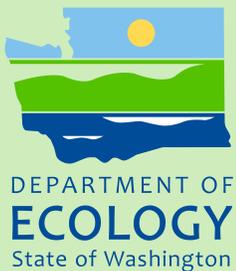




Aquatic Algae Control Program

Report to the Washington State Legislature
(2010-2011)



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Cover Photograph: Cyanobacteria bloom on Anderson Lake in Anderson Lake State Park, Jefferson County. Photograph by Neal Harrington.

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Aquatic Algae Control Program

Report to the Washington State Legislature (2010-2011)

by

Kathy Hamel



Collecting a blue-green algae scum sample. Photograph by Dan Smith, city of
Federal Way

Water Quality Program
Washington State Department of Ecology
Olympia, Washington

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Table of Contents

List of Figures and Tables.....	iv
Figures.....	iv
Tables.....	iv
Acknowledgements.....	v
Introduction.....	1
Legislative update.....	1
What are harmful freshwater algae?.....	1
Aquatic Algae Control Program budget.....	2
Harmful Algae Blooms.....	3
Concern about toxic blooms.....	3
Algal toxins.....	4
Why we test for toxins.....	4
How Ecology’s Freshwater Algal Identification and Toxicity Testing Program works.....	5
Making use of the information.....	6
Recreational guidance levels for toxic blue-green algae blooms.....	6
Freshwater Algae Toxicity Testing and Algal Identification (2010-2011).....	8
Identification.....	8
2010 toxicity testing.....	8
2010 Microcystins.....	8
2010 Anatoxin-a.....	9
2010 other toxins.....	11
2011 toxicity testing.....	11
2011 Microcystins.....	11
2011 Anatoxin-a.....	13
2011 other toxins.....	14
What do toxicity results mean?.....	15
Toxicity Testing and Algal Identification Program limitations.....	15
Update on Waughop Lake.....	16
Aquatic Algae Control Grant Program.....	17
Freshwater algae grant program overview.....	17
Saltwater algae grant program overview.....	17
Completed aquatic algae grant projects.....	18
Completed freshwater algae grant projects.....	18
Completed saltwater algae grant projects.....	22
Active aquatic algae grant projects.....	24
Freshwater algae grant projects.....	24
Other Algae-Related Projects.....	26
Algal toxins in fish and sediments.....	26
Centers for Disease Control and Prevention (CDC) grant project.....	26
Aquatic Algae Control Program Contacts.....	27

List of Figures and Tables

Figures

Figure 1. Decision matrix	7
Figure 2. Locations and relative toxicities of the lakes sampled for microcystin in 2010.	9
Figure 3. Locations and relative toxicities of the lakes sampled for anatoxin-a in 2010.	10
Figure 4. Locations and relative toxicities of the lakes sampled for microcystin in 2011.	12
Figure 5. Locations and relative toxicities of the lakes sampled for anatoxin-a in 2011.	14

Tables

Table 1. Lakes with the highest microcystin concentrations in 2010 (over 50 µg/L)	9
Table 2. Lakes with the highest anatoxin-a concentrations in 2010 (lakes over 1 µg/L)	10
Table 3. Lakes with the highest microcystin concentrations in 2011 (lakes over 50 µg/L)	12
Table 4. Lakes with the highest anatoxin-a concentrations in 2011 (lakes over 1 µg/L)	13

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Introduction

This report summarizes activities of the Aquatic Algae Control Program for 2010-2011 and is the third legislative report for this program. The earlier legislative reports are available on Ecology's website at www.ecy.wa.gov/programs/wq/plants/algae/index.html. 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.

Legislative update

The Washington State Legislature (Legislature) established funding for the Freshwater Algae Control Program in 2005 and directed the Washington State Department of Ecology (Ecology) to give priority to lakes in which *harmful freshwater algae* have occurred within the past three years.

In 2011, the Legislature removed the June 30, 2012, expiration date from the enabling legislation. The Legislature also changed the name to the Aquatic Algae Control Program and expanded the program to include both freshwater algae and saltwater nuisance algae. The

Legislature defined saltwater nuisance algae to mean *native invasive algae (sea lettuce), non-native invasive algae, and algae producing harmful toxins*. Because sea lettuce blooms only periodically, the Legislature agreed that Ecology could establish a contingency fund for saltwater projects. Ecology will make contingency funds available on a first-come-first-served and as-needed basis to deal with monitoring and removal of sea lettuce, new infestations of marine non-native invasive algae, and marine algae producing toxic blooms. Ecology anticipates that it will be able to direct the majority of the Aquatic Algae Control Program funding towards freshwater algae projects.

What are harmful freshwater algae?

Harmful freshwater algae are blue-green algae (also known as cyanobacteria) that occur in dense populations known as blooms. Blue-green algae blooms can look like a spill of green, blue, or even red or white paint in Washington lakes and ponds. These blooms are harmful because some blue-green algae blooms produce potent toxins that can cause human illness and kill pets and livestock. Even when not producing toxins, blue-green blooms are distressing to lake residents



Toxic Blue-green bloom on Ketchum Lake
Photo: Gene Williams, Snohomish County



Photo - M. Murphy

and the public because they are unsightly and smelly when decomposing, can affect recreational use, and can cause economic losses to lake-based businesses like resorts.

Blue-green blooms typically occur when plant nutrients such as phosphorus and nitrogen are in plentiful supply in the water. Some blue-green algae species have the ability to fix nitrogen directly from the atmosphere using specialized cells. This ability can provide these species with a competitive advantage over algae that must get nitrogen only from the water.

Plant nutrients enter water from point and nonpoint pollution such as stormwater inputs, agricultural runoff, and urban land use practices (external nutrient sources). Sediments may also release nutrients into the overlying water when it becomes low in oxygen. Scientists call this process internal nutrient loading. Ecology believes that the best long-term solution for preventing blue-green blooms is to reduce nutrient inputs from both external and internal nutrient sources.

Other factors that can affect bloom formation include light, temperature, and zooplankton grazing. Blue-green blooms can occur at any time of the year, but most blooms occur during the summer and fall with toxicity seeming to peak in the fall for most blooms. Cool weather during the spring and summer of 2010 and 2011 seemed to reduce the number of blooms and overall toxicity of blooms that occurred in Washington as compared to previous years.

The Freshwater Algae Control Program includes the following elements:

- Toxicity testing and identification of the genera of algae that cause blue-green algae blooms in Washington freshwaters.
- A searchable online database for toxicity and algal identification results.
- A freshwater algae listserv.
- A grant program that funds freshwater algae projects.
- Partnership with the Washington State Department of Health (DOH) for
 - Algal toxin-related questions.
 - Investigation of algal-related human and animal illness.
 - Development of recreational guidelines for toxin levels.
- Ecology and DOH websites with blue-green algae information.

Aquatic Algae Control Program budget

Program funding comes from vessel registration fees (RCW 88.02.045). One dollar of each fee is deposited into the Freshwater Aquatic Algae Control Account (program name changed by the Legislature in 2011 to the Aquatic Algae Control Account). This action generates approximately \$540,000 per biennium. The Legislature appropriates these funds to Ecology to manage the program.



Ecology typically offers about \$150,000 each year as grants to state and local governments for freshwater algae projects. The 2009 Legislature directed Ecology to provide \$140,000 in grants using funds from the Freshwater Algae Control Program *to manage and study excessive saltwater algae with an emphasis on the periodic accumulation of sea lettuce on Puget Sound beaches*. Because of this proviso, and the need for carry over funds for continuing grant projects awarded earlier, Ecology was not able to offer freshwater algae grants for Fiscal Year (FY) 2010. Instead, Ecology funded grants for sea lettuce removal and research. During FY 2011, Ecology awarded a \$30,000 contract to DOH to develop recreational guidelines for the algal toxins saxitoxin and cylindrospermopsin. In 2011, Ecology awarded nine Freshwater Algae Control Program grant projects for a total of \$326,775 for projects to start in FY 2012 (July 1, 2011 start date for many projects).

In addition to its grant program, Ecology budgets about \$60,000 per year for laboratory costs for algal identification and toxicity testing of bloom samples. Remaining funds pay for staff time for algae program grant administration, technical assistance, and data entry.

Harmful Algae Blooms

Concern about toxic blooms

Toxic blue-green blooms are a public health issue and can be an indicator of nutrient enrichment. Recreating in lakes with toxic blooms can expose people to toxins. Some residents use lake water as a drinking water source, and they may ingest algal toxins. People may even inhale a toxic aerosol when irrigating lawns with water from lakes with a toxic blue-green bloom.

Human health effects from algal toxins are diverse and may include skin rashes and lesions, vomiting, gastroenteritis, conjunctivitis, and eye, ear, and throat irritations. Exposure to neurotoxins can cause more fast-acting and severe symptoms. Depending on the size of the person or animal, type of toxin, and amount of toxin exposure, neurotoxins may cause staggering, loss of muscle coordination, difficulty in swallowing, labored respiration, complete muscle paralysis, and death. People may also experience tingling around the mouth and fingertips as well as slurred speech.



Photo – Joan Hardy

Pets and livestock are at particular risk for ingesting algal toxins and becoming ill or dying. They are far more likely to drink or swim in water with algal scums, and cats and dogs often lick algae from their fur. With the inception of this program, many health districts are now testing algal blooms and posting toxic lakes with warning signs. These actions may have resulted in fewer pet deaths recently as more people became aware of the threat to their animals

from algal toxins. Using Program grant funds, DOH started a program to educate veterinarians about algal toxins.

Algal toxins

Ecology can currently test for four algal toxins: microcystin, anatoxin-a, saxitoxin, and cylindrospermopsin. Microcystin is the most commonly tested for and detected toxin, followed by anatoxin-a. Saxitoxin and cylindrospermopsin are much less common in freshwater water bodies. These two toxins have been detected only a few times in Washington lakes and ponds.

- Neurotoxins affect the nervous system. Neurotoxins are fast acting and do not accumulate in the body. Neurotoxins tested for under this program include:
 - Anatoxin-a – produced by *Anabaena*, *Planktothrix*, and *Aphanizomenon*
 - Saxitoxin – produced by *Anabaena*, *Aphanizomenon*, *Lyngbya*, and *Cylindrospermopsis*

- Hepatotoxins affect the liver. Hepatotoxins can be slower acting and cumulative. Hepatotoxins tested under this program include:
 - Microcystin – produced by *Microcystis*, *Anabaena*, *Planktothrix*, *Nostoc*, *Hapalosiphon*, *Anabaenopsis*
 - Cylindrospermopsin – produced by *Cylindrospermopsis*, *Aphanizomenon*, *Umezakia*



Photo - Ecology files

The most commonly detected algal toxin- microcystin – is a suspected tumor-promoter, and animal studies show that microcystins are capable of interfering with brain development in mice. In studies from China, microcystins have been associated with higher rates of primary liver and colorectal cancer in people drinking waters with high densities of cyanobacteria. Blue-greens also produce polysaccharides that can cause skin rashes and irritation. Another algal toxin called BMAA is associated with neurological disorders in humans.

Why we test for toxins

Lake residents and the public are concerned about algae blooms. They want to know whether it is safe for them or their pets to swim in or drink the water. Toxicity testing is the only sure way to tell if a blue-green bloom is producing toxins. Because a single species of blue-green algae can have toxic and non-toxic strains, it is not possible to predict the toxicity of a bloom based solely on algal identification, cell counts, or visual assessment. Sometimes the most visually unappealing bloom may not be toxic while some blooms that do not look bad can be highly toxic. Also, a bloom that is not producing toxins one day can become toxic soon after. Blue-green blooms often contain a mix of algae species capable of producing toxins.

Washington's freshwater algae identification and toxicity testing element of the algae program provides timely information about:

- Washington lakes, ponds, and rivers experiencing algae blooms.
- The time of year and duration of the blooms.
- The species/genera of the algae producing the bloom.
- The toxin produced by the bloom.
- The concentration of the toxin.

Ecology contracts with King County Environmental Laboratories (KCEL) for algal identification and toxicity testing. KCEL identifies algae to the genus level and notes the dominant and subdominant algae in the sample. The laboratory analyzes all samples for microcystin, the most common algal toxin. On request, the laboratory analyzes for anatoxin-a, saxitoxin, and cylindrospermopsin. Since the program started its testing program in 2007, KCEL has tested water bodies from 22 Washington counties.

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

- Anybody may contact Ecology if he or she thinks that a water body is experiencing an algal bloom.
- If, from their description of the water body, Ecology decides that a bloom is occurring, staff explain how to collect and mail algae samples to KCEL.
- If the sampler is a lake resident, Ecology will send them a sampling kit (see photograph).
- More often, Ecology works with staff from local health jurisdictions. Some routinely monitor lakes for algae blooms and depend on this program for toxin analyses.
- There is no cost to the public or local health jurisdictions to get samples analyzed.
- Ecology encourages samplers to collect from areas of algae scums and asks them to immediately ship or deliver the sample to the laboratory (one-day delivery).
- Laboratory turn-around for microcystin and algal identification takes about three days, but testing for other toxins may take a week or more.
- KCEL sends out preliminary results via email to Ecology, DOH, and the sampler. KCEL follows up with the final data within a few days.
- Ecology posts all results immediately to a searchable, online database at <https://fortress.wa.gov/ecy/toxicalgae/InternetDefault.aspx>
- Ecology also posts information to its freshwater listserv if a water body tests at or above the recreational guidelines for toxins.



Ecology sampling kit. Photo - Jon Jennings

Making use of the information

Local health authorities may use the toxicity data to determine what actions it takes to protect humans from algal toxins. Actions range from no action, recreational advisories, recreational closures, or closure of the entire water body for all activities. Generally, lakes are sign posted and some health districts or lake managers send out email alerts to notify local residents. These warnings alert residents to take extra precautions with themselves, their children, and pets to minimize exposure to the toxic algae. Ecology posts the actions taken by the local health authority to its online algae database.

Recreational guidance levels for toxic blue-green algae blooms

When the program began in 2006, Ecology funded DOH to develop a statewide strategy to assist local health authorities to decide:

- What actions are appropriate in water bodies experiencing toxic algae blooms.
- The levels of toxin that may trigger actions to protect human health.

DOH established statewide provisional recreational guidance values for four algal toxins:

- Microcystin at 6 µg/L.
- Anatoxin-a at 1 µg/L.
- Saxitoxin at 75 µg/L.
- Cylindrospermopsin at 4.5 µg/L.

DOH developed a three-tiered lake management protocol to deal with toxic blooms (Figure 1). The protocol includes the use of signs for posting CAUTION, WARNING, and DANGER. DOH makes these signs available to local health authorities. Although DOH developed these protocols and procedures, local health authorities not state agencies have the regulatory authority to post signs and close water bodies to recreation.



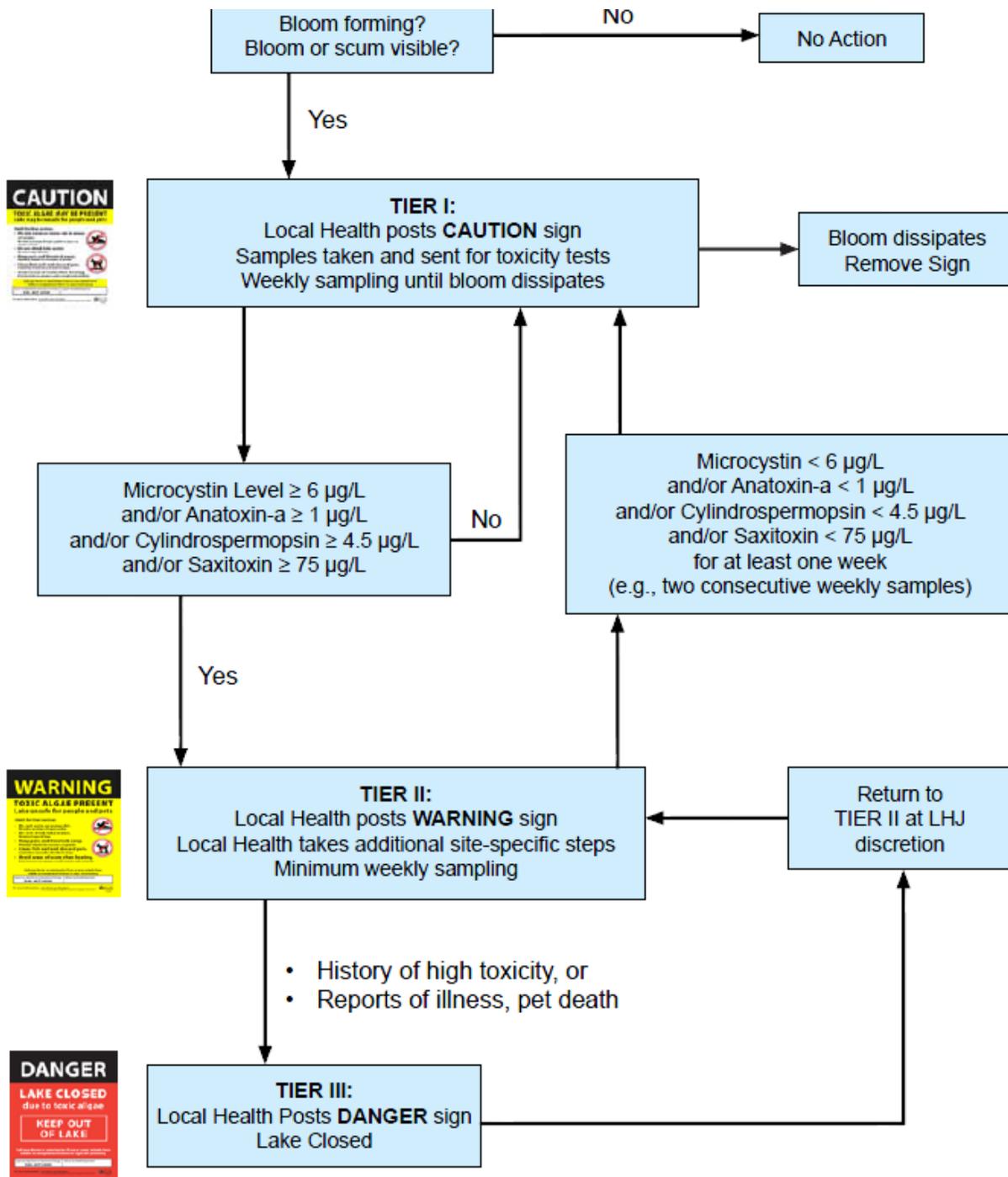


Figure 1. Decision matrix

Freshwater Algae Toxicity Testing and Algal Identification (2010-2011)

There was an uncharacteristically cool spring and summer in 2010. The cool, cloudy weather appeared to affect both the number and toxicity of blooms. Toxin levels in 2010 in most lakes did not approach some of the high levels seen in previous years. However, many of the lakes still produced regular algae blooms in spite of the cooler and less sunny weather. Although 2011, started out cool and cloudy, the season ended with warmer weather and this was reflected in the number and toxicity of blooms.

After several years of consistent toxicity testing, a pattern seems to be emerging for some lakes. For example, Anderson Lake in Jefferson County blooms in the spring and summer with high toxin levels in the spring/summer. Most other lakes seem to produce their highest toxin concentrations in the late summer and fall. Waughop Lake, Pierce County appears to produce a continual toxic bloom year-round, at times with extremely high toxin concentrations.

Identification

Ecology encourages samplers to submit weekly samples as long as a bloom persists and for two weeks following a bloom. KCEL identifies algae for the first sample submitted for each water body and thereafter for every other sample to save on laboratory costs. Identifying the algae helps the laboratory and the sampler to decide which toxin analysis is appropriate for the genera identified. Several years of algae identification has shown that algal scums are not composed of single genera but typically contain a mix. However, it is not possible to determine which alga is producing the toxin based on algae identification.



2010 toxicity testing

In 2010, samplers collected bloom samples from 54 lakes and ponds in 15 counties for algal identification and blue-green algae toxin testing. Due to unseasonably cool weather in the Pacific Northwest during 2010, there were fewer extended blooms and subsequent human and animal illnesses in 2010 compared with 2009.

2010 Microcystins

Of 53 lakes tested for microcystins, 34 lakes (64%) had detectable concentrations (0.05 $\mu\text{g/L}$ or higher). 23 lakes (43%) had levels over the state recreational guidance level of 6 $\mu\text{g/L}$ and 11 lakes (20%) had levels higher than 50 $\mu\text{g/L}$ (Figure 1). The highest microcystin concentration detected in 2010 (853 $\mu\text{g/L}$) was from Waughop Lake in Pierce County. Some of the blooms that were not producing microcystins, were toxic for another algal toxin (mostly anatoxin-a).

The highest microcystin concentration in 2010 was less than observed in the two previous sampling years (853 µg/L in 2010, 18,700 µg/L in 2009, and 4,620 µg/L in 2008). Ecology hypothesized that the cool and cloudy spring and summer affected algal toxicity concentrations. Note that highest toxicities occurred in the fall or late summer (Table 1).

Table 1. Lakes with the highest microcystin concentrations in 2010 (over 50 µg/L)

Lake and County	Microcystin Concentration µg/L & Month Detected	Lake and County	Microcystin Concentration µg/L & Month Detected
Waughop Lake, Pierce	853 µg/L (October)	Ketchum Lake, Snohomish	503 µg/L (October)
Burien Lake, King	815 µg/L (October)	Kitsap Lake, Kitsap	173 µg/L (November)
Lawrence Lake, Thurston	791 µg/L (November)	Tanwax Lake, Pierce	109 µg/L (October)
Cassidy Lake, Snohomish	732 µg/L (September)	Lake Spokane, Spokane	58 µg/L (September)
Black Lake, Thurston	669 µg/L (September)	Patterson Lake, Thurston	54 µg/L (August)
Silver Lake, Pierce	665 µg/L (October)		

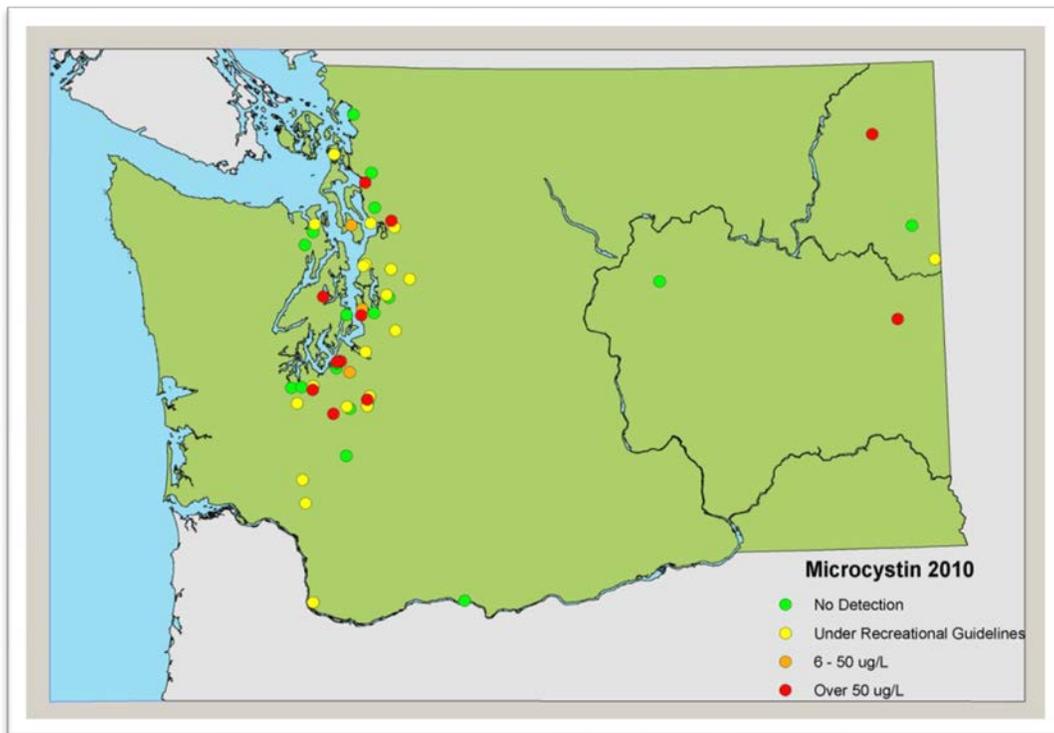


Figure 2. Locations and relative toxicities of the lakes sampled for microcystin in 2010.

2010 Anatoxin-a

Of the 41 lakes tested for anatoxin-a in 2010, 10 lakes (24%) had detectable concentrations and 5 lakes (12%) had levels over the state recreational guidance level of 1 µg/L anatoxin-a. The

highest anatoxin-a concentration detected in 2010 was 538 µg/L in Clear Lake in Pierce County. Previously, the highest concentration of anatoxin-a was detected in 2008 in a sample from Anderson Lake (172,640 µg/L). In 2010, the highest concentration of anatoxin-a from Anderson Lake was 103 µg/L. Note that anatoxin-a occurs throughout all seasons: winter, spring, summer, and fall.

Table 2. Lakes with the highest anatoxin-a concentrations in 2010 (lakes over 1 µg/L)

Lake and County	Anatoxin-a Concentration µg/L and Month Detected
Clear Lake, Pierce	538 µg/L (January)
Lone Lake, Island	265 µg/L (April)
Anderson Lake, Jefferson	103 µg/L (May)
Lake Spokane, Spokane	31.1 µg/L (October)
Tule Lake, Pierce	2.7 µg/L (August)

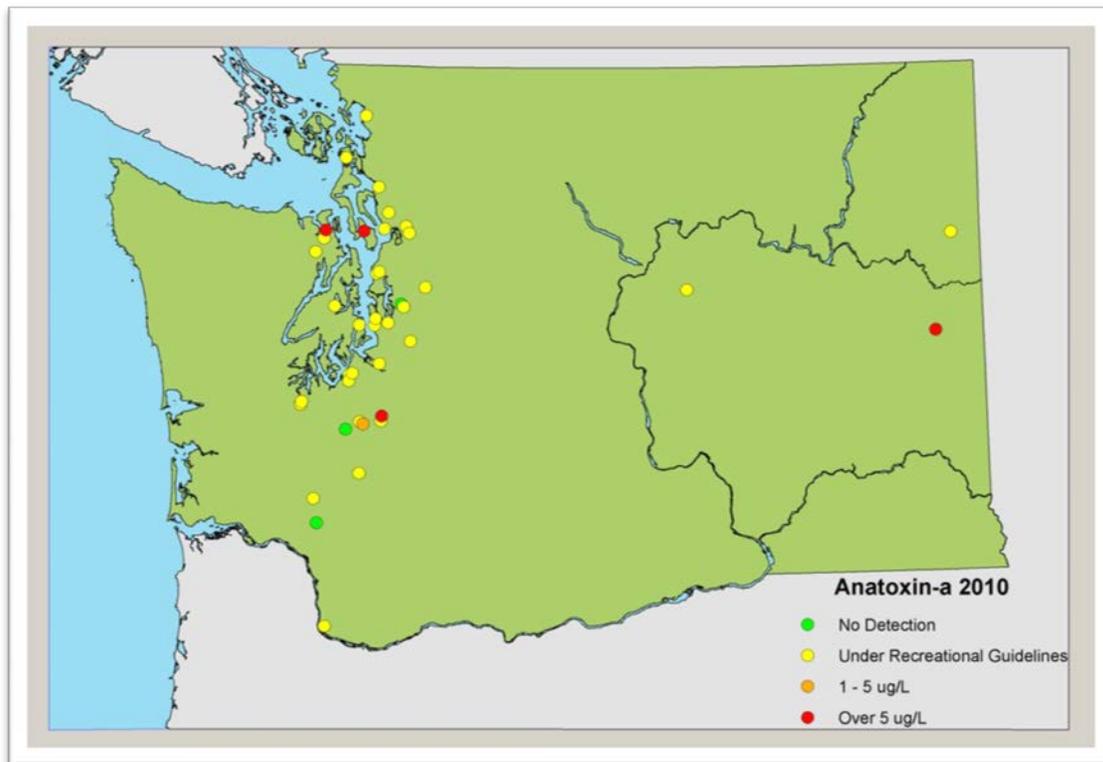


Figure 3. Locations and relative toxicities of the lakes sampled for anatoxin-a in 2010.

2010 other toxins

Two lakes tested over the recreational guidelines for both microcystin and anatoxin-a - Lone Lake in Island County and Lake Spokane in Spokane County. However, the times when anatoxin-a levels were high, microcystin concentrations were low, and vice versa.

In 2010, most samples from Waughop Lake tested positive for saxitoxin (maximum concentration 0.567 µg/L detected on March 9, 2010). This concentration was well below the recreational guideline for this toxin (75 µg/L).

In 2010, thirty lakes in Pierce, King, and Snohomish Counties were tested for cylindrospermopsin. Sunday Lake, in Snohomish County, was the only lake that tested positive for this cyanotoxin (0.107 g/L cylindrospermopsin maximum concentration). This was below the recreational guideline for cylindrospermopsin (4.5 µg/L).

2011 toxicity testing

In 2011, samplers collected bloom samples from 72 water bodies in 15 counties for algal identification and blue-green algae toxin testing. Bloom numbers and toxin concentrations were less in the spring/summer while the weather remained cool and cloudy, but this changed in the fall as the weather improved with warm sunny weather.

2011 Microcystins

Of the 72 water bodies (lakes, ponds, and one creek) tested in 2011, 51 water bodies had detectable microcystin concentrations (71%). There were 11 lakes with microcystin concentrations over 50 µg/L in 2010 and almost twice as many lakes with microcystin concentrations over 50 µg/L in 2011 (18 lakes or 25%). About 42% of the water bodies had microcystin levels above the state recreational guideline of 6 µg/L. **The highest microcystin concentration detected in 2011 (26,400 µg/L) was from Lake Spokane in Spokane County in October. This is the highest concentration of microcystin observed in any sample collected for Washington's toxicity testing program, although Lake Waughop was close behind at 25,200 µg/L from a sample collected in August!** Some of the blooms that were not producing microcystins, were toxic for another algal toxin (mostly anatoxin-a). As noted for 2010, the highest microcystin concentrations occurred in the fall or summer (Table 3).

Table 3. Lakes with the highest microcystin concentrations in 2011 (lakes over 50 µg/L)

Lake and County	Microcystin Concentration µg/L and Month Detected	Lake and County	Microcystin Concentration µg/L and Month Detected
Lake Spokane, Spokane	26,400 µg/L (October)	Lake Jean, King	100 µg/L (September)
Waughop Lake, Pierce	25,200 µg/L (August)	Moses Lake, Grant	73.9 µg/L (October)
Cassidy Lake, Snohomish	5,160 µg/L (November)	Lake Steilacoom, Pierce	68 µg/L (September)
Offut Lake, Thurston	1,620 µg/L (November)	Sunday Lake, Snohomish	67.6 µg/L (October)
Kitsap Lake, Kitsap	755 µg/L (October)	Green Lake, King	64.4 µg/L (January)
Ketchum Lake, Snohomish	551 µg/L (July)	Lone Lake, Island	59.3 µg/L (August)
Potholes Lake, Grant	331 µg/L (August)	Howard Lake, Snohomish	56.3 µg/L (October)
Long Lake, Thurston	167 µg/L (October)	Pattison Lake, Thurston	55.3 µg/L (October)
Duck Lake, Grays Harbor	124 µg/L (September)	Lake St. Clair, Thurston	50 µg/L (October)

Figure 4 shows the locations and relative toxicities of the lakes sampled for microcystin in 2011.

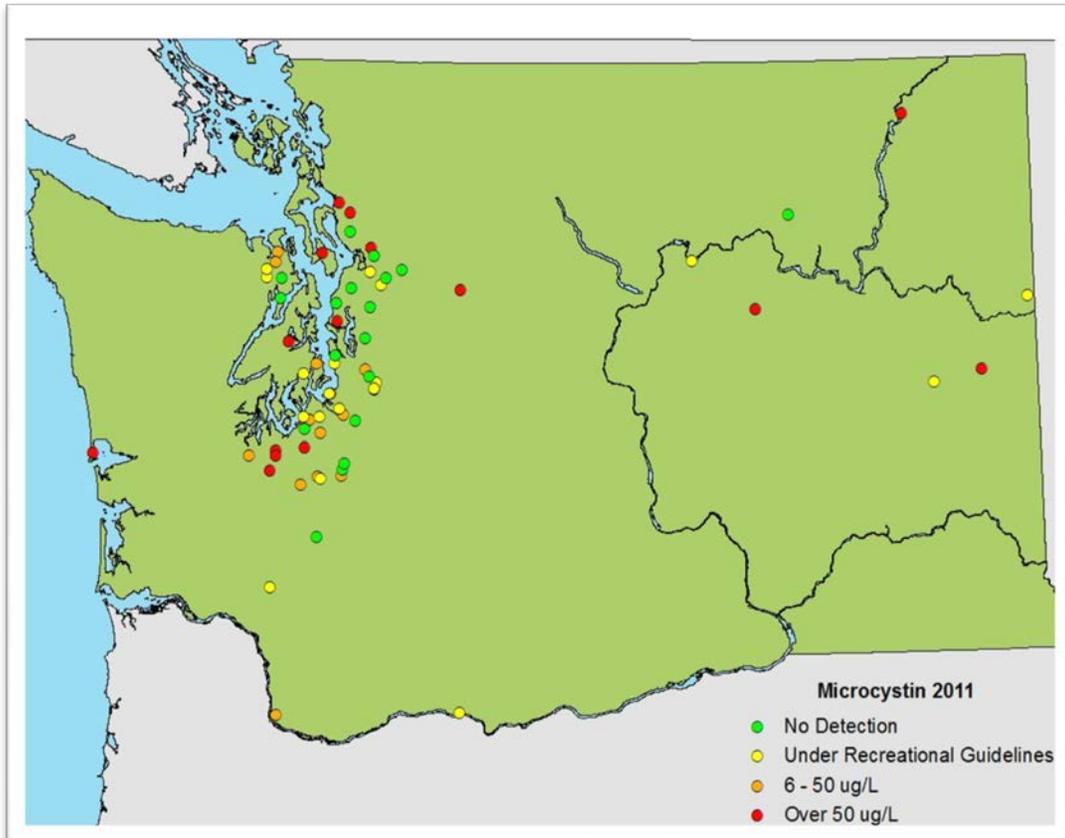


Figure 4. Locations and relative toxicities of the lakes sampled for microcystin in 2011.

2011 Anatoxin-a

Of the 46 lakes tested for anatoxin-a in 2011, 26 lakes had detectable anatoxin-a concentrations (57%), however most of these water bodies had levels below the state recreation guideline of 1 µg/L for anatoxin-a. There were 6 lakes with anatoxin-a concentrations over 1 µg/L (13%). The highest anatoxin-a concentration detected in 2011 (1929 µg/L) was from Anderson Lake in Jefferson County. This is far below the concentration of 172,640 µg/L detected in Anderson Lake in 2008, but ten times higher than the concentration of anatoxin-a in Anderson Lake in 2010. Anderson Lake is a consistent spring producer of anatoxin-a. Some of the blooms that were not producing anatoxin-a, were producing microcystins (e.g., Waughop Lake). Some lakes produced high levels of both toxins (e.g., Lake Spokane). The highest concentrations of anatoxin-a occurred during the spring, summer, and fall (Table 4).

Table 4. Lakes with the highest anatoxin-a concentrations in 2011 (lakes over 1 µg/L)

Lake and County	Anatoxin-a Concentration µg/L
Anderson Lake, Jefferson	1090 µg/L (June)
Clear Lake, Pierce	1170 µg/L (December)
Kitsap Lake, Kitsap	592 µg/L (October)
Lake Spokane, Spokane	114 µg/L (October)
Rufus Woods, Douglas	37.4 µg/L (July)
Long Lake, Kitsap	2.74 µg/L (October)
Bay Lake, Pierce	1.17 µg/L (December)

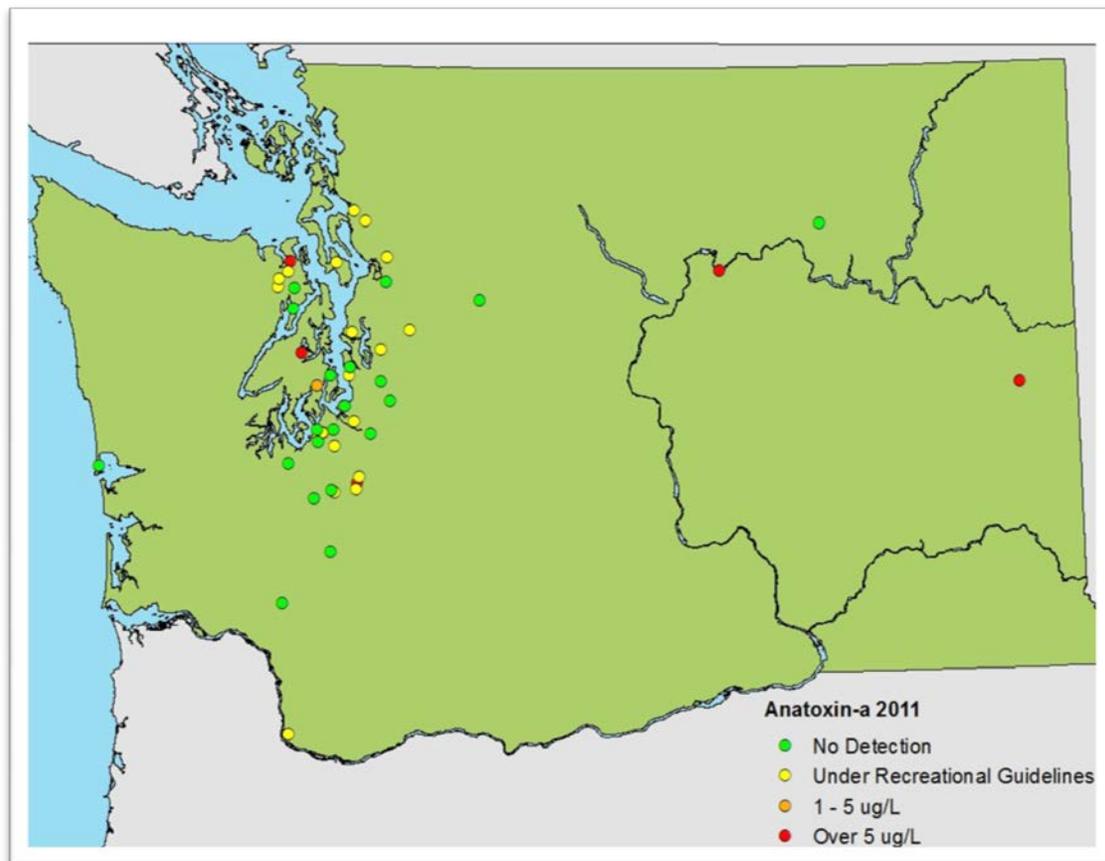


Figure 5. Locations and relative toxicities of the lakes sampled for anatoxin-a in 2011.

2011 other toxins

There were 7 lakes tested for saxitoxin, but only Waughop Lake tested positive (0.192 $\mu\text{g/L}$ highest level detected). All saxitoxin concentrations detected in Waughop Lake were far below the recently established state recreational guidelines for this toxin in freshwater of 75 $\mu\text{g/L}$. Six lakes were tested for cylindrospermopsin, but there were no detections of this toxin in 2011.

Two lakes tested over the recreational guidelines for both microcystin and anatoxin-a – Kitsap Lake (October 18) in Kitsap County and Lake Spokane (October 17) in Spokane County. Lake Spokane also tested above the recreational guidelines for both toxins in 2010. The peak toxin concentrations coincided in both Kitsap Lake and Lake Spokane, meaning that in each water body the blooms were simultaneously producing high levels of two toxins. Unfortunately, there was no algae identification for either sample on these dates. However, generally bloom samples are a mix of two or more blue-green genera. Some genera can produce both anatoxin-a and microcystins (e.g., *Anabaena* spp., *Oscillatoria* spp.). About 25% of the blooms in 2011 had *Anabaena* spp. present, while *Oscillatoria* blooms occurred less frequently.

What do toxicity results mean?

- Washington has a significant number of lakes with toxic blue-green algae blooms found in all areas of the state.
- Although blue-green algae have the capability to produce many toxins, two toxins, microcystin and anatoxin-a, appear to be most prevalent in Washington waters and are of the most concern for the health of humans, pets, and livestock.
- Weather appears to play a role in the severity of toxic blooms. The cooler and wetter spring and summer of 2010 seemed to reduce blooms and toxin concentrations.
- Some lakes, such as Waughop Lake, produce toxic blooms throughout the year.
- Most lakes with a history of toxic blooms experience annual toxic episodes.
- Many lakes produce blooms with toxin concentrations that trigger recreational advisories or restrictions. Toxic algae can cause economic impacts to lake-related businesses.
- Pets have died on some Washington lakes after contact with algal toxins and people have gotten sick from exposure to toxic blooms.

Phosphorus is the most important nutrient that contributes to algae blooms in freshwater systems. Lakes with toxic algae blooms are likely impaired by too high levels of phosphorus.

Toxicity Testing and Algal Identification Program limitations

Ecology relies on volunteers to report blooms, and to collect and ship algae samples to KCEL for identification and toxicity testing. This ad hoc sampling approach, while providing useful information, is not a comprehensive or systematic look at all blooms that occur in Washington in any one year. Sampling efforts often taper off in the fall and winter even though blooms can still occur. Although Ecology instructs samplers to collect scum samples, sampling logistics may prevent them from collecting the densest scum on the water body. Relying on volunteer samplers makes it difficult to draw conclusions from bloom data such as comparing lakes or the number of lakes with blooms from year to year. With a downturn in the economy, many health jurisdictions have not been able to support the level of sampling in 2011 that they did in previous years. However, local health jurisdictions rely heavily on the Freshwater Algae Control Program for valuable information about toxic algae blooms in Washington's freshwaters that enables them to protect human and pet health. Ecology also uses toxicity data to help set funding priorities for control and prevention activities.

Update on Waughop Lake

Waughop Lake is located within the city of Lakewood's Fort Steilacoom Park. The lake has a surface area of approximately 33 acres and a mean depth of seven feet. There are no natural surface water inflows or outflows. However, stormwater from an adjacent college campus provides some inflow to the lake. There is no residential development along the shoreline, although there is a paved trail around the lake providing numerous points of access to the water. Tacoma-Pierce County Health Department (TPCHD) has monitored Waughop Lake for algal toxins for several years.



Waughop Lake 2011 – Photo by Don Russell

The lake has an ongoing problem with toxic cyanobacteria. In 2009, TPCHD posted a warning advisory. In June 2010, TPCHD issued an additional advisory recommending against eating fish from Waughop Lake based on a number of factors, including the ongoing bloom in the lake and an Ecology study that detected microcystins in the tissue of fish collected from the lake. On August 10, 2011, TPCHD closed the lake to swimming, boating, and fishing, although the walking path around the lake remained open. Dr. Anthony Chen, Director of TPCHD said that, “*Algae in Waughop Lake have reached levels that could be dangerous for humans and pets.*” Luckily, nobody has reported human illness or animal illness or death from contact with Waughop Lake to date.



2011 Bloom in Waughop Lake – Photo by Don Russell

Waughop Lake has been the most persistently toxic lake of all state lakes sampled for blue-green toxins in Ecology's toxicity testing program. TPCHD staff reported the first toxic sample from the lake in 2008 and the peak microcystin concentration that year was 1,050 $\mu\text{g/L}$ (July 23). In 2009, the peak microcystin concentration was 4,380 $\mu\text{g/L}$ (September 28). In 2010, the highest concentration was 3,190 $\mu\text{g/L}$ (October 7), and in August 2011, it was 25,200 $\mu\text{g/L}$ – *over 4,000 times higher than the recreational guidance level of 6 $\mu\text{g/L}$!* The 2011 sample is also the second highest microcystin concentration recorded from a Washington lake. As well as being a consistent producer of microcystin, Waughop blooms also produce saxitoxin at low levels.

During most sampling dates, several genera of toxin-producing blue-greens were present in Waughop Lake; *Microcystis*, *Anabaena*, and *Aphanizomenon*.

Aquatic Algae Control Grant Program

Freshwater grant program overview

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

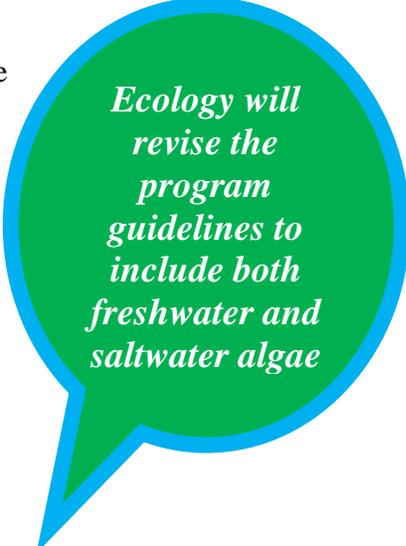
The competitive grant application period generally opens in the fall of each year, but funding levels are dependent on revenue collections, cash flow of previously-awarded grant projects, and legislative appropriations. Ecology:

- 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.
- Typically awards grants in late December or early January.
- Encourages recipients to complete their grant projects within two years.
- Has a freshwater algae grant website www.ecy.wa.gov/programs/wq/plants/algae/grants/index.html with grant guidelines and application form.

Changes to program statutes occurred during the 2010-11 legislative session, leading Ecology to revise program guidelines to include both freshwater and saltwater algae for FY 2013.

Eligible freshwater algae grant activities include:

- Algae control and management
- Planning
- Nutrient reduction activities
- Education and outreach
- Monitoring
- Pilot projects
- Research
- Equipment purchase



*Ecology will
revise the
program
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include both
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saltwater algae*

Saltwater algae grant program overview

All types of seaweeds, including sea lettuce, are essential components of the Puget Sound ecosystem. Seaweeds provide food for sea birds, fish, and other marine animals, as well as shelter for several fish species. However, a few Puget Sound inlets and coves are fertile grounds for blooms of sea lettuce (several species in the genus *Ulva*). Sea lettuce can grow rapidly and



Sea lettuce – photo by Dan Smith

accumulate on beaches in thick piles driven by winds and currents. Sea lettuce tends to occur in shallow bays and inlets during warm, less-windy summers influenced by nutrients (nitrogen) from a variety of sources. At times, the decay of sea lettuce accumulations can release hydrogen sulfide and other sulfur-containing chemicals that can affect human health at high concentrations. Health effects include eye irritation, respiratory distress, and headache. Residents living near these beaches and their local governments would like to be able to manage the accumulated sea lettuce to reduce its impact on their enjoyment of the shoreline.

The 2009 Legislature included language in the state's operating budget for Ecology to provide \$140,000 in grants *for capital and operational expenses used to manage and study excessive saltwater algae with an emphasis on the periodic accumulation of sea lettuce on Puget Sound beaches*. Eligible saltwater algae grants included:

- Projects managing sea lettuce accumulations.
- Research on environmental processes that produce blooms and distribute algae.
- Long-term trends of sea lettuce accumulations.
- Research to determine impacts of these accumulations on habitat, human health, and quality of life.

At the direction of this legislative budget proviso, Ecology developed saltwater algae grant guidelines and an application for sea lettuce projects (www.ecy.wa.gov/programs/wq/plants/SWalgae/index.html).

Completed aquatic algae grant projects

The following grant project descriptions are for projects completed in 2010 or 2011. Earlier legislative reports have project descriptions for grants finished in prior years. Readers may contact Ecology's Water Quality Program Financial Management Section to obtain copies of final reports for any algae grant projects (see contact information at the end of the report).

Completed freshwater algae grant projects

Recipient: Snohomish County Public Works (grant awarded in FY 2008)

Title: Cyanobacteria Prevention and Early Detection

Project goals were to:

- Increase public awareness of toxic cyanobacterial blooms and their causes.
- Reduce risks to human and animal health from toxic algae blooms.
- Help citizens control nutrient sources that fuel these blooms.

Snohomish County conducted extensive monitoring to identify toxic algal blooms and to examine lake and environmental conditions that led to the toxic blooms. County staff monitored toxic blooms in three lakes (Cassidy, Ketchum, and Loma) and collected weekly data on chlorophyll *a* and phycocyanin levels (a pigment found in blue-green algae). Results showed that phycocyanin measurements are a valuable tool in tracking toxic algae. However, Snohomish County could not identify any factors that they could readily use to predict the onset of toxic blooms.

Snohomish County also monitored effectiveness of SonicSolution® units in Lake Ketchum. The manufacturer claims that these units prevent algae blooms by using ultrasound to control algae growth. Snohomish County concluded that there was insufficient evidence to show that these units have a significant impact on controlling algae populations based on chlorophyll *a* and phycocyanin concentrations. Lake Ketchum typically experiences toxic blooms in spite of having had these units in place for many years.

Snohomish County completed public education and outreach efforts through workshops about algae, nutrients, lake health, and on-site septic systems. These efforts may result in behavioral changes that positively affect water quality. The project reduced public health risks by implementing early detection and notification measures and by conducting extensive monitoring to identify patterns that lead to toxic algal blooms.

Grant amount \$28,500

Recipient: Jefferson County (grant awarded in FY 2008)

Title: Lake Assessment and Toxic Cyanobacteria Monitoring Project

Jefferson County assessed nutrient concentrations and limnological conditions of four lakes from February 2009 to April 2010. Anderson Lake, Gibbs Lake, and Lake Leland all experienced toxic cyanobacterial blooms that led to their closures in the three years prior to the study. Sandy Shore Lake, a comparison lake, did not have any cyanobacteria blooms during that time.

This project had three main goals:

1. Develop a comprehensive understanding of cyanobacterial cell density, toxins, lake conditions, and nutrients to direct future monitoring and control efforts.
2. Provide information to make public health recommendations for lake users and managers.
3. Use results from this project to help other agencies and jurisdictions prepare for and respond to cyanobacterial blooms.

Using the monitoring data collected for this project, Jefferson County developed four management recommendations:

1. Use toxicity testing and not algal cell counts to trigger lake toxic algae alerts.
2. Make changes to an aeration system currently in place in Anderson Lake. The system no longer controls the release of phosphorus from lake sediments.
3. Request that the Department of Fish and Wildlife (Department) suspend stocking fish in Anderson Lake until the Department can make changes to the aeration system.
4. Find funding sources to treat Anderson Lake with alum to prevent phosphorus release from the sediments.

Grant amount \$50,000

Recipient: Kitsap County Health District (grant awarded in FY 2009)

Title: Kitsap Lake Phosphorus Reduction Plan

Toxic blue-green algae lake closures and public health advisories have kept the public from using Kitsap Lake as a recreational area during peak usage times. The primary goal of the project was to produce a plan to control and eliminate sources of phosphorus loading, thus reducing the public health exposure risks associated with the toxic blue-green blooms. County staff also conducted public education and outreach to the local community.

Kitsap County assessed phosphorus inputs to Kitsap Lake from streams, storm water, and internal lake cycling over a 12-month period during 2009. They conducted supplemental sampling in August 2010 to compare summer phosphorus levels between the two years. Based on their analysis, county staff concluded that the cause of the blue-green blooms in Kitsap Lake is internal recycling of phosphorus from sediments during low oxygen events occurring during a six-week period each summer. They concluded that the most effective way to remedy this situation would be to treat the lake with alum.

Grant amount \$50,000

Recipient: City of Lakewood (grant awarded in FY 2009)

Title: Lake Steilacoom Aluminum Sulfate Feasibility Study

Lake Steilacoom has historically experienced blooms of toxic blue-green algae resulting in reduced recreational use of the lake and some pet deaths. Over the years, the city of Lakewood in collaboration with the Lake Steilacoom Improvement Club has explored several options to reduce algal abundance. Lakewood originally planned to experiment with solid aluminum sulfate blocks to reduce phosphorus inputs from two lake inflows. Early in the project, recipients determined that this approach was not feasible. Instead, Lakewood and Ecology modified the project scope of work by substituting an alum treatment study for the original project. Consultants conducting the alum study recommended the use of a microfloc alum injection system for Lake Steilacoom. They also made recommendations about how to proceed, including suggestions for additional testing and research.

Grant amount \$12,650



Applying calcium hydroxide to Lake Steilacoom

Photo – Doug Dorling

Recipient: Foster Creek Conservation District (grant awarded in FY 2009)

Title: Rock Island Lakes Nutrient Source Investigation

Hammond Lake in the city of Rock Island in Douglas County has very high concentrations of phosphorus associated with dense blooms of blue-green algae. Shallow water, lack of submersed aquatic plants, and abundant sunlight and phosphorus create ideal conditions for algal growth. Blooms in Hammond Lake sometimes produce toxins.

Foster Creek Conservation District evaluated sources of phosphorus to Hammond Lake including:

- Internal phosphorus loading from lake sediments.
- Phosphorus loads from agriculture, an adjacent golf course, and an old landfill.

Foster Creek Conservation District's consultant analyzed lake water, sediments, ground water from piezometers, and ground water from public and private wells. They also reviewed literature and investigated management practices at the golf course.

Their study showed that phosphorus is available in Hammond Lake from both internal and external sources. The consultant concluded that Hammond Lake will not recover without efforts to reduce phosphorus loading. They recommended:

1. Modifying fertilizer application practices at the golf course.
2. Reducing inputs from nearby septic systems.
3. Managing phosphorus inputs from an old community burn site.
4. Reducing orchard fertilizer runoff.

The consultant also recommended dredging or an alum treatment to reduce internal phosphorus sources. Foster Creek Conservation District will pursue further funding to implement these phosphorus reduction recommendations.

Grant amount \$48,450

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

Title: Pierce County Cyanobacterial Project

The project focused on 29 lakes in Pierce County. The primary goal was to reduce the risk of health impacts to community members from toxic algae exposure by:

- Increasing awareness among community members about human health risks and risks to pets from toxic algae blooms.
- Improving monitoring of lakes to ensure both timely discovery of blue-green blooms and an ability to quantify the extent of toxic algae blooms.
- Improving collection of data related to algae blooms to assist with ongoing surveillance and appropriate policy actions.

To expand public awareness of blue-green algae, the Health Department:

- Completed a pre-and post-project community survey.
- Distributed a toxic algae brochure.
- Held three workshops for lakefront residents.
-

To improve lake monitoring, the Health Department:

- Developed an Algae Watch Program and established a group of volunteers to participate in the program.
- Set up a database to track blooms both qualitatively and quantitatively.
- Refined a Public Warning System based on DOH guidelines, their own experience, and results of their surveys.

Grant amount \$45,901

Recipient: Clark County Public Works (grant awarded in FY 2009)

Title: Cyanobacterial Growth and Grazing in Vancouver Lake

Vancouver Lake has experienced numerous blooms of cyanobacteria in the past decade. These blooms have closed the lake for several days every summer since 2006. Clark County collaborated with scientists at Washington State University to monitor the plankton community and to implement a program to quantify growth rates of algae and grazing rates of zooplankton on these algal populations over the course of a bloom cycle. More specifically, scientists:

- Measured the abundance and taxonomic composition of cyanobacteria, algae, and zooplankton in Vancouver Lake over a year.
- Conducted zooplankton grazing experiments over a bloom cycle to determine if there are seasonal and annual differences in the balance of cyanobacteria/algal growth and zooplankton grazing.

Measurements of cyanobacteria/algal growth rates and protozoan/zooplankton grazing rates over two years indicate that grazers at various stages of the bloom may have a significant impact on certain types of cyanobacteria. For managers and policy makers, these results must be combined with future food web studies to provide a more complete understanding of whole lake food web dynamics. Such information would allow recipients to determine whether Clark County could use biomanipulation to control cyanobacteria blooms in Vancouver Lake.

Grant amount \$48,137

Completed saltwater algae grant projects

Recipient: City of Federal Way (grant awarded in FY2010)

Title: Dumas Bay Saltwater Algae Management

Dumas Bay is a large, shallow embayment of Puget Sound with a history of sea lettuce accumulations. Federal Way documented problematic blooms in 2005 and 2006 when odors from hydrogen sulfide gas production from decomposing algal mats affected both shoreline residential communities and those further inland. Grant project goals were to provide public education, planning for the formation of a Beach Management District, and implementation of a program to monitor air quality and beach conditions.

Major achievements of this project include:

- Formation of a Dumas Bay Steering Committee.
- Increased community awareness about sea lettuce blooms.
- A scope of work for emergency sea lettuce removal.
- Acquisition of a multiple year Hydraulic Project Approval for emergency removal of sea lettuce.
- Implementation of a public education campaign that included a website, quarterly newsletters, periodic flyers, and E-subscribe notices.
- A stormwater audit of the Twin Lake Country Club that focused on identification of nutrient sources in Joe's Creek watershed.
- A hydrogen sulfide air-monitoring program to track and document hazardous air concentrations and development of community notification procedures.
- Beach surveys to document sea lettuce deposition.

The local community did not form a Beach Management District. Their opinion was that factors that cause algal mat accumulations are out of the control of the local community. Local residents also strongly believe that government agencies should study, fund, and remedy the situation causing sea lettuce to grow and accumulate in Dumas Bay.

Grant amount \$34,965



Sea lettuce accumulation in Dumas Bay
Photo: Dan Smith

**Recipient: City of Federal Way
(grant awarded in FY2010)**

Title: Dumas Bay Saltwater Algae Research

Unlike freshwater blooms that are generally limited by phosphorus, nitrogen typically limits the growth of marine/estuarine algae. The city of Federal Way contracted with scientists at Seattle Pacific University to examine nitrogen content in green algae (sea lettuce) and water from several sites in Dumas Bay and comparison sites elsewhere in Puget Sound to determine the source of nitrogen fueling seaweed growth. Scientists determined, through stable isotope analysis, that the primary

nitrogen source is likely to be marine in origin and is consistent with nitrogen sources seen throughout Puget Sound. However, sea lettuce growing near the mouth of Joe's Creek is strongly influenced by an alternate nitrogen source, most likely a fertilizer.

Scientists listed possible local nitrogen sources to Dumas Bay:

- Animal wastes on the beach, including from both domestic animals and wildlife (particularly shorebirds)
- Fertilizer use in the watershed.
- Native and introduced nitrogen-fixing plants growing in the watershed.
- Remineralization of nitrogen from disturbed soils or rock formations within the watershed.

There was no evidence that sewage is having an influence on Dumas Bay saltwater algae growth. Other sources of nitrogen (e.g., atmospheric deposition, upwelling) are regional and beyond human control.

Grant amount \$37,987

Recipient: Western Washington University

Title: Penn Cove Algal Accumulations

The excessive growth of sea lettuce in Penn Cove has been associated with low oxygen conditions that led to fish and invertebrate die-offs in 2003. Western Washington University (WWU) studied Penn Cove sea lettuce accumulations to determine whether nitrate from sewage effluent or from other sources cause excessive growth. WWU also sampled and analyzed for

hydrogen sulfide, dimethyl sulfide, and dopamine to determine the amount of toxins that sea lettuce accumulations produce. They did not detect any of the above chemicals during the study period. They concluded that algae use nitrogen sources from upwelling and the Skagit River to fuel growth. These data strongly suggest that reductions in nitrogen loading to Penn Cove would help control the growth of sea lettuce in the western end of the cove.

Grant amount \$35,000

Active aquatic algae grant projects

Freshwater algae grant projects

Recipient: Snohomish County

Title: Lake Ketchum Algae Control Plan

Through this plan, Snohomish County will identify measures needed to control both internal and external nutrient sources at Ketchum Lake. The plan goals are to reduce the growth of cyanobacteria and stop toxic algal blooms that currently impair use of this lake.

Grant amount \$39,300

Recipient: Thurston County Public Health

Title: Blue-green Algae Toxin Monitoring and Response

Thurston County had five lakes with simultaneous toxic algae blooms in 2010. Thurston County will develop an efficient and effective means of communicating toxic algae advisories to lake residents and users. Staff will also examine an alternative to the grab sampling method of testing for the presence and quantification of microcystin.

Grant amount \$50,000

Recipient: Washington State Department of Health

Title: Harmful Algae Bloom Exposure Reduction

Animal illnesses are sentinels for human health impacts from toxic cyanobacteria exposure. Washington DOH proposes to raise citizen awareness and provide stakeholder outreach through the creation and distribution of animal safety alert posters, the distribution of fliers, and by conducting teleconference workshops for veterinarians about cyanotoxin symptoms and treatment options for exposed animals.

Grant amount \$36,336

Recipient: City of Kent

Title: Lake Fenwick Whole-Lake Alum Treatment

The city of Kent will apply alum to Lake Fenwick to reduce elevated phosphorus levels and to meet Total Maximum Daily Load phosphorus requirements. Reducing internal phosphorus loading will improve lake aesthetics, fish habitat, and reduce the likelihood that toxic algae blooms will develop.

Grant amount \$50,000

Recipient: King County Water and Land Resources

Title: Practical Applications in Algae Management

King County will test three techniques to prevent algal scum accumulation along shorelines and/or remove scums from areas used for recreation and from areas where pet exposure to scums is high. These methods will provide local resource managers with low-cost, simple tools to reduce risk and/or prevent the need for beach closures.
Grant amount \$33,518

Recipient: City of Federal Way

Title: Federal Way Lake Algae Project

Federal Way will implement a comprehensive freshwater algae bloom management program. Efforts will include response to public reports/complaints, field evaluations, site inspections, water quality sampling, sample delivery and analyses, public notifications, data reporting, and community outreach.
Grant amount \$33,518



**Newman Lake Bloom
Photo – Jacob McCann**

Recipient: Grant County Health District

Title: Moses Lake, Potholes Cyanobacteria Surveillance

Grant County Health District will conduct a one-year sampling program for phosphorus in Moses Lake and Potholes tributaries. They will also collect algae samples to analyze for toxins. The District will notify the public about toxic blooms.
Grant amount \$26,429

Recipient: Jefferson County Public Health

Title: Jefferson County Lakes Toxic Algae

Jefferson County Public Health will continue their previous grant-funded project (see their completed project report above). County staff will sample lakes for algal toxins, post signs when toxin levels exceed state recreational guidelines, and undertake outreach activities to educate the public about toxic algae threats.
Grant amount \$30,000

Recipient: City of Lakewood

Title: Zero-valent Iron Nutrient Inactivation

The city declined to continue with this grant project.
Grant amount \$11,250

Other Algae-Related Projects

Algal toxins in fish and sediments



Ecology is conducting ongoing studies (www.ecy.wa.gov/biblio/1003011.html) through its Environmental Assessment Program to determine if fish from lakes with toxic blue-green blooms accumulate toxins in their edible tissue. Studies so far have shown that potentially significant concentrations of microcystins are found in fish collected from lakes experiencing toxic blooms. There were no detections of anatoxin-a from fish tissues, likely because anatoxin-a is an unstable compound that breaks down quickly. A follow-up study compared two methods (high pressure liquid chromatography and enzyme-linked immunosorbent assay) to detect microcystin. This study uncovered discrepancies in detections between the methods. Ecology is attempting to resolve these analytical differences. In the meantime, DOH recommends that people clean fish and discard all internal organs from fish caught in lakes with blue-green blooms.

Ecology is also determining whether microcystin can persist in sediments in Washington lakes that experience toxic blooms based on reports of microcystin persisting in sediments in the scientific literature (www.ecy.wa.gov/pubs/1003112.pdf). Ecology took composite sediment samples from several lakes, some from sediments in deeper water, and some from sediments in shallow water sites from the same lake. Preliminary results indicate that microcystins persist in sediments with greater concentrations of microcystin occurring in deep water sediments. One explanation may be that deep-water sites are colder and darker versus shallow sites that are exposed to full sunlight that may help degrade the toxins.

Centers for Disease Control and Prevention (CDC) grant project

In 2008, DOH entered into a five-year cooperative agreement with CDC to investigate toxic bloom-green blooms in Washington lakes. DOH formed partnerships with Ecology, King and Snohomish Counties, Tacoma-Pierce County Health Department, Seattle University, and National Oceanic and Atmospheric Administration to accomplish the following objectives:

- Investigate human and animal illnesses related to algal toxins.
- Enter toxin data collected under the Ecology program into a national algae database in addition to data on human and animal illnesses caused by toxic blooms in Washington.
- Expand regional monitoring to obtain environmental data associated with toxic blooms.
- Test for microcystin and anatoxin-a toxicity in 30 lakes in Pierce, King, and Snohomish counties.
- Test for cylindrospermopsin and saxitoxin in selected lakes.

- Coordinate and expand outreach efforts to educated local agencies and the public about toxic blooms to prevent exposure and thereby lessen the threat of blue-green toxins to public health.

2011 concludes three full years of monitoring 30 lakes every other week between June and October. DOH and its partners plan to analyze data and publish peer-reviewed journal articles in 2012 and 2013.

Aquatic Algae Control Program Contacts

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

Washington State Department of Ecology

- Lizbeth Seebacher (program coordination and grants program), 360-407-6938
Lizbeth.Seebacher@ecy.wa.gov
- Tricia Shoblom (freshwater 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 and animal toxicity), 360-236-3173
Joan.Hardy@doh.wa.gov

Online Resources

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