Recent Advances in Lake Okeechobee Science:
Insights for Restoration and Climate Adaptation
August 27, 2024

Managing the Seemingly Unmanageable: SFWMD's Integrative Lake Okeechobee Cyano-HAB Monitoring and Mitigation Program

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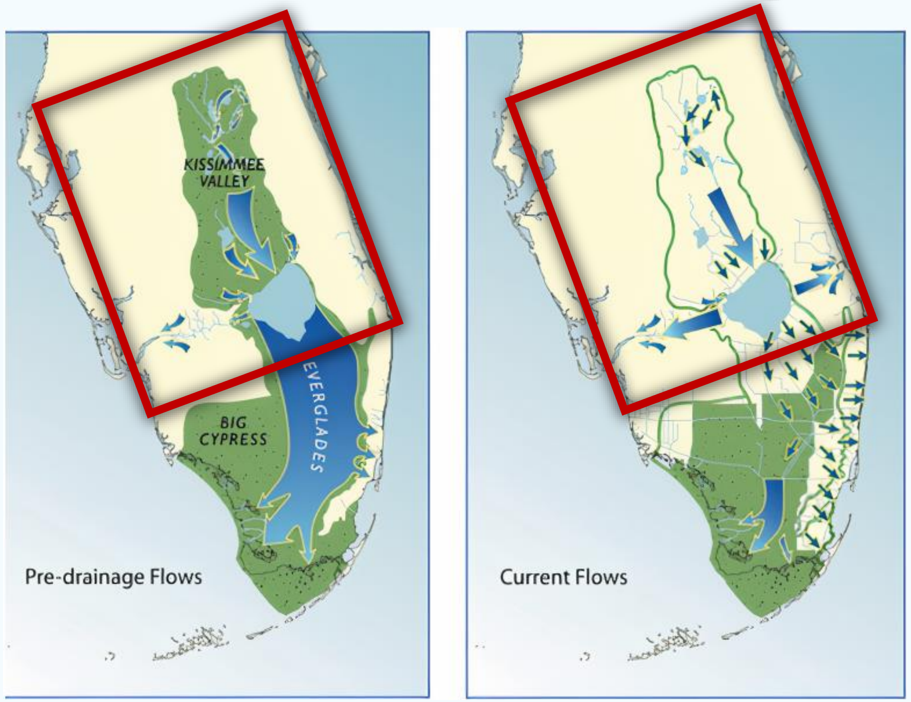
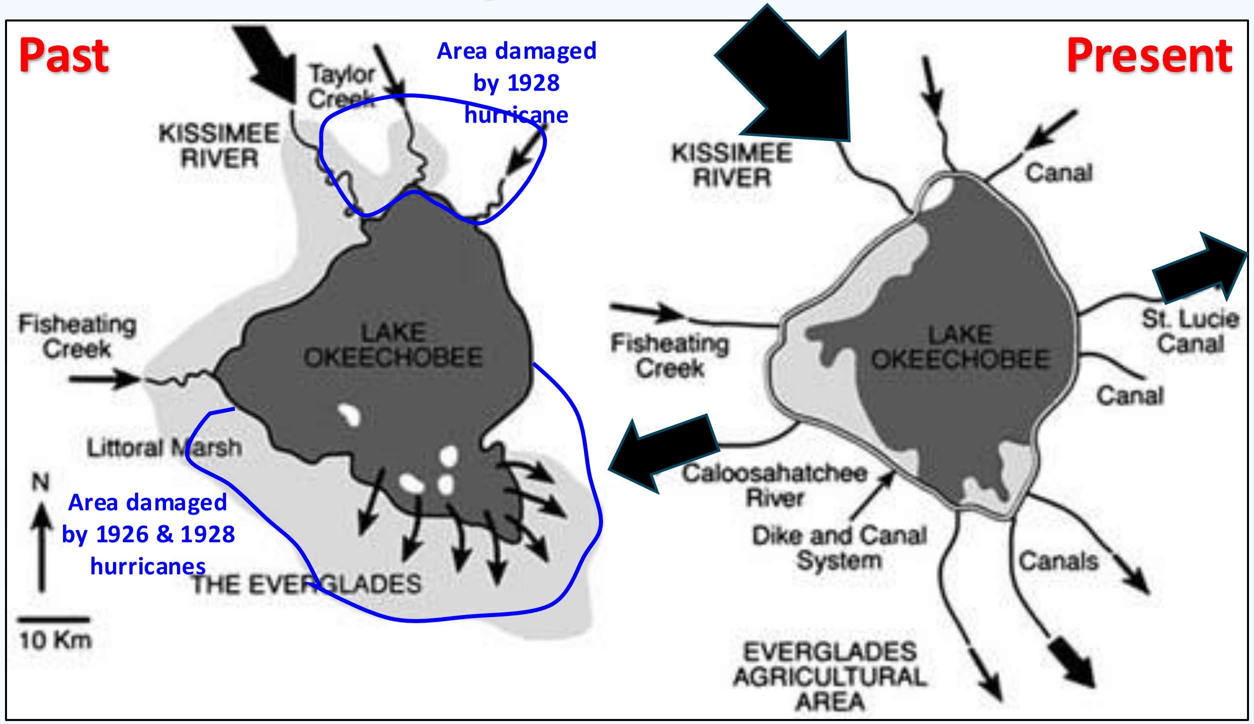
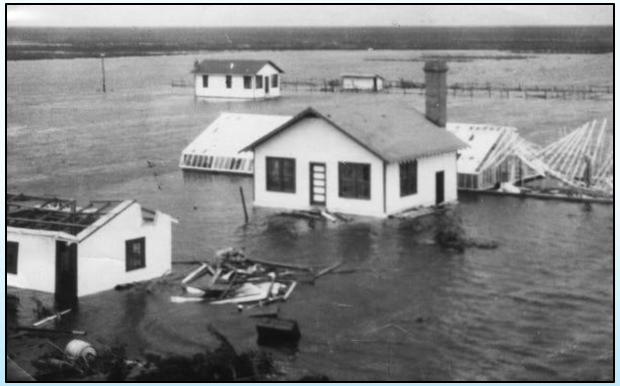
Photo Source: NASA

Factors Leading To the Lake Okeechobee Ecosystem Imbalance





- 1800s-1900s - Agricultural and urban expansion in the surrounding watershed
- 1930s & 1960s - Construction of the Herbert Hoover Dike for flood control
- 1920s-1970s - Excavation of inflow and large outflow canals, structures and pump stations
- 1960s-1970s - Kissimmee River channelization for flood control
- Climate warming



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Phytoplankton – Sensitive Indicators of Lake Okeechobee Ecosystem Health

What are Blooms?

- Rapid growth of algae and cyanobacteria that can cause harm to people, animals and/or the environment
- Naturally occurring events that become unnatural in imbalanced ecosystems

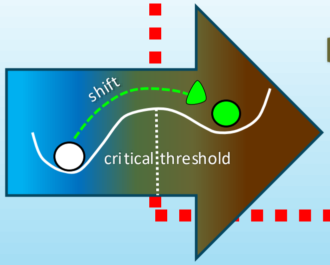
Regional water quality differences drive HAB dynamics in Lake Okeechobee

- **Continuous and high internal and external nutrient loadings; N:P ratios imbalance**
- **Year-round warm waters & abundant sunlight**
- **Sufficient light availability in the littoral zone**
- **Long water residency time (>2 years)**
- **Periods of water column stability**

Pre-Development/Healthy/Balanced Ecosystem

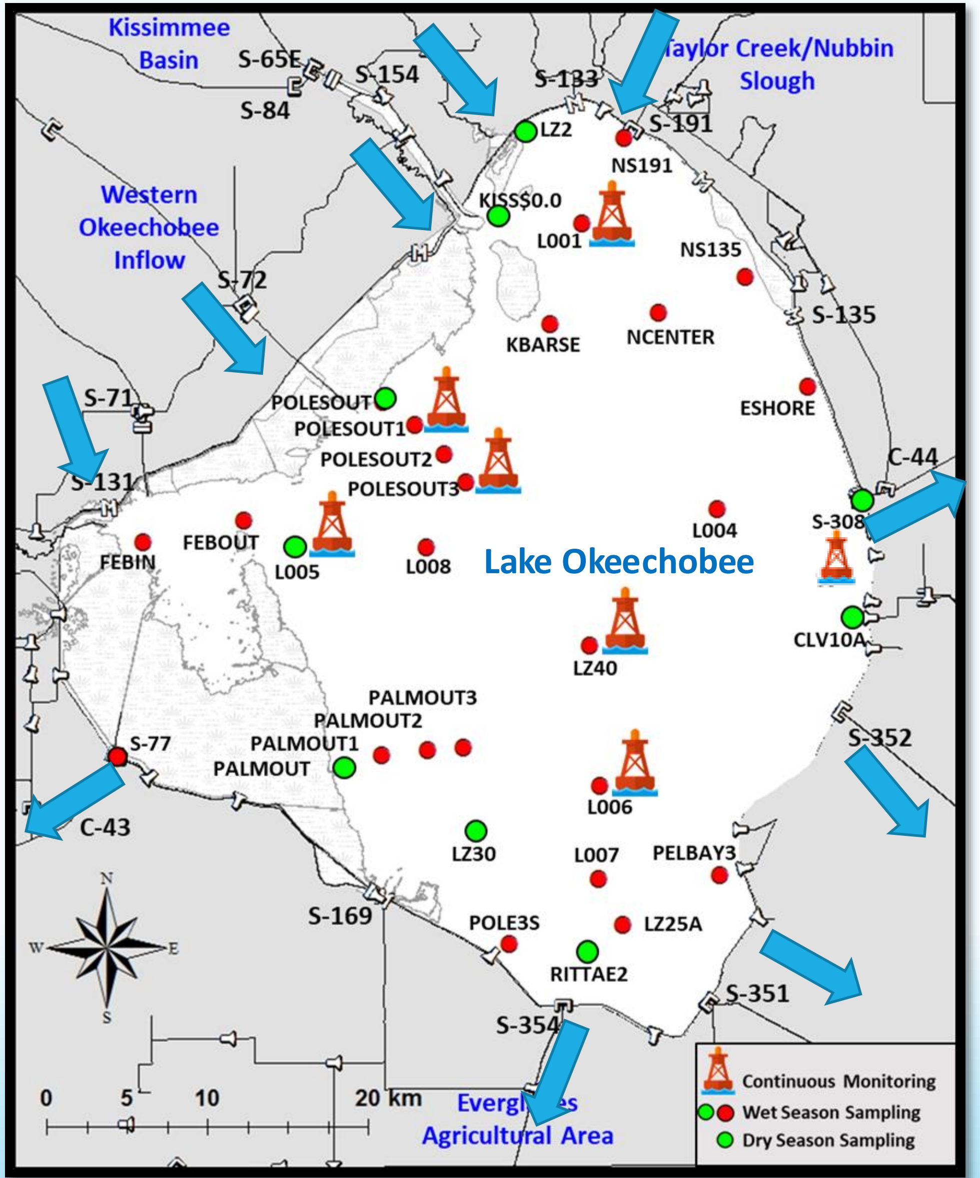
Current Eutrophic/Imbalanced Ecosystem

Balanced nutrient + sediment inputs = high water clarity = balanced phytoplankton and SAV growth = DO levels suitable for healthy fish and benthic communities



High nutrient + sediment loads = low water clarity = widespread HABs + SAV loss = low DO levels = fish and benthic community die-offs

The Past is the Key to the Future – Long-Term Water Quality and Phytoplankton Monitoring



WHY DO WE MONITOR?

- To detect current, ongoing, and emerging problems
- Determine-trends in water quality, HABs and toxins they produce
- Provide a valuable foundation for developing predictive models
- Determine compliance with drinking water standards
- Measure effectiveness of water policies and restoration efforts

WHERE AND HOW FREQUENTLY DO WE MONITOR?

- 32 routine monitoring sites (19 original + 13 new) + 7 continuous
- Expanded monitoring since March 2020 (orig. sites POR since mid-1970s)
- Bi-monthly during wet season and monthly during dry season

WHAT DO WE MONITOR?

- Temperature, Turbidity, Color, TSS
- Total Depth; Secchi Depth
- Dissolved Oxygen, pH
- TN, NH4+, NO_X, TP, SRP, Si
- Chlorophyll *a* (phytoplankton biomass proxy)
- Toxins (microcystins, cylindrospermopsin, anatoxin-A, nodularin-R)
- Dominant phyto-taxa, and diatoms and soft algae counts

*pink color indicates new Lake O. monitoring network components

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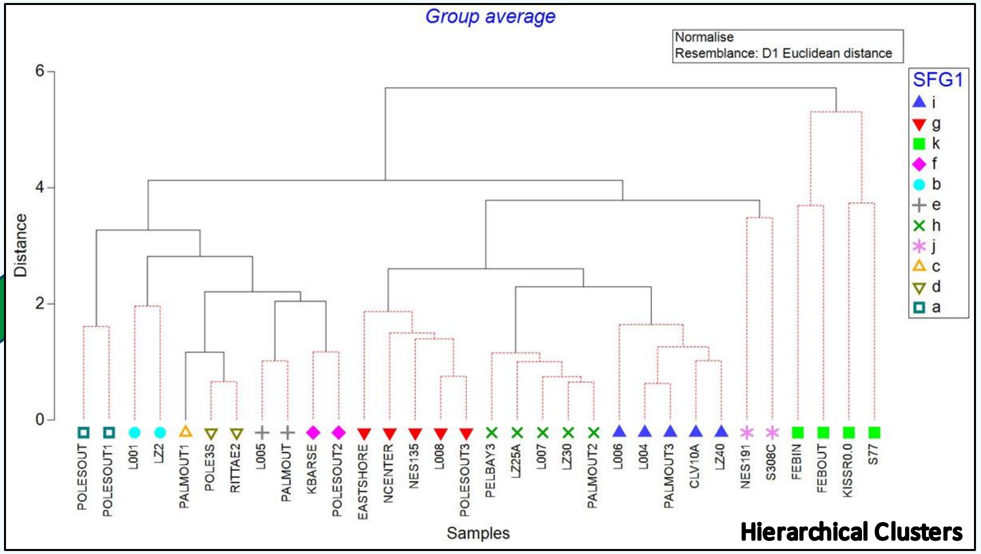
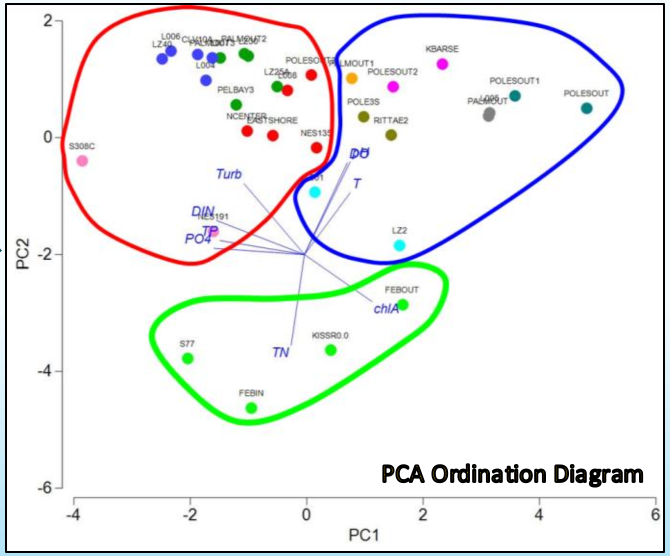
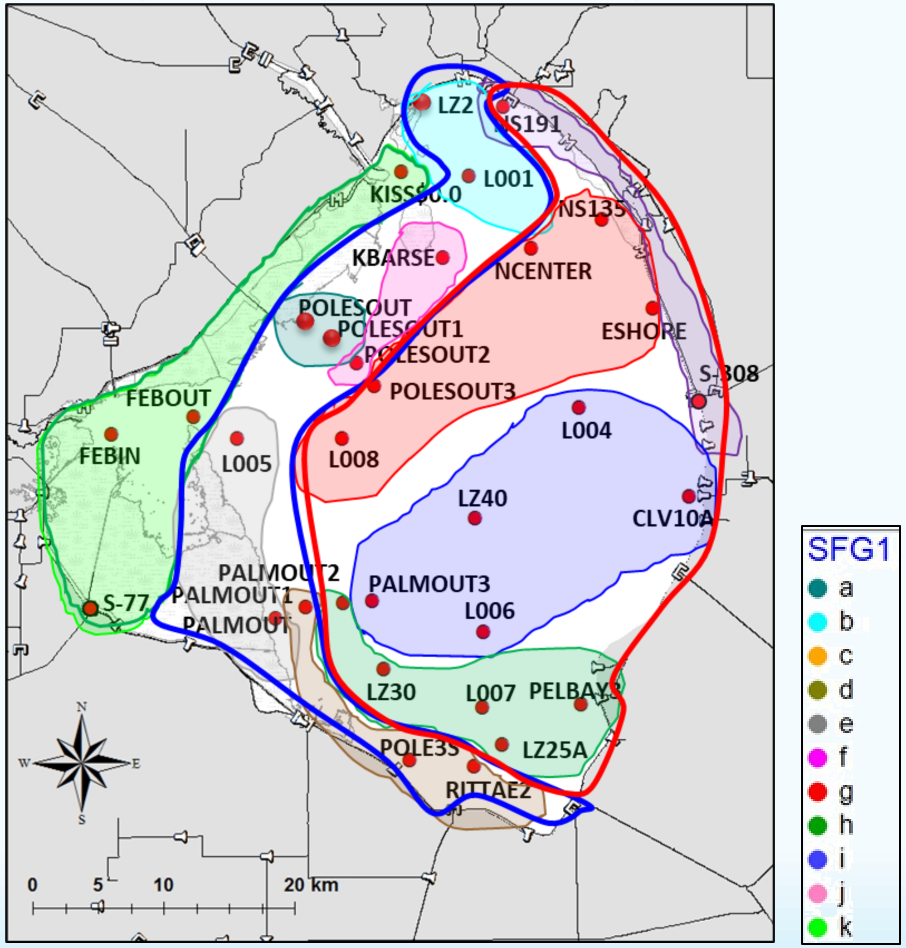
Spatial Water Quality Differences





Spatial Water Quality Differences
(POR: 05/WY2020 – 04/WY2024)



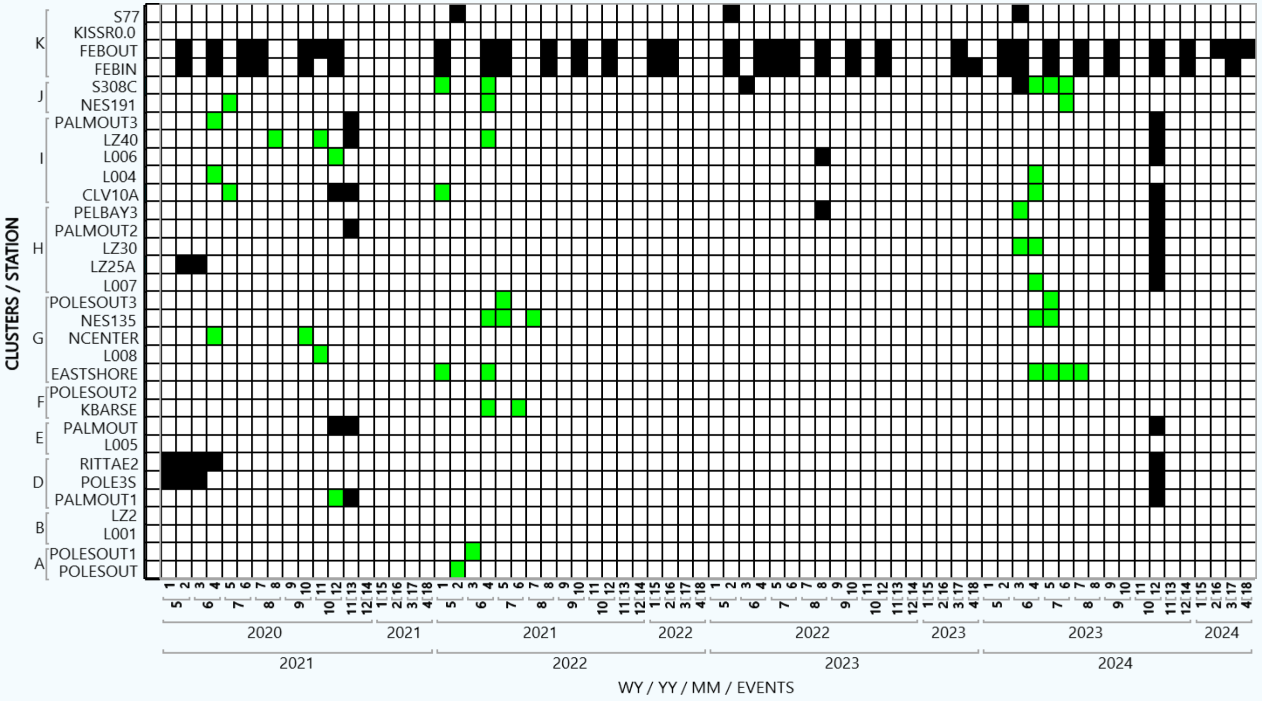
Major Zones

- Shallow Water Littoral
- Intermediate Depth Transitional
- Deepest Pelagic

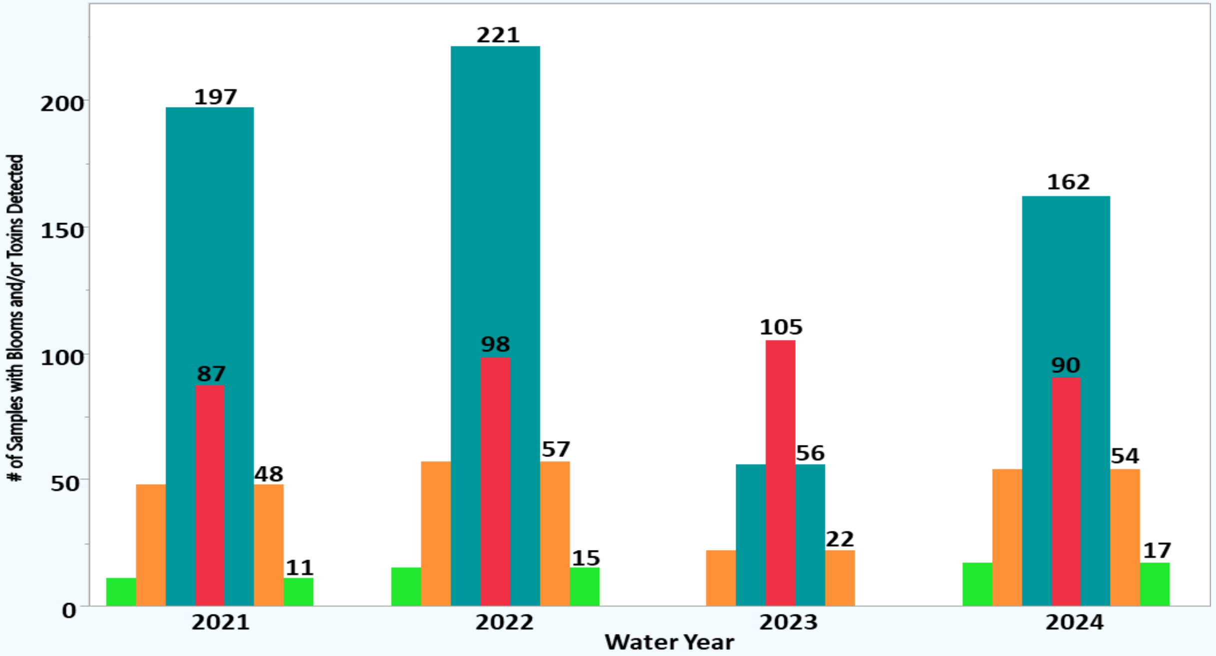
- ❑ Cluster analysis distinguished 9 site clusters and 3 major zones with distinct water quality conditions (PERMANOVA, $F = 8.31$, $p = 0.001$)

Not All Cyano-Blooms Are Created Equal

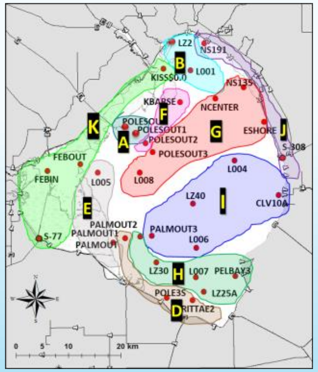
Spatiotemporal Differences



Annual Differences



Blooms (chl a >40 µg/L)
Toxins (Tot. MC >MDL)
Blooms & Toxins (Tot. MC >MDL)
Blooms & Toxins (Tot. MC >8 µg/L (EPA Rec.))
Not Sampled



- Not all Cyano-Blooms are toxic (strain-dependent); MC-Toxins often detected at sites with NO blooms (bloom defined as chl *a* > 40 µg/L)
- Out of the 2269 samples collected between March 2020 – April 2024, where both MCs and chl *a* were measured, only 181 (~8%) indicated presence of toxic blooms and 43 (~2%) toxic blooms with MC >8 µg/L (EPA Rec.))
- Highest number of toxic blooms (MC > MDL) was detected in north-central and NW transitional zones (Cluster G, A and F, respectively) and toxic blooms with MC > 8 µg/L in central, central-north and NE zones (Clusters G, I, and J)

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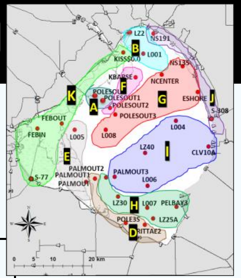
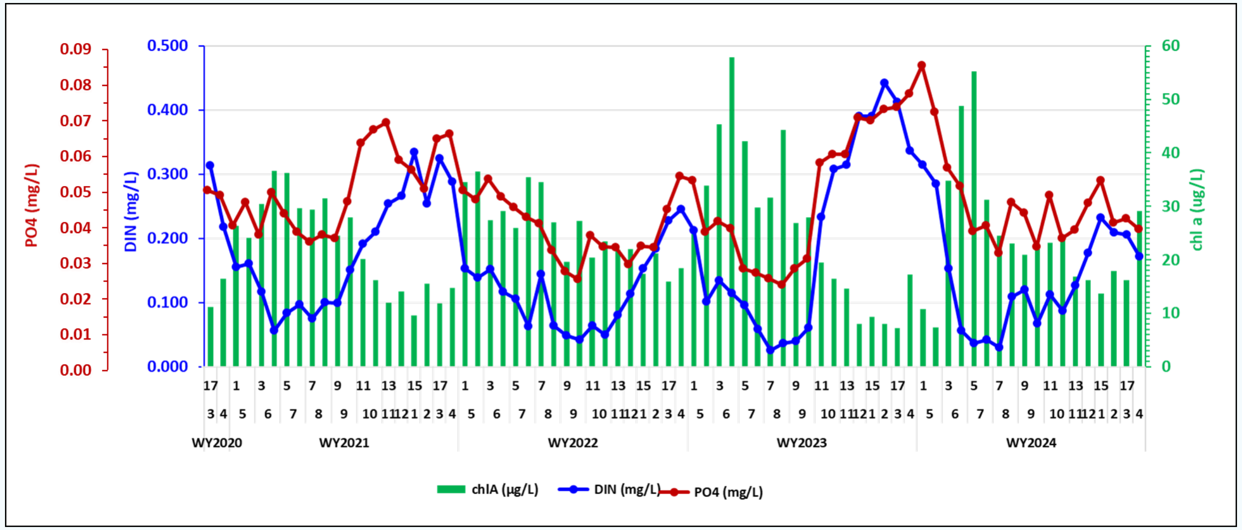
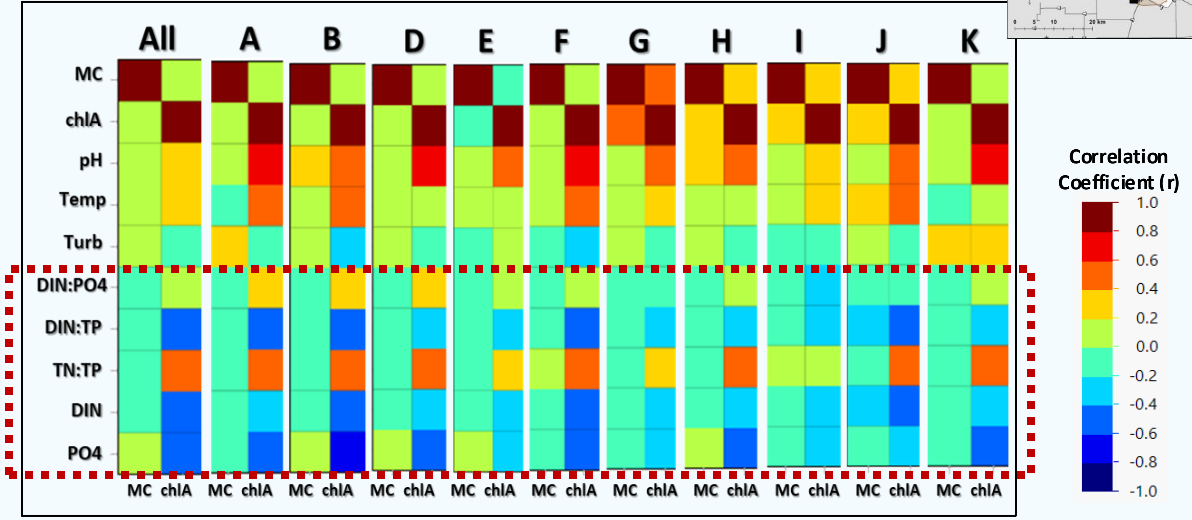


Role of Nutrients in Bloom and Toxicity Dynamics

Temporal Changes in Chlorophyll *a* vs. Inorganic Nutrients



Regional Differences in Pearson's Correlations



- DIN limitation in the summer due to high uptake by cyanos and algae, and denitrification; SRP & TP abundant in the system
- Strength of correlation between inorg. nutrients and chl *a* vary by region (max. DIN vs. chlA r=-0.60 in J-Cluster and SRP vs. chlA r=-0.63 in B-Cluster)
- The molecular make-up of microcystins toxins (produced by *M. aeruginosa*) are nitrogen-rich; high DIN needed for production
- Weak negative correlations between MC toxins and DIN imply that other factors may also be affecting toxin production (cyano strains)

Partial least-squares (PLS) regression

X	VIP
T	0.7951
TN	1.4879
TP (mg/L)	0.8941
PO4_MG_L	1.2127
Turb (NTU)	0.7498
Secc (m)	0.7373
Depth (m)	0.4870
DIN (mg/L)	1.2415

- About 58% (R^2 = 0.58) of variance in chl *a* data can be explained by 8 WQ variables, which TN, DIN and PO4 explaining most of that variance
- Remaining factors: winds, hydrodynamics, internal nutrient cycling, grazing etc.

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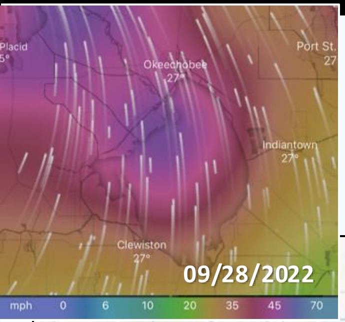
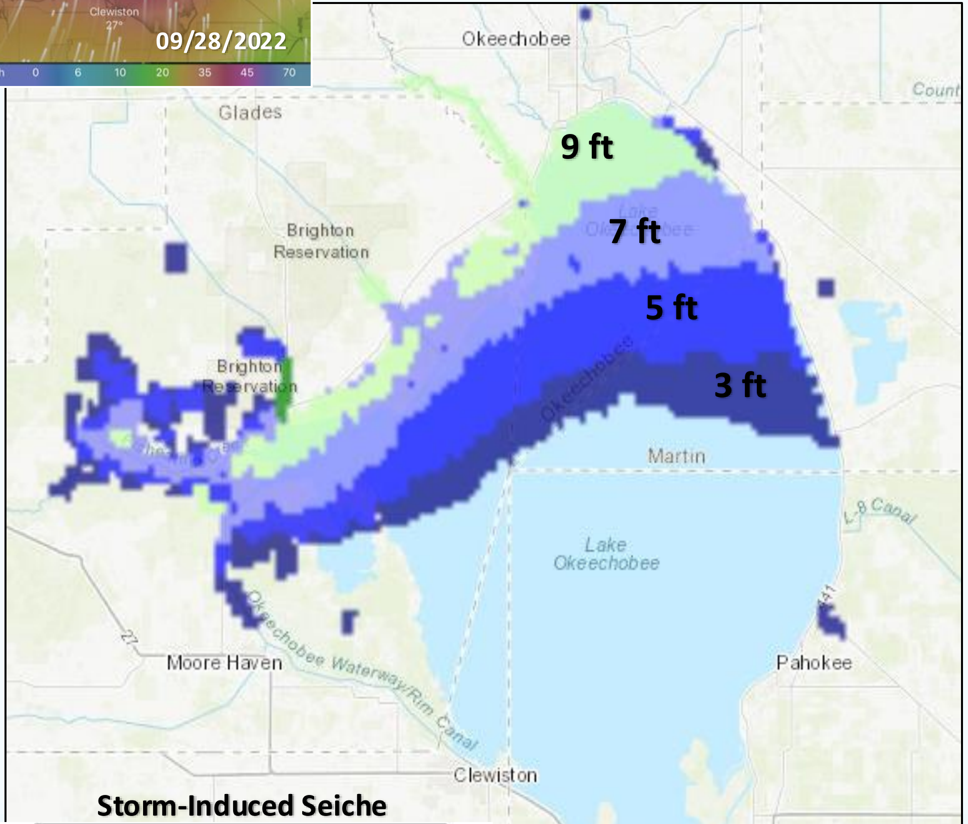
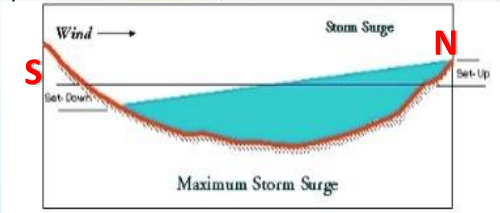
Short-Term Effects of Hurricane Ian on Lake Okeechobee Stage and Flows



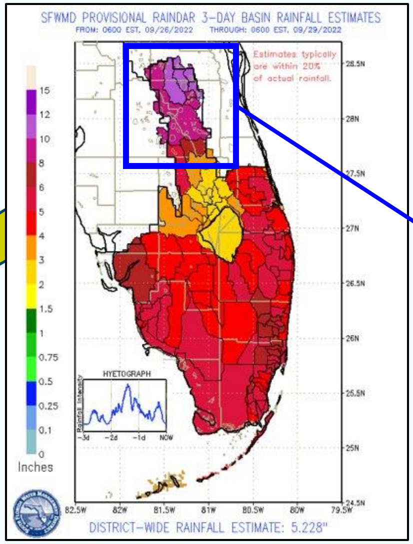
Predicted Surge on 09/28/2022

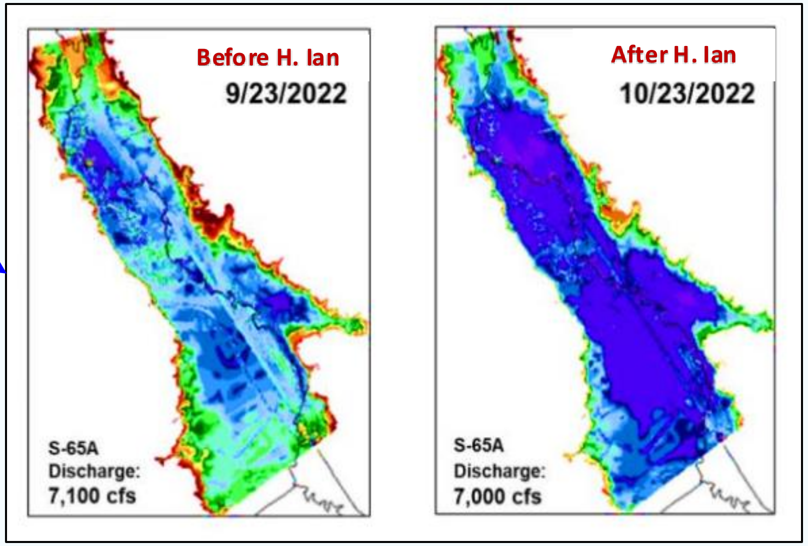


Storm-Induced Seiche

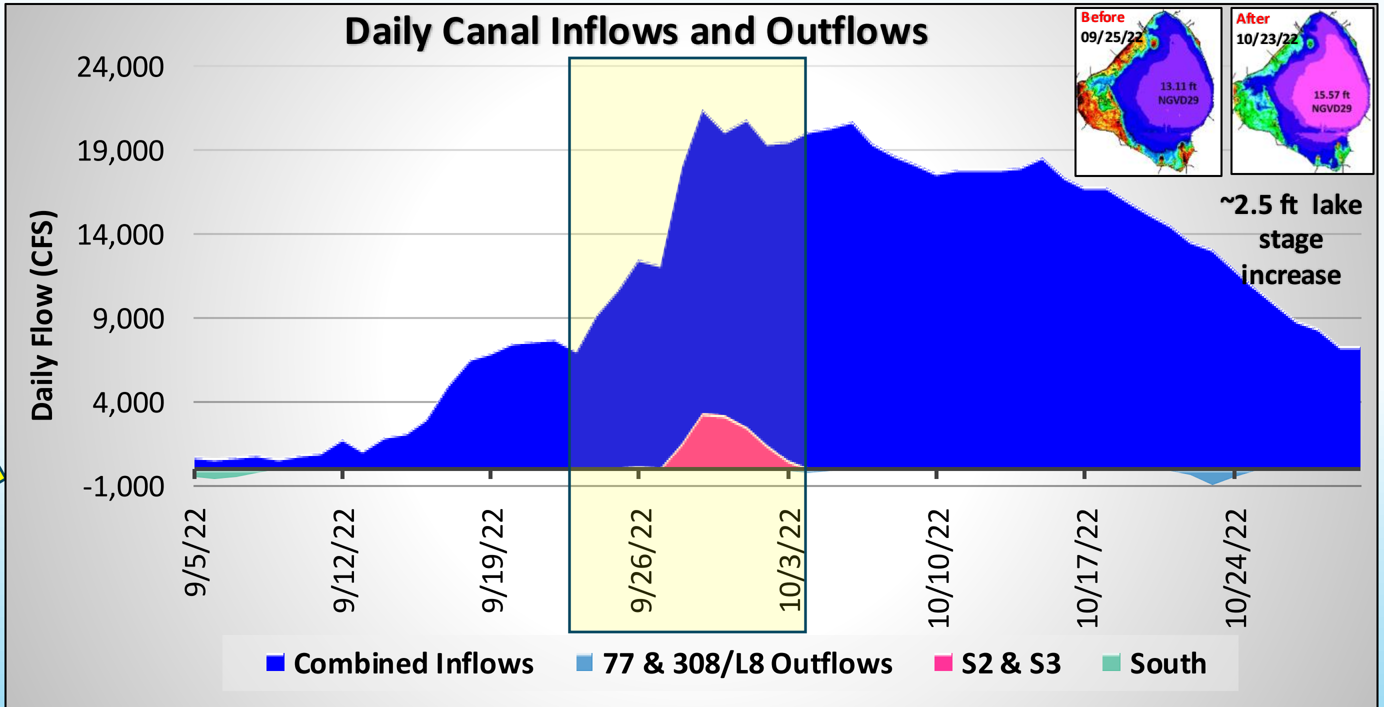


Source: NOAA

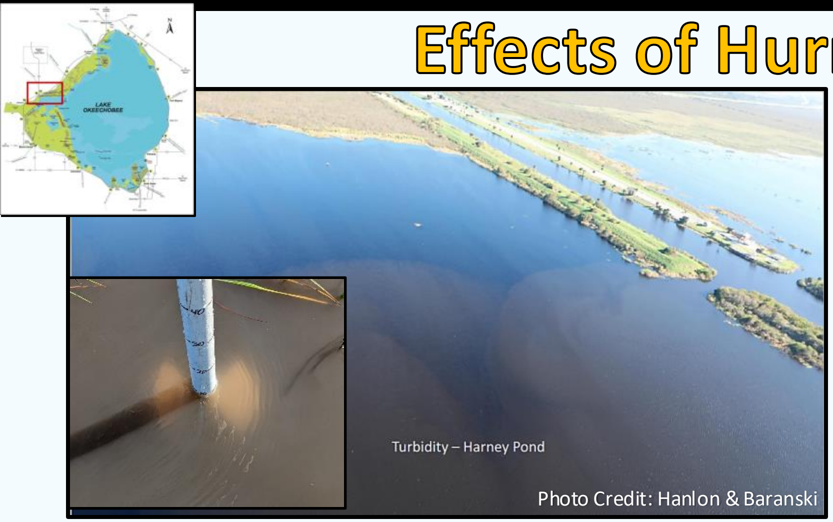


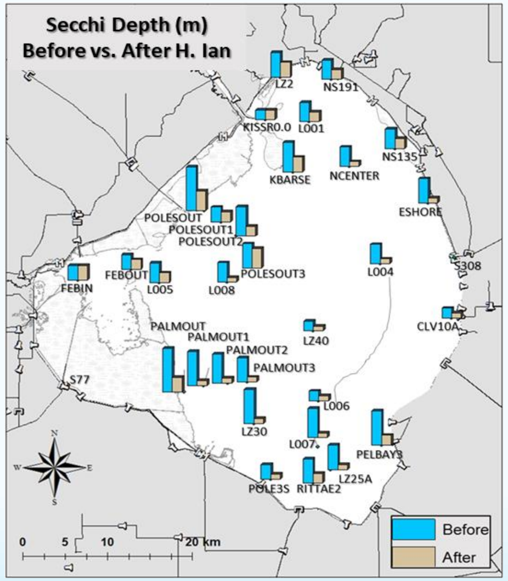


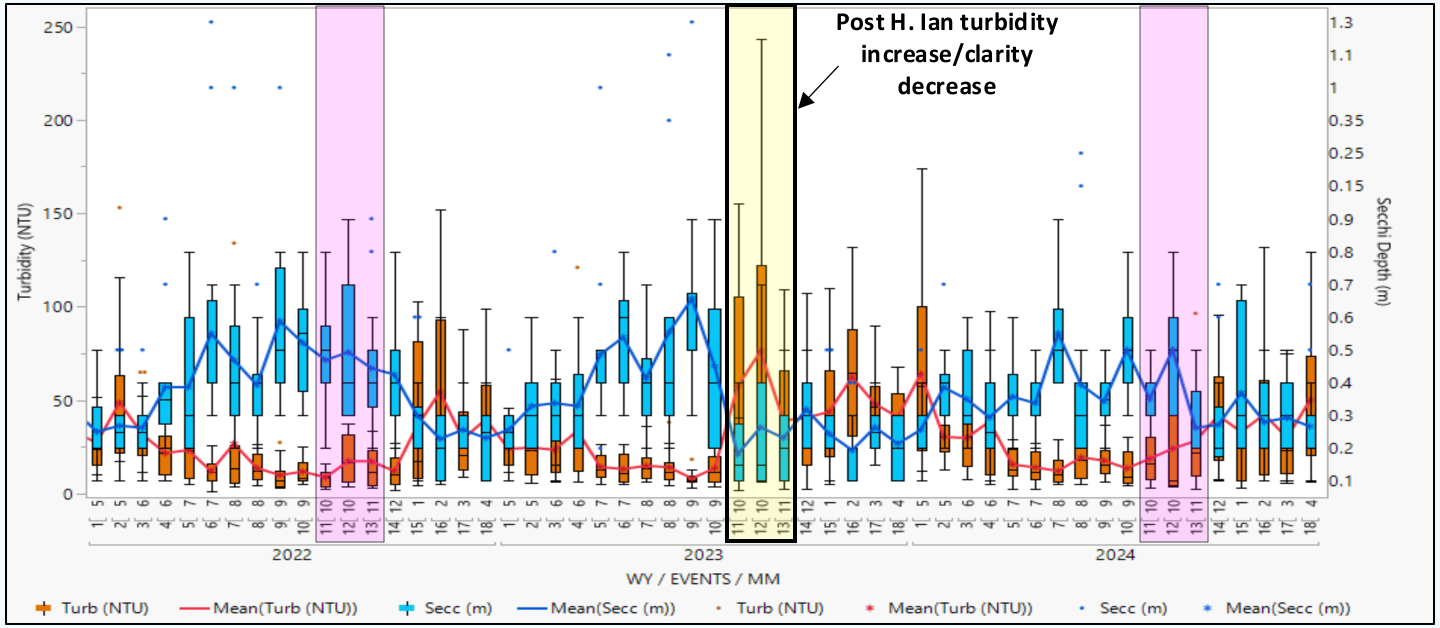
Significant increase in canal Inflows and Lake's stage



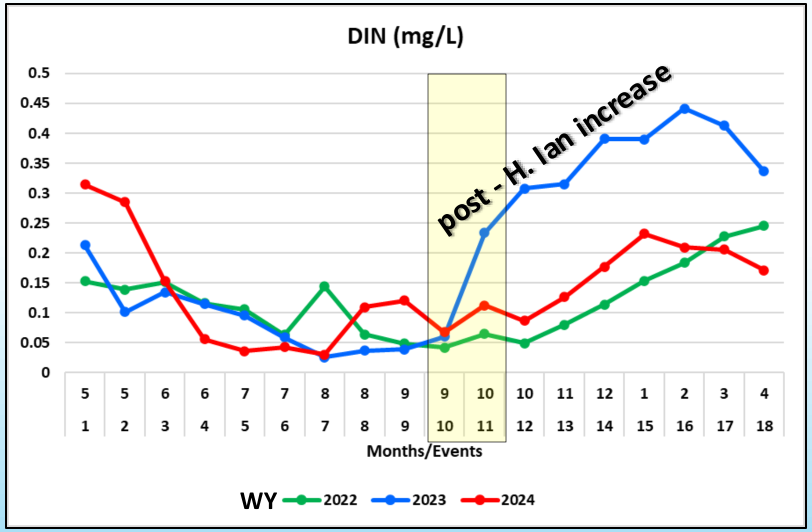
Effects of Hurricane Ian on Lake Okeechobee Water Quality

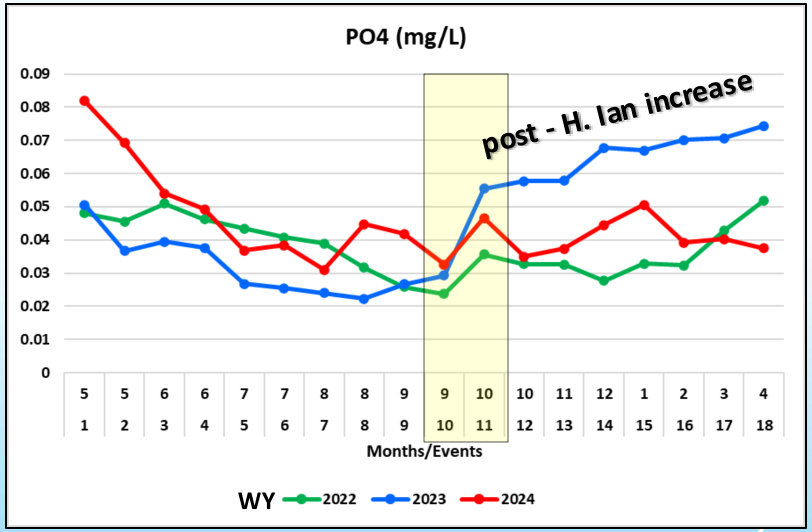






Post- H. Ian Nutrient Pool Increase





- Sig. increase in nutrient concentrations and turbidity, and decrease in water transparency

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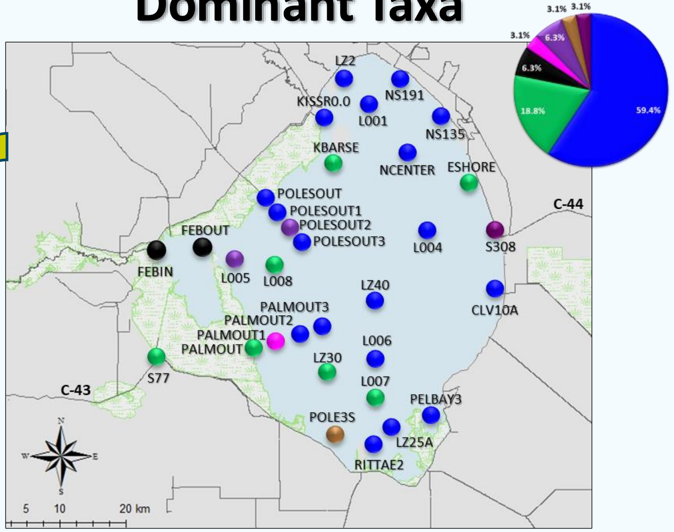
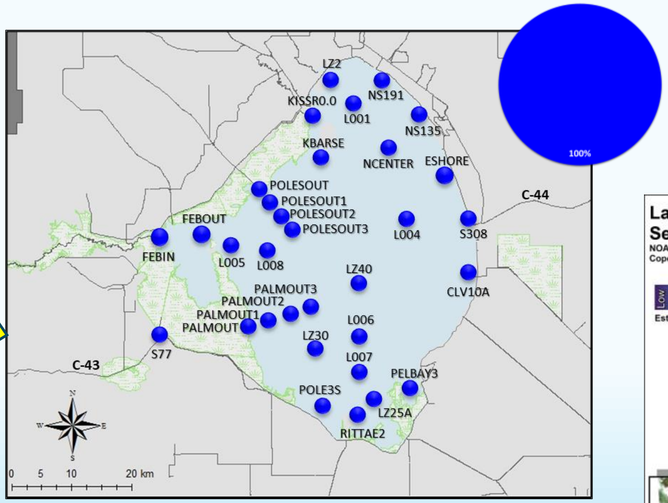
Short-Term Effects of Hurricane Ian on Lake Okeechobee Cyano-HABs

Dominant Taxa

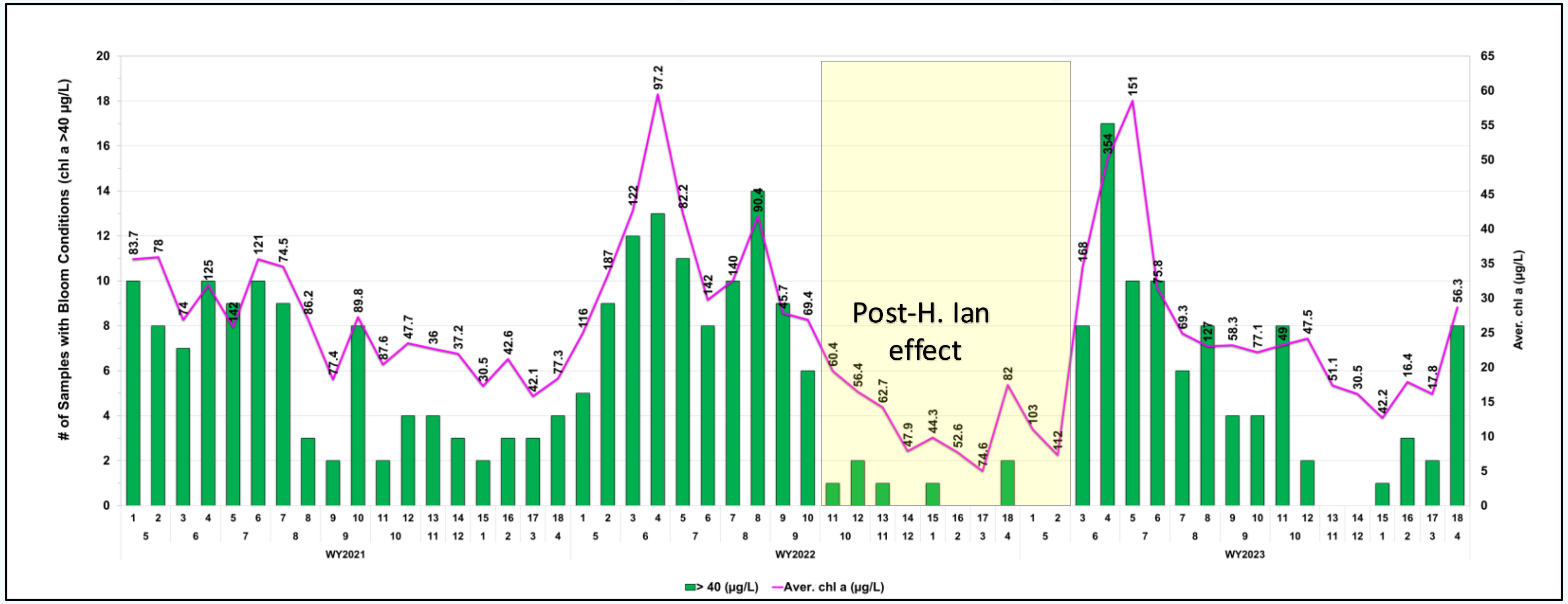


Post- H. Ian shift from diverse to mixed communities

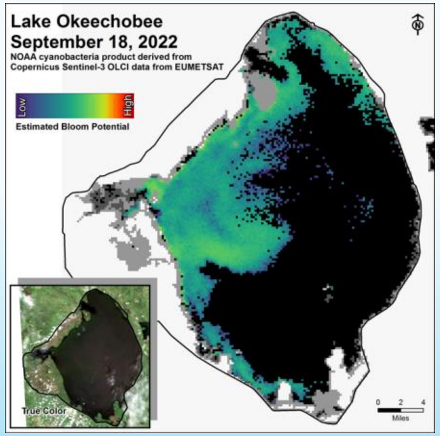


- Not Sampled
- Mixed Communities
- *Microcystis aeruginosa*
- *Planktolyngbya limnetica*
- *Cylindrospermopsis raciborskii*
- *C. raciborskii/P. limnetica*
- *Carteria cordiformis*

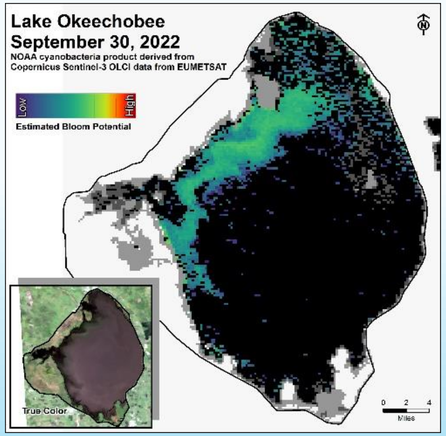
Post- H. Ian Cyano-Bloom Dissipation



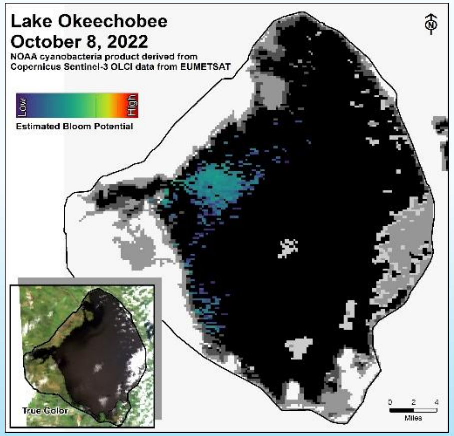
1 Week Before H. Ian



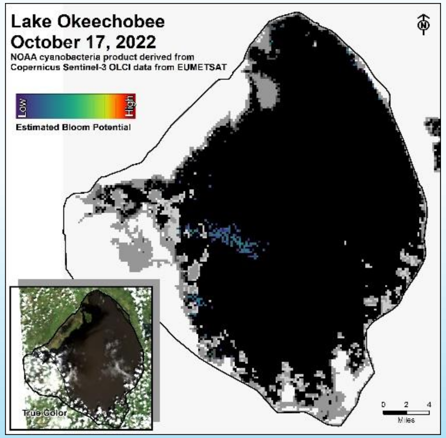
3 Days After



2 Weeks After



3 Weeks After



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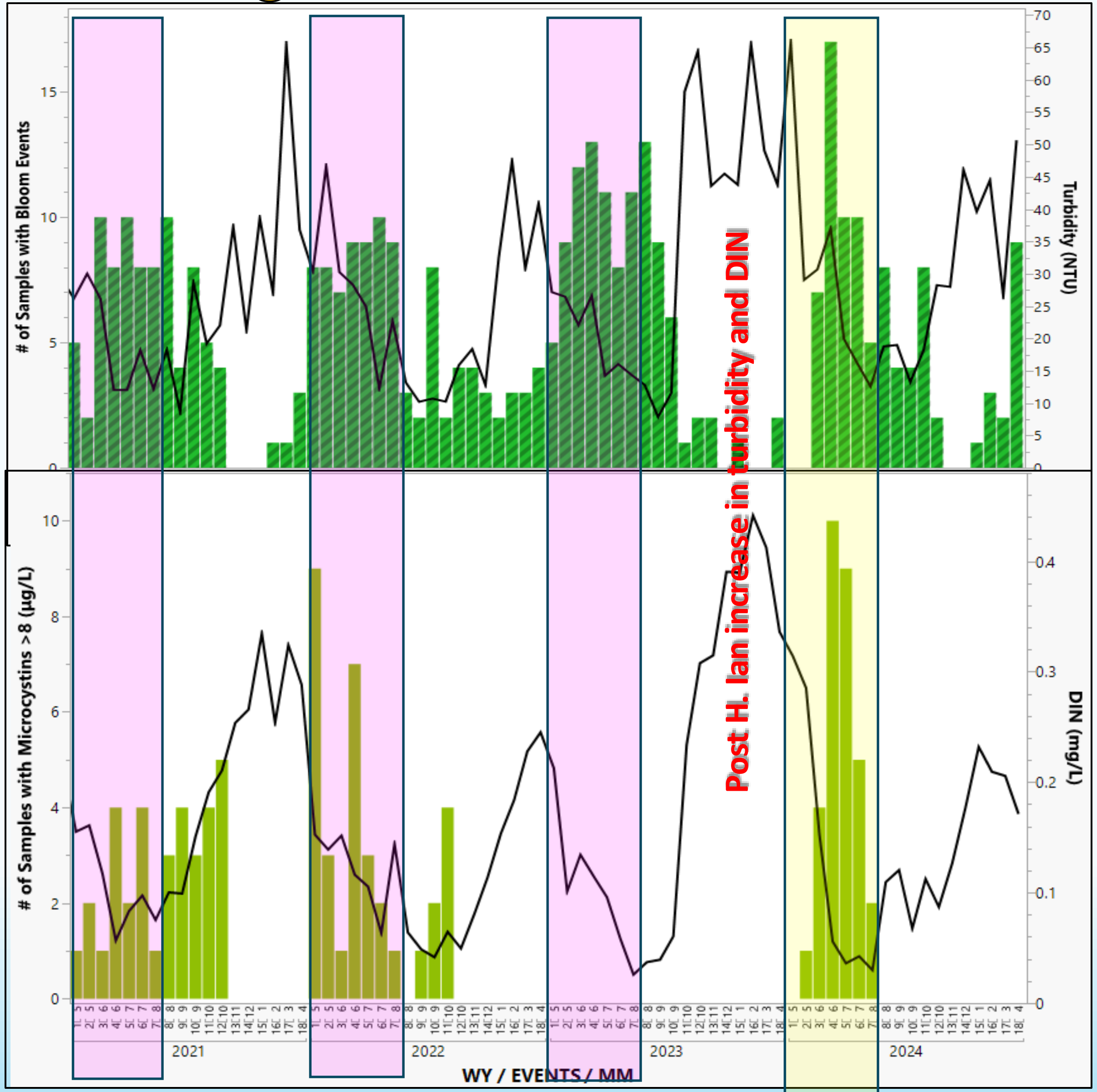
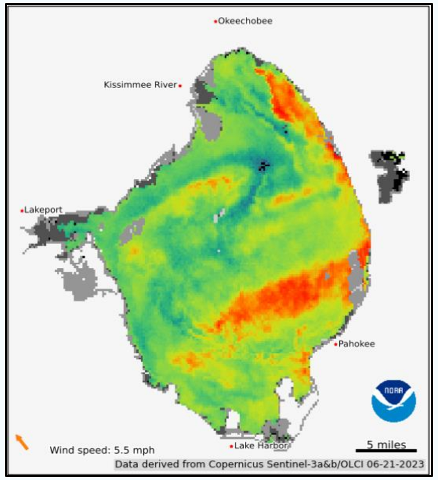
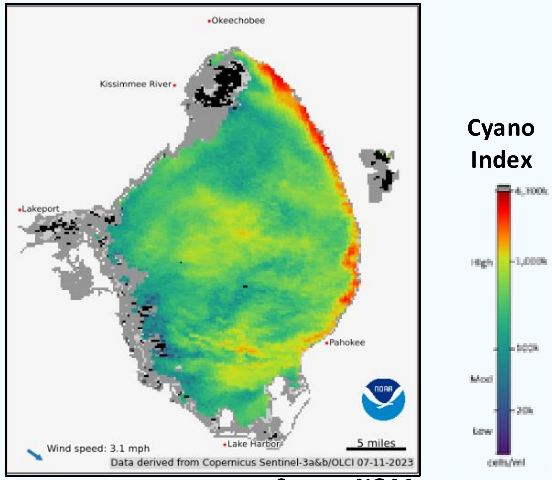
Long-Term Effects of Hurricane Ian on Lake Okeechobee Cyano-HABs



# of Samples with Blooms (chl a >40 µg/L)
# of Samples with Microcystins >8 µg/L (EPA Rec. Standard)
Average DIN (mg/L) and turbidity (NTU)





Cyano Index

Source: NOAA

- Formation of a large nutrient pool following 2022 H. Ian resulted in extensive and toxic cyano-HABs in the following 2023 wet season
- The molecular make-up of microcystins toxins are nitrogen-rich; high DIN is needed for production; large post- H. Ian pool of DIN resulted in toxic in the 2023 wet season
- High post- H. Ian turbidity postponed onset of cyano-HABs until June (usually present as early as March)

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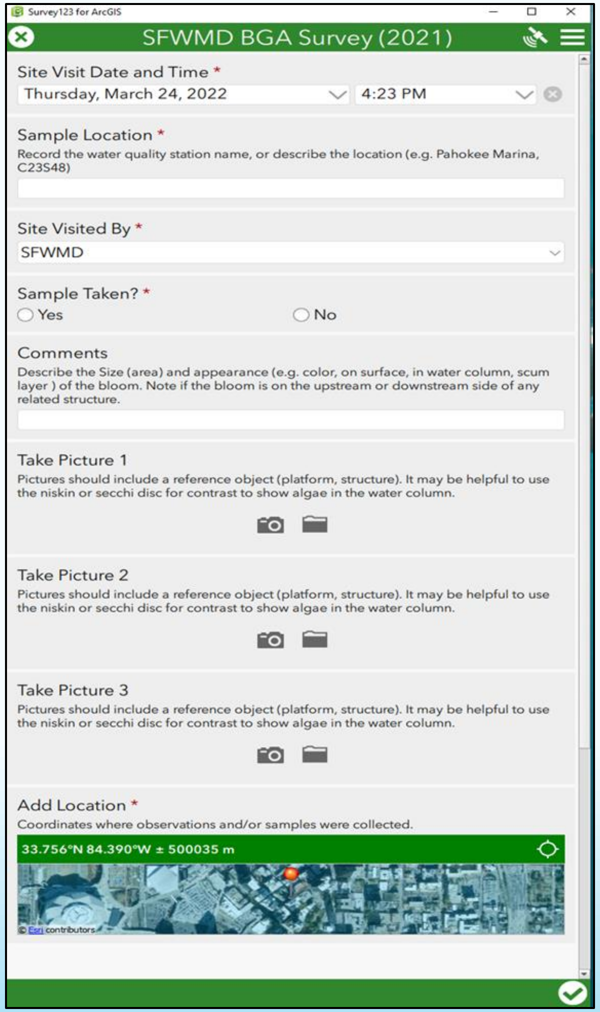
Cyano-HAB Mitigation Strategies: Treatment vs. No Treatment

Daily Visual Assessment of BGA Condition at 5 Lock/Outflow Structures by USACE and 2x/Week at all Strategic Locations by SFWMD Staff

Bloom Location and Extent Recorded and Made Available to SFWMD via Survey 1-2-3


Survey123 for ArcGIS

SFWMD BGA Survey (2021)

Site Visit Date and Time *
Thursday, March 24, 2022 | 4:23 PM

Sample Location *
Record the water quality station name, or describe the location (e.g. Pahokee Marina, C23S48)

Site Visited By *
SFWMD

Sample Taken? *
Yes | No

Comments
Describe the Size (area) and appearance (e.g. color, on surface, in water column, scum layer) of the bloom. Note if the bloom is on the upstream or downstream side of any related structure.

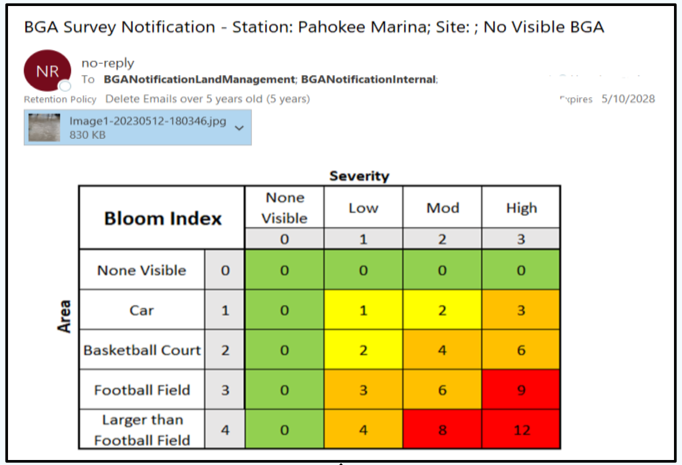
Take Picture 1
Pictures should include a reference object (platform, structure). It may be helpful to use the niskin or secchi disc for contrast to show algae in the water column.

Take Picture 2
Pictures should include a reference object (platform, structure). It may be helpful to use the niskin or secchi disc for contrast to show algae in the water column.

Take Picture 3
Pictures should include a reference object (platform, structure). It may be helpful to use the niskin or secchi disc for contrast to show algae in the water column.

Add Location *
Coordinates where observations and/or samples were collected.
33.756°N 84.390°W ± 500035 m

Automatic Internal Daily Updates on the BGA Status & Pre-and Post-Treatment BGA Conditions


BGA Survey Notification - Station: Pahokee Marina; Site: ; No Visible BGA

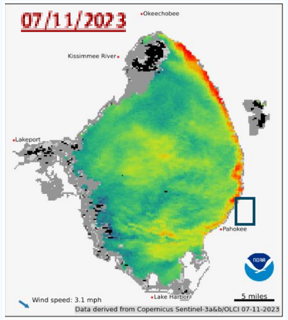
NR no-reply
To BGANotificationLandManagement; BGANotificationInternal;
Retention Policy Delete Emails over 5 years old (5 years) Expires 5/10/2028
Image1-20230512-180346.jpg 830 KB

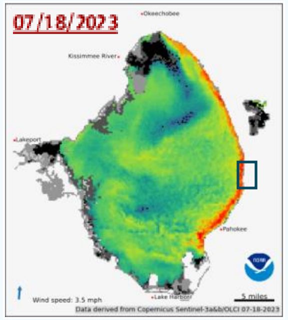
Severity

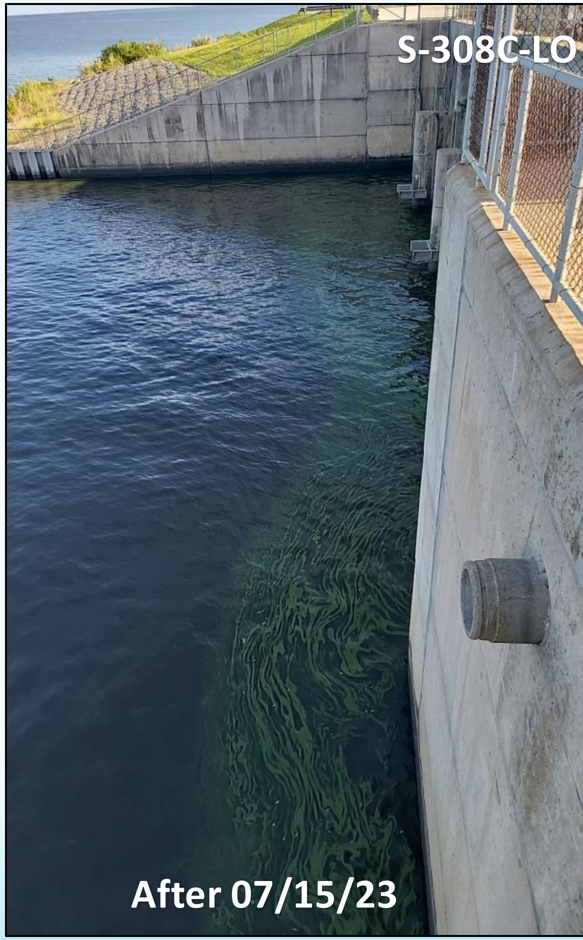
Bloom Index			None Visible	Low	Mod	High
			0	1	2	3
Area	None Visible	0	0	0	0	0
	Car	1	0	1	2	3
	Basketball Court	2	0	2	4	6
	Football Field	3	0	3	6	9
	Larger than Football Field	4	0	4	8	12

Decision Point: Treatment vs. No Treatment & Pre- and Post-Treatment Water Quality, Toxin and Phytoplankton Assessment

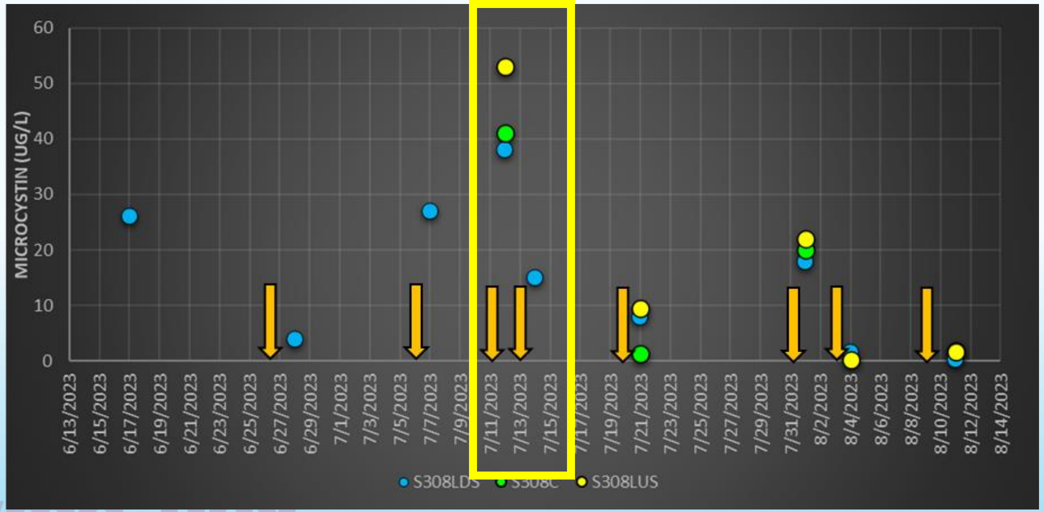
C-HABs Mitigation using LGOxy Algaecide – 2023 Bloom Season







Total Microcystins Toxin Concentrations



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Thank You!