The Greater Everglades Ecosystem
Restoration Conference
Coral Springs, FL
April 21–24, 2025

# Management Strategies for Mitigating HABs at the Complex Nexus of Eutrophication and Climate Change

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*Principal Scientist*

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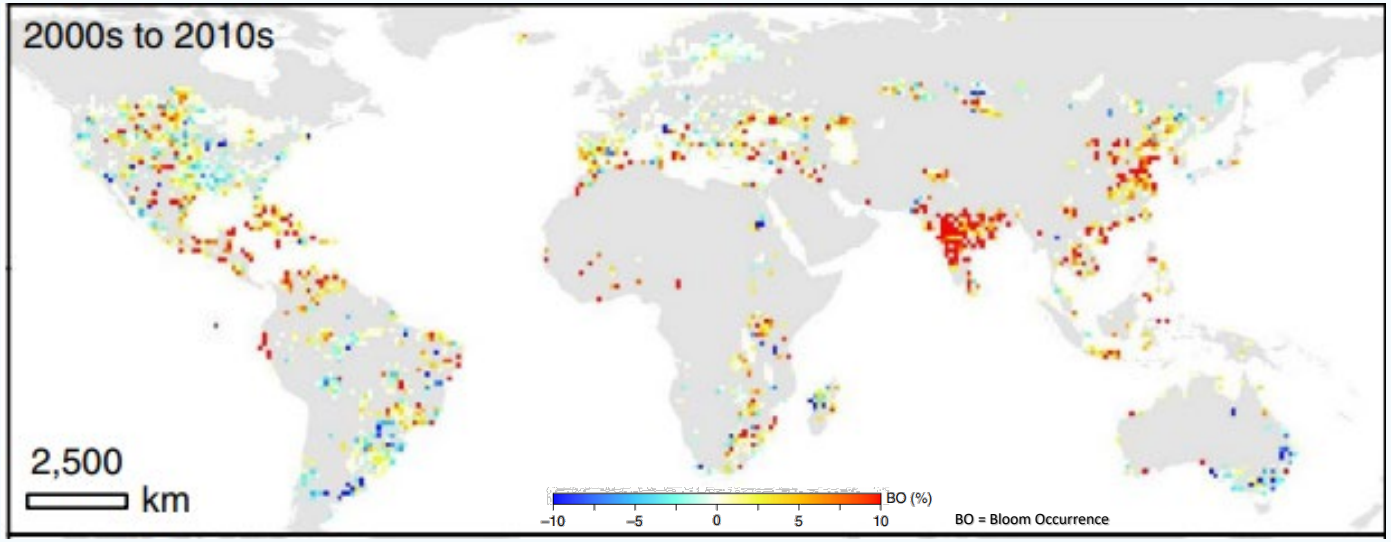
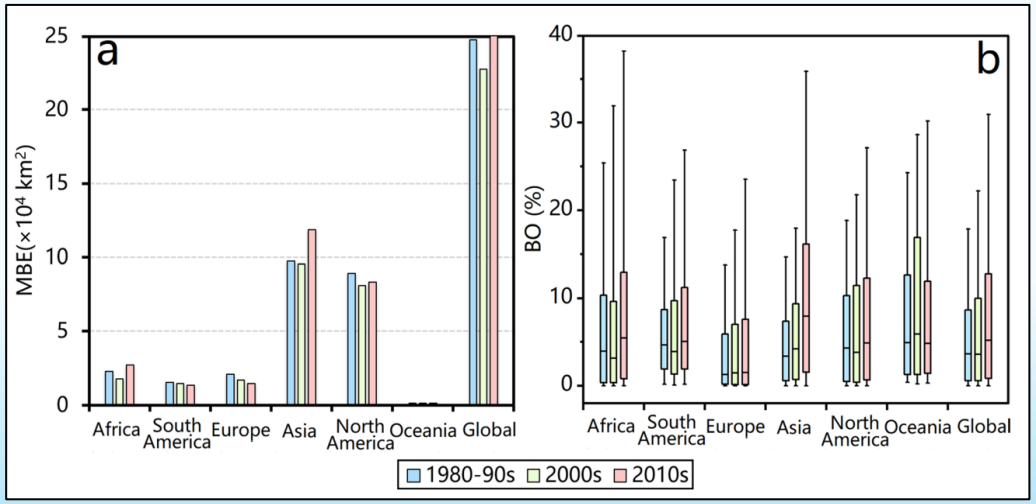
South Florida Water Management District
West Palm Beach, FL

Photo Source: FWC, Red Tide, West Coast of FL

# Session Introduction: Global Expansion of HABs

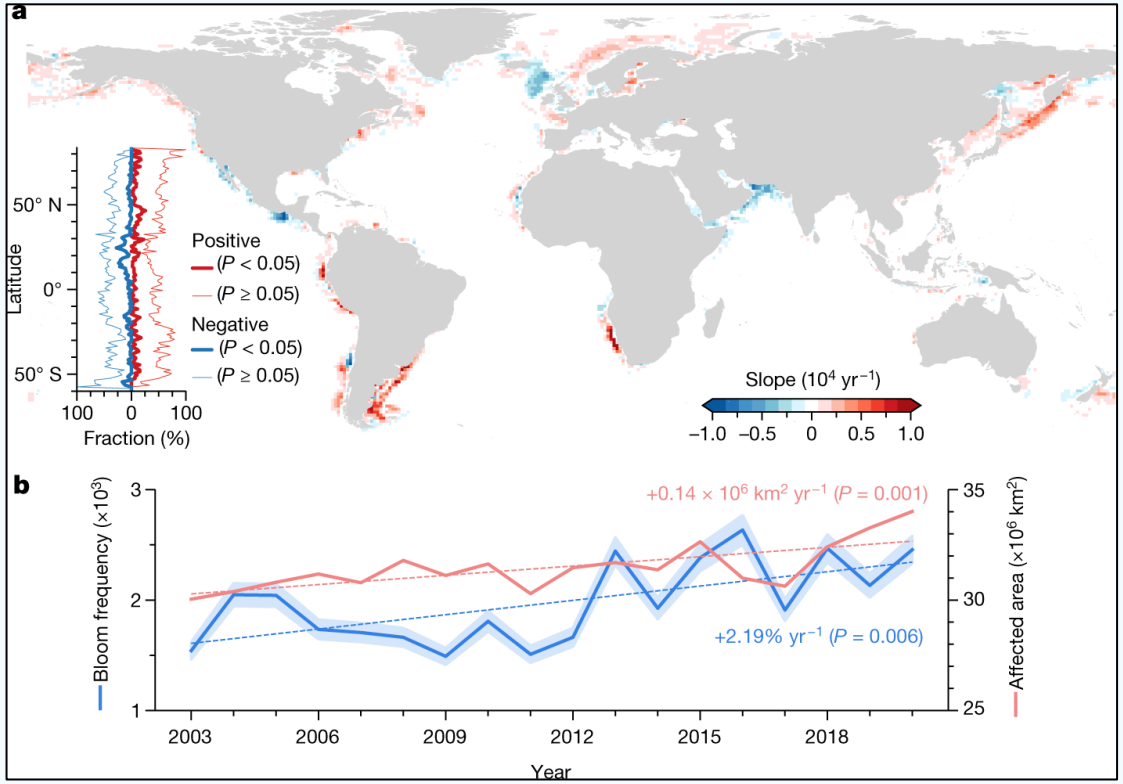
## Lacustrine Bloom Occurrences




Source: Hou et al., Nature (2022)

## Coastal Bloom Occurrences




Source: Dai et al., Nature (2023)

- Lacustrine bloom occurrences increased by ~44% and global max. bloom extent by ~19% from 2000s to 2010s (Hou, et al. 2022)
- Coastal median bloom occurrences increased by ~59% and bloom-affected area expanded by ~13% between 2003 and 2020 (Dai et al., 2023)

# Session Introduction: HAB Prevention, Control and Mitigation


**Prevention**

- ✓ Nutrient runoff reduction
- ✓ Watershed management
- ✓ Nutrient pollution control

**Control**

- ❑ **PHYSICAL**
  - ✓ Surface skimming
  - ✓ Mechanical mixing
  - ✓ Clay flocculation
  - ✓ Hydrologic manipulations
- ❑ **BIOLOGICAL**
  - ✓ Bio-flocculation
  - ✓ Bio control agents
  - ✓ Resuspension to enhance natural processes
- ❑ **CHEMICAL**
  - ✓ Algaecides
  - ✓ Nanobubble aeration
  - ✓ Different chemical control agents

**Mitigation**

- ✓ Monitoring/Early warning
- ✓ Public outreach/Education
- ✓ Harvest restrictions
- ✓ R & D of new HAB control and prevention approaches

# Session Introduction: Featured Presentations

1) **Dr. Anna Wachnicka (SFWMD):** *"A Comprehensive Overview of the Lake Okeechobee C-HAB Management Strategies and Selected Mitigation Projects."*

2) **Dr. Toshi Urakawa (FGCU):** *"Lake Guard Oxy Treatments for Cyanobacterial Blooms at Lake Okeechobee Outflow Structures."*

3) **Dr. Cynthia Heil (MOTE Marine Lab):** *"Use of Curcumin for Mitigation of the Toxic Dinoflagellates Karenia brevis and Alexandrium monilatum."*

4) **Dr. Kathryn Coyne (Univ. of Delaware):** *"Immobilization of Algicidal Bacteria for Management of Algal Blooms: A Case Study."*

5) **Dr. Martin Page (USACE-ERDC):** *"Physical and Economic Scalability Analysis of the Harmful Algal Bloom Interception, Treatment, and Transformation System (HABITATS)."*

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# A Comprehensive Overview of the Lake Okeechobee C-HAB Management Strategies and Selected Mitigation Projects

*Anna Wachnicka, PhD*

*Principal Scientist*
Water Resources Division/Applied Sciences Bureau
South Florida Water Management District
West Palm Beach, FL

*Co-authors: LeRoy Rodgers[1], Stuart VanHorn[1], Rory Feeney[1], Mandy Michalsen[2]*

1. 2.

sfwmd.gov

Photo Source: Joe Raedle

# SFWMD HAB Research Focus Areas and Management Strategies

## Detection & Monitoring
(well-established)

- ✓ Bloom detection using NOAA/NASA satellite remote sensing imagery
- ✓ Daily visual assessment of BGA condition at strategic locations
- ✓ Bloom assessments with drones and airplanes on as needed basis
- ✓ Long-term bi-/monthly and continuous WQ, toxins and phytoplankton monitoring

## Data Mining
(well-established)

- ✓ Inter- and intra-annual spatial and temporal HAB and toxin dynamics
- ✓ Biotic and abiotic controls of HABs and toxins

## Modeling & Forecasting
(ongoing efforts)

- ✓ Using data-driven machine learning and hydrodynamic models and satellite remote sensing imagery for developing short-term and seasonal operational HAB forecasts

## Prevention, Control & Mitigation
(well-established & new efforts)

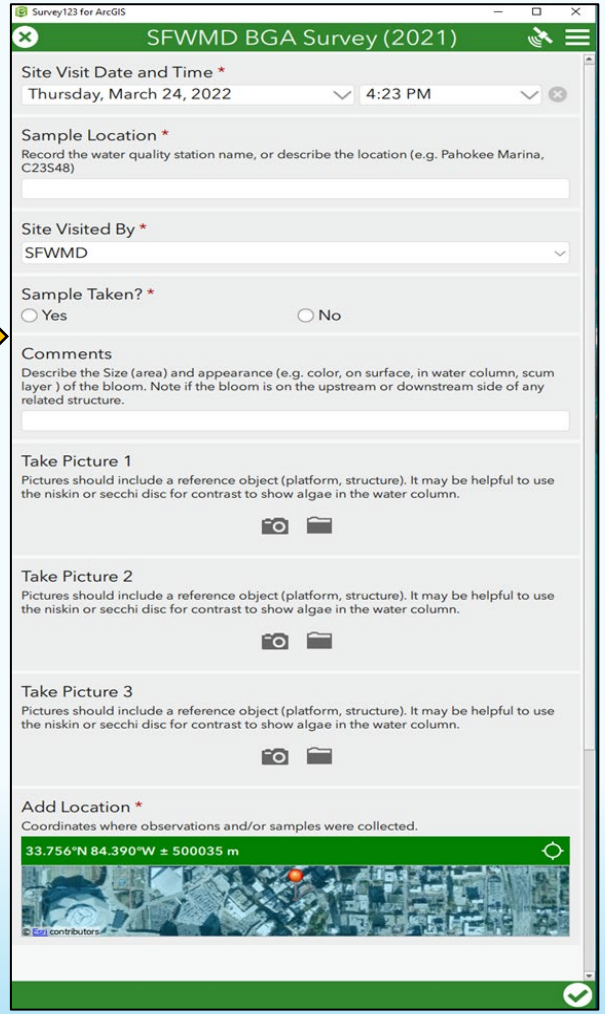
- ✓ Long-term strategies: watershed-based reductions of point and nonpoint nutrient inputs and nutrient hotspots elimination
- ✓ Short-term strategies: BGA biomass and toxin control at priority locations and system-wide HAB mitigation actions

# SFWMD C-HAB Mitigation Strategies: Treatment vs. No Treatment

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



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




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

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

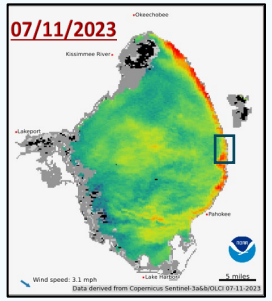
NR no-reply
To BGANotificationLandManagement; BGANotificationInternal;
Retention Policy Delete Emails over 5 years old (5 years) Expires 5/10/2028
Image1-20230512-180346.jpg 830 KB

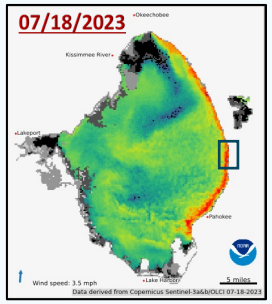
Severity

| Area: Bloom Index | | None Visible | Low | Mod | High |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| 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 WQ, Toxin and Phyto Assessments**

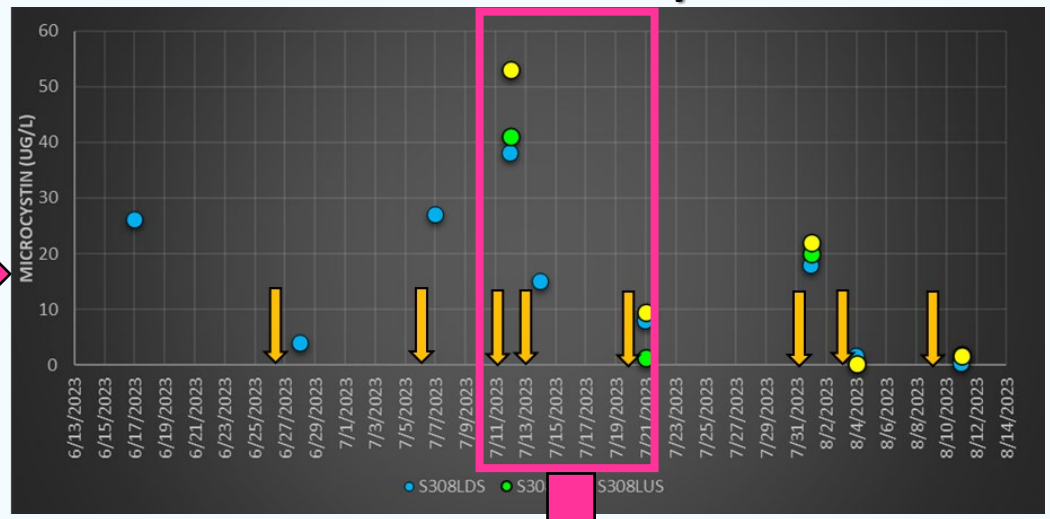
# 2023 C-HAB Mitigation at Port Mayaca (S-308/C-44)





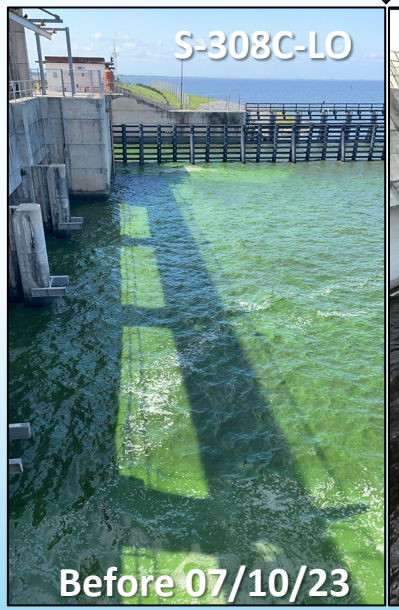
## Before - After Treatment Microcystins Toxin Conc.

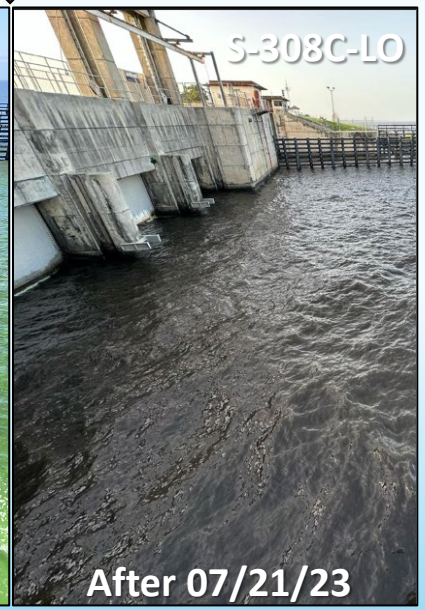



## 2023 Bloom Index Record for Port Mayaca (S-308)


| Bloom Index | | Severity: None Visible | Low | Mod | High |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| 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 |

Area




*Provisional data and subject to change

# 2021 C-HAB Abatement at the Pahokee Marina - Bloom Drivers & Outcomes

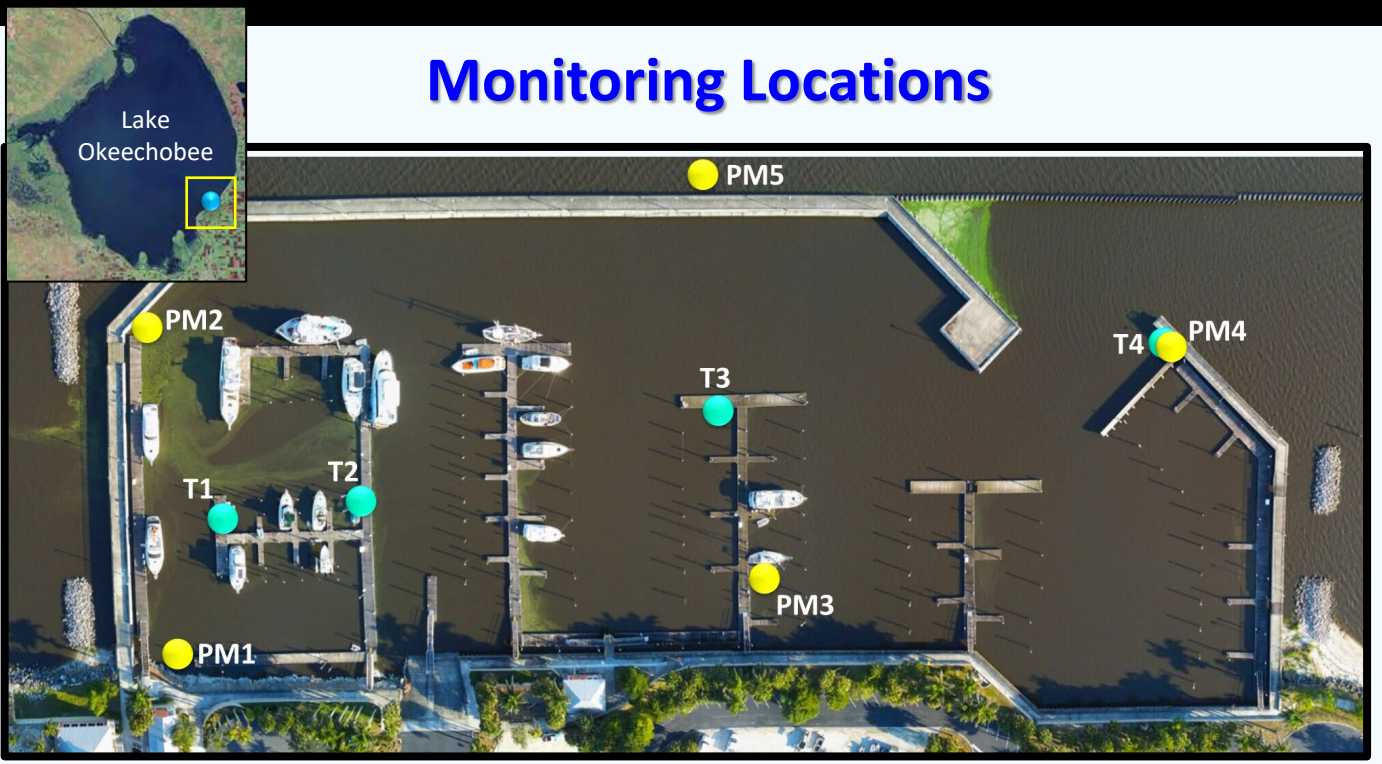

**Photos Source (SFWMD)**

- Enclosed Marina with Stagnant Water
- \+
- Early Spring Surface Water Temperature Increase
- \+
- Nutrient Over-Enrichment
- \+
- Constant Influx of BGA Scum from Lake O. during summers

→ **BGA Scum Trapping, Accumulation, and Fast Growth in Nutrient-Enriched/Warm Marina Waters (C-HAB boom & bust)** =

- Cyano-Toxins Lysis
- Aerosolization of Cyano-Toxins
- DO Depletion
- Recycled Nutrients Sustain Blooms
- High Turbidity/Shading
- Surf. Water Temp. Increase
- OM & Nutrient Accumulation in Sed

## Monitoring Locations




Weekly WQ Monitoring  Continuous WQ Monitoring + Ultrasonic Transducers

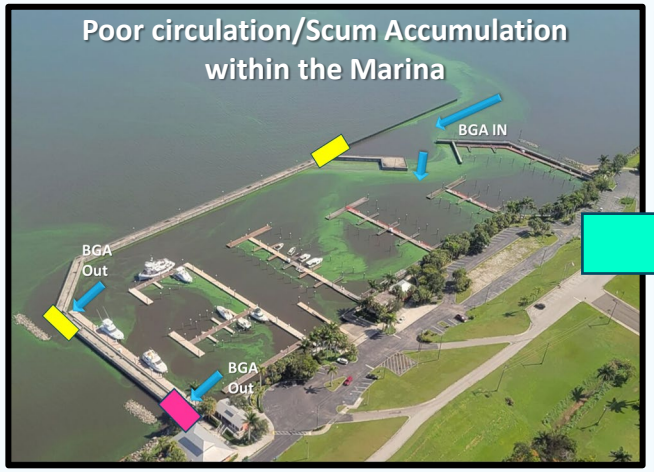

Ultrasonic Transducers and AquaTroll 600 Multiparameter Sondes Installation (May 2021)

# 2021 C-HAB Abatement at the Pahokee Marina

- ❑ **Multi C-HAB Control Approaches**
  - ✓ Chemical
  - ✓ Mechanical
- ❑ **4 Monitoring Locations (Pre- & Post-Treatment)**
  - ✓ Weekly WQ (physicochemical + biological)
  - ✓ Microcystin toxins
  - ✓ Dominant taxa
- ❑ **4 Continuous Water Quality Monitoring Stations**
  - ✓ Physicochemical
  - ✓ Biological

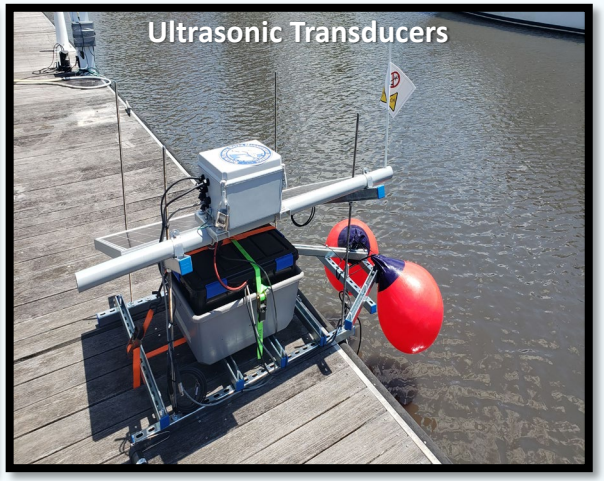
# 2021 Multi Approach C-HAB Abatement at the Pahokee Marina

## Long-Term Circulation Improvements

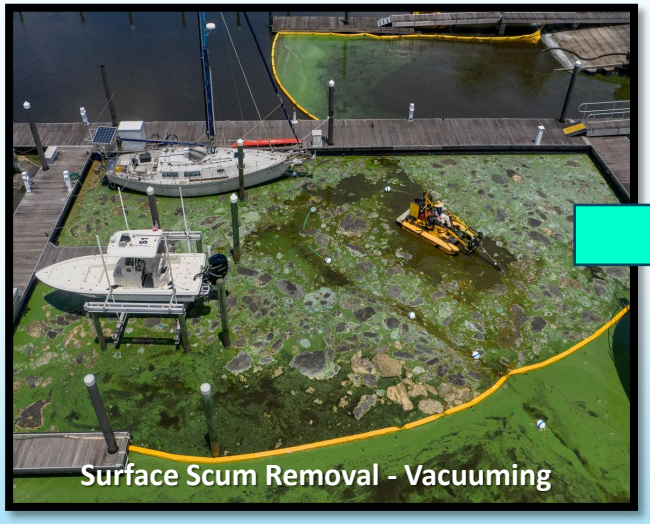




## Mechanical Mixing & Ultrasonication


## Mechanical Surface Scum Removal

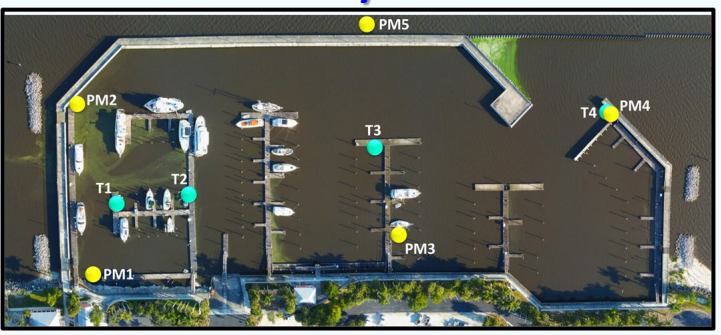




## Surface Water Aeration & Chemical Treatment

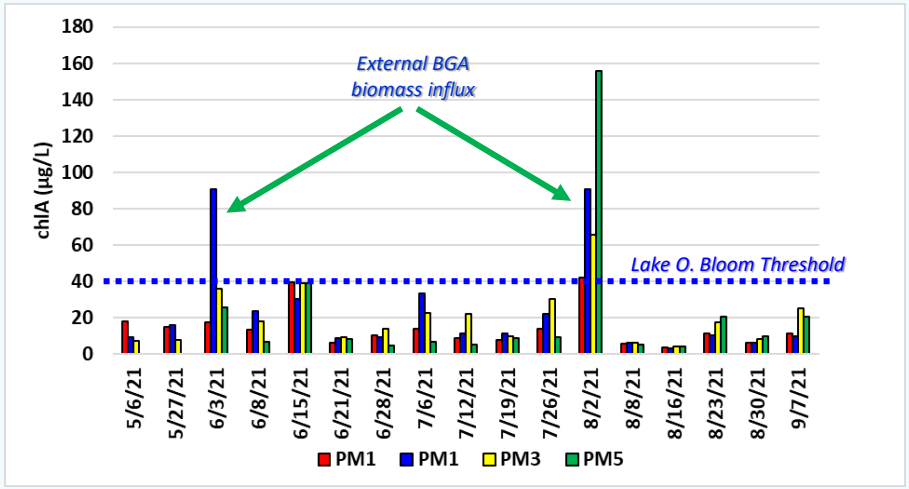

# Did the Multi Approach C-HAB Abatement Strategy at the Pahokee Marina Work?

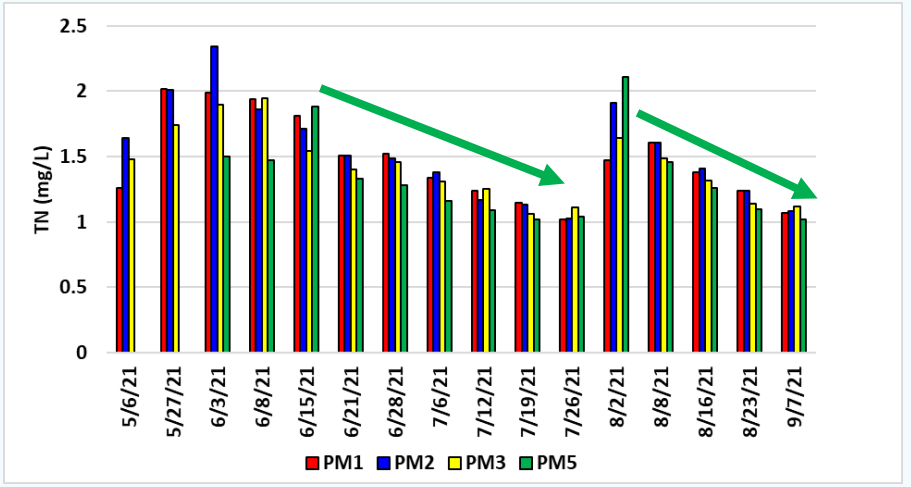
## Study Sites

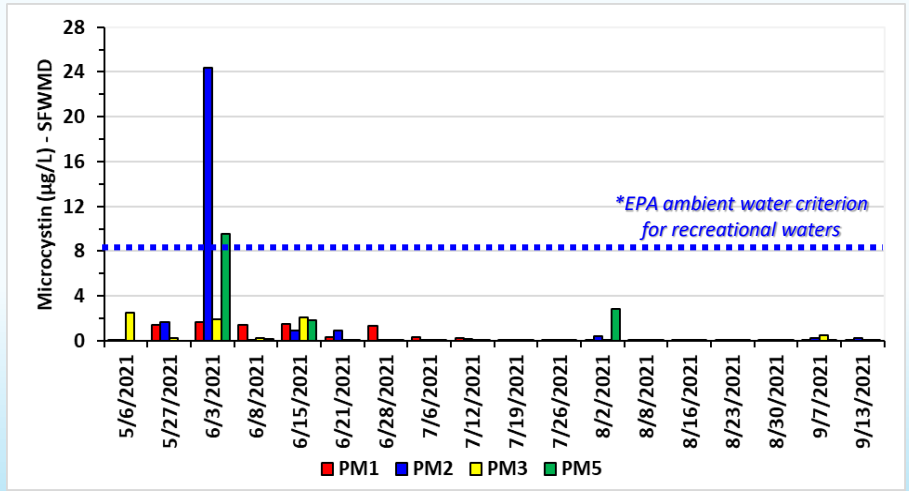


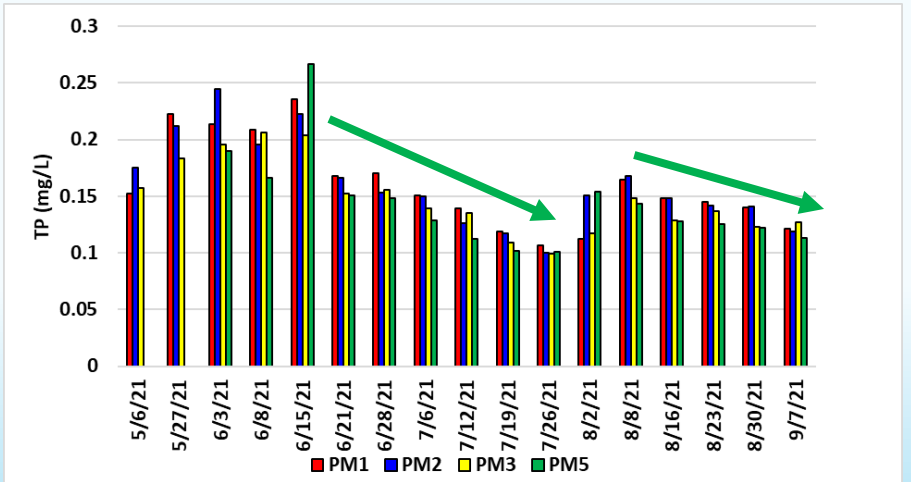



Photos Source (SFWMD)



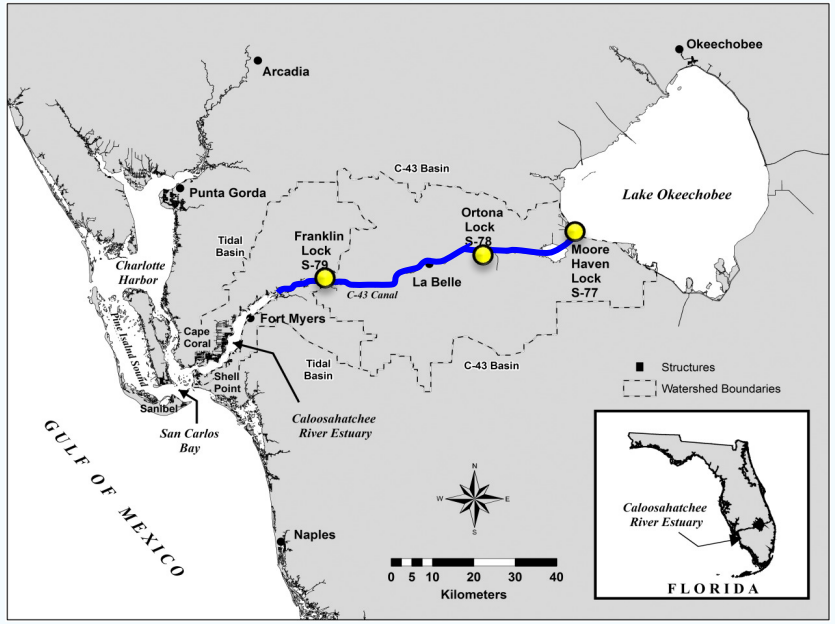



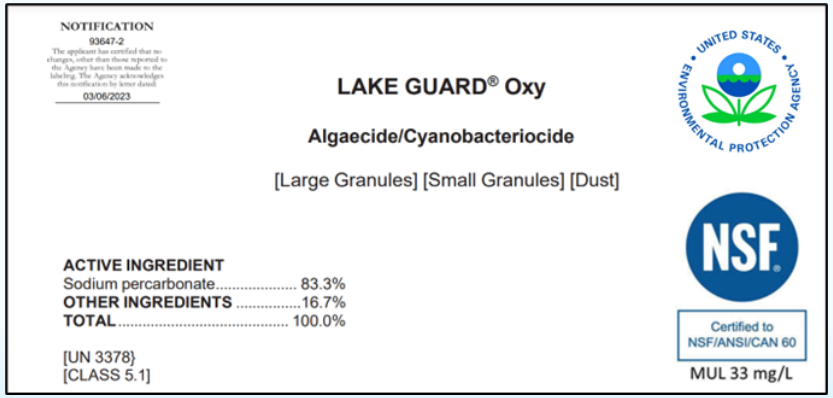

*Provisional data and subject to change
** PM4 monitoring discontinued

# 2021 Lake Guard® Oxy Product Demo Poject in the Caloosahatchee Canal (C-43)

## Study Area







NOTIFICATION
93647-2
03/06/2023

LAKE GUARD® Oxy

Algaecide/Cyanobacteriocide

[Large Granules] [Small Granules] [Dust]

ACTIVE INGREDIENT
Sodium percarbonate..... 83.3%
OTHER INGREDIENTS .....16.7%
TOTAL..... 100.0%

[UN 3378]
[CLASS 5.1]

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NSF

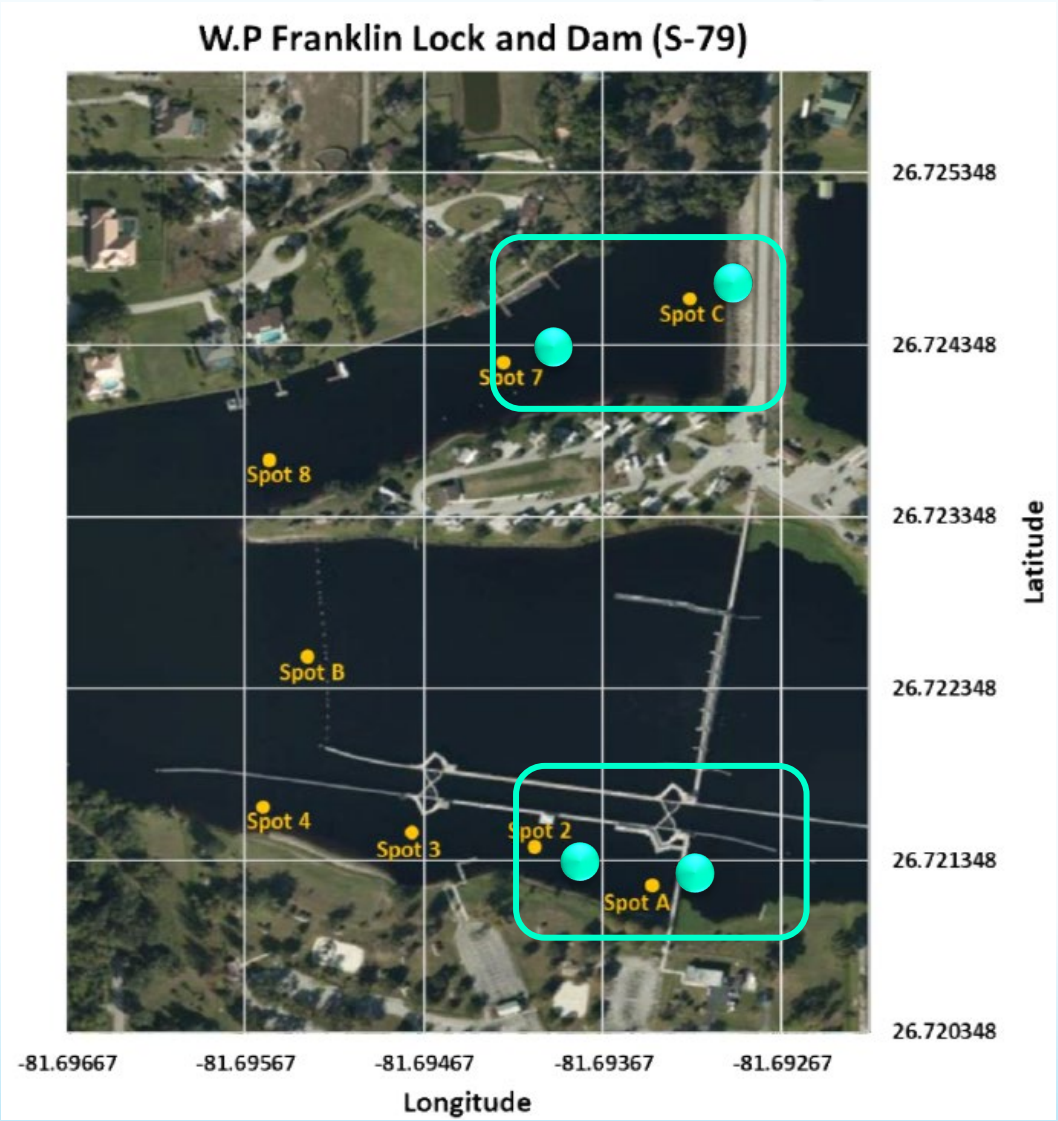
Certified to NSF/ANSI/CAN 60

MUL 33 mg/L

- ❑ **Treatment period: 15 days**
- ❑ **Treatment application number: 112**
- ❑ **Residential areas treated: 56**
- ❑ **C-43 Canal length treated: 48 miles (~77 km)**
- ❑ **Lake Guard®Oxy application rates: 0.5-30 lb/acre**
- ❑ **Lake Guard® Oxy decomposition product: $H_2O$ and $O_2$ (within 24-48 hrs)**

Data Source: Bluegreen Water Technologies LLC. Final Report (2021)

# 2021 Lake Guard® Oxy Product Tests in the Caloosahatchee Canal (C-43)




Source: Bluegreen Water Technologies LLC. Final Report (2021)

BEFORE Treatment: May 26, 2021


AFTER Treatment: May 30, 2021


**Microcystins Toxins Concentration (Before/After Treatments**

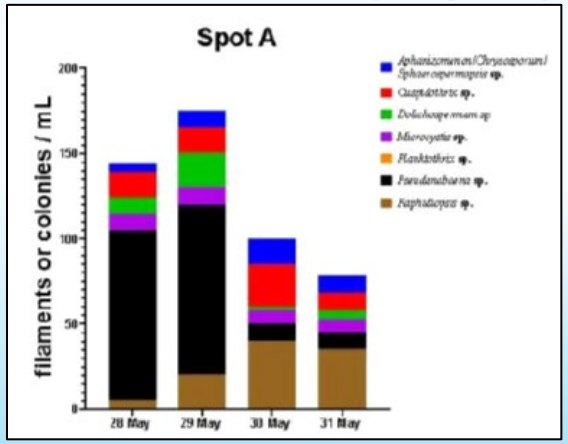
| Spot C | microcystins / nodularins | saxitoxins |
|---|---|---|
| 28 May | --- | --- |
| 29 May | 310 | 0.07 |
| 30 May | 1.76 | 0.09 |
| 31 May | 0.53 | 0.1 |

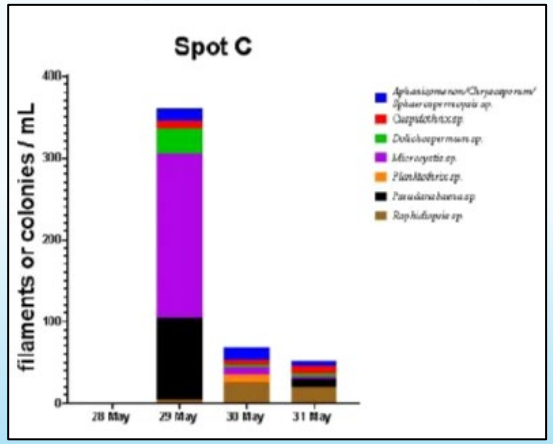
| Spot 7 | microcystins / nodularins | saxitoxins |
|---|---|---|
| 28 May | --- | --- |
| 29 May | 1.55 | 0.09 |
| 30 May | 0.7 | 0.08 |
| 31 May | 0.67 | 0.1 |

| Spot A | microcystins / nodularins | saxitoxins |
|---|---|---|
| 28 May | 8.2 | 0.08 |
| 29 May | 7.94 | 0.09 |
| 30 May | 0.27 | 0.1 |
| 31 May | 0.48 | 0.11 |

| Spot 2 | microcystins / nodularins | saxitoxins |
|---|---|---|
| 28 May | 2.33 | 0.11 |
| 29 May | 3.59 | 0.07 |
| 30 May | 0.8 | 0.1 |
| 31 May | 2.02 | 0.1 |

**Abundance of Potentially Toxigenic Cyanobacteria (Before/After Treatments)**



# 2024-2026 Lake Guard® Oxy Treatment Efficacy Tests

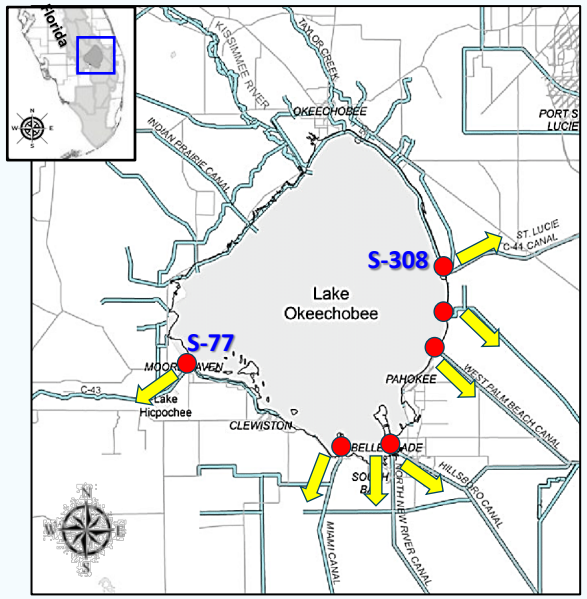
## ❑ Problem Statement

- ***Lake Okeechobee cyano-HABs, if transported downstream, can pose a risk to the ecological integrity and sustainability of the downstream aquatic ecosystems which are source of drinking water, irrigation, fishing and recreational resources***

## ❑ Importance of the Project

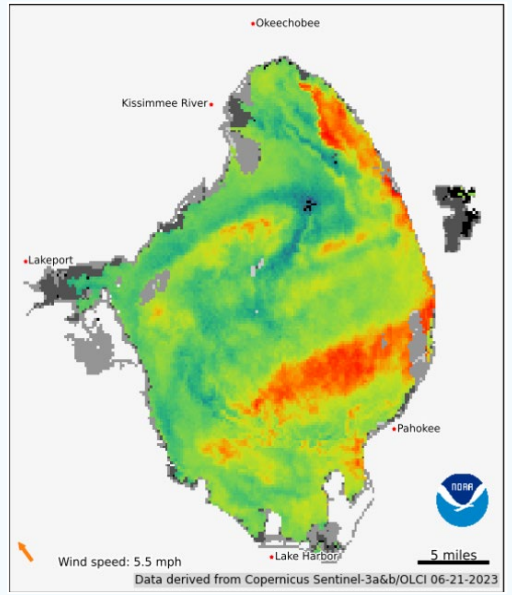
- ***Strategic, optimized timing and dose of algaecide application to decrease risk of transporting potentially toxic C-HAB biomass to downstream ecosystems***

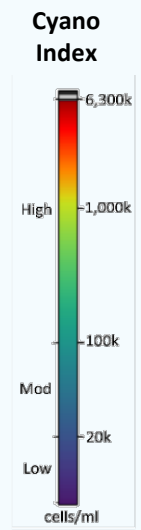
**Lake O. Major Outflow Structures**




*Map source: SFWMD*

**C-HAB Distribution on Lake O.**




*Map Source: NOAA-NCCOS*




*Photo courtesy of SFWMD*

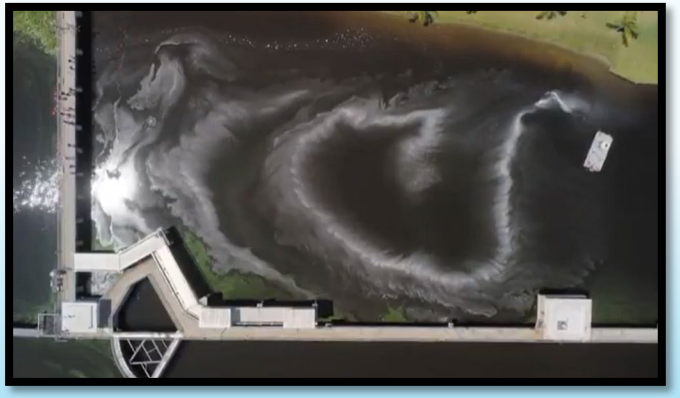
*Photos courtesy of S. Kuhns*

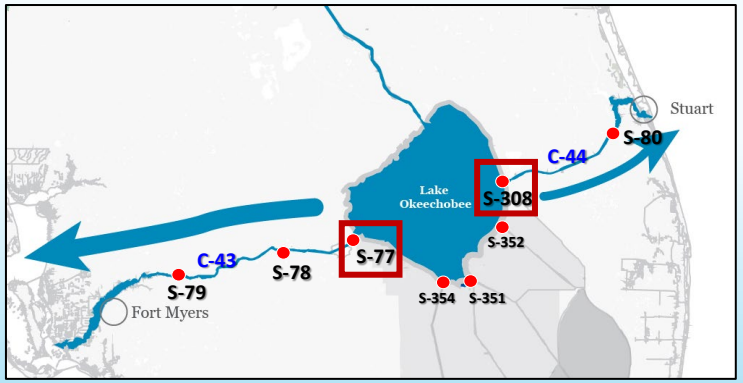
# Project Goal

*1) Determine efficacy of the Lake Guard® Oxy treatments under flow and no-flow scenarios at a selected Lake Okeechobee outflow structure(s) and canal(s) during bloom seasons*

**To achieve this goal, the proposed work has the following objectives:**

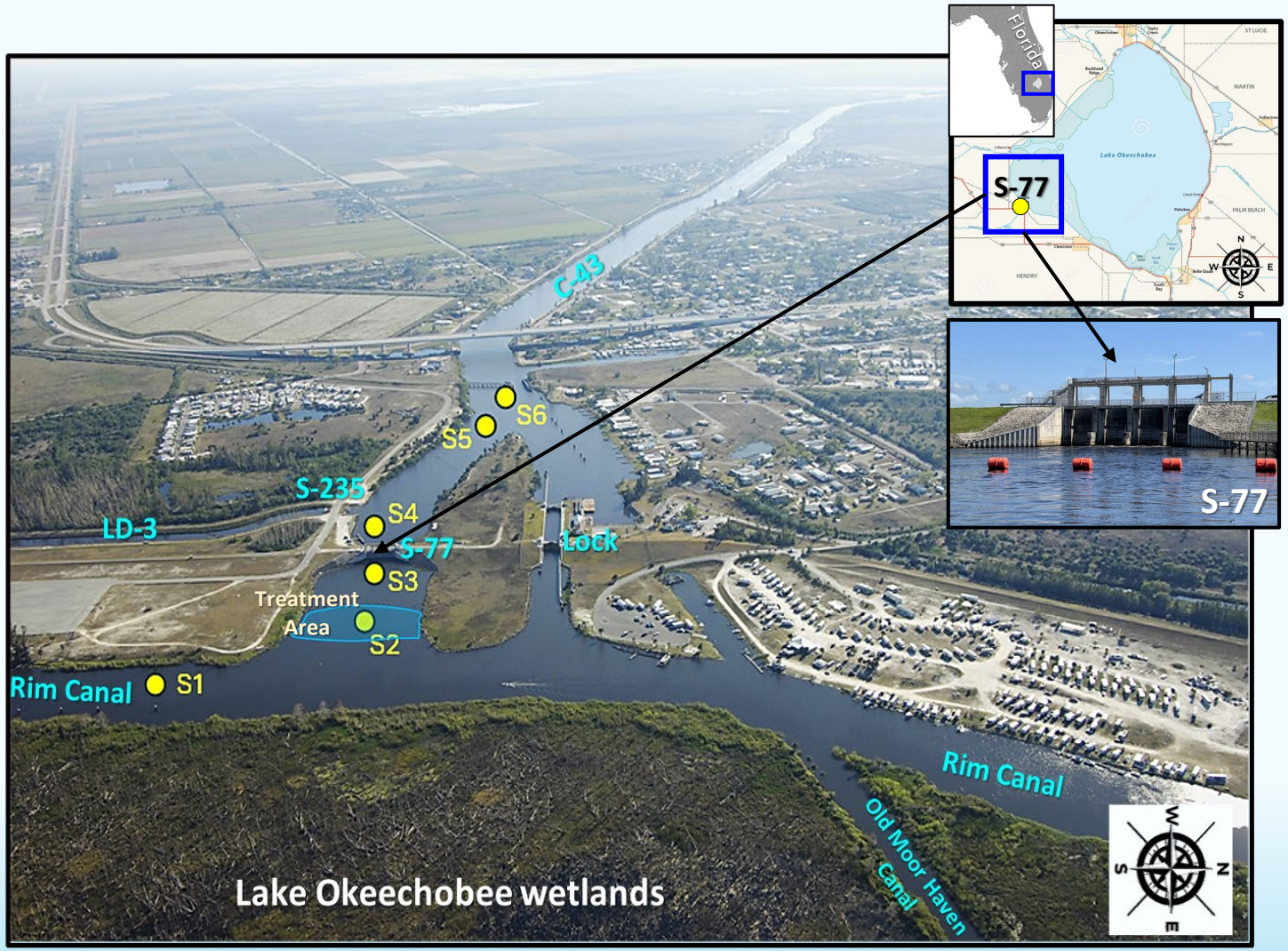
1) **Examine the fate and dynamics of $H_2O_2$ after treatments**
2) **Understand the influence of the treatments on cyanotoxins**
3) **Understanding the ecological responses of cyanobacteria and other phytoplankton, zooplankton and microbial communities to treatments**
4) **Understand changes in water quality related to treatments**





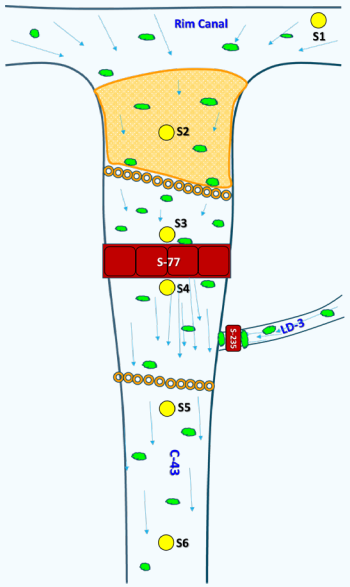

# 2024 Study Location - S-77 Structure/C-43 Canal

- **6 sampling locations along E-W transect along the C-43 Canal**
- **4 Sampling Events**
  - **Pilot Survey**: 06/17, 2024
  - **Test 1:** 06/24-26, 2024
  - **Test 2:** 07/1-3, 2024
  - **Test 3:** 07/15-17, 2024 2024
- **Sampling Components**
  - **Phytoplankton dynamics (Omics methods + microscopy)**
  - **Zooplankton dynamics (microscopy)**
  - **H2O2 concentrations**
  - **Microcystin toxins**
  - **Standard physicochemical and biological water quality parameters (nutrients, chl *a*, temp, turb, pH, DO, PAR)**



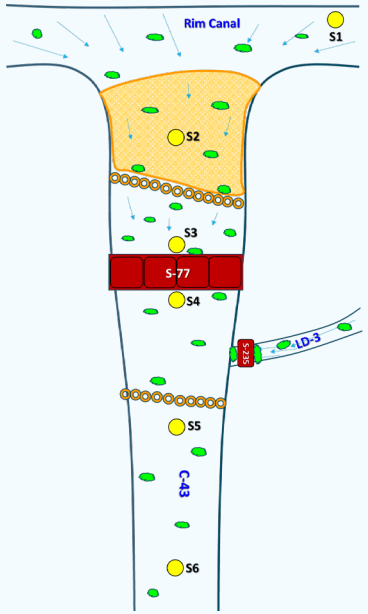
# 2024 Lake Guard® Oxy Tests at the S-77/C-43 Location

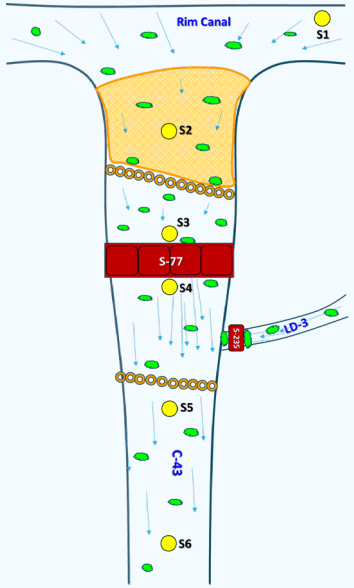
## TEST 1 (06/24/2024)




- ✓ S-77 flows ~500 cfs
- ✓ S-77 flows continuous
- ✓ S-235 no flows during surveys
- ✓ 30 lbs/acre* (45 lbs/1.5 ac) LGOxy applied

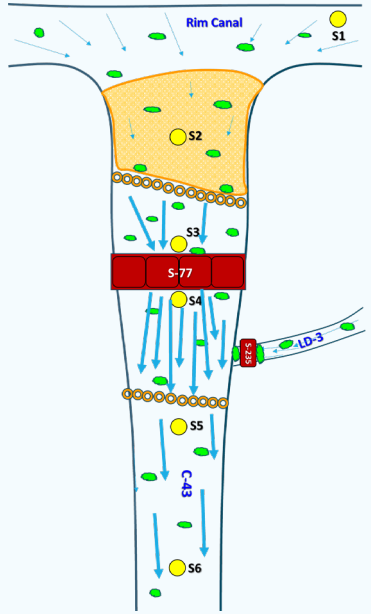
## TEST 2 (07/01/2024)



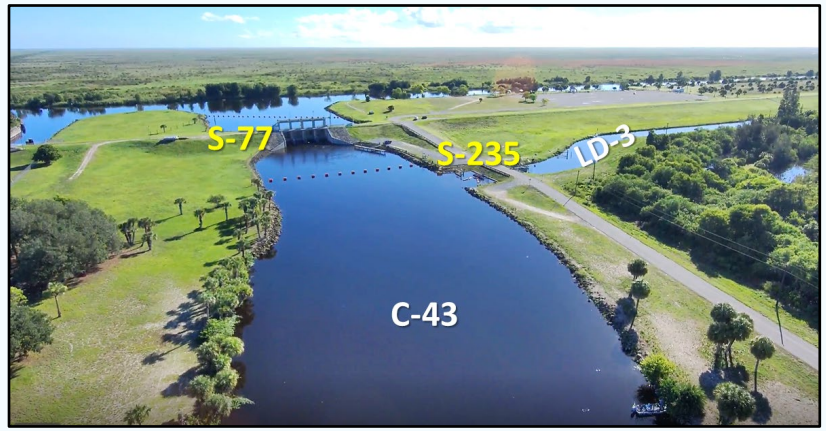




- ✓ No flows from S-77 before and during product application
- ✓ S-77 flows @ ~500 cfs ~1.5 hr after treatment
- ✓ S-235 no flows during surveys
- ✓ 30 lbs/acre* (45 lbs/1.5 ac) LGOxy applied

## TEST 3 (07/15/2024)

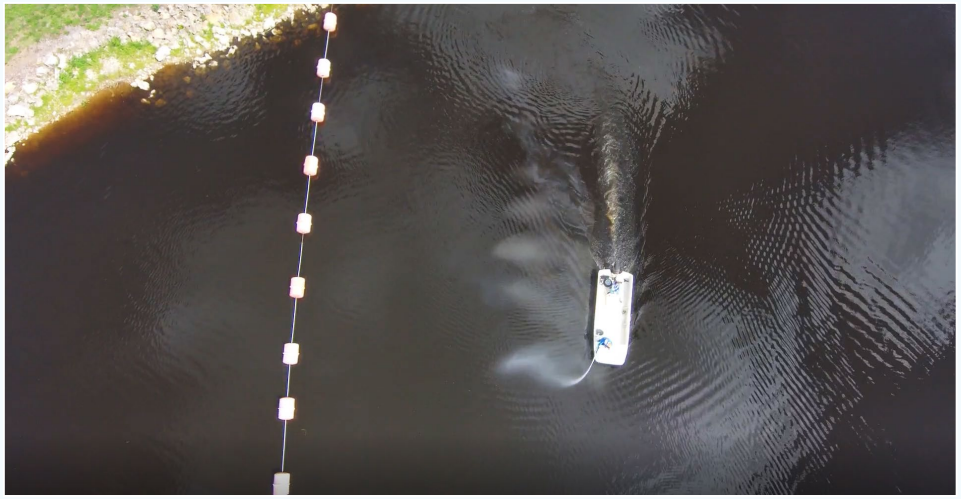


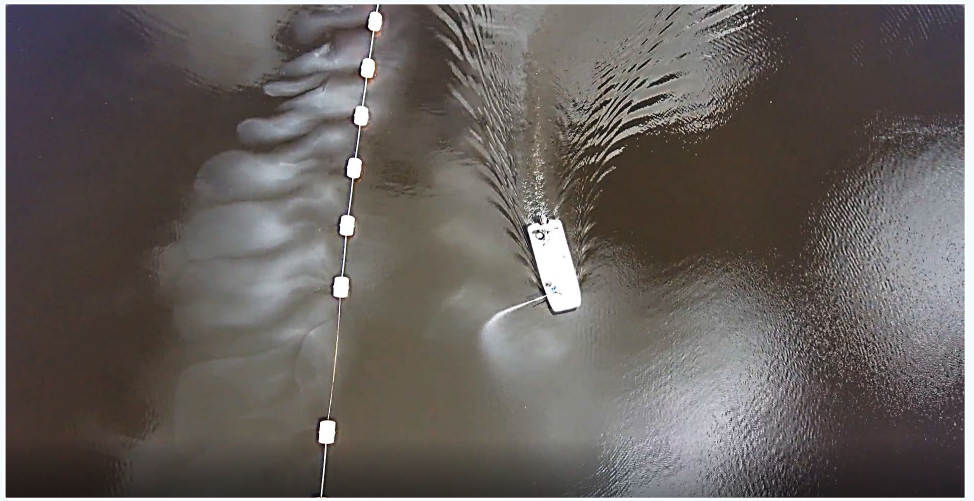

- ✓ S-77 flows ~1000 cfs
- ✓ S-77 flows continuous
- ✓ S-235 no flows during surveys
- ✓ 30 lbs/acre* (45 lbs/1.5 ac) LGOxy applied

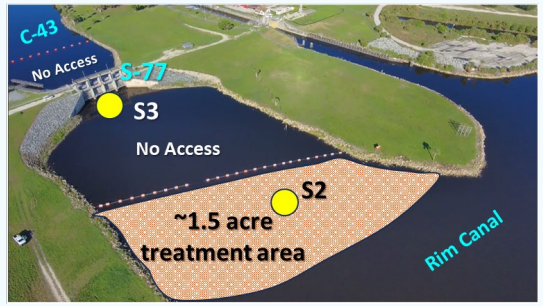



** When cyano-cell density is between 20,000-100,000 cells/mL (or chl a between 10-50 µg/L) use 5-30 lbs./acre Lake Guard® Oxy (US EPA, Pesticide Product Label, Lake Guard Oxy,03/06/2023)*

# Tracking Lake Guard® Oxy Algaecide Distribution with Drones









- Distance between orange buoys and structure ~300-480 feet
- LGOxy transport ~10-15 min from treatment area to the structure @ 500 cfs

Photos Source (SFWMD)

# Acknowledgements

SFWMD BGA TEAM

## SOUTH FLORIDA WATER MANAGEMENT DISTRICT

- ❑ Land Resources Bureau
- ❑ Water Quality Bureau
- ❑ Applied Sciences Bureau
- ❑ Data Management/IT Team/Drones Team

## PARTNERING AGENCIES & UNIVERSITIES

- ❑ USACE-ERDC, -JAX, -CLEW
- ❑ FDEP
- ❑ FGCU, NSU

# THANK YOU!