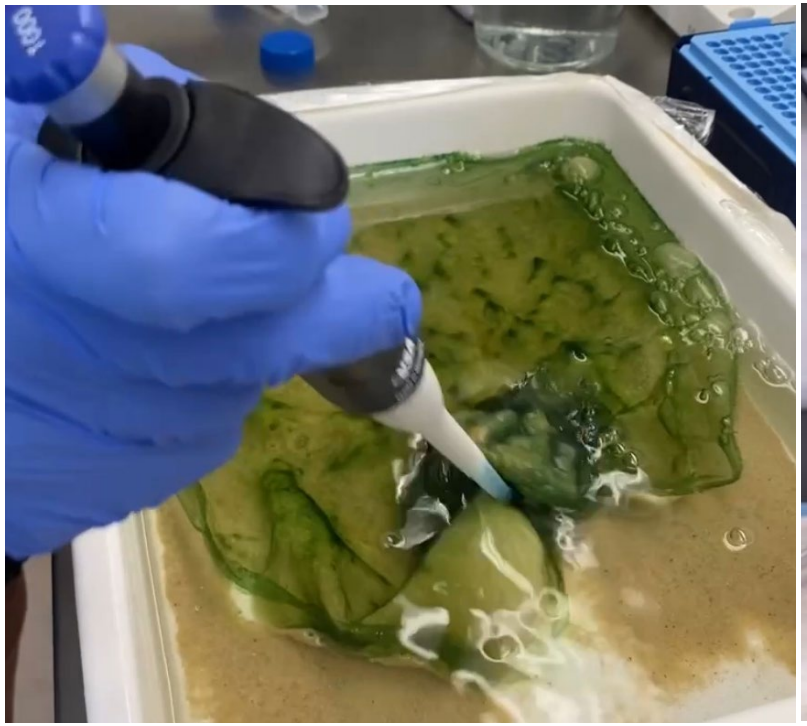
Moving Forward

- Florida Benthic HAB working group?
  - Freshwater vs. Marine (or both!)
- Funding for sustained sampling programs
- Focused Signage
- Public awareness
- Differences between marine and freshwater field methods:
  - sampling
  - scale
  - complexity
- Relationship with other blooms

Marine Mat Properties

Current and Future Prospects

- Cultures are vital! (fund culture collections!)
  - Biologically relevant rate evaluations
  - toxins and secondary compounds
  - Reproducibility



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Thank you

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@vivalgae

Marine Benthic CyanoHABs