Assessment of *E.coli* and Microcystins in *Cladophora* Mats in the Nearshore Waters of Grand Traverse Bay, Little Traverse Bay, and Saginaw Bay

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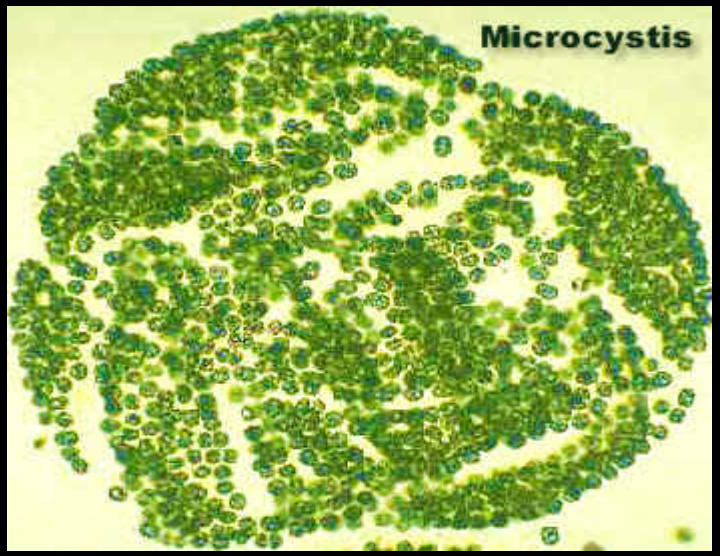
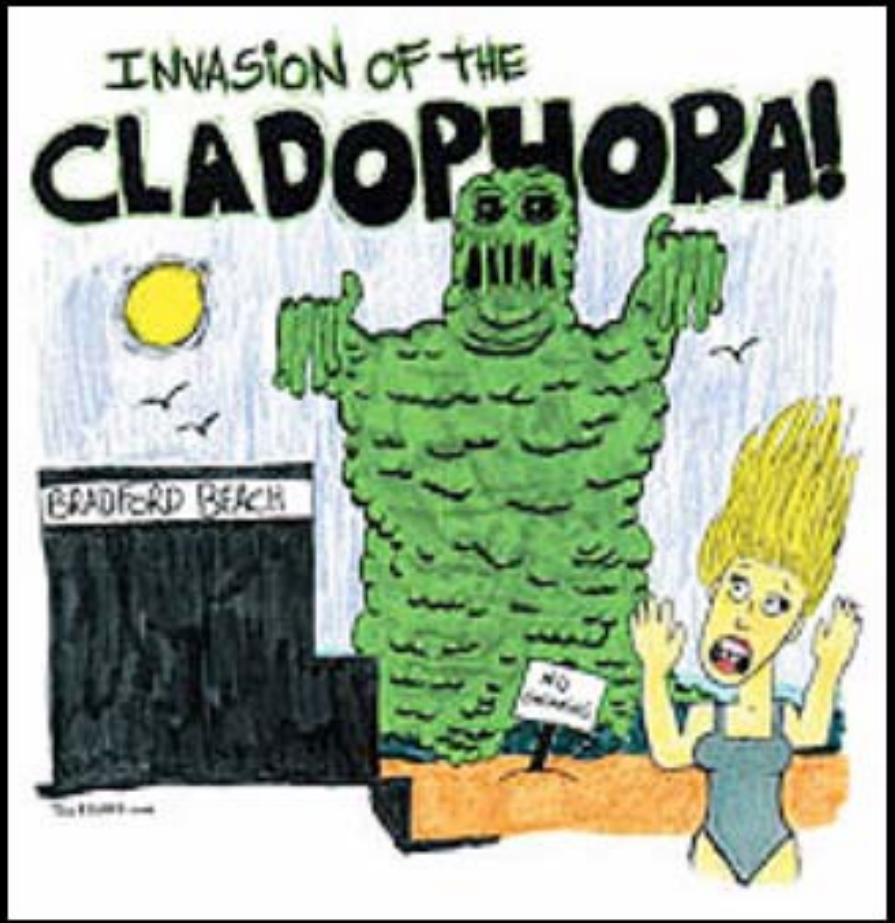
Harmful Algal Blooms vs Cladophora

- Blooms tend to stay in water column
- Can produce liver, skin, or nervous system toxins
- Blooms not known to harbor E. coli
-
- Peak growth often occurs late summer
-
- When blooms die, sink to bottom, often responsible for depleted oxygen on bottom
- Colonial (circular cells)
- Grows in response to nutrients, light
- Planktonic (passively moves in water)
- Microalgae (microscopic cells)
- Zebra mussels promote by selectively filtering other algae, leaving toxic cyanobacteria and rapidly recycling nutrients that stimulate growth

- Can wash up on shore in mats
- Not known to produce toxins
- Mats (on beach and in water) have contained E. coli
- Peak growth often occurs early summer
- When blooms die, float to surface, final location depends on wind and water circulation
- Filamentous (end to end), branched
- Grows in response to nutrients, light
- Benthic (bottom dwelling)
- Macroalgae (grow up to 3 ft long)
- Zebra mussels promote by providing substrate for growth and providing localized nutrient source

Cyanobacteria vs *Cladophora*





Source: "Unknown"

Why Saginaw Bay

Basins of Lake Huron

- Total area = 58,000 km^2
  - Main: 67%
  - Georgian Bay: 24%
  - North Channel: 4%
  - Saginaw Bay: 5%

5% area 50% commercial fish production

Cladophora

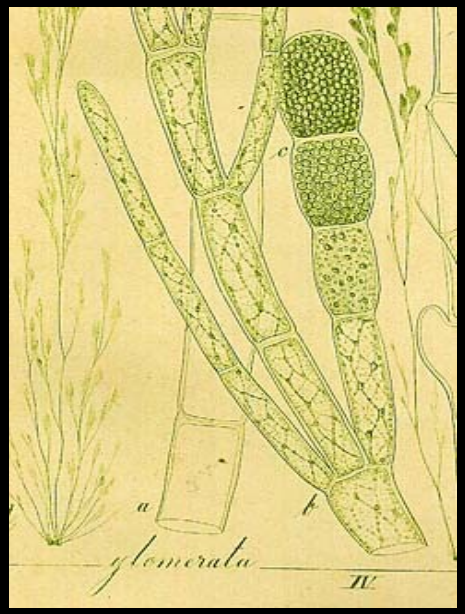
- Worldwide distribution with freshwater and marine species
- Appearance is often variable dependant on age of the alga or the surrounding environment (phenotypic plasticity)
- May appear as long streaming filaments or short tuffs, attached to rocks or as loose floating filaments (mats)
- Present in the Laurentian Great Lakes before the 1950's (Prescott 1951)

Lake Erie early June

Lake Ontario late June

Cladophora in the Great Lakes

- ***Cladophora*** **is a filamentous green alga, first identified in Lake Erie in 1848.**



http://www.mlswa.org/UnderWaterPlantGuide/cladophora.htm

- **Windrows of** ***Cladophora*** **were known from Lake Erie in the 19th century.**

Taken from Taft & Kishler, 1973.
Provided by M. Auer

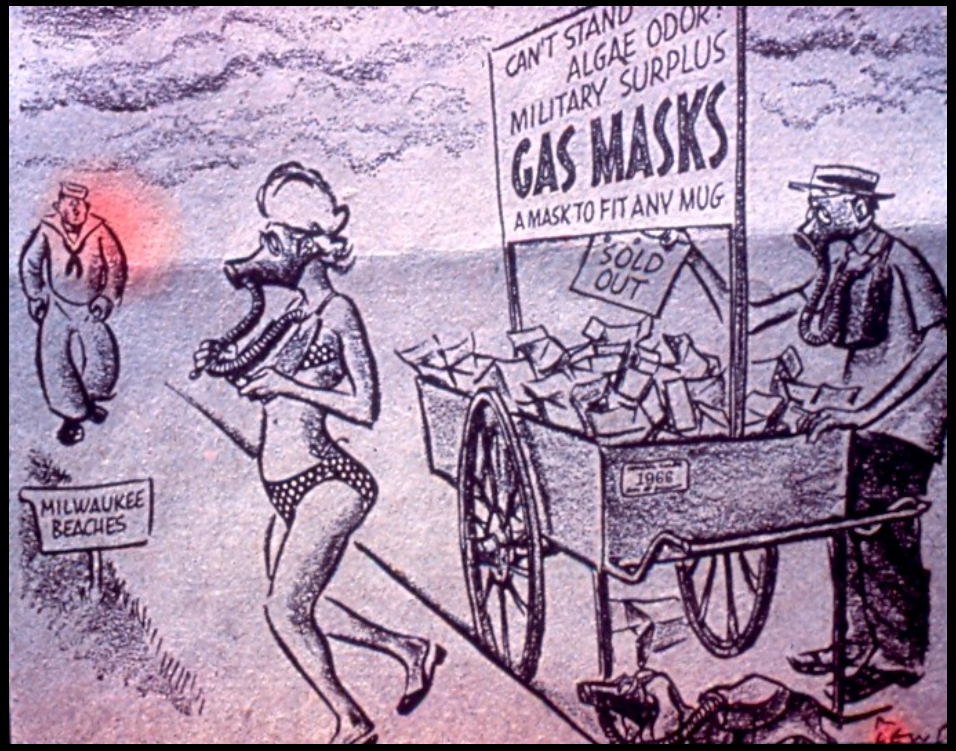
Cladophora in the Great Lakes

- **Nuisance growth of *Cladophora* was prevalent in Lake Ontario by the late 1950s.**

Auer et al. 2007 SOLEC ppt

Cladophora in the Great Lakes

- **Problems were also encountered in Lake Michigan.**



Provided by Marty Auer; original courtesy of Daniel F. Jackson.

Cladophora in the Great Lakes

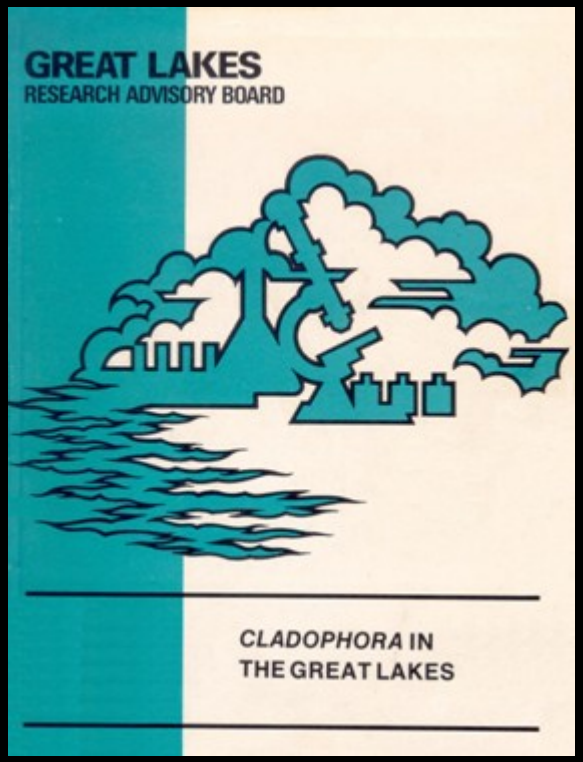
- **Great Lakes Water Quality Agreement**

  Five of the six goals set forth under Annex 3, Control of Phosphorus, relate to nuisance algal growth.

Image by Richard Lorenz

Cladophora in the Great Lakes

- **Awakening**



"Cladophora in the Great Lakes"

H. Shear and D.E. Konasewich

Great Lakes Research Advisory Board
International Joint Commission, 1975

"I wish I could inundate you with pictures … pictures of bikini-clad young lovelies standing waste deep in certain waters … ten pounds of green stringy material festooning their otherwise delightful limbs … the only stimulus needed to complete your abhorrence of the situation would be the accompanying flies and pig-pen odor which go hand-in-hand with rotting protein. Gentlemen, Cladophora is a big problem.

Carlos M. Fetterolf, Jr.
Executive Secretary, Great Lakes Fisheries Commission

Auer et al. 2007 SOLEC ppt

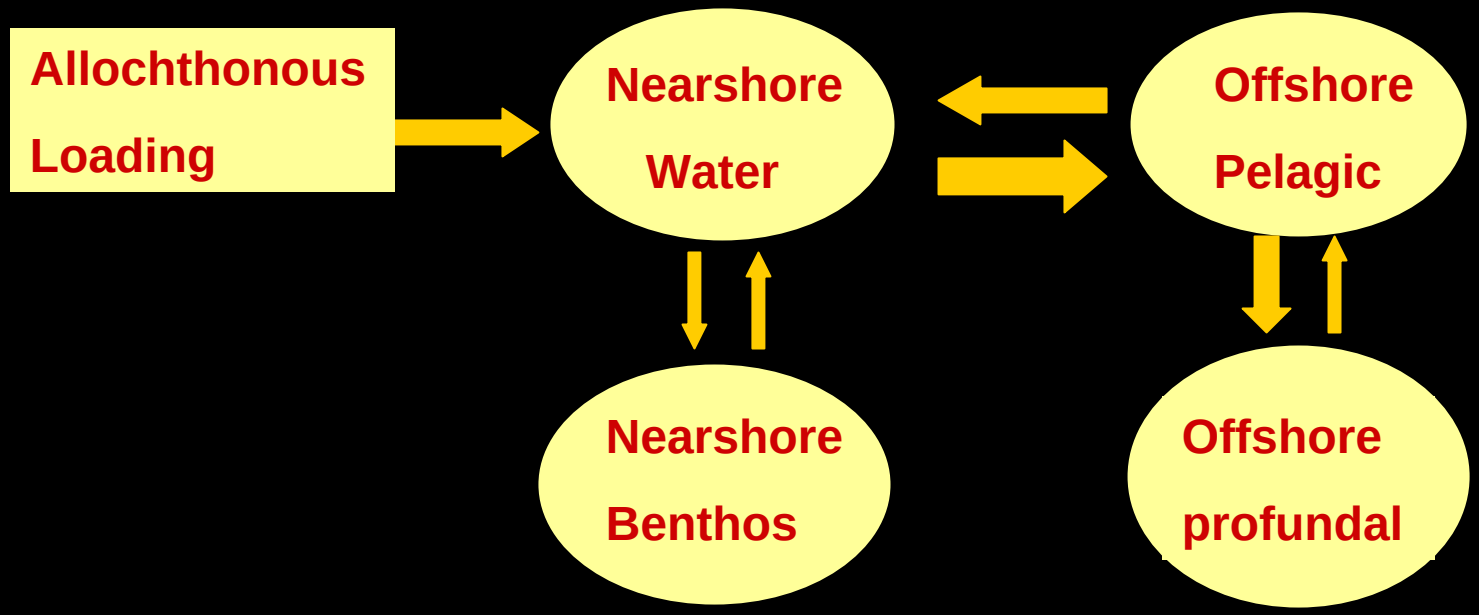
Zebra and quagga mussel impacts

- Prodigious filter feeders
- Dreissenid mussels have altered substrates transparency, food web
- Resulted in extirpation of native mussel, altered substrates, increased macrophytes and Cladophora
- Reduced benthic diversity
- Mussels are here to stay!

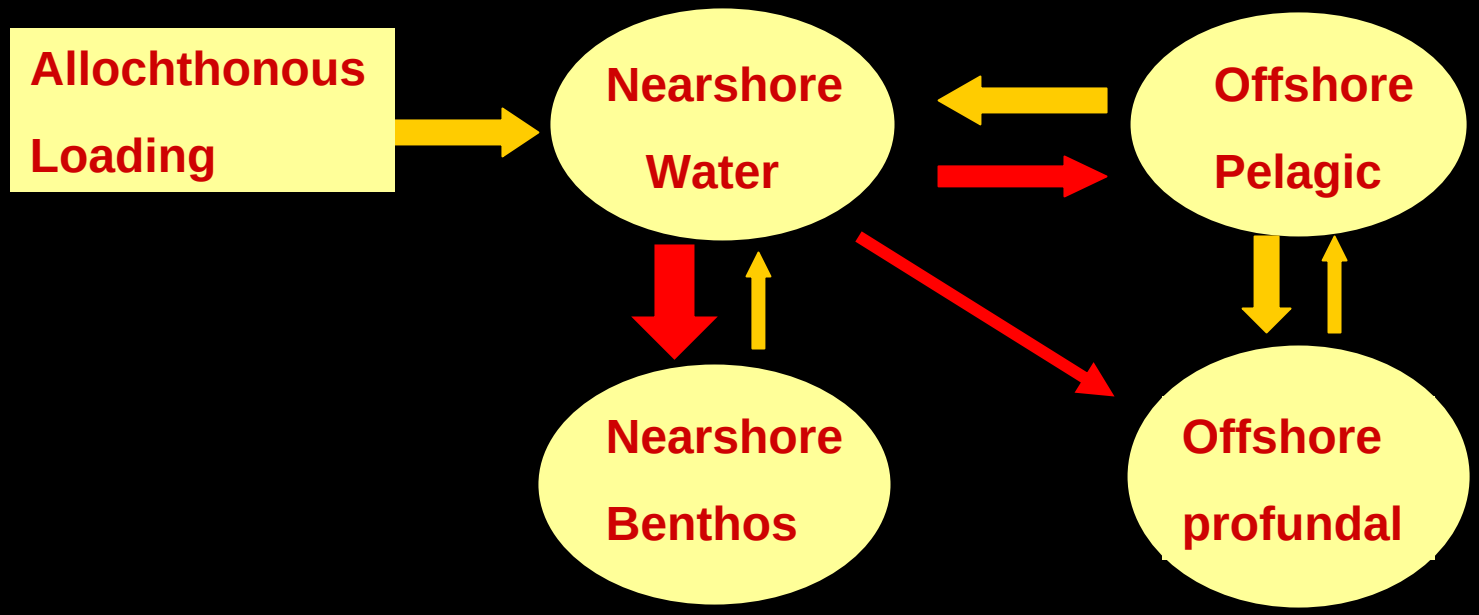
The Nearshore Shunt

Hecky et al. (2004) describe the role of zebra mussels as ‘ecosystem engineers’, creating a nearshore phosphorus shunt that can stimulate *Cladophora* growth.

Image from http://www.glwi.uwm.edu/research/aquaticecology/cladophora/



Before zebra mussels the nearshore was a zone of limited retention and a source of nutrients for the offshore pelagic

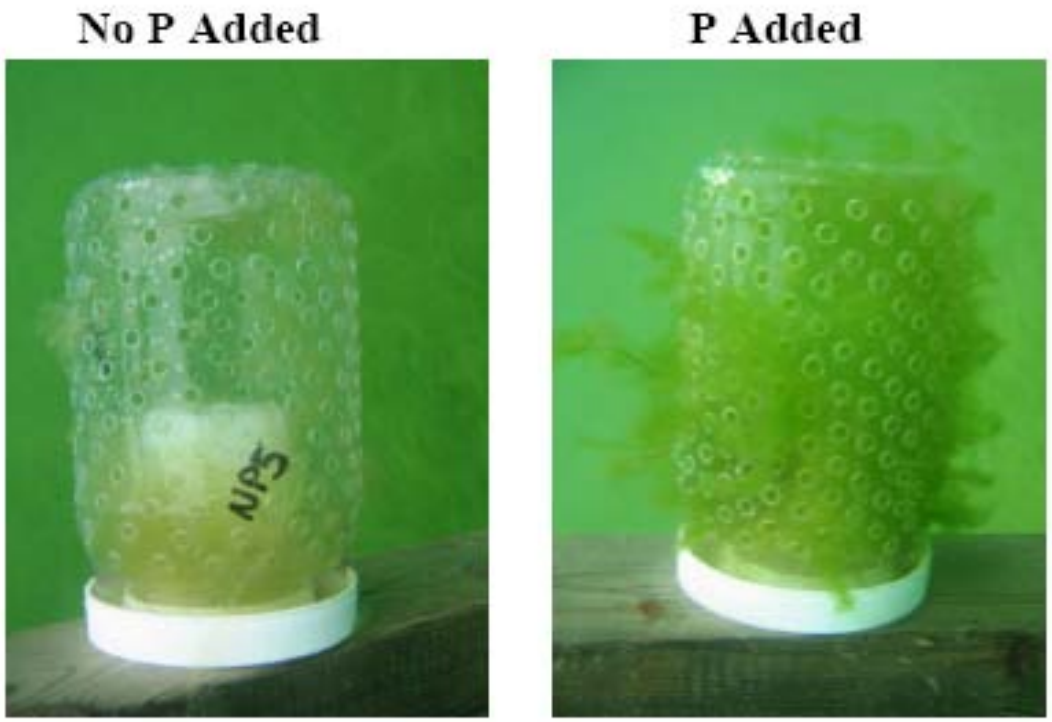


After zebra mussels colonization, the nearshore is more retentive of nutrients, and timing and mechanism of release are altered

Cladophora Growth Requirements

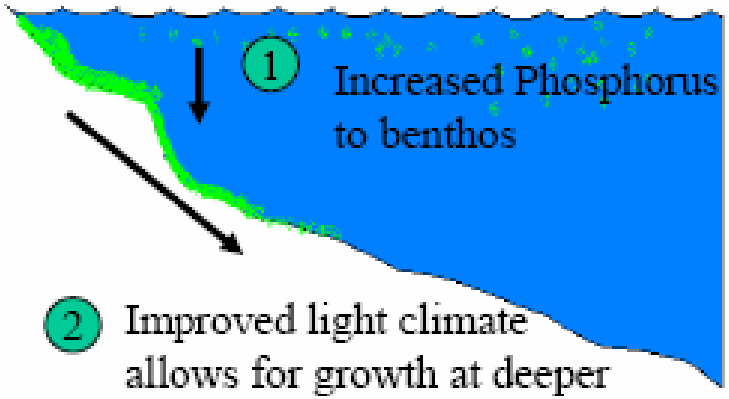
- Benthic algae requires hard substrate
- Common in highly eutrophic waters
- High light intensity
- Moderate temperatures 18-24°C
- Moderate tolerance for currents and wave action
- Biomass associated with anthropogenic P

Phosphorus Enrichment Studies



Higgins et al 2006

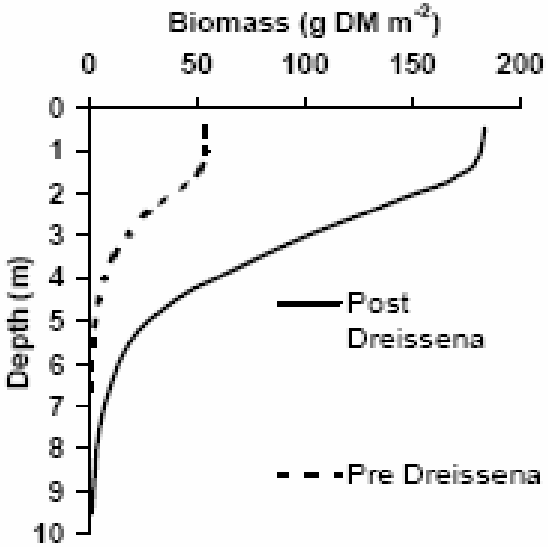
Dreisenna influences on *Cladophora* growth



-Increase in SRP + 2ug/L

-Increase water clarity 0.1 kPAR (m^{-1})

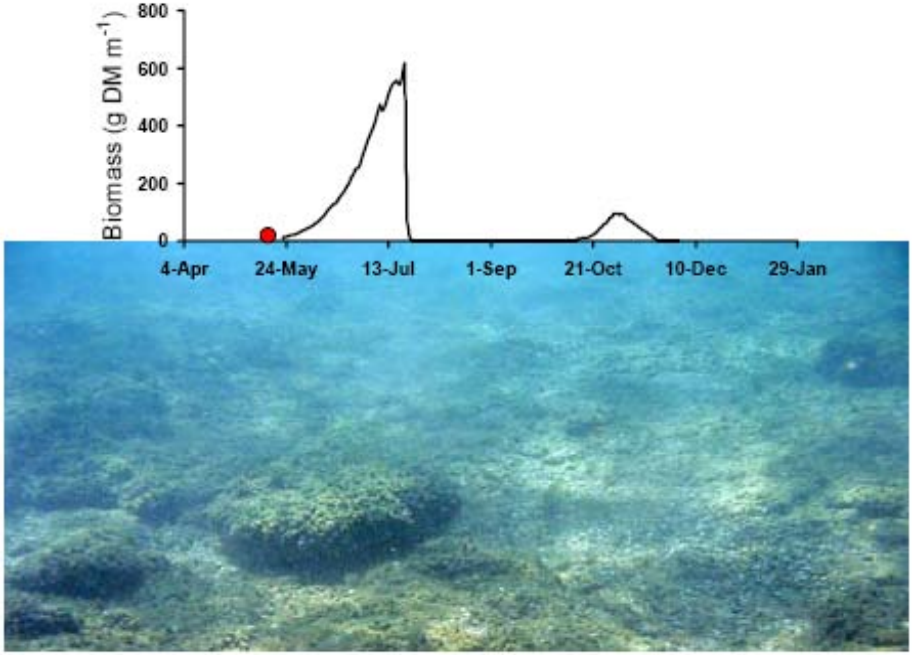
(Markarewicz et al. 2000; Higgins et al. 2005)

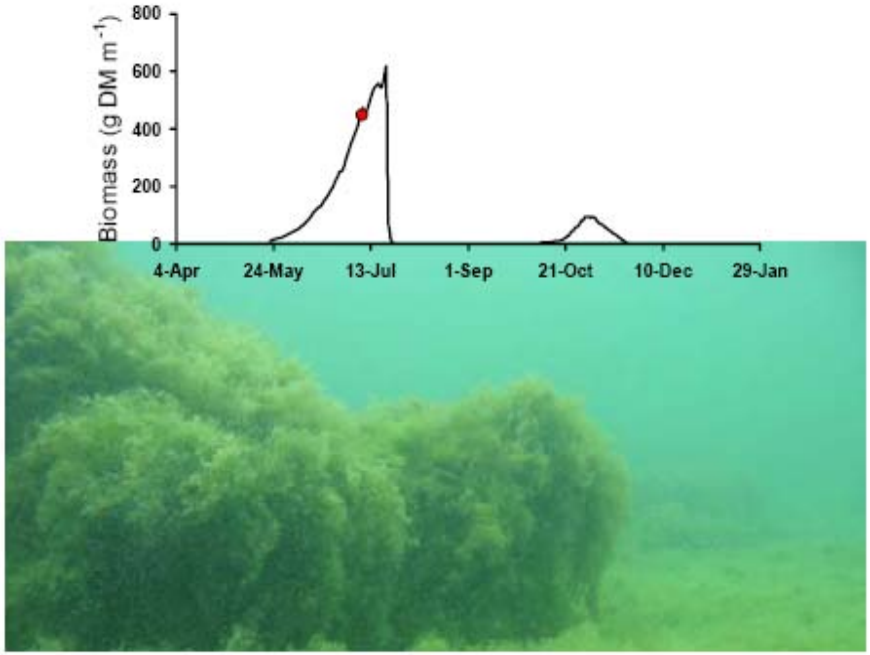


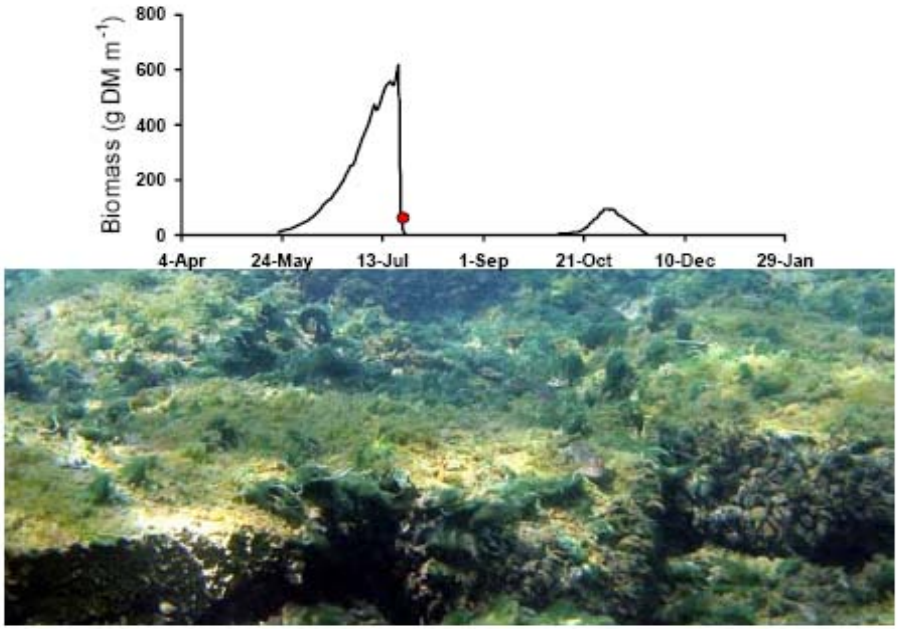
Model predicts 4X increase

Post *Dreissena*

Higgins et al 2006







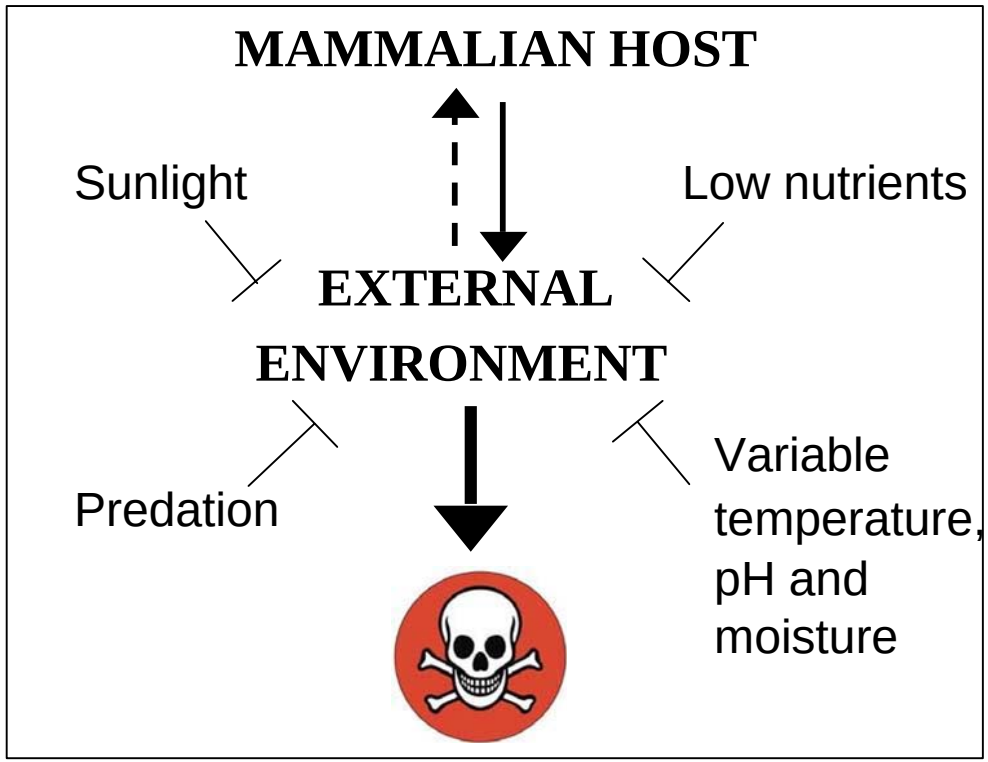
Lake Erie Cladophora Growth
3m offshore
(Higgins 2006)

The Link Between *Cladophora* and *E. coli*

- Cladophora wash ashore and carry with them large numbers of zebra mussels and small crustaceans that shelter in the algae
- The mussels and crustaceans may contribute to the odor as the decompose or become food for waterfowl
- The attraction of waterfowl results in deposition of fecal material that contains high levels of *E coli*.

E.coli Outside the Host — Secondary Habitat

- A battle for survival
- Low rate of survival
- Low probability of colonizing a new host

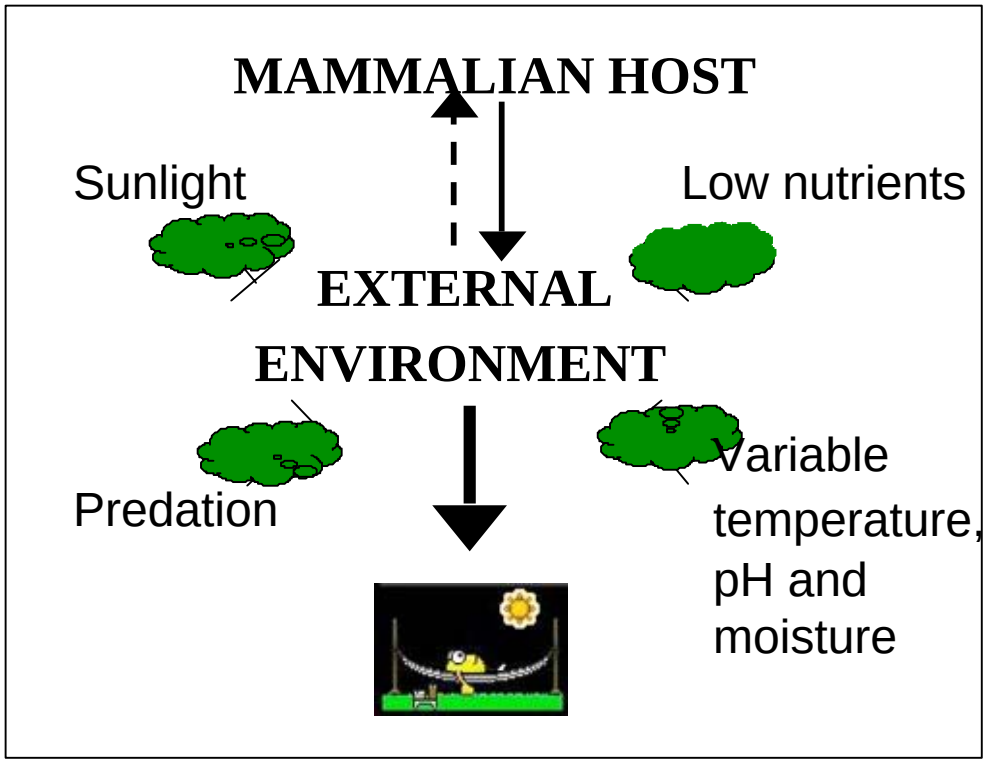


Adapted from Winfield and Groisman. 2003.

Kleinheinz and Englebert 2004

Potential *Cladophora* impact on *E.coli* Survival

- Block UV light
- Increased nutrients
- Moisture retention
- More stable microbial community
- Changes the minimum at each site to favor growth and survival!



Adapted from Winfield and Groisman. 2003.

Kleinheinz and Englebert 2004

Potential Sources of *E. coli*

- CSOs, SSOs, and septic systems
- Urban and agricultural runoff
- Waterfowl, domestic pets, and wildlife
- Sand, algae, and interstitial waters

250,000-500,000 CFU/100 ml

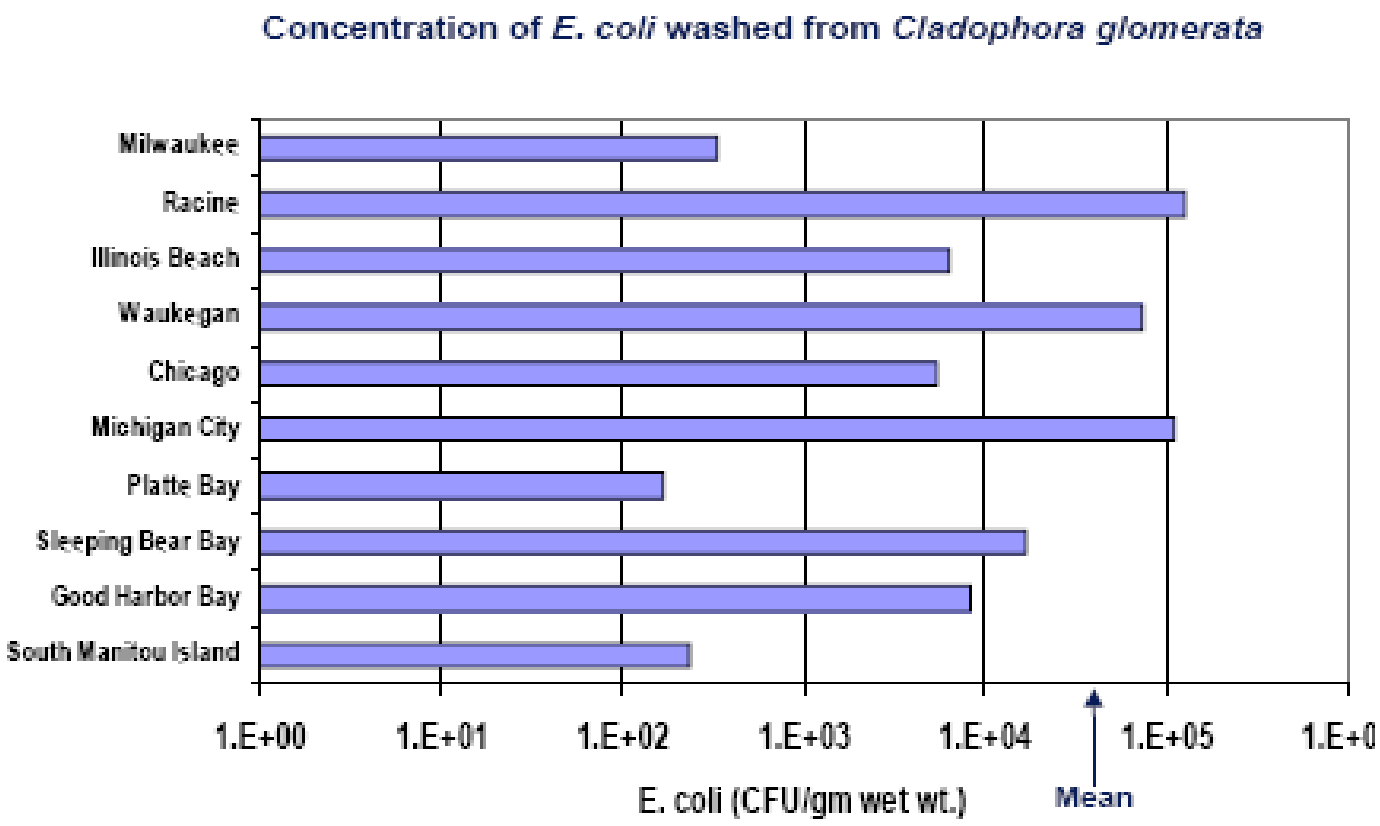
Beach closure 130 CFU/100ml

240,000 CFU/100 ml

10,000-100,000 CFU/100 ml

368,000,000 CFU/g feces

Olapade et al. 2006

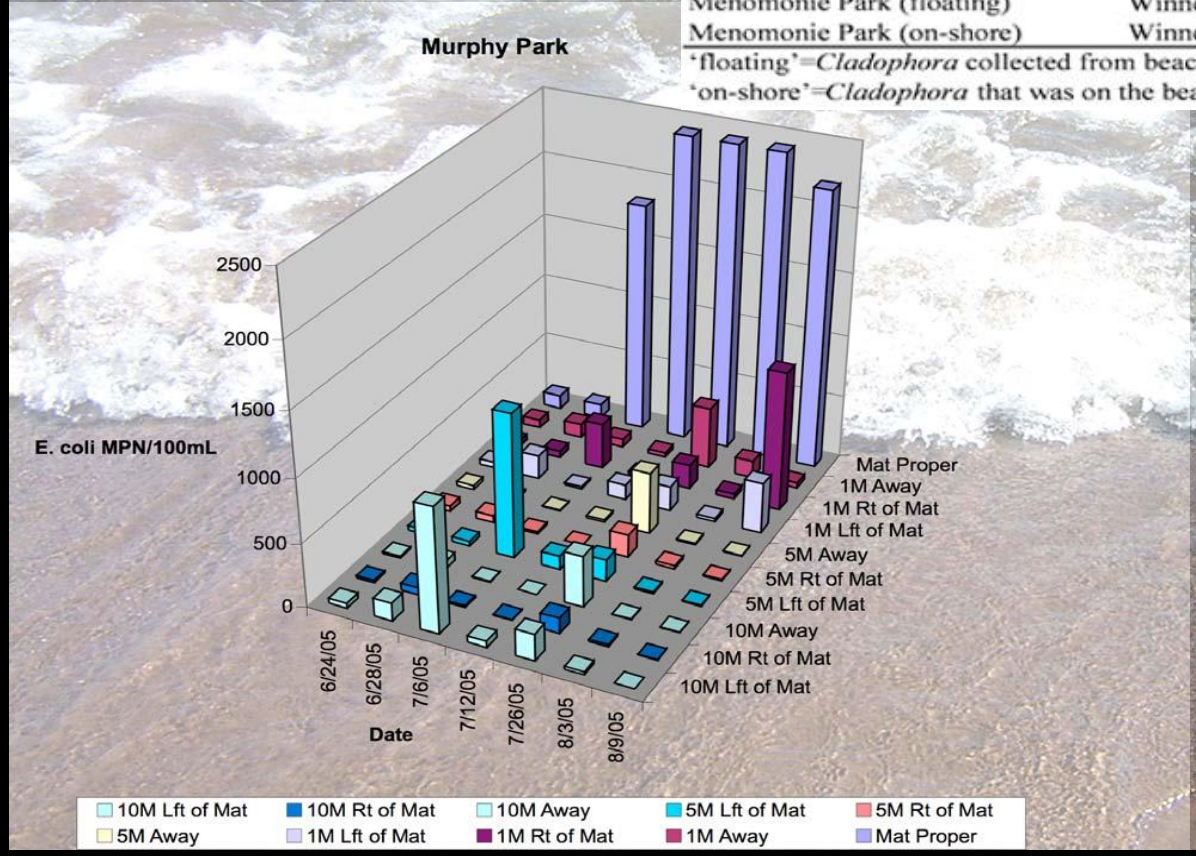


Kleinheinz (U of W)

Table 1. *E. coli* concentrations recovered from *Cladophora* mats on beaches in Wisconsin.

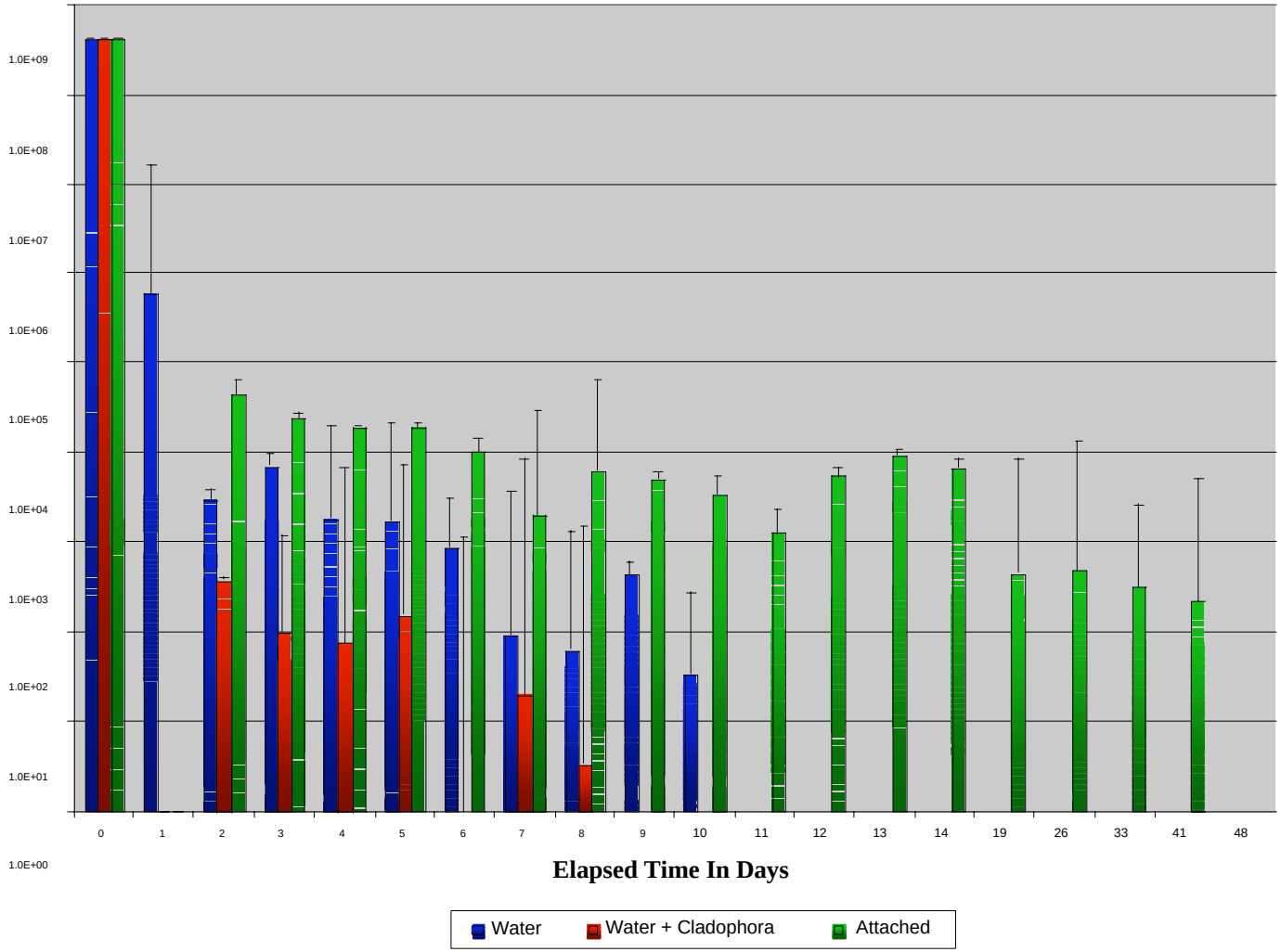
Beach	County	*E. coli* (CFU/g Dry Weight *Cladophora*)	*E. coli* seasonal average in water (MPN/100 ml water)
Murphy (floating)	Door	22,515	244.1
Murphy (on shore)	Door	17,670	244.1
Whitefish Dunes (on shore)	Door	39,501	50.1
Sister Bay (floating)	Door	10,874	89.8
Baileys Harbor (on shore)	Door	1,729	93.8
Sunset (floating)	Door	1,254	165.4
Menomonie Park (floating)	Winnebago	16,790	121.4
Menomonie Park (on-shore)	Winnebago	31,288	121.4

'floating'=*Cladophora* collected from beach water
'on-shore'=*Cladophora* that was on the beach



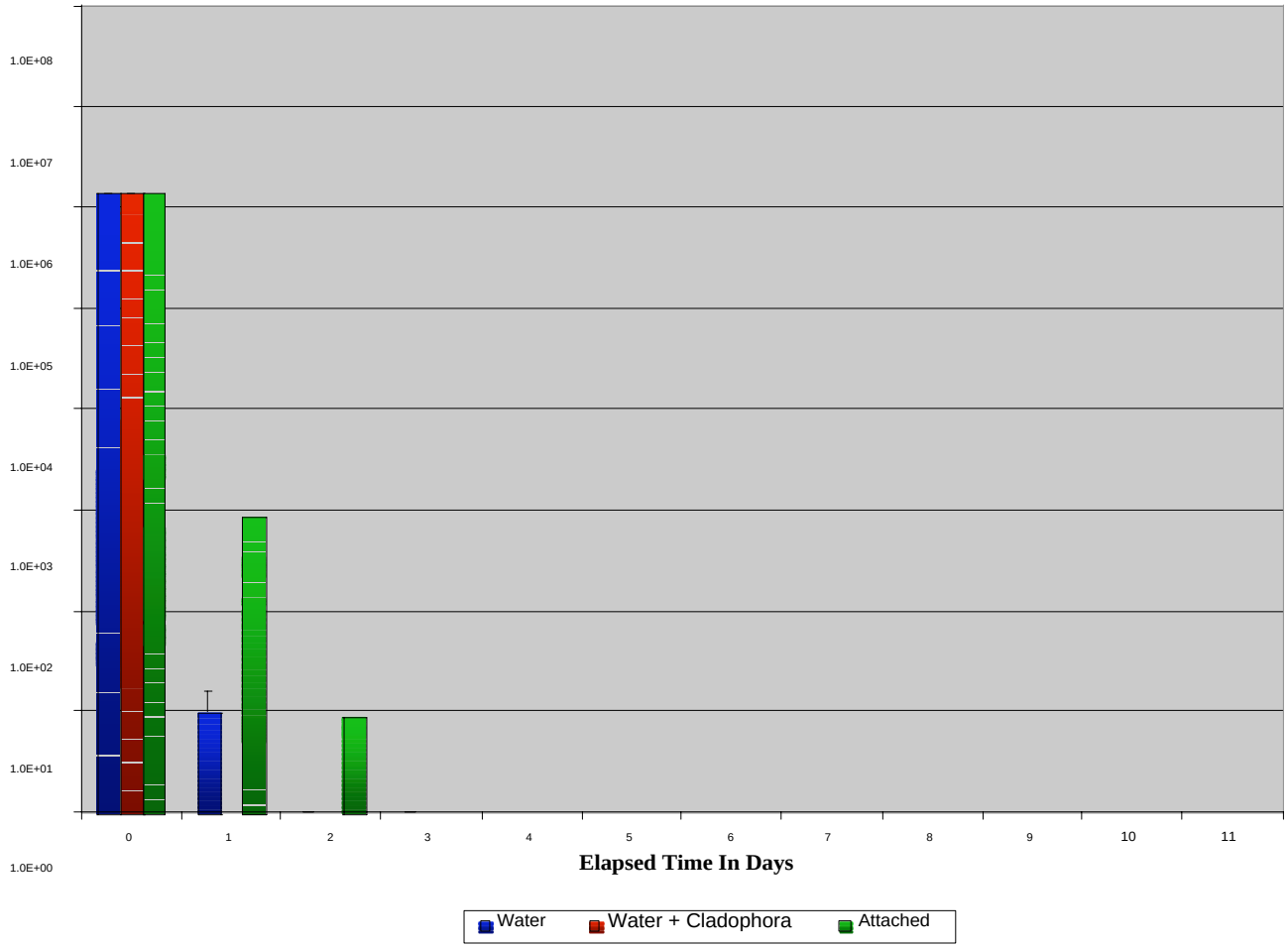
Kleinheinz (U of W)

E.coli Survival in the Lab Microcosm

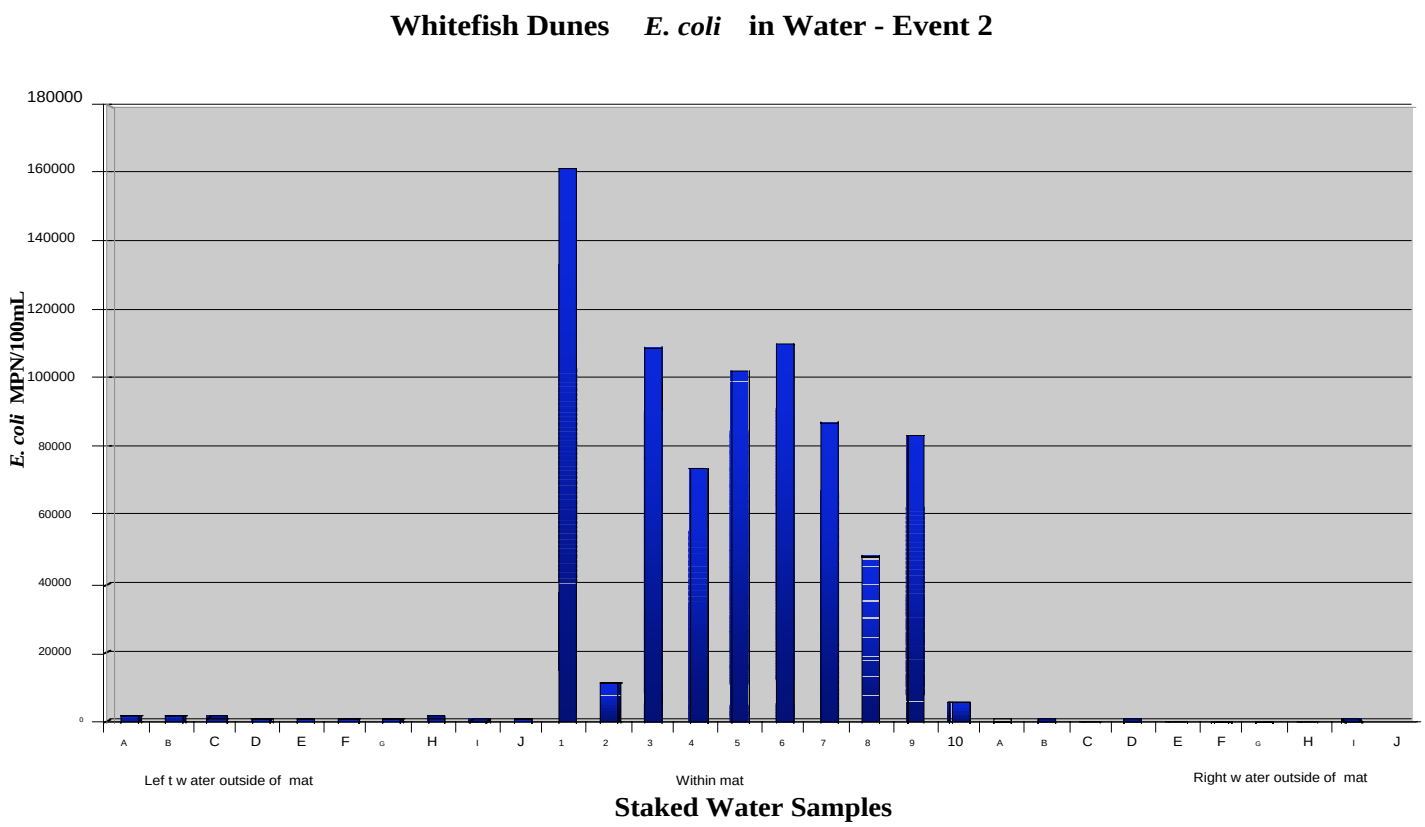


Kleinheinz (U of W)

Shigella Survival in the Lab Microcosm



Kleinheinz (U of W)

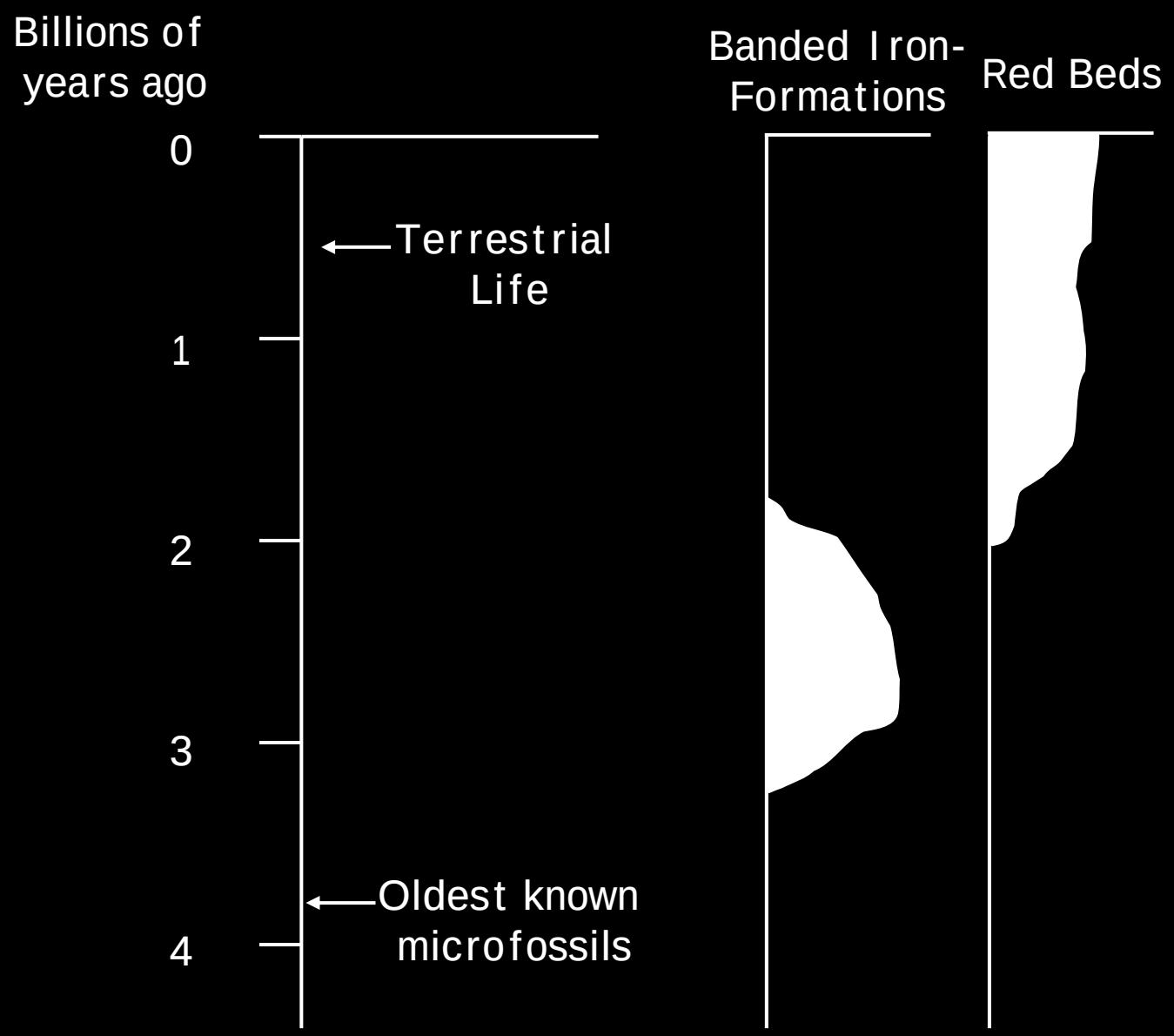


What we know

- ***Cladophora*** **does harbor** ***E.coli*** **in large concentrations suggesting it allows for survival and possibly growth within mats.**
- **Decomposing** ***Cladophora*** **has high levels of** ***E coli*** **while fresh** ***Cladophora*** **contains low numbers.**
- **Pathogens may not survive to the extent that** ***E. coli*** **does in** ***Cladophora*** **mats and we see no evidence of possible pathogen growth.**
- **Mats may harbor 'confined'** ***E.coli*****, and the** ***E.coli*** **from the mats may not migrate far and significantly impact beach water quality.**
- **Observational data does not appear to have a direct relationship with** ***E.coli*** **ound during beach monitoring.**
- **More work is needed on the genetic make-up of** ***E.coli*** **found in the** ***Cladophora*** **mats.**
- **Additional field data is needed on weather impacts and how mat movement may impact beach health.**

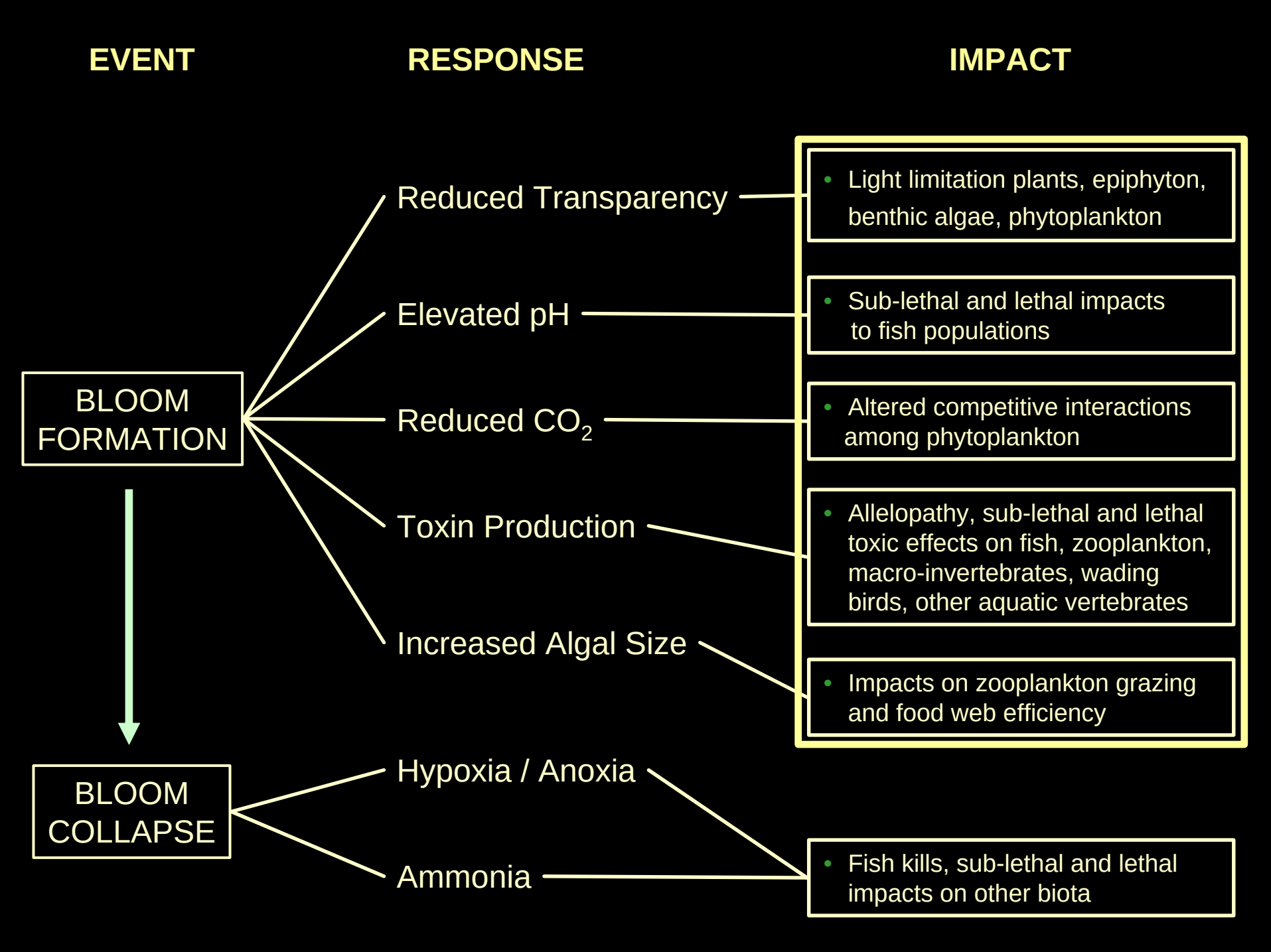
Cyanoabacteria

- Oxygen producing prokaryotes
- Lack cellulose and chloroplast
- 3.5 billion years old
- Adapted to extreme environments; desiccation, permafrost, high UV, low light, low nutrient, and wide temperature range environments
- Unicellular, colonial, filamentous
- Planktonic and benthic
- 30% can fix nitrogen
- Primitive organism – complex biochemistry


Billions of years ago
0
1
2
3
4
Terrestrial Life
Oldest known microfossils
Banded Iron-Formations
Red Beds

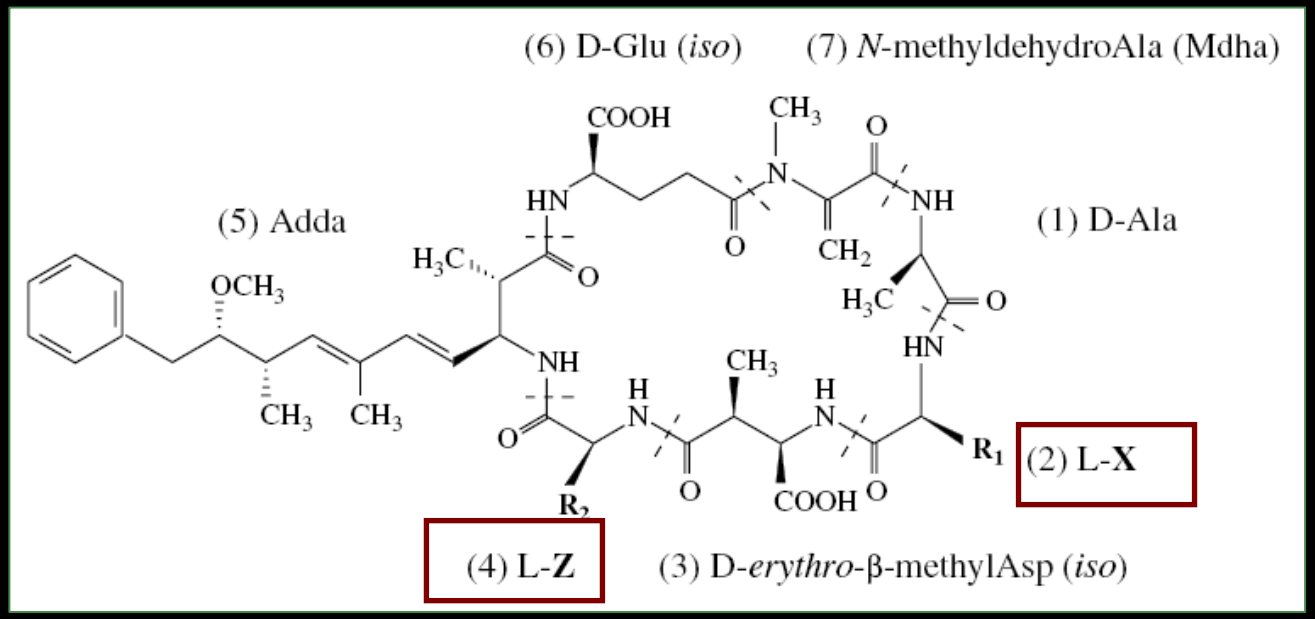
Cyanoabacteria Blooms

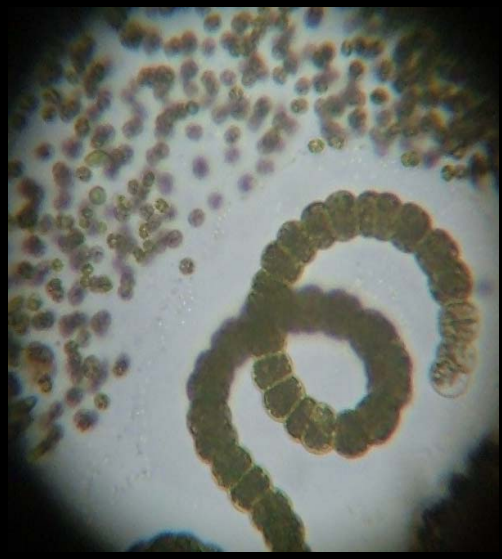
- Increased water temperature
- Stable water column (species dependent)
- Reduced flow / continuous low flow (rivers)
- Depletion of nitrate nitrogen relative to ammonia
- Low DIN:SRP ratio
- Elevated pH, depletion of free carbon dioxide
- Selective grazing by zooplankton or zebra mussels on “edible algae”
- High availability of soluble P or sediment source


EVENT
RESPONSE
IMPACT
BLOOM FORMATION
BLOOM COLLAPSE
Reduced Transparency
Elevated pH
Reduced CO_2
Toxin Production
Increased Algal Size
Hypoxia / Anoxia
Ammonia
• Light limitation plants, epiphyton, benthic algae, phytoplankton
• Sub-lethal and lethal impacts to fish populations
• Altered competitive interactions among phytoplankton
• Allelopathy, sub-lethal and lethal toxic effects on fish, zooplankton, macro-invertebrates, wading birds, other aquatic vertebrates
• Impacts on zooplankton grazing and food web efficiency
• Fish kills, sub-lethal and lethal impacts on other biota

Microcystins

- Microcystins are one group of cyanotoxins
- Frequently found in freshwater lakes
- Produced by several different genera of cyanobacteria
- Form a family of cyclic hepatotoxins (>80 analogues)
- These variations result in differences in toxicity





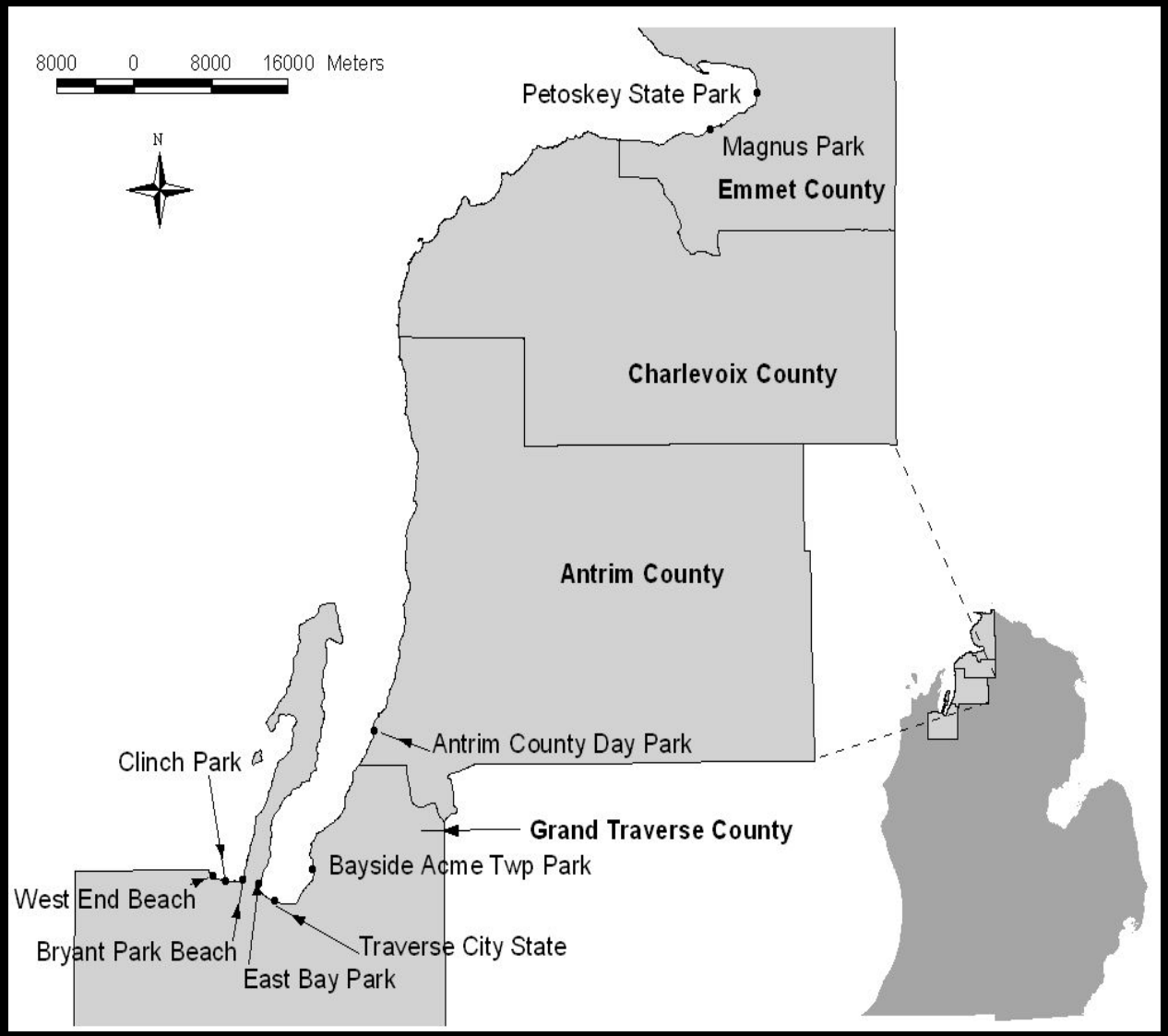
This Project

- The main project goal is to conduct an assessment of the ability of *Cladophora* mats to sequester *E. coli* and microcystin LR and RR in nearshore waters of Grand Traverse Bay, Little Traverse Bay, and Saginaw Bay.
- The secondary goal is to communicate this information in an understandable manner to decision makers and stakeholder groups associated with the respective watersheds.
- Eight locations in Saginaw Bay, six locations in Grand Traverse Bay, and 2 locations in Little Traverse Bay will be sampled in triplicate for *E. coli* and microcystin LR and RR during the summer of 2008.

This Project

- The locations will be sampled weekly for 8 weeks in July and August.
- Grab samples of floating *Cladophora* mats will be collected at each location and analyzed individually for *E. coli* and as a composite for microcystin LR and RR.
- *E. coli* will be analyzed by the Colilert-18 method (APHA 1998) using a phosphate buffer extraction (Whitman et al. 2003). Microcystin LR and RR will be analyzed by HPLC/MS (Lawerence et al. 2001; Boyer et al. 2004).

Sampling Locations



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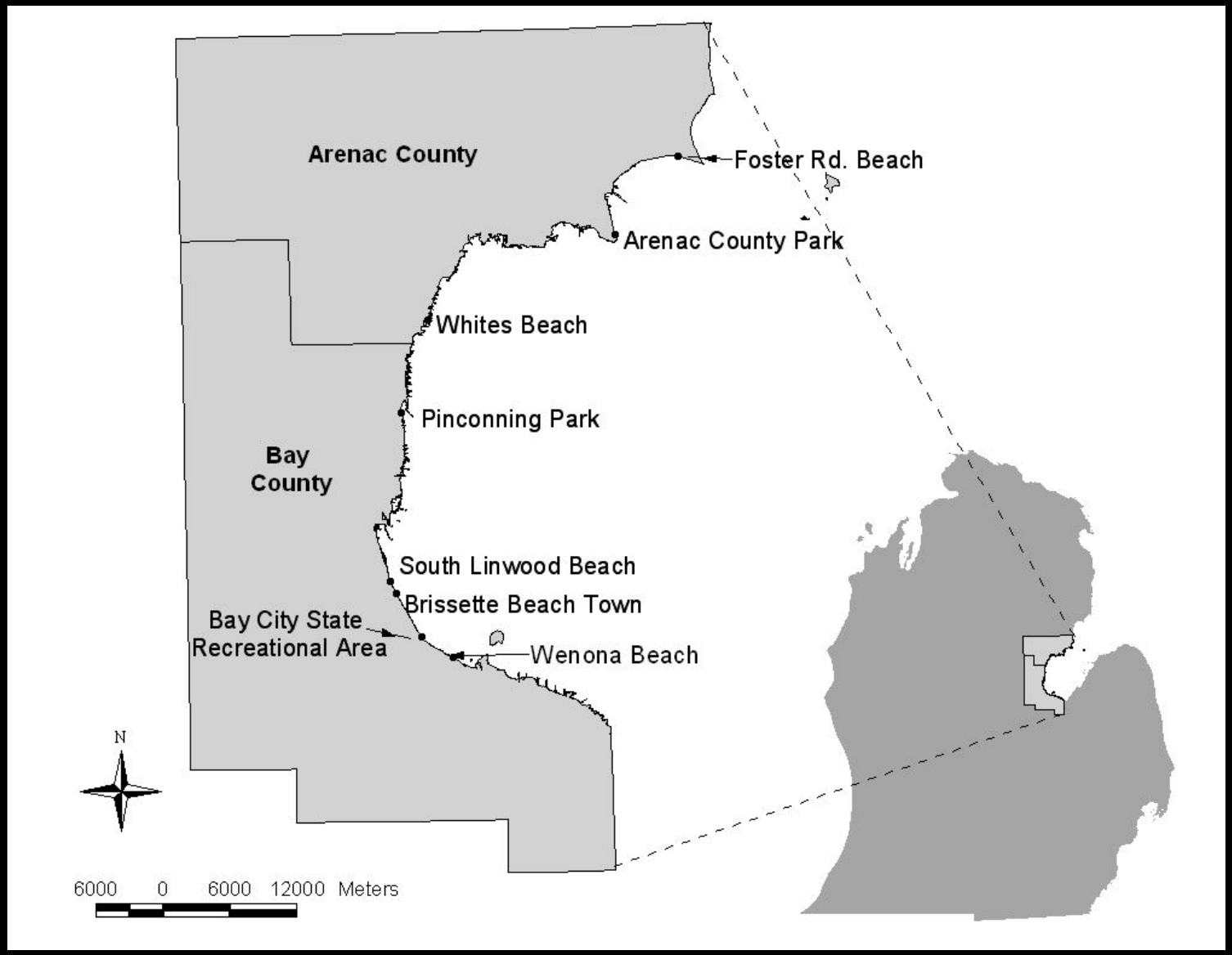

Acknowledgements

- ***Michigan Department of Environmental Quality***
- ***Annis Water Resources Institute***
- ***Northwestern Michigan College* Great Lakes Water Studies Institute**
- **Watershed Center Grand Traverse Bay**
- **Tip of the Mitt Watershed Council**