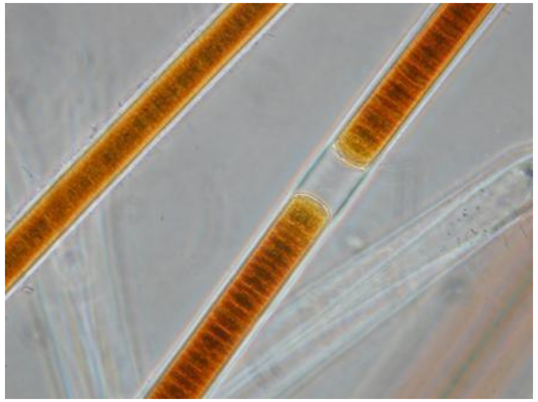
Causes of benthic cyanobacteria overgrowth in submersed aquatic vegetation (SAV) beds in Chesapeake Bay: Potential consequences for ecosystem resilience

Judy O'Neil & Jeff Cornwell

UMCES Horn Point Lab

Cassie Gurbisz St. Mary's College of Maryland

Brooke Landry & Cath Wazniak MD DNR



SAV Workgroup 14 March 2022

Outline

- What are these cyanobacteria mats?
- Some background on *Lyngbya* (*Microseira*) spp.
- MD Sea Grant study on Susquehanna Flats
- Nutrient and toxin dynamics
- Integrate parameters into model
- Input from SAV groups?

Global distribution of *Lyngbya majuscula* blooms

SAV and benthic filamentous cyanobacteria populations have been changing at global and local scales.
Globally, increasing coastal nutrient loads have led to widespread SAV (and seagrass) loss across ocean bioregions (Waycott et al. 2009; Dunic et al. 2021).

Potential Chesapeake problems?

Lyngbya spp

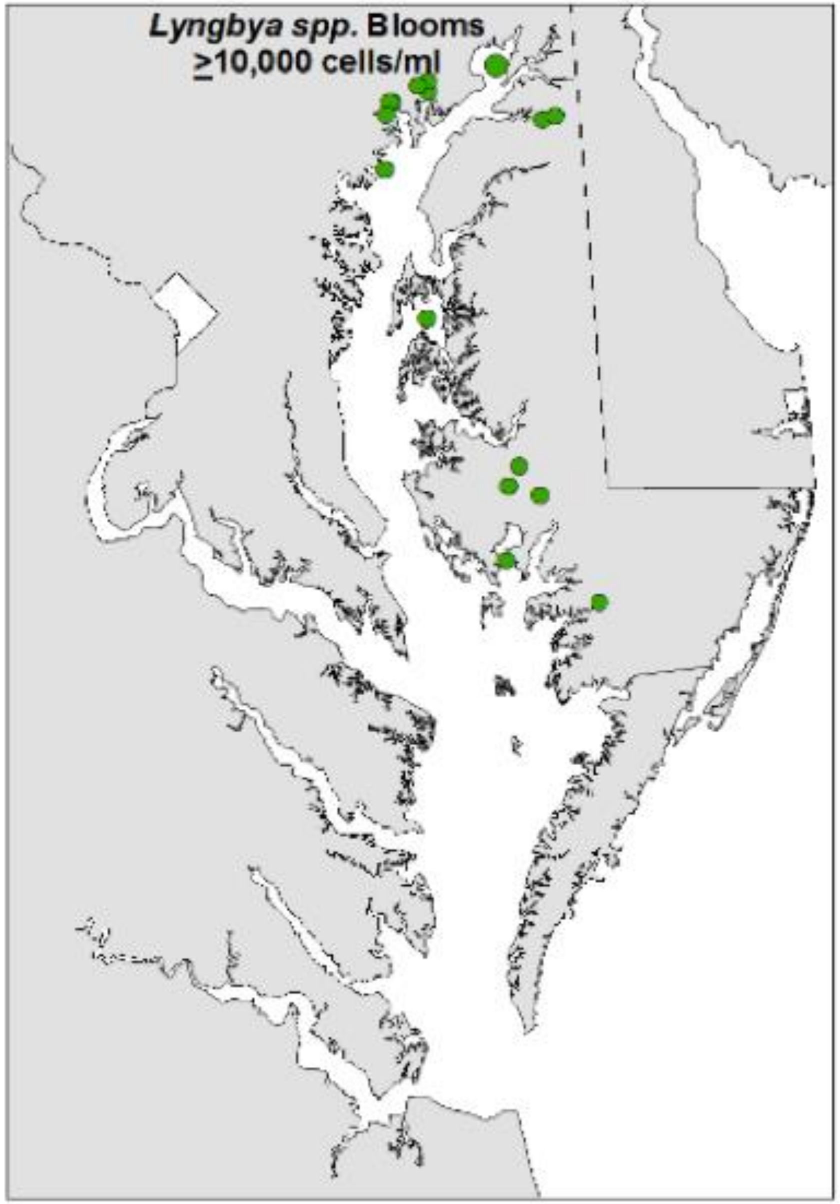
Lyngbya spp. Cells that make up the colonies of this filamentous cyanobacteria are characterized by cells ~30 to 40 µm and 5 µm thick, and a thick, sheath.

O'Neil et al. 2012

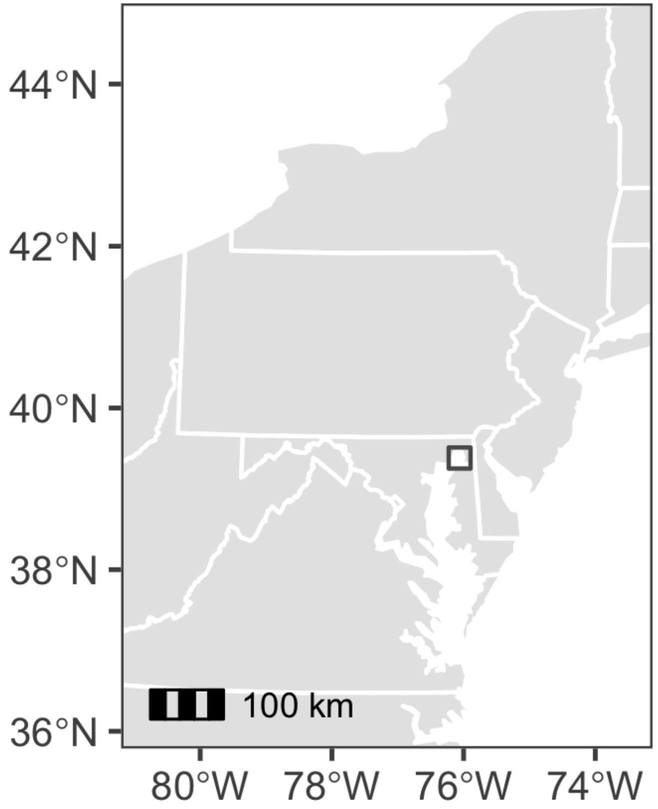
- Cyanobacteria have species that exist across the salinity spectrum from fully fresh to full marine.
- Attaching to seagrasses, forming mats, but also floats in the water column and can exist as single filaments.
- The toxins produced by *Lyngbya* vary extensively by species, and environmental conditions but include neurotoxins and dermatitis producing agents in many world regions, including Florida (Osborne et al. 2001);
- To date there have not yet been any definitive human health issues in the Chesapeake region, although some anecdotal reports…

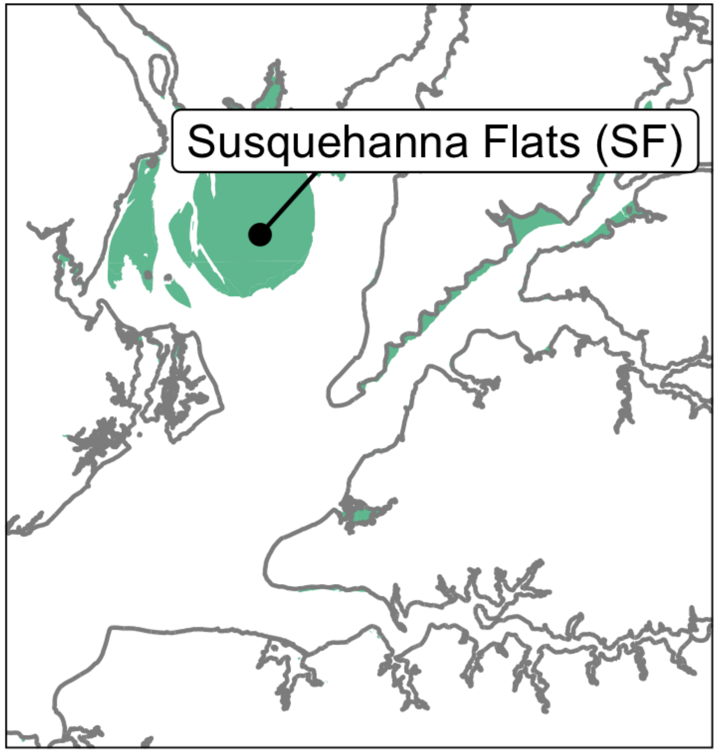
Lyngbya in Chesapeake

- Map of *Lyngbya* blooms in CB (MD DNR and ODU monitoring data 2000-2014).
- Blooms defined as more than 1,000 cells/ml or mats observed.
- First identified as *Lyngbya wolleii* overgrowing SAV on the Susquehanna Flats
- Taxonomy in flux- renamed *Microseira wollei* (need molecular confirmations from these samples
- Mixed assemblage including *Oscillatoria etc.*



Study Site Susquehanna Flats

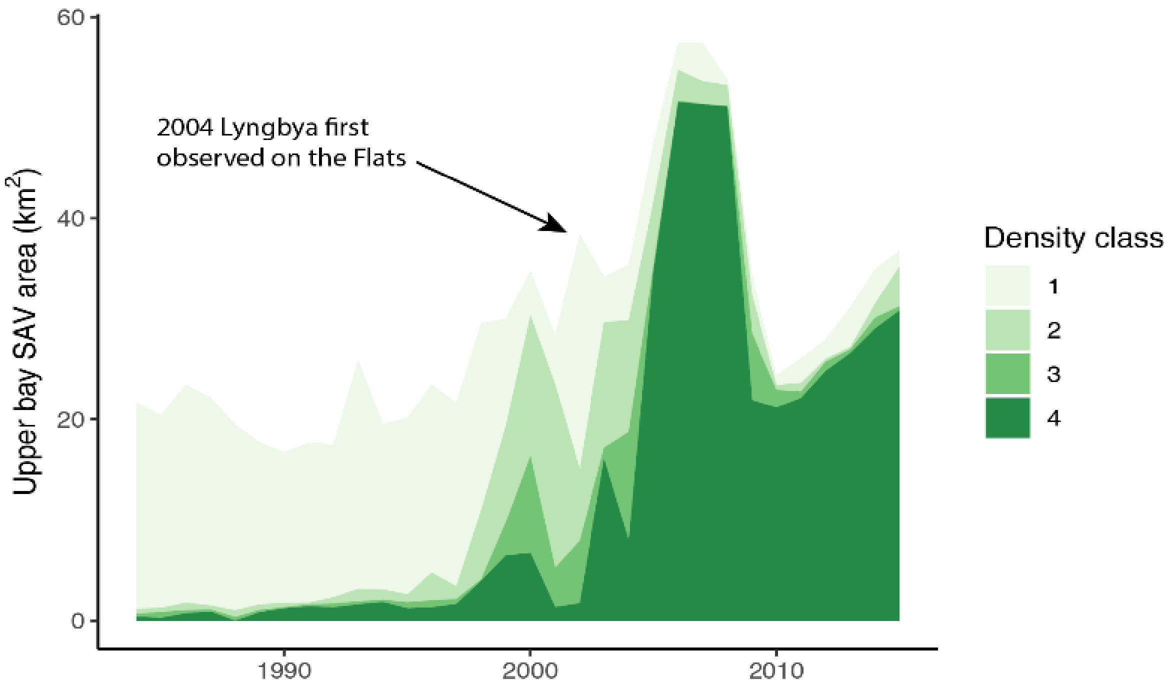




- tidal fresh head /oligohaline portion of Chesapeake Bay, at the mouth of the Susquehanna River (~50 km², 1 m average depth).

SAV recovery on Susquehanna Flats

- Recovery corresponded with enhanced water clarity during an extended dry period and long-term reductions in nutrient loading (Orth et al. 2010; Gurbisz & Kemp 2014).
- These and other CB SAV resurgences have been widely publicized because they demonstrate the potential efficacy of decades-long regional nutrient management efforts.



Lyngbya in the Chesapeake

- Since 2004 *Lyngbya* found growing extensively in the Susquehanna flats regions of the Bay.
- *Lyngbya* has been found in other locations including the Potomac River and Sassafras River and other locations
- Expected that the range of this cyanobacteria will expand with climate change,
- Summer time blooms have already expanded in recent years to areas of New England (O’Neil et al. 2012).

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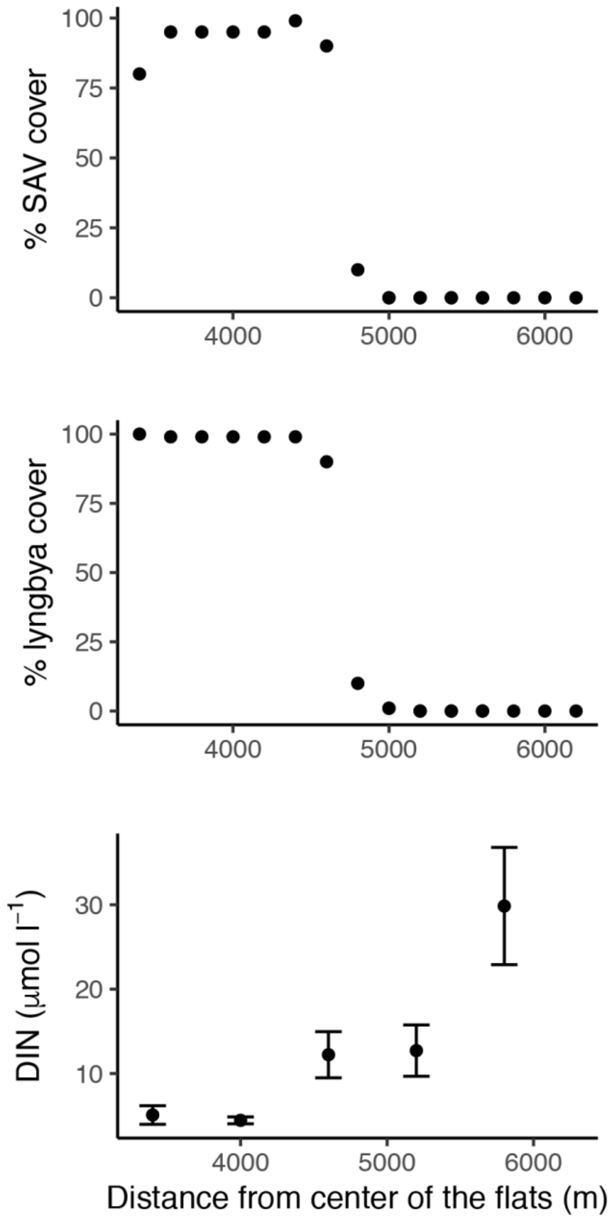
Spatial cover

- Data from 2014 showing increased *Lyngbya* coverage on the inside,
- low-N area of the SF SAV bedcompared to outer edges ofthe bed (Gurbisz unpubl.)
- Why cyanobacteria in the center?

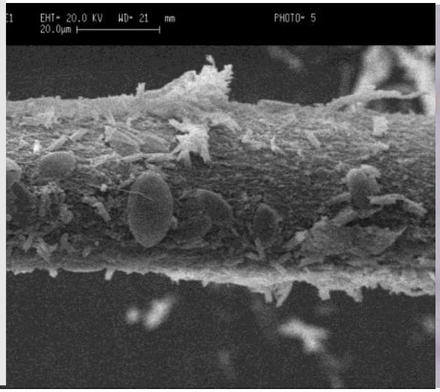


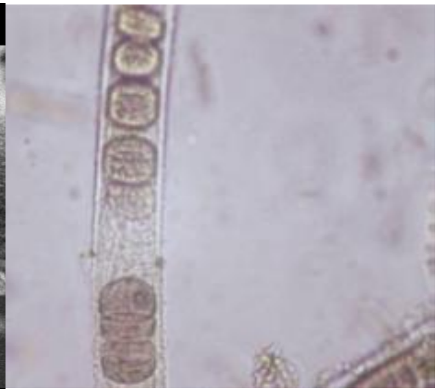
Lyngbya spp:

- Non-heterocystous cyanobacterium-
- wide salinity range fresh water: *L. wollei*
- Characteristically wide cells (~40um)
- Distinctive sheath
- Fixes nitrogen via nitrogenase enzyme, competitive advantage in N poor environment

$$N \equiv N \xrightarrow[\text{ATP}]{\text{Nitrogenase}} NH_3$$







Microcoleus lyngbyaceus
'Stinging Limu' (Hawaii)
'Fire-weed'

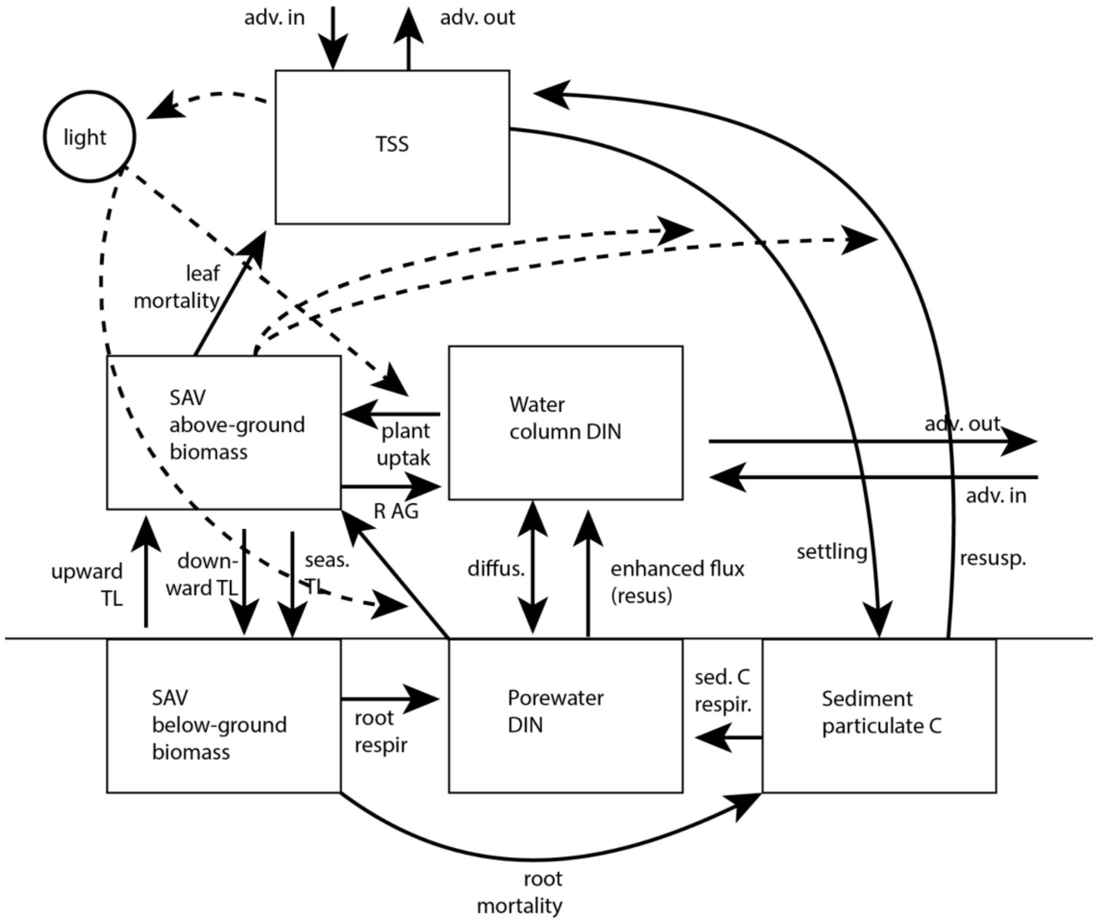
'Mermaid Hair'
'Blanket Weed'
'Smartass-weed'

How do cyanobacteria affect nutrient cycling on SAV beds?

- Most of these cyanobacteria fix atmospheric N_2 into a biologically useful form of N, they could be altering the role of SAV beds as a net N sink – seasonally turning them into a N source instead.
- Additionally, the overgrowth of benthic cyanobacteria atop SAV leads to reduced light
- availability and inhibition of gas exchange, which may decrease SAV photosynthetic rates and increase sediment anoxia and nutrient fluxes

Watkinson et al. 2005; O'Neil et al. 2012; Tiling & Proffitt 2017.

Conceptual diagram of current model state variables and processes



Gurbisz et al.

- These co-occurring cyanobacteria have not been taken into consideration in previous studies of ecological and biogeochemical dynamics on SF or other regions of CB.
- Seasonal nitrogen-fixation not incorporated into CB biogeochemical models…

Major Cyanobacterial toxins: (from O'Neil, Davis, Burford, Gobler (2012))

Toxin Group	Primary target organ in mammals	Cyanobacterial Genus
Microcystins	Liver	*Microcystis, Anabaena,, Planktothrix (Oscillatoria), Nostoc, Hapalosiphon, Anabaenopsis, Trichodesmium, Synechococcus*
Nodularian	Liver	*Nodularia*
Cylindrospermopsin	Liver	*Cylindrospermopsis, Umezakia, Aphanizomenon, Lyngbya, Raphidiopsis*
Anatoxin-a	Nerve synapse	*Anabaena, Planktothrix (Oscillatoria), Aphanizomenon*
Anatoxin-a(S)	Nerve synapse	*Anabaena*
Saxitoxins	Nerve axon	*Anabaena, Planktothrix (Oscillatoria), Aphanizomenon, Lyngbya*
Palytoxin	Nerve axon	*Trichodesmium*
Aplysiatoxins	Skin	*Lyngbya, Schizothrix, Planktothrix (Oscillatoria)*
Lyngbyatoxin-a	Skin, G.I. tract	*Lyngbya*
Lipopolysaccharides	Irritant;exposed tissue	All
BMAA	Nerve synapse	All

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Anatoxin-a(S)	Nerve synapse	*Anabaena*
Saxitoxins	Nerve axon	*Anabaena, Planktothrix (Oscillatoria), Aphanizomenon, Lyngbya*
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Toxins from Susquehanna Flats unknown…

- it is unclear whether these cyanobacteria produce harmful toxins, as documented in other geographic regions.
- Collaborating with Dr. Greg Boyer on cyanobacteria toxins
- Bioassays on effects of nutrients on toxin from cyanobacteria mats.

ESF State University of New York College of Environmental Science and Forestry

Questions to be addressed:

1) what factors are driving benthic cyanobacteria proliferation on SF and other regions of CB,

2) what effect do they have on ecosystem processes, including SAV and nutrient dynamics, and

3) are they producing toxins known to cause adverse reactions in humans or animals?

Our **objectives** are to:

1. determine what conditions support cyanobacteria growth by conducting field surveys of cyanobacteria distribution in relation to SAV biomass and environmental variables at SF and several additional sites in tidal fresh and oligohaline tidal tributaries,

2. determine the effects of environmental variables: (nutrients, light etc.) on cyanobacteria production, nutrient uptake, N_2 fixation, and potential toxin production by conducting lab bio-assay experiments

3. assess the effects of cyanobacteria on biogeochemical rate processes and SAV via nutrient flux experiments and ecological simulation modeling exercises, and

4. determine whether toxins are present in cyanobacteria tissue and the water column.

Three-pronged approach:field surveys, laboratory experiments, and ecosystem simulation modeling.

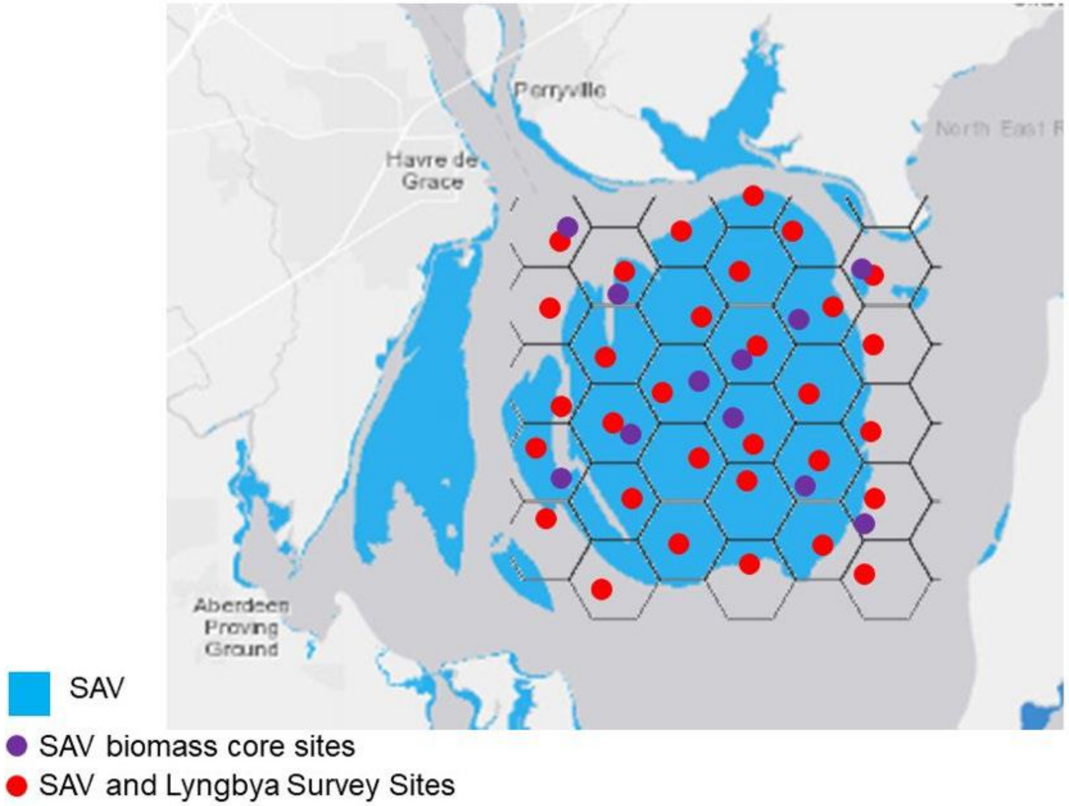
1) Field surveys to explore how *Lyngbya* presence corresponds with environmental conditions within and across sampling sites and test for the presence of toxins.

2) Laboratory experiments are designed to determine what factors control *Lyngbya* growth and how *Lyngbya* affects local nutrient dynamics from a process-based perspective.

3) The simulation modeling exercise will use rates and parameters determined via the field surveys and laboratory experiments to assess how *Lyngbya* affects SAV production and resilience.

Field Surveys

1. Seasonal spatial surveys to determine the extent of cyanobacteria abundance in relation to SAV abundance
2. environmental conditions on the SF and ***several additional sites*** in the tidal fresh and oligohaline reaches of CB tributaries.
3. The SF survey will contain ~30 sampling stations (with 10 substations for SAV/ *Lyngbya* biomass/coring)



Environmental parameters measured

- Vertical profiles of salinity, temperature, dissolved
- oxygen, pH, temp and PAR.
- In addition, water samples will be collected for nutrient, chl *a*,
- TSS, and toxin analysis
- Flux measurement

- Bioassays:

Additions of N and P and N+P

With measurements of:

-*Lyngbya* growth

-Nutrient uptake (N-15)

- Nitrogen fixation
- Toxin content

Role of SAV folks?

- Let us know where and when you see filamentous cyanobacteria at your sites…
- Happy to collaborate on other parameters of interest etc….
- Engagement with stakeholder groups?

Summer field trips 2022:

- Early season: June 6-10
- Later season: July 25-29

- PLUG FOR **World Seagrass Conference & International Seagrass Biology Workshop-** including field trip to Susquehanna Flats

Thanks….
Questions?

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