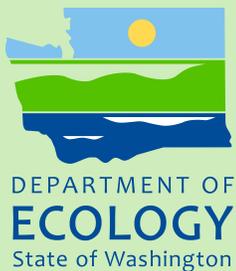




Freshwater Algae Control Program

Report to the Washington State Legislature
(2008-2009)



December 2009
Publication No. 09-10-082

Publication and Contact Information

This report is available on the Department of Ecology's website at <http://www.ecy.wa.gov/biblio/0910082.html>

For more information contact:

Water Quality Program
P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360-407-6600

Washington State Department of Ecology - www.ecy.wa.gov

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Yakima 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Cover Photo: Blue-green algae bloom on Waughop Lake, a popular dog-walking venue located in Fort Steilacoom Park. Photograph by Don Russell

To ask about the availability of this document in a format for the visually impaired, call the Water Quality Program at 360-407-6600. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.

Freshwater Algae Control Program

Report to the Washington State Legislature (2008-2009)

*by
Kathy Hamel*



Blue-green algae bloom on Lake Steilacoom, Pierce County. Photo Don Russell

Water Quality Program
Washington State Department of Ecology
Olympia, Washington

This page is purposely left blank

Table of Contents

Table of Contents	iii
List of Figures and Tables.....	iv
Figures.....	iv
Tables.....	iv
Acknowledgements.....	v
Introduction.....	1
Harmful algae blooms.....	4
Why are Ecology and the Legislature concerned about toxic blooms?.....	4
Why does Ecology pay for testing of blue-green algae blooms for toxins?.....	6
How Ecology’s Freshwater Algal Identification and Toxicity Testing Program works	9
Recreational Guidance	11
Freshwater Algae Control Toxicity Testing and Algal Identification (2008-2009)	13
Identification.....	13
2008 Toxicity testing	13
2008 Microcystins	13
2008 Anatoxin-a	15
2009 Toxicity testing	16
2009 Microcystins	16
2009 Anatoxin-a	18
2009 Illness reports.....	19
Case studies.....	20
Waughop Lake, Pierce County.....	20
Anderson Lake, Jefferson County	22
What do toxicity results mean?	24
Algal Identification and Toxicity Testing Program Limitations	24
Other issues	25
Freshwater Algae Control Grant Program	26
Grant program overview	26
Completed grant projects	27
Active grant projects.....	28
New Freshwater Algae Initiatives.....	30
Grant opportunities	30
Fish tissue study.....	31
Freshwater Algae Control Program Contacts	31

List of Figures and Tables

Figures

Figure 1. Bloom samples per month.....	2
Figure 2. Three-tiered management approach to toxic blue-green algae blooms.....	12
Figure 3. Percentage of blue-green genera identified in algal samples since program inception.	13
Figure 4. Water bodies tested for microcystin in 2008.....	14
Figure 5. Water bodies tested for anatoxin-a in 2008.....	15
Figure 6. Water bodies tested for microcystin in 2009.....	17
Figure 7. Water bodies tested for anatoxin-a in 2009.....	18

Tables

Table 1. Blue-green algae toxins and the target organ in mammals.	5
Table 2. Comparison of blue-green algae toxins to the toxicity of other known poisons	7
Table 3. Water bodies tested for algal toxins.....	8
Table 4. Lakes with highest microcystin concentrations in 2008.....	14
Table 5. Lakes with highest anatoxin-a concentrations in 2008.....	15
Table 6. Lakes with highest microcystin concentrations in 2009.....	17
Table 7. Lakes with highest anatoxin-a concentrations in 2009.....	18
Table 8. 2008 and 2009 microcystin concentrations in Waughop Lake.....	21
Table 9. 2008 and 2009 microcystin and anatoxin-a concentrations in Anderson Lake	23

Acknowledgements

The author of this report would like to thank the following people/entities for their contribution to this report:

- Dr. F. Joan Hardy at the Washington State Department of Health for her technical expertise, review, and editing.
- King County Environmental Laboratories for laboratory analysis and timely turnaround of samples.
- Local government samplers and lake residents who reported blooms and sampled blooms for the Freshwater Algae Control Program.
- Melanie Tyler, Diane Smith, and Duane Weaver for review and editing.
- Jocelyn Winz and Kelsey Highfill for editing and formatting the final report.
- Jon Jennings for map production.
- Tricia Shoblom for data entry and laboratory liaison.



**Blue-green algae bloom on Wapato Lake in Tacoma.
Photo: Lindsay Tuttle**

Introduction

This report summarizes activities of the Freshwater Algae Control Program for 2008-2009. The statute establishing the program (RCW 43.21A.667) *directs Ecology to submit a biennial report to appropriate legislative committees describing the actions taken to implement this section along with suggestions on how to better fulfill the intent of chapter 464, Laws of 2005. The first report is due December 1, 2007.*



**Lake Ketchum blue-green algal scum.
Photo: Marisa Burghdoff**

The Washington State Legislature established funding for this program in 2005 and directed the Washington State Department of Ecology (Ecology) to focus attention on *harmful freshwater algae*. Harmful algae are blue-green algae (also known as cyanobacteria) that can occur in dense populations called blooms. Blue-green algae blooms sometimes look like a green, blue, or even a white paint spill, and their appearance is alarming to the public and lake residents.

Blue-green blooms are harmful because some species produce potent toxins that can cause human illness and kill pets and livestock. Even when not producing toxins, blue-green blooms are distressful to lake residents and users because they are unsightly, smelly when decomposing, affect recreational use, and can create economic losses to lake-based businesses.

Blue-green algae blooms typically occur when plant nutrients such as phosphorus and nitrogen are in plentiful supply in the water. Some blue-green species even have the ability to acquire nitrogen directly from the atmosphere through specialized cells. These nitrogen-fixing species sometimes have a competitive advantage over other algae. Plant nutrients enter the water through point and nonpoint pollution such as stormwater inputs, agricultural runoff, and urban land use practices. Sediments may also release nutrients into the water when they become low in oxygen. This is called internal nutrient loading.

Factors such as light, temperature, and zooplankton grazing can influence blue-green algae bloom formation. In Washington, blue-green blooms happen at all times of the year, although

most blooms occur during the summer and fall (Figure 1). The best long-term solution for preventing blue-green blooms is to reduce nutrient inputs from both external and internal nutrient sources.

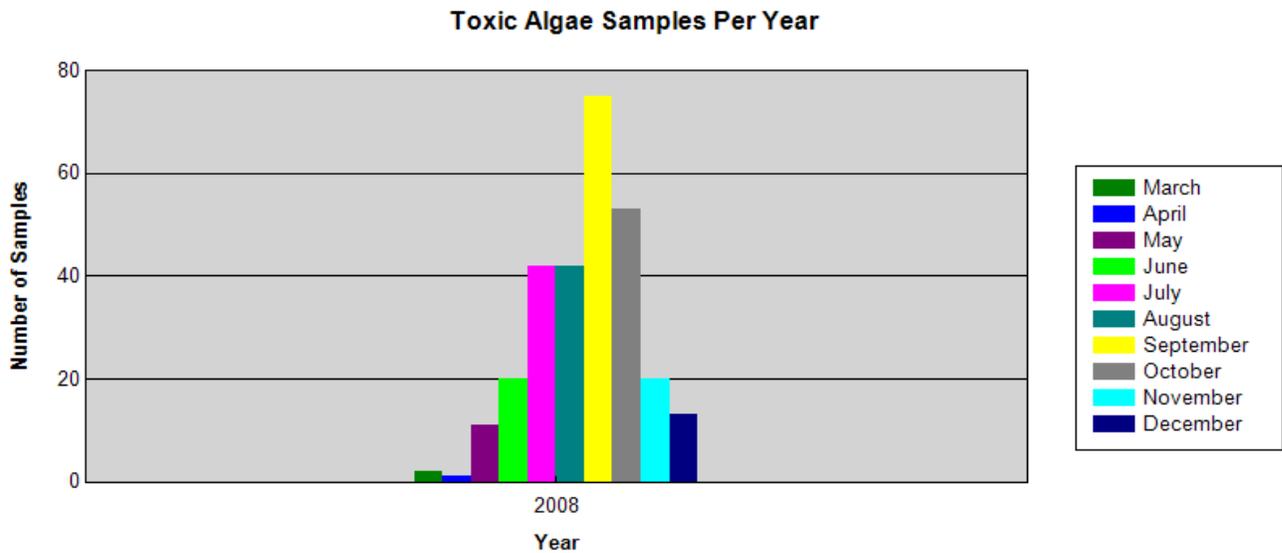


Figure 1. Bloom samples per month

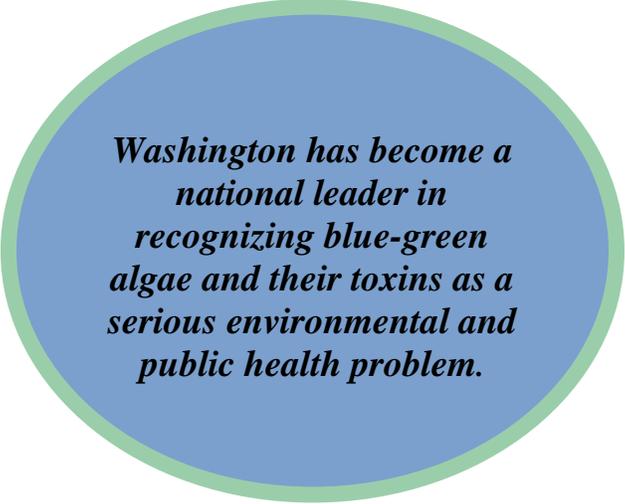
Elements of the Freshwater Algae Control Program include:

- A grants program that funds freshwater algae projects with priority going to projects dealing with harmful algae blooms (HABs).
- Toxicity testing of blue-green algae blooms. Ecology funds testing for two common algal toxins - microcystin and anatoxin-a.
- Identification of bloom-forming algae in Washington's lakes, ponds, and rivers.
- A searchable on-line database for the public to view algal identification and toxicity testing results for Washington freshwaters.
- A freshwater algae electronic mailing list.
- Partnership with the Washington State Department of Health (DOH) for health-related questions about algal toxicity, development of recreational guidelines for toxic algae blooms, and development of warning signs and educational materials.
- Ecology and DOH websites with information about freshwater algae, management methods, and human and pet health risks from toxic blue-green algae blooms.

Program funding comes from vessel registration fees (RCW 88.02.045). One dollar of each vessel registration fee is deposited into the Freshwater Aquatic Algae Control Account. This generates approximately \$500,000 per biennium for the Freshwater Algae Control Program. The legislature appropriates these funds to Ecology to manage the program.

Ecology typically offers approximately \$150,000 annually to state and local governments in the form of grants for freshwater algae projects. Ecology awarded funding to local governments experiencing problems with toxic algae for nine grant projects during 2008 and 2009.

Ecology budgets about \$50,000 per year for laboratory costs for algal identification and toxicity testing. Remaining funds pay for staff time for algae program grant administration, technical assistance, reporting, and data entry.



Washington has become a national leader in recognizing blue-green algae and their toxins as a serious environmental and public health problem.

Harmful algae blooms

Why are Ecology and the Legislature concerned about toxic blooms?

Toxic blue-green blooms are emerging as a state, national, and international public health issue. Headlines in the New York Times (10/14/07) described a toxic bloom in a lake in China that affected drinking water for more than two million people. Nationally, the Centers for Disease Control and Prevention (CDC) established a surveillance system to track toxic blooms, human illnesses, and animal deaths associated with biotoxins. In 2008, 75 percent of the blooms analyzed for algal toxins in Washington produced toxins. By establishing a state freshwater algal identification and toxicity-testing program, Washington has become a national leader in recognizing blue-green algae and their toxins as a serious environmental and public health problem.

Playing, wading, swimming, or water skiing in lakes with toxic blue-green algae blooms can expose humans to toxins. Some residents use lake water as a drinking source, and these people may ingest algal toxins. Human health effects from these toxins are diverse and may include skin rashes and lesions, vomiting, gastroenteritis, conjunctivitis, headaches, and eye, ear, and throat irritations.

Exposure to neurotoxins can result in more severe symptoms. Depending upon the size of the person or animal, type of toxin, and amount of toxin consumed, neurotoxins may cause staggering, loss of muscle coordination, difficulty swallowing, labored respiration, complete muscle paralysis, and death. Humans may also experience tingling around the mouth and fingertips as well as slurred speech. Some blue-green algae genera can produce more than one type of toxin (Table 1).



Decomposing blue-green bloom in Tempo Lake. Photo Rob Banes

Table 1. Blue-green algae toxins and the target organ in mammals. ¹

Toxin Group	Primary Target Organ in Mammals	Blue-green Algae Genera Known to Produce Toxin
Microcystins* (Most commonly detected freshwater algal toxin)	Liver	<i>Microcystis, Anabaena, Planktothrix (Oscillatoria), Nostoc, Hapalosiphon, Anabaenopsis</i>
Anatoxin-a* (Second most commonly detected freshwater algal toxin)	Nerve synapse	<i>Anabaena, Planktothrix (Oscillatoria), Aphanizomenon</i>
Cylindrospermopsins (One detection in Washington's freshwaters)	Liver	<i>Cylindrospermopsis, Aphanizomenon, Umezakia</i>
Saxitoxins (Causes paralytic shellfish poisoning in marine waters – uncommon in freshwaters, but detected in Waughop Lake in Pierce County in 2009)	Nerve axons	<i>Anabaena, Aphanizomenon, Lyngbya, Cylindrospermopsis</i>

* Ecology tests for these algal toxins in Washington blooms. Cylindrospermopsins and saxitoxins are being tested in 30 lakes in Pierce, King, and Snohomish County lakes under a grant between DOH and the Centers for Disease Control and Prevention.

¹ Table Modified from: WHO. 1999. *Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring and management*. Edited by Ingrid Chorus and Jamie Bartram. E & FN Spon. London and New York.



Hunting dogs are often exposed to blue-green toxins.
Photo: Joan Hardy

People are particularly concerned about the deaths of family pets (dogs and cats), but wildlife, waterfowl, and fish have also died after exposure to toxic blue-green algae blooms. Several years ago, thousands of young trout died in net pens in Lake Lawrence, Thurston County during a blue-green bloom. Washington State Department of Fish and Wildlife attributed that fish kill to either a lack of oxygen resulting from algal decomposition or possibly algal toxins. In late

2007, veterinarians reported that two hunting dogs died in separate incidents after swimming in Potholes Reservoir in eastern Washington. That bloom tested toxic. In earlier years, both dogs and cats have died after exposure to toxic blooms in other Washington lakes (Anderson Lake, Lake Steilacoom, Liberty Lake, Lake Sammamish, and American Lake).

The Department of Health is currently working with veterinarians to help them recognize symptoms of blue-green algae poisoning and report suspected incidents to the state. DOH is also investigating a number of human illnesses that occurred after people swam in lakes with toxic algae. An incident at Silver Lake in Cowlitz County in July 2009 involved four humans and two dogs becoming ill after swimming in the lake. Silver Lake, described as pea soup green by local residents, had detectable levels of the algal toxin microcystin in the water at that time. In August 2009, workers in Grant County developed severe rashes following exposure to an algal scum in a Columbia River backwater. Other 2009 human and animal incidents are under investigation.

Why does Ecology pay for testing of blue-green algae blooms for toxins?

Lake residents request information about whether blue-green algae blooms occur in their lakes, pond, and rivers and want to know whether it is safe for them or their pets to swim in or drink the water. Citizens and local health districts need to know if a bloom is producing toxins and at what concentrations. The public often seeks advice from local health authorities and environmental agencies about what actions to take if a toxic bloom occurs.

Laboratory tests are the only way to tell if a blue-green algae bloom is producing toxins.

Laboratory tests are the only way to tell if a blue-green algae bloom is producing toxins. Because a single species of blue-green algae can have toxic and non-toxic strains, the toxicity of a bloom

is not possible to predict based solely on algal identification or visual assessment. Further, a bloom that is not toxic one day may become toxic the next. Blue-green blooms often contain several genera of algae capable of producing toxins. Algal toxins can be more toxic than some poisons more familiar to the public (Table 2).

Table 2. Comparison of blue-green algae toxins to the toxicity of other known poisons²

Algal Toxins	LD ₅₀ µg/kg*	Known Poisons	LD ₅₀ µg/kg*
Saxitoxin	9	Ricin	0.02
Anatoxin-a (s)	20	Cobra toxin	20
Microcystin LR	50	Curare	500
Anatoxin-a	50	Strychnine	2000

* LD₅₀ = Lethal dose 50% - The dose of toxin that kills 50 percent of a test population. The lower the number, the stronger the toxin.

Washington’s Freshwater Algal Identification and Toxicity Testing Program provides timely information about:

- Washington lakes, ponds, and rivers experiencing algae blooms.
- Time of year that the blooms occur.
- Duration of the bloom.
- Type of algae (species/genera) in a water body during an algal bloom.
- Toxin concentrations. Microcystin concentrations are measured for all samples; anatoxin-a concentrations are determined from bloom samples containing species capable of producing this toxin.
- Actions that local health authorities take to protect human health.



Aerial view of a blue-green bloom on Liberty Lake near Spokane. Photo: Liberty Lake Water and Sewer District

² **Table Modified from:** Carmichael. 2008. AWWA Webcast Program. *Harmful Algal Blooms: Cyanobacteria and their Toxins.*

Since program inception, water bodies from 22 counties have been tested for algal toxins (Table 3).

Table 3. Water bodies tested for algal toxins. *The water bodies in bold text had detectable toxin concentrations.*

County	Water Bodies Tested
Clallam	Sutherland Lake
Clark	Vancouver, Round
Cowlitz	Horseshoe, Silver Lakes
Douglas	Jameson and Hammonds Lake
Grant	Potholes Reservoir and Columbia River
Grays Harbor	Aberdeen, Duck, Fake, Silvia Lakes
Island	Cranberry, Honeymoon, Lone, and Goss Lakes
Jefferson	Anderson, Leland, Gibbs, Teal Lakes
King	Beaver, Bellevue, Cottage, Desire, Echo, Green, Hicks, Lorene, Marcel, Phantom, Sawyer, Shadow, Spring, Steel, Tuck, Union, Walker, Washington, Wilderness Lakes, French Creek
Kitsap	Kitsap, Long, Wildcat, and Horseshoe Lakes, Kitsap Creek
Kittitas	Fiorito Lake, Rowland Lake
Klickitat	Columbia River
Lewis	South County Park Pond
Mason	Fawn and Lost Lakes
Okanogan	Lake Roosevelt, Palmer Lake
Pierce	American, Armstrong, Bay, Clear, Harts, Lower Twin, Ohop, Palmer, Silver, Spanaway, Steilacoom, Tanwax, Tule, Wapato, Waughop Lakes, Bresman Pond, Chambers Creek, Morey Creek
Skagit	Cavanaugh Lake
Snohomish	Ballenger, Blackmans, Cassidy, Chain, Ketchum, Loma, Lost, Martha, Stevens, Sunday Lakes
Spokane	Liberty, Medical, and Newman Lakes
Stevens	Black Lake
Thurston	Lawrence, Scott, St. Claire, Tempo Lakes
Walla Walla	Graybill Pond

Ecology contracted with a local laboratory, King County Environmental Laboratories (KCEL) for algal identification and toxicity testing. KCEL is experienced with analyzing toxins from blue-green algae blooms. The laboratory identifies algae to the genus level and notes the dominant and sub-dominant genera in the sample. The laboratory analyzes water samples for microcystins and anatoxin-a. These two groups of algal toxins are generally of greatest concern for human health, are the toxins most associated with pet and livestock deaths, and are the most commonly occurring freshwater algal toxins worldwide.

How Ecology's Freshwater Algal Identification and Toxicity Testing Program works

- If a lake resident, government staff, lake manager, or a health professional thinks a lake is experiencing an algal bloom, they contact Ecology. Ecology personnel ask them to describe the bloom and may direct them to a website with bloom photographs.

<http://www.ecy.wa.gov/programs/wq/plants/algae/monitoring/AlgaeBlooms.html>. (Sometimes lake residents may confuse pollen or even silt in the water for an algae bloom.)

- If Ecology decides that a bloom is likely occurring, staff explain how to collect and mail samples to the laboratory. Ecology discourages people from sending in filamentous green algae samples because these algae are harmless.



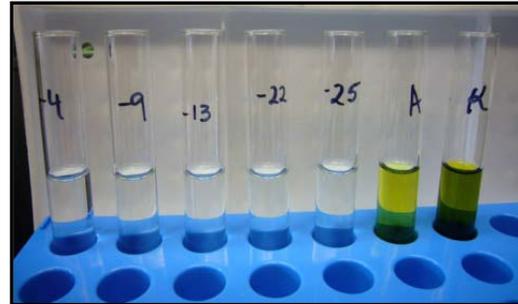
Ecology sampling kit. Photo: Jon Jennings

- Most often, staff from the local health jurisdiction collect and send in the sample. However, Ecology can send lake residents a sampling kit with sampling instructions so that they can sample the lake. A sampling kit includes an amber glass bottle, an ice pack, mailing labels, and a Styrofoam shipping container (see photograph).

In some lakes, sample collection can continue for months due to high levels of toxicity and prolonged blue-green blooms.

- Because blue-green algal bloom distribution is often patchy within a lake, Ecology prefers that people collect samples from areas where algal scum collects, when possible.
- The sample is kept on ice before it is shipped to the laboratory (one-day delivery).
- When the sample arrives at the laboratory, scientists take a subsample and identify the algae. They freeze the rest of the sample to break open cells to release any toxins. They then analyze for microcystin using an enzyme-linked immunosorbent assay (ELISA) test.
- The laboratory handles anatoxin-a samples somewhat differently. Depending on bloom density, they may ask the sampler to collect up to several liters of water. Because of higher costs and difficulty of analysis, they only analyze a subset of samples for anatoxin-a each year. The laboratory uses a high-pressure liquid chromatography method to analyze for anatoxin-a.
- If the bloom is toxic—or if potentially toxin-producing blue-green algae are present—Ecology asks samplers to collect additional samples (generally on a weekly basis) for toxicity testing. In some lakes, sample collection can continue for months due to high levels of toxicity and prolonged blue-green blooms.

- Ecology also asks samplers to collect samples from lakes with toxic blooms for two weeks after the bloom subsides. As blooms die and decay, they often release toxins into the water that may persist even though the blue-green algae bloom is no longer visible.
- Laboratory turn-around time for algal identification and microcystin testing is rapid (generally three days). Anatoxin-a testing takes a week or more.
- The laboratory e-mails an Excel spreadsheet with results to Ecology, DOH, and the local health district (if they collected the sample). If a lake resident sent in the sample, Ecology notifies the resident, and, if the bloom is toxic, notifies the appropriate local health authorities.
- Within days of receiving the information, Ecology posts all results to a searchable, on-line, publicly accessible database at <https://fortress.wa.gov/ecy/toxicalgae/InternetDefault.aspx>.
- Ecology also posts all toxic blue-green algae results to its freshwater algae electronic mailing list if the sample tests at or above the recreational guidelines for that toxin. Join the electronic mailing list at <http://www.ecy.wa.gov/PROGRAMS/wq/plants/algae/ListServe.html>.
- The local health authority—not the state—determines what actions, if any, are taken to protect human health from algal toxins. Actions range from no action, recreational advisories, recreational closures, to closure of the entire water body for all activities. Ecology posts the actions taken by the local health authority on its on-line database.



Colorimetric testing for algal toxins.
Photo: Gabriela Hannach

*The local health authority
 —not the state—
 determines what actions, if
 any, are taken to protect
 human health from algal
 toxins.*

Recreational Guidance

Recreational guidance levels for toxic blue-green algae blooms

Under an interagency agreement with Ecology using Freshwater Algae Control Program funds, DOH developed a statewide strategy to assist local health authorities to decide:

- What toxin concentrations trigger actions to protect human health.
 - DOH established Washington's provisional recreational guidance value for microcystin at 6 µg/L
 - Washington's provisional recreational guidance value for anatoxin-a is 1 µg/L.
- What actions are appropriate to implement in water bodies experiencing toxic algae blooms.

In addition to developing recreational guidance levels for microcystin and anatoxin-a, DOH identified events that trigger health advisories or lake closures and produced signs suitable for posting at affected lakes. DOH makes these signs available to local health districts.

DOH developed a three-tiered lake management protocol to deal with toxic blooms (Figure 2). Different management tiers call for posting different signs.



**Duck Lake blue-green bloom.
Photo: Eric Khambatta**

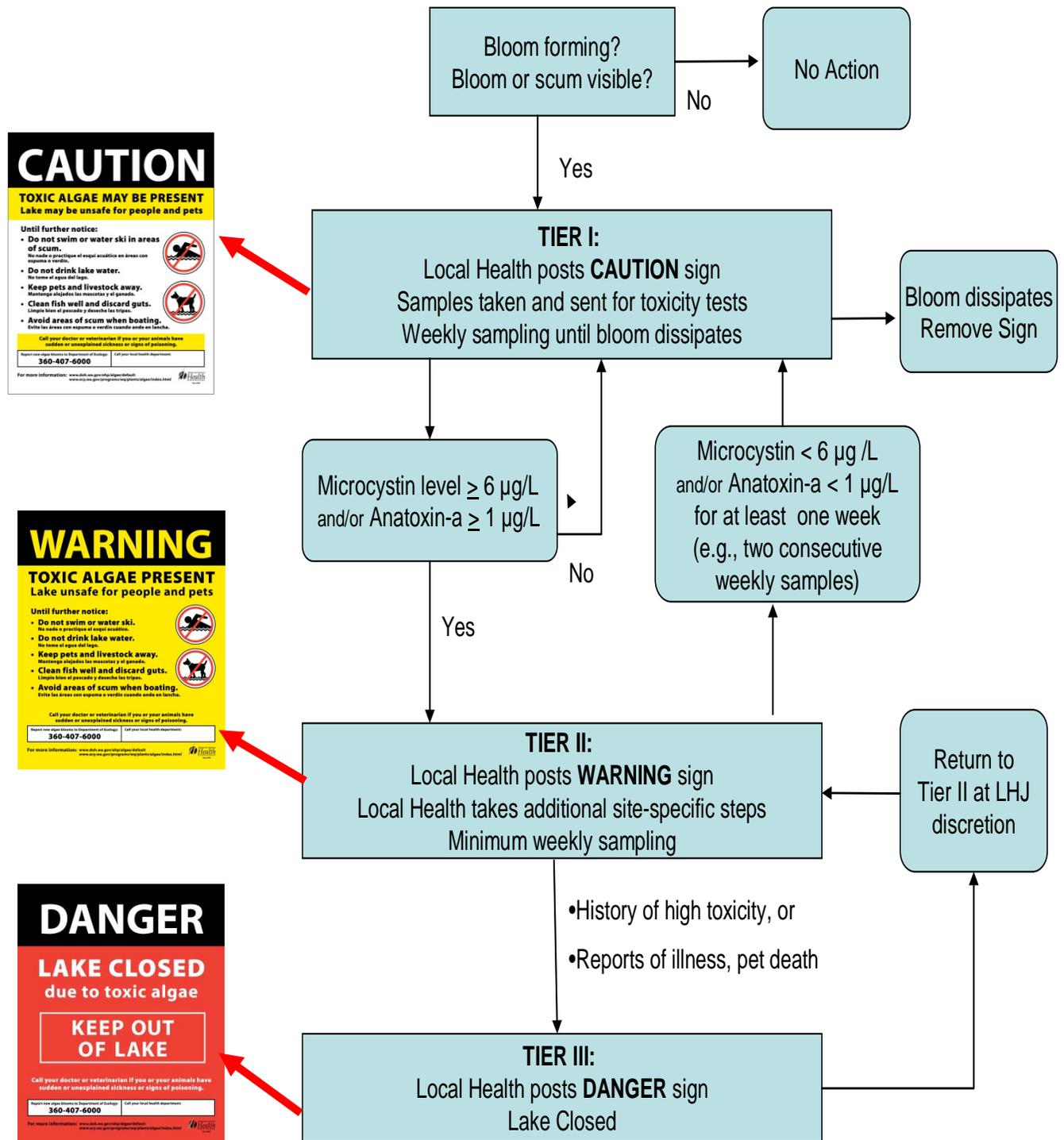


Figure 2. Three-tiered management approach to toxic blue-green algae blooms.

Freshwater Algae Control Toxicity Testing and Algal Identification (2008-2009)

Washington lakes produce a significant number of toxic blue-green algae blooms with some blooms producing toxins at extremely high concentrations. Several blooms have continued for very long periods (years).

Identification

Ecology asks samplers to collect blue-green algae scum samples. Most algal scums are composed of several genera of blue-green algae, including *Anabaena*, *Microcystis*, *Aphanizomenon*, *Oscillatoria*, *Lyngbya*, and *Gleotrichia* (Figure 3). *Woronichinia* is not known to produce toxins, although it seems to occur during many toxic blooms. Most times, blooms have several potentially toxic genera appearing in the same sample.

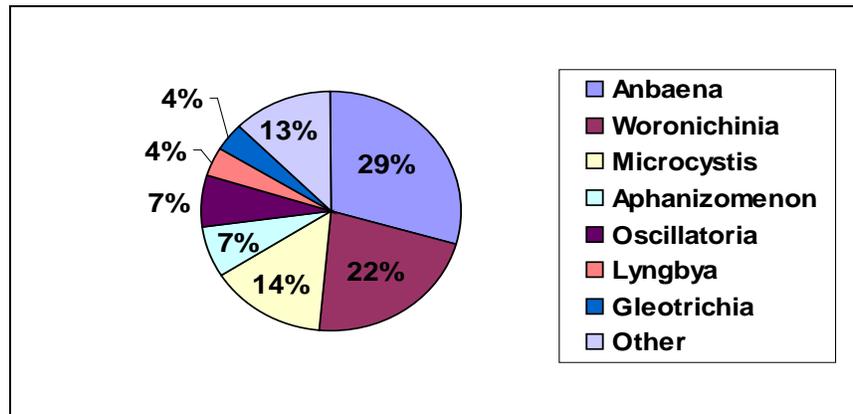


Figure 3. Percentage of blue-green genera identified in algal samples since program inception.

2008 Toxicity testing

In 2008, samplers collected bloom samples from 53 water bodies in 17 counties for algal identification and blue-green algae toxin testing. Depending on the lake and bloom conditions, many lakes were sampled multiple times to track the progress of each bloom.

2008 Microcystins

Of the 53 lakes tested for microcystin, 40 lakes had detectable concentrations $> 0.05 \mu\text{g/L}$ (75%), 18 lakes had levels over the state recreational guidance level of $6 \mu\text{g/L}$ (34%), and 14 lakes had levels higher than $50 \mu\text{g/L}$ (26%). See Table 4. The highest microcystin concentration detected in 2008 was $4,620 \mu\text{g/L}$ from Ohop Lake in Pierce County. Water bodies were sampled in most

parts of the state. The map below shows the locations and relative toxicities of the lakes sampled for microcystin in 2008 (Figure 4).

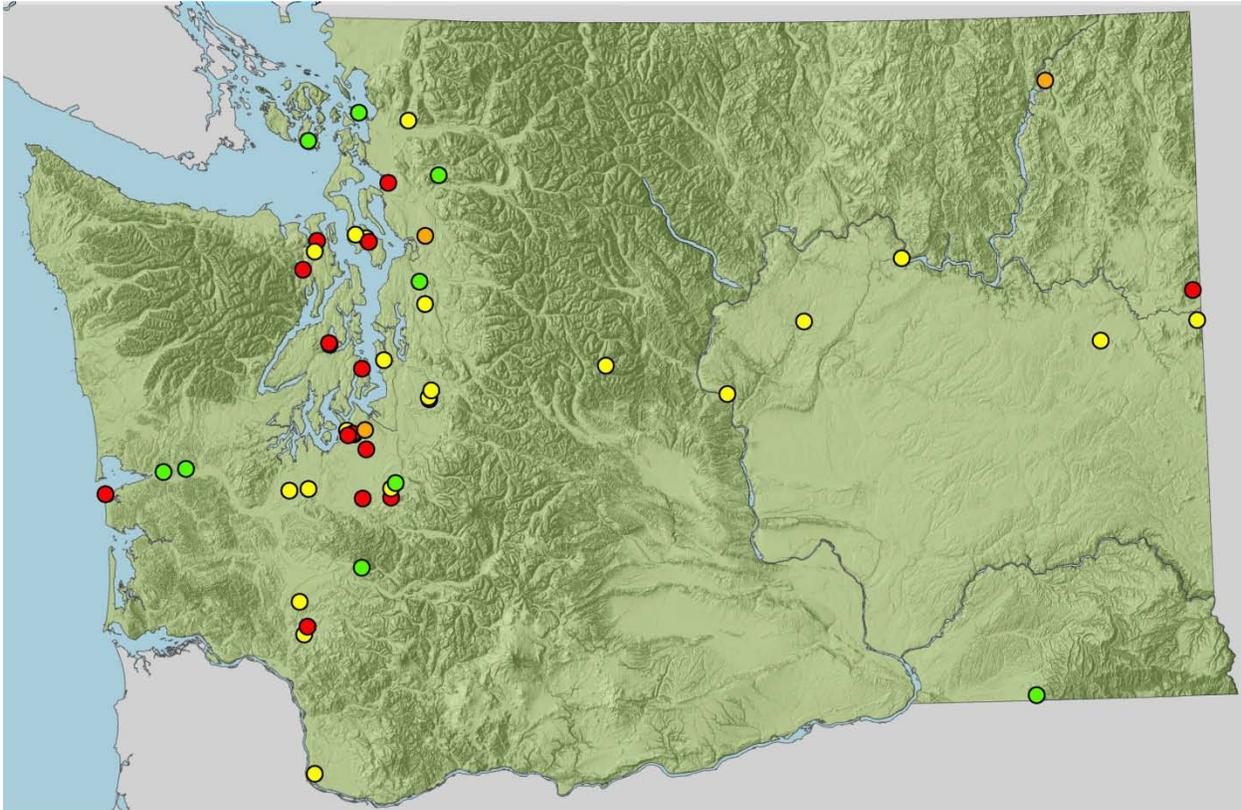


Figure 4. Water bodies tested for microcystin in 2008.

Green: no detection; Yellow: concentrations under 6 µg/L; Orange: 6-50 µg/L; Red: > 50 µg/L

Table 4. Lakes with highest microcystin concentrations in 2008

Lake and County	Microcystin Concentration µg/L	Lake and County	Microcystin Concentration µg/L
Ohop Lake, Pierce	4,620.00	Harts Lake, Pierce	334.00
Anderson Lake, Jefferson	3,120.00	Newman Lake, Spokane	191.00
Waughop Lake, Pierce	1,050.00	Leland Lake, Jefferson	191.00
Tuck Lake, King	813.00	Fake Lake, Grays Harbor	119.00
Spanaway Lake, Pierce	628.00	Lone Lake, Island	107.00
Steilacoom Lake, Pierce	594.00	Kitsap Lake, Kitsap	77.70
Ketchum Lake, Snohomish	416.00	Bay Lake, Pierce	62.60

2008 Anatoxin-a

Of the 24 lakes tested for anatoxin-a in 2008, 18 lakes had detectable levels of anatoxin-a (75%) and 7 lakes had levels over the state recreational guidance level of 1 µg/L (29%). See Table 5. The highest anatoxin-a concentration detected was 172,640 µg/L in Anderson Lake in Jefferson County. This is one of the highest anatoxin-a concentrations detected worldwide!

The map below (Figure 5) shows the locations and the relative toxicities of the lakes sampled for anatoxin-a in 2008.

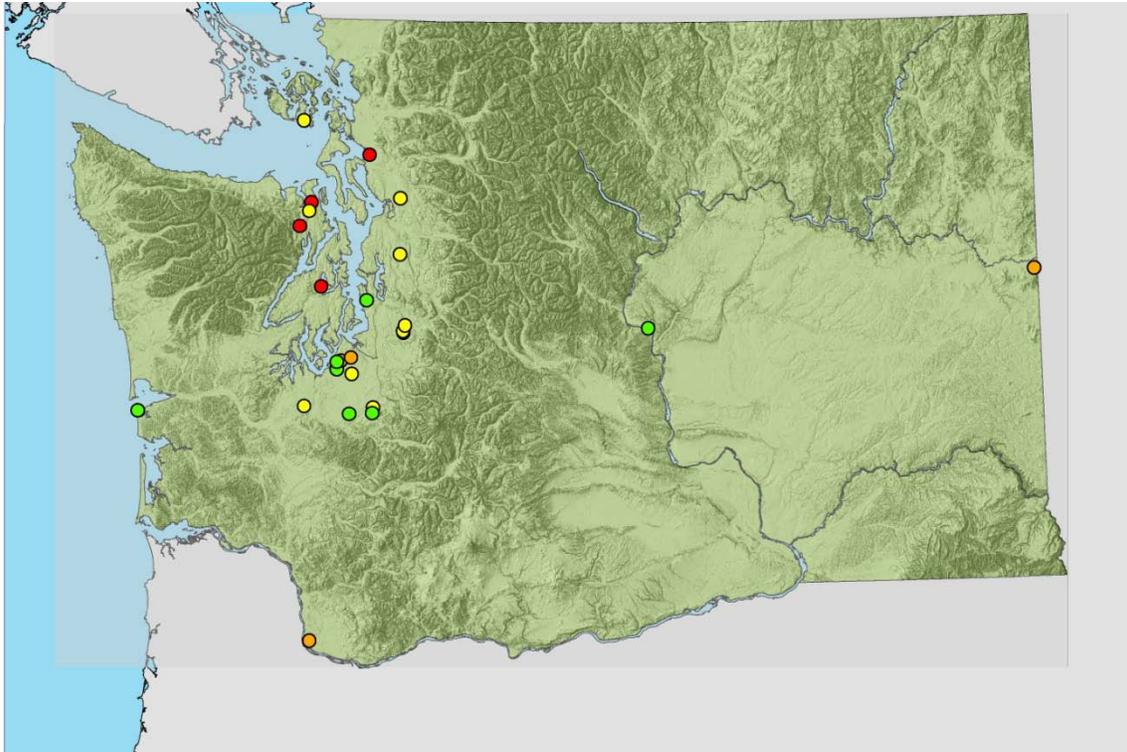


Figure 5. Water bodies tested for anatoxin-a in 2008

Green: no detection; Yellow: anatoxin-a levels under 1 µg/L; orange: 1-5 µg/L; red: > 5 µg/L

Table 5. Lakes with highest anatoxin-a concentrations in 2008

Lake and County	Anatoxin-a Concentration µg/L
Anderson Lake, Jefferson	172,640
Leland Lake, Jefferson	22.10
Ketchum Lake, Snohomish	12.90
Kitsap Lake, Kitsap	5.56
Wapato Lake, Pierce	3.16
Steilacoom Lake, Pierce	2.53
Liberty Lake, Spokane	2.20
Vancouver Lake, Clark	2.18

2009 Toxicity testing

In 2009, samplers collected bloom samples from 69 water bodies from 19 counties for algal identification and blue-green algae toxin testing. Fewer lakes had extreme concentrations of anatoxin-a in 2009. We do not know what caused this variability in toxin production in these lakes.

2009 Microcystins

Of the 69 lakes tested for microcystin, 44 lakes had detectable concentrations $> 0.05 \mu\text{g/L}$ (64%), 19 lakes had levels over the state recreational guidance level of $6 \mu\text{g/L}$ (28%), and 11 lakes had levels higher than $50 \mu\text{g/L}$ (16%). See Table 6. The highest microcystin concentration detected in 2009 was $18,700 \mu\text{g/L}$ from Lake Spokane. This is the highest microcystin level detected to date in any Washington bloom.



**Blue-green bloom on Jameson Lake.
Photo: Courtesy of Tim Behne**

The map below shows locations and relative toxicities of lakes sampled for microcystin in 2009 (Figure 6).

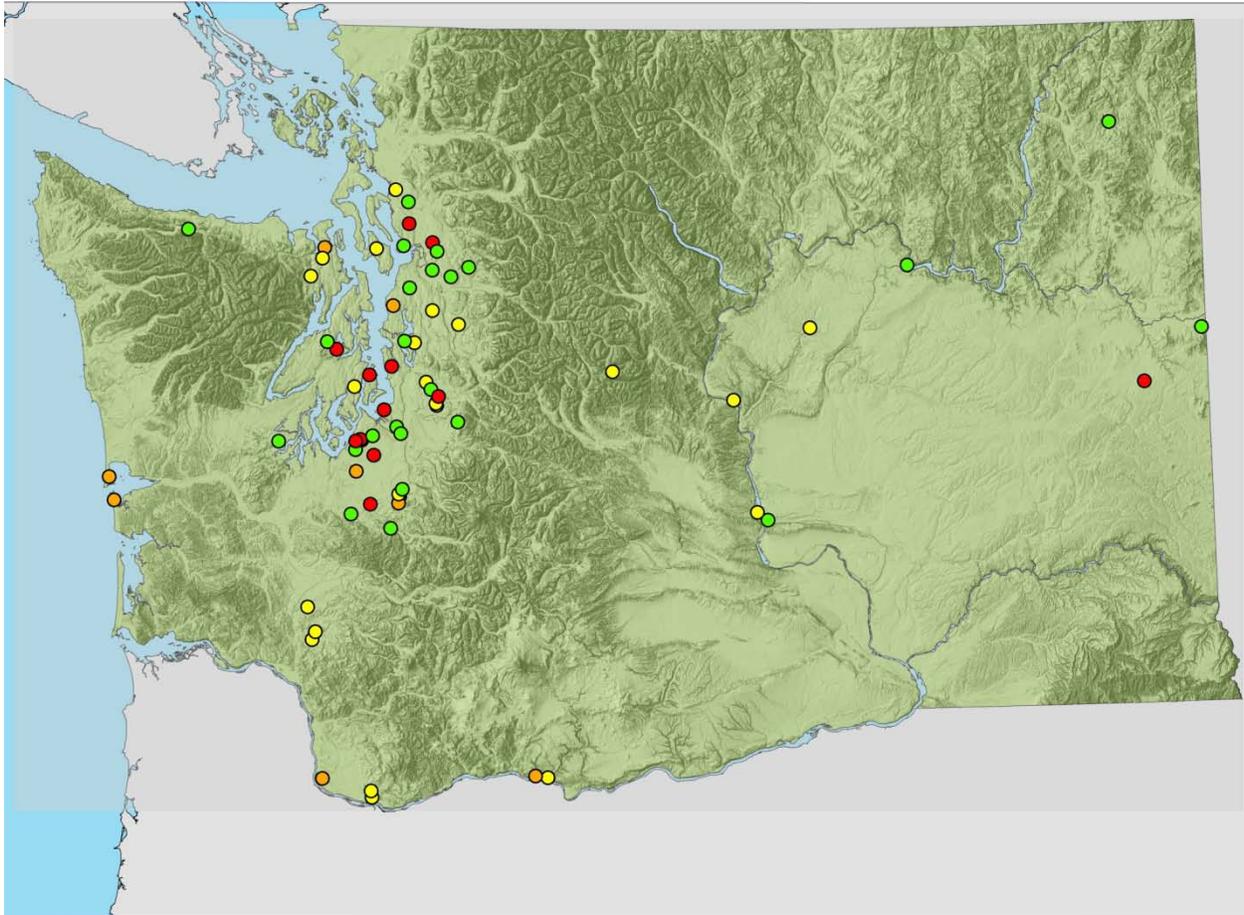


Figure 6. Water bodies tested for microcystin in 2009

Green: no detection; Yellow: concentrations under 6 µg/L; Orange: 6-50 µg/L; Red: > 50 µg/L

Table 6. Lakes with highest microcystin concentrations in 2009 >50 µg/L

Lake and County	Microcystin Concentration µg/L	Lake and County	Microcystin Concentration µg/L
Lake Spokane, Spokane	18,300.00	Wilderness Lake, King	468.00
Kitsap Lake, Kitsap	8,230.00	Tuck Lake, King	161.00
Cassidy Lake, Snohomish	4,600.00	Steilacoom Lake, Pierce	119.00
Waughop Lake, Pierce	4,380.00	Harts Lake, Pierce	74.10
Lorene Lake, King	2,160.00	Loma Lake, Snohomish	74.10
Spanaway Lake, Pierce	944.00		

2009 Anatoxin-a

Of the 32 lakes tested for anatoxin-a in 2009, 14 lakes had detectable levels of anatoxin-a (about 44%) and 5 lakes had levels over the state recreational guidance level of 1 µg/L (16%). The highest anatoxin-a concentration detected was 144 µg/L in Anderson Lake. The same lake produced anatoxin-a levels more than 10 times higher in 2008 (172,640 µg/L). We do not currently understand what controls toxin levels or annual toxin variability. The map below (Figure 7) shows locations and relative toxicities of lakes sampled for anatoxin-a in 2009.

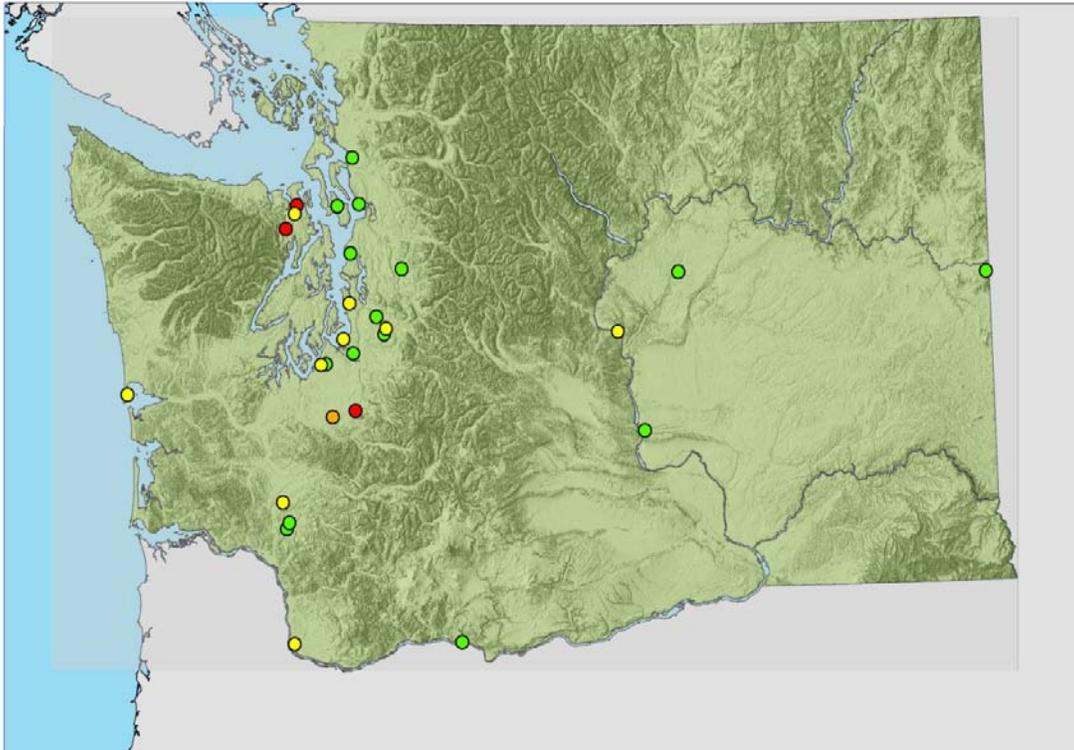


Figure 7. Water bodies tested for anatoxin-a in 2009

Green: no detection; Yellow: anatoxin-a levels under 1 µg/L; orange: 1-5 µg/L; red: > 5 µg/L

Table 7. Lakes with highest anatoxin-a concentrations in 2009

Lake and County	Anatoxin-a Concentration µg/L
Anderson Lake, Jefferson	144.00
Leland Lake, Jefferson	122.00
Spanaway Lake, Pierce	77.40
Clear Lake, Pierce	47.20
Harts Lake, Pierce	1.74

2009 Illness reports

DOH received calls for assistance in determining the causes for over 100 lake-related illness reports during the summer of 2009. Not all were HAB related. However, toxicity data from the Freshwater Algae Control Program on algal toxicity allowed local health jurisdictions to focus investigations on the appropriate target.



Lone Lake Island County. Photo: Susan Horton

Case studies

Waughop Lake, Pierce County

Waughop Lake routinely experiences prolonged toxic blue-green algae blooms. The small (33 acre), shallow (mean depth of 7 feet) lake is located within Fort Steilacoom Park in the city of Lakewood. Fort Steilacoom Park features a large, popular off leash dog park and many people walk their dogs along the trail adjacent to Waughop Lake.

People also fish in the lake, and there is evidence that fish accumulate blue-green algal toxins in their edible tissue. Using funds appropriated by the Legislature, Lakewood funded an experimental calcium hydroxide

addition to the lake in 2008. As the data show, this treatment did not prevent blue-green blooms from occurring or becoming toxic in Waughop Lake.



Waughop Lake with an extensive toxic algal bloom.
Photo: Don Russell

There is evidence that fish accumulate blue-green algal toxins in their edible tissue.

In 2008, Tacoma-Pierce Health Department staff started sampling for toxicity in May. The initial microcystin concentration was 35.8 $\mu\text{g/L}$. The lake continued to produce high levels of microcystins through December when sampling stopped for the year. The peak microcystin concentration for 2008 was 1,050 $\mu\text{g/L}$ on July 23 - 175 times higher than the recreational guidance level of 6 $\mu\text{g/L}$. Sampling resumed in February 2009 with the lake continuing to produce toxins. In 2009, the peak microcystin concentration was 4,380 on September 28, 2009 – 700 times higher than the recreational guidance levels. During most sampling dates, two to four genera of toxin-producing blue-greens were present; the most common genera were *Microcystis*, *Anabaena*, and *Aphanizomenon*. Table 8 below shows the microcystin concentrations on each sampling date for 2008 and 2009

Table 8. 2008 and 2009 microcystin concentrations in Waughop Lake. *Bold = Algal toxins greater than recreational guideline concentration. Grayed out = Algal toxins detected but less than recreational guideline concentration.*

Sampling Dates	Microcystin Concentration µg/L	Sampling Dates	Microcystin Concentration µg/L
2008		2009	
May 22	35.80	May 11	3.25
July 15	406.00	May 20	No detection
July 23	1,050.00	May 27	7.87
July 30	73.60	June 14	382.00
Aug 6	138.00	June 24	2.95
Aug 12	56.20	June 29	25.53
Aug 20	136.00	July 8	14.20
Aug 27	4.70	July 13	31.40
Sept 3	16.70	July 22	34.90
Sept 9	42.30	July 27	60.10
Sept 16	148.00	July 30	237.00
Sept 23	59.60	Aug 6	12.90
Sept 29	67.70	Aug 10	128.00
Nov 3	0.98	Aug 19	1.09
Nov 17	65.40	Aug 24	7.36
2009		Sept 1	495.00
Dec 1	65.50	Sept 8	79.70
Dec 8	51.70	Sept 14	686.00
Feb 11	20.80	Sept 21	23.70
Feb 18	68.80	Sept 28	4380.00
Feb 23	31.60	October 7	3190.00
Mar 2	0.80	October 8	3060.00
Mar 18	4.59	October 12	433.00
April 6	58.00	October 19	1110.00
April 15	13.70	November 2	461.00
April 20	7.90	November 11	283.00
April 27	16.20	December 1	76.00
May 4	3.25		

Based on these results, it is apparent that blue-green algae in Waughop Lake are consistently producing microcystin – and often at high levels. Anatoxin-a has only been detected at low concentrations in Waughop Lake. Tacoma-Pierce County Health Department posts signs around the lake warning people about the toxins. However, it is troublesome to have a lake in an urban park where there is the potential for people and pets to contact toxins.

Anderson Lake, Jefferson County

Anderson Lake in Jefferson County is a 70-acre lake in the heart of Anderson Lake State Park. One of highlights of this park is the rainbow trout fishing, but fishing has been off limits for the past several years due to dense toxic blue-green algae blooms.

In 2006, two dogs died immediately after swimming in Anderson Lake and another dog was sickened. Since that time, the Jefferson County Health District has taken an active role in monitoring the lake for blue-green blooms and their toxins. The Health District posts the lake with warning signs and Washington State Parks has closed the lake to fishing and boating, although the rest of the park is open to hikers and mountain bikers.

Unlike Waughop Lake which primarily produces microcystins, Anderson Lake blooms produce two toxins; anatoxin-a (*at times at extremely high concentrations*) and microcystins. Sometimes both toxins are simultaneously present in concentrations well over their respective recreational guidelines (see Table 8). Anderson Lake blue-green blooms are composed of a mix of several toxin-producing genera.



**Blue-green scum at the boat launch on Anderson Lake.
Photo: Rob Banes**

One of the highest
anatoxin-a
concentrations—
172,640 μ g/L —
detected worldwide
was from
Anderson Lake.

Table 9. 2008 and 2009 microcystin and anatoxin-a concentrations in Anderson Lake. Bold =Algal toxins greater than the recreational guideline concentration Grayed out = Algal toxins detected but less than the recreational guideline concentration

2008			2009		
2008 Sampling Dates	Microcystin Concentration µg/L	Anatoxin-a Concentration µg/L	2009 Sampling Dates	Microcystin Concentration µg/L	Anatoxin-a Concentration µg/L
April 22	13.60	300.00	April 15	0.74	7.30
May 5	No detection	Not sampled	April 20	0.16	2.90
May 12	No detection	0.85	April 27	0.10	2.30
May 27	No detection	Not sampled	May 4	6.89	Not sampled
June 2	6.23	6,000.00	May 11	0.07	0.76
June 9	No detection	2,353.00	May 18	No detection	22.10
June 16	No detection	66.40	May 26	0.41	104.00
June 23	0.58	172,640.00	June 1	0.06	144.00
June 30	0.47	90,256.00	June 8	0.11	Not sampled
July 7	0.65	5,280.00	June 15	0.27	4.16
July 14	0.19	1.95	June 22	0.65	1.95
July 28	0.09	3.93	June 29	No detection	1.42
Aug 4	0.08	0.80	July 6	0.74	1.62
Aug 11	134.00	200.80	July 13	0.48	1.37
Aug 19	0.45	1.82	July 20	0.15	1.11
Aug 25	4.07	0.53	July 27	0.18	3.01
Sept 2	5.26	0.20	Aug 3	0.69	9.19
Sept 9	73.00	1.78	Aug 10	0.23	1.53
Sept 16	45.60	0.51	Aug 17	0.27	1.30
Sept 22	77.00	Not sampled	Aug 20	0.41	1.00
Sept 29	26.90	Not sampled	Aug 31	17.80	0.80
Oct 6	3,120.00	Not sampled	Sept 8	3.33	0.42
Nov 4	7.42	Not sampled	Sept 14	1.30	Not sampled
			Sept 21	0.34	Not sampled
			Sept 28	0.29	Not sampled
			Nov 2	0.09	Not sampled

Although Anderson Lake had dense toxic blue-green algae blooms present in both 2008 and 2009, microcystin and anatoxin-a concentrations were significantly lower in 2009. Nobody knows why.

With anatoxin-a concentrations sometimes reaching thousands of times higher than the recreational guidelines, Jefferson County Health Department staff is wary even of sampling the lake. At those times, a capsized boat could potentially result in their death from this potent neurotoxin. The Health Department posts signs around the lake and locals know not to fish or take their dogs swimming in Anderson Lake. Using grant funding from Ecology, Jefferson County is hoping to learn more about this bloom and nutrient sources to the lake.

Blue-green blooms are generally indicative of nutrient-enrichment.

There is a strong correlation between lakes with toxic blooms and those lakes listed on Washington's 303(d) list of polluted waters for phosphorus.

What do toxicity results mean?

- Washington has a significant number of lakes with toxic blue-green algae blooms and some people have become ill after swimming or recreating in waters with blue-green toxins.
- Some of the blooms are associated with the death of pets and human illness.
- Some blooms are ongoing for months or even years! Several lakes with prolonged and very toxic blooms are in public parks.
- Toxicity seems to wax and wane over time (note the changes between 2008 and 2009 from Anderson Lake).
- The Center for Disease Control and Prevention (CDC) is concerned enough about toxic blooms to fund a national initiative to determine the connection between human and animal health and blue-green algae toxins. Washington is participating in this study.



Sampling in Steel Lake.
Photo: Dan Smith

Algal Identification and Toxicity Testing Program Limitations

Washington's Freshwater Algal Identification and Toxicity Testing Program relies on volunteers to collect and ship algae bloom samples. Depending on volunteers for sample collection does not allow a systematic look at every bloom in Washington. There are many lakes experiencing blue-green

algae blooms where there are no volunteers interested in collecting samples. Although Ecology pays for algal identification and toxin analysis, it does not pay for sampling or shipping costs.

Local health districts (particularly those districts in western Washington) and lake management programs have been the most interested in the algae control program. Their staff sends in the majority of samples. While some districts will faithfully sample week after week, others simply do not have the time or resources for frequent sampling. Although many of Washington's 35 local health districts take an active interest in this program, and are prepared to take action when a lake resident reports a bloom, some do not. Only local health districts have the legal authority to close a lake to protect human health.

Other issues

Due to their workload, the laboratory limits the number of samples per year for this program. Although this number has been adequate to date, the limit may prevent sampling some lakes in the future, particularly as more people and health districts become interested in the program. To help with this concern, certain samplers have started to pretest for microcystins using a less expensive ELISA kit to screen samples. They send in only those samples that initially test positive for toxicity for the more detailed laboratory analysis.



Ketchum Lake. Photo Marisa Burghdoff

To conserve funds, Ecology now limits algal identification to every other sample that comes in from the same lake during prolonged blooms. As the program grows in popularity, Ecology may not be able to fund the program at higher budget amounts.

Other toxins not tested as part of this program may be a problem in Washington water bodies. Ecology routinely tests for two freshwater biotoxins: microcystins and anatoxin-a. During the first year of the CDC grant (2009), laboratory testing identified saxitoxin in a lake. Saxitoxin is the main toxin that causes Paralytic Shellfish Poisoning (PSP) in marine waters. In another case, managers sent algal samples to the CDC in August 2009 for tests to determine the presence of three toxins that cause severe dermal irritation. KCEL does not have the capacity to test for these toxins at this time. Thus, the Freshwater Algae Control Program may miss identifying several biotoxins that may be present in our lakes, rivers, and streams.

Freshwater Algae Control Grant Program

Grant program overview

The Freshwater Algae Control Grant Program provides financial assistance to state and local governments, tribes, and special purpose districts to prevent and control excessive freshwater algal growth, with a priority placed on lakes experiencing harmful algae blooms. Projects involving any public or private lake, river, or stream are eligible for funding.

The competitive grant application period generally opens October 1 and closes November 1 of each year. Ecology:

- Directs about two-thirds of Freshwater Algae Control Program funding to grants (approximately \$150,000 per year).
- Limits grant amounts to \$50,000 per project.
- Requires 25 percent local match.
- Awards grants in late December or early January of each year.
- Encourages recipients to complete their grant projects within two years.
- Provides grant guidelines on its website at <http://www.ecy.wa.gov/biblio/0710076.html> and the grant application at <http://www.ecy.wa.gov/biblio/ecy070288.html>.

Eligible freshwater algae grant activities include:

- Control and management
- Planning
- Nutrient reduction activities
- Education and outreach
- Monitoring
- Pilot projects
- Research
- Equipment purchase
- Ecology awarded grants in Fiscal Year (FY) 2008, FY 2009, and FY 2010, but is unable to offer grants for Fiscal Year 2011.



Algal scum

Completed grant projects

Recipient: Tacoma-Pierce County Health Department (FY 2008)

Pierce County Toxic Algae Project

This project enabled the Tacoma-Pierce County Health Department (TPCHD) to better detect, quantify, and inform the public about toxic algae blooms. Pierce County has the most lakes with toxic blooms in the state. The project focused on 29 lakes in Pierce County, either considered to be at the greatest risk of having a toxic bloom, or the most impacted if a toxic bloom occurred. The primary goal of the project was to reduce the risk of health impacts to community members associated with exposure to toxic algae.



Blue-green bloom. Photo: Courtesy King County

TPCHD expanded public awareness of blue-green algae by:

- Completing pre-and post-project surveys.
- Distributing a toxic algae brochure.
- Holding three workshops for lakefront residents.

TPCHD improved lake monitoring by:

- Developing an Algae Watch Program that established a group of volunteers to participate in the program.
- Setting up an Access database to track blooms both qualitatively and quantitatively.

Finally, TPCHD refined their Public Warning System based on DOH guidelines, their own experience, and the survey results.

Grant amount \$47,993

Recipient: City of Lakewood (FY 2008)

Lake Steilacoom Calcium Hydroxide Application

Lake Steilacoom, a shallow, nutrient-enriched lake in Pierce County, has experienced prolonged blooms of toxic blue-green algae. These blooms interfere with recreational use and are a health hazard to people and animals. Several pets have died in the past after swimming in or drinking Lake Steilacoom algae-infested waters. The Lake Steilacoom Improvement Club has tried several algae control methods over the years to reduce these blooms; most have been unsuccessful.

Results from a small pilot project suggested that the addition of calcium hydroxide might be effective in binding phosphorus to alleviate blue-green blooms in the lake. The Lake Steilacoom Improvement Club funded the experimental application of a granulated formulation of calcium oxide to Lake Steilacoom. Calcium oxide rapidly turns into calcium hydroxide when added to water. The Ecology grant provided funds for lake monitoring associated with that treatment, analytical laboratory costs, a quality assurance plan, and a monitoring report.



**Applying calcium hydroxide to Lake Steilacoom.
Photo: Doug Dorling**

Calcium hydroxide treatment in Lake Steilacoom began in May 2008 and continued through July. The applicator applied a total of 86,000 pounds of calcium oxide to the lake. Using grant funds, the city of Lakewood hired Herrera Environmental Consultants to monitor and evaluate the treatment.

Results: Herrera concluded that the amount of calcium oxide applied to the lake did not have a significant impact on reducing the occurrence of blue-green blooms in Lake Steilacoom. In spite of the treatment, high concentrations of microcystins were present during the months of August, September, and October. The highest microcystin concentration observed in Lake Steilacoom (594 $\mu\text{g/L}$) in 2008 was 100 times higher than the Washington's recreational guideline of 6 $\mu\text{g/L}$. The Freshwater Algae Control Program grant provided \$50,000 towards the cost of the project with other funds coming from the Lake Steilacoom Improvement Club.

Grant amount \$50,000

Active grant projects

Recipient: Snohomish County Public Works (FY 2008)

Cyanobacteria Prevention and Early Detection

This project focuses on three lakes – Cassidy, Ketchum, and Loma – that have suffered from toxic blue-green algae blooms in recent years. Snohomish County is working with lake residents to reduce nutrients that feed algal growth and create an early detection system for toxic blue-green algal blooms. Public education, technical assistance, and septic system testing will help citizens reduce the amount of nutrients entering these lakes in order to reduce the frequency of blue-green blooms. The early detection and notification activities of this project will identify potentially harmful algal blooms at an early stage and provide the public with information to help them avoid exposure to and impacts from blue-green algae.

Grant amount \$28,500.



Photo: Joan Hardy

Recipient: Jefferson County (FY 2008)

Lake Assessment and Toxic Cyanobacteria Monitoring Project

Jefferson County is assessing the ecology of three publicly accessible lakes (Anderson, Gibbs, and Leland) that have experienced toxic cyanobacterial blooms in the past two years. These toxic blooms led to public health closures of these lakes. Anderson Lake has produced some of the highest levels of anatoxin-a in the world. Jefferson County plans to modify its existing lake monitoring program based on results of the assessment.

Grant amount \$50,000

Recipient: Kitsap County Health District (FY 2009)

Kitsap Lake Phosphorus Reduction Plan

Goals of this project are to:

- Identify, reduce, and control phosphorus pollution in Kitsap Lake by assessing phosphorus inputs from streams, stormwater, and lake sediments.
- Develop countywide lake stewardship volunteer groups to assist in phosphorus reduction education.

Grant amount \$50,000

Recipient: City of Lakewood (FY 2009)

Lake Steilacoom Aluminum Sulfate Application

This project is for the experimental application of solid block formulations of aluminum sulfate and sodium aluminate (alum) to Lake Steilacoom inflow sources to reduce phosphorus concentrations in the lake. Reducing phosphorus eliminates one of the key environmental elements necessary to produce and sustain toxic blue-green algae. Lakewood will also undertake an Alum Treatment Feasibility Study. If solid block aluminum sulfate application is not practical, Lakewood will focus its efforts/funding on the alum feasibility study.

Grant amount \$12,650

Recipient: Foster Creek Conservation District (FY 2009)

Rock Island Lakes Nutrient Source Investigation

The Foster Creek Conservation District will investigate sources of external nutrient inputs to the Rock Island Lakes in Douglas County. The grant recipient will develop a network of

groundwater wells to investigate the influence of septic systems, land uses, and agriculture on the water quality of these small, but popular eastern Washington lakes.

Grant amount \$48,450

Recipient: Tacoma-Pierce County Health Department (FY 2009)

Pierce County Cyanobacterial Project

This project builds upon the 2008 algae grant by improving the monitoring and communication program in Pierce County for blue-green algae blooms. Staff will coordinate sampling in 10 lakes for the CDC grant, assess the use of quick test methods as a public health tool, and expand work under the “algae watch program.”

Grant amount \$45,901

Recipient: Clark County Public Works (FY 2009)

Cyanobacteria Growth and Grazing in Vancouver Lake

The Vancouver Lake Watershed Partnership and Washington State University-Vancouver have collaborated to gain a better understanding of the dynamics of recurring blue-green algae blooms in Vancouver Lake. They will assess the balance of blue-green algae and other non blue-green algal growth rates with the grazing rates of zooplankton consumers.

Grant amount \$48,137

New Freshwater Algae Initiatives

Grant opportunities

Having a state-funded program for blue-green algae opens the door for federal grants and other funding opportunities. The CDC is very interested in evaluating the public health impact of blue-green algal toxins. The fact that Washington already has a toxic algae program in place enhanced Washington’s ability to acquire this grant funding. In 2008, DOH entered into a five-year cooperative agreement with the CDC to investigate toxic blue-green blooms in Washington lakes under the Harmful Algae Bloom-Related Illness Surveillance System project (HABISS). DOH formed partnerships with Ecology, King and Snohomish Counties, Tacoma-Pierce County Health Department, and Seattle University to accomplish the following objectives:

- Investigate human and animal illnesses related to algal toxins.
- Enter historical microcystin toxicity information from lakes and human and animal health data into the CDC HABISS database.
- Expand regional monitoring to obtain environmental data associated with toxic blooms for HABISS.
- Test for microcystin and anatoxin-a toxicity with more regularity in 30 regional lakes in Pierce, King, and Snohomish counties.

- Investigate two algal toxins previously undetected in Washington lakes: cylindrospermopsin and saxitoxins.
- Coordinate and expand outreach efforts to educate local agencies and the public about toxic blooms to prevent exposure and thereby lessen the threat of blue-green algal toxins to public health.

Fish tissue study

Currently, Ecology is conducting a study to see if fish from lakes with toxic blue-green blooms accumulate toxins in their edible flesh. Results indicate that fish caught from lakes with toxic blooms can accumulate microcystins in their muscle tissue and liver. Until Ecology and DOH fully analyze the results, DOH advises people to clean the fish and discard all internal organs from fish caught in lakes with blue-green algae blooms.

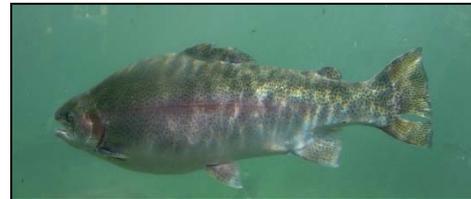


Photo: Joan Clark

Freshwater Algae Control Program Contacts

For more information about the Freshwater Algae Control Program, contact the following staff:

Washington State Department of Ecology

- Kathy Hamel (blue-green algae program coordination), 360-407-6562, Kathy.Hamel@ecy.wa.gov
- Melanie Tyler (blue-green algae grants), 360-407-7489, Melanie.Tyler@ecy.wa.gov
- Tricia Shoblom (algae bloom sampling program), 425-649-7288, Tricia.Shoblom@ecy.wa.gov

Washington State Department of Health

- Joan Hardy (blue-green algae-related human health toxicity), 360-236-3173, Joan.Hardy@doh.wa.gov
- Rob Banes (blue-green algae-related outreach), 360-236-3243, Rob.Banes@doh.wa.gov

On-Line Resources

- Ecology's algae website: <http://www.ecy.wa.gov/programs/wq/plants/algae/index.html>
- Department of Health toxic algae website: <http://www.doh.wa.gov/ehp/algae/default.htm>



**Toxic blue-green algae bloom discharging downstream from
Spanaway Lake in Pierce County.
Photo: Don Russell**