Harmful Algal Blooms (HABs) – A Primer on Cyanobacteria Blooms and Red Tide

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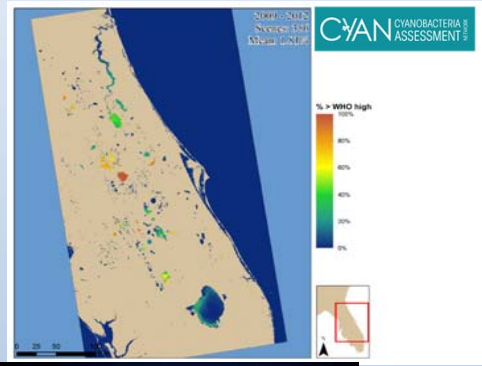

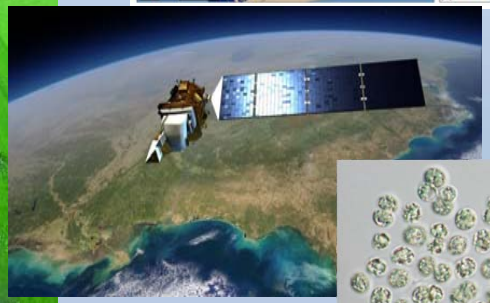

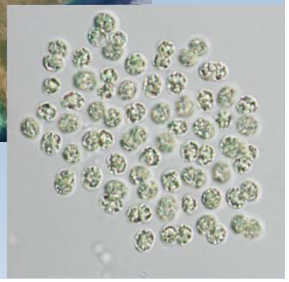

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Outline….

Cyanobacteria Blooms vs. Red Tide Outbreaks

Environmental Health Concerns of Blooms

Potential Causative Factors of Blooms

Scientific Studies Underway and Planned

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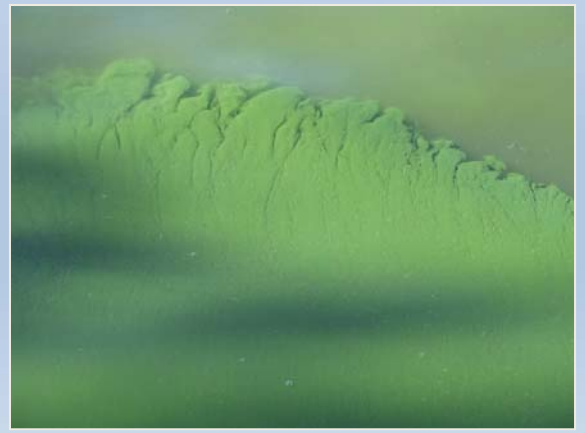
Harmful Algal Blooms (HABs) Definitions

Algae – an umbrella term that includes all photosynthetic microbes including cyanobacteria

Algal Bloom – an overabundance of algae that can be concentrated by hydrology and/or weather to form an accumulation or scum.

Harmful Algal Bloom (HAB) – an algal bloom that imparts harm (toxicity, hypoxia, aesthetics) related to health and/or economy.



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Potential Concerns Associated with HABs and Associated Toxins….

- **Environmental Health**
  - **Wildlife**
  - **Livestock**
  - **Companion Animals**
  - **Humans**
- **Full and Sustainable Resource Utilization**
  - **Drinking Water Treatment**
  - **Consumption (e.g. fish)**
  - **Tourism**
- **Economics**

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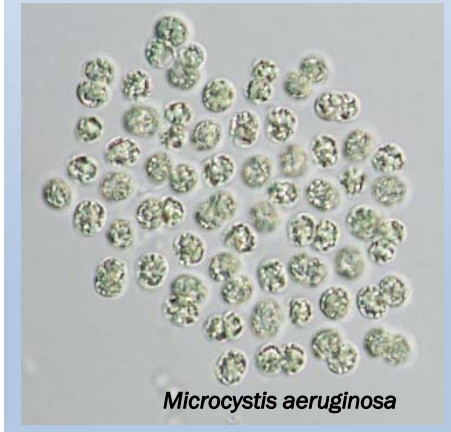
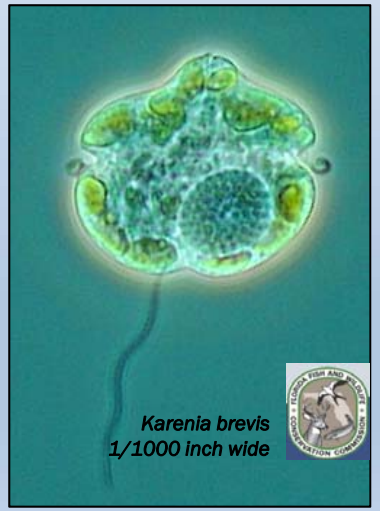
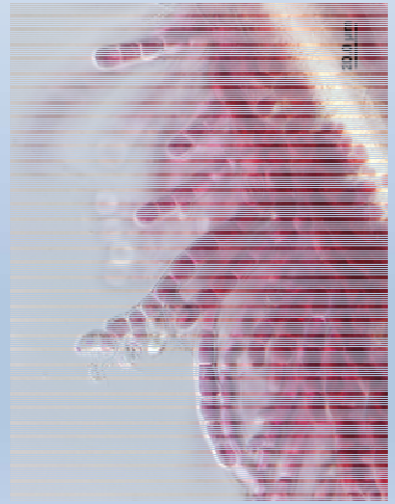
Cyanobacteria = Blue-Green Algae	Dinoflagelletes members responsible for Red Tides	Red Algae members responsible for red drift algae
• Bacteria • chlorophyll; phycocyanin	• Algae • Chlorophyll; carotenoids	• Algae • Chlorophyll; phycoerythrin


Microcystis aeruginosa


Karenia brevis
1/1000 inch wide



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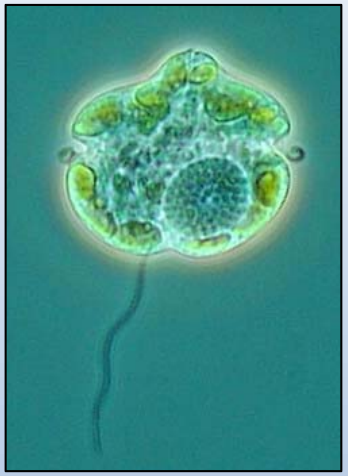
Cyanobacteria….

Red Tides (Karenia)….

commonalities

- **Near shore accumulation**
- **Vertical migration**
- **Turbulence is disruptive**
- **Nutrients**



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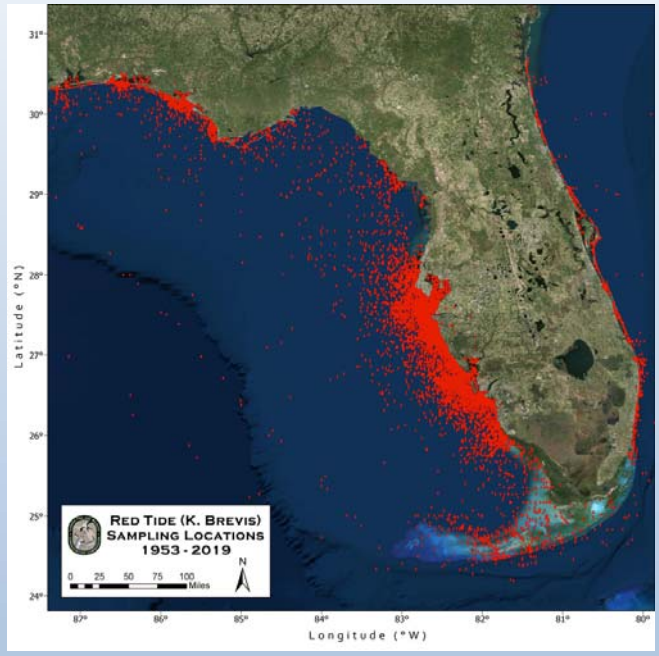
FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

Where Does Red Tide Occur in Florida….

- Initiates offshore in the Gulf of Mexico, subsurface
- Transported inshore via currents and winds
- Most common in SW FL
- Atlantic can be impacted if blooms are transported to the E. coast
- Other Gulf states and Mexico also affected



FWC's observations of *K. brevis* since 1953

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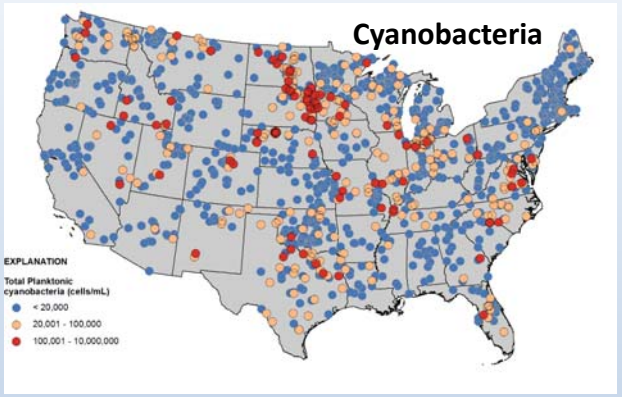
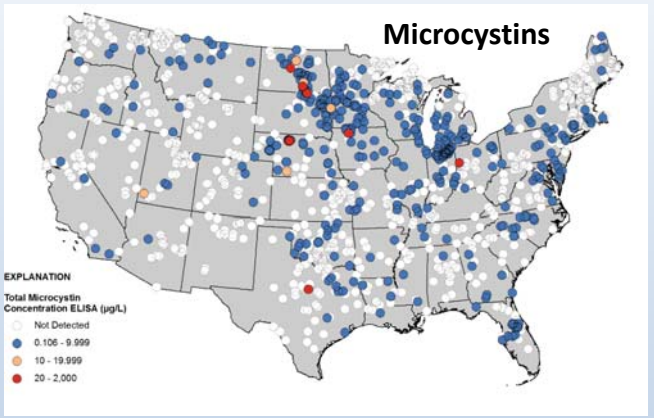
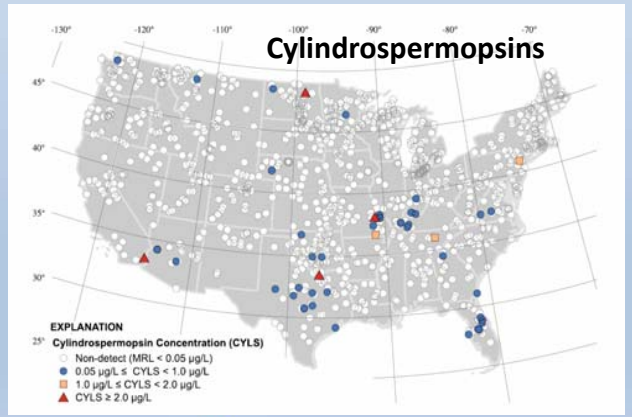
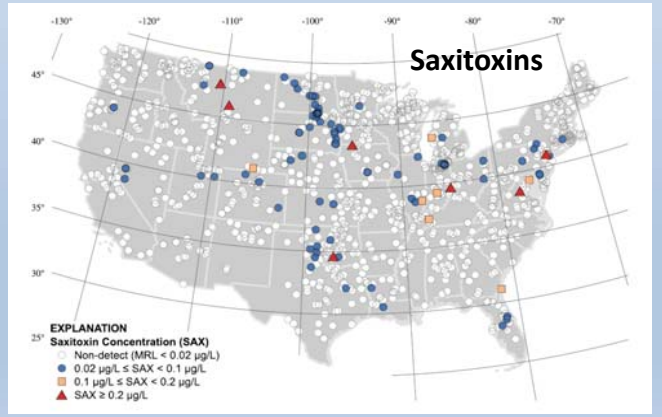
Florida Fish and Wildlife Conservation Commission

Algal Blooms Do Not Always Produce Toxins….









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https://doi.org/10.1016/j.hal.2016.04.001

https://toxics.usgs.gov/highlights/2016-05-31-cyanotoxins_in_lakes.html

Are Inland Cyanobacteria and Toxins Transported Into Estuaries?

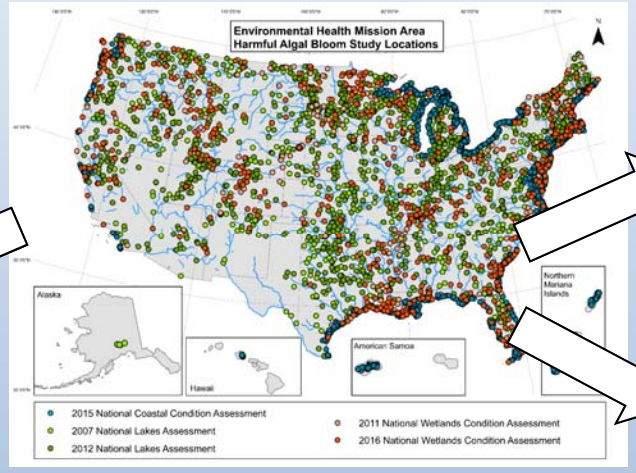
OPEN ACCESS Freely available online PLOS one

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

Melissa A. Miller[1,2*], Raphael M. Kudela[2], Abdu Mekebri[3], Dave Crane[3], Stori C. Oates[1], James Tinker[4], Michelle Staedler[5], Woutrina A. Miller[6], Sharon Toy-Choutka[1], Clare Dominik[1], Gregg Langlois[8], Michael Murray[9], Kim Ward[9], David A. Jessup[1]

Abstract

"Super-blooms" of cyanobacteria that produce potent and environmentally persistent biotoxins (microcystins) are an emerging global health issue in freshwater habitats. Monitoring of the marine environment for secondary impacts has been minimal, although microcystin-contaminated freshwater is known to be entering marine ecosystems. Here we confirm deaths of marine mammals from microcystin intoxication and provide evidence implicating land-sea flow with trophic transfer through marine invertebrates as the most likely route of exposure. This hypothesis was evaluated through environmental detection of potential freshwater and marine microcystin sources, sea otter necropsy with biochemical analysis of tissues and evaluation of bioaccumulation of freshwater microcystins by marine invertebrates. Ocean discharge of freshwater microcystins was confirmed for three nutrient-impaired rivers flowing into the Monterey Bay National Marine Sanctuary, and microcystin concentrations up to 2,900 ppm (2.9 million ppb) were detected in a freshwater lake and downstream tributaries to within 1 km of the ocean. Deaths of 21 southern sea otters, a federally listed threatened species, were linked to microcystin intoxication. Finally, farmed and free-living marine clams, mussels and oysters of species that are often consumed by sea otters and humans exhibited significant biomagnification (to 107 times ambient water levels) and slow depuration of freshwater cyanotoxins, suggesting a potentially serious environmental and public health threat that extends from the lowest trophic levels of nutrient-impaired freshwater habitat to apex marine predators. Microcystin-poisoned sea otters were commonly recovered near river mouths and harbors and contaminated marine bivalves were implicated as the most likely source of this potent hepatotoxin for wild otters. This is the first report of deaths of marine mammals due to cyanotoxins and confirms the existence of a novel class of marine "harmful algal bloom" in the Pacific coastal environment; that of hepatotoxic shellfish poisoning (HSP), suggesting that animals and humans are at risk from microcystin poisoning when consuming shellfish harvested at the land-sea interface.



USGS science for a changing world

Water Quality and Bed Sediment Quality in the Albemarle Sound, North Carolina, 2012–14

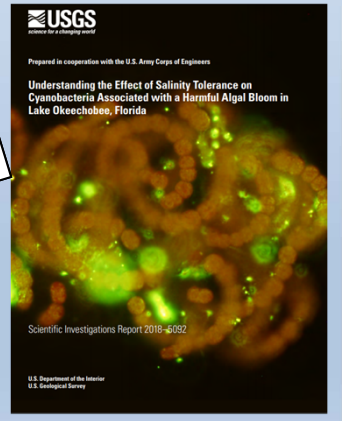
Open-File Report 2016–1171

U.S. Department of the Interior
U.S. Geological Survey

USGS science for a changing world

Prepared in cooperation with the U.S. Army Corps of Engineers

Understanding the Effect of Salinity Tolerance on Cyanobacteria Associated with a Harmful Algal Bloom in Lake Okeechobee, Florida



Scientific Investigations Report 2018–5092

U.S. Department of the Interior
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https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0012576&type=printable
https://pubs.usgs.gov/sir/2018/5092/sir20185092.pdf
https://pubs.usgs.gov/of/2016/1171/ofr20161171.pdf

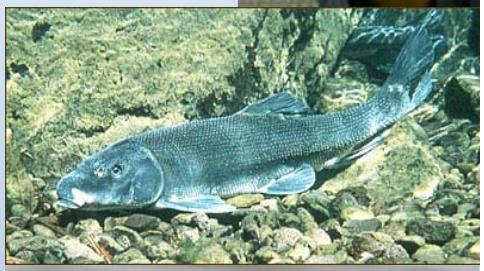
Ongoing: Investigating Toxin Exposure….

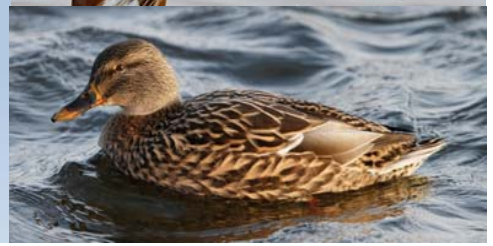
Toxicity and Pathology Studies

- **Fish**
- **Birds**

Biomarkers of Toxin Exposure

Toxin Bioaccessibility from Consumption





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Ongoing: Identifying Drivers of Toxin Production and Control….

Laboratory and Field Evaluation of:

- **Temperature**
- **Nutrients**
- **Metals**
- **Microbial succession**
- **Organic chemicals**

Impact of Natural Process (volcanic ash, forest fire ash, and atmospheric dust) on algal bloom formation and toxin production

- **Cyanobacteria (*Microcystis)***
- **Red Tide (*Karenia*)**

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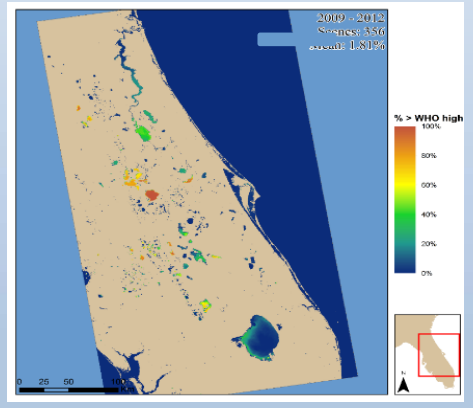
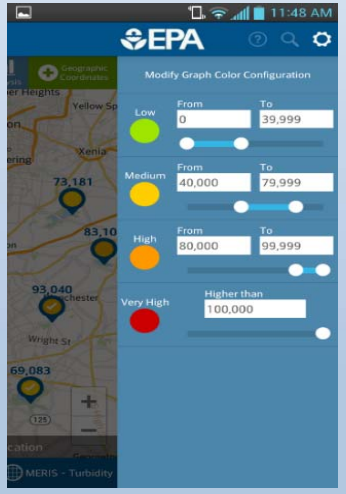
Agencies Collaborate on Development of Cyanobacteria Assessment Network





https://eos.org/project-updates/agencies-collaborate-develop-a-cyanobacteria-assessment-network
https://www.epa.gov/water-research/cyanobacteria-assessment-network-cyan

Lake Okeechobee Early Warning System Research

Fixed Monitoring Locations

S-79

S-80

Moving Boat Surveys

- Latitude and Longitude
- Satlantic SUNA
  - Nitrate
- YSI EXO
  - Temp, Sp. Cond, pH, turbidity, DO, Chl and Phycocyanin Fluorescence, fDOM

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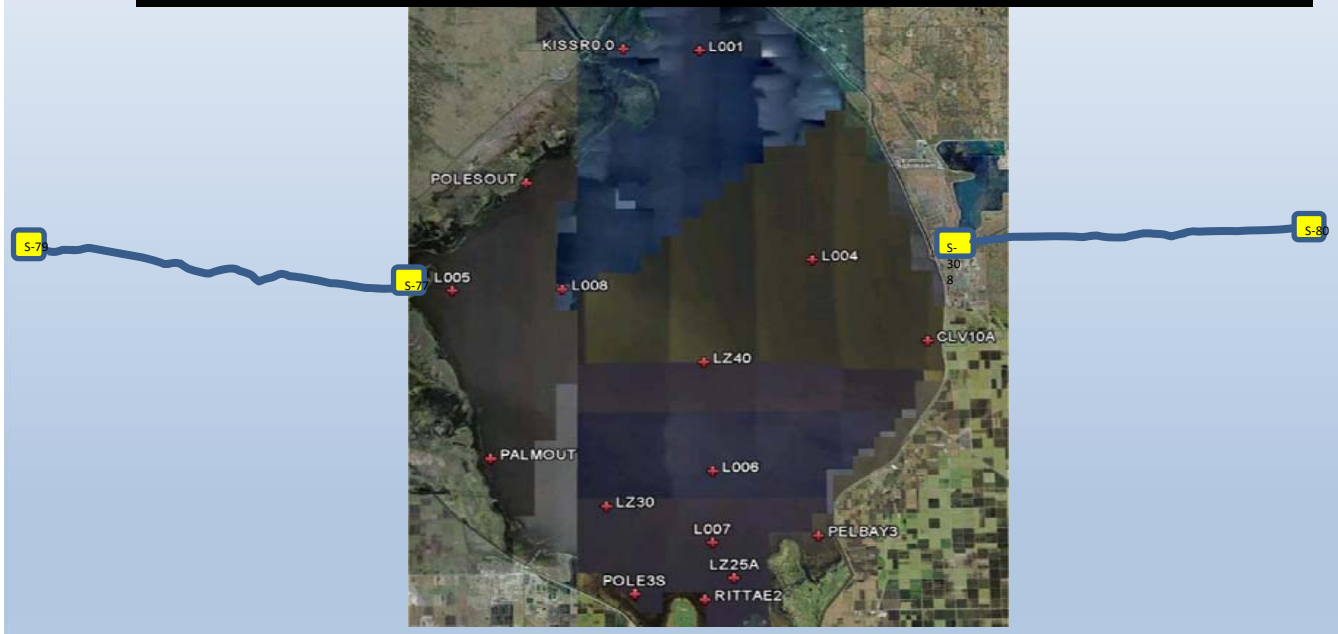
Multi-Agency Lake Okeechobee Research on Cyanobacteria Bloom Dynamics

Q: Where in the Lake Okeechobee do we see the blooms develop (monthly) and what are the suite of organisms that allow bloom formation? Do the current physical and chemical parameters explain the dynamics of these blooms?



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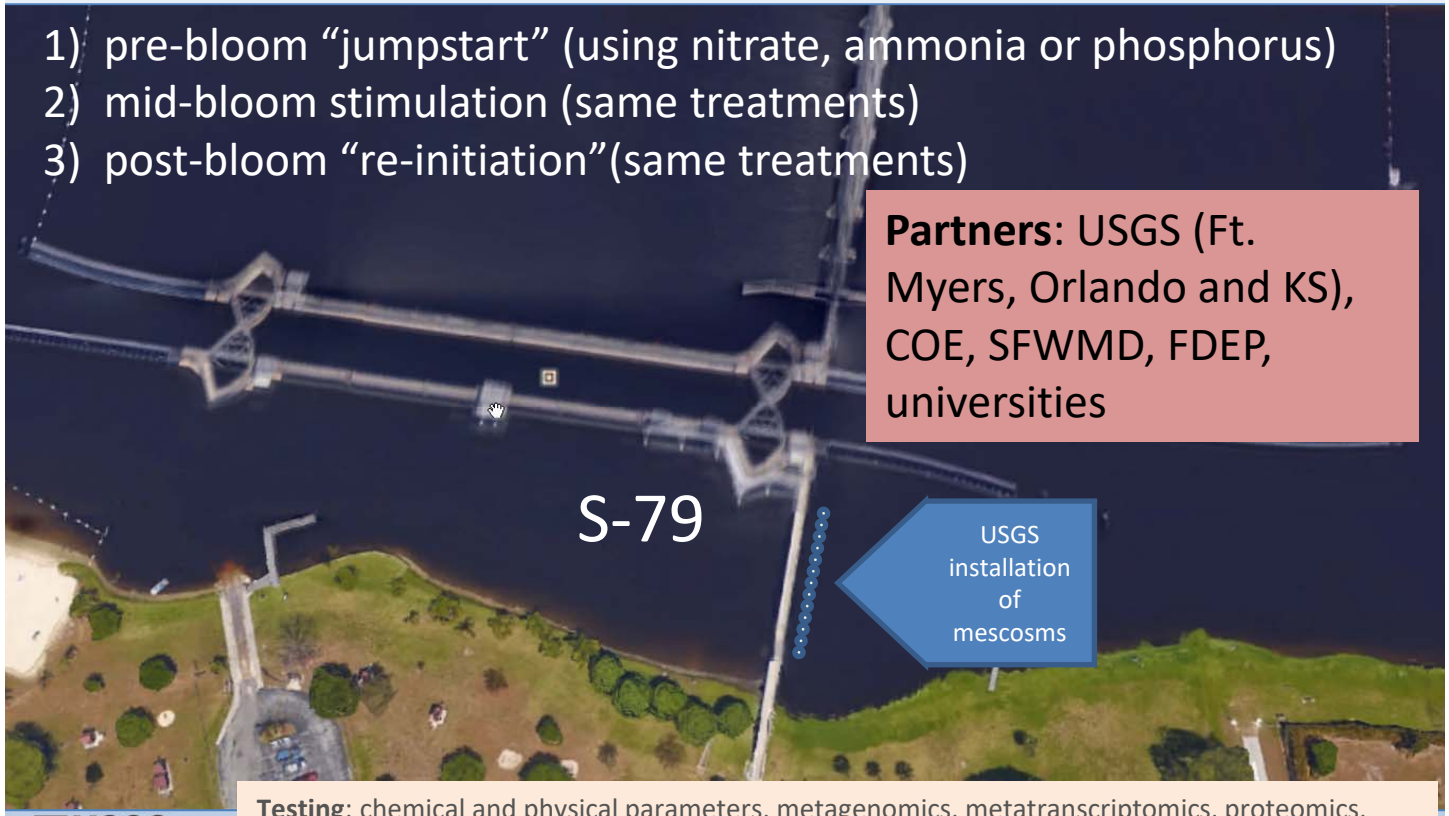
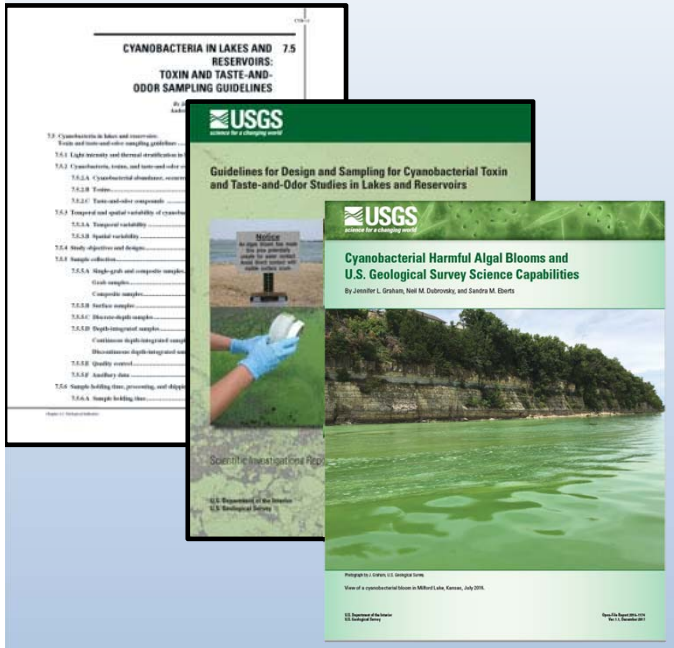
Testing: chemical and physical parameters, metagenomics, cyanotoxins-genes and toxins, and species ID and quantification

Multi-Agency Lake Okeechobee Research on Cyanobacteria Bloom Dynamics



Communicating Capabilities and Outcomes



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http://water.usgs.gov/owq/FieldManual/Chapter7/7.5
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https://pubs.er.usgs.gov/publication/ofr20171054
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