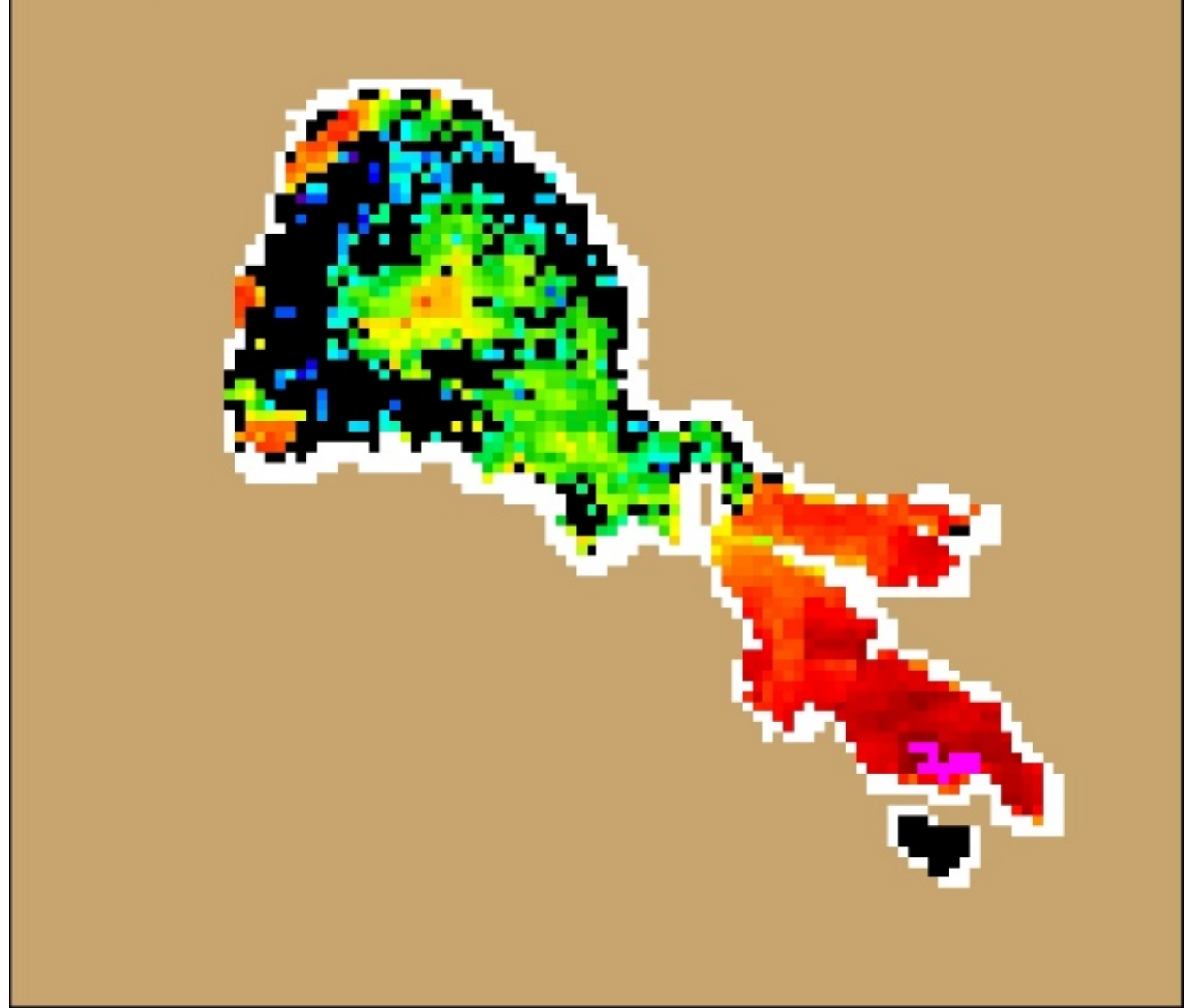# Use of Satellites to Examine Cyanobacteria in California's Large Waterbodies

Randy Turner

San Francisco Estuary Institute

Background

- Cyanobacteria can grow in a diverse range of environments

- Given adequate light and nutrients, cyanobacterial Harmful Algal Blooms (cyanoHABs) can negatively affect aquatic life.

- Some species produce toxins

- SWAMP contracted with SFEI to: Process, analyze and report on satellite imagery provided by NOAA to better understand risks to public health from cyanoHABs
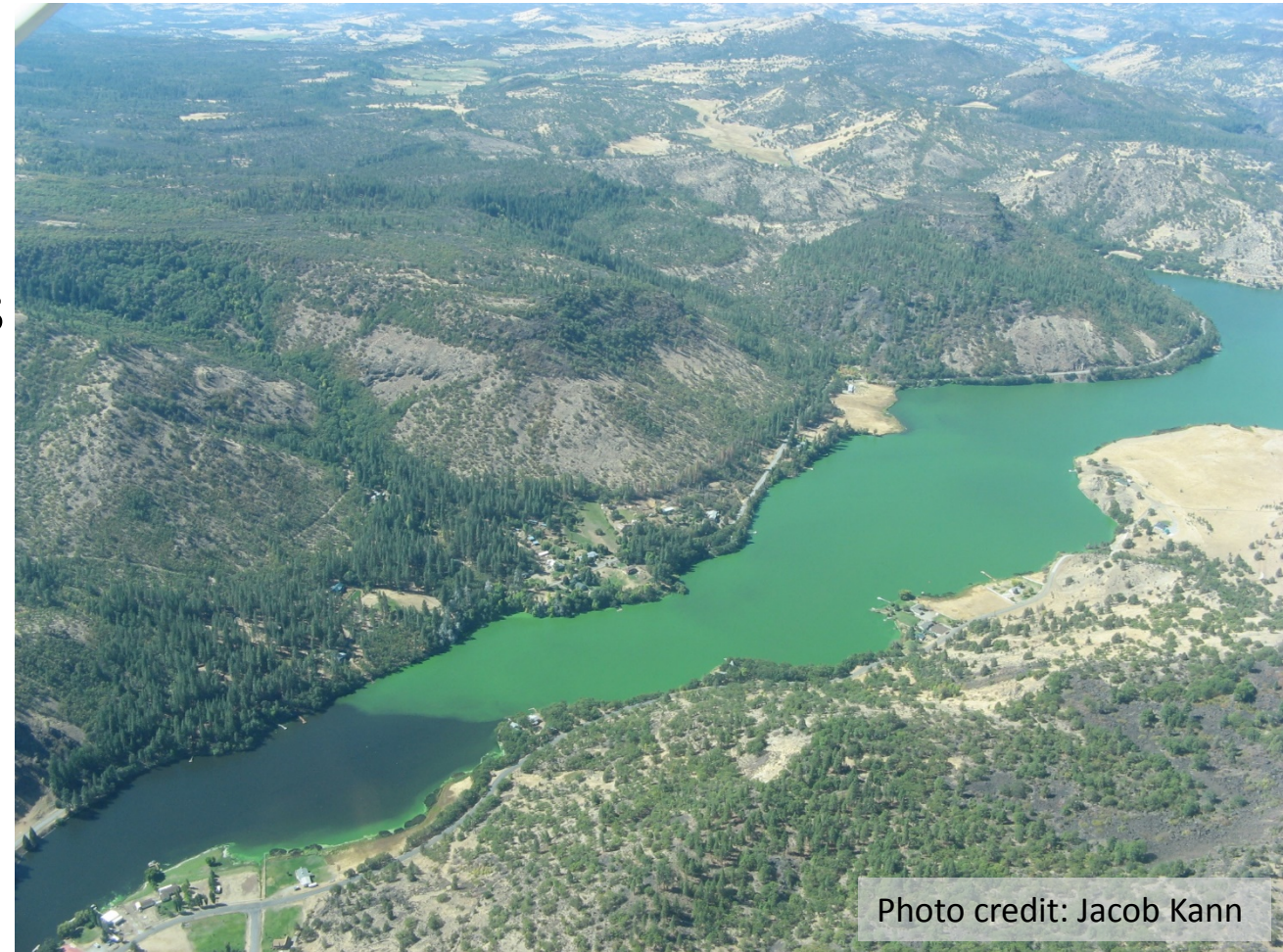

Photo credit: Jacob Kann

Contract with SWAMP

- Develop infrastructure for processing satellite imagery
- Historic Data
  - Analyze MERIS satellite data for 255 waterbodies (2002-2012)
  - Status and Trends report
- Future Data
  - Analyze data from OLCI on Sentinel-3 satellite (launched Feb. 2016)
- Reporting
  - Create web portal for viewing imagery and related data
  - Inform waterbody managers when bloom conditions occur
  - Issue regular bulletins and newsletters to public

Satellite Basics

- Flyover every few days
  - Swath 1,150 km wide
- Spatial resolution is 300m x 300m (per pixel)
- Satellite analyzes light absorption signature in each pixel at key spectral bands
- Can estimate concentrations separately for:
  - Total algal biomass
  - **Cyanobacteria**
  - Non-cyanobacteria
- All cyanobacteria
- Not toxins

225 meters
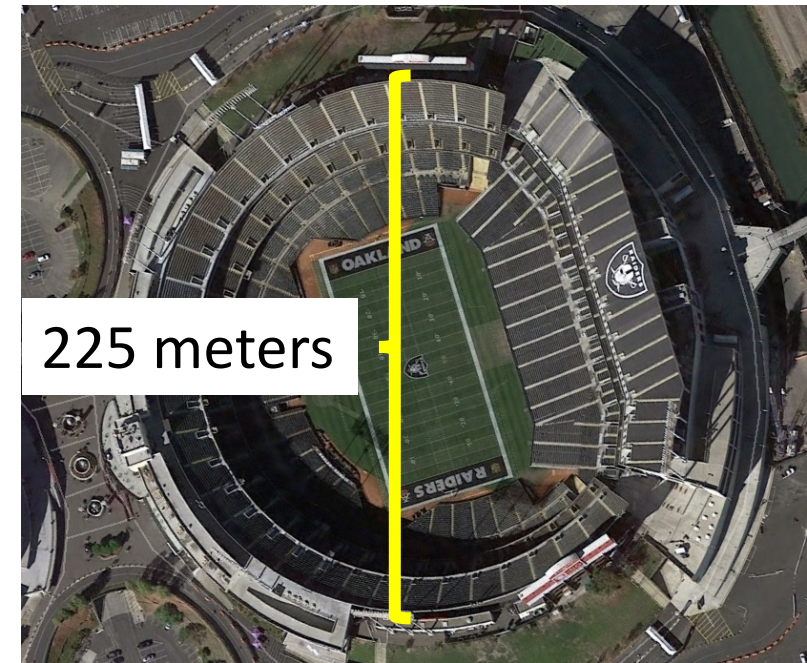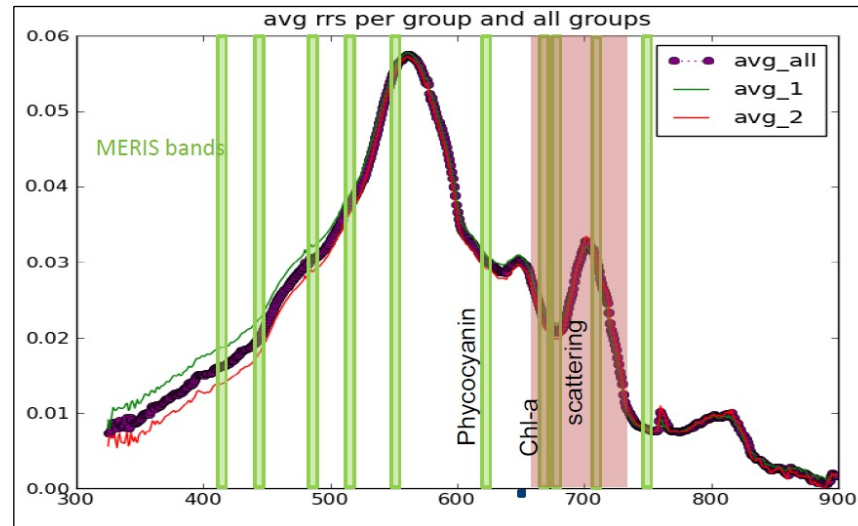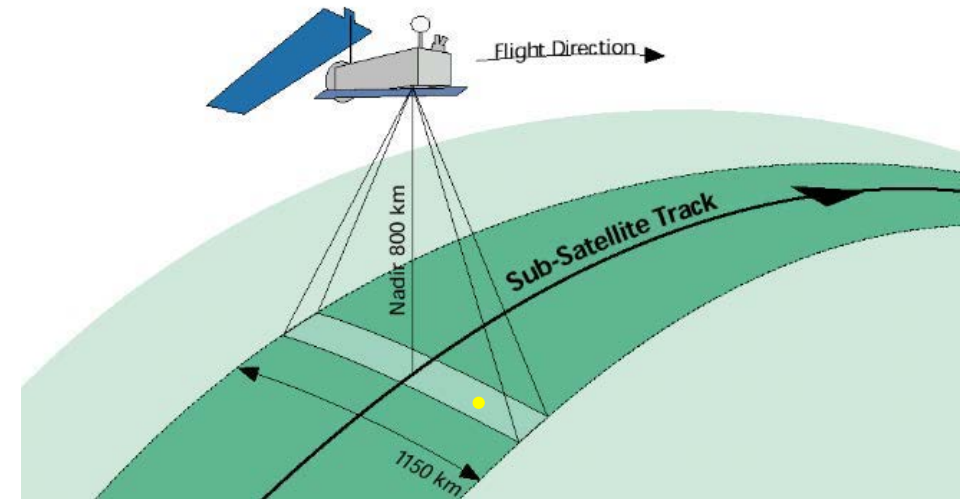
Satellite Basics

- Each pixel assigned a value of N (1-249)

- Wind, clouds, etc. impact blooms

- Generate 10 day max composite
  - testing monthly composites also…
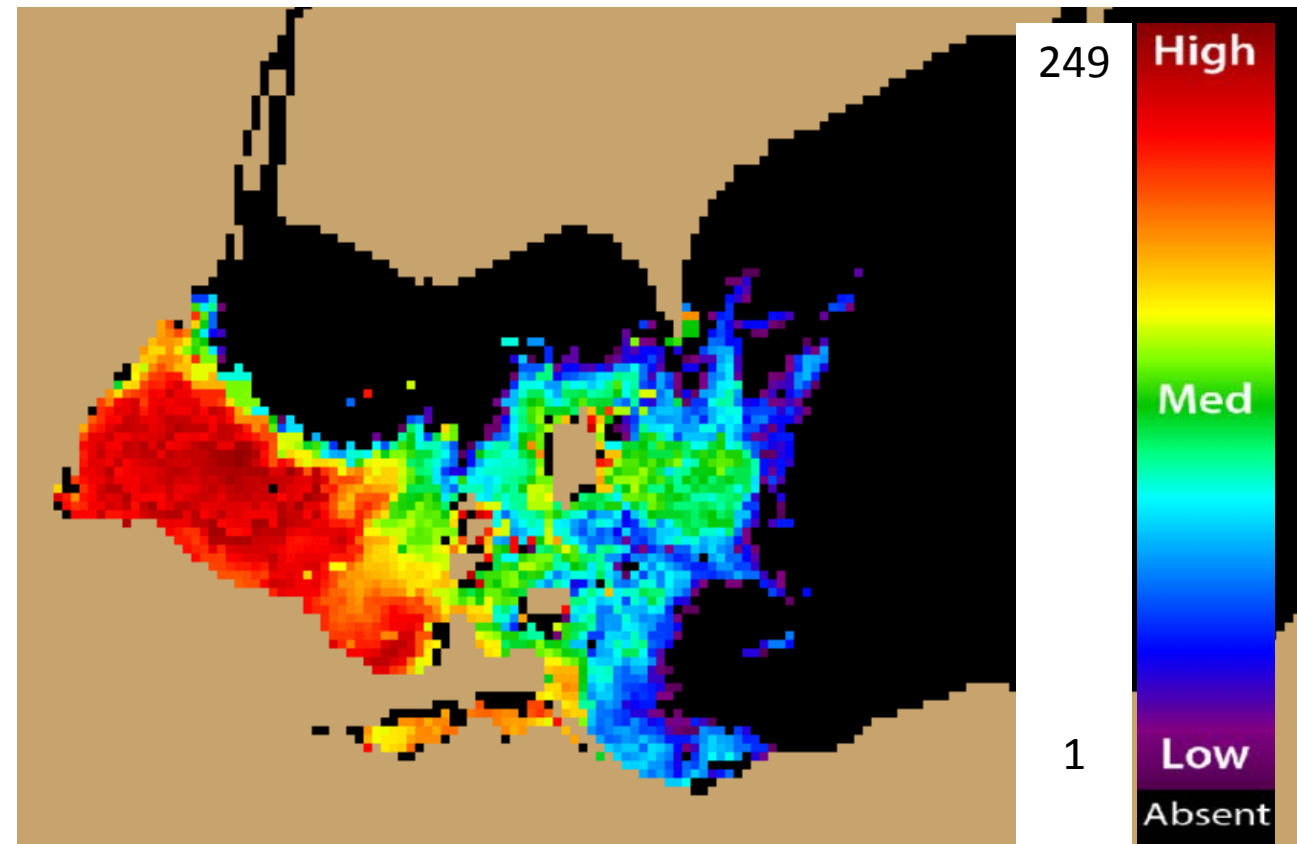
Data Processing

- Review all scenes for previous 10 days

- For each pixel location, determine maximum value

- Generate running 10 day max composites

6/30/2009

7/2/2009

7/4/2009

7/5/2009

7/6/2009

7/8/2009

7/9/2009

10 Day Max Composite
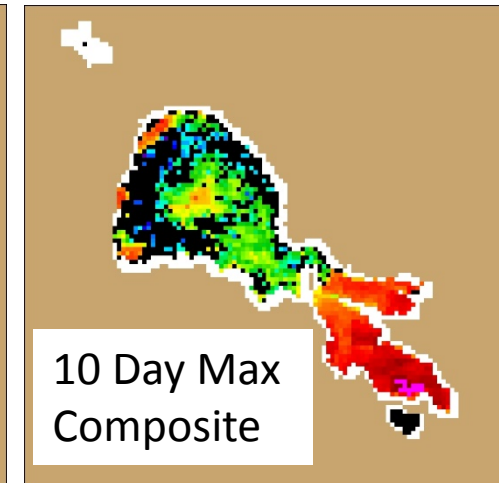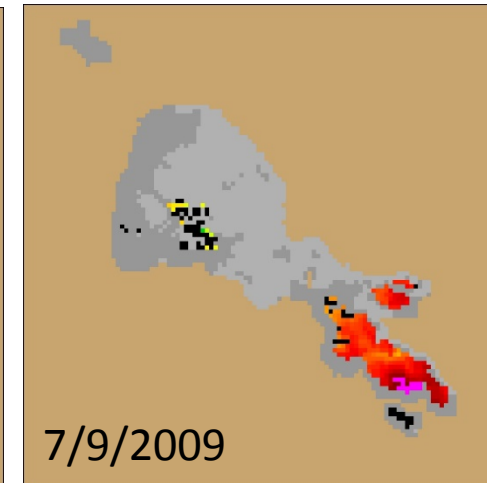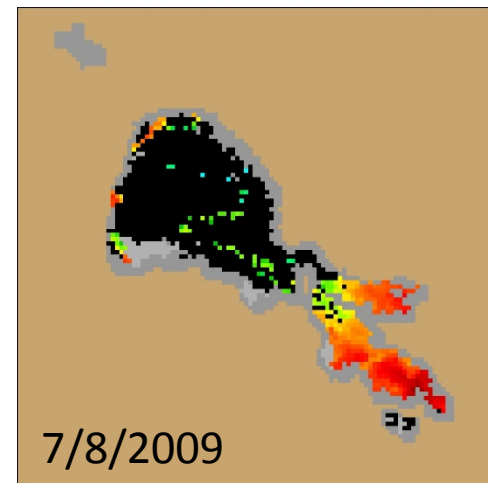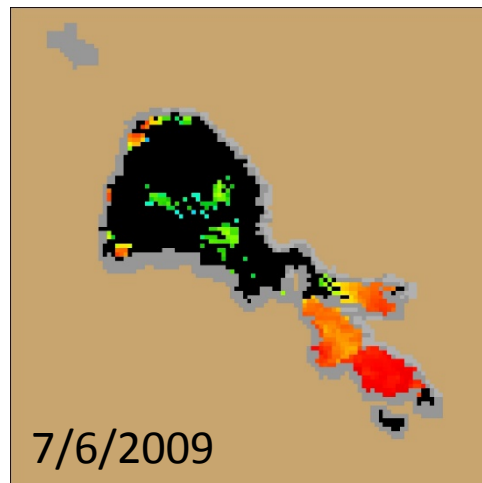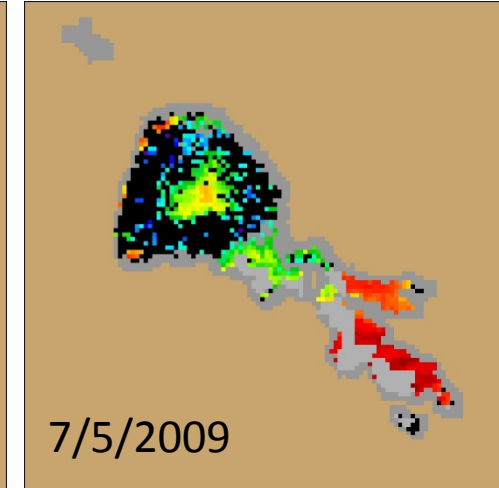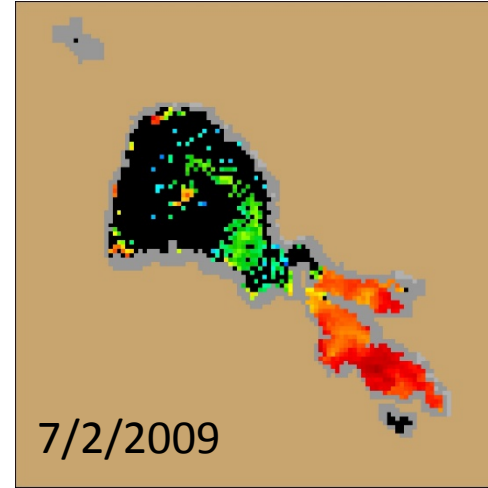
Generate Statistics

- Valid composites need >17 pixels
  - NOAA recommended

- Estimate concentration in:
  - Cyanobacterial Index (CI)
  - Chlorophyll-a (ug/L)
  - **Microcystis sp. (cells/mL)**

- From each 10 day max composite, generate waterbody-wide estimates for:
  - Mean
  - Median
  - **90th percentile of max**
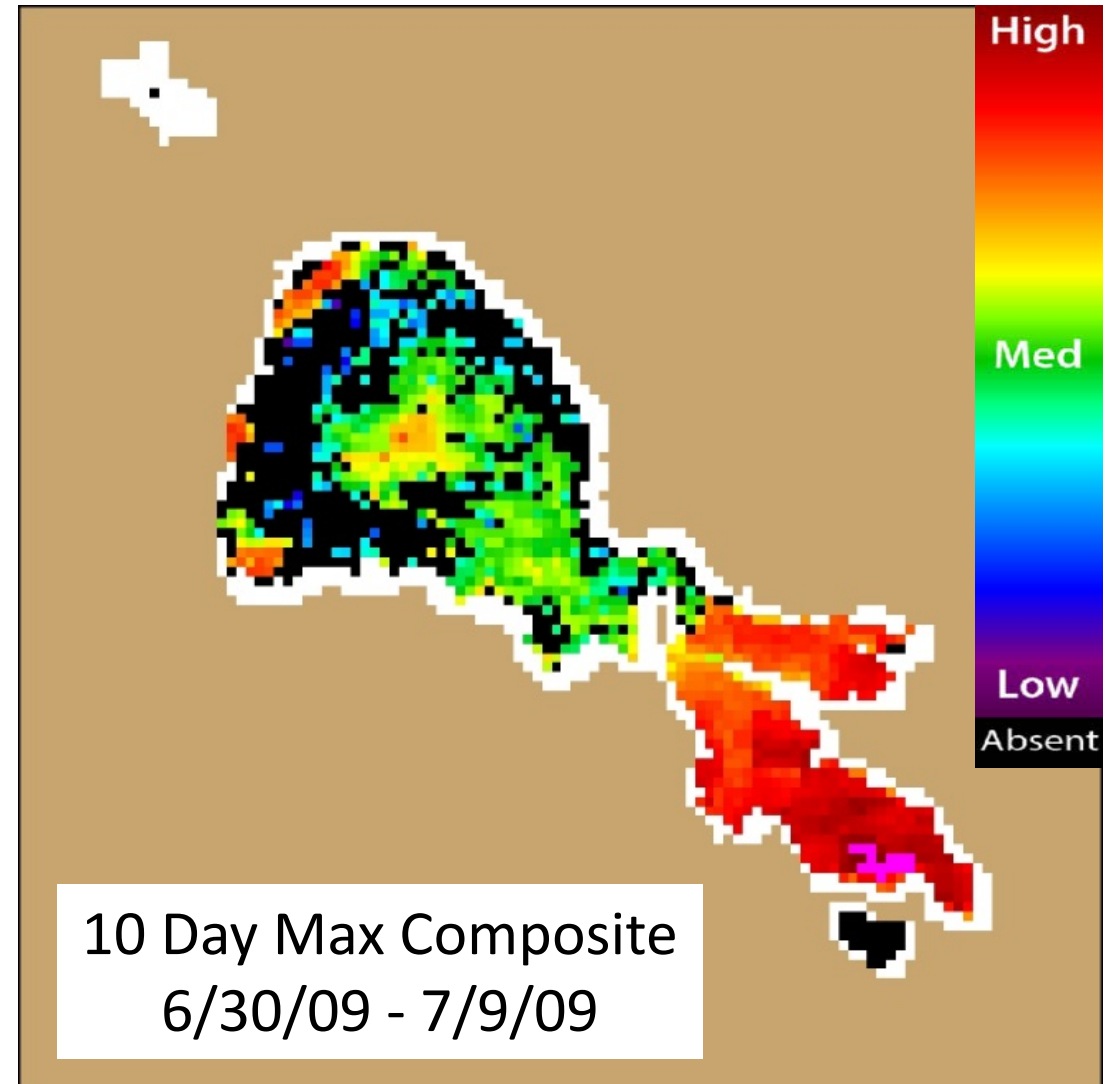
10 Day Max Composite
6/30/09 - 7/9/09

Generate Statistics

| | | | Cyano Mean | Cyano Median | Cyano 90th % |
| | | | >17 | >17 | >17 |
start_date	end_date	Pixels	MC (cells/mL)	MC (cells/mL)	MC (cells/mL)
6/22/2009	7/1/2009	1757	109,648	131,826	1,995,262
6/23/2009	7/2/2009	1779	123,027	154,882	1,949,845
6/24/2009	7/3/2009	1739	109,648	134,896	1,949,845
6/25/2009	7/4/2009	1739	109,648	134,896	1,949,845
6/26/2009	7/5/2009	1721	134,896	181,970	1,778,279
6/27/2009	7/6/2009	1709	125,893	186,209	1,548,817
6/28/2009	7/7/2009	1709	125,893	186,209	1,548,817
6/29/2009	7/8/2009	1733	134,896	194,984	1,584,893
6/30/2009	7/9/2009	1721	**125,893**	**186,209**	**1,621,810**

- Mean and Median can underestimate public health risk

- 90th percentile value is region of high public health risk
  - Similar to event response grab samples

High

Med

Low

Absent

10 Day Max Composite
6/30/09 - 7/9/09

Thresholds

	Cyano Mean >17 MC (cells/mL)	Cyano Median >17 MC (cells/mL)	Cyano 90th % >17 MC (cells/mL)
start_date	end_date	Pixels			

start_date	end_date	Pixels	Cyano Mean >17 MC (cells/mL)	Cyano Median >17 MC (cells/mL)	Cyano 90th % >17 MC (cells/mL)
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6/30/2009	7/9/2009	1721	**125,893**	**186,209**	**1,621,810**

	Action Trigger	Warning TIER 1	Danger TIER 2
Primary Thresholds [a]			
Total Microcystins [b]	**0.8** µg/L	**6** µg/L	**20** µg/L
Anatoxin-a	**Detection [c]**	**20** µg/L	**90** µg/L
Cylindrospermopsin	**1** µg/L	**4** µg/L	**12** µg/L
Secondary Thresholds			
Cell Density (*Toxin producing cells*)	**4,000** cells/mL	--	--
Site Specific Indicators of Cyanobacteria	Blooms, scums, mats	--	--

Level	Value (cells/mL)
CA Action Trigger	4,000
Satellite 'background' level	~10,000

Thresholds

start_date	end_date	Pixels	Cyano Mean >17 MC (cells/mL)	Cyano Median >17 MC (cells/mL)	Cyano 90th % >17 MC (cells/mL)
6/22/2009	7/1/2009	1757	109,648	131,826	1,995,262
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Level	Value (cells/mL)
CA Action Trigger	4,000
Satellite 'background' level	~10,000
WHO Low Risk	**<20,000**
WHO Moderate Risk	**20,000-100,000**
WHO High Risk	**>100,000**

Thresholds

start_date	end_date	Pixels	Cyano Mean >17 MC (cells/mL)	Cyano Median >17 MC (cells/mL)	Cyano 90th % >17 MC (cells/mL)
6/22/2009	7/1/2009	1757	109,648	131,826	1,995,262
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Cell Density (*Toxin producing cells*)	**4,000** cells/mL	--	--
Site Specific Indicators of Cyanobacteria	Blooms, scums, mats	--	--

Level	Value (cells/mL)
CA Action Trigger	4,000
Satellite 'background' level	~10,000
WHO Low Risk	<20,000
WHO Moderate Risk	20,000-100,000
WHO High Risk	>100,000
'Very High Risk'	**>1,000,000**

Thresholds

start_date	end_date	Pixels	Cyano Mean >17 MC (cells/mL)	Cyano Median >17 MC (cells/mL)	Cyano 90th % >17 MC (cells/mL)
6/22/2009	7/1/2009	1757	109,648	131,826	1,995,262
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Secondary Thresholds				
Cell Density (*Toxin producing cells*)		**4,000** cells/mL	--	--
Site Specific Indicators of Cyanobacteria		Blooms, scums, mats	--	--

Understand Exceedance of 'thresholds'
- How often?
- How long?
- How many waterbodies?

Level	Value (cells/mL)
No Data	N/A
Low Risk	**10,232- 20,000**
Moderate Risk	**20,000-100,000**
High Risk	**100,000-1,000,000**
Very High Risk	**>1,000,000**

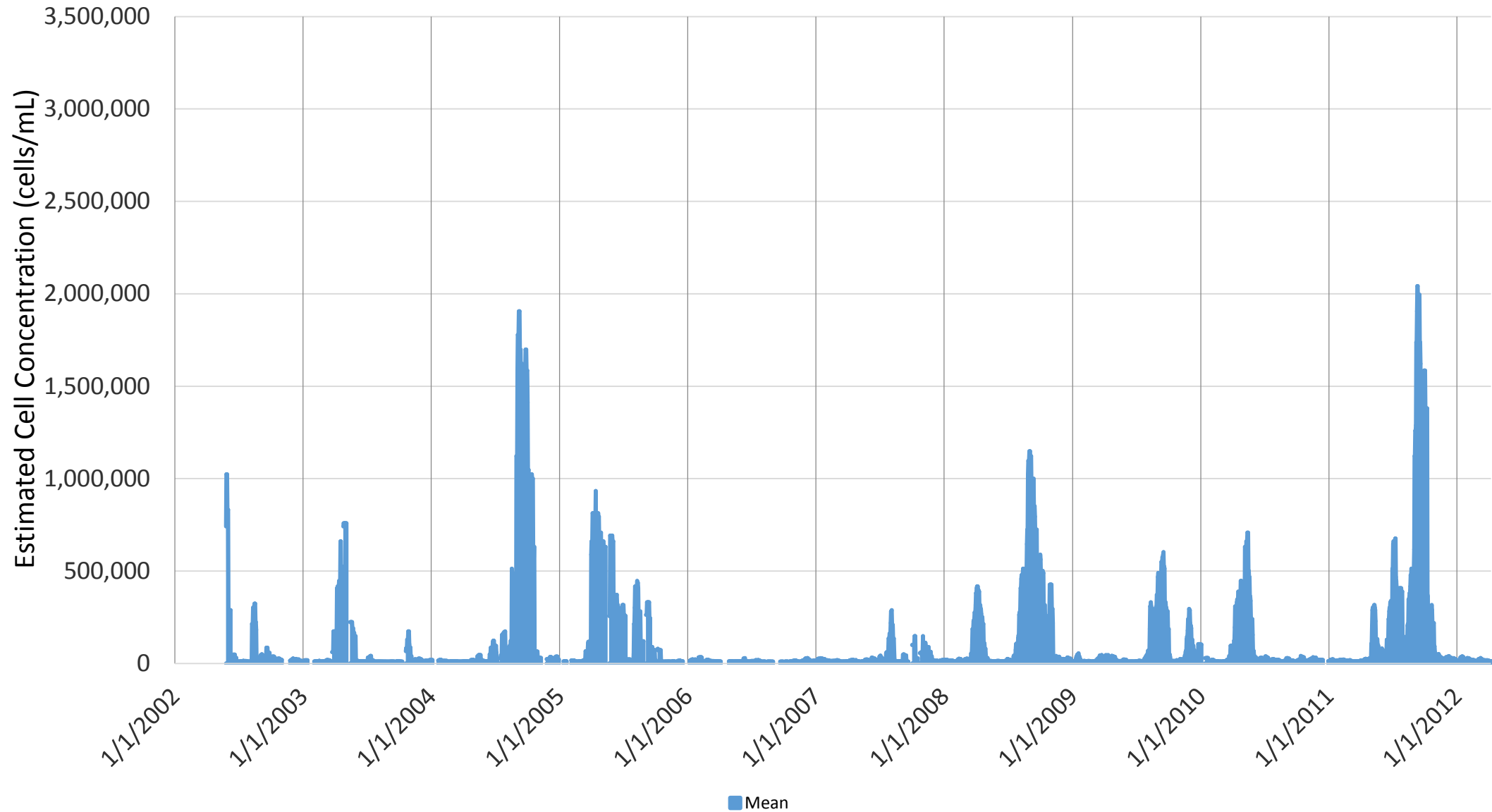# Historic Satellite Data for San Luis Reservoir

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All data is preliminary Please do not cite
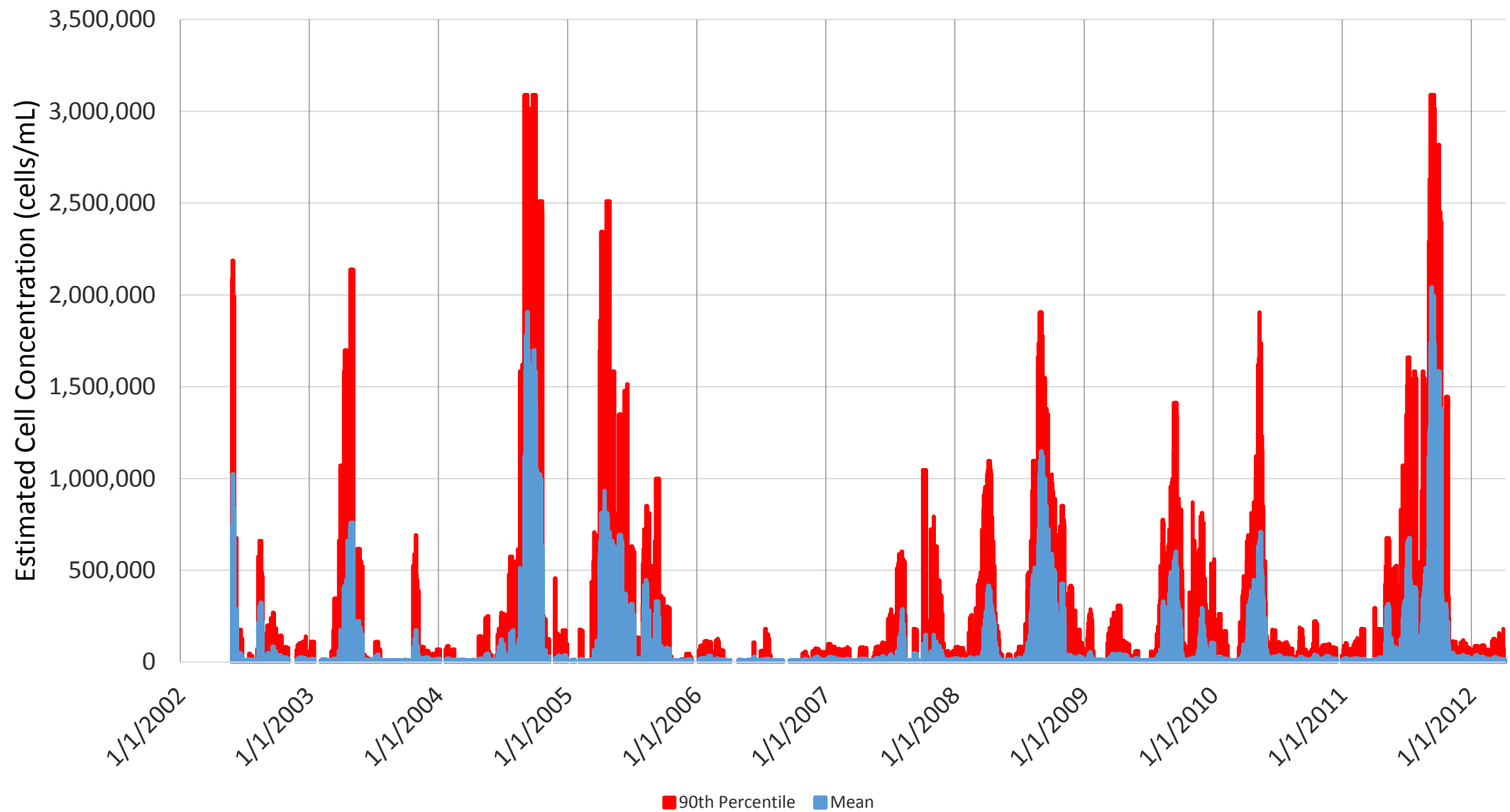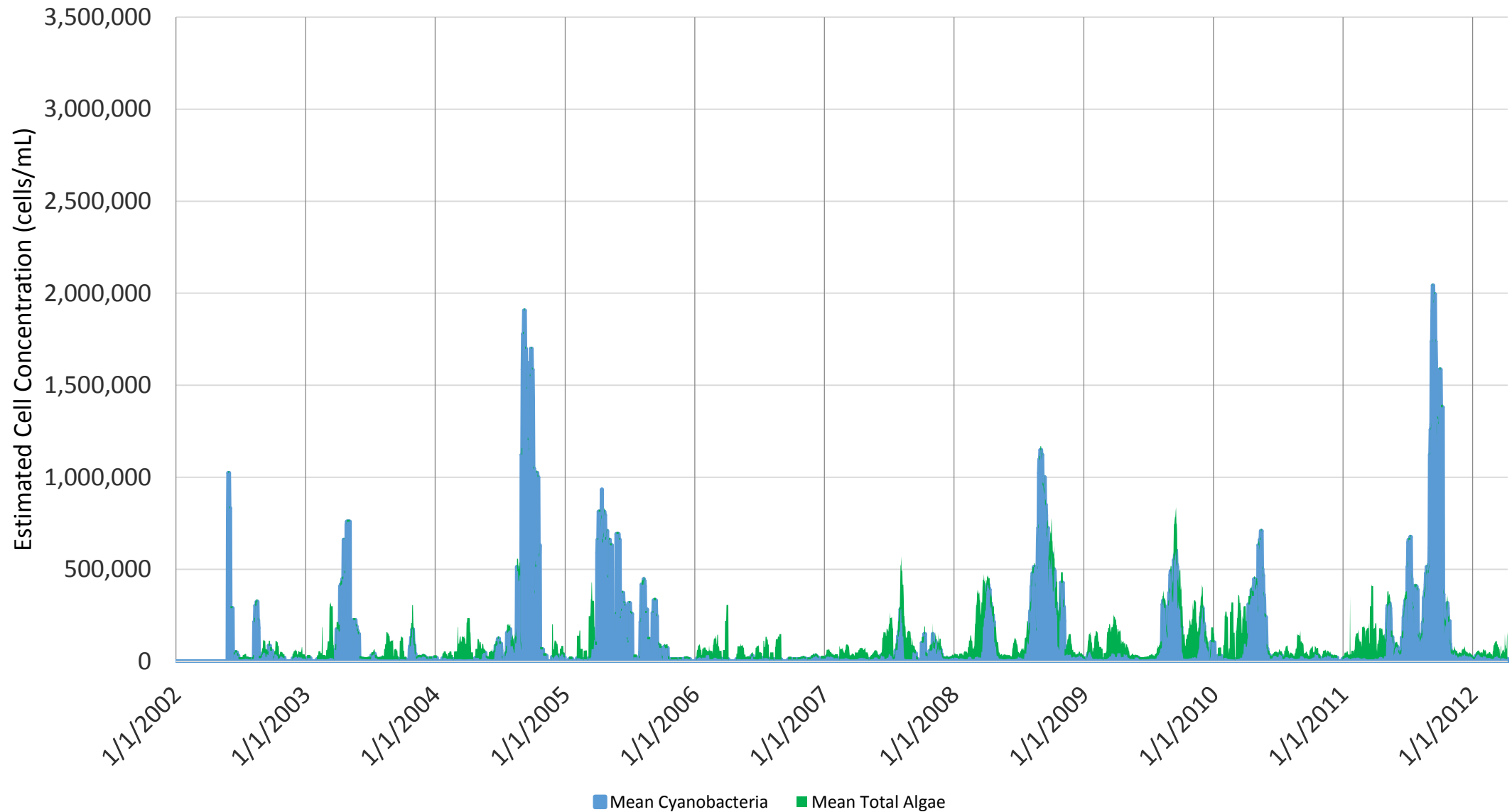

Consider ± 15% uncertainty
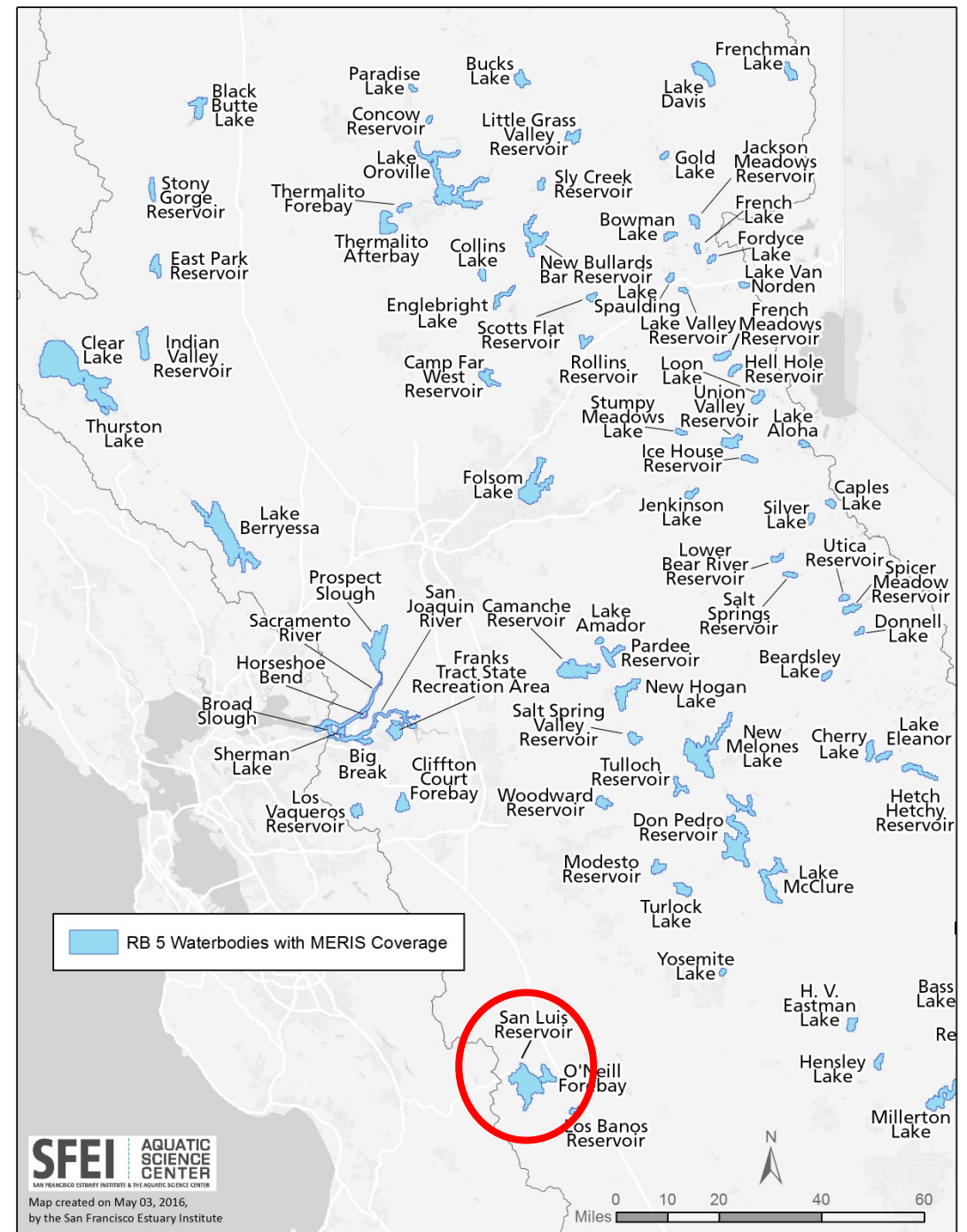
Mean cyanobacteria cell concentration, estimated in Microcystis cells/mL for San Luis Reservoir, CA, 2002-2012

Mean and 90% percentile of max value for cyanobacteria cell concentration, estimated in both Microcystis cells/mL and Chlorophyll-a (ug.L), for San Luis Reservoir, CA, 2002-2012
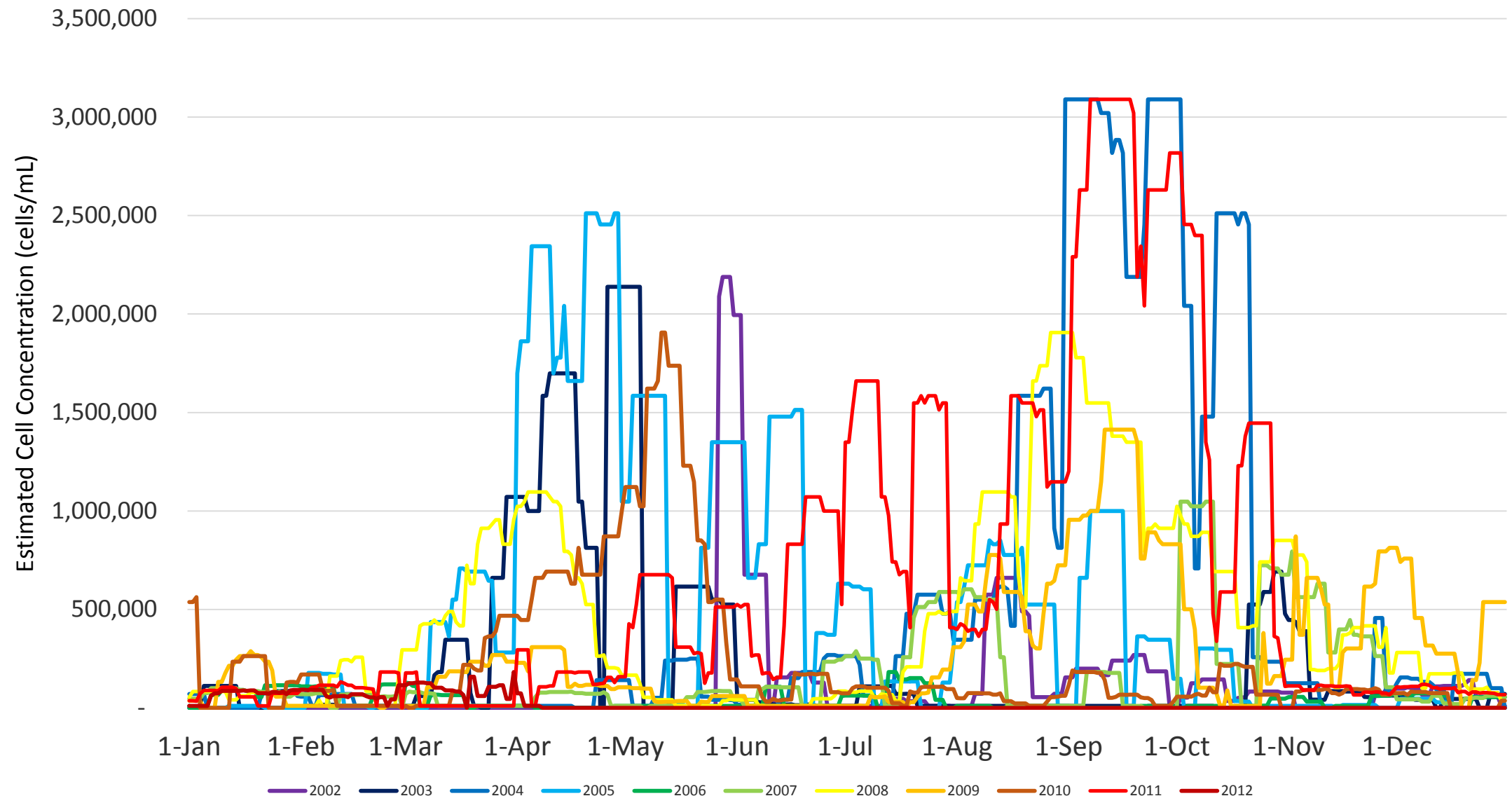
Mean cyanobacteria and mean total algal cell concentration, estimated in Microcystis cells/mL for San Luis Reservoir, CA, 2002-2012

90th percentile of maximum cyanobacteria cell concentration, estimated in Microcystis cells/mL for San Luis Reservoir, CA, 2002-2012

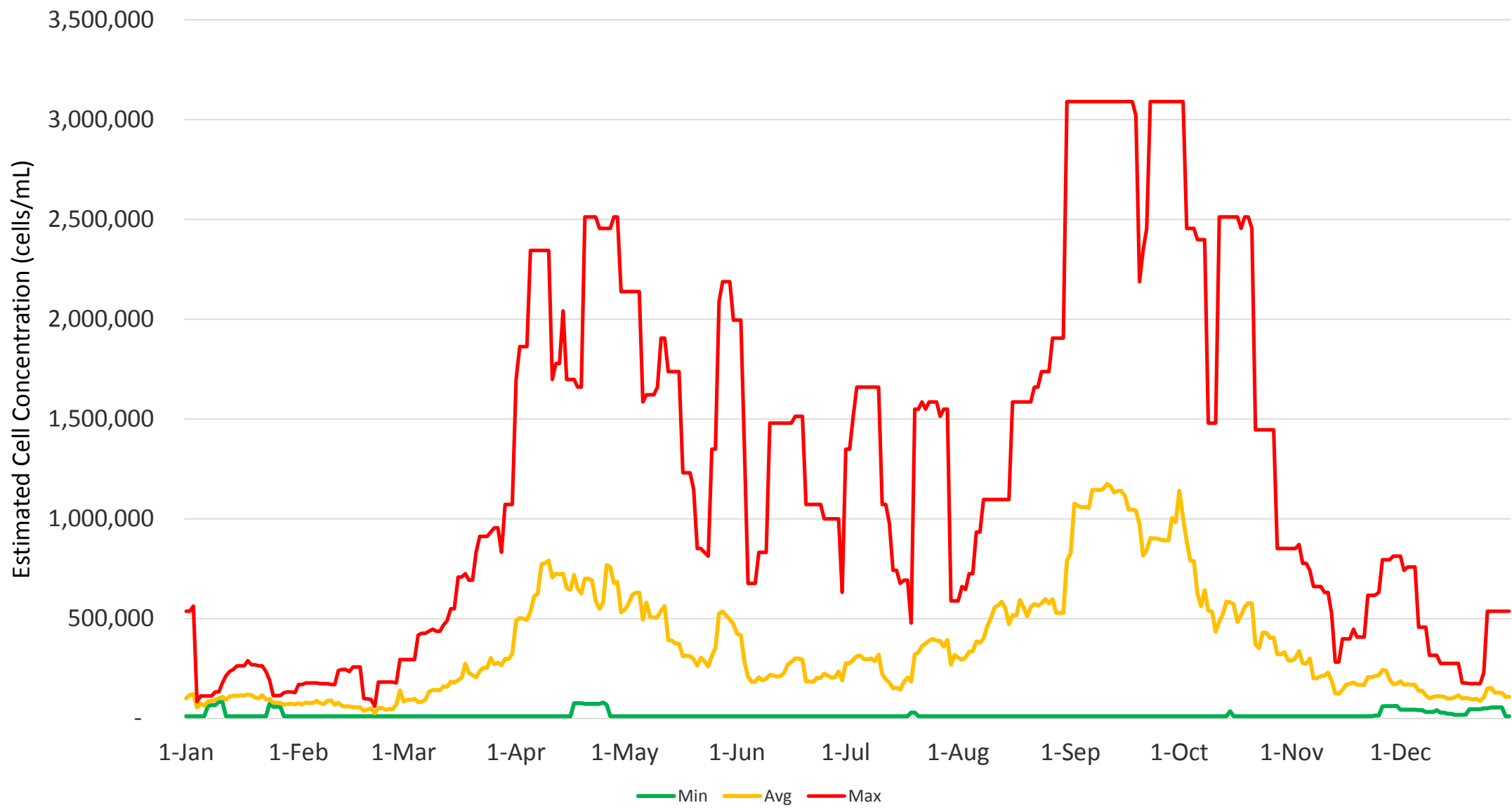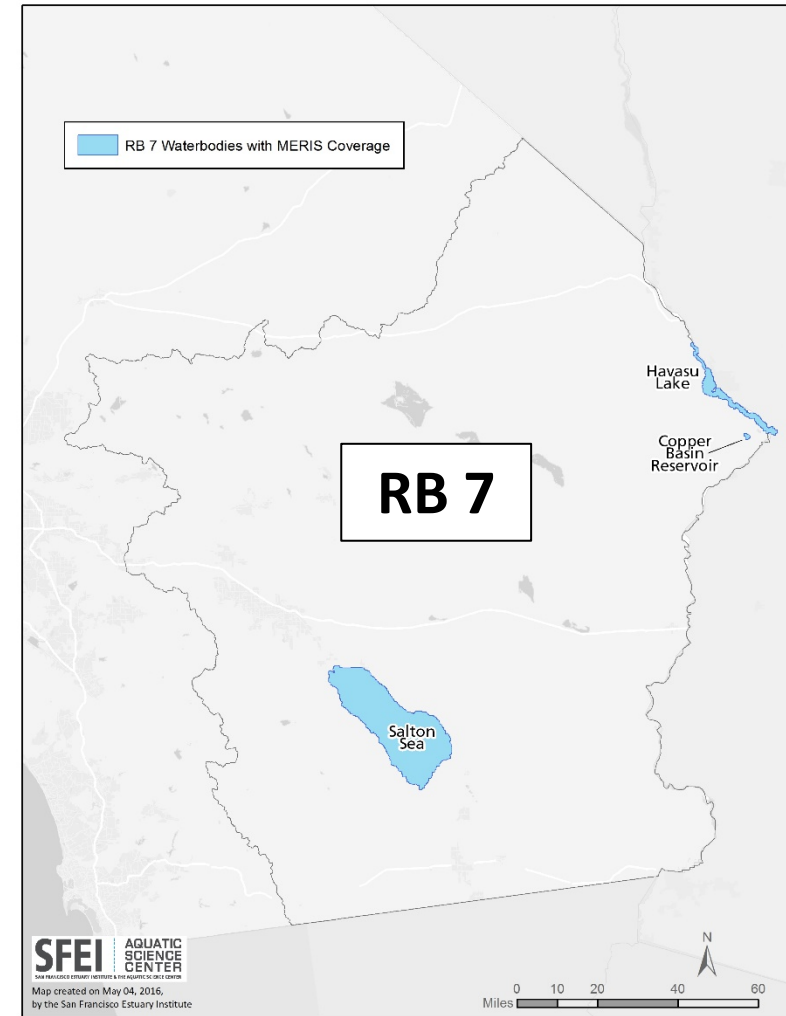Daily minimum, average, and maximum of 90th percentile of maximum cell concentration, estimated in Microcystis cells/mL for San Luis Reservoir, CA, 2002-2012

Region 7, 8, and 9 Summary
Monthly composites (not 10 day)
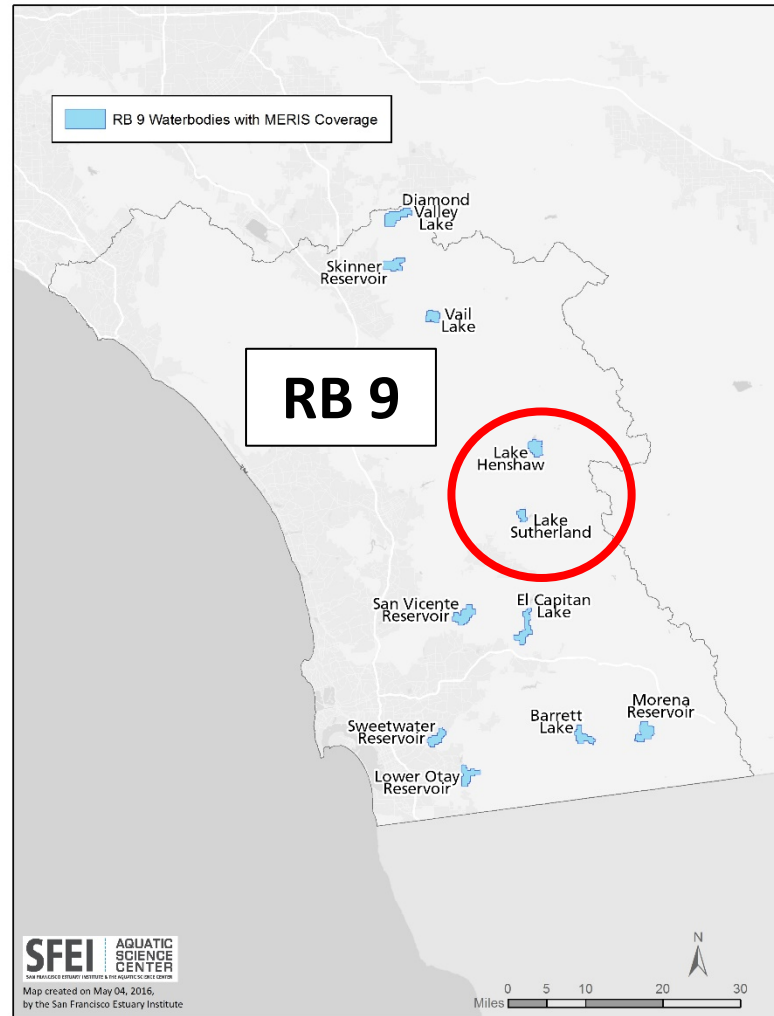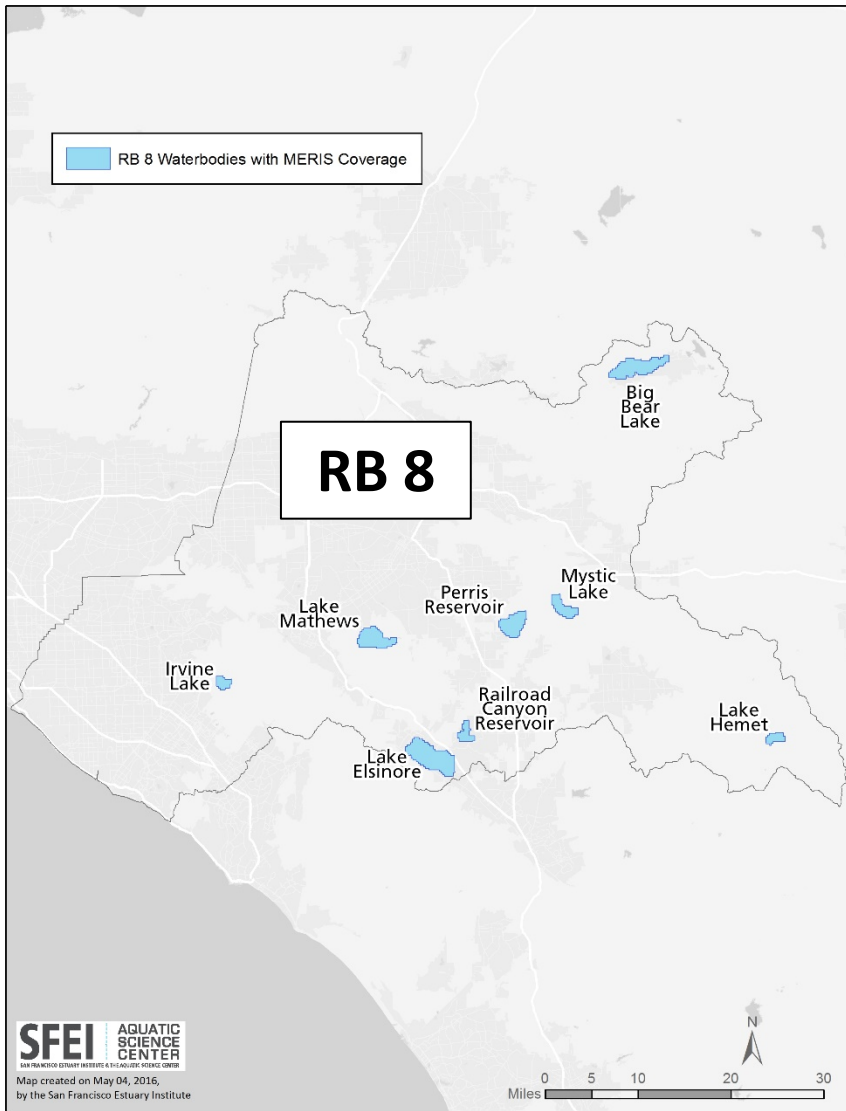
Number of months where composites meet >17 pixels threshold for waterbodies within Regions 7, 8, and 9 for June, 2002- March 2012

Number of months where 90th percentile concentration estimates of Microcystis exceed given cells/mL thresholds within monthly composites for waterbodies within Regions 7, 8, and 9 for June, 2002- March 2012

Legend:
- >1,000,000
- 100,000 - <1,000,000
- 20,000 - <100,000
- >10,232 -<20,000
- Pixel Threshold Not Met
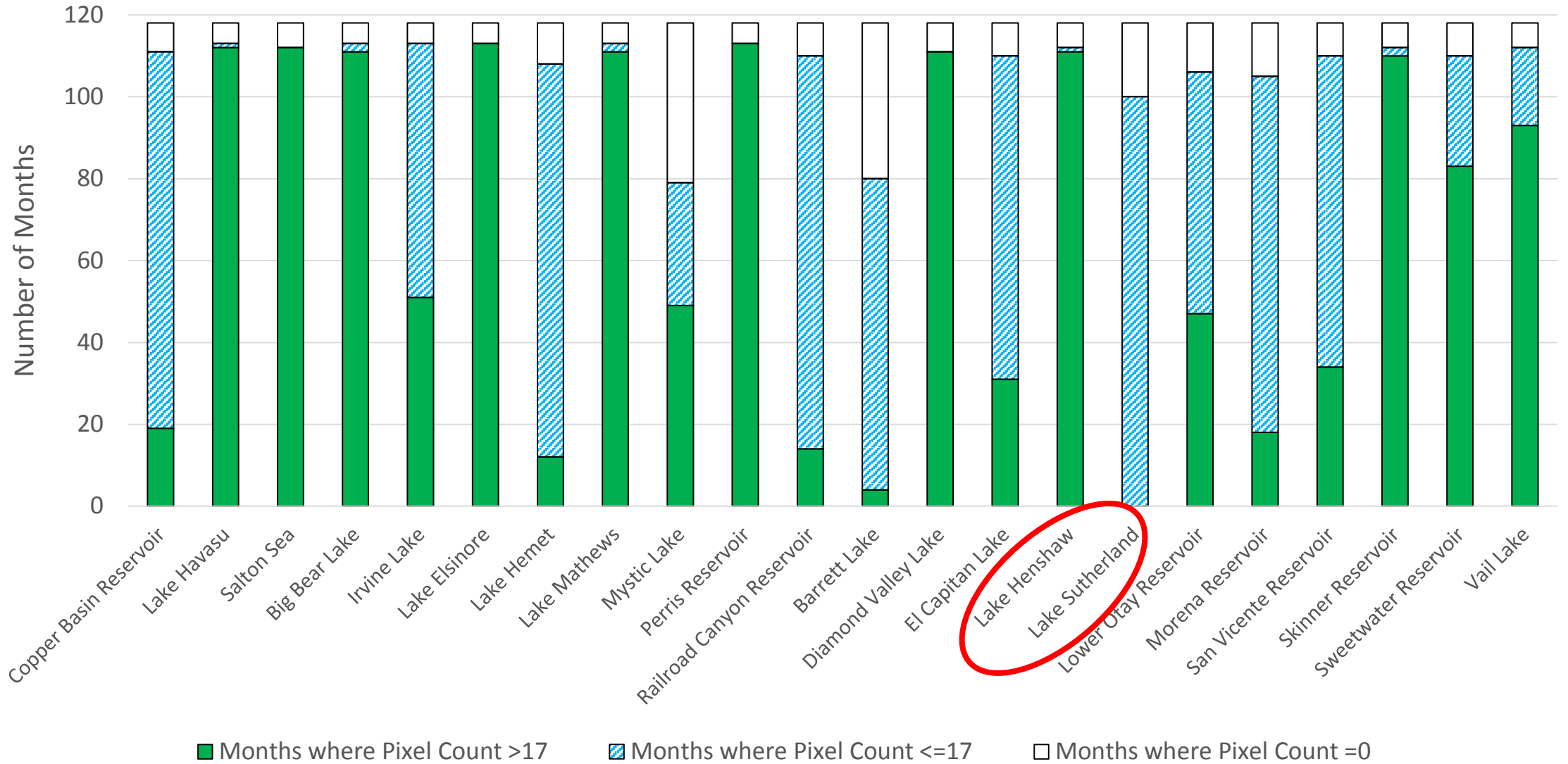
Statewide Summary

- 255 waterbodies
- Monthly composites (not 10 day)
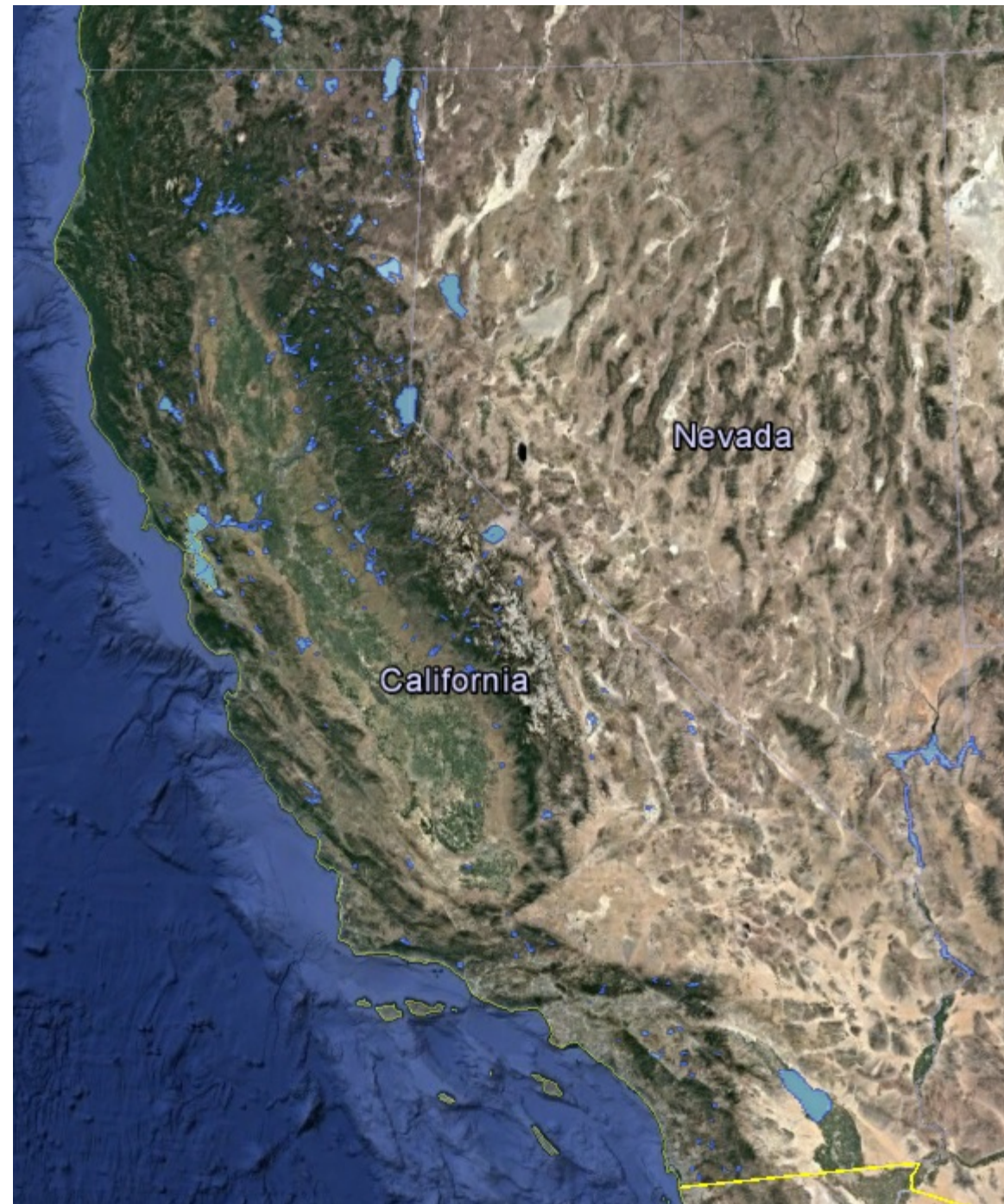
Monthly Exceedances Southern California

Monthly 90th Percentile Cyanobacteria Concentrations (June 2002 - March 2012)

- Months no data (< 17 Pixels)
- Months 10,232 - 20,000 cells/mL
- Months 20,000 - 100,000 cells/mL
- Months 100,000 - 1,000,000 cells/mL
- Months >1,000,000 cells/mL
- Water Board Regions

Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors
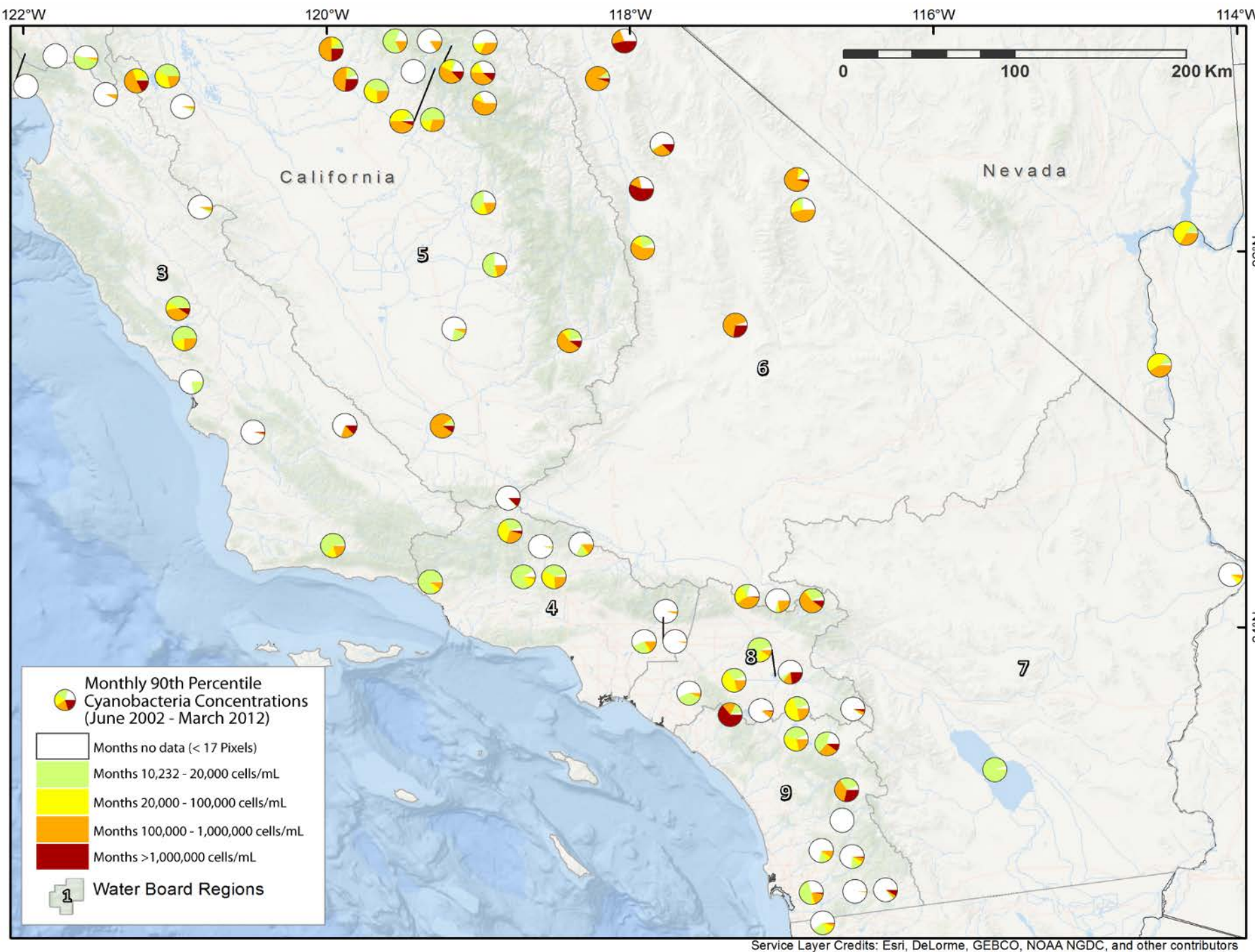
Monthly Exceedances Central California
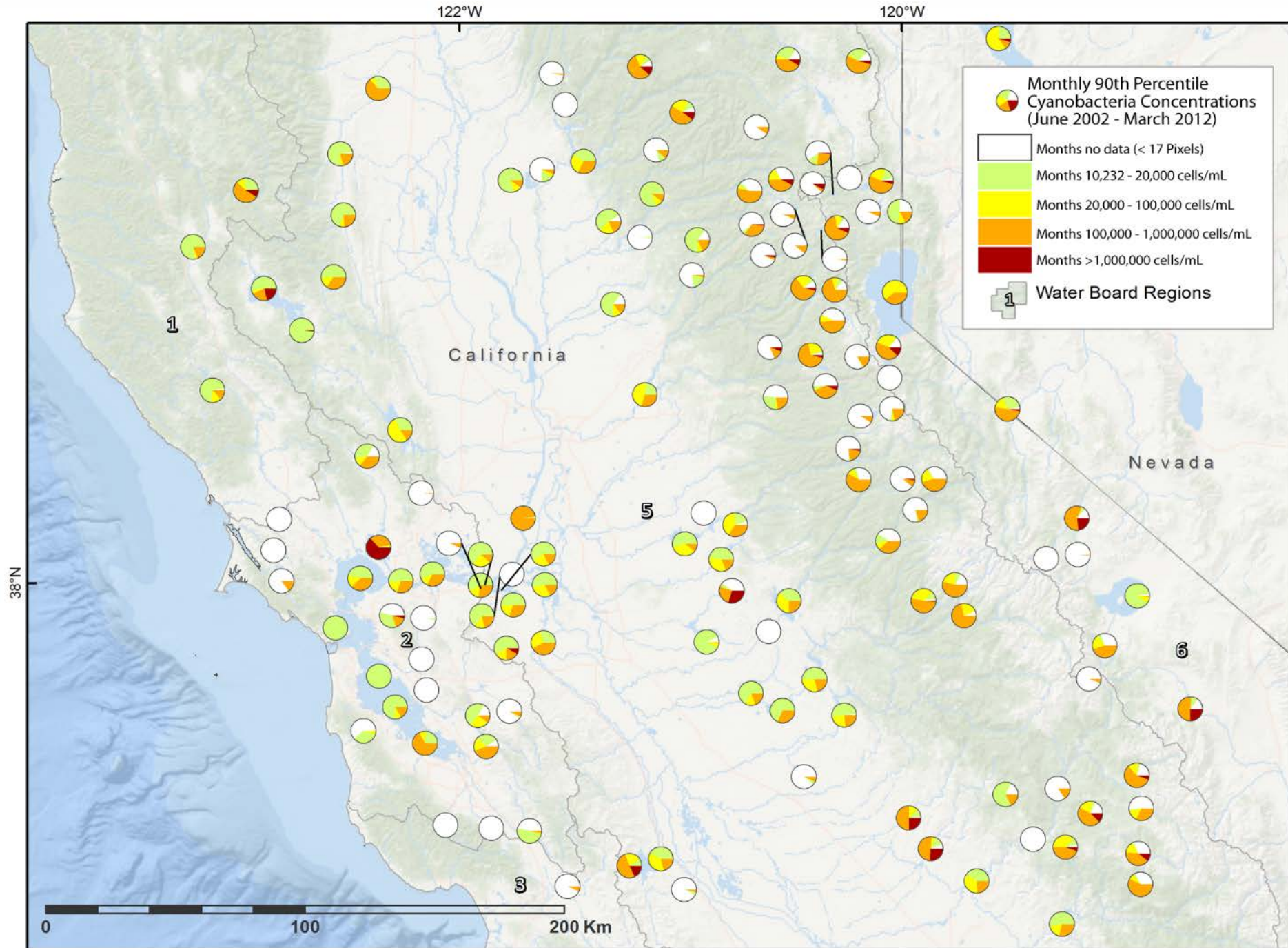
Monthly Exceedances Northern California
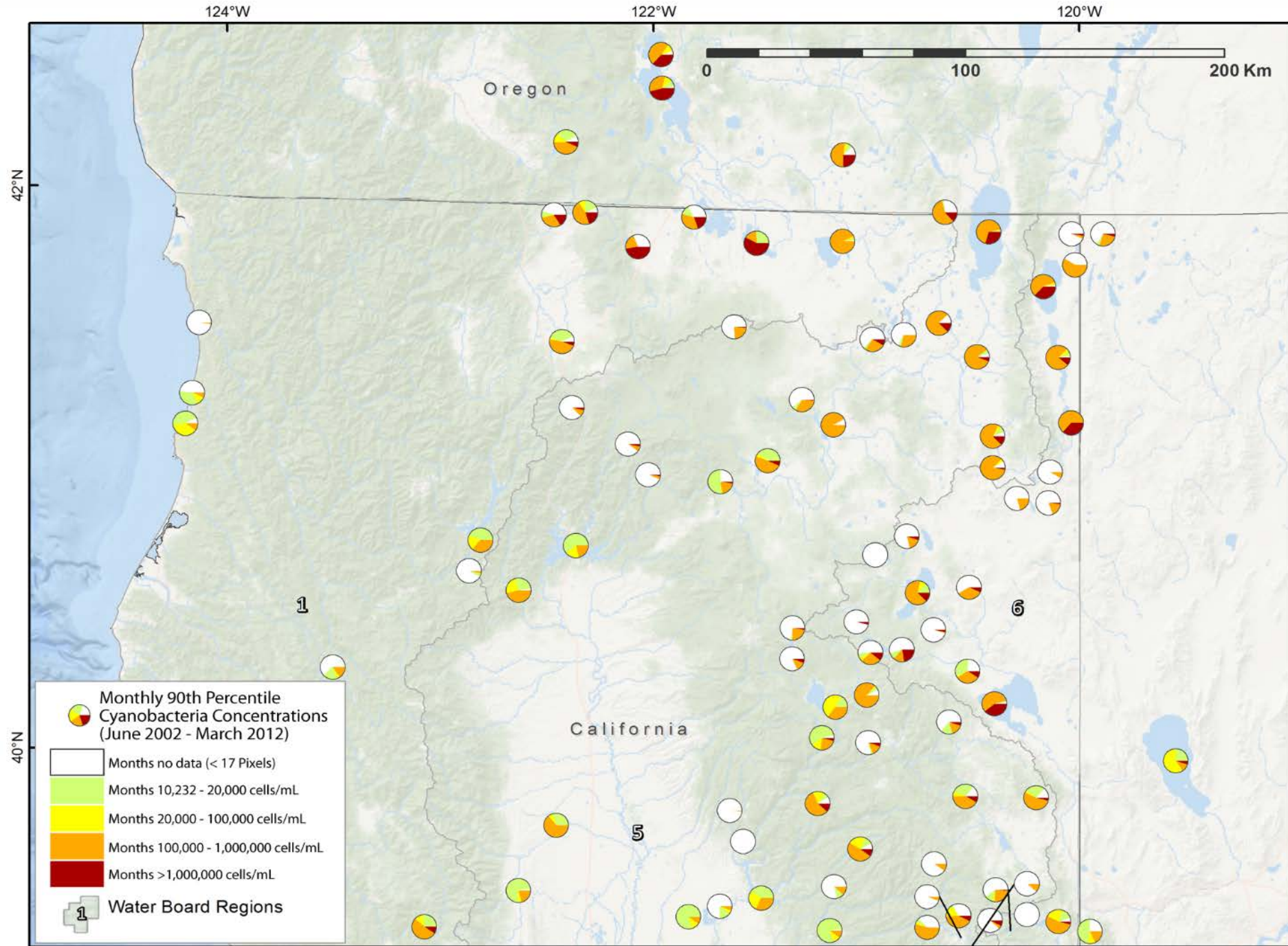
Number of 255 selected waterbodies where monthly composite pixel counts are >17; <=17; or 0, for June 2002 to March 2012

Y-axis: Number of Waterbodies

Legend:
- Number of waterbodies where Pixel Count >17
- Number of waterbodies where Pixel Count <=17
- Number of waterbodies where Pixel Count =0
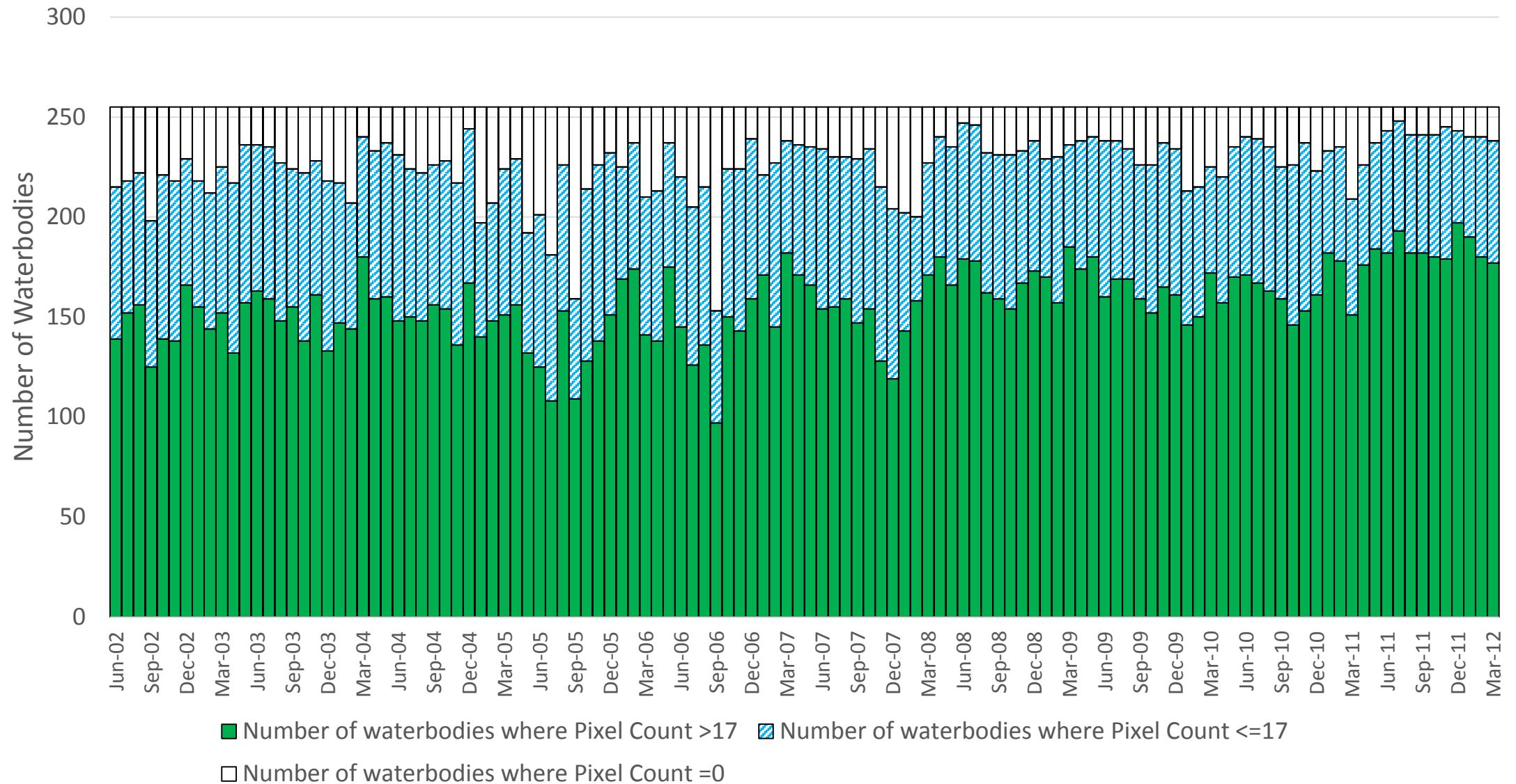
Number of 255 selected waterbodies where 90th percentile values within monthly composites exceed defined cells/mL thresholds, for June 2002 to March 2012
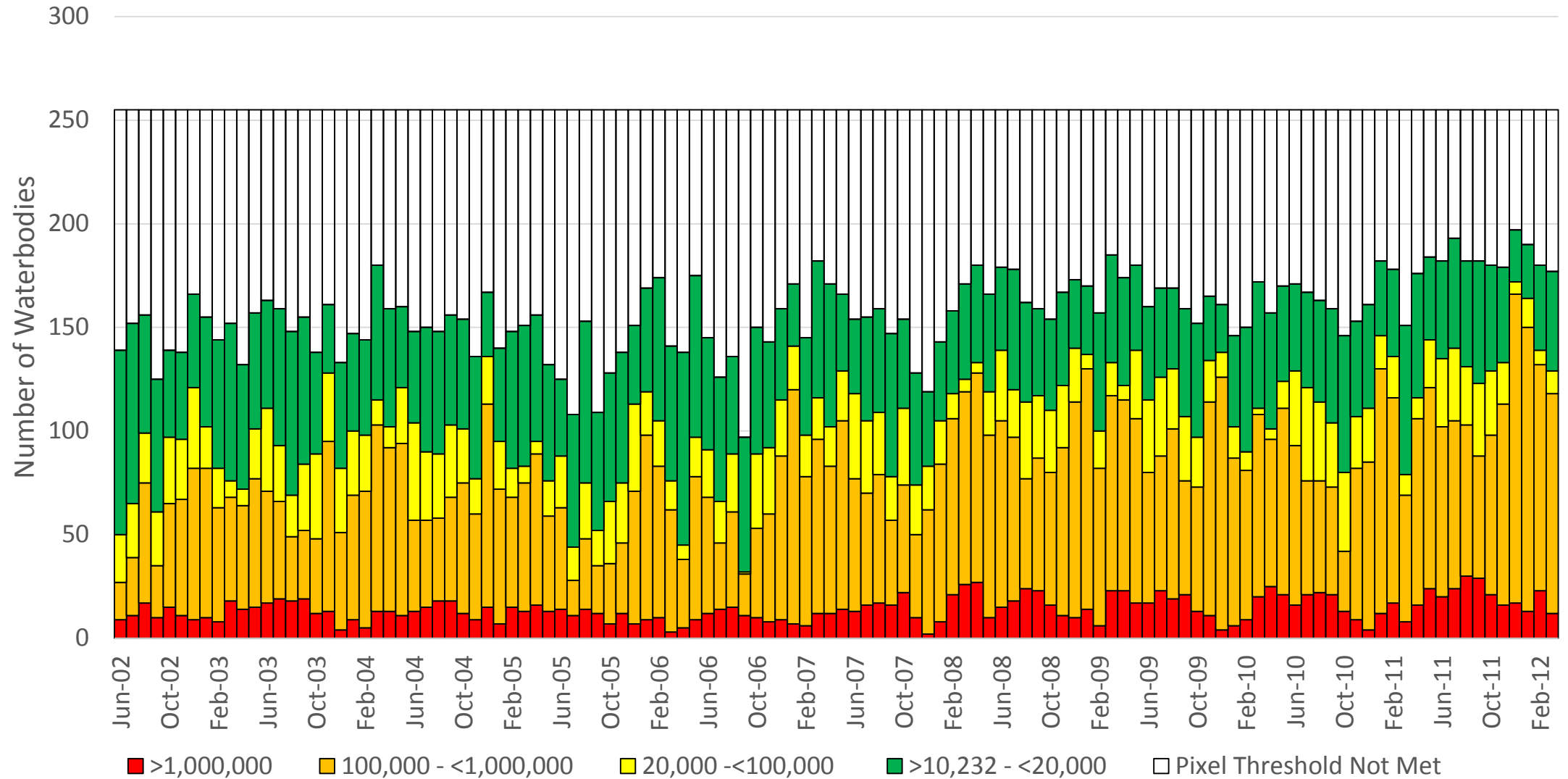
Average number of 255 selected waterbodies in California where 90th percentile values for monthly composites exceed thresholds of 20,000; 100,000; or 1,000,000 cells/mL, for 2002 to 2012
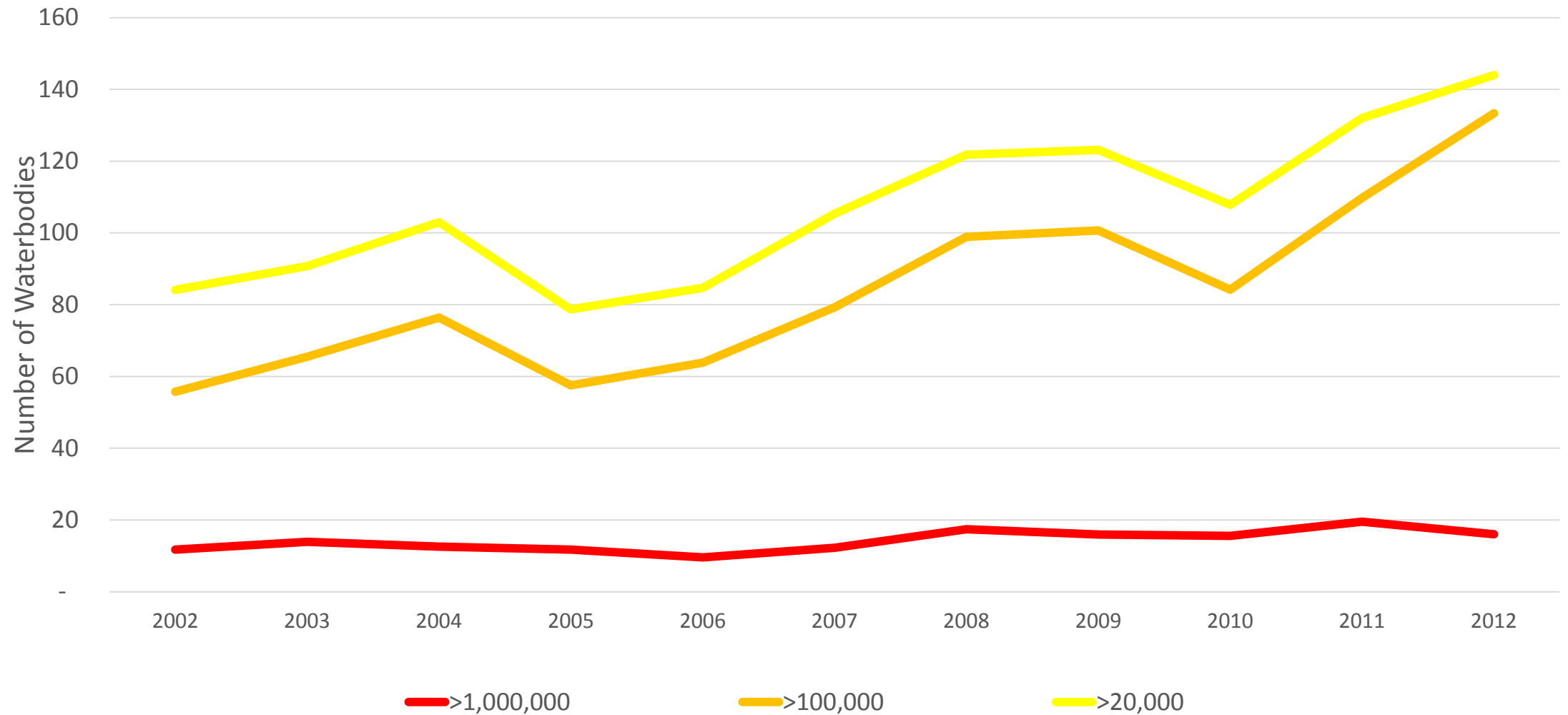
Monthly average number of 255 selected waterbodies in California where 90th percentile concentration estimates of Microcystis concentrations exceed thresholds of 20,000; 100,000; or 1,000,000 cells/mL, for 2002 to 2012
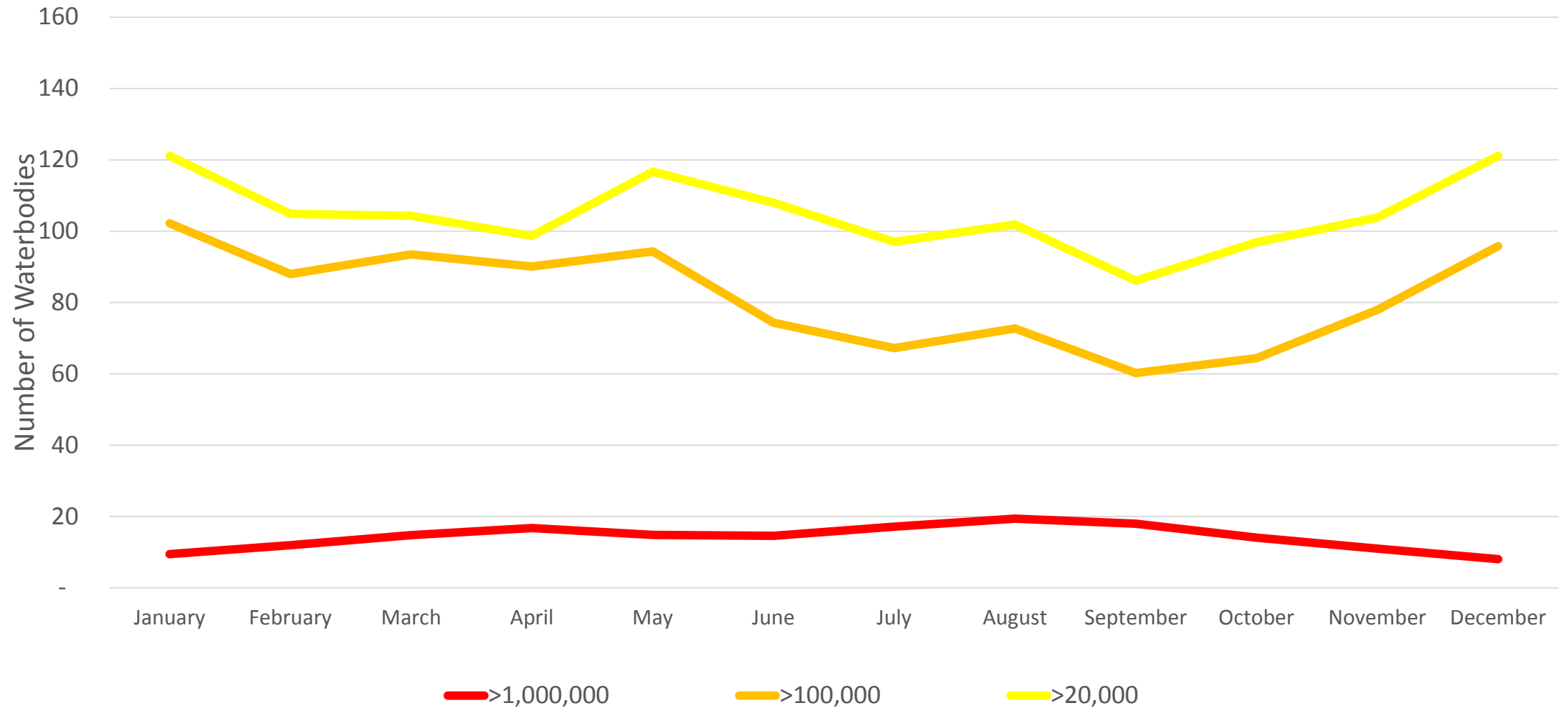
Satellites- What They Can't Do

- Cyanobacteria blooms can be detected but…
  - Clouds block images
  - Screening tool
    - No direct comparisons to HAB thresholds
    - Values are estimates (NOAA recommends +-15% uncertainty)
  - Estimates all cyanobacteria (including non-toxin producers)
  - Doesn't measure toxin levels
  - Less confidence with data for lowest algal densities
  - False positives can occur
  - Limited to large lakes (currently)
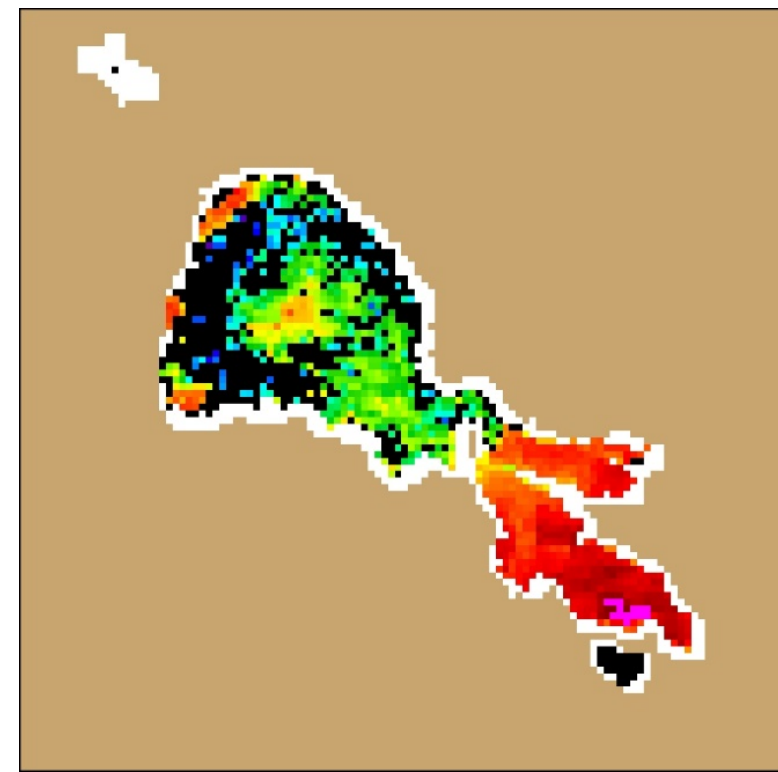
Satellites- What They Can Do

- Cyanobacteria blooms can be detected and…
  - Provide understanding of bloom conditions from 2002-2012
    - Identify trends and severity of blooms
  - Data can help understand bloom drivers, management
  - Monitor ~150 waterbodies in CA at once
  - Inform public about changing bloom status and location
  - Communicate data to help guide event response monitoring by:
    - Waterbody managers
    - County public health officials
    - Regional Board/SWAMP

Bev needs YOUR contact information!
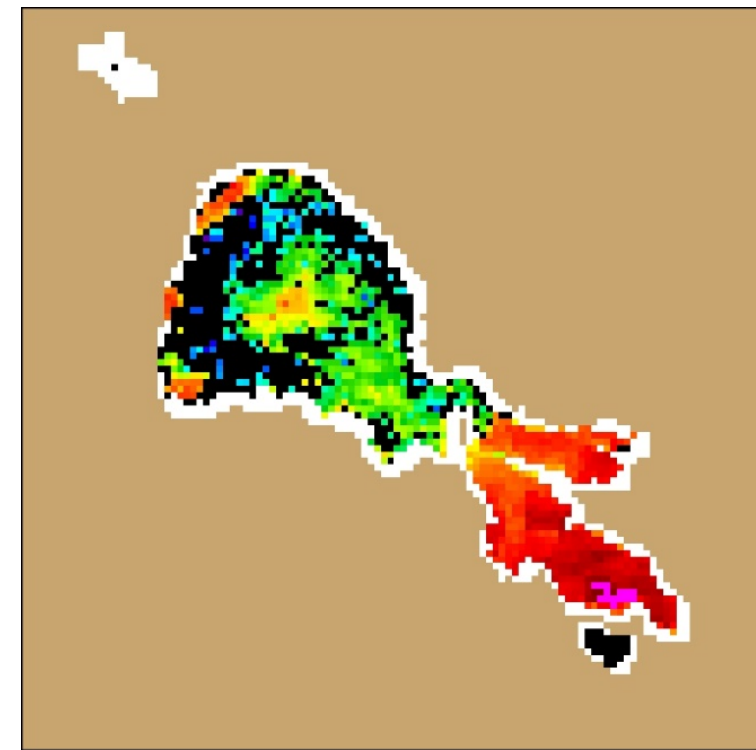
Further Research Needed

- Continue testing satellite data for interference/accuracy
  - Alkali lakes?
  - Halobacteria? (Owens Lake)
  - High elevation/clear water? (Lake Tahoe)
- Satellite raster data is available through SFEI. Compare against:
  - Water quality/cyanoHAB data
  - Weather
  - Inflow/lake levels
  - Geology
  - 303 (d) listings
  - Etc.

Questions?

Randy Turner
San Francisco Estuary Institute
randyt@sfei.org
707-499-5521

Interactive Maps for MyWaterQuality Portal

- <u>DRAFT</u> mock-ups of what interactive maps may look like
- Posted Waterbody map
- Satellite Data map

Search Query | Find By Location | Map/Layer Options

Water Board Region 2

Anderson Lake

Broad Slough

Calaveras Reservoir

Carquinesz Strait

Central Bay

Laguna Lake

Lake Curry

Lake del Valle

Lake Hennessey

Lower South Bay

Napa River island slough complex

New York Slough

Nicasio Reservoir

Quarry Lakes

Richardson Bay

Sacramento River

San Antonio Reservoir

San Joaquin River

San Pablo Bay

South Bay

Suisun Bay

Upper Crystal Springs Reservoir

Water Board Region 3

San Felipe Lake

Hernandez Reservoir

Lake San Antonio

Nacimiento Reservoir

Whale Rock Reservoir

Soda Lake

Lopez Lake

Lake Cachuma

SFEI | AQUATIC SCIENCE CENTER

Clear Lake
Danger Advisory
In effect
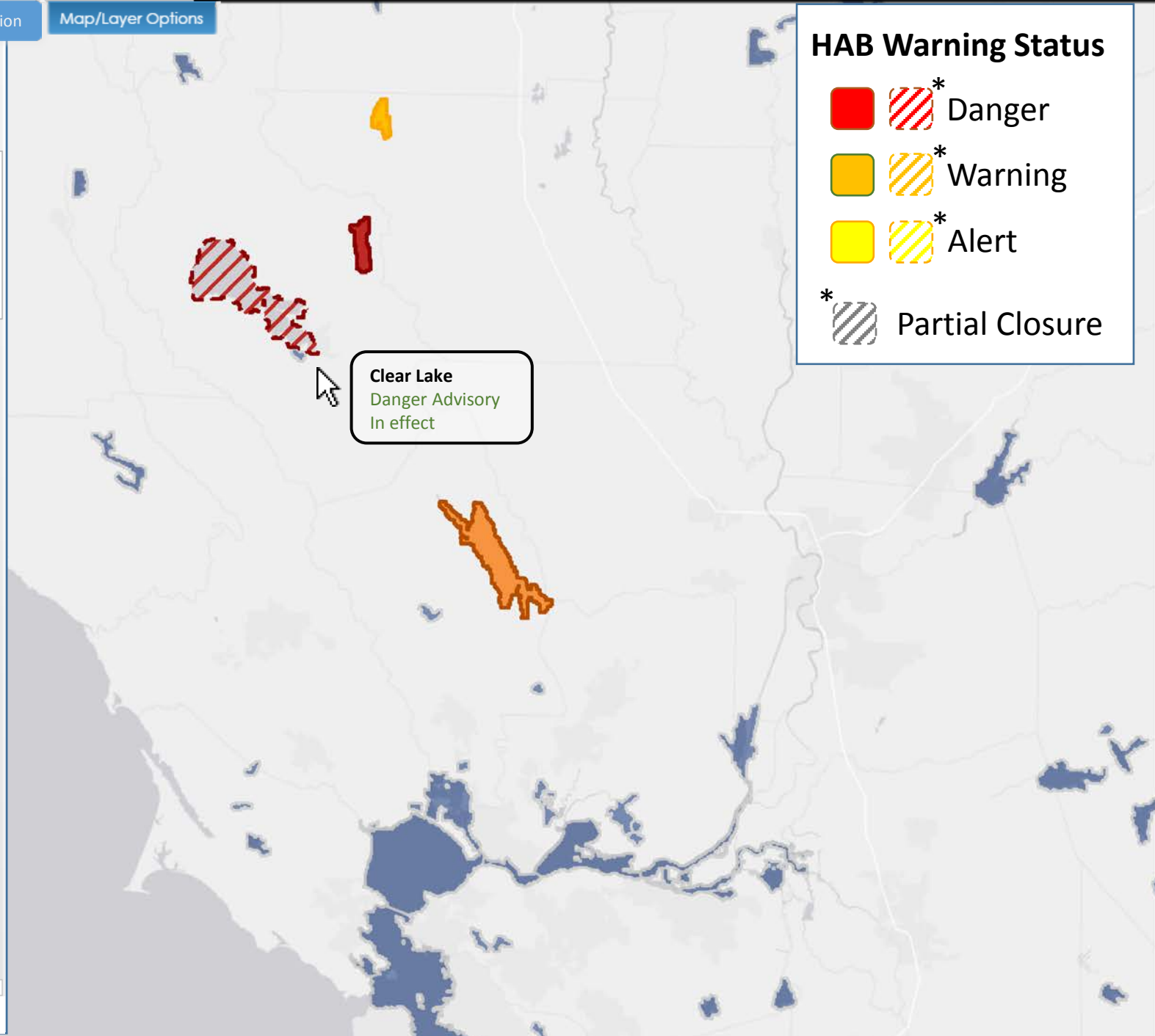
HAB Warning Status

🟥 ▨* Danger

🟧 ▨* Warning

🟨 ▨* Alert

* ▨ Partial Closure

Clear Lake, Lake County, CA

Current Advisory: State and county agencies are urging swimmers, boaters and recreational users to avoid contact with blue-green algae now blooming in Clear Lake located in Lake County, CA. The lake has been posted with advisories warning of any contact with the water because of possible toxins associated with the algae. (Read More)

2013   2014   2015

Display Last [10 ▼] Days

| **Trends** | Water Quality | Data Table |

Cyanobacteria Estimated Biomass & Toxicity

Chl (µg/L)

Lake Biomass Mean: 62 ug/L
Lake Biomass 90th Percentile: 117 ug/L

May-11   Jun-11   Jul-11   Aug-11   Sep-11   Oct-11   Nov-11

Clear Lake CEDEN Analytes

☐ [Select One ▼]

──── Lake Biomass Mean

──── Lake Biomass 90th Percentile

MERIS 10-Day Composite Biomass Estimate
May 20, 2014 – May 30, 2014

Base Layer: 10 Day Biomass estimate ▼

Search Query | Find by Location | Map/Layer Options »

◇ CEDEN Sample Location

MERIS 10-Day Composite Biomass Estimate
May 20, 2014 – May 30, 2014

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2013   2014   2015

Display Last 10 ▼ Days

Trends | Water Quality | Data Table

Cyanobacteria Estimated Biomass & Toxicity

Chl (µg/L)
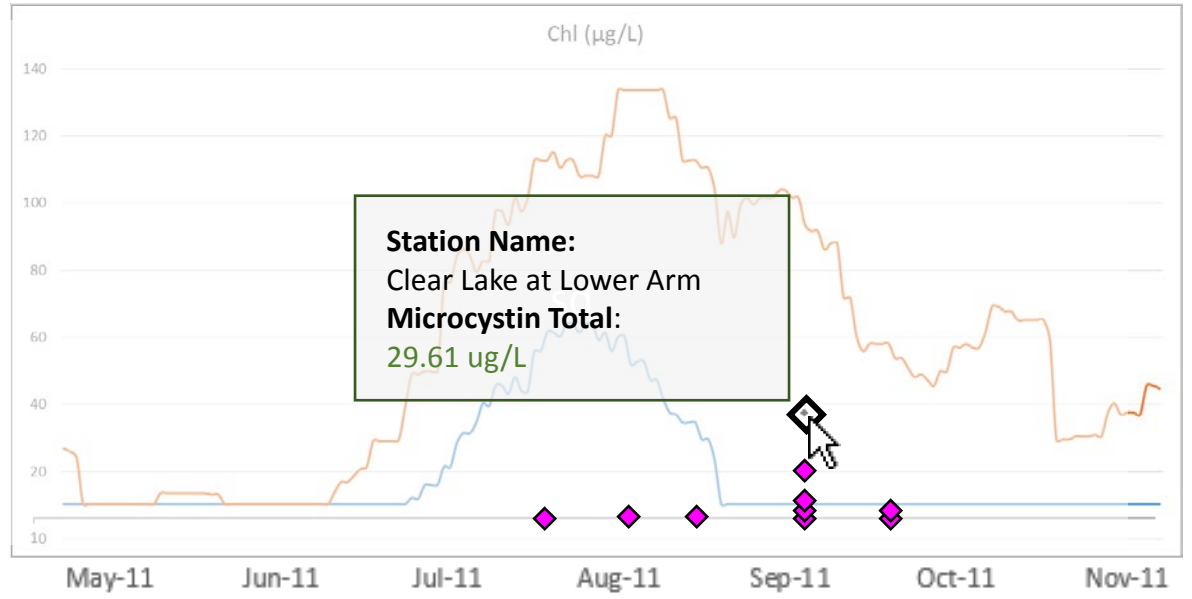
Station Name:
Clear Lake at Lower Arm
Microcystin Total:
29.61 ug/L

Clear Lake CEDEN Analytes

☑ ◇ Microcystin Total (ug/L) ▼

—— Lake Biomass Mean
—— Lake Biomass Median

Search Query | Find by Location | Map/Layer Options | »

Clear Lake, Lake County, CA

Current Advisory: State and county agencies are urging swimmers, boaters and recreational users to avoid contact with blue-green algae now blooming in Clear Lake located in Lake County, CA. The lake has been posted with advisories warning of any contact with the water because of possible toxins associated with the algae. (Read More)
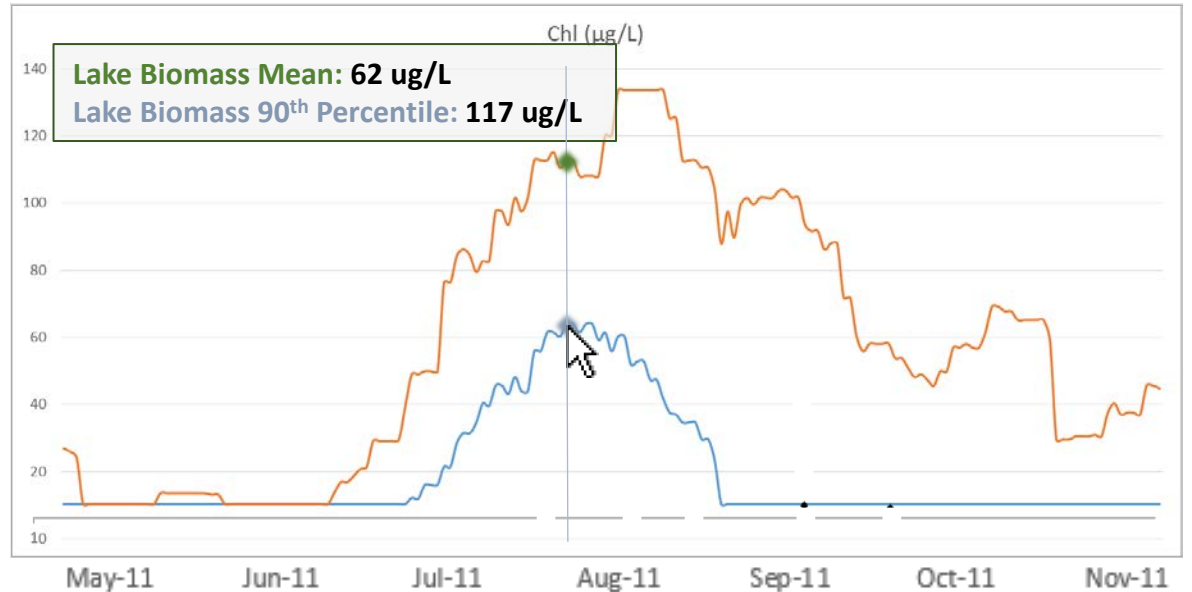
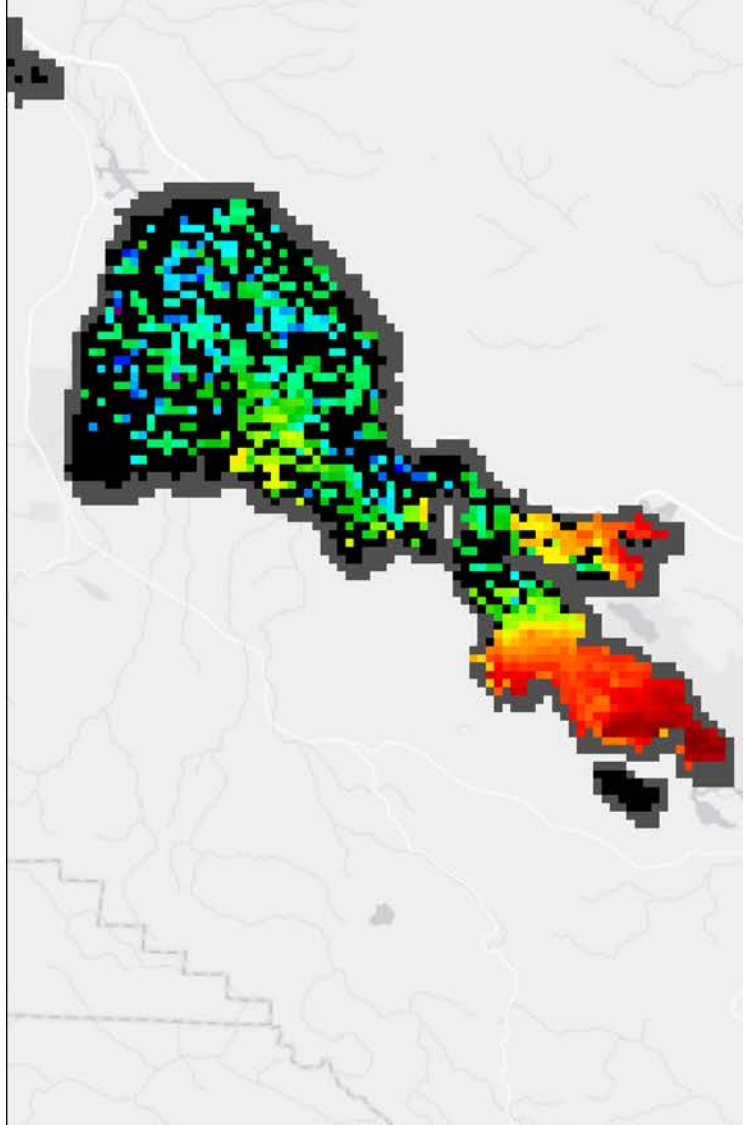2013 | 2014 | 2015
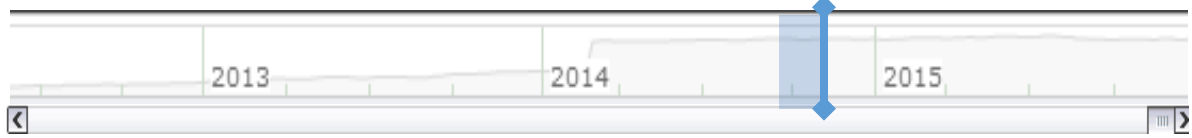
Trends | **Water Quality** | **Data Table**

Select Data for Waterbody ▲

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CEDEN Data

MERIS Analysis Data

From Jan 8, 2016 To Feb 8, 2016 | **Download Table**

						H	I	J	K	L	M	N	O	P	Q	R
						Pixel Values				ug/L						
						median	mean	perc90	var	min	max	stdev	median	mean	perc90	var
						5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
						5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
5	12/25/2010	1/3/2011	1638	1638	1	176	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
6	12/26/2010	1/4/2011	1638	1638	1	176	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
7	12/27/2010	1/5/2011	1638	1638	1	176	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
8	12/28/2010	1/6/2011	1638	1638	1	176	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
9	12/29/2010	1/7/2011	1708	1708	1	176	6	1	1	31	1	10.41	33.02	10.45	10.41	10.41	10.80	10.41
10	12/30/2010	1/8/2011	1708	1708	1	176	6	1	1	31	1	10.41	33.02	10.45	10.41	10.41	10.80	10.41
11	12/31/2010	1/9/2011	1674	1674	1	108	5	1	1	30	1	10.41	14.81	10.45	10.41	10.41	10.80	10.41
12	1/1/2011	1/10/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
13	1/1/2011	1/11/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
14	1/2/2011	1/12/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
15	1/3/2011	1/13/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
16	1/4/2011	1/14/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
17	1/5/2011	1/15/2011	1727	1727	1	137	15	1	1	211	3	10.41	19.38	10.55	10.41	10.41	61.53	10.43
18	1/6/2011	1/16/2011	1727	1727	1	137	15	1	1	211	3	10.41	19.38	10.55	10.41	10.41	61.53	10.43
19	1/7/2011	1/17/2011	1727	1727	1	137	15	1	1	211	3	10.41	19.38	10.55	10.41	10.41	61.53	10.43
20	1/8/2011	1/18/2011	1713	1713	1	147	19	1	1	374	5	10.41	21.80	10.62	10.41	10.41	133.61	10.44
21	1/9/2011	1/19/2011	1713	1713	1	147	19	1	1	374	5	10.41	21.80	10.62	10.41	10.41	133.61	10.44
22	1/10/2011	1/20/2011	1698	1698	1	147	19	1	1	368	5	10.41	21.80	10.62	10.41	10.41	133.61	10.44
23	1/11/2011	1/21/2011	1742	1742	1	147	20	1	1	411	6	10.41	21.80	10.63	10.41	10.41	133.61	10.45
24	1/12/2011	1/22/2011	1742	1742	1	147	20	1	1	411	6	10.41	21.80	10.63	10.41	10.41	133.61	10.45
25	1/13/2011	1/23/2011	1746	1746	1	147	21	1	1	431	6	10.41	21.80	10.63	10.41	10.41	133.61	10.45
26	1/14/2011	1/24/2011	1746	1746	1	147	21	1	1	431	6	10.41	21.80	10.63	10.41	10.41	133.61	10.45
27	1/15/2011	1/25/2011	1722	1722	1	147	17	1	1	281	4	10.41	21.80	10.58	10.41	10.41	133.61	10.44
28	1/16/2011	1/26/2011	1731	1731	1	147	24	1	1	562	8	10.41	21.80	10.68	10.41	10.41	133.61	10.47
29	1/17/2011	1/27/2011	1731	1731	1	147	24	1	1	562	8	10.41	21.80	10.68	10.41	10.41	133.61	10.47
30	1/18/2011	1/28/2011	1715	1715	1	146	20	1	1	418	6	10.41	21.54	10.63	10.41	10.41	133.61	10.46
31	1/19/2011	1/29/2011	1715	1715	1	146	20	1	1	418	6	10.41	21.54	10.63	10.41	10.41	133.61	10.46
32	1/20/2011	1/30/2011	1660	1660	1	146	20	1	1	417	6	10.41	21.54	10.63	10.41	10.41	133.61	10.46
33	1/21/2011	1/31/2011	1576	1576	1	146	20	1	1	417	6	10.41	21.54	10.63	10.41	10.41	133.61	10.45

MERIS 10-Day Composite Biomass Estimate
May 20, 2014 – May 30, 2014