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www.livingriverscouncil.org

August 16, 2011

The Living Rivers Council (LRC) was established to protect, restore, defend and preserve watersheds in natural harmony with the people and wildlife that depend on healthy water for economic vitality, recreational enjoyment and ecological sustainability. We will pursue these goals through education, research, consensus building, and advocacy.

Central Valley Regional Water Quality Control Board
CVRWQCB
11020 Sun Center Dr. #200
Rancho Cordova, Ca.
95670-6114
916.464.3291
Betty Yee-Triennial Report
Holly Glover-Nutrient TMDL
Genivieve Sparks-alternate
Janis Cooke-Mercury TMDL

Lake County Special District
Mark Dillinger
230 N. Main Street
Lakeport, Ca. 95453-4816

Lake County Department of Water Resources
Thomas R. Smythe
255 N Forbes Street
Lakeport, Ca. 95453

Lake County Public Works
Gary Hanson
255 N Forbes Street
Lakeport, Ca. 95453

Lake County Environmental Health
Raymond Ruminski
255 N Forbes Street

Lakeport, Ca. 95453

Clear Lake Advisory Committee
Betsy Cawn

CLEAN
Clean Lake Environmental Network
Chuck and Holly Lamb
www.Cleanlake.org

Lake County Board of Supervisors
City Councils

Re: Sacramento and San Joaquin Total Maximum Daily Load, TMDL, Triennial Report Comments Clear Lake, Lake County California, Nutrient and Mercury TMDL & Central Valley Regional Water Quality Control Board
Public Hearing to be held on this matter October 12/13/14, 2011
11020 Sun Center Dr., Rancho Cordova, Ca. 95670-6114

Attention Betty Yee:

CLEAR LAKE WATERSHED

Clear Lake is located 80 miles north of San Francisco and is the oldest lake in California. Clear Lake is part of the Sacramento and San Joaquin River Basins. The Clear Lake watershed basin has been shaped by faulting, tilting, volcanism and erosion over a period as long as 2 million years. It is considered a shallow lake ranging from 27 to 60 feet and is feed by volcanic springs. It lies at the base of the 4,200 foot Mt. Konocti, a volcanic cone. The Lake is 68 square miles with 100 miles of shoreline including the Upper, Lower and Oaks Arms. Temperatures range from 61-40 degrees in the winter and 76 in the summer. The only outlet to this large lake is Cache Creek which is located in the Lower Arm of the Lake. A dam is located 5 miles below the Lake. The Clear Lake watershed is 441 square miles. The beneficial uses of this unique Lake are: municipal, agriculture, recreation, warm freshwater, warm spawning , wildlife and cold freshwater habitats. The two largest streams are Scotts Creek and Middle Creek , which join in the Middle Creek marsh area before draining into the Upper Arm through Rodman Slough. These two creeks drain 30% of the watershed. Vegetation ranges from grasslands , chaparral-type plants in the lowlands to coniferous forest to the upper elevations. The confluence of Cache Creek is the Sacramento River, hence the Delta, hence the San Francisco Bay estuary.

FOOD WEB

A total of 260 aquatic species have been found in Clear Lake. Most of these are 101 algae species and 94 invertebrates, macrophytes (aquatic plants near the water surface that provide habitat/food for fish plus and if in decline show water quality problems) (23 species), microheterotrophs (8 species) and 29 species of fish (13 native and 16 introduced). The major amphibious/terrestrial links to these aquatic species are frogs, mink, otter, birds and humans. (Thomas H. Suchanek)

Clear Lake is considered ‘a naturally productive lake’ due to its biomass abundance consisting of diatoms, green algae, water plants and macrophytes which where considered to be the first abundant life according to core samples. Macrophytes were dominant until 1920s when mining released sediments to the Lake changing the clarity of the Lake thus increasing the turbidity. Clear Lake supports abundant aquatic and terrestrial biological resources.

CLEAR LAKE HITCH

Clear Lake Hitch, is an ancient fish endemic to Clear Lake and it lives in deep water but spawns in the tributaries of Clear Lake. The Chi-Council for the Clear Lake Hitch, a local group that tracks the status of Clear Lake Chi, document that Hitch is in ‘precipitous decline’. This decline is in keeping with water quality decline. Clear Lake Splittail became extinct in 1970 along with Pacific Lamprey, Thicktail Chub and Hardhead in 2000. While little is known about their disappearance, fish need clean water, healthy habitats with adequate flows throughout their life cycle. Human impacts to Clear Lake fish habitats are certain to be causing fish declines.

Limnologist recommend that the native fish assemblage be restored to help correct the imbalance of algae blooms and improve the water quality of Clear Lake.

In 2009 during the three year drought in California Clear Lake suffered a devastating infestation of cyanbacteria/blue-green algae with mats forming around the entire Lake. These mats extended hundreds of feet from the shore line. The Lower Arms of the Lake were particularly impacted completely eliminating beneficial uses. The blue-green algae produced toxins which caused public health alarms to go off.

Additionally, there have been numerous fish kills as oxygen was sucked out of the water. People reported to LRC seeing fish near the shorelines jumping out of the water.

Cyanobacteria AKA blue-green algae

Cyanobacteria are true bacteria but differ from other bacteria by having photosynthetic ability. Blue-green algae can occur as single cells, strands of cells called trichomes, or accumulated cells called colonies. A ‘bloom’ or increase in cells to form colonies causes reduced water quality and can produce toxins.

Life cycle of cyanobacteria: they fix gaseous nitrogen and are efficient at storing phosphorous. Buoyancy of this species varies due to the changing size of their internal pockets of gas. They will migrate to calm water in response to nutrient or light gradients. They produce spores (akinetes) which will lie dormant for years and then when conditions are ripe they will seed a water body. Optimal conditions for this bacteria are: high temperatures, long sunny days, high levels of phosphorus and nitrogen and calm winds which allow the cells to migrate to the surface. Reproduction takes place through trichome fragmentation, the splitting of the chain of cells, and is promoted by photosynthesis. They can produce an oily looking film or blue-green scums many inches thick.(Resource #10)

CLEAR LAKE NUTRIENT TMDL

Clear Lake is on the 303(d) of the Clean Water Act since 1998 and 2002 due to impairments of water quality from excessive nutrients causing ‘intense algae growth’ that severely impacts the surrounding economy and stops all beneficial uses (2009, 2011) of the Lake during the algae blooms of cyanbacteria also known as blue-green algae. Cyanobacteria algae blooms are destructive to the lake’s natural ecology and they destroy beneficial uses of the lake.

The purpose of developing the Nutrient TMDL for Clear Lake is to reduce the frequency and intensity of the algae blooms that are a result of nutrient cycling. (TR 4.2.1.3)

The primary goal of the Nutrient Total Maximum Daily Load, TMDL,is to reduce external phosphorous from the watershed in order to meet the Nutrient TMDL of chlorophyll-a which shall not exceed 73ug/l.

In reports from the 19th and early 20th centuries, scum forming algae are hardly mentioned, but vegetation growth from the bottom of the lake was frequently observed. Bottom dwelling plants need relatively clear water to thrive. Increased turbidity and blue-green-algae scums were conspicuous by the late 1930’s and bottom dwelling algae and waterweeds have been absent in most recent years since that time. The cause of this increased turbidity comes from sediment entering the lake from human activities in the watershed such as: mining, forestry, vineyards and other agricultural activities, construction, roads and grazing. Mobilized sediment carries pollution such as nutrients (phosphorus) and mercury directly into the Lake.

The delicate natural ecology of the lake consisting of an equilibrium of water plants, algae and diatoms, has been severely altered by humans causing a shift in the lake water quality. The blue-green algae or cyanobacteria becomes opportunistic given warm days and high nutrients and then it explodes and infests the lake. Some infestations are now toxic.

Nutrients (phosphorus) sources are mostly from fertilizers used by irrigated agriculture, residents and massive sewer spills over the years totaling 7,390,306 gallons or 140 spill events (attachment herein 1 Big Valley Rancheria map 2003-2010). Again, cyanobacteria have seeds that lie in the sediment for years.

Lakebed core samples from the last 15,000 years historically shows that Clear Lake has high total phosphorus coming from lakebed sediments. However, external phosphorus has been determined to be excessive coming from the tributaries draining the watershed. The external phosphorus loading of the Lake comes from water running overland either by sheet flow or stream flows where phosphorus mobilizes with sediment and overloads the Lake. It then severely impairs water quality and ultimately, when the conditions are ripe can explode into a cyanobacteria infestations also known as an ‘algae bloom’.

LRC prefers to call ‘algae bloom’ a ‘cyanobacteria infestation’. While cyanobacteria is frequently described as ‘ancient bacteria naturally occurring in the environment for millions of years’ it turns opportunistic given the right conditions in the lake and can over populate quickly and dominate the fragile Lake ecosystem due to: 1)unnatural loading of nutrients and metals to the Lake causing an increase in food for the cyanobacteria that otherwise would be in equilibrium with other algae 2) lack of fresh water flows caused by diversion to the Central Valley for farm lands 3) failure of precipitation or drought 4) climate change/warming of the lake 4) increase in pollution like sediment loading to the Lake during storm events 5) severe damage to native fish assemblage where the native fish once fed on the ‘eutrophic’ elements of the Lake. These variables interact to cause significant cumulative impacts to Clear Lake water quality that results in total loss of beneficial uses of the Lake with devastating economic impacts.

Scum producing cyanobacteria engulfs the Lake with algae mats that can be as thick as three feet at the shoreline and extend 100s of feet into the lake (2009, 2010 and 2011). LRC has witnessed this personally by its members. The smell will drive you away from the Lake as it is a dead stench like rotting eggs.

Some cyanobacteria such as Microcystis, Aphanizomenon, Anabaena spiroides, Lyngbya cincinnati produce cyanotoxins such as: dedromoaphlysiatoxin (neurotoxins-paralytic) and lyngbyatoxin a dermotoxin causing ‘swimmer’s itch’. (resource #3) In 2009 Clear Lake was plagued with Lyngbya and public officials were forced to warn people not to enter the water that rashes might occur and pets could be at risk of death if they drank the water. Cyanobacteria can become toxic at anytime. The dominant Anabaena species growing in Clear Lake in 2010 was identified as Anabaena spiroides. This scum-forming filamentous cyanobactrium species can produce at least two types of toxins: anatozin-a and microcystins, a hepatoxin capable of causing liver failure and acting as tumor-promoters. (resource #4 see pictures of these bacteria).

In 2009-2011, Clear Lake had summers plagued with scum producing algae mats. While 2009 was a drought year, **2011 has not been a drought year**. In fact 2011 has had high amounts of rainfall into June and the Lake has been plagued with scums regardless of high rainfall years. This suggests that the Nutrient TMDL is not effective and or the responsible parties are not compliant with the Nutrient TMDL limit. The 2004 Technical Report bases the Clear Lake Nutrient TMDL on the argument that drought conditions exacerbate the natural chemical balance of the lake and can cause an infestation of toxin producing cyanobacteria/blue-green algae. Further the 2004 Technical Report makes the claim that normal to high rainfall shows that the Lake water quality improves.

Tetra Tech did extensive modeling for the 2004 Technical Report to determine the amount of chlorophyll-a the Lake can tolerate. However, this modeling could be inaccurate and the actual tipping point for which algae blooms occur is much below 73ug/l. Recent data results by UC Santa Cruz for the SWAMP 2011 Monitoring of Clear Lake shows that on June 16, 2011 the chlorophyll-a sample was highest at 27.89 ug/L and four days later the Lake exploded in an cyanobacteria infestation/bloom. (see resource #4)

LRC requests that the CVRWQCB re-evaluate the efficacy of the current Nutrient TMDL limit of 73 ug/L adopted by the SWRCB based on this new research that the Water Board funded.

Additionally, the interactions of metals with cyanobacteria could exacerbate onset of blooms. Little is known about this variable but all the literature done over the years by top experts on the recurrent algae blooms suggests that metals (phosphorous, mercury, iron) influence algae growth. (see all resources listed)

There is a tipping point with algae blooms such that so much nutrient/phosphorous (other metals) is entering the lake from external sources that dilution from rain events is not enough any longer to achieve the current Nutrient TMDL limit. Additonally, it is not clear that responsible parties who are suppose to reduce sediment to the lake are compliant.

Clear Lake has had cyanobacteria/blue-green scum mats depriving the people of public trust values even during high rainfall years.

2007	2008	2009	2010	2011
Drought Scum Toxins	drought scums toxins	drought scums toxins	Normal rainfall Scums toxins	Above normal rainfall Scums/toxins

CYANOBACTERIA GLOBAL PROBLEM

More importantly, the Basin Plan should reflect that multiple contaminants to the State water bodies are collectively causing toxic stews that create toxic cyanobacteria infestations throughout fresh and salt water resources around the globe. Scientists are studying these mysterious cyanobacteria mats. The Basin Plan should discuss the significant cumulative impacts to watersheds where human impacts severely change the water quality such that multiple impacts are exacerbating fresh water resources in ways we have never seen before i.e., Japan's fishing industry is all put shut down due to invasions of jelly fish that feed off of nutrient loading to the oceans around this island nation. Floating algae mats miles long have been spotted off the Pacific coast and estuaries around the globe. National Marine Fisheries have found dead dolphins where their livers have been poisoned by cyanobacteria.

MONITORING

Monitoring data from 2007-2011 that tracks chlorophyll-a throughout the drought and high rainfall years is NOT available to the public in analytic form so that the public can see that TMDL limits are NOT being met. Responsible parties lack the will to get aggressive in cleaning up the water quality and public officials lay claim that they do not know why the lake has blooms or that the lake naturally has algae blooms.

The Clear Lake Nutrient 2004 Technical Report, TR, which the TMDL is based on (and is on line for the public) is severely out of date with the actual conditions going on with the Lake for example:

1. Irrigated agriculture land uses such as vineyards has increased significantly since 2004 which produces a large amounts of the erosion runoff to the lake. Fertilizers are a source pollution to the lake and contribute to the excessive phosphorous that is causing the blue-green

algae blooms. The Basin Plan should be updated regarding these important pollution source.

2. The State Department of Water Resources, DWR, has water quality data available on their website in their water quality library. DWR does not sample consistently during the warmest months when water quality plummets. (2011 sampling dates were more frequent during the summer but this data does not have easy access to the public). Chlorophyll-a is not posted by the DWR library but instead is sent to the CVRWQCB, Holly Grover. LRC had to personally request the data. It should be readily available to the public, since public funds paid for the study.

3. Lake County Water Resources Department with funds from the Water Board, is now working with a UC Santa Cruz, PhD, Cecile Mioni, who is documenting 2011 water quality data including Chlorophyll-a but this data has not gone public nor has it been anlyized for the public. Holly Grover, CVRWQCB, states that she is using this data to update the 2012-14 TMDL. This research project shows that chlorophyll-a quickly climbs to 27.89ug/l in the Clear Lake Lower Arms on June 16th, 2011. Additionally phosphorous and temperatures were high and secchi depths dropped dramatically. Four days after these data were collected, Clear Lake suffered a devastating cyanobacteria bloom and it continues to date (August 24, 2011) LRC was notified by Lake County Department of Water Resources, that July 2011 data collection is more shocking than June's data. July 2011 data of chlorophyll-a more than tripled. (recent data from CVRWQCB, Holly Grover) These data have been collected during severe scum infestations of cyanobacteria and this shows the lake is not compliant with the Nutrient TMDL.(see chart inserted herein page 10)

	1/25/2011	6/12/2011	7/19/2011
	mg/m3 (ppb)		
CL-01 0.5M	8.07	3.07	60.6
CL-01 0.5M dup	6.33	4.78	
CL-01 3M	6.34	12.3	32.3
CL-01 3M dup			
CL-01 6M	5.13	9.9	21.6
CL-01 6M dup			
CL-03 0.5M	75.6	13.6	136

CL-03 3M	62.4	13.5	78.5
CL-03 6M	35.6	14	67
CL-03 9M	56.3	12.1	55.3
CL-04 0.5M	37.4	16.7	
CL-04 3M	37.3	14.6	
CL-04 6M	60.4	15.7	
CL-04 9M	54.2	18	
CL-04 12M	93.8	17.1	
Secchi Depth CL-01	4.6 m		
Secchi Depth CL-03	3.0 m		
Secchi Depth CL-04	3.9 m		

4. Page 26 of the TR states that Lake County Monitoring lacks monitoring data (1999) therefore eluding to the fact that the 2006 Nutrient TMDL modeling could have been ineffective and not valid for today’s conditions.

5. Stream incision due to increased rate of runoff from wildland conversions to vineyards is a major cause of channel erosion but the Nutrient and the Mercury TMDL fails to discuss this major landuse source of nutrient and mercury loading to the Lake.

MERCURY (Hg)

Mercury is a heavy metal which is detrimental to life and it bio-accumulates in the environment. One thermometer of mercury entering the natural aquatic environment can pollute 9,000 cans of tuna.

Clear Lake was listed on the 303 (d) list of the Clean Water Act in 1988 due to high levels of mercury (Hg) in fish and the lakebed sediments. The Mercury TMDL for Clear Lake was approved by the State Water Resources Control Board in 2010.

The primary goal of the Mercury TMDL is to reduce mercury in ‘trophic levels 3 & 4 to .09 & .19 mg/kg Hg. This is a high priority of this Basin Plan Ammendment.

However, the current TMDL for mercury **does not** clean up mercury contamination to safe levels for native populations who historically ate 1 ½-3 pounds of fish daily. There are tribes identified in the Mercury TMDL: Big Valley Rancheria, Elem Pomo, Habematolel Pomo Upperlake, Lower Lake Rancheria

Koi Nation, Middletown Rancheria, Robinson Rancheria, Scotts Valley Band of Pomo Indians.

The Mercury TMDL lacks environmental justice for Native Americans who depend on the native fish for their food.

The Sulphur Banks Mercury Mine/Herman Pit (1840-1960) is located in the Oaks Arm of the Lake. This site was abandoned by the Bradly Mining Company who did open pit mining. Expert research (resource #7) states that it is the main pollution source of mercury attaching to sediment during storm events and entering the Lake. This site contributes to significant pollution to Clear Lake, hence the Sacramento River, hence the San Francisco Bay Delta hence the Pacific Ocean. Clear Lake is considered one of the most polluted lakes for mercury in the world.

When the Herman Pit overflows into the natural environment of the Lake microbes convert mercury to methyl Hg which is more toxic.

According to the 1994 research document, The Causes and Control of Algal Blooms in Clear Lake, (page III-8) the Lake is now a USEPA SuperFund cleanup site (Chamberlin et.al., 1990; Suchanek et al., 1993). Larger individuals of largemouth bass and other sport fish often have body burdens in excess of .5 ppm mercury, which has lead to a health advisory on eating fish from Clear Lake. The problem stems from the large quantity of inorganic mercury stored in the sediments, mostly in the Oaks Arm. There may also be an interaction between excessive algal growth and the mercury problem. Some data indicates that heavy loads of organic matter to the sediment, as it might result from the collapse of blue-green blooms, may fuel microbial activities (microbes methylate mercury).

The Mercury TMDL relies on the EPA's superfund designation to clean up Hg as a source pollutant.

Resource (7) T. H. Suchanek, ' These data provide preliminary evidence of how a relatively extensive aquatic ecosystem has been contaminated with methyl Hg from a point source (Sulphur Banks mercury mine inorganic Hg) over several decades.

The research literature shows that cyanobacteria/blue-green algae thrive in the presence of metals such as iron, phosphorous and mercury .

CLEAR LAKE WATER DIVERSIONS

The State Water Resource Control Board, SWRCB, has on-going jurisdiction over water diversions in the State. Clear Lake supplies the Central Valley with water for farmers. During drought conditions Clear Lake's water quality plummets causing a total loss of public trust values such as fishing, swimming and recreation. The SWRCB should assert their jurisdiction and protect the natural environment of Clear Lake by reducing the water allocations to farmers during droughts. This should be part of the Basin Plan update. Clear Lake has numerous water diversions that send water to farmers in the Central Valley. The SWRCB has documented 1,777 illegal water diversions in Napa, Marin, Sonoma, Mendocino and Humboldt Counties.

How many illegal water diversions are contributing to the decline of fish and water quality in the Clear Lake Basin?

CLIMATE CHANGE

The Basin Plan should take into consideration the impacts to Clear Lake associated with climate change. The lake is shallow and warm naturally. Since 1920 human impacts have caused the Lake to increase in temperature and become contaminated by sediment loads. Diversions lower the Lake during the warm months. As temperatures increase and drought becomes more frequent, Clear Lake is vulnerable to increases in scum producing algae infestations.

TMDL LIMITS FOR NUTRIENTS ARE NOT ADEQUATE

The 2004 Nutrient Technical Report repeatedly relies on data that says that Clear Lake experiences out breaks of blue-green algae during drought conditions. This is incorrect because in 2010 and 2011 when precipitation/water year rainfall was above normal, Clear Lake had repeated outbreaks of cyanbacteria mats plaguing the entire Lake especially in the Arm's shoreline where temperature and turbidity increase and secchi depth dramatically decreases. The TMDL relies on this information which is incorrect given the on-going nutrient loading, increased development in the watershed, lack of enforcement and utter disregard for construction and road Best Management Practices (BMPs). Irrigated agriculture escapes the nutrient and mercury TMDLs by lack of BMPS and no regulations over increased rate of runoff due to deforestation of wildlands.

Modeling to establish the limits of pollution for nutrients loading to Clear Lake must be recalibrated because algae blooms have increased in frequency and intensity dramatically despite high rainfall in to June of 2011. The *73ug/l chlorophyll-a limits were determined by modeling to be the target for reducing nutrient loading, however this is more the tipping point than a 'target'. This limit should be reduced because the lake is experiencing increase blue-green infestations during high precipitation years, which indicates that the target is not low enough.*

Enforcement :

The responsible parties for preventing pollution to the Lake do not enforce the Clean Water Act such as:

- Developers do not always install BMPs or if they install them, they often are not installed properly
- After storm events, BMPs are not properly maintained
- Yearly, sewer leaks pollute the Lake due to inadequate and old leaking infrastructure, (see Map attachment) by Big Valley Rancheria EPA. Current bond measures and infrastructure plans are moving forward. However, the Lake County Special District must prevent further spills
- CVRWQCB should issue fines for continued sewer pollution events to the Lake
- Illegal water diversion must be stopped
- LRC made a formal complaint to the SWRCB regarding water diversions in 2009 that were exacerbating the cyanobacteria infestation.

MORITORIUM

There should be a moratorium on any new construction in the basin until sewer infrastructure has been updated to carry the current capacity and projected growth. The nutrient loading to the Lake as a result of the failing sewer systems throughout the Lake County Special District is causing tremendous damage to the Lake's ecosystem and water quality.

Laws should be put in place locally to protect the Lake from development that will cause sewer leaks in the future.

BASIN PLAN AMMENDMENT RECOMMENDATIONS FOR CLEAR LAKE:

1. Lake County Public Works, the Department of Water Resources and the State Department of Water Resources, DWR, and any other public resource agencies should post all monitoring data on the internet for easy public access to this important information. This should include:

2. Responsible agencies should post to the internet all sewer discharges to the Lake.

2. Revise the months that data collection of chlorophyll-a is being done. The Department of Water Resources, DWR, collects/or posts (makes public) data for months of December and June. This is not the height of the cyanobacteria/blue-green algae blooms. Chlorophyll-a data collection must be collected during the warmest months i.e., July, August and possibly September.

3. The Mercury TMDL relies on the EPA Plan aka Record of Decision for Operable Unit 1 by 7/31/2011 and Operable

Unit 2 by 3/31/2013. However, the Sulphur Banks Mercury Mine Herman Pit could spill into Clear Lake toxic water when at flood stage of the pit. Given climate change and possible intense storm events, the sooner the EPA's project plan is implemented the better.

4. Secchi or clarity of the Lake: Now you can hardly see your hand in front of your face when your able to swim. While the DWR, collects Secchi data the current TMDL does not utilize this data and interpret it for the TMDL.

5. Fish kills-shoreline residents document to the local resource agencies fish kills. Some have actually witnessed fish leaping out of the water near the shoreline or they wash up on the shoreline. There is little information about this available to the public.

6. Limnologist recommend restoration efforts should take place to restore the natural fish assemblage of the Lake which will help deplete the algae blooms. Every effort should be made to diminish the introduction of non-native fish.

7. Responsible agencies should be accountable to the public for their non responsiveness to the TMDL implementation plans, lack of enforcement and irresponsible actions that lead to pollution events to the Lake.

8. The responsible agencies must enforce the Clean Water Act and issue fines to developers that do not install and utilize BMPs properly.

9. Water Diversions-the 2004 Technical Report fails to adequately discuss the impacts of water diversions on the health of the lake. During drought conditions the SWRCB could reduce water diversions/allocations due to harm to native fish.

10. Public figures, politicians and some environmental groups, announce and proclaim that the Lake is 'naturally eutrophic' or 'naturally productive' and they dismiss cries for help this way. Time and time again, Lake County leadership falls flat when teachable moments present themselves to educate the public about cyanobacteria and the causes of poor water quality. We the public can not count on the 'authorities' to speak the truth about Clear Lake's devastating water quality problems to urge the stakeholders to roll up their sleeves and get busy reducing sediment at every opportunity.

11. The Basin Plan must discuss the environmental impacts to Clear Lake as a result of climate change.

12. The Nutrient TR states that ‘biostimulatory substances’ in Clear Lake shall not contain stimulate or promote aquatic growths in concentrations that cause aquatic growths that adversely affect beneficial uses. The 73ug/l limit for nutrients allowed to the Lake is too high. The Bain Plan should reduce this limit to improve water quality conditions.

13. In 1990 the EPA required NPDES Phase I permits to discharge polluted storm water to water bodies. Phase one applies to municipalities of 100,000 populations and Phase II applies to certain municipalities of 10,000 population. The Mercury TMDL states that the County has a MS4 Phase II NPDES Permit CAS000004-2003b. The Basin Plan should require the County to post their permit and show monitoring results for transparency for the public to show compliance with the Clean Water Act.

14. Mercury and other metal contamination to the Lake likely exacerbate blue-green algae growth. The Nutrient TMDL relies on the Mercury TMDL success and the restoration of the Sulphur Banks/Herman Pit superfund project!

15. Modeling for Clear Lake Nutrient TMDL has been ineffective and may be completely off target for improving water quality.

16. TMDLs require that the Water Boards (WB) consider all other impairments/limiting factors in the basin and find nexus where WBs can help improve water quality. Clear Lake is an important water body in rapid decline of the water quality and far from achieving or even moving towards the TMDL that was established in 2006. In fact, the Lake’s water quality is getting precipitously worse. The WB should have an integrated approach to water quality improvement such as: 1) reduce water diversions both in the future and with current water rights 2) cancel any conditional waiver programs and step up the TMDL program to closer supervision by the WB.

SUMMARY:

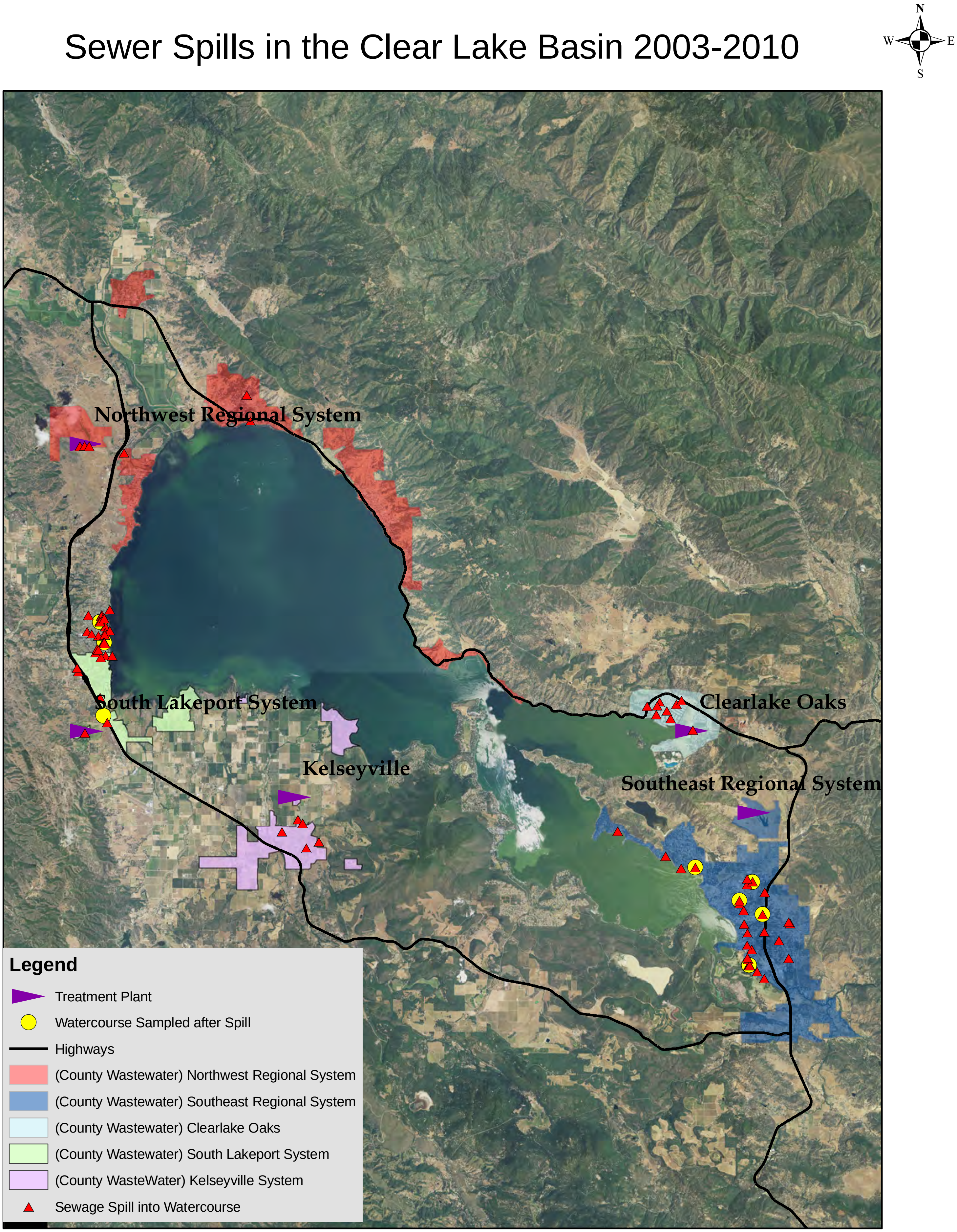
Between drought conditions, increased land uses such as wildland conversion to vineyards, poor road conditions, lack of effective best management practices and numerous sewer leaks that discharge nutrients to the Lake and over allocations of water to down stream diverters combined with defunct and out of date nutrient TMDL modeling along with lack of current data all have put Clear Lake in jeopardy. Living River Council is concerned about the lack of improvement to the water quality of Clear Lake. During the summer and warm months Clear Lake's water quality plummeted causing fish kills and loss of public trust values such as fishing, swimming and recreation. Mercury impacts to the Lake are dependent on the Superfund Record of decision now on hold due to ‘technical difficulties’for restoration efforts. Heavy metals are contributing to significant cumulative impacts to water quality and are dangerously not fully understood by the Water Boards. The Triennial update for Clear Lake must reevaluate modeling that sets TMDL limits to improve future water quality for this important watershed to the Delta.

Chris Malan
Living Rivers Council
Manager

Resources:

1. Central Valley Regional Water Quality Control Board, 2004 Technical Report
2. CVRWQCB 2006 Staff Report
3. Algal Toxins Bioassessment-Clear Lake, July/August 2010
4. SWAMP 2011 monitoring in Clear Lake and San Francisco Bay/Delta, Cecile Mioni, PHD, UCSC, Institute of Marine Sciences
5. The Causes and Control of Algal Blooms in Clear Lake, Thomas H. Suchanek, SWRCB, LCFCWCD
6. Big Valley Rancheria, Sarah Ryan
7. Redistribution of Mercury from contaminated Lake Sediment of Clear Lake, Ca. Thomas Suchanek
8.Ecological Society of America-Mercury Cycling and Bioaccoumuation in a Mine-dominated Aquatic Ecosystem: Clear Lake California
9. National Toxicology Program: Blue-Green Algae, Evidence for Possible Carcinogenic Activity.
10. Aquatic Invasive Species: Blue-Green Algae

Sewer Spills in the Clear Lake Basin 2003-2010

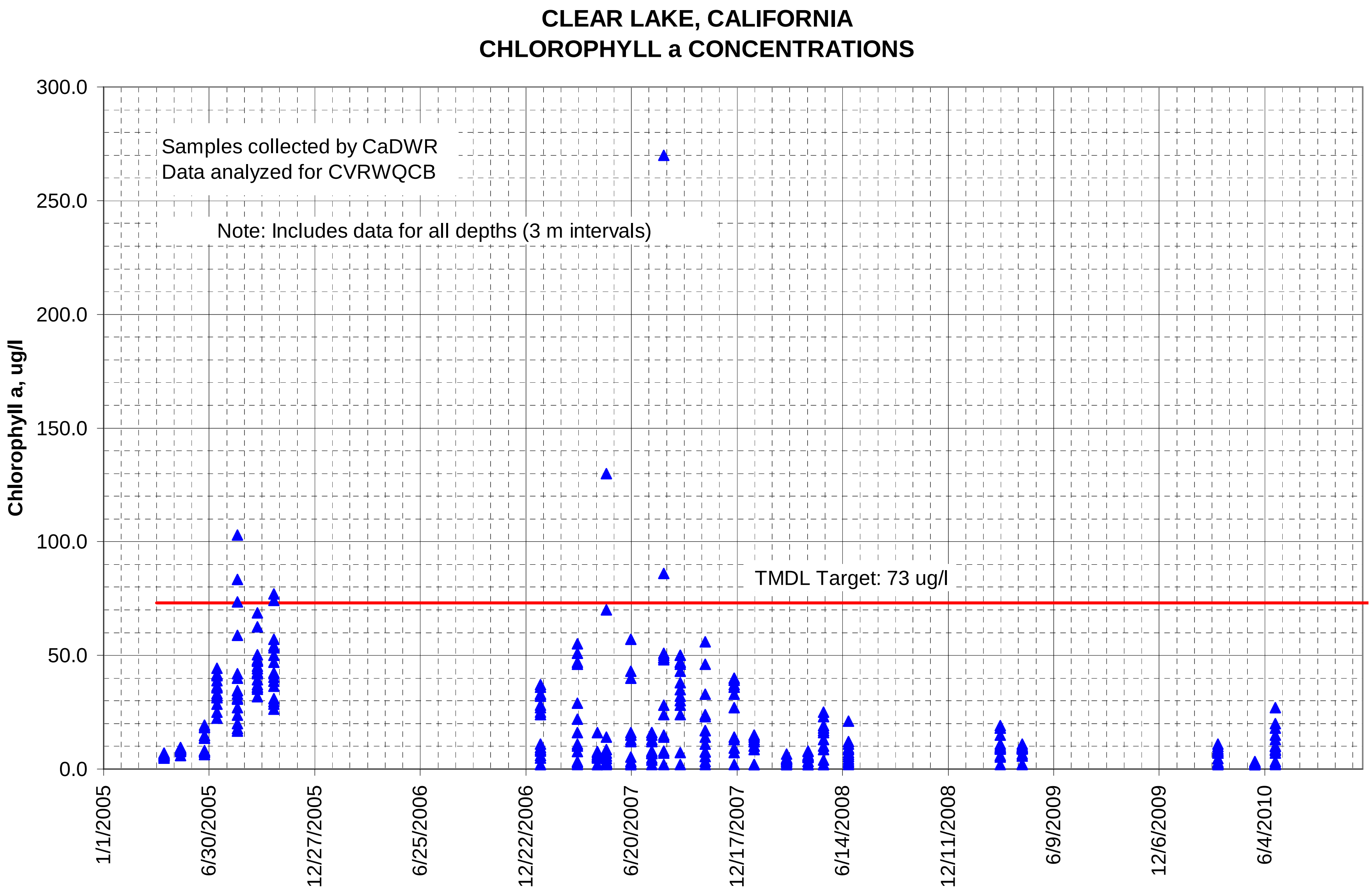


1 inch = 15,851 feet

7,373,686 Gallons Spilled into Watercourse
7,390,306 Total Gallons Spilled
140 Spill Events
8 Sampled after Spill

Data From:
State of California Region 5 Central Valley Water Quality Control Board
Executive Officer's Reports, 2001 - 2010 and Lake County Environmental Health
Wastewater Spills & Monitoring 2003 - 2010

BIG VALLEY RANCHERIA EPA Sept. 2010



CLEAR LAKE, CALIFORNIA
CHLOROPHYLL a CONCENTRATIONS
Samples collected by CaDWR
Data analyzed for CVRWQCB
Note: Includes data for all depths (3 m intervals)
TMDL Target: 73 ug/l
Chlorophyll a, ug/l
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1/1/2005
6/30/2005
12/27/2005
6/25/2006
12/22/2006
6/20/2007
12/17/2007
6/14/2008
12/11/2008
6/9/2009
12/6/2009
6/4/2010

DRAFT REPORT

Algal toxins bioassessment – Clear Lake, July/August 2010

Prepared by Cécile Mioni & Raphael Kudela

The University of California, Santa Cruz
Institute of Marine Science
1156 High Street
Santa Cruz, CA 95064

April 2011

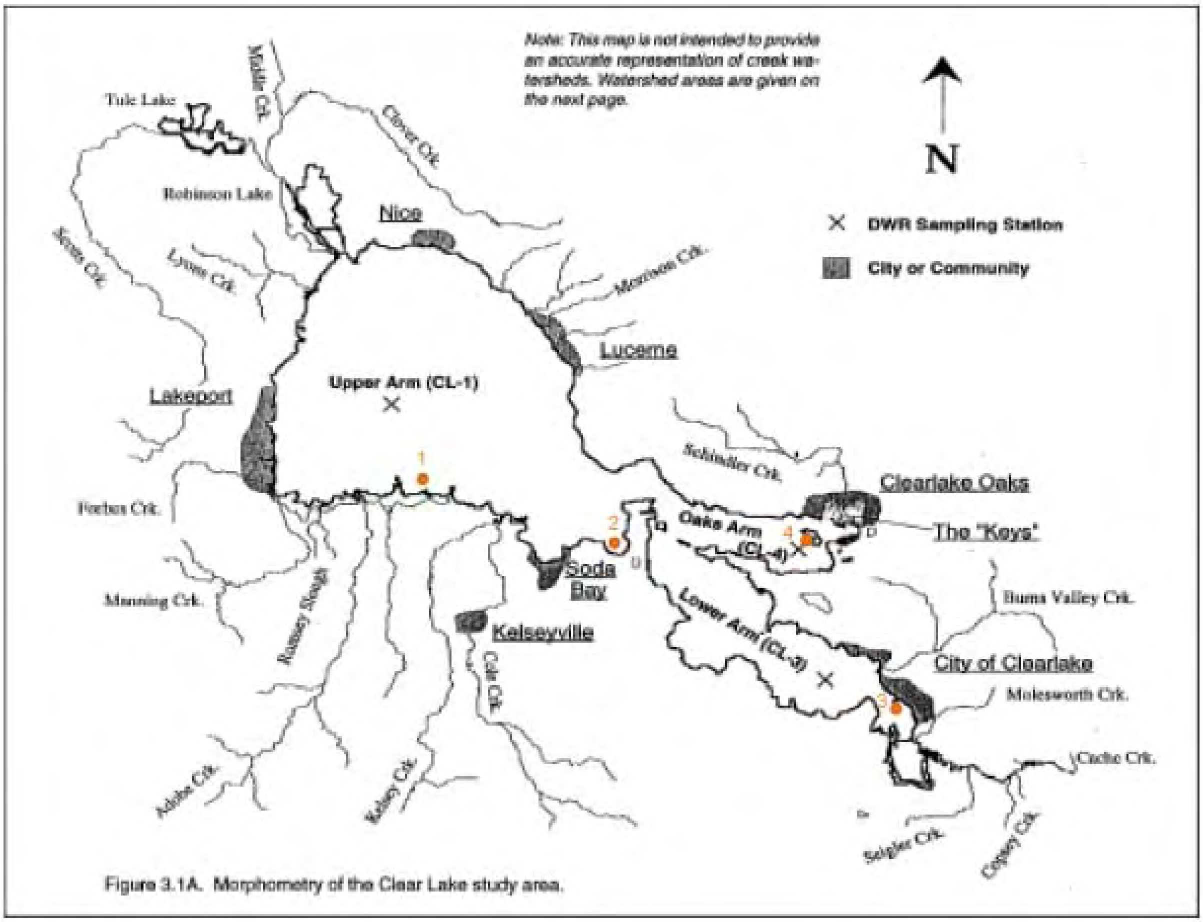


Figure 3.1A. Morphometry of the Clear Lake study area.

Figure 1: Study are map. CL-1, CL-2 and CL-3 discrete monitoring stations are historical DWR monitoring stations (Richerson 1994). They were also used for a toxicology study performed in 1990 (ODWSESP 1991). The stations 1, 2, 3, 4 are continuous monitoring stations (SPATT samples, HOBOS) and are located at coastal buoys (county owned). Discrete samples were also collected monthly at these stations

Algal toxins bioassessment – Clear Lake, July/August 2010

Cécile Mioni & Raphael Kudela, UCSC

The following draft report describes the results from a series of monthly investigations into the toxicity of cyanobacteria in Clear Lake, California. Individuals from the Lake County Water Resources Department and the University of California, Santa Cruz all redirected efforts to gather samples, carry out assays, and/or interpret results. The findings can be summarized as follows:

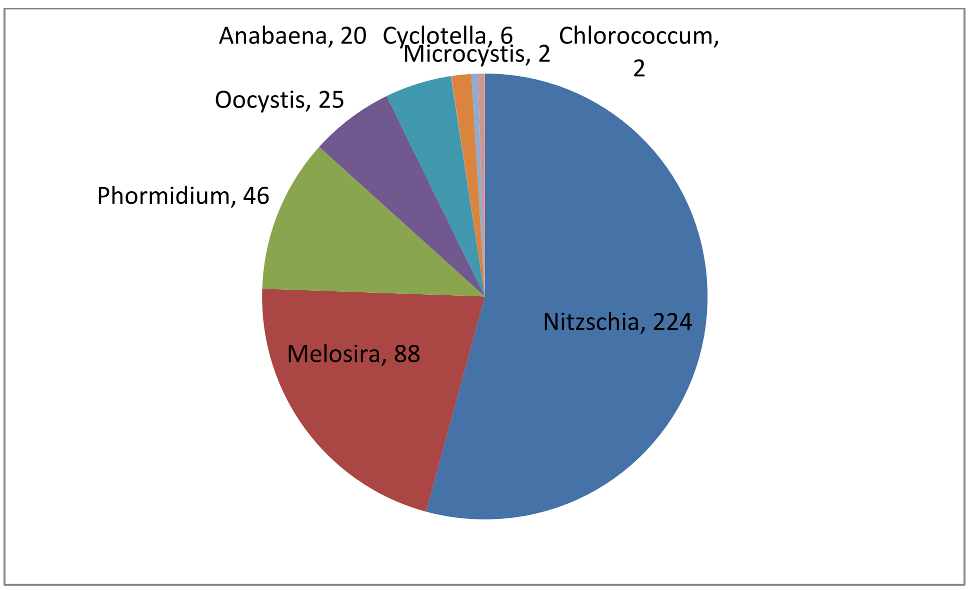


Figure 2: Algal composition a bloom sample collected in August 2010 at station 5B located in the northern Lower Arm. The bloom was dominated by: *Nitzschia* (diatoms), *Melosira* (diatoms), *Phormidium cincinnatum* (aka *Lyngbya cincinnati*, cyanobacteria), *Oocystis* (green alga), *Anabaena spiroides* (cyanobacteria) and *Microcystis aeruginosa* (cyanobacteria). Note: *Microcystis* is a floating species and does not settle to the bottom of a Utermohl chamber. Therefore the number of *Microcystis* enumerated in the sample is underestimated.

Presence of toxic cyanobacteria in Clear Lake

Thirty-one surface water samples were collected from Clear Lake for algal toxicology analysis at seven stations (Figure 1). One sample collected in August at the epicenter of the bloom (northern part of Lower Arm, station 5B) was sent to EcoAnalysts, Inc. for taxonomy analysis. Cyanotoxin concentrations (microcystins, anatoxin-a and saxitoxins) were analyzed using ELISA (microcystins, saxitoxins) and LC/MS (microcystins, anatoxin-a) analysis at the University of California, Santa Cruz. Some pictures of the bloom are included in the appendix section of this report.

Taxonomy results indicate that the algal bloom assemblage was composed of a mixed assemblage of diatoms, green algae and cyanobacteria. The cyanobacteria comprised a significant fraction of the algal assemblage and included several potentially harmful cyanobacteria such as: *Aphanizomenon* (June samples), *Microcystis aeruginosa* (mostly June and September), *Anabaena spiroides (throughout summer)*, and *Lyngbya cincinnati* (aka *Phormidium cincinnatum*, throughout summer). In the sample collected in August 2010 in the northern section of the Lower arm (station 5B, epicenter of the bloom) and analyzed by Ecoanalyst, Inc., *Lyngbya cincinnati* and *Anabaena spiroides* were the two dominant cyanobacteria species (Figure 2).

According to the literature, Clear Lake has been seriously impaired by seasonal blooms of scum-forming cyanobacteria (Richerson 1994). Over the entire 23 year period for which the DWR phytoplankton taxonomy data record summarized in the Richerson's report (1994), the three most common scum-forming cyanobacterial genus were *Anabaena*, *Aphanizomenon* and *Microcystis. Microcystis* blooms have been documented in both the Oaks Arm and the Lower Arm of Clear Lake in the mid 1970's with the largest blooms recorded by DWR occurring in the Lower Arm in 1991 (Richerson 1994). *Aphanizomenon* showed similar trends and was the most important scum former for most years up to 1985, when it suddenly became much less important (Richerson 1994). *Anabaena* was never responsible for blooms on the scale of *Microcystis* and *Aphanizomenon* in any arm but was a common component of the midsummer scums throughout the record, becoming much more important after 1980 before diminishing as the drought progressed (Richerson 1994). *Lyngbya* was not observed until 1984 (Richerson 1994) and the first large bloom event dominated by this mat-forming filamentous cyanobacterium was not observed until 2009 (Tom Smythe, *pers. com*.). Please note that the DWR taxonomy data records alternatively identified this cyanobacterium as *Phormidium,* *Lyngbya* or *PlanktoLyngbya* so the historical records might be misleading with regard to the presence/abundance of this cyanobacterium.

Taxonomists from Ecoanalysts, Inc. identified the dominant mat-forming cyanobacterium from August 2010 mat sample as *Lyngbya Cincinnati* (synonym: *Phormidium cincinnatum*). Although some freshwater *Lyngbya* species can produce the cyanotoxins saxitoxin, dedromoaplysiatoxin and lyngbyatoxin-a (Onodera et al. 1997, Puscher and Humbert 2007), the literature contains no information with regard to the toxicity of this specific *Lyngbya* strain. Over the course of our study, we did not detect any saxitoxin or its analogues (potent neurotoxins responsible for the human poisoning syndrome called paralytic shellfish poisoning) in any of the Clear Lake surface water samples (see below). Lyngbyatoxin-a (a dermatoxin causing “swimmer itch”) wasn’t monitored as part of this study but LC/MS preliminary results indicate that a compound with similar chemical properties was present in some discrete surface samples. Our future toxicology studies will attempt to determine the toxicity of this filamentous cyanobacteria strain using LC/MS and a lyngbyatoxin-a standard acquired from SCRIPPS (Dr. Jensen). Indeed, although no swimmer itch appear to have been reported among swimmers in summer 2010, 8 cases of “swimmer’s itch” were reported on June 19 of 2010 and may have been the result to exposure to dermacyanotoxins such as lyngbyatoxin-a (ODWSESP 1991). These cases were then diagnosed as schistosome dermatitis but mot cercaria were found in the swimming area or elsewhere in Clear Lake. On the day of the outbreak, no cyanobacteria were found in the swimming area water samples but cyanotoxins. However, cyanobacteria cell counts can underestimate the risk of cyanotoxin poisoning because cyanotoxins may persist in the water after a bloom has subsided.

The dominant *Anabaena* species growing in Clear Lake during summer 2010 was identified as *Anabaena spiroides*. It was the second most abundant cyanobacterium in the mat sample collected in August 2010. Compiled literature evidences suggest that this scum-forming filamentous cyanobacterium species can produce at least two types of toxins: anatoxin-a and microcystins (Puschner and Humbert 2007). Microcystins are nonribosomal peptide toxin that inhibits protein phosphatases in a broad range of eukaryotes from zooplankton to humans. These potent hepatotoxins are capable of causing liver failure and acting as tumor-promoters (Falconer 1991, Carmichael 1995, Chorus 2001, Grosse et al. 2006). Microcystins constitute the larger group of cyanotoxins with over 80 variants identified to date. Microcystin-LR is the most common congener of the series. Most microcystins display a LD-50 (intraperitoneal) ranging between 50 and 100 µg/kg in mice although Microcystin-RR are slightly less toxic with a LD-50 of 600 µg/kg in mice (Rinehart et al. 1994). Anatoxin-a(s) is a highly toxic neurotoxin structurally similar to an organophosphorus pesticide, with a LD-50 (intraperitoneal) in rats of about 20 µg/kg and 31 µg/kg in mice, respectively (Cook et al. 1988, Falconer 1996).

Microcystis spp. are bloom-forming single-celled, colonial, freshwater cyanobacteria and have been observed world-wide. In summer 2010, *Microcystis* colonies sizes varied from a dozen to several hundred of cells in the surface water of Clear Lake and were observed throughout the summer. They were not the most abundant components of the cyanobacteria mat from June-August but their relative abundance increased as compared to the other genera in September 2010. *Microcystis aeruginosa* strains can produce a multiple of toxins in addition to microcystin (Okino et al. 1995, Namikoshi and Rinehart 1996). Some *Microcystis aeruginosa* strains may also produce anatoxin-a (Park et al. 1995) and microviridins (Okino et al. 1995). Most microviridins show inhibitory activities against serine-type proteases. One of the peptide isoforms, microviridin J, has been shown to inhibit the molting process of *Daphnia* (small, planktonic crustaceans), and ultimately leading to death (Rohrlack et al. 2004).

Presence of cyanotoxins in Clear Lake

Previous studies suggest that the possibility that a cyanobacterial bloom may be toxic is more than 50% (Olson 1964). The ability to produce cyanotoxins may be regulated both by environmental factors and genotype (Kaebernick et al. 2000, Downing et al. 2005, Kardinaal et al. 2007) but these links are not well understood. Although recurrent cyanobacteria blooms have plagued Clear Lake for the past century, there is only one toxicology survey available to date that was conducted by the Office of Drinking Water and the Special Epidemiological Studies Program in 1990 (ODWSESP 1991). This study was focused on microcystin toxin only and did not examine other cyanotoxins. Results from this study reported large temporal and spatial variability as well as trace level (2.6×10^{-3} µg/L) of this cyanotoxin in one surface water sample collected in a swimming area of the lake and measured via immunoassay/ELISA (ODWSESP 1991). Among the 20 algae samples analyzed for toxicity using mouse bioassay, only two samples collected in Oaks arm (station CL-4) on June 28, 1990 were reported toxic. The most toxic of these samples contained 3.4 mg hepatotoxin/g of lyophilized algae (ODWSESP 1991). Based on these results, the study concluded that the oral NOAEL (No observed adverse effect level) for a 60 kg (ca. 132 lbs) adult would need to ingest 3.17 lbs of wet algae from Clear Lake.

Results from our study (LC/MS analyses) confirm a low level of microcystins, below the recreational advisory limit of 8 µg/L, however microcystin concentrations exceeded the WHO advisory limit for drinking water (1 µg/L) in several samples (Table 1). There were discrepancies between the ELISA and the LC-MS results. We believe that these discrepancies results from other compounds present in the water that could interfere with the ELISA kit optical reading and are working on modifying our methods to solve the issue (e.g. dilution, filtration at smaller pore size). Some compounds are also interfering with the detection of Microcystin-YR on the LC-MS and therefore we did not add this variant to the table below. The LC-MS results are

Table 1: Levels of cyanotoxins (µ/L) as measured by LC/MS (total microcystins –MC- and individual variants, anatoxin-a -ANA) and ELISA (saxitoxin –PSP-).

Date	Station	Name	MC-RR	MC-YR	MC-LR	MC-LA	Total MC	ANA	PSP
6/23/2010	Stn 1	Lakeport	0	NA	0	0		0	0
6/23/2010	CL1	Upper Arm	0	NA	0	0		0	0
6/23/2010	Stn 2	Horseshoe bend	0	NA	0	0		0	0
6/23/2010	Stn 3	Man	0	NA	0	0		0	0
6/23/2010	CL3	Lower Arm	0	NA	0	0		0	0
6/23/2010	Stn4	Rattlesnake island	0	NA	0	0		0	0
6/23/2010	CL4	Oaks Arm	0	NA	0	0		0	0
7/22/2010	Stn 1	Lakeport	0.617	NA	2.998	0	**3.615**	0	0
7/22/2010	CL1	Upper Arm	0	NA	0	0		0	0
7/22/2010	Stn 2	Horseshoe bend	0	NA	0	0		0	0
7/22/2010	Stn 3	Man	0	NA	0	0		0	0
7/22/2010	CL3	Lower Arm	0	NA	0	0		0	0
7/22/2010	Stn4	Rattlesnake island	0	NA	0	0		0	0
7/22/2010	CL4	Oaks Arm	0	NA	0	0		0	0
7/22/2010	Stn 5	north lower arm	0	NA	0	0		0	0
7/22/2010	Stn 6	Horseshoe bend	0	NA	0	0		0	0
8/16/2010	Stn 1	Lakeport	0	NA	0	0		0	0
8/16/2010	CL1	Upper Arm	0	NA	0	0		0	0
8/16/2010	Stn 2	Horseshoe bend	2.586	NA	0	0	**2.586**	0	0
8/16/2010	Stn 3	Man	0	NA	0	0		0	0
8/16/2010	CL3	Lower Arm	0	NA	0	0		**0.52**	0
8/16/2010	Stn4	Rattlesnake island	0	NA	3.193	0	**3.193**	0	0
8/16/2010	CL4	Oaks Arm	2.265	NA	0	0	**2.265**	0	0
8/16/2010	Stn 5B	north lower arm	0	NA	0	0		**7.78**	0
9/9/2010	Stn 1	Lakeport	0	NA	1.73	0	**1.73**	0	0
9/9/2010	CL1	Upper Arm	0	NA	0	0	0	0	0
9/9/2010	Stn 2	Horseshoe bend	0	NA	0	0	0	0	0
9/9/2010	Stn 3	Man	0	NA	0	0	0	0	0
9/9/2010	CL3	Lower Arm	0	NA	0	0	0	0	0
9/9/2010	Stn4	Rattlesnake island	0	NA	0	0	0	0	0
9/9/2010	CL4	Oaks Arm	0	NA	0	0	0	0	0

considered more accurate than ELISA (high-throughput assay) and therefore, these are the results that we will keep in the database. All samples are expressed in ppb (µg/L). The microcystin levels measured in Clear Lake during Summer 2010 are much lower than that reported other local lakes with similar cyanobacteria biomass (e.g. Pinto Lake, Miller et al. 2010).

Anatoxin-a was detected in two of the samples collected in the lower arm in August 2010 (CL-3 and station 5B, table 1). At both collection sites, anatoxin-a was well below the suggested action levels for recreational use (50 µg/L, OEHHA/EPA 2009).

Saxitoxins were below the detection limit or not present in the lake surface water (using Abraxis ELISA kits only).

Other cyanotoxins (e.g. lyngbyatoxin-a) might have been present in the surface water but we did not have a standard and therefore cannot quantify the compound or validate that it is actually lyngbyatoxin-a. Based on the LC-MS results, the mass seems to match lyngbyatoxin-a but the level appear low. We have acquired a lyngbyatoxin-a pure extract from SCRIPPS (Dr. Jensen) and will attempt to calibrate the LC/MS to measure this toxin during Summer 2011.

As noted in the toxicological report from 1991, cyanotoxin concentrations in Clear Lake display a high variability in space and time. Except for September 2010 samples, Upper arm is usually the least toxic as compared to the Lower Arm and Oaks Arm. The possible sources of variation that may be responsible for this variability in cyanotoxin concentrations are:

(i) *Variability in cyanobacterial bioma*ss. A higher biomass of cyanotoxin producers may result in higher toxin concentrations. Indeed, the cyanobacterial biomass was usually lower in the Upper Arm as compared to the Lower Arm and Oaks Arm. The growth of cyanobacteria can be influenced by several environmental drivers in lakes that have not been identified and previous studies have pointed out the influence of prominent winds on the accumulation of cyanobacteria in the Lower Arm and Oaks Arm (Richerson 1994).

(ii) *Physiological variability*. Cyanotoxin production is affected by several environmental factors (nutrient availability, light conditions, and temperature) as demonstrated by controlled laboratory experiments. We did not observe any significant correlations between cyanotoxin concentrations and nutrient concentrations. The lack of significant correlation might be related to a low amount of samples presenting detectable levels of toxins.

(iii) *Variability in cyanobacterial species and genotype composition.* The cellular content and diversity of cyanotoxins vary among species and even among different genotypes within the same species. As a result, changes in the species composition of cyanobacteria, and also changes in genotype composition within the same species may lead to fluctuations in cyanotoxin concentration. During Summer 2011, we will collect samples for molecular analysis in the attempt to identify the potentially harmful cyanobacterial strains as well as to determine their toxigenicity (presence/absence of toxic genes).

Because toxins concentrations vary greatly on a spatiotemporal scale, we also monitored the cyanotoxins using the SPATT (Solid Phase Adsorption Toxins Tracking) methodology which is a modification of a method originally developed for marine lipophilic toxins by Dr Kudela (UCSC) for continuous toxin tracking by passively absorbing dissolved toxins from the water column. SPATT devices were attached at buoys located at the continuous monitoring stations (maps). Unfortunately, we weren't able to attach the SPATT devices in the proximity of the surface and therefore, the results presented here are representative of deep (1-2 m) rather than sub-/surface (0.1-0.2m) waters. SPATT samples were analyzed for microcystin and anatoxin-a detection using LC/MS as described above and the daily cyanotoxin production was computed (Table 2). Microcystis LA was the most abundant variant at the SPATT depth although it wasn't detected in the discrete surface water samples. No anatoxin-a toxin were detected in the SPATT. These results confirms the spatio-temporal heterogeneity of the cyanotoxins concentration and speciation, not only horizontally (e.g. between stations) but also with depth. It could be possible that cyanobacteria from the mat might be producing different toxins than the cyanobacteria growing in the water column. Another hypothesis would be that discrete samples collected at a given time may not representative of the cyanotoxin cocktail due to the influence of mixing (winds, currents) while SPATT integrate these variations. We will attempt to maintain the SPATT devices in the surface of the the water column next summer to allow a better comparison between the continuous toxin measurements and the discrete toxins measurements.

Conclusion

Based on our results, it doesn't appear that there is any significant recreational toxin exposure risks in Clear Lake surface waters. However, the microcystins levels measured during Summer 2010 were several orders of magnitude higher than that reported for the same stations for Summer 1990 (ODWSESP 1991). More research is needed to determine if the cyanotoxin level increase between the two studies is a real trend or if the discrepancies are related to the technologies used ("old" ELISA kits and mouse assay vs. "newer" ELISA kits and LC/MS).
This study also indicate that more that Clear Lake might be a cyanotoxin cocktail (microcystin, anatoxin-a and maybe other cyanotoxins). Indeed, the only toxicology report available for Clear Lake was focusing on Microcystin toxins only (ODWSESP 1991). Our future efforts will focus on expanding the range of monitored toxins in order to gain a more comprehensive understanding of this system.

Table 2:
Clear Lake SPATT samples

Analysis: LC/MS

Column: Zorbax Rapid-Resolution HT

Extraction: 50% MeOH

Analyzed For: MCY-LR, MCY-RR, MCY-YR, MCY-LA, Anatoxin-a

	--------------------------ppb in extract----------------------------						--------------------------ng / g / day ----------------------------						
Sample	[MCY-RR]	[MCY-LR]	[MCY-YR]	[MCY-LA]	[ANA-A]	Extract Vol	Duration (days)	[MCY-RR]	[MCY-LR]	[MCY-YR]	[MCY-LA]	[ANA-A]	
CL072210.1	1.36	4.99	0	13.88	0	10	30	0.15	0.55	0.00	1.54		0.00
CL072210.2	0.98	5.24	0	12.29	0	10	30	0.11	0.58	0.00	1.37		0.00
CL072210.3	0	6.03	0	30.61	0	10	30	0.00	0.67	0.00	3.40		0.00
CL072210.4	0	0	0	12.52	0	10	30	0.00	0.00	0.00	1.39		0.00
CL081601.1	0	5.71	0	14.79	0	10	30	0.00	0.63	0.00	1.64		0.00
CL081601.2	0	0	0	10.1	0	10	30	0.00	0.00	0.00	1.12		0.00
CL081601.3	3.13	5.52	0	20.64	0	10	30	0.35	0.61	0.00	2.29		0.00
CL081601.4	0	3.97	0	22.5	0	10	30	0.00	0.44	0.00	2.50		0.00

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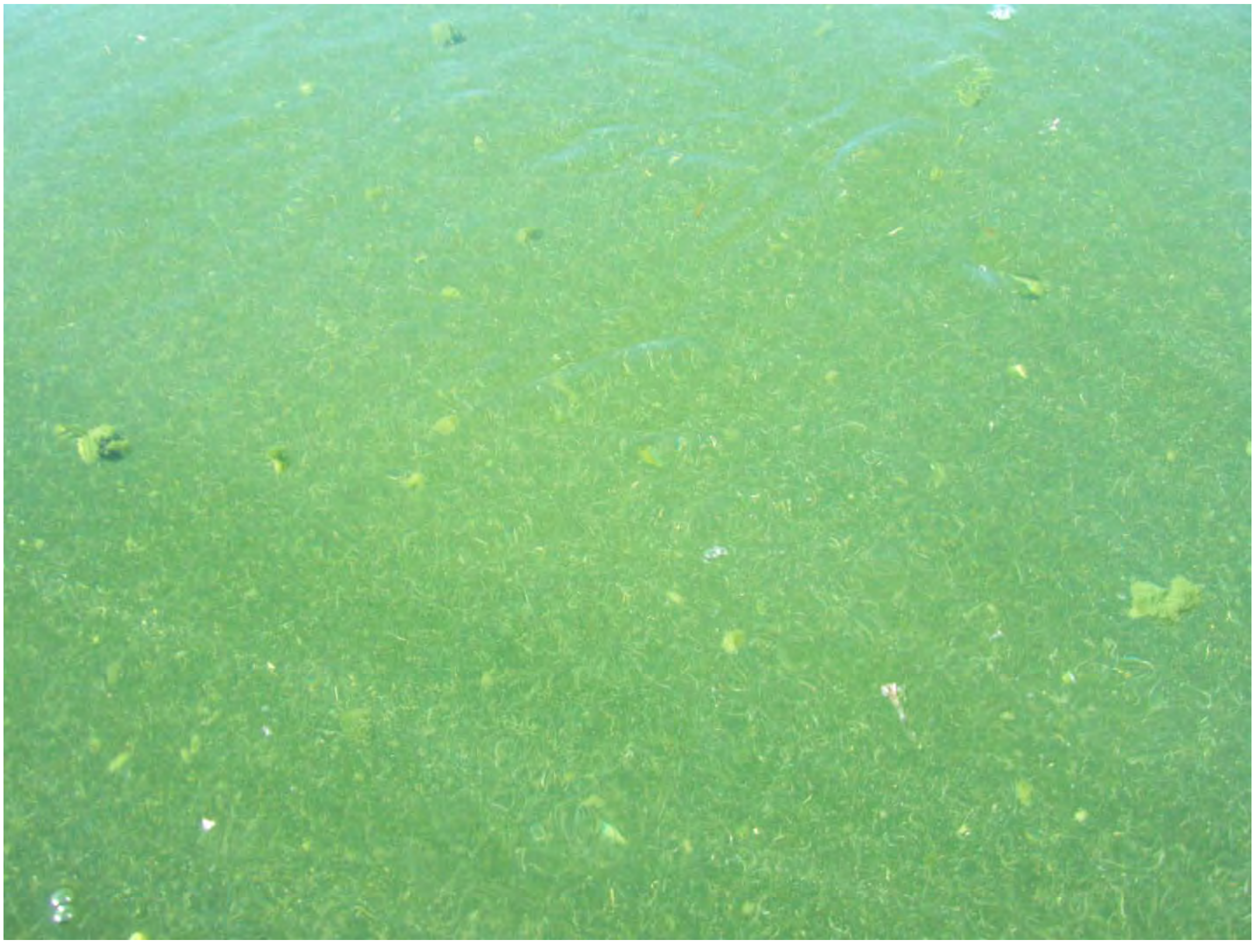
APPENDIX

Clear Lake - June 2010



Picture of cyanobacteria growth observed in the surface water of the Lower Arm of Clear Lake (June 2010). The filamentous cyanobacteria were *Anabaena sp*., *Aphanizomenon sp*. and *Lyngbya Cincinnati* (*Phormidium cincinnatum*). Some macrocolonies can be seen floating in surface. Other potentially harmful cyanobacteria such as *Microcystis spp*. were also present but not as these filamentous cyanobacteria. *Picture: Cécile Mioni*

Clear Lake – July 2010

Lyngbya cincinnati was the dominating cyanobacteria present in the mat in the Lower Arm.

Some clumps were rotting in the surface of the lake, releasing some fool odor.

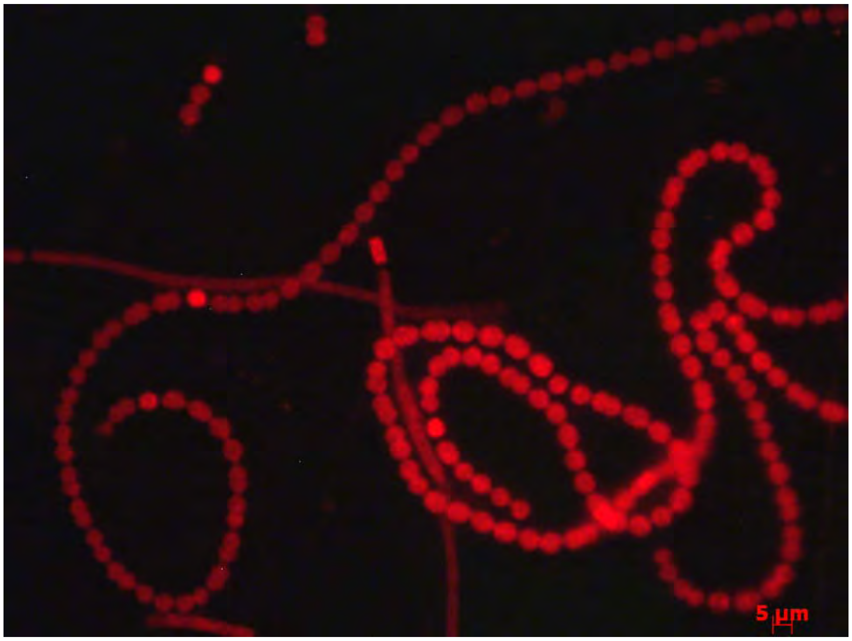
Picture: Cécile Mioni

Horseshoe bend cyanobacterial scum/mat was dominated by *Anabaena* and *Lyngbya.*

We saw a couple of dead fish but we did not investigate the cause of death.

Picture: Cécile Mioni

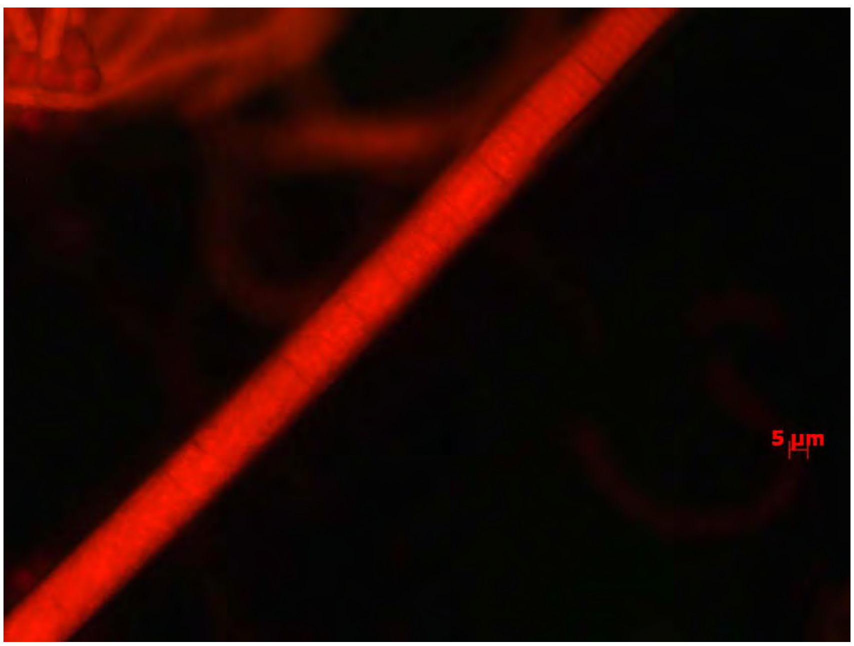
Selected micrographs (epifluorescence microscopy) of Clear Lake samples



Heterocystous *Anabaena spiroides* and *Aphanizomenon sp*.

Oaks Arm sample, station 4 (June 23, 2010)

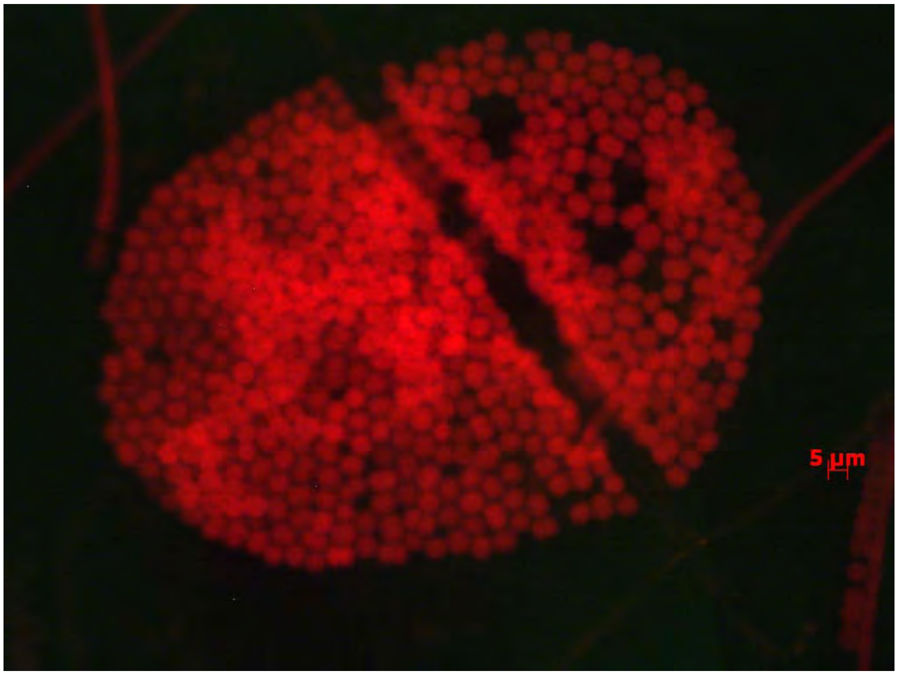
Picture: Cécile Mioni



One *Lyngbya cincinnati* filament (*Gleotrichia* filaments can also be seen on the top left corner of the image and a blurry *Anabaena* spiroides filament can be seen right by the scale).

Oaks Arm sample, station 4 (June 23, 2010)

Picture: Cécile Mioni



One *Microcystis aeruginosa* colony

Oaks Arm sample, station 4

(June 23, 2010)

Picture: Cécile Mioni

SWAMP 2011 monitoring in Clear Lake & San Francisco Bay/Delta
June 2011 Summary Report

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The following summary report describes the initial field observations and a summary of the initial results from the first month (June 2011) of the SWAMP-funded monitoring of blue-green algae bloom and their toxicity in Clear lake and the San Joaquin Delta. The main goal of this study is the assessment of the toxicity of the cyanobacteria in Clear Lake and the San Francisco Bay/Delta. Investigators from the Lake County Water Resources Department, the California of Water Resources and the University of California, Santa Cruz all redirected efforts to gather samples, carry out assays, and/or interpret results in agreement with our scope of work and the QAPP. Additionally, extra taxonomy samples (2) and a toxin sample (1) were collected by Lake County Water Resources Department in Clear Lake on June 23, 2011 to investigate a bloom event that occurred in the Lower Arm (near Station 513LAK004) shortly after our scheduled SWAMP sampling event took place (June 16, 2011). These extra samples were collected and will be processed with respect to the QAPP SOPs.

San Francisco Bay/Delta –

Surface water samples were collected at the sampling stations of the San Francisco Bay/Delta with the assistance of the Environmental Monitoring Program of the California Department of Water Resource on June 6 (SWAMP stations 544CCC001, 544CCC003 and 544CCC004) and June 7 of 2011 (SWAMP stations 544SAC004 and 544SJC010) on board of the R/V San Carlos. These sampling events occurred after a series of late Spring storms. The surface water temperatures at the sampling stations were 16.8°C in average (from 16.1 to 17.8°C). These surface water temperatures were lower than that observed at the same time of year in previous years and might explain the absence of *Microcystis aeruginosa* at the sampling sites. Indeed, compiled evidence gathered from the literature as well as from our past monitoring programs in the Delta suggest that *M. aeruginosa* blooms initiate at surface water temperatures greater than 20°C (Lehman et al. 2008). The mean dissolved inorganic nitrogen and orthophosphate were greater in the Delta than in Clear Lake and were not limiting. Chlorophyll *a* levels were low, averaging 1.81µg/L and spanning from 0.85 µg/L at station 544SJC010 to 2.38 µg/L at station 544CCC001. Taxonomy/cell enumeration samples were processed at UCSC using epifluorescence microscopy. No *M. aeruginosa* cells or colonies were observed in these samples reflecting pre-bloom conditions. The toxicology analysis of the water samples collected for cyanotoxin assessment is in progress. Solid Phase Adsorption Toxin Tracking (SPATT) resins were deployed on June 16 at the continuous EMP/DWR monitoring stations and will be retrieved mid-July. This continuous toxin tracking device will enable to detect if a toxic bloom occurred after this June sampling event.

Clear Lake –

Surface water samples were collected in Clear Lake on June 16, 2011 with the assistance of the Lake County Water Resources Department at the stations 513LAK001, 513LAK002, 513LAK003, 513LAK004, 513LAK005, 513LAK006, and 513LAK007. Observations from the field indicate that a cyanobacteria bloom was initiating in the lower arm as well as in horseshoe bend and in Oaks arm. The highest cyanobacterial biomass was observed in the lower arm. No mat or scum were observed on June 16, 2011 and the biomass was lower than that observed in June 2010. Strong wind conditions might have contributed to dispersal.

Based on our field observations the cyanobacterial assemblage was dominated by filamentous cyanobacteria and *Gloeotrichia* colonies. Microscopic enumeration/taxonomy analyses of the samples are in progress. Samples analyzed to date at UCSC indicate the presence of four filamentous cyanobacteria: *Gloeotrichia* (figure 1A), *Aphanizomenon sp.* (figure 1B), *Anabaena sp*. (figure 1C) and *Lyngbya cincinnati* (figure 1D). *Gloeotrichia*, *Aphanizomenon sp*. and *Anabaena sp*. were the most abundant filamentous cyanobacteria in the assemblage at all stations. *Lyngbya cincinnati* was not present at all station processed to date and when present, its contribution to the cyanobacterial assemblage was rare (<1 %). Among the samples examined so far, *Microcystis aeruginosa* was only detected in the lower arm (station 513LAK004). *Microcystis aeruginosa* is a known producer of the hepatoxin microcystin. Interestingly, we observed filamentous cyanobacteria (*Pseudanabaena*?) associated with *Microcystis aeruginosa* colonies at this station (figure 2). Similar consortia were observed in the Delta in 2008 and 2009 at stations displaying elevated microcystin levels. *Gloeotrichia* and *Aphanizomenon* can produce a series of cyanotoxins, including the hepatototoxin microcystin toxins. We are hoping to identify this associated filamentous cyanobacterium with the assistance of the taxonomists from EcoAnalyst, Inc. *Aphanizomenon* can also produce the hepatotoxin cylindrospermopsin and the neurotoxin saxitoxin. *Anabaena* can produce the neurotoxin anatoxin-a and some *Lyngbya* strains produce dermatoxins (skin irritant) including aplysiatoxin and Lyngbyatoxin-a. Toxicology assessments are in progress and the presence of these toxins is being investigated. The dominance of filamentous cyanobacteria in Clear Lake could be explained by their ability to alleviate nitrogen limitation by N_2 fixation while *Microcystis* (a non nitrogen fixer) is dependent on combined N sources. Indeed, dissolved inorganic nitrogen levels were significantly lower in Clear Lake than in the Delta and the nitrate+nitrite levels were near the limit of detection. Moreover, filaments of *Gloeotrichia*, *Aphanizomenon* and *Anabaena* with heterocysts (specialized cells for N_2 fixation) were observed at all stations processed to date. These observations provide strong evidence that these filamentous cyanobacteria are actively fixing N_2.

Chlorophyll *a* levels on June 16, 2011 were globally higher than that observed in the Delta, averaging 11.54 µg/L (Table 1). The lowest Chl *a* level were observed at the upper arm stations (Station 513LAK001: 1.63 µg/L, Station 513LAK002: 2.91) and the highest Chl *a* levels were observed in the Lower Arm at station 513LAK005. Preliminary analysis of the data collected in Clear Lake on June 16, 2011 suggest that there was a significant direct correlation between Chl *a* levels and orthophosphates ($R= 0.8164$, $R^2 = 0.6664$, figure 3) and ammonium ($R = 0.7686$, $R^2 = 0.5908$, figure 3D). Nitrate+Nitrite levels were extremely low. The Chl *a* levels appear to be negatively correlated with secchi depths (figure 3B). The highest phytoplankton biomass coincided with the highest Electrical Conductivity (EC, figure 3C). Surface water temperatures were significantly higher in Clear Lake than in the Delta, averaging 23.3°C, and therefore within the optimal range of temperature for cyanobacteria growth (Table 1). No significant correlations were observed however between surface water temperature and Chl *a* (figure 3A).

A massive mat-forming bloom event occurred in the Lower Arm 4 days after our sampling event (June 20, 2011) just northwest of station 513LAK004 (figure 4). In order to investigate this cyanobacterial bloom, extra surface water samples for taxonomy/enumeration and toxicology assessment were collected by Lake County at station 513LAK004 on June 23, 2011. However, this extra sampling event took place under strong winds conditions and no mats were evident at the time of sampling (figure 5). These strong winds might have dispersed the mats. Field observations suggest that the cyanobacteria assemblage was dominated by filamentous cyanobacteria. Microscopic taxonomy/enumeration as well as toxicology analysis of these extra samples are in progress.

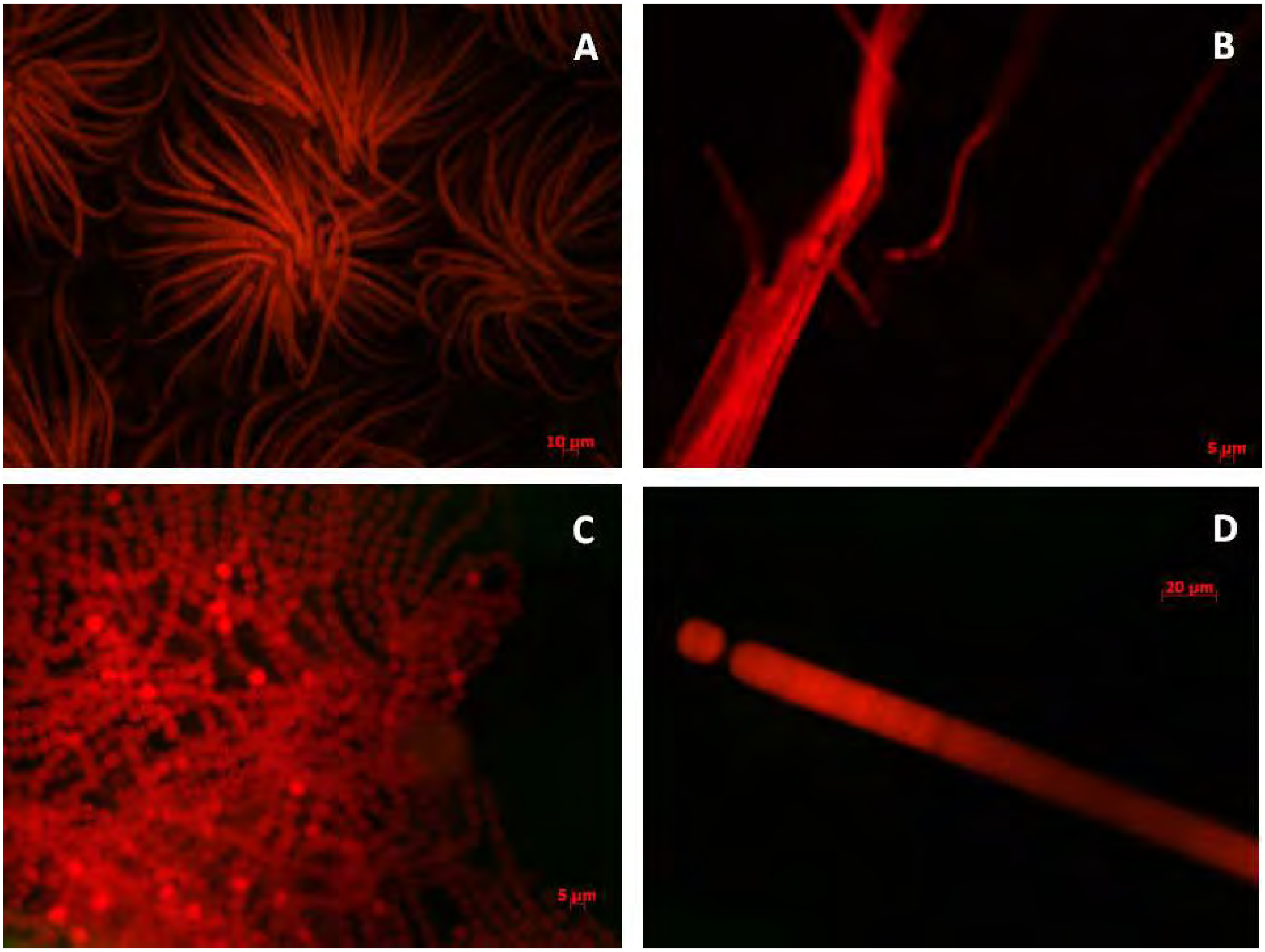

Figure 1: Micrographs of filamentous cyanobacteria observed in Clear Lake samples collected on June 16, 2011: A. *Gloeotrichia sp*., B. *Aphanizomenon sp*., C. *Anabaena sp*., D. *Lyngbya cincinnati*. Surface water samples (50 mL each) were collected for enumeration/taxonomy analysis of the cyanobacteria assemblage by epifluorescence microscopy (UCSC). Samples were fixed with 2.5% (v/v) glutaraldehyde and filtered through 1-µm pore size, 25-mm diameter, black polycarbonate filters (GE Osmonics). The abundance of autofluorescing phycoerythrin containing cells (aka cyanobacteria) was determined on a Zeiss Axioplan epifluorescence microscope using green excitation (Zeiss filter set 20, excitation 546-nm bandpass, and emission 575–640-nm bandpass filters).

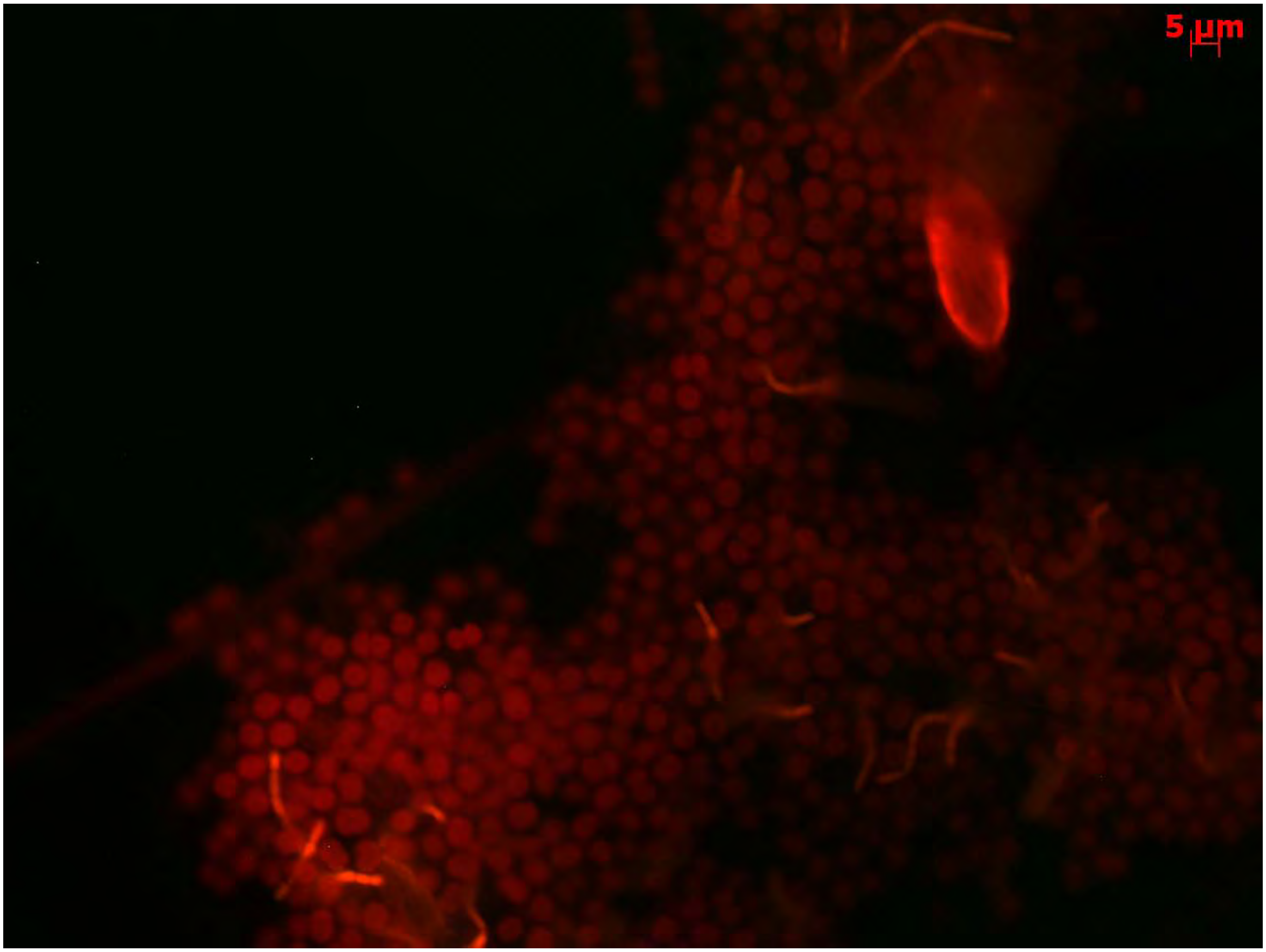

Figure 2: Micrograph of Microcystis aeruginosa colonies observed in Clear Lake sample collected on June 16, 2011 at station 513LAK004. Association with a filamentous cyanobacterium (possibly *Pseudanabaena*) can be seen on this micrograph. Surface water samples (50 mL each) were collected for enumeration/taxonomy analysis of the cyanobacteria assemblage by epifluorescence microscopy (UCSC). Samples were fixed with 2.5% (v/v) glutaraldehyde and filtered through 1-µm pore size, 25-mm diameter, black polycarbonate filters (GE Osmonics). The abundance of autofluorescing phycoerythrin containing cells (aka cyanobacteria) was determined on a Zeiss Axioplan epifluorescence microscope using green excitation (Zeiss filter set 20, excitation 546-nm bandpass, and emission 575–640-nm bandpass filters) with a x40 objective.

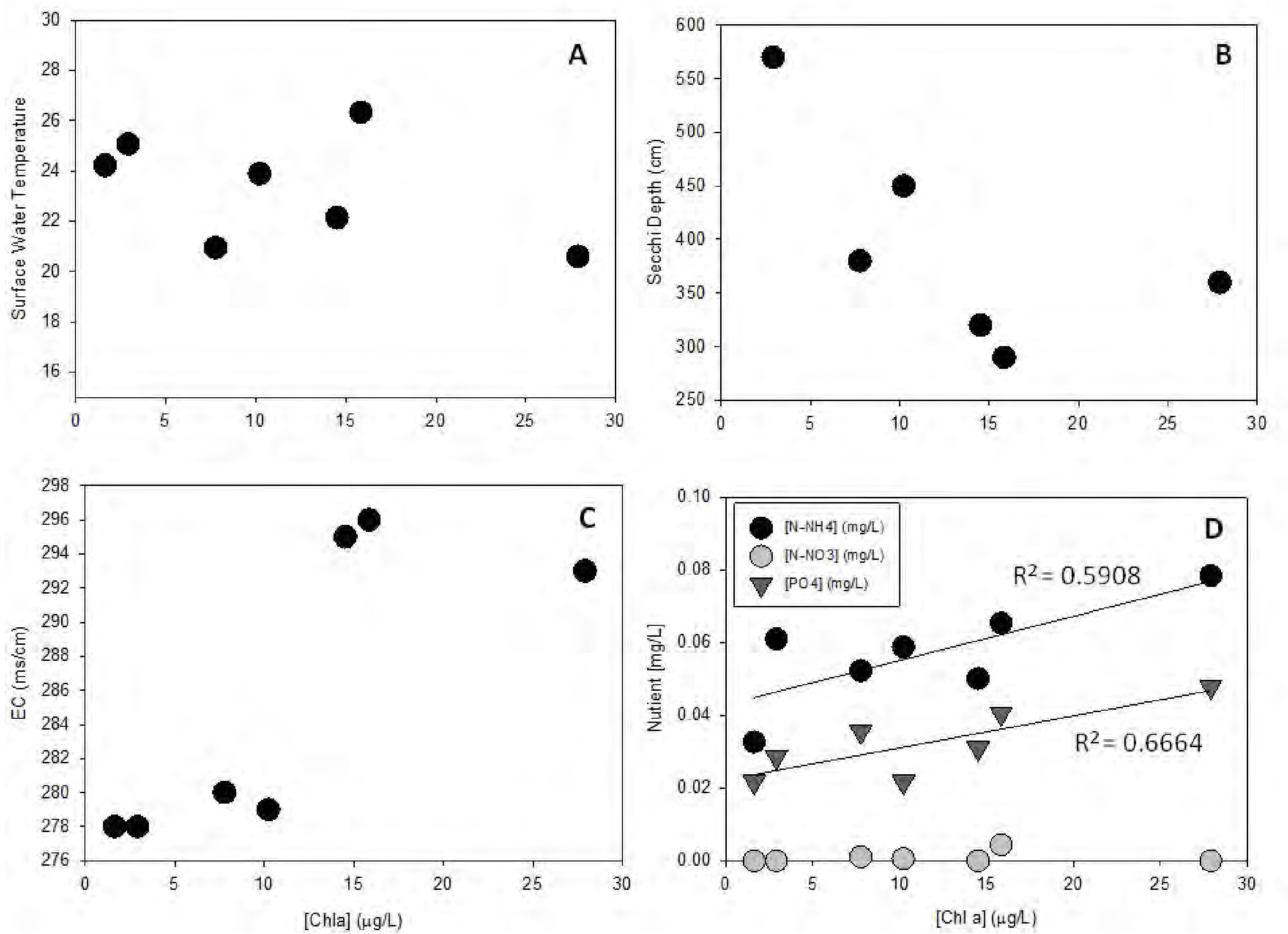

Figure 3: Correlations between Chlorophyll a concentrations and some key water quality variables observed in surface water samples from Clear Lake (June 16, 2011). A: Temperature, B. Secchi Depth, C. EC, D. Dissolved inorganic nutrients.

Figure 4. Picture of the cyanobacteria bloom located northwest of station 513LAK004 (lower arm, Manakee cove, near Clearlake) as observed on June 20, 2011 (credit: Samir Tuma, Kila properties). Cyanobacteria mats can be observed in surface.

Figure 5. Picture of the cyanobacteria bloom located at Redbud park, south of station 513LAK004 (Manakee cove, lower arm, near Clearlake) as observed during the sample collection on June 23, 2011. Strong winds dispersed the newly formed mats before the sampling event took place (credit: Tom Smythe).

Table 1. Water quality variables in Clear Lake in June 2011.

Date	Station ID	Temperature	pH	DO (mg/L)	DO (%)	EC (ms/cm)	Secchi (cm)	[N-NH4] (mg/L)	[N-NO3] (mg/L)	[N-NO2] (mg/L)	[PO4] (mg/L)	NH4/P	[DOC] (uM)	[Chla] (mg/L)
6/16/2011	513LAK001	24.22	8.25	6.05	72.3	278	>390	0.033	0.000	0.000	0.022	1.507	273.79	1.63
6/16/2011	513LAK002	25.07	8.33	7.41	89.9	278	570	0.061	0.000	0.000	0.029	2.133	269.09	2.91
6/16/2011	513LAK002							0.057	0.000	0.000	0.028	1.996		
6/16/2011	513LAK003	23.89	8.24	7.38	87.7	279	450	0.059	0.001	0.000	0.022	2.713	269.49	10.22
6/16/2011	513LAK004	26.33	8.08		94.2	296	290	0.065	0.004	0.000	0.040	1.613	297.39	15.84
6/16/2011	513LAL005	20.6	8.21	10.1	113	293	360	0.078	0.000	0.000	0.048	1.637	276.79	27.89
6/16/2011	513LAK006	22.14	8.13	7.58	87	295	320	0.050	0.000	0.000	0.031	1.617	270.49	14.51
6/16/2011	513LAK007	20.95	8.27	10.25	115	280	380	0.052	0.001	0.000	0.035	1.472	274.49	7.77