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# *Impacts of Climate Change on the Occurrence of Harmful Algal Blooms*


## Summary

Climate change is predicted to change many environmental conditions that could affect the natural properties of fresh and marine waters both in the US and worldwide. Changes in these factors could favor the growth of harmful algal blooms and habitat changes such that marine HABs can invade and occur in freshwater. An increase in the occurrence and intensity of harmful algal blooms may negatively impact the environment, human health, and the economy for communities across the US and around the world. The purpose of this fact sheet is to provide climate change researchers and decision–makers a summary of the potential impacts of climate change on harmful algal blooms in freshwater and marine ecosystems. Although much of the evidence presented in this fact sheet suggests that the problem of harmful algal blooms may worsen under future climate scenarios, further research is needed to better understand the association between climate change and harmful algae.


*Microcystis bloom in Lake Neatahwanta, NY, August, 2010. Courtesy of James Hyde, NYS DOH.*

## Background

Algae occur naturally in marine and fresh waters. Under favorable conditions that include adequate light availability, warm waters, and high nutrient levels, algae can rapidly grow and multiply causing "blooms." Blooms of algae can cause damage to aquatic environments by blocking sunlight and depleting oxygen required by other aquatic organisms, restricting their growth and survival. Some species of algae, including golden and red algae and certain types of cyanobacteria, can produce potent toxins that can cause adverse health effects to wildlife and humans, such as damage to the liver and nervous system. When algal blooms impair aquatic ecosystems or have the potential to affect human health, they are known as harmful algal blooms (HABs).

In recent decades, scientists have observed an increase in the frequency, severity and geographic distribution of HABs worldwide. Recent research suggests that the impacts of climate change may promote the growth and dominance of harmful algal blooms through a variety of mechanisms including:

- Warmer water temperatures
- Changes in salinity
- Increases in atmospheric carbon dioxide concentrations
- Changes in rainfall patterns
- Intensifying of coastal upwelling
- Sea level rise

## Temperature

Harmful algae typically bloom during the warm summer season or when water temperatures are warmer than usual. As temperatures become warmer due to climate change, the growth of harmful algae may be favored over other non-harmful algae through a combination of mechanisms:

*Warmer temperatures create a competitive advantage for certain types of harmful algae.* As seen with the toxin-producing cyanobacteria *Microcystis*, certain harmful algae grow faster than other non-harmful algae at relatively high temperatures, some of them at temperatures above 77°F. This competitive advantage increases the likelihood of HAB events.

*Warmer temperatures increase thermal stratification, favoring the growth of some harmful algae.*
The density of water is strongly influenced by temperature and varies with depth in the water column. Surface waters are usually warmer and less dense compared to bottom waters that are usually colder and denser. During summer months, warming of surface waters can create a physical force strong enough to resist the wind's ability to mix the water. These layers can restrict the vertical movement of oxygen and nutrients in water. This process is known as thermal stratification.

The warming of surface waters increases the frequency, strength, and duration of stratification, which favors the growth of harmful algal blooms. Cyanobacteria and dinoflagellates have the ability to control their depth in water. In stratified waters, these algae can float or swim upwards to form dense surface blooms that block the sunlight for other algae and aquatic organisms that live in deeper layers and are unable to migrate to the surface. Under stratified conditions, these algae may also encounter less competition for nutrients in surface water, increasing their competitive advantage. Most bloom-forming cyanobacteria can form gas vesicles, regulating their vertical position and migrating up and down to obtain nutrients from deeper waters while returning to the surface as blooms.

*Warmer temperatures decrease the viscosity of water, favoring the growth of harmful algal blooms.*
Viscosity is a description of the thickness of fluids. Fluids that have a higher viscosity like honey, are thicker, and therefore do not flow as easily as liquids with a lower viscosity, such as water.

Warmer temperatures reduce the viscosity of water, which increases the speed at which small aquatic organisms can vertically migrate. This makes it easier for small cyanobacteria to float to the surface to form harmful algal blooms. On the other hand, a decrease in viscosity promotes the sinking of larger algae and organisms that are not capable of migrating towards the surface. This may increase the competitive advantage of cyanobacteria over other algae.

*Harmful algal blooms themselves increase water temperature, further favoring their growth.*
Harmful algal blooms absorb light from the sun which increases the temperature of surface water. This positive feedback mechanism further favors the growth of harmful algal blooms and promotes their competitive advantage in aquatic ecosystems.

## Salinity

Climate change may cause summer droughts to increase in intensity and duration worldwide. During a drought, the amount of water flowing into lakes and reservoirs decreases. Combined with warmer temperatures that cause more evaporation, water levels of fresh water bodies decrease. This causes the salinity, or concentration of salt in the water body, to increase. Although certain toxin-producing cyanobacteria are quite salt tolerant, temporary increases in salinity can also cause salt stress leading to leakage of cells and the release of toxins. Increases in salinity during drought conditions can also create favorable conditions for the invasion of marine algae into what are usually freshwater ecosystems. This is currently occurring in our southwestern and south central US lakes where marine alga, *Prymnesium parvum*, or golden algae, has been increasing since 2000, causing significant fish kills in inland waters.

## Carbon Dioxide

All algae, including harmful species, require carbon dioxide ($CO_2$) for photosynthesis. Increases in atmospheric carbon dioxide will increase the levels of dissolved carbon dioxide in marine and freshwater ecosystems, favoring those algae that can grow faster in elevated dissolved carbon dioxide conditions. In addition, cyanobacteria that can float to the surface have a distinct advantage over other competing algae because they can directly utilize carbon dioxide from the atmosphere. As atmospheric carbon dioxide concentrations increase due to human activities such as the burning of fossil fuels and deforestation, cyanobacteria that can float to the surface will have greater access to carbon dioxide for growth, increasing the occurrence of harmful algal blooms.

This also could lead to changes in the chemistry of ambient waters. Higher photosynthesis converts carbon dioxide into living algal biomass, some of which dies and settles to the bottom. The eventual decomposition of this surplus organic material is analogous to our own breathing activity because it consumes oxygen and increases carbon dioxide in areas with poor circulation.  This can contribute to increases in acidity (i.e., lower pH).  This ecological source of acidification is added to the direct acidifying effects of atmospheric carbon dioxide, commonly known as ocean acidification.  Like temperature, these changes in water chemistry can change the competitive relationships between HABs and other algae, and can also change the ability of zooplankton to control HABs through their grazing activity.

## Rainfall

Future climate projections suggest an increase in extreme weather events. For example, the incidence of intense storms causing rainfall to occur in more concentrated bursts followed by long dry periods of drought may increase. Extreme rainfall could increase the transport of nutrients from land into water bodies via runoff. If followed by drought conditions as is projected, water bodies may retain those nutrients for longer periods of time, which increases the potential for HAB development.

## Sea Level Rise

Scientific models predict that sea level could rise from 18 cm up to one meter by the year 2100. This would increase the extent of continental shelf areas, providing shallow, stable coastal waters that may favor the growth of harmful algae and/or expand their habitat inland.

## Coastal Upwelling

Coastal upwelling is a naturally occurring process, in which alongshore winds move coastal surface water offshore which is replaced by deep water that moves along the ocean floor towards the coast. This "upwelled" water brings nutrients from the ocean floor to the surface leading to high productivity. Harmful algal blooms' growth in upwelling systems vary due to atmospheric oscillations (upwelling or downwelling by interannual fluctuations), and is subject to water-column stratification, nutrient availability, and the intensity and persistence of upwelling conditions. Global climate change may alter the timing and intensity of coastal upwelling. Along ocean boundaries, such as the west coast of the US, upwelling may intensify and deliver more nutrients to coastal waters, favoring the growth of both harmful algal blooms and benign species.

## For More Information

For more information on water and climate change, visit http://water.epa.gov/scitech/climatechange/.

To learn more about harmful algal blooms, go to: http://go.usa.gov/gYTH

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