Introduction
Algae are found in all salt and freshwaters worldwide. Although algae are very simple in their structure and sometimes consist only of a single cell floating in water, they are tremendously important for the health of our planet. Algae provide the base of food chains that support whales, seals, sharks and all other marine organisms in the oceans. In freshwaters, they also support food chains that lead to animals as diverse as bass, bald eagles and grizzly bears. Another essential role of algae is that they produce between 40-50% of the oxygen that we breathe through the process of photosynthesis!

The number of algae species is unknown, but it is likely more than 100,000, ranging from single cells to the large seaweeds found along our coastlines. Identification of freshwater algae can be difficult because the cells, or even clusters of cells, tend to be small and a microscope is usually required for accurate identification. In addition to cell shape and size, a key feature for proper identification is the color. Although all algae contain the green pigment chlorophyll, other pigments can also be present and can give the organisms different colors. Green algae are green because of chlorophyll, but diatoms and dinoflagellates are brown because xanthophyll pigments are present in higher concentrations than chlorophyll. The blue-green algae (also called the cyanobacteria)
contain phycocyanin, a blue pigment that, along with chlorophyll, gives the cells a bluish-green color under the microscope.

Algae grow rapidly and reproduce primarily by cell division and by the formation of spores. They do not produce flowers or seeds. Most of the time people don’t notice them, even though they are present in most bodies of water from bird baths to large lakes. Under certain circumstances, algae grow so prolifically that we do notice them. This is when water turns pea-soup green, or when masses of what is commonly called “moss” float on the surface of the water. It is these algae that often need to be managed because of the problems they can cause.

In addition to being unsightly, excessive algal growth (often called blooms) can lead to fish kills. This happens when the algae in a body of water die (crash) all at once. Crashes can be caused by a variety of factors including cell aging, nutrient depletion or sudden changes in weather, such as a shift in water temperature or a period of prolonged cloudiness. Bacteria and fungi that break down the dead algal cells (organic matter) require large amounts of oxygen; as algae decompose, oxygen in the water is depleted, which results in oxygen-starved and dying fish. Since it is difficult to predict when and under what circumstances an algal bloom will crash, it is essential that waters be managed so that excessive growth does not occur. Once a body of water becomes infested with algae, control measures can be used to reduce the frequency and severity of blooms, but it is extremely difficult to eliminate the problem. Because of the many different types of algae and the need to initiate control measures so that fish kills do not occur, it is usually best to consult with a professional lake or pond manager for advice on management strategies. Hiring a certified aquatic pesticide applicator knowledgeable about algae control is also a good move when chemical treatments are recommended.

The algae that cause obvious changes to the color of the water itself are called phytoplankton. These algae consist of single cells or clusters of cells that can only be identified with a microscope. Another major group of algae forms long filaments, or strings, which get tangled together and form clumps or mats. Although these mats start growing along the bottom of a body of water, the oxygen they produce from photosynthesis gets trapped as air bubbles in the mats, causing them to detach from the bottom of the pond or lake and float to the surface. This is when mat-forming algae become visible and cause problems when people try to fish, swim or boat through the mats.

A third group of freshwater algae is the Chara-Nitella group. These algae look like flowering plants because they appear rooted and have “leaves” that are arranged along
a stem. Chara, also called stonewort, usually grows in very hard water and is often calcified (covered with scale) and brittle, whereas Nitella tends to grow in softer waters. These algae provide valuable habitat for fish and stabilize sediments; however, in shallow water some species can grow to the surface and be troublesome.

Algae are usually identified by the taxonomic group to which they belong. From a management standpoint, the two major groups are blue-green algae and green algae. Phytoplanktonic blue-green algae are usually responsible for the pea-soup green color of water. These algae can be extremely harmful not only because they have the potential to cause fish kills by depleting oxygen when they die, but also because some produce toxic compounds that can poison livestock, pets and wild animals that drink contaminated water (Chapter 14). In a few instances, humans have been sickened by drinking contaminated water; also, deaths have been recorded outside the United States. Such poisoning is very rare, but it is always wise to prohibit people from drinking or swimming in water that is dark green in color. Blue-green algae can also cause water to taste or smell foul and can cause fish flesh to taste musty.

Some filamentous blue-green algae form mats but most species of mat-formers are green algae. Mats that float on the surface often get “sunburned” from exposure to high light. The tops of the mats will look yellow; however, if the mat is pulled apart, the green color of the filaments or strings below the surface will be obvious.

Almost all of the algae that cause problems are native to the US and humans have been living with them for centuries. The conditions that promote algae include those typical of small, shallow ponds or lakes that become very warm in the summer and have little or no wave action. The main reason algae are such problems now is because of the impacts we humans have had on our water resources. Like other plants, algae require light, water and carbon dioxide to survive and grow. Light is seldom a problem in shallow waters. Algae and plants also need nitrogen, phosphorus and other nutrients in order to grow. The increase of nitrogen and phosphorus in lakes, rivers and ponds from many sources – including sewage and runoff from fertilized lawns, farm fields and livestock pastures – has caused algal blooms to proliferate in many bodies of water. Excessive algae growth is a key indicator of eutrophic conditions in lakes and ponds (see Chapter 1 for a discussion of trophic states). Even the Gulf of Mexico, which receives nutrient-laden waters from the Mississippi River, has suffered from algae blooms and fish kills.

What can be done to reduce the incidence and severity of an overabundance of algae?

Nutrient reduction and inactivation
A difficult but essential first step is to reduce the factors that cause algae to grow. This is most easily accomplished when constructing a body of water such as a pond. New ponds should be situated away from obvious sources of nutrients and dug deeply enough to prevent light from reaching the bottom. Unfortunately, reducing the input of nutrients into an established pond or lake can be quite difficult. Good watershed management plans are required to reduce obvious sources of nutrients such as upstream inputs from sewage outfalls, lawn or farm field fertilization and livestock operations. Every lake association should initiate and follow through on a watershed management plan. Nutrient sources from around the shoreline – including fertilization of lawns close to the water’s edge – should be reduced as well. Fertilization should be prohibited within at least 10 to 20
feet of the shoreline and fertilizers without phosphorus should be used in areas that have to be fertilized.

Turfgrasses are usually maintained along the shoreline, but these grasses have shallow roots and do little to prevent erosion. Recent interest has focused on planting shorelines with native emergent vegetation such as sedges, rushes and colorful plants such as pickerelweed, cardinal flower and arrowhead. These native plants, which are sold by companies promoting environmental restoration, have longer and more substantial root systems than turfgrasses, which allows them to hold soil better, prevent erosion and potentially absorb more nutrients from subsurface runoff.

Some nutrient inactivation methods in the water itself can help reduce algae blooms. Alum is a material that combines with phosphorus and causes it to precipitate to the bottom so that it is no longer available for algal growth. However, the long-term value of an alum application can be greatly reduced if inputs of phosphorus from the shoreline and watershed continue unabated. Also, alum lowers the pH of the water, which can be detrimental to fish life. Buffers are usually added to prevent this, so the application of alum is best left to an experienced contractor.

Another option is to install aerators. The introduction of oxygen into a body of water changes the chemistry of the water so that phosphorus is precipitated to the bottom. Aeration is also valuable for fish life and the introduction of air (oxygen) to the water promotes the bacterial breakdown of organic matter that has accumulated on the bottom over time. Fountains that just spray water from the pond surface are not effective aerators because they only aerate the top few feet of water. Effective aeration devices are those that deliver oxygen to the bottom waters. They can be purchased or constructed and work on one of two principles. One is to pump air into weighted tubes along the pond bottom. The oxygen bubbles into the water through holes in the tubes. This is
the most commonly used device in ponds. The second type of aerator, called a hypolimnetic aerator, moves low-oxygen bottom water to the surface, oxygenates it and then recirculates the aerated water to the bottom of the lake. These units are typically used on stratified lakes where the bottom waters are cold and the aerated cold water must be returned to the bottom in order to support cold-water fish.

Several enzyme and bacterial products are on the market and claim to reduce the amount of nutrients available to algae. The enzymes are thought to break down organic matter so that it is easier for the natural bacteria to take up the nitrogen and phosphorus that is released during decomposition of the organic matter. Adding a product that contains bacteria is intended to supplement the natural bacteria population. In theory, bacteria are better competitors for nutrients than are algae. Consequently, the bacteria should reduce the amount of nitrogen and phosphorus that is available for algae growth, resulting in clear water. Unfortunately, very little research has been conducted on the effectiveness of these products and testimonials are mixed, so their usefulness is controversial.

Nutrient reduction/inactivation strategies can help improve the overall health of a body of water. On the other hand, they seldom cure algae problems because it is usually difficult to identify the source of inputs of nitrogen and phosphorus. Is it lawn fertilization? Is it from the recycling of nutrients from the lake or pond sediments? Is the soil naturally rich in nutrients? Or is it from a number of other potential sources? Without this information, it is difficult to develop a nutrient reduction strategy that results in relatively rapid and long-term control of algae.

**Other control options**

Reducing light penetration through the use of EPA-registered dyes can be helpful in algae control. Dyes should be applied early in the growing season before algae appear at the surface. However, since algae often start growing in shallow water, the dye may not be at a high enough concentration in those areas to sufficiently reduce algal populations. Once algae begin to grow in shallow water, they can then spread to the upper portions of the deeper water relatively quickly. Since the dye concentration in the water must be maintained throughout the growing season, dyes are more effective on bodies of water that have little to no outflow. Dyes alone are seldom effective for controlling algae, but they can be used after an algicide treatment to reduce regrowth.

Mat-forming algae can be raked out manually or with mechanical harvesters. Raking is typically done around boat docks and in swimming areas. Since mat-formers are mostly free-floating, new mats can rapidly reinfest an area that has been raked. The
only biological control agent (Chapter 8) being used for algae control is the tilapia (*Tilapia zillii*), a fish that has been introduced into and can only survive in waters of the southern US. Tilapia are stocked in very high numbers in the cooling reservoirs of some southern power plants, but they are not used by the public. The grass carp or white amur (Chapter 10) does not feed on phytoplankton. When young, grass carp will consume some mat-forming algae, but they do have preferences (slimy algae are rejected; coarser algae might be eaten). As the grass carp age, they tend to feed more on submersed plants than on algae.

**Algicides**

Direct control of algae is most frequently accomplished with algicides. Copper sulfate (Chapter 11) has been used for algae control since the early 1900s and is used on more surface acres of water than any other product that controls algae or aquatic plants. One of the benefits of copper sulfate is that phytoplanktonic blue-green algae are more sensitive to it than are phytoplanktonic green algae. As a result, noxious blue-green algae can often be removed without harming the green algae, which are usually desirable because they are an important component of the aquatic food chain. Both copper sulfate and the copper chelated products are also used to control mat-forming algae. Liquid formulations of chelated copper products are particularly effective for this purpose because they can be easily mixed with water and sprayed directly onto the algae mats.

Copper sulfate and copper chelates are widely used throughout the world to treat reservoirs that collect and store drinking water. Our ability to safely treat water with copper products to control blue-green and other algae is predicated on the low dosages used, the fact that copper precipitates out of the water and into the sediments within several days in moderately hard to hard waters, and on the inability of copper to bioaccumulate (build up over time) in fauna in the food chain. Animals and humans actually require small amounts of copper in their diets and the element is often included in human vitamin supplements and in animal feed. Copper from treated water that is consumed by humans and
other animals passes through the body and is expelled in the urine rather than moving into the
body’s tissues. Copper products can be applied to water with no restrictions on water use (e.g.,
swimming, fishing, drinking); however, they should be used very carefully or not at all in waters that
contain sensitive fish species such as trout, koi and goldfish.

Copper products are effective and widely used, but they do not solve the underlying issue of why
the algae are there in the first place. These algicides do offer short-term relief, which can be
extremely valuable in terms of preventing fish kills (if treatment is initiated before the bloom
becomes severe) and opening up the water for fishing, swimming and other activities. However, it is
extremely unlikely that copper applications will kill all the algae or their spores, so regrowth almost
always occurs. Furthermore, copper products are very short-lived in the water and algae can start to
reappear quickly, sometimes within several weeks. As a result, the potential for retreatment has to
be part of any management plan that uses copper products.

There are very few alternatives to copper for direct algae control. The amine salt of endothall has
algicidal activity and can be sprayed along the edges of ponds for control of mat-forming algae.
Read and follow the herbicide label for endothall carefully as this herbicide can be toxic to fish if
not used correctly. Compounds that are based on sodium carbonate peroxyhydrate release
hydrogen peroxide (Chapter 11) into the water, which rapidly kills the algal tissue it comes into
contact with. Unlike copper, hydrogen peroxide breaks down rapidly in water to produce hydrogen
and oxygen, so it leaves no residues. A uniform application of the sodium carbonate peroxyhydrate
granules is necessary to ensure optimum results because the hydrogen peroxide products only
control algae that come into direct contact with the granules. Since hydrogen peroxide products are
fairly new to the market and have not been available for very long, they have not been tested for
effectiveness as extensively as copper. Research is still needed to determine which algal species are
most effectively controlled by these products.

Another chemical approach that has received much publicity is the use of barley straw for algae
control. English researchers found that bundles of barley straw placed in water released a toxin that
killed algae as the straw decomposed. A number of barley products, including barley straw extracts,
are on the market. The potential of the toxin to kill algae is well established but the conditions
under which the activity occurs are as yet unknown. In other words, we do not know which algal
species are affected nor do we know what effects water temperature, water hardness, nutrient
status, etc. might have on the effectiveness of this treatment. Anecdotal evidence suggests that the
method is inconsistent; that is, it might work on one body of water but not on another, and the
reason for this is not known. Caution, along with much reading and study, are recommended before
attempting to use barley straw to control algae.

Summary
Algae problems are usually the result of too many natural- or human-derived nutrients in a body of
water. As long as light, nutrients and water are available, something green will grow. Even
swimming pools can develop algae problems because different types of algae have different
nutrient requirements and all water – even rainwater – contains nutrients. The algae that cause most
problems are blue-green algae and mat-forming green algae. Due to their diversity and ability to
reproduce quickly, algae are difficult to control. Many products claim to reduce algal populations,
but unless they make direct claims of algae control, they do not have to be registered for use with
the EPA and are largely untested. Products that are registered with the EPA include some dyes and algicides such as the copper, peroxide and endothall products. Specific use directions are explicitly stated on the labels, which are excellent sources for further information.

For more information:

- Algae control with barley straw (Ohio State University Extension Fact Sheet)
  http://ohioline.osu.edu/a-fact/0012.html
- Algae: some common freshwater types (Microscopy UK)
- Blue-green algae (cyanobacteria) blooms (California Department of Public Health)
  http://ww2.cdph.ca.gov/Healthinfo/EnvironHealth/Water/Pages/bluegreenalgae.aspx
- Blue-green algae photo gallery (Vermont Department of Health)
- Harmful algal blooms (HABs) (Centers for Disease Control and Prevention)
  http://www.cdc.gov/hab
- Identifying and managing aquatic vegetation (Purdue University)
  http://www.extension.purdue.edu/extmedia/APM/APM_3_W.pdf

- Plant identification: algae, AQUAPLANT (Texas A&M University)
  http://aquaplant.tamu.edu/database/index/plant_id_algae.htm
- Surf your watershed (United States Environmental Protection Agency)
  http://cfpub.epa.gov/surf/locate/index.cfm

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