



# Clear Lake Cyanotoxin Monitoring Program

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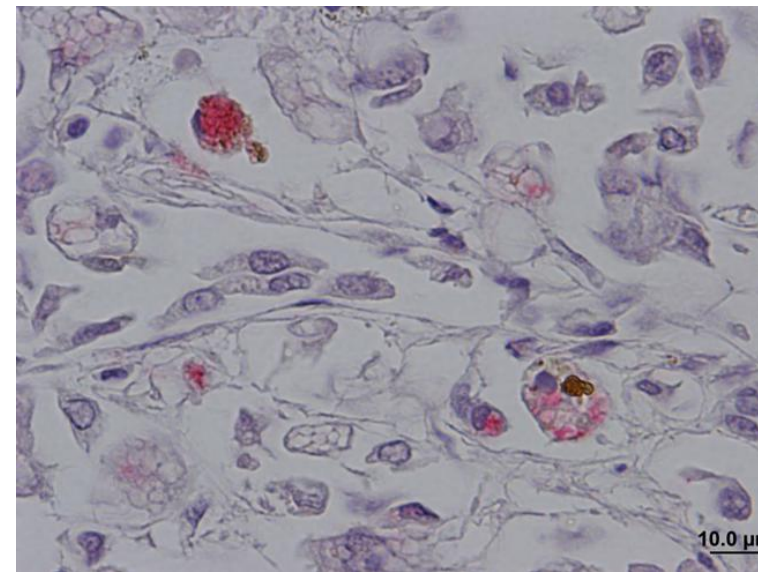
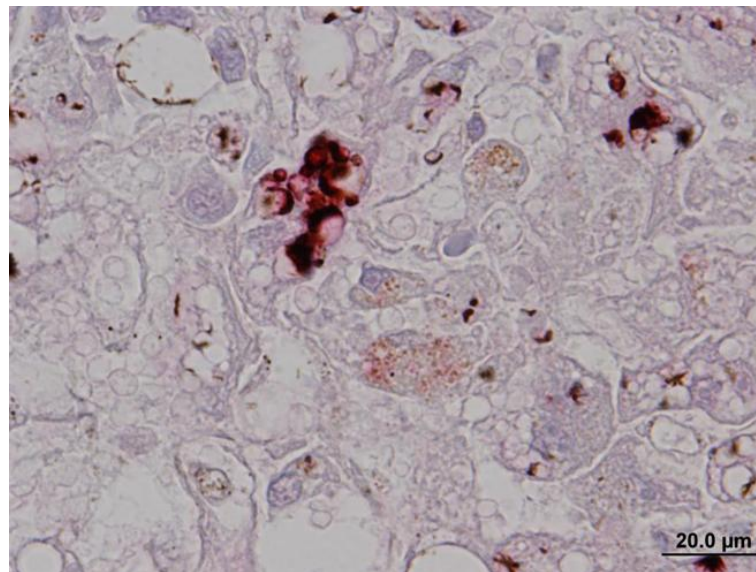
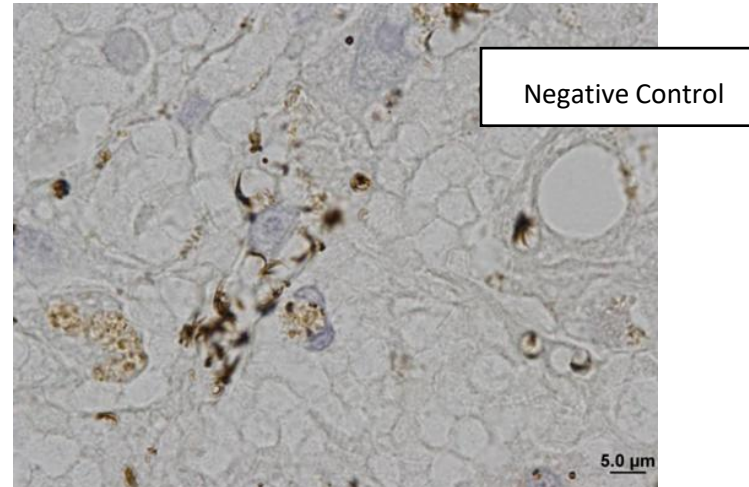
# Types of Cyanobacteria in Clear Lake

## Toxin-Producing Cyanobacteria

Genera	Toxin	Type	Short Term Health Effects	Long Term Health Effects
Anabaena, Microcystis, Oscillatoria, Planktothrix	Microcystins	Hepatotoxin	Gastrointestinal, liver inflammation, and hemorrhage and liver failure leading to death, pneumonia, dermatitis	Tumor promoter, liver failure leading to death
Anabaena, Aphanizomenon, Cylindrospermopsis, Lyngbya	Saxitoxins	Neurotoxin	Tingling, burning, numbness, drowsiness, incoherent speech, respiratory paralysis leading to death	Unknown
Anabaena, Aphanizomenon, Oscillatoria, Planktothrix	Anatoxins	Neurotoxin	Tingling, burning, numbness, drowsiness, incoherent speech, respiratory paralysis leading to death	Cardiac arrhythmia leading to death
Aphanizomenon, Cylindrospermopsis	Cylindrospermopsin	Hepatotoxin	Gastrointestinal, liver inflammation and hemorrhage, pneumonia, dermatitis	Malaise, anorexia, liver failure leading to death
Aphanizomenon, Oscillatoria	Lipopolysaccharide	Endotoxin	Gastrointestinal, dermatitis	Unknown
Lyngbya	Lyngbyatoxins	Dermatotoxin	Dermatitis	Skin tumors (Fujiki et al. 1990), unknown

Lopez, C.B., et al. 2008. Scientific Assessment of Freshwater Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms, Hypoxia, & Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

# Clear Lake Dog Death 2013




# Program Goals

- Protect Tribal beneficial uses of Clear Lake through real-time data collection and education
- Share resources and information in collaborative approach for monitoring the lake
- Determine seasonal water quality trends as related to occurrences of cyanobacteria blooms through collection of shoreline/recreational area water chemistry, bacteria and nutrient data
- Provide data on cyanobacteria related toxins in a timely manner to support public health decisions
- Advocated for signage that indicated safe thresholds for recreational use of Clear Lake
- Formed Task Force to notify local, state and federal agencies of elevated cyanotoxin levels at the Clear Lake shoreline

# Monitoring Program – Rationale for Choosing Sites

	Site Name	Site ID	Location and Rationale for sampling
	<b>ELEM SITES</b>		
12	<b>Austin Park</b>	AP01	Boat Launch, Clubhouse, Fishing Pier, Picnic Area, BBQ, Restrooms, Sports Fields (Softball), Tennis, skate park and Playground, Local events venue, dog walking area, Burns Creek inlet 400 ft north
13	<b>West of Sulphur Bank Mine</b>	SBME01	Tribally important site, gravel beach 800 ft south of Waste Ruck Dam, Capping project for SBMM is 400 ft off shoreline
14	<b>Clearlake Oaks (Shoreline by water Intake)</b>	CLOAKS01	Boat Launch, Canoeing, Docks, Fishing, Kayaking, Lake Swimming, Picnic Area, Restrooms, & dog walking area
15	<b>Elem Indian Colony Site 1</b>	ELEM01	Elem Culturally important site, swimming, fishing, boating, native plants
16	<b>Lucerne Park</b>	LUC01	Boat launch, swimming and recreational area, playground, fishing,
17	<b>Shady acres</b>	SHADY	Boat Launch, Canoeing, Docks, Fishing, Kayaking, campground, only outlet to Clear Lake
18	<b>Redbud Park</b>	RB	Boat Launch, Canoeing, Docks, Fishing, Kayaking, Lake Swimming, Picnic Area, Playground & Restrooms, Bass Tournaments, Baseball fields
19	<b>Keeling Park</b>	KP	Launching dock, Recreational activities, Fishing. Veg. Willows and Pondweed ( <i>Potamogeton</i> )

# Water Monitoring Log

		<b>WATER QUALITY, CYANOBACTERIA AND CYANOTOXIN MONITORING , CLEAR LAKE, 2015</b>					
		Date:			Date:		
Time:am/pm:				Time:am/pm:			
<b>Site: Rodman Slough</b>	<b>.5 m</b>		Units	<b>Site: Keeling park</b>	<b>.5 m</b>	Units	
Activity depth			Meters	Activity depth		Meters	
Barometric Pressure			mmHg	Barometric Pressure		mmHg	
Temp,Air			deg F	Temp,Air		deg F	
Temp,Water			deg C	Temp,Water		deg C	
SpC			mS/cm	SpC		mS/cm	
Res			K <sup>∧</sup> -cm	Res		K <sup>∧</sup> -cm	
Sal			ppt	Sal		ppt	
TDS			g/L	TDS		g/L	
DO%			Sat	DO%		Sat	
DO			mg/L	DO		mg/L	
pH			Units	pH		Units	
Turbidity			NTU	Turbidity		NTU	
Chlorophyll-a			ug/L	Chlorophyll-a		ug/L	
Phycocyanin			ug/L	Phycocyanin		ug/L	
<b>Comments:</b>				<b>Comments:</b>			

SITE #	SITE NAME	IDENTIFIED CELLS
1	KP	Lyngbya anabaena Microcystis - few
4	LUC01	Lyngbya - anabaena few
3	CLOAKS1	Anabaena Microcystis few
4	ELEM01	Anabaena, Lyngbya <del>Lyngbya</del> Microcystis - few
5	AP01	Microcystis Anabaena Lyngbya few
6	RED	Microcystis Anabaena Lyngbya few
7	SHAD AC	Microcystis Lyngbya Anabaena few
8	HIGH WC	not done
9	SBMELO1	Lyngbya, Anabaena Microcystis Gloeotrichia few
10	CLO WD	not done

DATE: 7/20/15



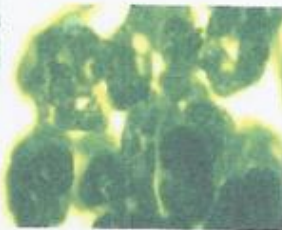
WORONICHIA



GLOEOTRICHIA



LYNGBYA



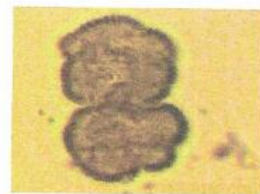
MICROCYSTIS



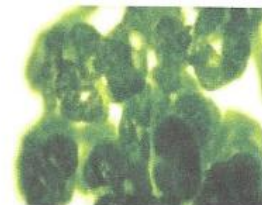
## Cyanobacteria Cell Identification Sheet

SITE #	SITE NAME	IDENTIFIED CELLS	ELISA TEST KIT RESULT (ppb)
1	KP01	anabaena (few)	
2	LUC01	anabaena (few)	
3	CLOAKS01	anabaena (few)	
4	ELEM01	—	
5	AP01	anabaena	a = .4 ppb
6	RED01	anabaena	a = .4 ppb
7	SHADY01	anabaena	a = .4 ppb
8	HIGH WC	—	
9	SBMELO1	anabaena	a = 1 ppb
10	CLOAKS WC	—	

DATE: 7/12/16



WORONICHINIA



MICROCYSTIS



APHANIZOMENON



GLOEOTRICHIA

## Sample 1: AP01

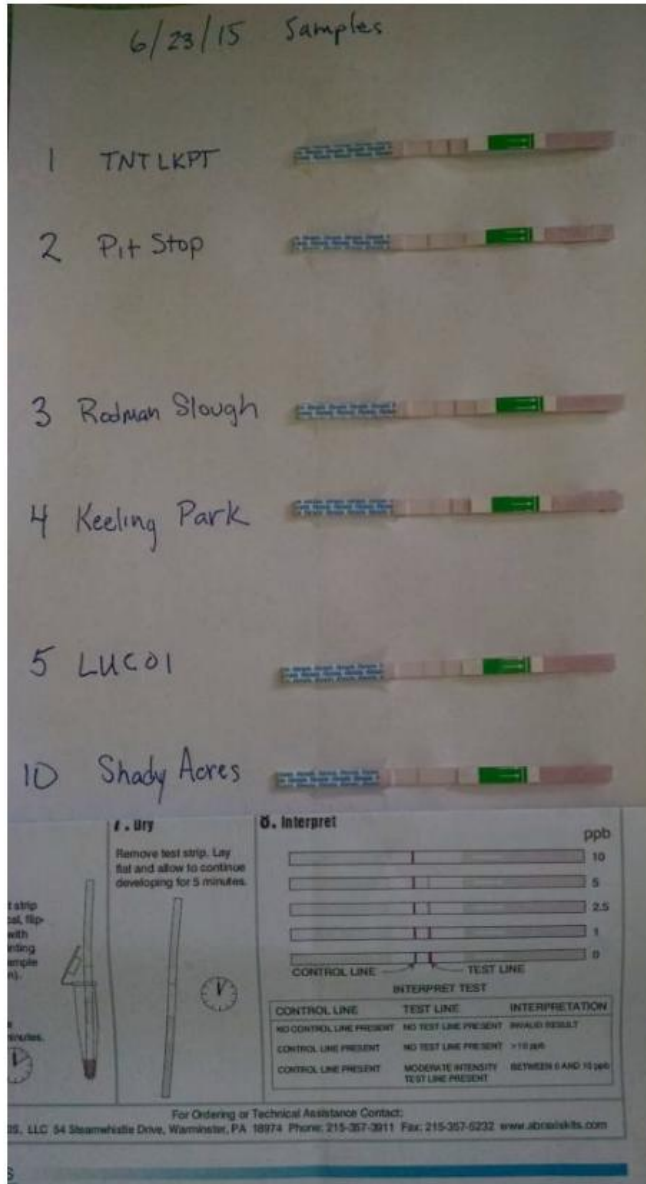
One mL of sample preserved with Lugols Iodine Solution was allowed to settle and was observed at 400X and 100X using a Nikon Eclipse TE200 Inverted Microscope equipped with phase contrast optics. The dominant algae in the AP01 sample collected on 9/6/16 were the filamentous blue-green algae (Cyanobacteria) *Dolichospermum pseudocompactum* (Figs. 1-2), *Limnothrix redekei* (Figs. 3-4) and *Anabaenopsis*



Fig. 10 *Aphanizomenon gracile* 400X (Scale bar = 10 μm)



# Testing for Presence of Microcystin with Abraxis Field Strips



Abraxis Strips versus lab results

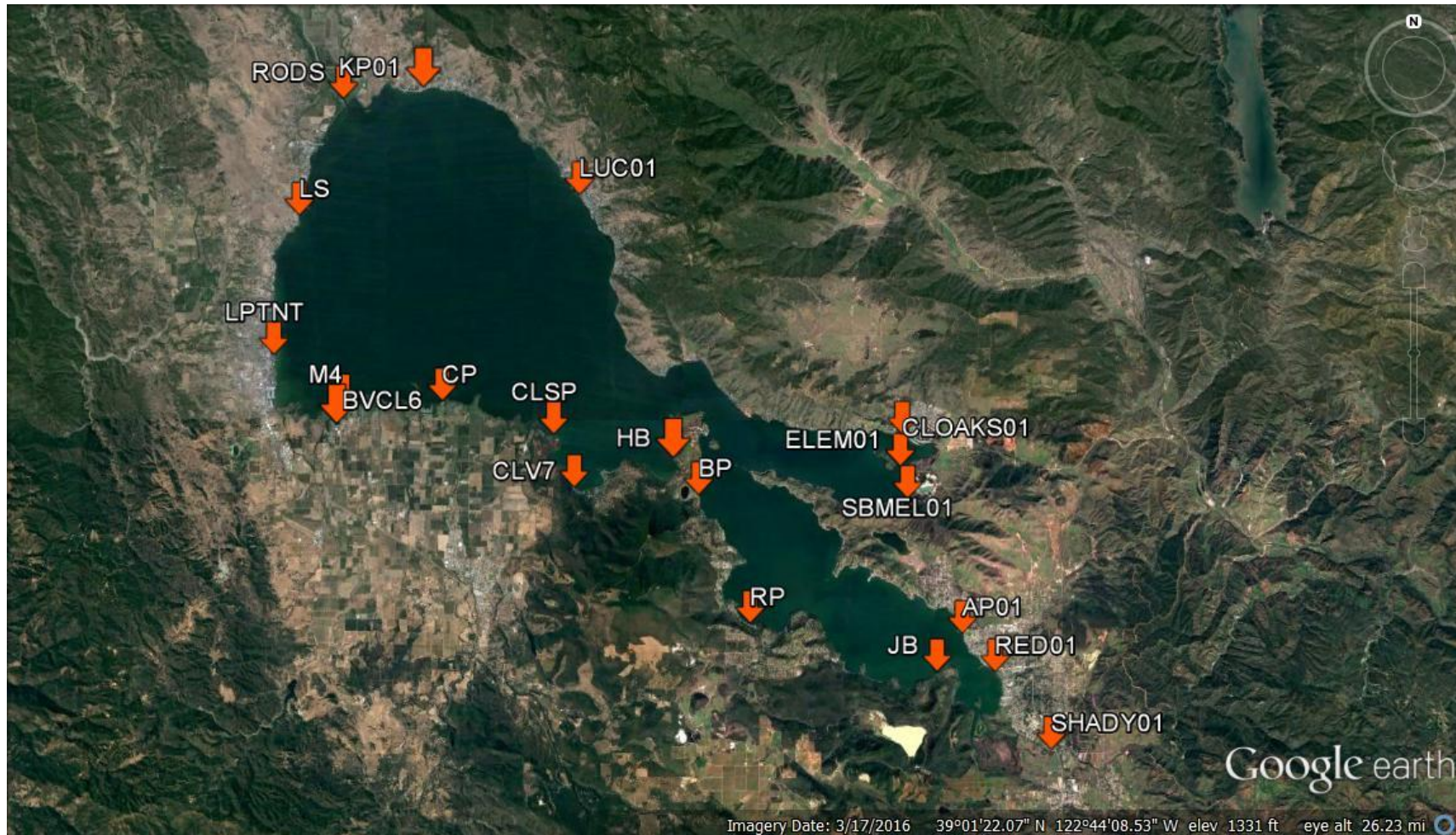
Strip vs lab	color coding in attached spreadsheet	bottom line	totals
30 "0" when detect	red	30 false negative	38 false positive or negatives or 41.3%
8 detect when no detect	green	8 false positive	
46 "0" when no detect	yellow	46 ok negative	54 read correctly or 58.7%
8 detect when detect	blue	8 ok positive	

# Collecting Chlorophyll-a and Phycocyanin Measurements

Cyanotoxin Monitoring Sites		Cell ID	Field Results			Lab Results (in ppb)
Site ID	Dates	Dominant Genus	Chlorophyll-a (µg/L)	Phycocyanin (µg/L)	phyco/chloro-a ratio	Total Microcystins (EPA)
BVCL6	6/14/2016	anabaenopsis	26.45	10.97	0.4	ND
	8/23/2016	anabaena	65.2	118.6	1.8	0.11
CLV7	6/27/2016	anabaena	35.22	627	17.8	0.34
	8/23/2016	anabaena (v. small)	84.53	100.51	1.2	ND
LPTNT	6/14/2016	anabaenopsis	15.74	7.97	0.5	ND
	8/23/2016	anabaena	249.8	277.55	1.1	ND
RODS	6/14/2016	anabaena	39.77	16.32	0.4	ND
	8/23/2016	-	99.4	95.2		

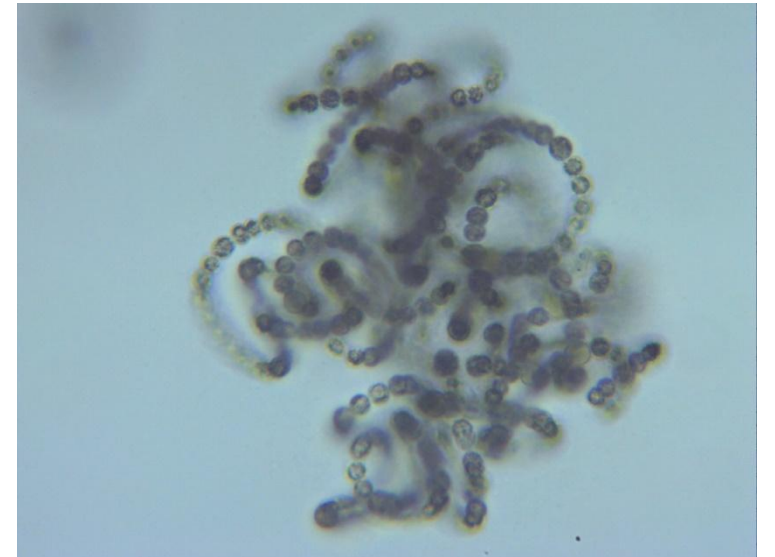
- Low and high phycocyanin measurement per site
- Ratio of phycocyanin to chlorophyll-a
- 59% of time when ratio is below 1.0. toxin level is ND

# Clear Lake Cyanotoxin Monitoring Locations



# Clear Lake Cyanobacteria Task Force

- Big Valley, Elem, Scotts Valley, Robinson Tribes
- Lake County Water Resources, Environmental Health, Public Health
- US EPA, including Region 9 Water Programs and Tribal Programs
- SWRCB
- OEHHA
- CDPH
- Cal EPA
- Central Valley Regional Water Quality Control Board



# Continually Developing Monitoring Program

- 2014 Program
  - Formed Clear Lake Cyanobacteria Task Force to respond to high toxin levels at Clear Lake
  - Monitored 8 sites
  - Mainly focusing on Microcystin levels – used Abraxis Algal Toxin strip test kits for detection
- 2015 Program
  - Monitoring 18 sites
  - Cyanobacteria cell identification under microscope to determine toxins to test for
  - Analyzing for Microcystin, Anatoxin-a, Cylindrospermopsin, Saxatoxin
- 2016 Program
  - Added more sites in Lower Arm
  - Using Fluorometer to get chlorophyll-a and phycocyanin levels
  - Microcystin analysis at every site and every sampling event

# How Often Did Clear Lake Cyanotoxin Monitoring Sites Exceed the Signage Threshold of 0.8 PPB?

*0.8 PPB is the CCHAB draft recommended voluntary guidance for public notification of microcystin cyanotoxins present at potential health risk levels*

SITE ID	ARM OF LAKE	NUMBER OF TIMES EXCEEDED 0.8PPB (VERSUS NUMBER OF SAMPLING EVENTS)				HIGHEST LEVEL RECORDED (MICROCYSTIN PPB)	
		2014	%age	2015	%age	2014	2015
BVCL6	U	1/6	17%	0/20	0%	1.2	ND
CLV7	U	6/7	86%	0/13	0%	105	ND
M4	U	2/6	33%	0/14	0%	8.3	ND
LPTNT	U	5/6	83%	0/12	0%	877.6	ND
RODS	U	not sampled		0/12	0%	not sampled	ND
CP	U	not sampled		0/11	0%	not sampled	ND
LS	U	not sampled		0/11	0%	not sampled	Trace
LUC01	U	4/6	67%	0/13	0%	13	ND
HB	U	not sampled		0/9	0%	not sampled	Trace
KP01	U	not sampled		0/12	0%	not sampled	ND
ELEM01	O	2/4	50%	4/14	29%	4.4	18.7
SBMELO1	O	7/7	100%	2/10	20%	5,311.70	278
CLOAKS01	O	7/7	100%	5/16	31%	16,920	21
BP	L	not sampled		3/11	27%	not sampled	9.4
RP	L	not sampled		3/10	33%	not sampled	134
SHADY01	L	not sampled		4/10	40%	not sampled	36.1
RED01	L	not sampled		4/12	33%	not sampled	65.5
AP01	L	9/9	100%	7/17	41%	769.2	10,162

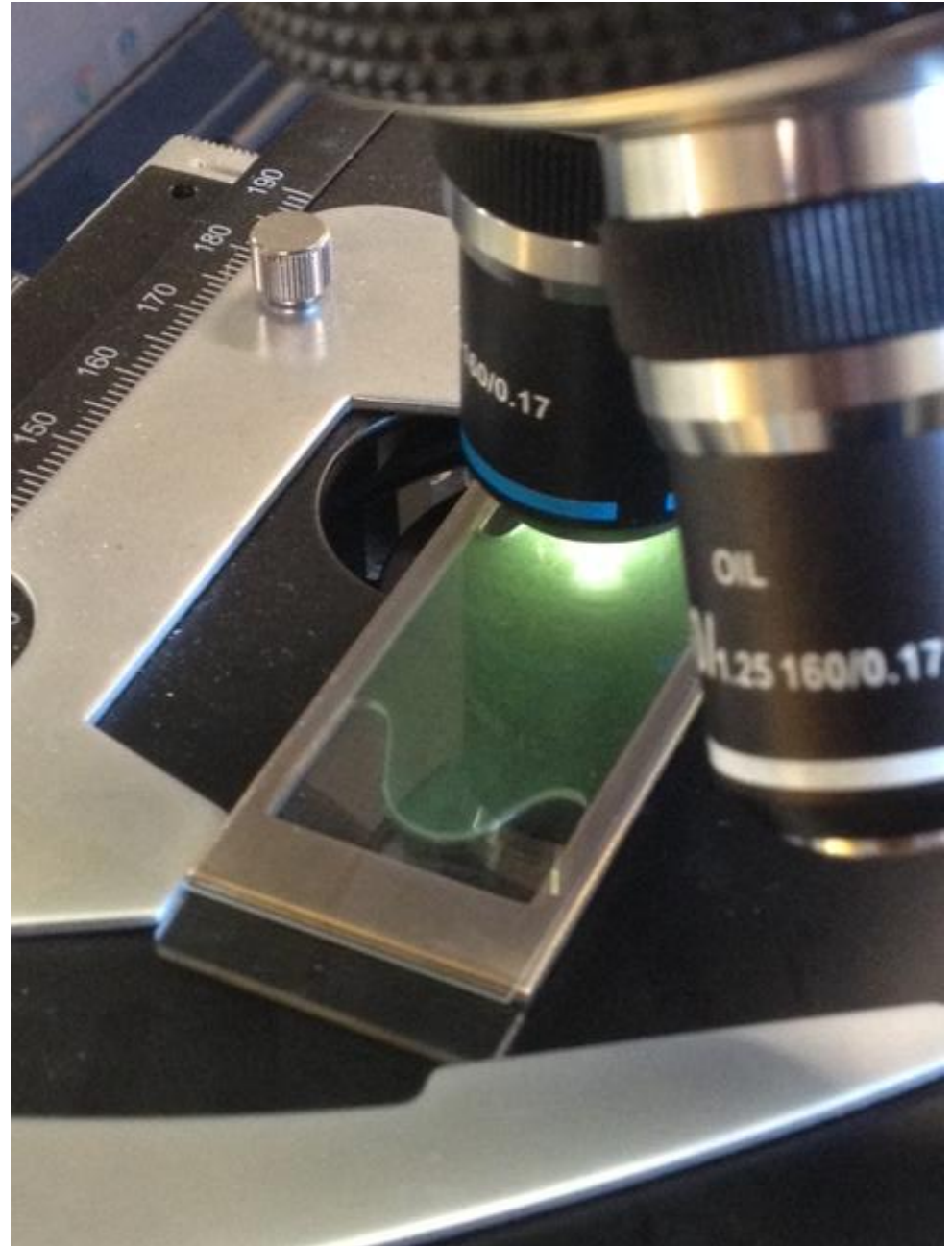
# 2016 Results – Cell ID, Field, Lab

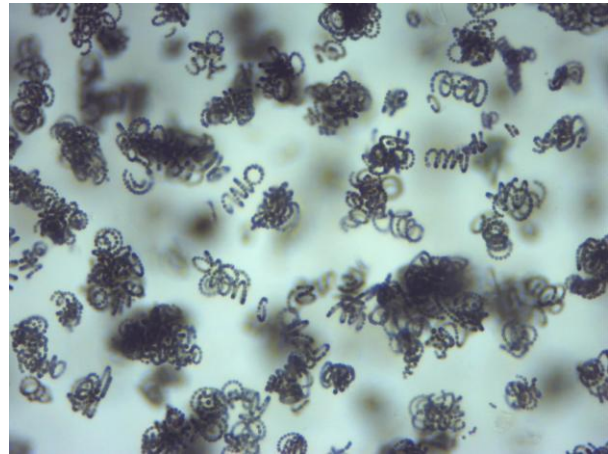
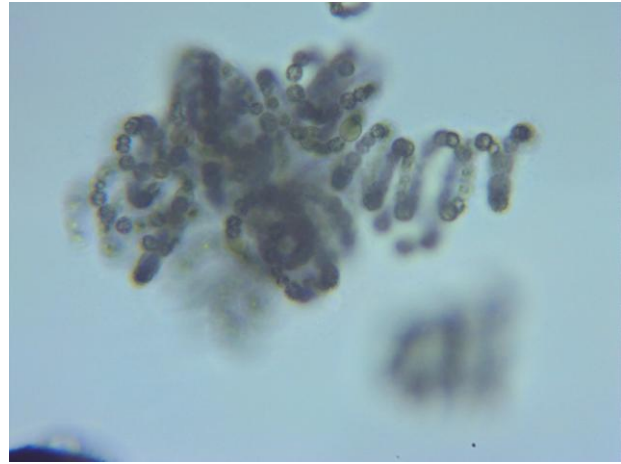
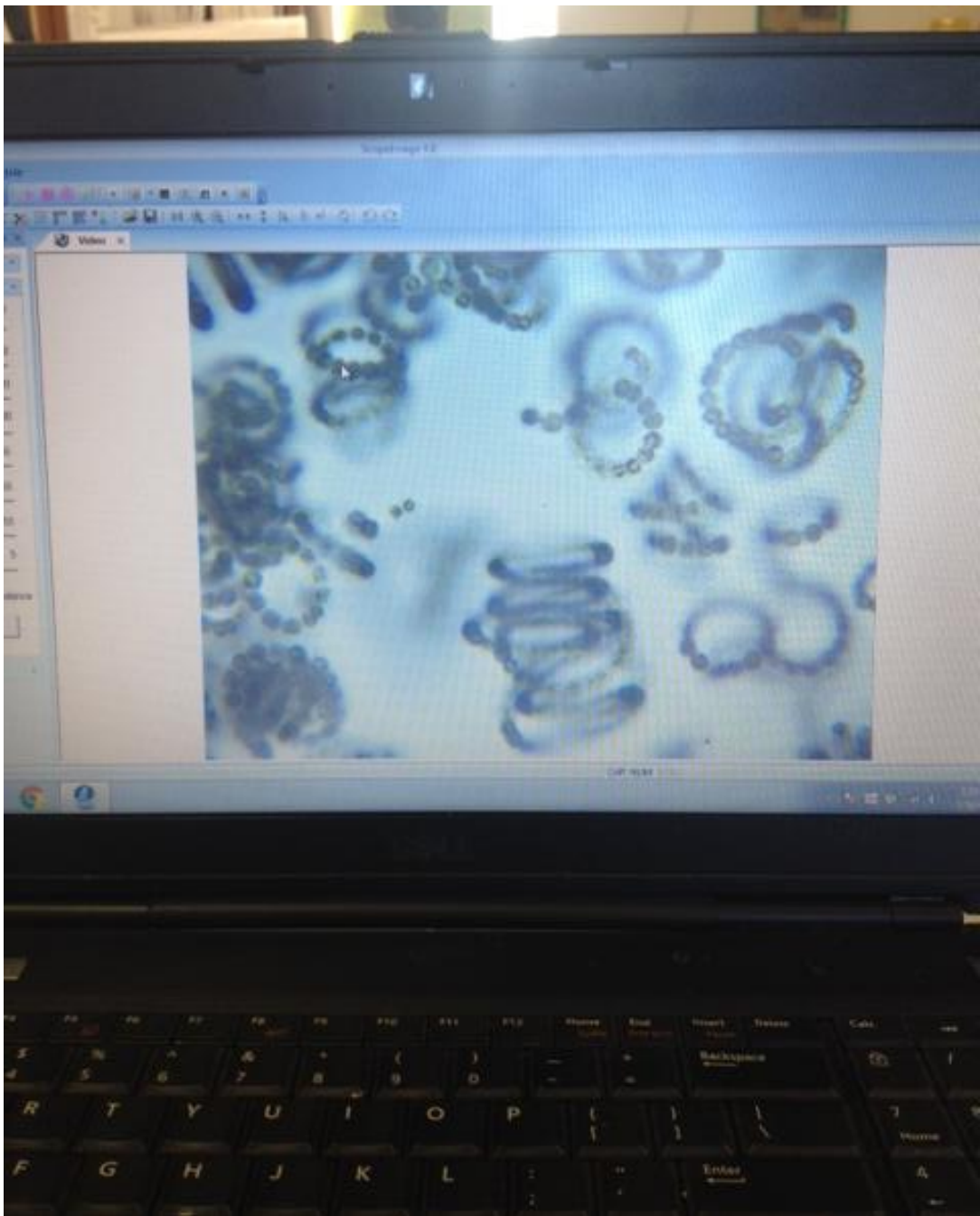
Cyanotoxin Monitoring Sites		Cell ID		Field Results					Lab Results (in ppb)				
Site ID	Dates	Dominant Genus	Other Identified	Chlorophyll-a (µg/L)	Phycocyanin (µg/L)	Abraxis Microcystin (ppb)	Abraxis Anatoxin-a (ppb)	Abraxis Cylindrospermopsin (ppb)	Total Microcystins (EPA)	Microcystins LA, LR, YR, RR (UC Davis)	Anatoxin-a	Saxitoxin	Cylindrospermopsin
HB	6/14/2016	anabaena		21.73	15.25	0.0			ND				
	7/12/2016	-	-	-	-								
	7/26/2016	anabaena		124.5	32	0.0	0.0						
RP	4/28/2016	none seen											
	5/13/2016	anabaena		47.57	out of range	2.5							
	5/26/2016	microcystis		27.14	12.98								
	6/2/2016	anabaena		21.45	34.48	2.5							
	6/14/2016	anabaena		25.47	24.46	2.5			ND				
	6/27/2016	anabaena		6.81	26.07	0.0	0.0		ND				
	7/12/2016	anabaena		65.21	86.34	0.0	0.4		0.11				
	7/26/2016	anabaena		148.2	480.6	0.0	0.4						
JB	5/4/2016	none seen		4.44	2.54								
	6/14/2016	anabaena		34.24	out of range	0.0			0.18				
	6/27/2016	anabaena		36.11	84.77	0.0	0.0		0.19				
	7/12/2016	anabaena				0.0			0.17		ND		
	7/26/2016	ananbaena (few)	anabaenopsis (few)	117.5	111.2	0.0							

# 2016 Results – Cell ID, Field, Lab

- Dominant genus Dolichospermum
- All sites had total microcystin analysis using ELISA method at Richmond EPA lab
- 83% of results were at equipment detection level (0.15 ug/l) or below







# Evidence of bloom plus Non Detect toxin levels



# Evidence of bloom plus low toxin levels



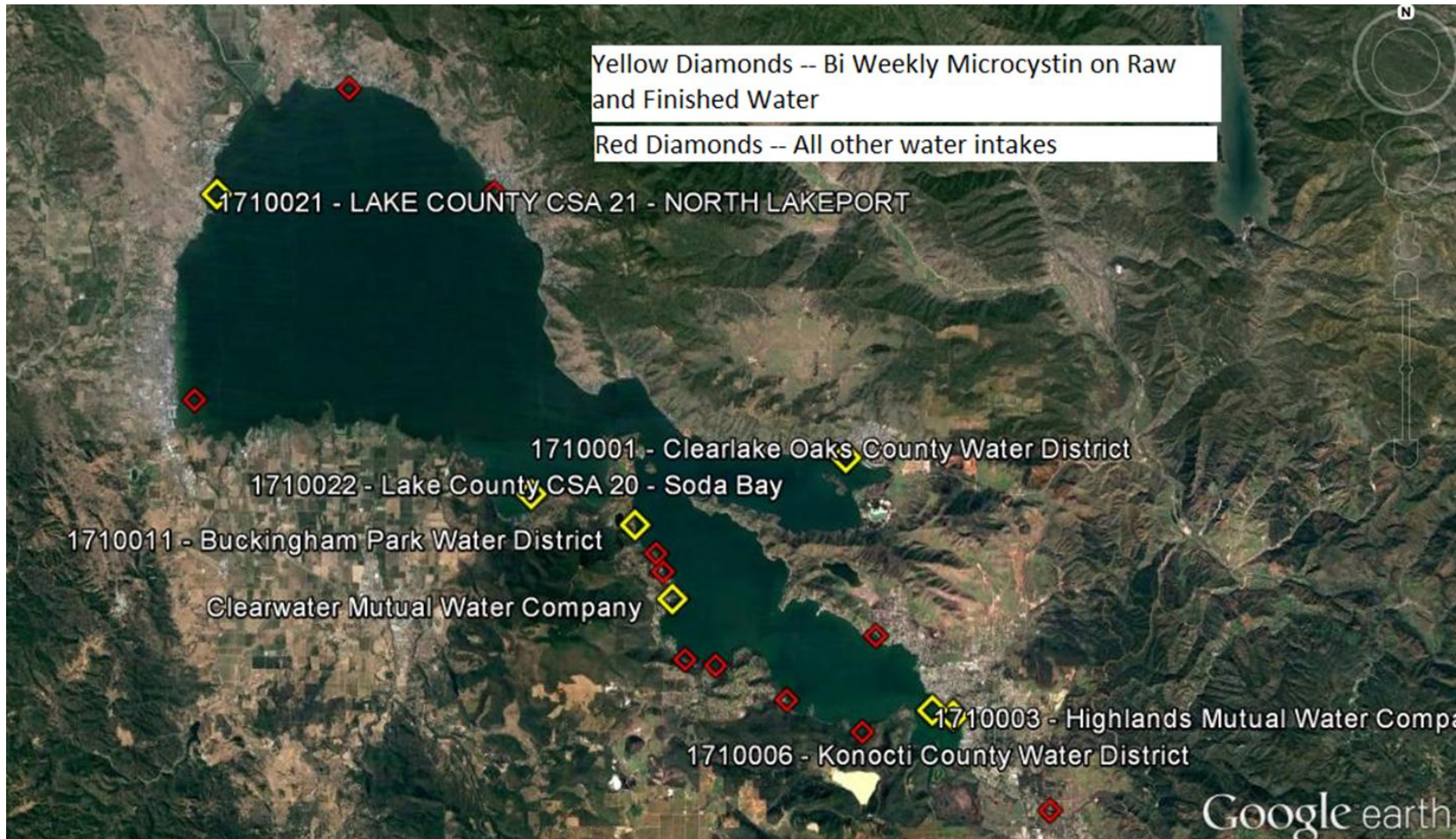
# Evidence of bloom plus high toxin levels



# No evidence of bloom plus toxin levels



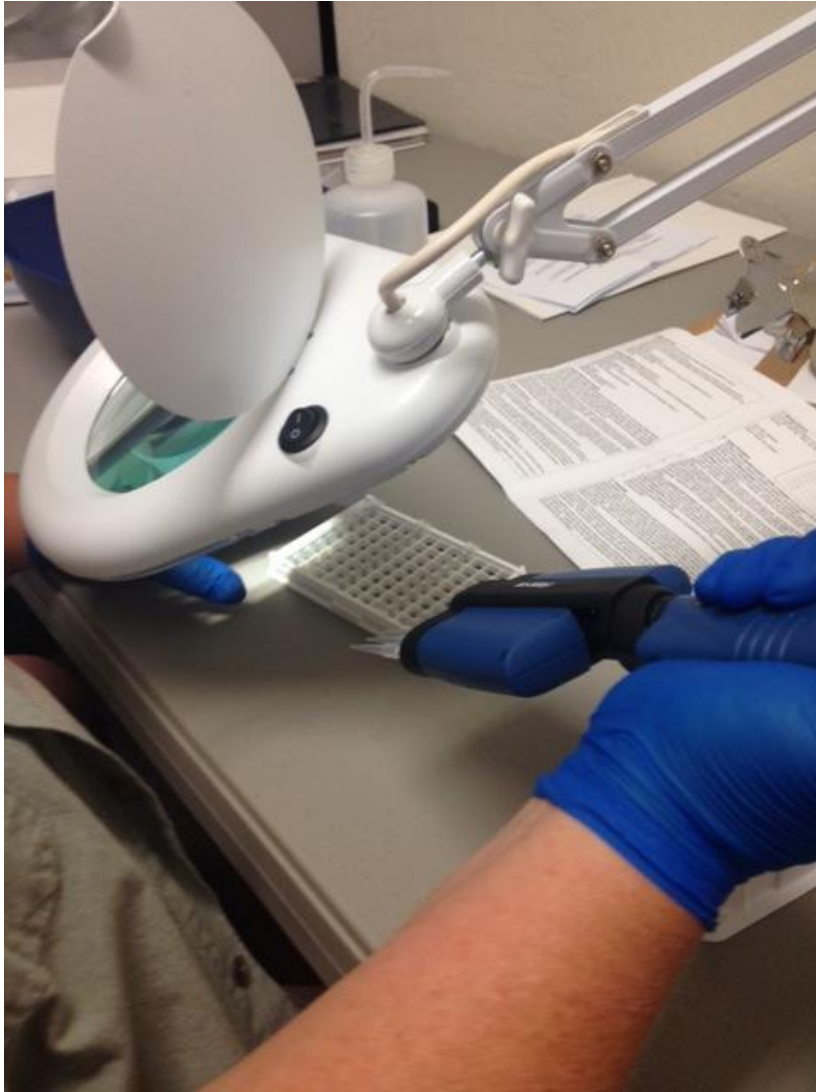
# Surface Water Public Water Systems, Clear Lake



There are 17 water purveyors pulling drinking water from the Lake

Clear Lake surface water serves more than 50% of Lake County residents

# Analyzing for Microcystin in Drinking Water





# 2016 Clear Lake Microcystin Concentrations (ug/L) for Public Water Systems

	RAW WATER									FINISH WATER						
	ROUND 1	ROUND 2	ROUND 3	ROUND 4	ROUND 5	ROUND 6	ROUND 7			ROUND 1	ROUND 2	ROUND 3	ROUND 4	ROUND 5	ROUND 6	ROUND 7
	6/27/2016	7/11/2016	7/25/2016	8/8/2016	8/29/2016	9/12/2016	9/26/2016			6/27/2016	7/11/2016	7/25/2016	8/8/2016	8/29/2016	9/12/2016	9/26/2016
Lake County CSA 20 - Soda Bay	0.16	0.18	0.18	<0.1	<0.1	<0.1	0.1			<0.1	<0.1	0.14	<0.1	<0.1	ND	<0.1
Clearlake Oaks County Water District	0.73	0.38	0.26	<0.1	0.13	<0.1	0.14			0.18	<0.1	0.16	<0.1	ND	ND	<0.1
Lake County CSA 21 - North Lakeport	0.33	0.21	0.19	<0.1	<0.1	<0.1	0.17			<0.1	<0.1	0.15	<0.1	ND	ND	<0.1
Buckingham Park Water District	0.12	0.27	0.24	<0.1	0.18	<0.1	0.36			0.2	<0.1	0.18	<0.1	ND	ND	<0.1
Clearwater Mutual Water Company		0.3	0.21	<0.1	0.2		0.34				<0.1	<0.1	<0.1	<0.1		<0.1
Highlands Mutual Water Company	0.38	0.27	0.19	<0.1	<0.1	<0.1	0.15			0.16	<0.1	0.14	<0.1	<0.1	ND	<0.1
Konocti County Water District		0.27	0.28	<0.1	0.1		0.16				<0.1	0.17	<0.1	ND		<0.1
California Water Service - Lucerne	0.4									0.24						

# Treatment Study at Clearlake Oaks County Water District

- Equivalent to conventional water treatment – coagulation, flocculation, sedimentation and filtration
- sampled raw water at weirs and 3 levels of clarifier and sludge water
- Total microcystin in raw water was ND
- Total microcystin in sludge water was 0.34 ug/l
- Using decay function, clarifier sludge raked out within 4.7 hours

# Implementing Non Point Source Management to Control Cyanobacteria Levels



# Projects and Data Usage That Have Grown from Our Program

- Grant Proposal -Joint Project with CDPH – reviewing ER and clinic visits and correlating with spikes in toxins at Clear Lake
- Fish and Shellfish Tissue analysis funding for Big Valley through CalEPA EJ and GAP
- Contract between EPA and CA Fish and Wildlife to review wildlife deaths at Clear Lake for cyanotoxin poisoning
- Utilization of chlorophyll-a and phycocyanin data for Clear Lake Nutrient TMDL





# Questions?

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