Natural Resources Facts
University of Rhode Island • College of Resource Development
Department of Natural Resources Science • Cooperative Extension

August, 1996 **Fact Sheet No.96-4**

Algae in Aquatic Ecosystems

Kelly Addy and Linda Green

Algae play a vital role in all aquatic ecosystems. Algae form the food and energy base for all organisms living in lakes, ponds, and streams. However, unnatural or excessive growth of algae (nuisance algal blooms) may interfere with our enjoyment of aquatic resources and may even be harmful. Because of their importance to aquatic ecosystems and susceptibility to changes in the environment, algal measurements are often key components of water quality monitoring programs. This fact sheet will describe algae and their role in aquatic ecosystems; characterize algal succession; describe how algal levels are measured and what these measurements indicate; and discuss how algal populations, especially nuisance algal blooms, may be controlled.

What are Algae?

There are two main forms of algae: micro and macro algae. This factsheet will focus on micro algae—microscopic, often unicellular plants. Unlike their larger plant relatives, algae do not have roots, stems, or leaves. Not all algae are green; algae come in a wide range of colors depending on which pigments are dominant in their cells. For example, if chlorophyll *a* is present in high concentrations, algae tend to be green, but orange and red colored algae are caused by high levels of carotene pigments. Micro algae are divided into two general groups: phytoplankton and periphyton. **Phytoplankton** live suspended in the water column. **Periphyton** live attached to rocks, sediment, plant stems, and aquatic organisms. Algae usually are single-celled (unicellular) with these cells either solitary or grouped in clusters (colonies) or strings (filaments).

Like their aquatic and terrestrial plant relatives, algae are primary producers, known as **autotrophs**. Autotrophs convert water and carbon dioxide to sugar (food) in the presence of sunlight. This process, **photosynthesis**, generates oxygen as a by-product. This oxygen contributes to the survival of fish and other aquatic organisms in lakes. Algae also form the base of lake food chains; all lake organisms depend either directly or indirectly on algae as a food source.

Phytoplankton need to stay near the water's surface in order to absorb sunlight for photosynthesis. Algae come in an amazing number of sizes and shapes which are actually adaptive strategies to prevent them from sinking away from the sunlight in the upper portion of the water column. These anti-sinking adaptations include flat, wide cell shapes and spines which increase friction and lessen gravitational influences. Some phytoplankton have developed mechanisms to move actively (Caduto 1990). Tail-like extensions, **flagella**, of some algae can move them through the water (Fig. 1). Some phytoplankton adjust the size of gas-filled sacs, **vacuoles**, to move through the water column.

Some algae reproduce via asexual reproduction, where the parent splits into two or more cells, while other algae are capable of sexual reproduction (Caduto 1990 and St. Amand 1995). A few algae can reproduce by either method with some algae alternating methods depending on environmental conditions. Some even adapt reproduction rates in response to water flow rates. For example, an alga may reproduce faster in turbulent waters, to replace cells swept downstream, than in still waters where algal biomass can accumulate (Caduto 1990).

Role in Aquatic Ecosystems

Increases in algal cell numbers are affected by season, temperature, amount of sunlight penetrating the water column, amount of available inorganic nutrients, competition from other algae and aquatic plants, and how

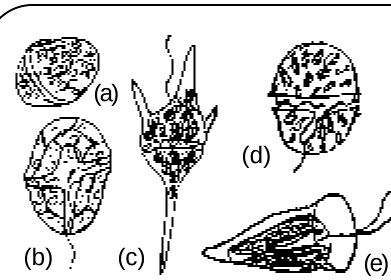
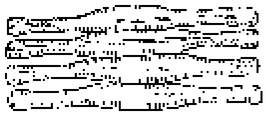


Fig. 1: *Peridinium* (a & b), *Ceratium* (b), *Gymnodium* (c), and *Dinobryon* (d) are algae very common in Rhode Island lakes (Source: St. Amand & Wagner 1995). They all have flagellae to move them through the water column. *Size:* Microscopic detail shown.

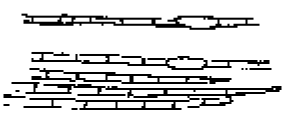
Kelly Addy is a Graduate Research Assistant in the Department of Natural Resources Science, University of Rhode Island. Linda Green is Program Director of University of Rhode Island Watershed Watch and a Research Associate IV in the Department of Natural Resources Science, University of Rhode Island.
Contribution #3400 of the College of Resource Development, University of Rhode Island, with support from Rhode Island Cooperative Extention and partial support from the Gloria Hurley Watershed Watch endowment of the URI Foundation.

Some Types of Algae

When viewed under a microscope, the symmetrical geometric patterns of **diatoms** can be seen (*Fragilaria* is shown here in microscopic detail). Silica is the primary component of the diatom skeleton, which cannot be decomposed. Preserved diatom skeletons in lake sediments are an important tool for scientists interested in determining a lake's history (Caduto 1990). The ancient remains of diatoms have even contributed to our current fossil fuel supplies (Caduto 1990).



Blue-green algae are actually blue-green bacteria, **cyanobacteria** (*Aphanizomenon* is shown here in microscopic detail) (Caduto 1990 and Monson 1992). Many blue-green algae are capable of converting atmospheric nitrogen into useful forms in a process known as nitrogen fixation. These species tend to flourish in mid to late summer when lake nitrogen concentrations are low. These species are also particularly resilient, they are able to over-winter as spores in the lake. The large colonies of blue-green algae are not a preferred food of lake organisms, which improves survival rates. Some blue-green algae produce toxins that, in high concentrations, have the potential to kill animals. Blue-green algae are best known as the dominant species of most algal blooms.



long the water stays in the lake (**residence time**) (Simpson 1991). When enough sunlight is available, such as in summer, the amount of phosphorus in the lake often controls the abundance of algae. Therefore, phosphorus is considered the **limiting nutrient** in most fresh waterbodies.

Some phosphorus enters a lake naturally. For example, autumn leaf fall, animal wastes, waterfowl, and atmospheric deposition contribute phosphorus tolake ecosystems. However, human activities often increase the amount of phosphorus. Man-made contributors of phosphorus to aquatic ecosystems include: phosphate containing detergents, lawn and garden fertilizers, improperly sited or maintained septic systems, urban storm runoff, agricultural drainage, wastewater treatment effluent, and road de-icers. As land becomes more developed, the amount of runoff and the nutrient concentration of runoff increases. When excess nutrients enter a waterbody, algal growth rates are stimulated, increasing populations to abnormally large sizes. Excessive amounts of algae on the surface of the lake may also occur as dense, smelly mats. Any excess of algal biomass is often referred to as an **algal bloom**.

Seasonal Changes in Algae

Algae are a very diverse group of organisms. More than 40 species can coexist in one lake! Throughout the year, however, algal species dominance of lakes changes in a yearly cycle, known as **algal succession** (Kortmann & Henry 1990). This natural succession of algae occurs in response to changes in season, temperature, wind, precipitation patterns, and nutrient cycles (Moore & Thornton 1988). Algal populations are abundant in spring and early summer when available light and nutrients are high and few organisms are present to feed on the algae. Toward the end of this stage, a phenomenon, commonly known as the **clear water phase** , occurs in many lakes. Spring algal populations are usually composed of small, highly edible species. As this phase approaches, zooplankton populations increase dramatically. These zooplankton consume algae rapidly, causing algal populations to crash, resulting in very clear water for a few weeks, hence the name "clear water phase."

These small, edible algal populations are gradually replaced by larger, colonial, non-edible species that are often covered by gelatinous sheaths. Because available nutrient concentrations are often limited in the summer, the total concentration of algae in summer can be less than in spring before the clear water phase. In late summer and fall, nutrients stored at the bottom of the lake become mixed through the water column generating a fresh supply of nutrients. This allows algal populations to flourish again and late season algal blooms to develop. During winter months, algae are able to survive, but usually at low concentrations due to colder water temperatures and lower amounts of available sunlight.

Nuisance algal blooms

Algae are necessary and beneficial to aquatic ecosystems. They form the food and energy basis for nearly all other aquatic organisms. However, unnaturally elevated levels of algal growth may interfere with use and enjoyment of lakes, ponds, and even streams. Nuisance algal levels usually decrease aesthetic beauty, by reducing water clarity, and often create taste and odor problems. Extremely high levels of algae can generate enough shade to prevent sunlight from reaching rooted aquatic plants (macrophytes), limiting their plant growth or even causing them to die (Fig. 2). Also, as more algae grow within the lake, there are more dead algae to be decomposed. Decomposition by bacteria consumes oxygen and may decrease or even completely deplete dissolved oxygen contents of some lakes during the summer. Complete lack of oxygen is a condition known as **anoxia** which can cause fish kills (see Natural Resources Facts, Fact Sheet No. 96-3, "Dissolved Oxygen and Temperature").

High levels of algae may raise the pH of waterbodies. Elevated pH levels are thought to be a by-product of photosynthetic uptake of carbon dioxide. Daily cycles of pH

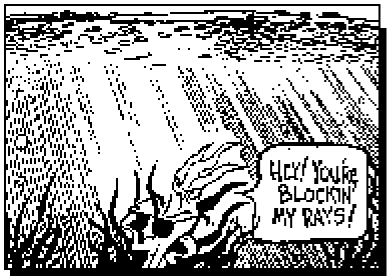


Fig. 2: Nuisance algal blooms may prevent sunlight from reaching aquatic plants lower in the water column.

can be observed. Higher pH levels may be noted late on sunny summer afternoons after photosynthesis has consumed carbon dioxide throughout the day. After sunset, pH levels may fall noticeably since photosynthesis has ended. These extreme fluctuations in pH stress sensitive aquatic life.

There is also concern that excessive amounts of algae may form the organic matter base of a reaction with the chlorine used at many water treatment facilities. This generates trihalomethanes (Moore & Thornton 1988). Trihalomethanes may be associated with cancer risks.

It is important to realize that algae occur in natural cycles of abundance in aquatic ecosystems (Fig. 3). Blooms of algae should only be considered problematic if they occur with increasing frequency as a direct result of human influence on the environment. Lake management emphasis should be geared toward maintaining healthy, natural levels of algae within waterbodies.

How are Algal Concentrations Measured?

Because algae are strong indicators of environmental change, many water quality monitoring programs measure algal concentrations to determine changes in water quality. In all plants and algae, photosynthesis requires the green pigment **chlorophyll *a***. Although the ratio of chlorophyll *a* to biomass can vary among algal groups, measurement of chlorophyll *a* concentration is considered a reasonable estimate of algal concentrations.

To measure chlorophyll *a* concentration, a lake water sample is taken. A known quantity of water from this sample is passed through a glass fiber filter disk. The filter catches the algal cells from the sample. The filter is stored in the cold and dark to minimize additional algal growth or degradation. Chlorophyll *a* is extracted with an acetone solution. Concentrations are determined by analysis with a fluorometer or a spectrophotometer. This method may be the most reliable method of determining algal concentrations because chlorophyll *a* is chemically extracted from the algal cells (Simpson 1991). Other benefits of this method include the ease and consistency of sampling which appeals to many volunteer water quality monitoring groups, including URI Watershed Watch.

There are some limitations associated with measuring algal biomass, the quantity of algae, using this technique. One limitation is that algae are not uniformly distributed through a waterbody. To compensate for this patchiness, multiple water samples should be taken on each sampling date. Alternatively, subsamples may be taken from a larger composite sample. A number of volunteer monitoring programs, including groups in Vermont, address this patchiness by taking an integrated sample, as suggested by EPA. In this approach, monitors extend a garden hose down to two times the Secchi depth measurement, producing a water sample representative of the water column.

Another limitation of this chlorophyll *a* measurement method is that some species of algae have naturally higher chlorophyll *a* levels than other algal species. Additionally, the chlorophyll *a* concentration within algae fluctuate during the day in order to maximize the efficiency of photosynthesis. Uniform and repeated measurements are the best way of dealing with these limitations. Taking water samples at the same time of day and at the same depth in the water column each time a sample is collected can reduce inconsistencies. URI Watershed Watch recommends taking chlorophyll *a* samples between 10am and 2pm at the deepest spot on the pond at a 1 meter depth.

A way to measure algal concentrations indirectly is by taking Secchi depth measurements, a measure of water clarity (see Natural Resources Facts, Fact Sheet No. 96-1, "Measuring Water Clarity). The degree of water clarity is a result of the amount of suspended materials in the water column. In areas of low sediment inputs to lakes, there is a strong relationship between Secchi depth measurements and chlorophyll a concentrations. Total phosphorus concentrations may also be used to estimate the potential amount of algae in a lake (see NRS Facts 96-2 "Phosphorus and Lake Aging").

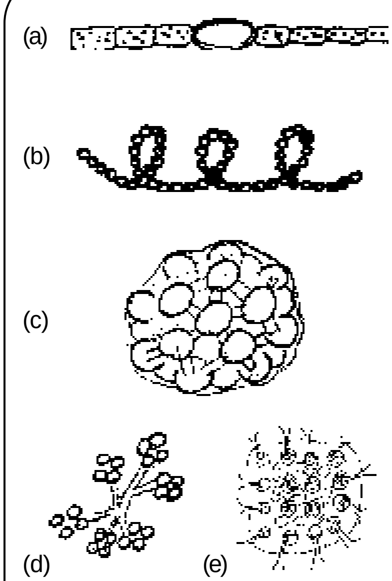


Fig. 3: *Anabeana* (a & b) are very common forms of blue-green algae found in RI lakes. *Coelastrum* (c), *Dictyosphaerium* (d), and *Gonium* (e) are very common forms of green algae found in RI lakes. *Size:* microscopic detail shown. (Source: St.Amand & Wagner 1995)

What do algal measurements mean?

Algal concentrations can be used to determine the trophic status of a lake. Trophic status is an indicator of the stage of the lake in terms of the natural process of lake aging, known as eutrophication.

Oligotrophic waters are clear to great depths and have few algae. Waterbodies with abundant algae are described as **eutrophic**; these are often turbid. In the middle of the spectrum, with moderate algal levels, are **mesotrophic** waterbodies.

Trophic status can be estimated from chlorophyll *a* concentrations, Secchi depth measurements, or total phosphorus concentrations. Each parameter used alone has its weaknesses, but when considered together, they help to create a more complete picture of a lake's water quality and the relationship between water quality and algal growth. By evaluating which particular algal species resides in a lake, even more information can be obtained about a lake's water quality.

How can Algal Populations be Controlled?

Due to the growing concern about nuisance algal growth in many lakes, mechanisms have been explored to limit algal growth (McComas 1993). The best way to limit algal growth is to limit the amount of nutrients that enter the lake (see Natural Resources Facts, Fact Sheet No. 96-2, "Phosphorus and Lake Aging" for suggestions). However, alternative methods of algal control have been developed. (McComas's 1993 edition of *LakeSmarts: The First Lake Maintenance Handbook* is highly recommended for more information on control strategies since this discussion is very general and brief.)

Chemicals can be added to lakes to reduce algal growth. Copper sulfate and various synthetic organic compounds are frequently used as herbicides. Buffered alum and/or calcium compounds are sometimes added to bind up phosphorus and make it unavailable for algal use. This approach works well if phosphorus is supplied by recycling within the lake, and inputs from surrounding areas are kept to a minimum. While these chemicals are effective in reducing algal growth, application requires RI DEM permits and must be applied by a licensed applicator. Even though considerable research has been conducted to assure the safety of these herbicides, controversy still exists over their long-term effects on ecosystems.

Other artificial control strategies include aeration, introduction or manipulation of biological controls, and physical removal of algae. Mechanical aeration adds oxygen to lakes in order to inactivate phosphorus or reduce the effects of algal blooms. Biological controls, such as grazers that consume algae, can limit the number of algae living in the lake. Physical removal of algae often involves filtering algae from the water. These control methods may be costly, and efficiency varies.

The best control method is limiting algal growth before it accelerates by limiting the amount of nutrients entering the waterbody. As long as algae do not reach nuisance levels, they play an important, essential role in a healthy aquatic ecosystem (Fig. 4).

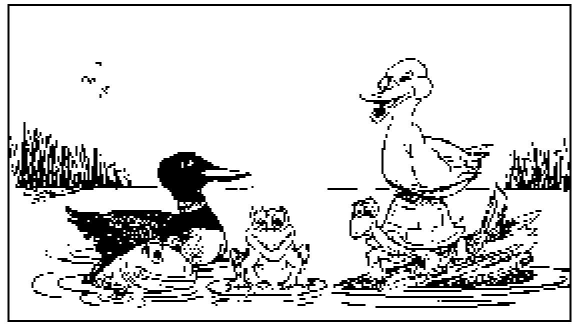


Fig. 4: Algae are at the base of what makes a happy, healthy aquatic ecosystem.

Special thanks to URI Professor Dr. Saran Twombly, URI Research Associate Elizabeth Herron, and Dr. Kenneth Wagner of Fugro East, Inc. for reviewing and commenting on this fact sheet. Algae graphics were obtained from St. Amand and Wagner's 1995 algal workshop (reference below). The University of Wisconsin Extension and Wisconsin DNR provided the other graphics used in this factsheet.

For more information:

Caduto, M.J. 1990. *Pond and Brook: A Guide to Nature in Freshwater Environments*. Prentice Hall, Inc. Englewood Cliffs, N.J.

Kortmann, R.W. and D.D. Henry. 1990. *Mirrors on the Landscape: An Introduction to Lake Management*. Connecticut Institute of Water Resources. University of Connecticut, Storrs, CT. Phone # (203) 833-8317.

McComas, S. 1993. *Lake Smarts: the First Lake Maintenance Handbook*. Terrene Institute, 4 Hebert St., Alexandria, VA 22305. Phone # (703) 548-5473.

Monson, Bruce A. 1992. *A Primer on Limnology, Second Edition.* Water Resources Research Center, College of Natural Resources, University of Minnesota, Room 302, 1518 Cleveland Avenue, N., St. Paul, MN 55108. Phone # (612) 624-9282.

Moore L. and K. Thornton, ed. 1988. *The Lake and Reservoir Restoration Guidance Manual*. First Edition. EPA 440/5-88-002. Phone # (904) 462-2554.

Natural Resources Facts, Fact Sheet No. 96-1, "Measuring Water Clarity," 1996. Cooperative Extension, URI.

Natural Resources Facts, Fact Sheet No. 96-2, "Phosphorus and Lake Aging," 1996. Cooperative Extension, URI.

Natural Resources Facts, Fact Sheet No. 96-3, "Dissolved Oxygen and Temperature," 1996. Cooperative Extension, URI.

Simpson. 1991. *Volunteer Lake Monitoring: A Methods Manual*. EPA 440/4-91-002. Phone # (202) 260-7018

St. Amand, A. 1995. Algae—nature's artwork. *Lakeline*. September: 10-11, 24-26.

St. Amand, A. and K.J. Wagner. 1995. Algal workshop: collection, identification, and ecology of freshwater algae. NALMS workshop series, Madison, WI.

For more information about URI Watershed Watch:
Please call Watershed Watch at (401) 874-2905
or e-mail riww@uriacc.uri.edu