

ASSESSING CYANOTOXINS IN CALIFORNIA FRESH WATER HABITATS

November 28-29, 2012 Workshop Summary and Recommendations

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Prepared for the Surface Water Ambient Monitoring Program



www.waterboards.ca.gov/swamp

CREDITS

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COVER PHOTOS

Jar containing Pinto Lake water collected during a *Microcystis* bloom: Robert Ketley

Sea otter with clam: Bryant Austin

Microcystis bloom in Iron Gate Reservoir: Jacob Kann

Traditional salmon bake at the Yurok Salmon Festival: Ken Fetcho

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***ASSESSING CYANOTOXINS IN CALIFORNIA FRESH WATER
HABITATS:***

Workshop Summary and Recommendations

November 28-29, 2012
Oakland, California

December 2012



**Prepared by San Francisco Estuary Institute
for the Surface Water Ambient Monitoring Program of the
California State Water Resources Control Board**

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SFEI Contribution No. 686

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FUNDING

The Surface Water Ambient Monitoring Program (SWAMP) provided funding for the workshop through the Bioaccumulation Oversight Group (BOG). The BOG is a subcommittee that was formed to develop plans for and to guide implementation of SWAMP bioaccumulation monitoring. The BOG also serves as a workgroup for the California Water Quality Monitoring Council and is charged with coordinating monitoring, assessment, and communication of information relating to bioaccumulation in California. In addition to funding this workshop, the BOG is considering allocation of funding to design and implement a statewide screening study of cyanotoxins in freshwater habitats in California.

Additional funding for the workshop was provided by the State Water Board's Training Academy. The Southern California Coastal Water Research Project provided additional support. StopWaste graciously provided a venue for Day 2 of the workshop.

EXECUTIVE SUMMARY

During recent decades, harmful algal blooms (HABs) seem to have dramatically increased in California freshwater habitats (Butler et al. 2012; Howard et al. 2012), reflecting overall trends nationwide and globally (Lopez et al. 2008). HABs involving cyanobacteria (CyanoHABs) have been causing problems in a number of water bodies in California and elsewhere. Potential consequences of CyanoHABs and associated cyanotoxins range from mere nuisances to serious health threats to humans and animals. There is clearly a need to monitor and assess the causes, occurrence, and consequences of CyanoHABs in freshwater habitats to provide the basis for effective management of this increasing problem.

On November 28–29, 2012, the Bioaccumulation Oversight Group (BOG) of the Surface Water Ambient Monitoring Program (SWAMP) of the California State Water Resources Control Board (State Water Board) convened a workshop on the issue of freshwater cyanotoxins. The impetus for the workshop was the recognition that there is a substantial gap in statewide monitoring efforts related to freshwater cyanotoxins. One of the major outcomes expected from the workshop were options for utilizing BOG monitoring and assessment resources to help filling these gaps.

Workshop Goals and Structure

Day 1 of the workshop featured a series of speakers and was open to the public, both in person and through WebEx, as the goal was to provide information on a) the current state of knowledge of freshwater cyanotoxins; and b) the current tools available for freshwater cyanotoxin monitoring. PowerPoint presentations from Day 1 are available at:
http://www.sfei.org/SWAMP_cyanotoxin_workshop.

Day 2 was limited to invited participants and featured panel discussions that were planned to address the development of a) a comprehensive screening study, and b) a proposed statewide assessment and monitoring program for CyanoHABs and cyanotoxins in California. This summary document describes the key findings and outcomes of Day 2.

Outcomes

Preliminary conversations and the initial discussions of Day 2 soon revealed that participants would welcome an opportunity for discussing currently unmet needs for managing CyanoHABs more broadly, before working more specifically on a screening study and monitoring program for cyanotoxins. The organizers adapted the workshop agenda accordingly and workshop participants used Day 2 as an opportunity to broadly discuss management priorities that require collaboration on a statewide scale, in addition and as an important context to discussing the options for utilizing BOG monitoring and assessment resources. The core question driving the discussions of Day 2 was:

“What information and tools are resources managers currently missing to respond to HABs effectively? “

Day 2 participants addressed the core question with recommendations for how to improve (1) information on cyanotoxins and CyanoHABs, (2) communication tools and frameworks, and (3) response capabilities.

Recommendations

The following six key recommendations were developed at the workshop:

- (1) Develop a **strategy**. The goal is to develop a long-term vision and a strategic plan for statewide coordination for addressing cyanotoxins within a year.
- (2) Develop and prioritize multi-agency **management priorities**. The initial step is to identify near-term policy actions of the various agencies responsible for CyanoHAB management.
- (3) Synthesize existing information and identify **data gaps**.
- (4) Develop standardized **protocols** for sampling and analytical methods.
- (5) Develop **communication tools** for sharing, accessing, and communicating data and information related to CyanoHABs, such as a web portal. Also provide opportunities for exchanging information, such as additional workshops.
- (6) Identify the best use of **BOG monitoring and assessment resources** and **additional partnerships and funding** to support the long-term effort. Available BOG monitoring funds could potentially be applied as seed funding to do initial groundwork, such as identifying and synthesizing existing data, improving communications, or developing sampling and analytical protocols.

Long-Term Vision

The proposed vision is a statewide network of partners that is coordinated by an overarching strategy to improve (1) information on cyanotoxins and CyanoHABs, (2) communication tools and

frameworks, and (3) response capabilities. The proposed model is the marine California Harmful Algal Bloom Monitoring and Alert Program (CalHABMAP, <http://www.habmap.info/>). Monitoring is one of several aspects of such a program. One of the key actions is to create a central website for data exchange, information access, and public outreach.

Next Steps

Workshop participants agreed that follow-up work should focus on developing a strategy for a coordinated statewide network within a year. One of the immediate next steps should be to establish a steering group to guide further development of the strategy and coordinate with the CalHABMAP group. Foundational work should also include (a) a synthesis of existing information and identification of data gaps; (b) a review of existing communication tools and frameworks for reporting information that could be built on or emulated (“steal from the best”) to improve communications; and (c) the standardization of analytical methods for the determination of cyanotoxins. A limited amount of BOG monitoring funds could potentially be applied as seed funding to conduct some of the initial groundwork. However, funding and potential partnerships to support the long-term effort still need to be identified.

INTRODUCTION

Cyanotoxins from harmful algal blooms have been causing problems in a number of water bodies in California and have resulted in drinking water supply concerns, wildlife and domestic animal deaths, human health risks, and restrictions on shellfish harvesting. In spite of these problems, there is no routine monitoring of harmful algal blooms (HABs) or associated cyanotoxins in water or organisms in California's freshwater habitats. To begin to address the need for assessing the causes, occurrence, and consequences of harmful algal blooms in California freshwaters, the State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP) held a workshop where leading scientists from California and experts from other parts of the country discussed strategies for cyanotoxin monitoring.

During recent decades, HABs seem to have dramatically increased in California freshwaters (Butler et al. 2012; Howard et al. 2012), reflecting overall trends nationwide and globally (Lopez et al. 2008). Most (but not all) freshwater HABs are associated with cyanobacteria (also known as blue-green algae), photosynthetic bacteria that are common in all aquatic ecosystems. Factors leading to the development of cyanobacterial HABs (CyanoHABs) vary, but climate change and urbanization are thought to be important influences (Roelke et al. 2012).

Potential consequences of CyanoHABs range from mere nuisances to serious health threats to humans and animals. Compounds produced by cyanobacteria and other algae can cause noxious taste and odor in drinking water (Graham et al. 2010). High biomass HABs can cause low oxygen events that kill fish and block sunlight, preventing the growth of other algae and disrupting food webs (Lopez et al. 2008). Algal toxins threaten human and animal health if ingested in fish, shellfish tissue, or water (Anderson et al. 2000). These impacts have been causing problems in a number of water bodies in California (Table 1).

Socioeconomic costs have not been well quantified but include economic losses to aquaculture, recreation, and tourism (Steffensen 2008). Of particular concern, and a great challenge for drinking water production, is the increased occurrence of toxic algal blooms in drinking water sources (Lopez et al. 2008; Merel et al. 2010). There is clearly a need to monitor and assess the causes, occurrence, and consequences of freshwater HABs to provide the basis for effective management of this increasing problem.

Of the freshwater HAB toxins, cyanobacterial toxins or cyanotoxins currently present the most significant threat to human and ecological health in California and elsewhere (Lopez et al. 2010). Several groups of cyanotoxins are known to occur in California freshwaters, including

hepatotoxins (liver-damaging toxins, such as microcystin or nodularin), neurotoxins (anatoxin, saxitoxin, and others), and pro-inflammatory compounds (for example, lipopolysaccharides). Cyanotoxins are increasingly being viewed as contaminants of emerging concern (Howard et al. 2012).

This document describes the results of the Cyanotoxin Workshop held by the California State Water Board at the San Francisco Bay Regional Water Board (Day 1) and StopWaste (Day 2) in Oakland on November 28–29, 2012. The purpose of the workshop was two-fold: 1) provide water quality professionals with current knowledge of cyanobacteria and cyanotoxins (Day 1, public), and 2) discuss the development of a screening approach for cyanotoxins in fresh water systems in California, using a pilot study of the occurrence of cyanotoxins as a starting point (Day 2, by invitation only). Participants of Day 2 included resource managers and scientists, from state and federal agencies, and universities, who were specifically invited for their experience, knowledge, and stakes in the issues (Tables 2 and 3). This workshop was focused on cyanotoxins in freshwater, because there is currently no monitoring and response program analogous to the marine CalHABMAP.

Table 1. Examples of freshwater CyanoHAB effects documented in California.

<p><i>Impacts of Freshwater CyanoHABs on Beneficial Uses</i></p>	<p><i>Documented effects and impacted Water Bodies or Areas</i></p>
<p><i>Fishing/Cultural</i></p>	<ul style="list-style-type: none"> • Klamath River postings (Kann 2006; Kann 2006; Kanz 2008)
<p><i>Drinking Water</i></p>	<ul style="list-style-type: none"> • Riverside County: taste and odor problems in Metropolitan Water District’s reservoirs (Izaguirre 2008)
<p><i>Wildlife</i></p>	<ul style="list-style-type: none"> • Delta: possible toxic and foodweb impacts of <i>Microcystis</i> blooms at multiple trophic levels (Lehman et al. 2010; Acuña et al. 2012) • Monterey Bay: <ul style="list-style-type: none"> - Sea otter poisoning and mortality cases linked to upstream freshwater sources of microcystins (Miller et al. 2010) - Deaths of at least 21 sea otters attributed to microcystin (Miller et al. 2010)

Table 2. Speakers and Panelists. Panelists are indicated with an asterisk ().*

Lilian Busse	<i>San Diego Regional Water Quality Control Board</i>
Val Connor	<i>State and Federal Contractors Water Agency (Water Contractors)</i>
Dave Crane	<i>California Department of Fish and Wildlife</i>
Jay Davis	<i>San Francisco Estuary Institute</i>
Ken Fetcho	<i>Yurok Tribe</i>
Betty Fetscher	<i>Southern California Coastal Water Research Project (SCCWRP)</i>
Dominic Gregorio	<i>State Water Resources Control Board (State Water Board)</i>
Meredith Howard	<i>Southern California Coastal Water Research Project</i>
Cathy Johnson	<i>US Fish and Wildlife Service (USFWS)</i>
Susan Keydel*	<i>US Environmental Protection Agency, Region 9</i>
Raphe Kudela*	<i>University of California, Santa Cruz</i>
Peggy Lehman	<i>California Department of Water Resources (DWR)</i>
Regina Linville*	<i>Office of Environmental Health Hazard Assessment</i>
Melissa Miller	<i>California Department of Fish and Wildlife</i>
Hans Paerl*	<i>University of North Carolina</i>
Alex Parker	<i>San Francisco State University</i>
Andy Reich*	<i>Florida Department of Health</i>
Barry Rosen*	<i>US Geological Survey</i>

Table 3. Agencies and organizations represented on Day 2.

*California Department of Fish and Wildlife
California Department of Public Health (CDPH),
Office of Environmental Health Hazard Assessment
California Department of Water Resources
California State University San Marcos
Central Coast Regional Water Quality Control Board
Central Valley Regional Water Quality Control Board
Delta Stewardship Council
Interagency Ecological Program
Florida Department of Health
Lahontan Regional Water Quality Control Board
Metropolitan Water District
Moss Landing Marine Laboratories
National Oceanic and Atmospheric Administration
North Coast Regional Water Quality Control Board
PacifiCorp
San Diego Regional Water Quality Control Board
San Francisco Bay Regional Water Quality Control Board
San Francisco Estuary Institute
San Francisco State University
Santa Clara Valley Water District
Southern California Coastal Water Research Project
State and Federal Contractors Water Agency
State Water Resources Control Board
University of California, Davis
University of California, Santa Cruz
University of North Carolina
University Southern California
US Environmental Protection Agency, Region 9
US Fish and Wildlife Service
US Geological Survey
Yurok Tribe*

THE WORKSHOP

Workshop Goals

The workshop had 2 main objectives:

- (1) Provide information on the current state of knowledge of freshwater cyanotoxins and CyanoHABs broadly (internationally and nationally) as well as within in California (including specific case studies) and the current tools available for freshwater biotoxin monitoring.
- (2) Develop a comprehensive screening assessment for CyanoHABs and freshwater cyanotoxins in California including a proposed monitoring program.

Workshop Structure

Day 1 of the workshop was open to broad participation, both in person and through WebEx, as the goal was to provide information on the current state of knowledge of freshwater cyanotoxins and CyanoHABs, both broadly (internationally and nationally) as well as within California (including specific case studies), and the current tools available for freshwater cyanotoxin monitoring.

Day 2 was limited to invited participants and was designed to (1) determine priority management questions, (2) discuss options for a comprehensive screening assessment and monitoring program for CyanoHABs and cyanotoxins in California, and (3) begin forming partnerships to facilitate program implementation.

Day 1

After introductory remarks by Jay Davis, Chair of the Bioaccumulation Oversight Group (BOG) of the California Water Quality Monitoring Council, thirteen speakers made presentations that were organized around four themes: (1) National and Statewide Perspectives and Policies, (2) Drivers and Consequences, (3) Case Studies, and (4) Monitoring and Analytical Tools (Figure 1). Betty Fetscher and Meredith Howard, both from the Southern California Coastal Water Research Project (SCCWRP), moderated the sessions. Each topic session was concluded with a panel discussion, to provide participants with an opportunity to ask questions and discuss specific issues with the speakers. Appendix A provides a summary of the Day 1 presentations. The presentations are available on the workshop website: www.sfei.org/SWAMP_cyanotoxin_workshop.



State Water Resources Control Board

AGENDA FOR CYANOTOXIN WORKSHOP
Wednesday, November 28, 2012

9:00	Jay Davis, SFEI: Welcome and Introduction: Background, goals of meeting
1) NATIONAL AND STATEWIDE PERSPECTIVES AND POLICIES	
9:15	Susan Keydel, USEPA Region 9 National perspective on cyanoHABs, management implications, data gaps in information needed to support management decisions
9:45	Dominic Gregorio, SWRCB Background on CyanoHABs; California policy update; critical data needs
10:15	Regina Linville, OEHHA Summary of findings from toxicological report and suggested action levels; public health perspective; critical data needs
10:35	Discussion
10:45	BREAK
2) DRIVERS AND CONSEQUENCES	
11:00	Barry Rosen, USGS Understanding Why Cyanobacteria Are Successful: Their Ecological Strategies, Unintended Consequences, and Monitoring Considerations
11:20	Alex Parker, SFSU Environmental factors driving bloom development and toxin production in California
11:40	Melissa Miller, CDFG Effects on California wildlife and the land-sea connection
12:00	Discussion
12:10	LUNCH
3) CASE STUDIES	
1:10	Ken Fetcho, Yurok Tribe Klamath Basin Studies
1:30	Peggy Lehman, DWR Bay-Delta studies
1:50	Betty Fetscher and Meredith Howard, SCCWRP Studies in Southern California
2:10	Discussion
2:20	BREAK
4) MONITORING AND ANALYTICAL TOOLS	
2:40	Raphe Kudela, UCSC Tools for field monitoring, SPATT technology
3:00	Andy Reich, Florida Department of Health Real-time assessments, locating blooms using imagery, and response strategies
3:20	Dave Crane, CDFG Analytical laboratory methods for toxin analysis
3:40	Hans Paerl, University of North Carolina CyanoHAB management and monitoring in waters experiencing human and climatically-induced environmental change: Implications for California
4:10	Discussion
4:20	Closing remarks, logistics
4:25	Adjourn

Figure 1. The Agenda for Cyanotoxin Workshop Day 1.

Day 2

Outcomes

The principal desired outcome proposed initially was to develop intended uses, management questions, and an outline for a statewide screening study to determine the overall scope of the cyanotoxin problem in California freshwater habitats. The recommendations developed at the workshop extended beyond a screening study and will serve as a basis for the development and implementation of a statewide coordination strategy including:

- A long-term vision for addressing cyanotoxins in California;
- Management questions to focus statewide monitoring and assessment;
- Tools for exchanging incident information and communicating HAB-related information to the public;
- Identification/development of a web portal;
- Identification of data sources and gaps;
- Low-cost screening methods for rapid assessments of potential blooms, determination of status and trends, and detection of toxins in samples;
- Standardized analytical methods for the determination of cyanotoxins; and
- Identification of potential partnerships to support this long-term effort.

TOPICS OF DISCUSSION

The discussions of Day 2 centered on four main topics. The day started with a session titled Key Management Questions and Uses of Monitoring Data (1). This discussion widened into a broad-based discussion of priorities, framed as Identification of Information Needs (2). Third, participants discussed a Long-Term Vision for Cyanotoxins in California (3). The final session of Day 2 was dedicated to the Screening Survey Approach and Design (4).

1. Key Management and Monitoring Questions and Uses of Monitoring Data

The first session started with short presentations from several management perspectives that addressed what the key questions are and what data would be most useful to collect in a monitoring program:

1. State Water Resources Control Board – Dominic Gregorio
2. BOG – Jay Davis
3. California Department of Water Resources – Peggy Lehman
4. Water Supply Contractors – Val Connor
5. California Department of Public Health –Lilian Busse (San Diego Regional Water Board)
6. US Fish and Wildlife Service - Cathy Johnson

The approach was to provide each speaker with three slide templates of points they were asked to address ((1) Key Management Questions, (2) Intended Data Uses, and (3) Current/Future Monitoring), and then open the discussion to the panel and the other participants. The resultant list of information needs is:

Management Questions

1. What are the natural vs. the anthropogenic drivers of CyanoHABs (nutrient relationships)? (State Board)
2. What are the interactions with other stressors? (State Board)
3. What is the overall scope of the cyanotoxin problem in California freshwater bodies? (BOG)
4. What are the control options to reduce or eliminate the impact of CyanoHABs? (DWR?)
5. How can flows be managed to eliminate Microcystis? (DWR?)

6. Is the water in the Delta safe to drink? What levels of cyanotoxins are present? When are the cyanotoxins present? What conditions promote the presence of cyanotoxins? (Water Contractors)
7. Is the water in the Delta safe for use on fruit and row crops? (Water Contractors)
8. How are cyanobacteria impacting the estuary food web? (Water Contractors)
9. How are cyanotoxins impacting threatened and endangered fish species? (Water Contractors)
10. Will data be useful for local environmental health departments in counties affected by seasonal blooms? (CDPH)
11. Will monitoring include surface water sources used for drinking water? If so, what do we do with the data since this is non-regulatory? (CDPH)
12. Which water bodies are most impacted by algal blooms? (USFWS)
13. Which federally listed species are the most likely to be impacted? (USFWS)
14. What direct and indirect impacts occur through cyanotoxin blooms? (USFWS)
15. What are the links to other contaminants? (USFWS)
16. What are the factors for toxin production, and what are the influences? (USFWS)

Intended Data Use

1. Focus management attention on problem water bodies (BOG)
2. Inform general prioritization of the problem by high level decision-makers (BOG)
3. Use by local environmental health agencies (CDPH)
4. Use by drinking water providers (CDPH)
5. Communicate potential health risk to the public (CDPH)
6. Use of available information to decide whether and when to issue and post public health warnings (CDPH)
7. Compare concentration data to drinking water benchmarks (Water Contractors)
8. Compare concentration data to agricultural benchmarks (Water Contractors)

9. Conduct a complex suite of analyses intended to sort out the role of cyanotoxins in fish abundances (Water Contractors)
10. Use for listing and recovery actions (USFWS)
11. Compare to other blooms such as *Azolla* (USFWS)
12. Use for conservation plans (USFWS)

Past/Current/Future Monitoring

1. Build on existing work, and then move forward. The BOG cyanotoxin effort should be part of the statewide Blue-Green Algae Working Group (BGAWG) effort (State Board)
2. No current monitoring and future monitoring to be determined. BOG has monitoring funds that could potentially be applied on this topic. There are other competing potential uses of the funds. To apply BOG monitoring funds to the cyanotoxin topic, we will need to make a compelling case that we can provide useful information on the priority management questions with the limited funds available (BOG)
3. No current monitoring conducted but future work in Sacramento-San Joaquin River Delta likely. Willing to provide funding to collaborative efforts (Water Contractors)
4. Leverage existing surface water monitoring programs to collect additional cyanotoxin data (specify toxins) (CDPH)
5. Combine with other water quality monitoring (USFWS)
6. Sample prey biota to determine link to wildlife (USFWS)
7. Conduct chemical profile of affected water bodies (USFWS)
8. Assess available information that has already been collected (i.e., existing data on cyanotoxins and other relevant existing datasets such as nutrients or land use changes). (Discussion)
9. Connect and engage with the marine CalHABMAP (<http://www.habmap.info/>). From a scientific standpoint, cyanobacteria are not just a freshwater problem and the coordination of information and resources between the freshwater and marine community will provide a more holistic approach (Discussion)
10. Focus statewide and/or regional monitoring on questions that represent multi-agency management priorities (Discussion)

Management questions should capture the data needs and policy questions of an agency or organization in a context that is useful for the assessment of CyanoHABs and can be translated into specific monitoring questions (Appendix B). The monitoring questions guide the selection of the sampling design, indicators, and assessment methods.

A number of different management questions were identified for consideration in the development of a statewide monitoring program and initial screening study. The participants agreed to postpone a detailed discussion of management questions to a later stage of the strategy development. However, the key management questions and intended data uses presented at the meeting should be considered for coordinating future monitoring.

2. Identification of information needs

Preliminary conversations and the initial discussions of Day 2 soon revealed that participants would welcome an opportunity for discussing currently unmet needs for managing CyanoHABs more broadly, before working more specifically on a screening study for cyanotoxins. For example, participants see a major need in the lack of an infrastructure for sharing, accessing, and communicating data and information on CyanoHABs. The organizers adapted the workshop agenda accordingly and workshop participants used Day 2 as an opportunity to discuss management priorities that require collaboration on a statewide scale, in addition and as an important context to discussing the options for utilizing BOG monitoring and assessment resources. Based on the much broader scale of these needs, the workshop expanded from a discussion of monitoring and assessment of cyanotoxins to a broader discussion of what information and tools resources managers are currently missing to respond to HABs effectively. And accordingly, the main focus of Day 2 shifted towards the development of a coordinated statewide network to improve CyanoHAB information, communication, and response.

Workshop participants agreed that there is existing work on CyanoHABs to build on, which could be better integrated to provide more comprehensive information. The Blue-Green Algae Working Group (BGAWG) was identified as a starting point for a coordinated statewide network that would be expanded to integrate additional programs.

The BGAWG is a multidisciplinary group that meets since 2006 to discuss monitoring and management of CyanoHABs and how to better inform the public regarding blue-green algae blooms and the potential health risks. The core group consists of the State Water Resources Control Board, the Office of Environmental Health and Hazard Assessment, and the California Department of Public Health. Other participants include Siskiyou County Environmental Health, Humboldt County Environmental Health, Del Norte County Environmental Health, the Department of Water Resources, the Central Valley Regional Water Quality Control Board, the North Coast Regional Water Quality Control Board, U.S. Environmental Protection Agency (Region

9), the Karuk tribe, the Yurok tribe, Metropolitan Water District of Southern California, and PacifiCorp. The BGAWG originated from the Klamath Blue-Green Algae Workgroup, which is addressing local concerns in the Klamath River watershed.

3. Long-term Vision for CyanoHABs in California

The group discussed what they, as a community, want to see addressed by a long-term strategy for CyanoHABs and how to make it happen. Day 2 participants developed two lists of features: a list of desired attributes corresponding to the expectations for what a long-term program focusing on CyanoHABs should accomplish and a list of essential elements to ensure its successful implementation (Table 4). U.S. EPA's (2003) Elements of a State Water Monitoring and Assessment Program (Figure 2) were used as a starting point. However, not all the 10 elements were considered equally important and relevant, due to the fact that the initial focus is on developing a coordinated statewide network rather than a monitoring and assessment program per se.

Participants agreed that rather than depending on a single effort such as BGAWG or BOG, the development of a long-term program would be shared among a coordinated statewide network of various groups. Based on this broader vision, participants then made recommendations for the best use of resources available through BOG as one of the next steps.

Two main aspects to consider for such a coordination effort are collaborative arrangements and funding. For example, how the three existing multi-stakeholder groups (BGAWG, BOG, HABMAP) will work together will need to be determined. It was also suggested that the ability to attract funding would depend on whether the effort could be expected to improve local response capabilities. Therefore, the statewide initiative would need to include a strong reporting and outreach element on a local level. County health departments and other local or specialized institutions (for example, environmental learning centers) would be key players, since they would be the most appropriate entities to engage in local outreach and response.

Participants agreed that the development of a communication strategy would be one of the top priorities. A number of existing communication tools and frameworks for reporting information already exist that could be built on or emulated ("steal from the best"). Participants agreed that it would be useful to collate information on existing communication tools and reporting frameworks for broad review, to obtain input on the most promising approaches. Existing tools that were identified include the Pinto Lake advisory postings, Florida's Slime Crime Tracker (Figure 3), the Klamath Basin blue-green algae tracker (Figure 4), the Southern California Coastal Ocean Observing System (SCCOOS), tracking tools developed by the Center for Disease Control (CDC), the U.S. FWS Oil Response Hotline, and websites maintained by DWR, CDPH, and the Oregon Health Authority.

Table 4. Workshop participants identified desired attributes (a), essential elements (b), and other important aspects of a long-term program for CyanoHABs:

(a) Desirable Attributes of a Long-Term Program

1. Increases awareness
2. Increases coordination
3. Collaborates with/among existing groups
4. Facilitates sharing of existing outreach materials
5. Monitoring is driven by data needs, which are identified by a summary of existing data
6. Provides a web-based one-stop shop for data and information
7. Includes an education component for
 - a. The general public
 - b. Medical doctors
 - c. Veterinarians
 - d. Local health agencies
 - e. Park staff (federal, state, regional, county, city parks)
 - f. Water quality managers
8. Uses the best available science
9. Improves the local response by providing information that addresses key questions:
 - a. Why is my water green?
 - b. Is it a health issue?
 - c. Is my pet sick because of toxic algae and what can I do?
 - d. Can I swim or raft?
10. Facilitates statewide information sharing
11. Provides a hotline

(b) Elements of a Statewide Long-Term Monitoring and Response Program for CyanoHABs¹

1. Strategy and tactics
2. Objectives (management questions)
3. Design(s)
4. Data management
5. Data assessment
6. Reporting information
7. Continuing peer review by a “Science Advisory Board (SAB)”, especially of the design

¹ U.S. EPA’s 10 basic monitoring program elements (Figure 2) were used as a starting point. However, not all the 10 elements were considered equally important and relevant, due to the fact that the initial focus is on developing a coordinated statewide network rather than a monitoring and assessment program per se.

8. Infrastructure planning (putting money into infrastructure, communication, and raising awareness)

(c) Other Important Aspects

1. Develop a communication strategy²
2. Procure funding
3. Focus on these priority resources: the Delta, streams, rivers, lakes and reservoirs, and coastal lagoons
4. In the proposed data summary document, include a summary of methods and tools and the following parameters (which should be referenced with lat/long information):
chlorophyll a, other pigments, community composition, biomass, cell counts, zooplankton, nutrient forms and ratios (nitrogen, phosphorus, silicon, iron), temperature, transparency (Secchi depth), turbidity
5. Develop regulatory thresholds for cyanotoxins

²Including outreach to the general public using social media.

Elements of a State Water Monitoring and Assessment Program

1. Monitoring Program Strategy
2. Monitoring Objectives
3. Monitoring Design
4. Core Indicators of Water Quality
5. Quality Assurance
6. Data Management
7. Data Analysis/Assessment
8. Reporting
9. Programmatic Evaluation
10. General Support and Infrastructure

Figure 2. U.S. EPA's Elements of State Water and Monitoring and Assessment Program (USEPA 2003) outlines 10 basic monitoring program elements.

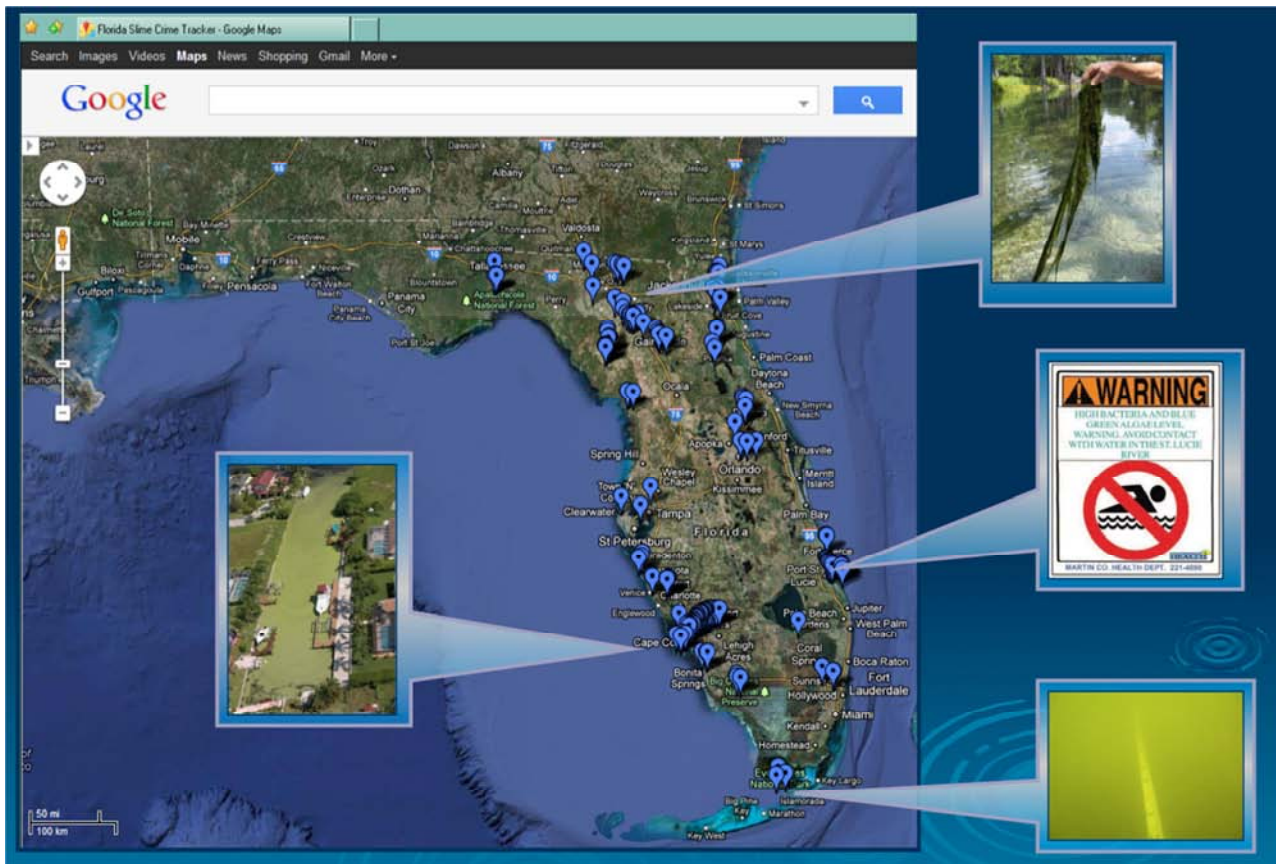


Figure 3. The interactive Slime Crime Tracker Map of the Florida Slime Crimes campaign lets users report bloom observations by uploading photos that document problems with toxic and nuisance algae.

Blue-Green Algae Tracker

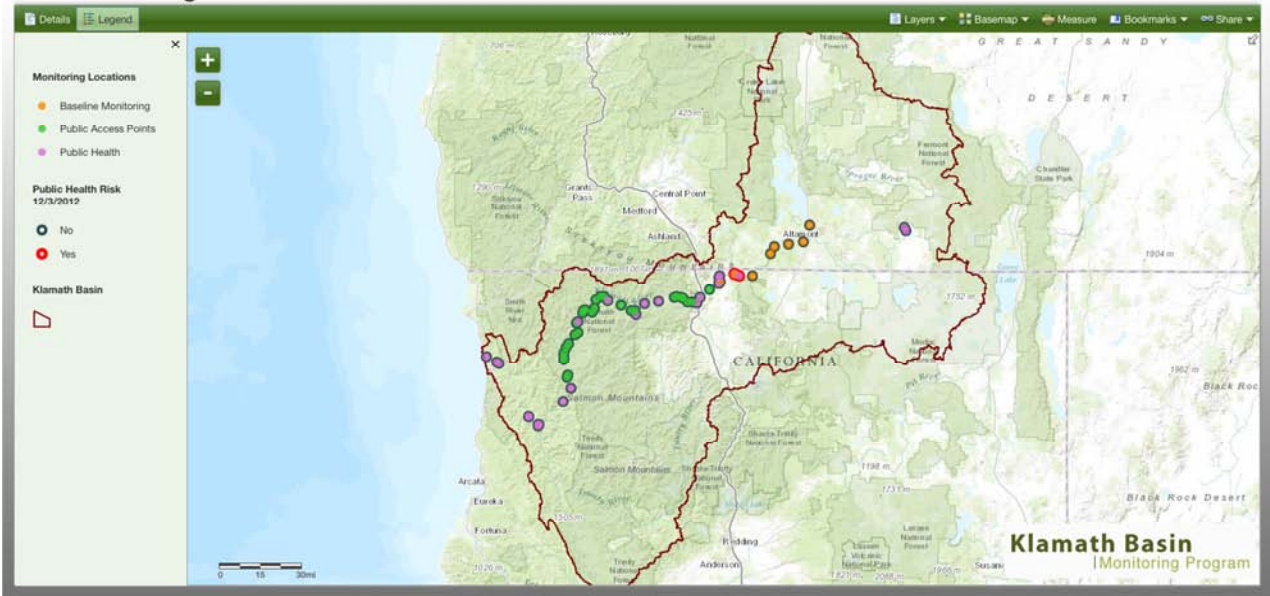


Figure 4. The Klamath Basin blue-green algae tracker utilizes up-to-date multi-agency information to track and map blue-green algae blooms throughout the Klamath Basin

4. Screening Survey Approach and Design

The outcomes of the “Information Needs” and “Long-term Vision” discussions suggested that currently the most valuable contribution by a proposed BOG initiative would be to conduct the initial groundwork for a screening study, such as identifying, compiling, and synthesizing existing cyanobacteria/cyanotoxin and supporting data, conducting a metadata analysis, and identifying management issues and data gaps. These products can then be used to inform strategy development for the proposed coordinated statewide network, including the development of management and monitoring questions. These products can lead to proposing an initial screening study and/or the development of a long-term monitoring and assessment program. There is broad consensus that existing monitoring and assessment approaches like EPA’s national probability survey are inadequate for meeting cyanotoxin response needs in California (Figure 5).

The recommendations made by participants in a discussion of a strawman screening survey fell mainly into two general categories:

- 1) Core issues to be immediately addressed by a statewide coordination strategy
- 2) Priorities and initial focus for a statewide screening approach.

Opinions differed widely on what an initial survey, if any, could and should accomplish. The limited amount of funding available for an initial effort (< \$500K from BOG/SWAMP) was seen as a constraint to planning a meaningful pilot monitoring study. Several suggestions were made for working within these constraints, such as identifying a high priority site (i.e., Pinto Lake) for piloting a sampling approach. Other participants suggested that large-scale approaches might be feasible if they employ inexpensive first-screen indicators, such as chlorophyll, inexpensive chemical analyses (i.e., ELISA³), or an initial review of available remote sensing data, which could then be followed up by targeted, more intensive sampling, if there is a potential problem.

Overall, the group emphasized the need to better address human health-related concerns (fishing, swimming, shellfish consumption), but impacts to wildlife and domestic animals (dogs, cattle) were also considered important. One of the identified priorities for future assessments was to better integrate information from environmental data collection efforts (i.e., ambient surface water monitoring) and human health tracking (such as the data available from CDC’s system). Several participants commented that monitoring should not be focusing solely on known problems (such as Pinto Lake) but also be planned to recognize problems that are currently being missed. Based on the input provided by participants, a monitoring program would be expected to:

³ Enzyme-linked immunosorbent assay (ELISA) is a test that uses antibodies and color change to identify a substance.

1. Be developed as an integral component of adaptive management of CyanoHABs (i.e., to provide actionable impact information). Monitoring and assessment would need to be linked with a health tracking system and a response program.
2. Assess the magnitude of the problem on a statewide scale, but also target water bodies that are either of particular concern or of heightened concern due to their popularity or significance for various uses (recreational, drinking water, wildlife, etc.). A synthesis of existing data will guide the scope, design, and approach of a monitoring and assessment program.
3. Select indicators, based on monitoring questions, from a long menu of options that range from rapid assessments (remote sensing, phycocyanin probes and other sensors) over first-screen indicators (chlorophyll a, algal abundance and species composition) to the determination of toxins (e.g., with passive samplers). For many indicators under consideration, management-relevant thresholds (water, fish, shellfish) still need to be developed.
4. Existing surface water monitoring programs could be leveraged to collect additional cyanotoxin data

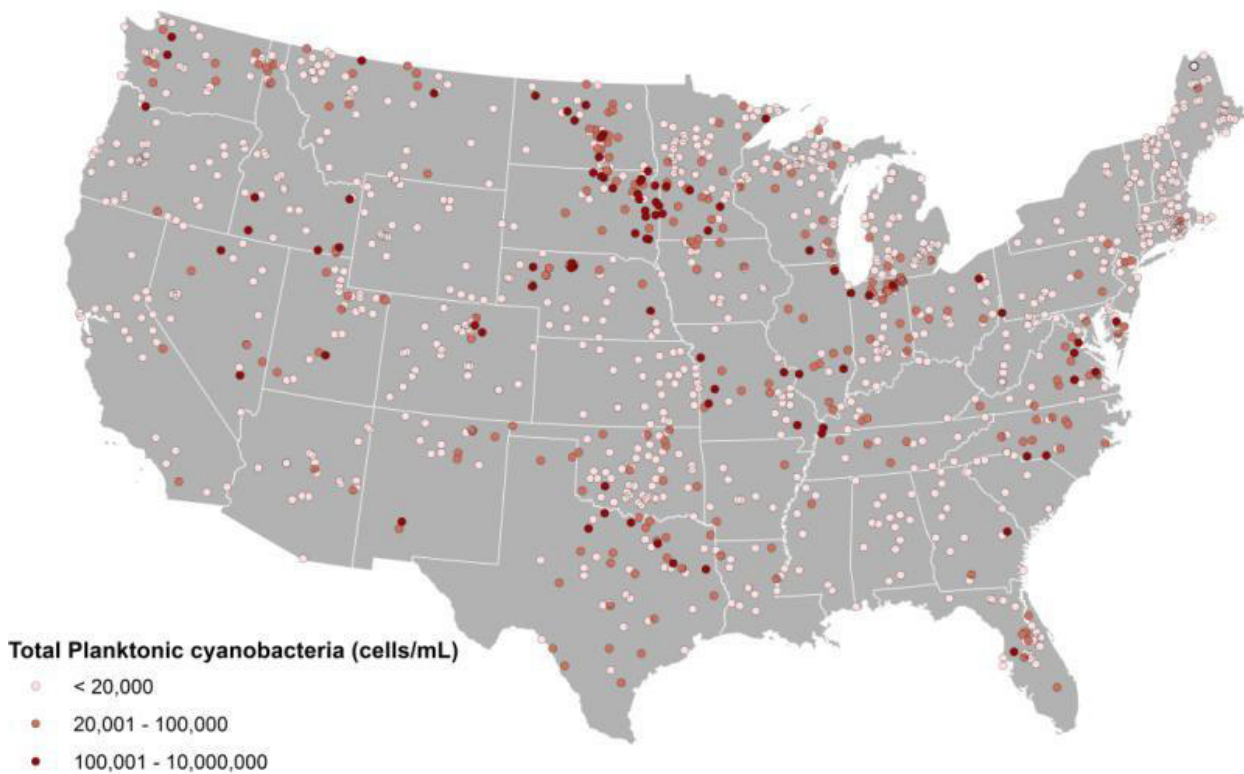


Figure 5. U.S. EPA's National Lakes Assessment (USEPA 2009) provides representative, actionable information that is collected in one day of sampling and compared against thresholds, but "misses" do not necessarily preclude the occurrence of a CyanoHABs at other times when the lake has not been sampled.

OVERALL RECOMMENDATIONS

While the development of a statewide screening study was touched on during the discussions of Day 2, the main emphasis was placed on the need for a more broad-based strategy for implementing a coordinated statewide network. What follows is a summary of recommendations for how to proceed, based on the group's discussions.

1. Develop a coordination strategy to provide the basis to address CyanoHAB related health and ecosystem impairments in California streams and rivers (including the Delta), lakes and reservoirs, and coastal waters. This coordination strategy should connect and engage the BGAWG, HABMAP, and the BOG. The new initiative will build on existing efforts to the extent possible.
2. Participants identified three milestones toward development of the strategy:
 - a. Identification and prioritization of the management questions, building on existing work on identifying management issues before and during the workshop.
 - b. A summary of existing monitoring efforts combined with a synthesis of existing cyanotoxin and supporting data. This information will be used to conduct a metadata analysis and support upcoming discussions about regional and statewide coordination, data integration, and funding.
 - c. Identification of existing tools, frameworks, and resources for sharing incident information and communicating HAB-related information to the public. This product will be helpful for understanding how CyanoHAB information can be better tracked and shared and more effectively reported.
3. Partnerships should be identified and developed to assure long-term funding and existing work by individual regions or agencies will be built on and enhanced. For example, the Klamath Basin Monitoring Program's HAB monitoring and research efforts may benefit from such a strategy and vice versa. A product of that partnership could be a statewide approach to assess and manage CyanoHABs that combines approaches for assessment (e.g, standardized methods) and response (e.g., response protocols).
4. Convene an expanded BGAWG under the umbrella of the California Water Quality Monitoring Council to tackle details of:

- Strategy development including the preparation of products describing: 1) existing data and gaps, and 2) available communication tools and incident tracking frameworks.
 - Management questions by identifying near-term policy actions of the various agencies responsible for CyanoHAB management.
5. Develop the communication component (i.e., reporting and outreach element) of the strategy, with an emphasis on building on existing communication resources, tools, and frameworks:
- a. Develop tools for use by resource managers, such as public response protocols, standardized sampling and analytical methods, and a web portal.
 - b. Learn from work done in other states, such as Florida, Oregon, and Washington. Particularly in Florida, much work has already been done regarding public health strategies, raising awareness about environmental issues related to HABs, exposure risk evaluations, potential exposure pathways, bloom reporting, communication strategies and response protocols, messaging, data exchange, and monitoring and forecasting cyanobacterial blooms.
 - c. Participants agreed that additional entities should be brought into the existing BGAWG group to provide the experience and knowledge needed to develop the approach and tools for the envisioned consolidation and reinvigoration of existing capabilities.
 - d. Improve public outreach concerning causes and consequences of CyanoHABs to increase public awareness and legislative support for CyanoHAB management.
6. The organization of new and/or expanded entities should be initiated by the BGAWG. Rather than depending on a single effort such as BGAWG or BOG, the development a long-term program would be shared among a coordinated statewide network of various groups.

NEXT STEPS

Workshop participants agreed that follow-up work should focus on developing a strategy for a coordinated statewide network within a year. Recommendation for immediate next steps include:

- Establish a steering group to guide further development of the strategy and coordinate with the HABMAP group.
- Determine membership for expanded workgroup and define scope of work for BGAWG (strategy development) and BOG (foundational work for strategy). Coordination of resources and activities is key.
- Compile and synthesize existing information and identify data gaps
- Review existing communication tools and frameworks for reporting incident information
- Identify and review existing communication tools and frameworks that could be built on or emulated (“steal from the best”) to improve data exchange, information access, and public outreach.
- Develop a framework for incident tracking that can be used and accessed by managers across the state.
- Begin developing a communications strategy.
- Begin developing public response protocols and standardizing analytical methods.

A limited amount of BOG monitoring funds could potentially be applied as seed funding to conduct some of this initial groundwork. However, funding and potential partnerships to support the long-term effort still need to be identified.

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APPENDIX A: DAY 1 PRESENTATIONS

National and Statewide Perspectives and Policies

1. “Freshwater cyanobacteria - a brief overview” (Susan Keydel, U.S. Environmental Protection Agency Region 9). Cyanobacteria can thrive in a wide range of conditions, including some that are less favorable to other types of algae, such as, for example, low temperature, low oxygen environments. Cyanotoxins include several categories of toxins, including dermatotoxins (lyngbyatoxin-a, aplysiatoxins, lipopolysaccharides), hepatotoxins (cylindrospermopsins, microcystins, nodularins), neurotoxins (anatoxins, β -N-methylamino-L-alanine or BMAA, neosaxitoxins, saxitoxins), and tastes and odors (geosmin, 2-methylisoborneol). There is no straightforward relationship between the occurrence of cyanobacteria and the presence of toxins, making testing necessary when blooms are present, to know what toxins are there. EPA’s critical information needs to protect human health include answers to the questions “what species are present?” and “what toxins are present?” CyanoHABs involve species that can fix nitrogen and thus are at an advantage in nitrogen-limited systems (Havens 2008). Designated uses affected by HABs include aquatic life (water quality, food web impacts), drinking water (impacted sources and required treatment), swimming (ingestion, inhalation, and dermal exposure), fishing, agriculture, and animal uses (wildlife, livestock, pets). The ability for better tracking where impacts are happening is a critical need. Techniques for communicating health issues in fun and accessible ways (e.g., Kansas uses Facebook postings) are helpful for reaching out to the general public. Posting warnings based on the likelihood of effects is also helpful. Oklahoma issues warnings based on the World Health Organization (WHO) Levels for Moderate and High Probability of Adverse Health Effects (MPAHEL/HPAHEL), i.e. $\geq 100,000$ cells/mL and/or ≥ 20 μ g/L microcystin. The State of Washington offers testing for waterbody samples.
2. “Investigating water quality problems created by cyanobacterial blooms in California: an overview of State Water Board activities 2006-2012” (Dominic Gregorio, State Water Resources Control Board). This presentation reviewed (1) how the statewide Blue-green Algae Working Group (BGAWG) evolved from collaborative efforts to address toxigenic CyanoHABs on Klamath River reservoirs; (2) the development of the voluntary BGAWG guidance manual (BGAWG 2010); (3) the status and results of recent and ongoing projects funded by the State Water Board; and (4) continuing information needs and priorities.
3. “Summary of findings from toxicological report and suggested action levels; public health perspective; critical data needs” (Regina Linville, OEHHA). This presentation suggested

that the CyanoHAB issue is not receiving all the attention it should be receiving, based on a risk assessment for six cyanotoxins found in California waters. The conclusion is based on new action levels for cyanotoxins developed by the California Office of Environmental Health Hazard Assessment (OEHHA) (Butler et al. 2012). These new action levels are health-protective chemical concentrations that are specific to people swimming in recreational waters, fishers eating sportfish and shellfish, and dogs or cattle drinking from water bodies or eating landed crusts and mats of cyanobacteria. The action levels are presented as a risk management tool and are not regulatory criteria. If exceedances are observed, the approach is to continue focused monitoring of the affected water body and take action as necessary. The reference doses and action levels presented in OEHHA's report may be informative in the development of regulatory criteria. The presentation emphasized that OEHHA's action levels do not apply to drinking water for humans.

Drivers and Consequences

4. "Understanding why cyanobacteria are successful: their ecological strategies, unintended consequences and monitoring considerations" (Barry Rosen, U.S. Geological Survey). The main reason for concern over cyanobacteria is their ability to produce toxins. The benefits of these toxins to cyanobacteria are not known, but several studies indicate that they could be serving as a chemical defense against predators, such as zooplankton (Haney 1987; Lampert 1987; Kurmayer and Jüttner 1999; Jang et al. 2007). The triggers of toxin production are also not well understood, and one of the questions remaining to be addressed is whether increasing temperatures will lead to an increase in the production of toxins during blooms. The presentation concluded with a plea for protective guidelines.
5. "Environmental factors driving bloom development and toxin production in California." (Alex Parker, San Francisco State University). The presentation showed results from an ongoing study of cyanotoxin production and the role of nutrients in the Sacramento-San Joaquin Delta (Delta). The study addressed two major questions: 1) "Are cyanobacteria favored at higher temperatures ("do cyanos like it hot")?" and 2) "How do nitrogen and phosphate availability and proportions in the Delta affect the development of cyanobacteria blooms?" Sampling locations were selected to include places that do not historically support cyanobacteria (e.g., Sacramento River at Rio Vista) as well as known "hotspots" for cyanobacteria (e.g., San Joaquin River at Antioch and Old River). The initial study results illustrate that the relationship between nutrient availability and cyanobacteria abundance is not straightforward: for example, one of the "hotspots" had relatively low nutrient concentrations overall, compared to other stations that had more nutrients and less cyanobacteria. Two known producers of cyanotoxins, *Microcystis*

aeruginosa and *Aphanizomenon flos-aquae*, were present in 25% and 64% of all samples taken in 2011. A site with particularly low chlorophyll concentrations (Mokelumne River) also had a particularly low proportion of cyanobacteria. A consistent pattern observed across all sites is that carbon uptake per cell (expressed as the “assimilation number”) decreases as the abundance of cyanobacteria increases. Another pattern observed is that there are dramatic increases in primary production at sites that support cyanobacteria, when there were increases in the photic zone (the part of the water column with enough light to allow photosynthesis)(see also Lehman et al. 2008). The presentation also covered preliminary results from nutrient addition experiments. The productivity in samples collected at Antioch increased by 250%, when ammonium was added. The growth in productivity by adding ammonium alone was higher than when any other single nutrient (nitrate, urea, phosphate) or any combination of nutrients was added.

6. “Effects of cyanotoxins on California wildlife and the land-sea connection” (Melissa Miller, DFG). Several groups of cyanotoxins are known to occur in California freshwaters, but communication obstacles, limited testing, and limited knowledge are currently hindering assessments of their impacts on wildlife. Diagnosing cyanotoxins as the cause of disease is daunting, due to the multitude of possible exposure routes for the different toxins and the lack of training for veterinarians. The presenter suggested that most cases of cyanotoxin poisoning in wildlife are probably missed, because cyanotoxins are not commonly monitored and investigated as a cause of disease. The presentation also covered a landmark investigation that implicated freshwater sources of microcystins in sea otter poisoning cases. In 2007, California Department of Fish and Game (DFG) staff began noticing stranded sea otters with jaundiced mucous membranes around Monterey Bay, and particularly near the mouth of the Pajaro River. Follow-up histopathological investigations revealed that these otters had severely damaged livers, and conversations with staff from the Regional Water Quality Control Board led to identifying microcystin-producing CyanoHABs in Pinto Lake, a reservoir on the Pajaro River, as a likely cause of the poisoning. The presentation concluded with a recommendation to improve monitoring by using a new tool—solid phase adsorption toxin tracking (SPATT)—as a generic indicator for the presence of cyanotoxins and follow-up testing of animals to identify high-risk areas.

Case Studies

7. “Klamath River case history” (Ken Fetcho, Yurok Tribe Environmental Program). The construction of nine major dams in the Klamath watershed has drastically altered the river and impacted living conditions in the Yurok reservation, which extends along the Lower Klamath River from the confluence with the Trinity River to its mouth. The Yurok have a

unique cultural relationship with the Klamath River and its salmon, and it is being affected by CyanoHABs. The presence of harmful algae impairs the use of the river by the Yurok for ceremonial and other purposes. In summer, dense algal blooms develop on Upper Klamath Lake, dominated by *Aphanizomenon*. In 2005, *Microcystis* was first detected in water samples from the Klamath River downstream of the lake. In response, the Yurok Tribe initiated a data collection effort to investigate the presence of microcystins in water and fish tissue samples. Fillets and livers of four Chinook salmon collected at the Yurok reservation and a fish hatchery (located upstream of the reservation but downstream of Upper Klamath Lake) did not contain any detectable amounts of microcystin. Fillet samples of two steelheads (one adult and one “half-pounder”) caught within the reservation also did not contain any detectable levels. However, liver samples from the adult steelhead contained trace amounts and liver samples from the juvenile specimen contained 54 µg/g (dry weight) microcystin. Stakeholders use conference calls that are held as part of the Public Utilities Commission’s Klamath Dam Removal Settlement to discuss whether to issue or lift advisory postings. The issuing and lifting of posting are equally important for ensuring the effectiveness of advisories.

8. “*Microcystis* in the Delta 2004 through 2008” (Peggy Lehman, California Department of Water Resources). Various environmental factors influence *Microcystis* blooms in the Delta, but flows are the one that can be best controlled. *Microcystis* in the San Francisco Estuary is actually two species, one in the freshwater portion and one in the marine portion of the estuary. Of each, there are several sub-species, which makes the evaluation of environmental factors complicated. Estuary scientists don’t see *Microcystis*, if light conditions are very low. The numbers of *Microcystis* generally increase, if there is more light in the system. *Microcystis* are most abundant in the San Joaquin and Old River portions, suggesting that flow management in this region is going to be a key factor affecting the distribution and abundance of *Microcystis* in the Delta.
9. “The prevalence of cyanotoxins in Southern California waterbodies” (Betty Fetscher and Meredith Howard, Southern California Coastal Water Research Project). Cyanotoxins are now viewed as “contaminants of emerging concern”, according to the SETAC 2012 national conference. In an initial study of Southern California waterbodies (including wetlands, lagoons, lakes, ponds, streams, rivers, estuaries, and seawater) in August 2009, all collected samples (100%) tested positive for the presence of three groups of cyanotoxins (microcystins, anatoxin-a, and lyngbyatoxin). In spring 2012, the SWAMP funded a probabilistic survey to assess the condition of depression wetlands in Southern California and this opportunity was used to obtain a grab sample from each site for a cyanotoxin analysis. Depression wetlands are typically shallow and conducive to the

growth of cyanobacteria. Microcystins were detected in about half of these samples (47%) and a small portion of the samples (5%) tested positive for saxitoxin. An ongoing pilot study is investigating the presence of cyanotoxins in wadeable streams, which may be particularly prone to cyanobacterial growth, when anthropogenic alterations cause modifications to hydrology and reduced riparian shading. Cyanotoxins are being investigated as a potential cause of “mystery toxicity”: toxicity of unknown causes that has been observed in the undeveloped and thus least impacted reaches of streams across Southern California.

Monitoring and Analytical Tools

10. “Tools for Field Monitoring: Solid Phase Adsorption Toxin Tracking (SPATT) and a few other methods” (Raphe Kudela, University California, Santa Cruz). SPATT is a passive sampling method that employs adsorbent resin sealed within a polyester mesh bag to accumulate algal toxins present in the water. One advantage of this method is that the absorbent resin can be varied, tested, and optimized to either selectively absorb lipophilic (lipid-loving) or hydrophilic (water-loving) toxins, or to pick up multiple toxins with a range of properties at once. Another advantage is that SPATT can integrate toxins over space by running water through the bag during cruises or through time by deploying SPATT bags over a period of time. The disadvantage is that the specific concentration of toxins in the water sampled cannot yet be back calculated. SPATT is best use as an inexpensive screening tool but it cannot replace other methods that measure the specific concentrations of toxins. If the goal is to evaluate whether toxin concentrations in water exceed regulatory limits for drinking water or recreational contact, many commercial kits and methods already exist to do this. Other methods such as remote sensing or hand-held fluorescence probes are promising and can provide rapid assessments of potential blooms.
11. “Florida public health protection strategies for cyanobacteria and their toxins” (Andy Reich, Florida Department of Public Health). Florida’s efforts are heavily concentrated on the public health concerns related to cyanotoxins and less so on the environmental aspects of CyanoHABs. There are no known impacts of freshwater HABs on species of concern such as the iconic manatee (whose biggest threats include Florida red tides, i.e., marine HABs, and boats). However, many environmental groups are using the public health information to raise awareness about environmental issues, since there is more and better information about the public health aspects of the issue than about environmental concerns. Numerous waterbodies in Florida where CyanoHABs occur are popular for swimming and other water-related recreational activities. Incidental ingestion is therefore the most common exposure pathway for cyanotoxins. Although previously

known from marine HABs, the inhalation of aerosols has been newly added to the list of potential exposure pathways. For example, helicopter pilots who are practicing landing maneuvers over some affected water bodies are considered at risk of inhaling cyanotoxins contained in spray that is being suspended by the rotating helicopter blades. The 67 county health departments lead the effort of getting information to the public. To reduce issues of conflicting messages between different agencies and ensure consistency, the Florida Department of Public Health (FDPH) has developed a letterhead template for standardized press releases by the counties. Advisories are usually issued before the results from toxin analyses come in and are therefore on the conservative side. Generally, Florida agencies are succeeding in being consistent with each other in their advisories (compare Fenech-Soler 2010 and Griggs 2010). The biggest challenges to the effectiveness of HAB advisories are issues of public perception and individual behavior. The approach taken by FDPH is to communicate a message of the importance of taking personal responsibility. The FDPH has also issued an animal safety card that targets an animal-loving audience of veterinarians, farmers, and pet owners (CDC 2010). The Florida Poison Information Center provides real-time access to its database. The Electronic Surveillance System for Early Notification of Community-based Epidemics (ESSENCE) is a web portal that allows querying three databases simultaneously for algal toxin-related illnesses. A cyanobacterial health bulletin summarizes satellite surveillance data and is sent out weekly. State agencies developed a technical report that provides information about HABs to public health employees (Abbott et al. 2009). Most of the public health protection strategies for HABs rely on collaboration with other agencies and outside funding, because no state funding has been made available to specifically address the issue. For example, current efforts to utilize satellite imagery for screening and to initiate follow-up if a HAB is detected are funded by the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA).

12. "Laboratory analysis of cyanotoxins" (David Crane, Cindy Tsai, and Abdou Mekebri; DFG and San Jose State University Research Foundation Fish and Wildlife Water Pollution Control Laboratory). There are more than 90 cyanotoxins known to exist, and their analysis is an active area of research. Toxin-producing genera generally produce more than one cyanotoxin. It is also not unusual to find several cyanotoxins (e.g., several microcystin congeners) in one sample. Analytical methods for most cyanotoxins are cost-prohibitive and, thus, low-cost screening methods are needed. Available analytical methods include the Protein Phosphatase Inhibition Assay (PPIA), which is very inexpensive, but not commercially available as a kit and not quantitative. There are at least two routinely used Enzyme Linked Immunosorbant Assay (ELISA) kits for microcystins and nodularin (Gurbuz et al. 2012). Disadvantages of the ELISA kits include false positives

and negatives, variable cross reactivity with different microcystin variants, and (sometimes severe) matrix interferences. The most reliable and sensitive analytical methods for microcystins are based on mass spectrometry, especially because its fragmentation is very specific and can be readily and reliably identified (Lawrence and Niedzwiadek 2001; Triantis et al. 2010). Comparisons of the results from microcystin analyses conducted with liquid chromatography tandem mass spectrometry (LC-MS/MS) and ELISA from samples obtained from Washington State were inconsistent, suggesting either false positives in the ELISA results or failure to detect unknown microcystins present in the sample by LC-MS/MS due to the lack of appropriate analytical standards.

13. "CyanoHAB management and monitoring in waters experiencing human and climatically induced environmental change: implications for California" (Hans Paerl, University of North Carolina, Chapel Hill). CyanoHABs are symptomatic of anthropogenic modifications of aquatic ecosystems. The presentation focused on a case study from Lake Taihu basin and other Chinese waterbodies that have been subject to massive alterations. The presentation suggested that the core of the problem in hypereutrophic lakes is that the nitrogen (N):phosphorus (P) nutrient balance is in excess to what is needed for balanced algal growth, as expressed by the Redfield ratio of 15:1 N:P. Based on in-situ experiments, both N and P inputs are excessive, but N is the truly limiting nutrient in the Taihu system (Xu et al. 2010). Based on nutrient enrichment experiments (bottle bioassays, mesocosms, whole lakes) for lakes from all parts of the world, N limitation is globally as common as P limitation, and addition of both nutrients combined are generally resulting in the largest responses of growth. Thus, both N and P need to be dealt with in order to restore eutrophic systems (Lewis et al. 2011). A conceptual model of nutrient input-bloom thresholds that takes climate change into consideration has been developed and needs to be tested (Paerl and Scott 2010). Chlorophyll levels are a first screen indicator for the presence of algal toxins. *Microcystis* is the dominant organism in Lake Taihu and its abundance correlates well with nutrient and chlorophyll levels.

APPENDIX B: STRAWMAN MANAGEMENT QUESTION

Management Question	No.	Monitoring Question	Relevant Beneficial Uses	Target Population	Survey/ Study Design	Matrices	Analytes	Type of samples	Frequency of sampling
What is the overall scope of the cyanotoxin problem in California fresh water bodies?	A	Which water bodies exceed available thresholds for cyanotoxins?	recreation, fishing, drinking water	lakes and reservoirs, rivers and streams	Targeted	water; sport fish and shellfish (subset); SPATT (subset)	microcystin, anatoxin-a, cylindrospermopsin	water grabs, fish and shellfish composites, time-integrated SPATT	2 visits per water body
	B	What percentage of water bodies exceed available thresholds for cyanotoxins?	same as above	same as above	Probabilistic	same as above	same as above	same as above	same as above
	C	(Secondary) What is the potential risk to humans, aquatic life, wildlife and domestic animals from living in, swimming in, drinking, or consuming fish or shellfish from this water body?	same as above	same as above	Targeted/ Probabilistic	same as above	same as above	same as above	same as above
	D	(Secondary) Do spatial patterns indicate particular regions of concern?	same as above	same as above	Targeted/ Probabilistic	same as above	same as above	same as above	same as above

Strawman management question translated into four specific monitoring questions. This is one of many strawman management questions that were developed in preparation of the workshop, based on known policy questions and data needs.