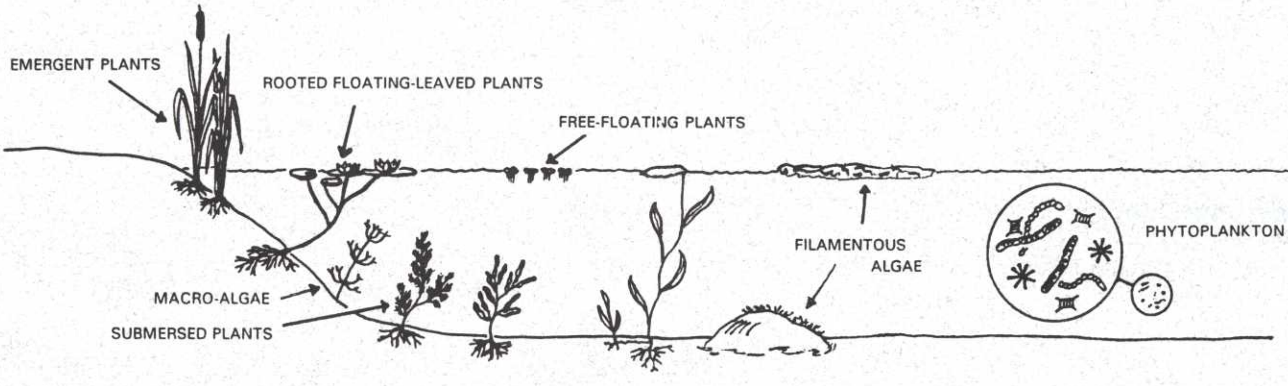
Lake Notes

Aquatic Plant Management Options

Aquatic plants are important and necessary components of a healthy lake ecosystem. Microscopic plants (algae) form the base of the aquatic food web. Larger algae and plants (macrophytes) provide spawning areas, food, and protective cover for fish; habitat for insects and snails; and food and nesting material for waterfowl. Rooted plants also help stabilize the lake bottom. Emergent and nearshore submersed plants help protect against shoreline erosion by calming waves and stabilizing shoreline soils. All aquatic plants produce oxygen and organic matter that help keep other lake organisms alive. But even with all these benefits, too many plants in a lake can have detrimental effects on the lake's inhabitants, ecology, and human uses.



Does your lake have a "macrophyte" or "algae" problem? **Macrophytes** are large vascular plants that live in wet conditions. They usually have "true" roots, stems, and leaves, and look similar to plants in your yard. Macrophytes can be grouped into four categories: emergent plants, rooted floating-leaved plants, submersed plants, and free-floating plants. ***Emergent plants*** are rooted in the lake bottom sediment but have most of their stems and leaves extending above (emerging from) the water surface. They are typically found along lakeshores and in wetlands where water depths are less than 4 feet. Common species include cattails, bulrushes, and arrowhead. ***Rooted floating-leaved plants*** have leaves and flowers that float on or extend just above the water surface, and are connected to their roots in the lakebed by a long stalk. Water lilies are a well-known example. ***Submersed plants*** are rooted in the lake bottom and grow up through the water. Stems and leaves remain below the water surface, though some species also produce floating leaves. Often their flowering stalks will extend above the water. Narrow- and broad-leaved pondweeds, watermilfoils, coontail, and naiads are common examples. The leaves of ***free-floating plants*** float on the water surface with their roots dangling in the water. Common examples include duckweed and watermeal.

Algae are plants with no "true" roots, stems, or leaves. ***Phytoplankton*** are microscopic and are suspended in the water. When abundant enough to color the water green or form paint-like scums, they are called "blooms." Among this group are many of the green algae, blue-green species, and diatoms. ***Filamentous algae*** are long, stringy, "mossy" types which can form floating mats that usually begin their growth on the lake bottom or water's edge. They also may appear as hair-like growth on logs, rocks, and other lake vegetation. *Cladophora*, *Spirogyra*, and *Hydrodiction* belong to this group. ***Macro-algae*** are large, easily-seen upright forms that resemble submersed macrophytes. They usually grow in hard water and often become calcified and brittle. Commonly called muskgrass, *Chara* and *Nitella* are two macro-algae.

Overview of Control Options

Before you dive in . . .

The basis for sound aquatic plant management should be a thoroughly thought out, whole-lake aquatic plant management plan with clearly defined goals. By thinking about the various uses of the lake, different levels and types of management will likely be revealed for different plant problems in different lake areas. For example, some questions you might ask yourself include: Are there zones around the lake that should be left alone, such as special habitat areas? Could a low level of control be applied in certain areas to preserve some intermediate level of plant growth? Under what circumstances or in what areas would it be necessary to achieve a high level of control (such as in a swimming or boat ramp area, or if invasive non-native plants have been identified)? Guidance for preparing an aquatic plant management plan is provided in several publications, a few of which are included in the reference list at the end of this fact sheet.

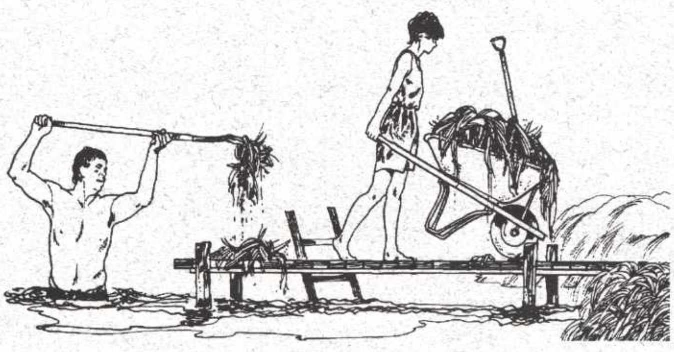
There exist a great number of macrophyte and algae management strategies to consider when developing (and updating!) your aquatic plant management plan. An overview of the most common options is presented here. A list of references for learning more about aquatic plant identification and management also is provided.

MACROPHYTE MANAGEMENT STRATEGIES

Manual Removal

HANDPULLING This method involves removing the entire plant (stems and roots) either with your hands or with the help of a spade or long knife. Hay baling or logger's pulp hooks can help with pulling up well-rooted plants such as water lilies or cattails. Handpulling is easiest in shallow water. In water more than 3 or 4 feet deep, a mask and snorkel or scuba equipment will be needed. Collect the uprooted plants and dispose of them well away from shore so they don't have a chance to wash back into the lake and regrow.

Handpulling allows the selective removal of individual nuisance plants; desirable plants can be left alone. Control may last more than one season where complete removal (roots included) has been achieved. Because this technique can be labor-intensive and time-consuming, it is most appropriate for small areas with low plant density. Handpulling can be very useful for clearing pondweeds (*Potamogeton* spp.) or small patches of water lilies from dock or swim areas. It's also very useful for aggressive control of sparse or small patches of Eurasian watermilfoil (*Myriophyllum spicatum*).



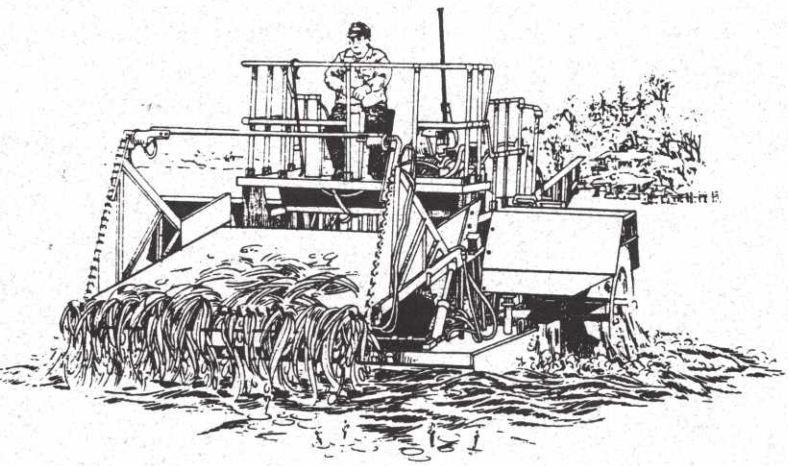
HAND CUTTING This manual method differs from handpulling in that plants are cut below the water surface but the roots generally are not removed. Several types of hand-held plant cutters are available commercially. Styles vary from straight-faced to V-shaped drag cutters that can be thrown from shore or a dock and pulled back through the plants, or can be dragged behind a boat. There are also several hand-held, battery-powered cutters on the market. Best results are seen by beginning trimming early in the year: once plants are thick, you may have problems with this technique.

Since the entire plant is usually not removed, hand cutting does not provide long-term control. Depending on the growth rate of the plant species, cutting may have to be done several times each year. Like handpulling, this technique results in the immediate removal of nuisance plants, and costs are low.

OTHER MANUAL TECHNIQUES include using rakes, drags, harrows, or cultivators. A good reference for some rather innovative methods is found in the *Lake Smarts* publication (see reference list).

Mechanical Removal

MECHANICAL HARVESTING A mechanical harvester cuts and removes aquatic vegetation. Harvesters typically are designed with one horizontal and two vertical cutter bars, plus two conveyor systems to gather, store, and offload the plant cuttings. Maximum cutting depths range from 5 to 8 feet, and cutting widths generally range from 4 to 12 feet. When the storage area on the harvester is full, it returns to shore where the cuttings are offloaded and removed for disposal. The cuttings can be used for compost or added to soil.



Harvesting is utilized during the growing season after macrophytes have grown to or near the surface. The extent of macrophyte control can be exactly limited by only harvesting in pre-determined areas. This is advantageous if there is concern about removing desirable macrophyte stands, or if rare/endangered species could be impacted. Partial harvesting of certain areas, such as in a criss-cross pattern through extensive plant beds, can reduce the area needing treatment yet improve access for boaters and greatly increase the amount of angler-coveted plant "edges." The removal of in-lake plant biomass may also reduce the oxygen demand and release of nutrients to the lake water during autumn dieback and decay.

Potential disadvantages to mechanical harvesting include the inability to operate the machinery in very shallow water and in areas requiring tight maneuvering (such as around docks and rafts). The duration of control is variable depending on plant species, frequency and timing of harvest, water depth, and depth of cut. Harvesting may need to be repeated one or more times per growing season. For instance, regrowth of Eurasian watermilfoil (*M. spicatum*) to pre-harvest levels typically occurs within 4 to 8 weeks.

Because not all plant fragments can be collected by the machinery, fragments of target and nontarget species alike can drift and take root elsewhere. Hence, shifts in plant species composition may occur as opportunistic species invade harvested areas. This is especially true of

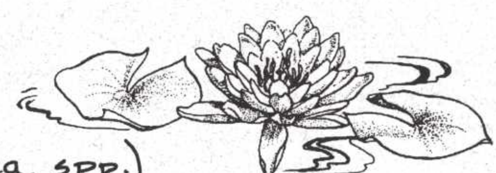
ENDANGERED SPECIES CONSIDERATIONS

Illinois lakes provide habitat for a variety of plant and animal species that are listed as endangered or threatened in the state. Common lake management practices can have both direct and indirect effects on these species. In some situations, Illinois law requires review of the potential for adverse effects on threatened or endangered species before any lake management activities are initiated.

The Illinois Department of Natural Resources (DNR), Natural Heritage Division, maintains a database tracking all known records of endangered and threatened species in Illinois. Aquatic animals of concern include several species of fish, mussels, crustaceans, and insects. Among plants, listed below are several of Illinois' endangered aquatic macrophyte species:

Common Name	Latin name
Water Marigold	*Bidens beckii*
Water-pennywort	*Hydrocotyl ranunculoides*
Grass-leaved Pondweed	*Potamogeton gramineus*
White-stem Pondweed	*Potamogeton praelongus*
Spotted Pondweed	*Potamogeton pulcher*
Fern Pondweed	*Potamogeton robbinsii*
Stiff Pondweed	*Potamogeton strictifolius*
Vasey's Pondweed	*Potamogeton vaseyi*
Seaside Crowfoot	*Ranunculus cymbalaria*
Pursh's Tufted Bulrush	*Scirpus purshianus*
American Bur Reed	*Sparganium americanum*
Green-fruited Bur Reed	*Sparganium chlorocarpum*
Horned Bladderwort	*Utricularia cornuta*
Flat-leaved Bladderwort	*Utricularia intermedia*
Small Bladderwort	*Utricularia minor*

Illinois law requires that all units of local and state government consult with the DNR before funding, authorizing, or carrying out any action that will alter existing environmental conditions. Actions requiring review include 1) dredging of soil, sand, gravel, minerals, organic matter, vegetation, or naturally-occurring materials of any kind, and 2) application of chemicals to the air, water, or land. Consultation with DNR is initiated by submitting an "Agency Action Report." Call 217/785-5500 for details on the endangered species consultation process and action reports. For more general information on endangered and threatened species, call 217/785-8290.



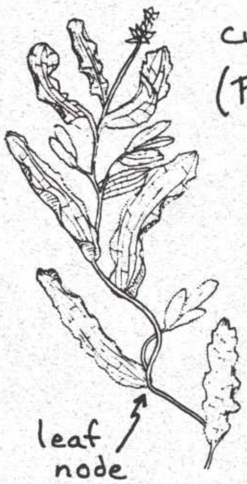
water lily (Nymphaea spp.)

Eurasian watermilfoil. Harvesting also may indiscriminately remove large numbers of small fish, although studies have found that overall population size has not been impaired. Capital costs for machine purchase are high and considerable maintenance is necessary, and so many lakes utilize private harvesting contractors.

MECHANICAL CUTTING This equipment provides only the cutting function: plant fragments are not collected for transport. Because it's very important to remove the cut plants from the lake, this system is only recommended if vegetation is sparse and if wind and currents can be used to direct the cuttings to a confined area or onto shore where they can be collected. Boat-, pontoon-, and barge-mounted cutters are available commercially.

MANAGEMENT STRATEGY NOTE

Plant cutting (whether via mechanical harvester, mechanical cutter, or hand cutting) is an excellent strategy for managing the broad-leaved pondweeds (e.g., *Potamogeton illinoensis, P. amplifolius, P. nodosus*), and full-season control often can be achieved with one cutting. It is best to cut these native pondweeds after they have flowered and set seed, and cut as deeply as possible. Northern watermilfoil (*Myriophyllum sibericum*) is also well-controlled seasonally via harvesting, although two cuttings likely would be needed. As noted above, Eurasian watermilfoil (*M. spicatum*) tends to grow back quickly (and actually spread) after harvesting; hence, several cuttings per growing season may be required. Ongoing studies in Minnesota on the control of the non-native curlyleaf pondweed (*P. crispus*) indicate that season-long control can be achieved by cutting after the plants grow to their 14th leaf node (about 3 feet in height) but before they reach the 20th node (when their winter buds—called turions—are produced).



Because some plants are better controlled by cutting than others (e.g., pondweeds vs. Eurasian watermilfoil), widespread mechanical harvesting in a lake with a mix of such species could lead to an accelerated and undesired domination by the less-susceptible species.

Physical Habitat Alteration

SEDIMENT REMOVAL (DREDGING) Dredging can reduce submerged plant growth either by removing nutrient-rich sediments and exposing sand/gravel, or by deepening the lake and thus reducing the amount of sunlight reaching the lake bottom. Of course, dredging also directly removes plants and roots. Long-term submersed plant control is possible only if the sand/gravel layer is too infertile to support plant growth or if the new depths are deep enough to limit sunlight reaching the lake bottom. If you know the Secchi disk transparency of your lake, you can estimate how deep plants might grow as two to three times the Secchi disk depth.

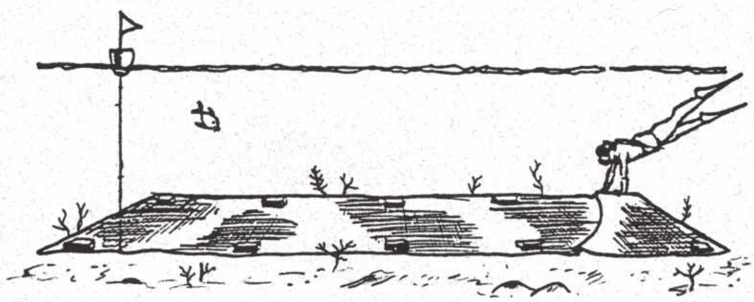
Because dredging is highly expensive, its use purely for aquatic plant control usually is not cost-effective. However, sediment removal for other management purposes may provide the added benefit of aquatic plant control in areas deepened below the lake's sunlit zone or where nutrient-poor sediments are exposed. Sources of incoming sediment then need to be controlled.

WATER LEVEL DRAWDOWN Drawing down a lake's water level results in exposing plants and roots to prolonged freezing and drying during the winter—or to hot, dry conditions in the summer. Winter drawdowns are the more common method. Some rooted plant species are permanently damaged and the entire plant, including roots and perhaps seeds, can be killed if exposed to freezing for two to four weeks. However, aquatic plant species vary in their response to drawdown. While some may decrease, others are unaffected or actually increase in abundance. A summary of responses of numerous aquatic plant species to both winter and summer drawdown is presented in *Attributes of Wisconsin Lake Plants* (see reference list).

Drawdown also can facilitate repair of structures such as dams and docks, fish management, sediment removal, installation of sediment covers to control plant growth, and debris removal. However, during the summer a significant problem can be loss of lake use. In winter, drawdown decreases the water volume and hence the oxygen available for fish under the ice, which could be especially critical for fish survival during a winter with heavy snow cover. In lakes with a small water volume, dissolved oxygen levels should be monitored regularly during the drawdown period and an aerator installed and operated as needed. Prolonged drying and freezing also can reduce the abundance of bottom-dwelling organisms that can be essential to fish diets. Additionally, drawdown can negatively impact adjacent wetlands and shoreline emergent plants, as well as cause destabilization of lakeshores and disruption of fish spawning.

Costs of drawdown are minimal if the lake level is controlled by an outlet structure with drawdown capability. Increased cost would accrue with pumping. Other costs might include recreational losses (such as a decrease in tourism).

SEDIMENT COVERS Sediment covers or "bottom barriers"—such as opaque sheets of polyethylene, polypropylene, synthetic rubber, fiberglass screen, nylon film, or burlap—can be installed on a lake bottom to block sunlight and thereby kill the plants underneath. Covers can be placed in any water depth, though divers are usually needed for deeper water installations. Sediment covers accomplish immediate control of nuisance plant conditions. Additionally, they are hidden from view and do not interfere with recreational uses.



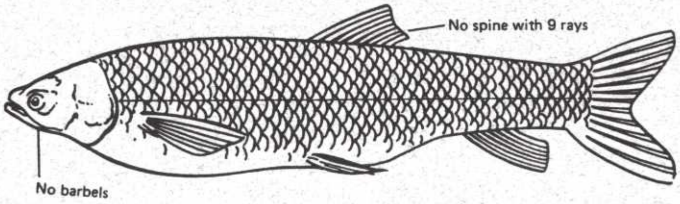
Due to the high cost of materials and labor-intensive installation, the use of sediment covers is most applicable in small areas such as around docks, in swimming areas, or amongst plant beds to maintain open fishing areas. Successful use depends on the type of material and the quality of installation. The most effective materials are gas-permeable such as polypropylene, fiberglass-PVC, and to a lesser extent burlap. Polyethylene, synthetic rubber, and nylon trap gases beneath them and therefore may become loose and float up from the bottom. Sediment covers must be placed flush with the lake bottom and staked down or anchored securely, which is easiest to do in the spring before the plants begin to grow. Installation is difficult over heavy plant growth. Applications in water much more than 3 feet deep is best done by divers (which greatly increases costs). Over time, the covers will accumulate sediments on their surface, which allows plant fragments to root. The covers must then be removed and cleaned. If satisfactory control has been achieved, some cover materials can be moved to other areas, thus increasing benefits. It's easiest to leave burlap in place, since it typically decomposes after one or two seasons.

LIQUID DYES Adding a specialized aquatic dye to the water can limit sunlight penetration and ultimately restrict submersed plant growth. A few dyes are available on the market (e.g., Aquashade®, Dolge Dye). Dyes impart a deep blue or aqua green color to the water—personal opinions vary as to the aesthetics of the altered water appearance. Application is easy in that it can be simply poured into the water from shore. The dye then spreads throughout the lake.

For maximum effectiveness, the dye must be added to the water early in the season before plants begin growing, and its concentration maintained. Only plants in water deeper than about three feet are controlled. Repeat dye treatments may be necessary throughout the growing season as the dye becomes diluted, broken down by sunlight, and biologically decomposed. These products should only be used in lakes and ponds with long water holding times (little or no inflow and outflow), and are generally most effective in smaller, shallower waterbodies where concentrations can be more easily and cost-effectively maintained. Dyes are not selective: all submersed macrophytes species will be affected. The macro-algae *Chara* and some filamentous green algae like *Spirogyra* also are reported to be well-controlled.

Biological Controls

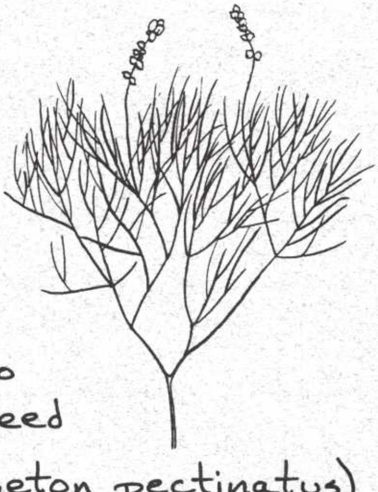
TRIPLOID (STERILE) GRASS CARP Triploid grass carp (*Ctenopharyngodon idella*), which are genetically sterile, may be used only in artificial impoundments in Illinois to control aquatic vegetation. Importation and stocking are strictly regulated. Grass carp cannot be stocked into any natural body of water including glacial lakes; slough potholes; bottomland or backwater lakes, streams, or rivers; water areas known to harbor rare, threatened, or endangered plants or animals; or any State Inventory Natural Area or Nature Preserve. Stocking permits are required and are available from your regional Illinois Department of Natural Resources (DNR) office or can be handled through several fish suppliers in Illinois. For more information on regulations, stocking rates, and suppliers, contact your local Illinois DNR office.



Careful consideration should be given before proceeding with a grass carp stocking program. Most commonly, stocking of grass carp has resulted in either complete macrophyte elimination or no noticeable change in macrophyte abundance. Rarely have grass carp stocking efforts resulted in successful reduction of macrophyte densities from high to more moderate levels. Furthermore, because grass carp prefer to eat those native species typically considered desirable in a lake ecosystem (including narrow- and broad-leaved pondweeds, naiads, *Chara*, elodea), they eat these plants first and leave behind those nuisance species likely targeted for control in the first place (such as Eurasian watermilfoil). This can then result in expansion of the nuisance plant(s). If stocking rates are high enough, however, even these less-tasty plant species will be consumed, leaving the lake devoid (or nearly so) of vegetation. Furthermore, some studies have shown that an increase in phytoplankton may accompany grass carp introduction, since the nutrient-rich wastes produced by these fish are available for immediate use by algae.

Grass carp become less voracious with age, and supplemental stockings are usually necessary about 7 years following the initial stocking. Once stocked, grass carp are notoriously difficult to remove. If plant coverage is 20 percent or less, macrophyte control would be better accomplished utilizing other techniques such as manual methods or sediment covers in targeted areas.

common elodea
(Elodea canadensis)



sago
pondweed
(Potamogeton pectinatus)

INSECTS Damage by insects holds some promise for lakes overgrown with Eurasian watermilfoil *(M. spicatum)*. A milfoil-eating weevil (*Euhrychiopsis lecontei*) was first associated with a milfoil decline in a Vermont lake in 1989, and subsequently has been found in a number of other lakes in the northern United States and in Canada. In 1995, the weevil was found in several milfoil-infested northeastern Illinois lakes. While the limited scientific evidence collected so far suggests that *E. lecontei* has the potential to be a useful biological control for Eurasian watermilfoil, most researchers are still cautious about touting it as a long-term management strategy for Illinois lakes.

Eurasian watermilfoil
(Myriophyllum spicatum)

The weevils have been found to feed almost exclusively on milfoil plants, and typically close to the water surface. The potential for weevil-induced damage to Eurasian watermilfoil, therefore, may be greatly reduced at lakes managed with widespread herbicide applications or extensive milfoil harvesting.

Other insects being researched for their potential effects on Eurasian watermilfoil include a fly (*Cricotopus myriophylii*) and a moth (*Acentria nivea*).

Chemical Application

HERBICIDES Herbicides are chemical pesticides used to disrupt the growth cycle of plants, typically by inhibiting photosynthesis. *Systemic* herbicides are absorbed and transported throughout the plant, thus killing the entire plant including the roots. *Contact* herbicides, on the other hand, only kill the portions of the plant in which the chemical comes in contact, thus leaving live roots capable of regrowth. Herbicides also can be classified as *broad-spectrum* (or *nonselective*) (will kill or injure a wide variety of plant species) or *selective* (effective on only certain species). Selectivity can be influenced by the application dose, timing, and method; herbicide formulation; and stage of plant growth. Before choosing to use a herbicide, it's a must to properly identify the macrophyte species in the proposed treatment area—both the target and non-target plants—in order to select the most appropriate chemical and dosage.

Herbicide application can often achieve full-season control, and sometimes control may extend into the following year. However, because the plants remain in the lake to decay, extreme care must be taken in the treatment's planning and implementation so that the lake's dissolved oxygen levels do not plummet from the sudden pulse of decomposing vegetation. Algal blooms may also occur as nutrients tied up in the decaying macrophytes are released to the water. And, herbicides also may kill aquatic invertebrates which are an important food for fish and waterfowl.

Chemical sprays may drift into areas not needing control. If spot treatments are conducted, it is nearly impossible to precisely define the total area affected since the chemical may spread within the lake after being applied. Many aquatic pesticides restrict certain water uses such as swimming, fishing, or lawn watering. Because herbicides can be selective or broad-spectrum (depending on herbicide concentration, plant susceptibility, timing of application, combination with other herbicides), each aquatic herbicide must be considered separately as to possible effects on both target and non-target species of aquatic plants and animals.

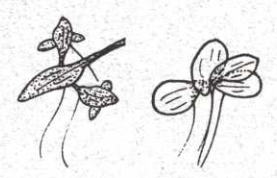
The *Illinois Pesticide Act* requires that any person who applies any aquatic pesticide must possess an Illinois Aquatic Pesticide Applicator license. This includes persons classified as commercial "for hire" applicators, government employees applying herbicides to an aquatic environment controlled by that governmental body, and commercial "not-for-hire" pesticide applicators. The only exception to this provision is that a private homeowner may apply "general-use" pesticides if he/she owns the *entire* body of water. In most instances, the Illinois Department of Agriculture has determined that homeowner associations fall within the commercial not-for-hire category, and thus a license is required. In all cases it is the applicator's responsibility to assure that herbicides applied are currently approved/registered by the U.S. Environmental Protection Agency (EPA) for aquatic use and that they are applied according to label directions. The applicator also is responsible for obtaining any necessary permits from the Illinois EPA before applying herbicides that may affect waters used for drinking water supply or food processing. For more information on regulations and applicator certification, contact the Illinois Department of Agriculture, Bureau of Environmental Programs (217/785-2427).

There are currently six herbicides with aquatic labels registered by the U.S. EPA and Illinois Department of Agriculture. A brief summary of each is presented below. Several of the references listed at the end of this fact sheet provide more detailed information.

- **Copper complexes** are primarily used for algae control (see discussion under "Algae Management") although some formulations (e.g., Komeen®, Cutrine®-Plus) also can be effective against certain submersed plants.
- **Diquat** (e.g., Reward®, Weedtrine-D®) is a nonselective, contact herbicide used to control submersed, free-floating, rooted floating-leaved, and emergent macrophytes. It also can be used to suppress certain types of filamentous algae.
- **Endothall** (e.g., Aquathol® K, Hydrothol® 191) is a generally nonselective, contact herbicide used for submersed vegetation control. Certain formulations also are able to control macro-algae and certain filamentous algae species.
- **Fluridone** (e.g., Sonar® A.S., Sonar® SRP) is a systemic herbicide that can be used for selective to broad-spectrum control of submersed, floating, rooted-floating, and emergent macrophytes.
- **Glyphosate** (e.g., Rodeo®) is a systemic, nonselective herbicide which is effective only against emergent and rooted floating-leaved plants.
- **2,4-D** (e.g., Aqua-Kleen®, Weedar® 64) is a systemic herbicide that can be used to selectively control broad-leaved/dicot plants.
- Two other systemic, relatively selective herbicides are undergoing testing for aquatic use: **triclopyr** (proposed trade name Renovate®) and **imazapyr**. Triclopyr's use will be to control certain submersed macrophytes, while imazapyr's primary use will be on emergent vegetation.

NEWLY EMERGING TECHNOLOGIES being studied to control nuisance macrophyte growth include funguses, plants competing with other plant species, plant growth regulators (substances that inhibit the plants from growing too tall), genetic engineering, and allelopathic substances (toxins produced by one plant species that interfere with the growth and reproduction of another plant species).

duckweed
(Lemna spp.)



ALGAE MANAGEMENT STRATEGIES

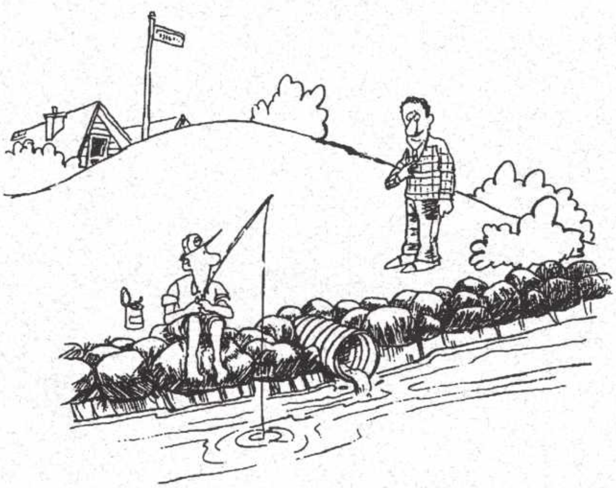
The two growth forms of algae most troublesome in lakes are phytoplankton and mats of filamentous algae. Frequently the quantity of algae is related to the concentration of an essential plant nutrient—oftentimes phosphorus. Sometimes the lake and/or watershed can be

manipulated to reduce nutrient concentrations enough to limit algal growth. Other methods, while not decreasing nutrient concentrations, are used to more directly control algal cells. A summary of various algae management strategies follows.

It's important to keep in mind that as phytoplankton abundance decreases due to the successful use of control strategies, macrophyte numbers may increase as light availability to deeper water depths is increased. This is not necessarily a negative consequence, since macrophytes are important in a lake's overall ecology and oftentimes are more readily managed.

Filamentous algae can sometimes become the primary plant nuisance in a lake or pond. It's important to realize that because filamentous algae often begin their growth on the lakebed and can get the nutrients they need from the sediment, reduction of nutrient levels in the lake water may not be enough to reduce nuisance populations.

DIVERSION If wastewater discharges (including industrial, municipal, and septic sources) flow directly into your lake or nearby upstream, the first step in reducing nutrient inputs involves the rerouting of such effluent away from the lake. Direct stormwater inputs also should be avoided or minimized as much as practical. Without a reduction of these external nutrient loadings, any long-term benefits from in-lake nutrient reduction strategies usually will not be seen.



WATERSHED BMPs "Best management practices" (BMPs) to reduce nutrient and sediment contributions include agricultural land and fertilizer management, urban construction erosion control, stormwater detention ponds designed to provide water quality benefits, streambank and shoreline stabilization, and actions you can do around your own property (see the *Lake Notes* fact sheets "Home and Yard," "Septic Systems," "Fertilizers and Pesticides," "Shoreline Buffer Strips," and other topics available from Illinois EPA's Lake and Watershed Unit, 217/782-3362).

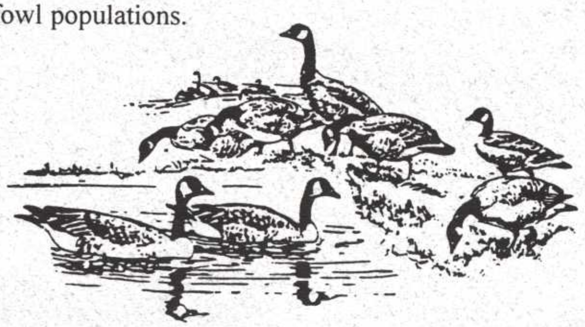
PHOSPHORUS PRECIPITATION/INACTIVATION The purpose of phosphorus (P) precipitation/inactivation is to lower the lake's P content by removing P from lake water (phosphorus precipitation) and by inhibiting P release from the bottom sediments (phosphorus inactivation). A compound—usually an aluminum salt—is added to the lake which binds with P, precipitates it as a floc particle, and then settles to the lake bottom. Aluminum sulfate (alum) is often used because it retains its P-sorbing ability over a relatively wide range of environmental conditions. Dispersion of aluminum sulfate into a lake can result in extremely clear water within a few hours to a few days. The floc particles that settle on the bottom carry with them inorganic and organic particles that were suspended in the water, as well as much of the lake water's phosphorus. Depending on the dosage of alum added, the consequent layer of aluminum hydroxide that settles over the lake bottom may be thick enough to form a barrier which impedes the release of sediment-bound P to the overlying water.

Alum treatments can result in relatively long-term reductions of P in lakes where inflowing sources of P have been well controlled, and in lakes where water depths, morphology, macrophyte growth, recreational uses, and lack of bottom-feeding fish minimize agitation of the delicate floc layer. Effectiveness has been seen for 10 to 12 years in deep, stratified lakes; and for up to 5 to 7 years in shallow, mixed lakes. Reservoir applications are rare since such waterbodies typically experience high sediment and nutrient loading rates which continue to add more P to the water and deposit sediments over the floc layer. In ponds and small lakes, buffered alum, ferric alum, and calcium salts also have been used to remove or inactivate P and thereby suppress nuisance algae blooms.

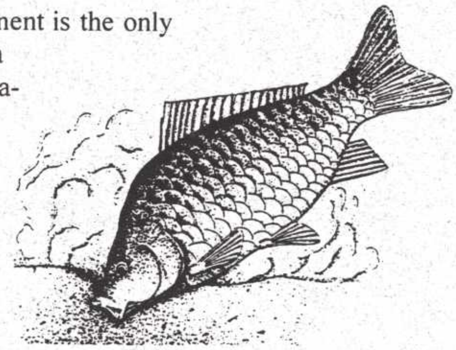
Phosphorus precipitation/inactivation is further discussed in *The Lake and Reservoir Restoration Guidance Manual* and in great detail in *Restoration and Management of Lakes and Reservoirs*. Guidance for small do-it-yourself projects can be found in *Lake Smarts*.

DILUTION OR FLUSHING The intent of dilution (adding low-nutrient water) is to lower the concentration of nutrients in the lake water such that algal growth is reduced. Flushing, on the other hand, involves the introduction of water in quantities great enough to literally flush algal cells through the lake before they have a chance to grow to nuisance proportions (15 to 21 days for most species). Experience with flushing on various lake systems suggests that a lot of water must be added each day (10 to 15 percent of a lake's water volume) in order to achieve significant reductions in algal populations.

WATERFOWL MANAGEMENT Waterfowl can be significant contributors to a lake's nutrient load. Studies on waterfowl phosphorus (P) loading show that geese contribute about 1/2 pound and ducks about 1/3 pound of P per bird per year. As you can imagine, at small waterbodies even a small population of resident birds or a large influx of migratory waterfowl can contribute a large proportion of the total nutrient loading to a lake. See the *Lake Notes* fact sheet "Canada Geese and Your Lake" for an overview of options for minimizing overabundant waterfowl populations.



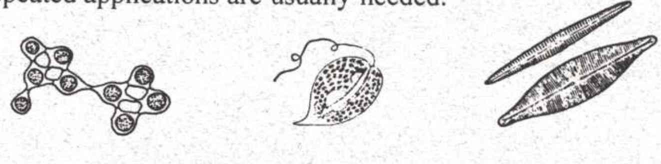
ROUGH FISH REMOVAL The bottom-feeding activities of "rough" fish, particularly the common carp, can contribute greatly to the resuspension of bottom sediments and the release of sediment-bound nutrients to the overlying lake water, thus contributing to algal growth. Habitat conditions are degraded by the increased sediment and algal turbidity and reduced macrophyte growth, which all can affect a lake's fishery. Management alternatives to reduce carp numbers include hook-and-line, seining, and partial lake treatments using the fish toxicant rotenone applied to areas of congregating carp (i.e., in shallow waters during carp spawning). When carp populations become overabundant, a whole-lake rotenone treatment is the only way to reestablish a balanced fish population. A profound increase in water transparency has been seen in several Illinois lakes following whole-lake carp eradication. A shift in the lake's plant population from algae to macrophyte dominance also may occur.



MANUAL REMOVAL The use of rakes, screens, and fish seines is an often-overlooked but potentially effective and inexpensive option for removing floating mats of filamentous algae from ponds, small lakes, and nearshore areas of larger lakes. Removal can be done from shore or boats. For example, fish seines can be used to "corral" floating algal mats and then pull them to shore for removal with rakes. Removal of algal mats in moderate to dense stands of emergent vegetation can pose problems since the vegetation's stems and leaves can get in the way. These manual removal techniques probably would not work for phytoplankton due to the small size of these algal species.

CHEMICAL APPLICATION Algicides (herbicides used on algae) have been widely used to control nuisance planktonic and filamentous algae growth for many years. Various formulations of copper—primarily **copper sulfate** and **copper chelate** products—are the most common algicides, and come in liquid and granular forms. Copper sulfate treatments of blue-green algae blooms to control taste and odor problems are a common practice in water supply impoundments.

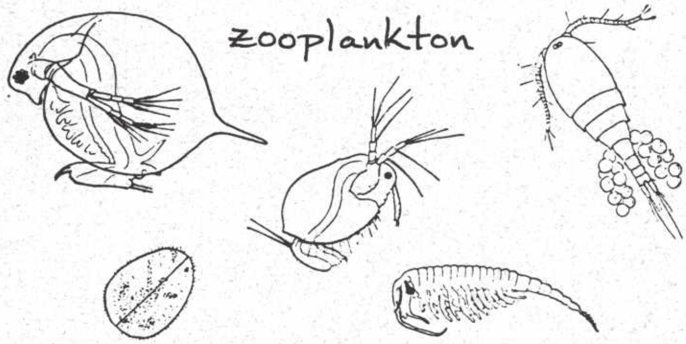
Copper is a compound required by plants and animals in very small amounts. However, application of copper at the recommended dose rates is very toxic to algae, inhibiting photosynthesis and preventing growth. Algae decay occurs within 3 to 5 days after application. However, because 1) the toxic action of copper upon algae is short-lived, 2) the supply of nutrients in the lake water is not reduced by an algicide application, and 3) nutrients from the decaying algae are released back into the water, new algae growth begins soon after application. It is also believed algae "rebound" is aided by a lower abundance of algae-eating zooplankton following application (copper is toxic to *Daphnia* species, one of the most common and effective algae eaters). So it's not surprising that control of nuisance algae typically ranges from only a few days to a few weeks, and repeated applications are usually needed.



It's necessary to wait 10 to 14 days between algicide applications to protect fish and other aquatic life. Also be aware that following an algicide treatment, decaying algae may deplete the water's oxygen content, leading to a fishkill. To safeguard against dissolved oxygen (D.O.) depletion, if the targeted algae cover more than one-third of the total water area, application should be done in sections and in a pattern providing fish escape routes to untreated water. Other compounds (oxidizing agents) may be applied along with an algicide to reduce the possibility of D.O. depletion.

Copper formulations can be toxic to trout and some other fish species at the recommended herbicide dose rates, especially if applied in soft water (less than 50 mg/L of carbonate hardness). However, as water hardness increases, fish toxicity decreases. Frequent application of copper-based herbicides can lead to excessive copper accumulations in the lake bottom sediments. This can be harmful to important bottom-dwelling insects. Copper also can be of concern in future lake management decisions. High concentrations of copper can be toxic to plants and animals, and may limit sediment disposal options for dredging projects.

BIOMANIPULATION The idea behind this technique is to use zooplankton (microscopic animals) to eat phytoplankton. Theoretically, the more zooplankton there are, the less algae there will be—thus leading to clearer lake water. In order to maintain enough zooplankton however, the number of zooplankton-eating fish ("planktivores" such as sunfish and minnows) must be controlled, or enough hiding places must be provided for the zooplankton. One way to control planktivores is by increasing the number of fish that eat planktivores (e.g., predator fish such as largemouth bass and walleye).



One problem encountered with biomanipulation is that even if more and more phytoplankton are consumed by zooplankton, the phytoplankton population may be able to compensate by replenishing their numbers at a faster rate. Also, the success of biomanipulation depends on the requirement to maintain a very high abundance of predator fish, which can sometimes be difficult. Until scientists are able to better explain the variation in the successful use of biomanipulation, this technique for lake management will remain limited.

ARTIFICIAL CIRCULATION The objective of artificial circulation (also referred to as destratification) is to eliminate or prevent thermal stratification (see the *Lake Notes* fact sheet "Lake Stratification and Mixing" for an explanation of this process). If the circulation system is correctly designed, lakewide mixing will occur at a rate adequate to eliminate temperature differences between top and bottom waters (i.e., "destratify" the lake).

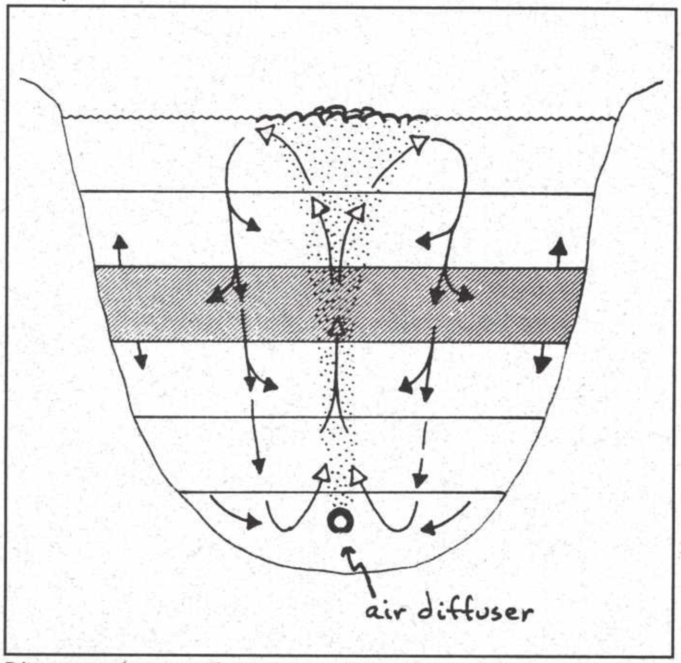


Diagram of water flow during lake circulation/destratification.

Such circulation *may* control algal blooms through one or more processes: 1) algal cells will be mixed to a greater depth and thereby will not receive sufficient sunlight to sustain growth, 2) algal groups that require mixing currents to remain suspended (e.g., diatoms) may have an advantage over "floating" species such as the more noxious blue-greens, 3) changes in the lake's water chemistry (pH, alkalinity, CO_2, iron) can lead to a shift from blue-green to less noxious green algae or diatoms, and 4) mixing of algae-eating zooplankton to greater depths reduces their vulnerability to sight-feeding fish; hence, if more zooplankton survive, their consumption of algal cells also may increase. Be aware that artificial circulation/destratification cannot be expected to reduce phosphorus release from the sediments in all cases. And if the circulation system is inadequately designed, algal production may actually be enhanced as a result of phosphorus transport from bottom waters into the upper waters where it becomes available for algal uptake.

More information on artificial circulation effects and types of systems can be found in the *Lake Notes* fact sheet "Lake Aeration and Circulation."

SELECTED REFERENCES FOR AQUATIC PLANT MANAGEMENT AND IDENTIFICATION

**A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans**. 1994. M.V. Gibbons, H.L. Gibbons, M.D. Sytsma. 50 pp. (available from Kathy Hammel, Coordinator, Washington State Dept. of Ecology, Freshwater Aquatic Weeds Management Program, P.O. Box 47600, Olympia, WA 98504-7600; 360/407-6562; e-mail: kham461@ecy.wa.gov ; cost: free).

**A Guide to Aquatic Plants: Identification and Management**. 1994. David Fink. 52 pp., line drawings (available from Minnesota Dept. of Natural Resources, Attn: Steve Enger, Ecological Services Section, 500 Lafayette Rd., Box 25, St. Paul, MN 55155-4025; 612/296-2835; cost: free).

**A Manual of Aquatic Plants**. 1957. Norman C. Fasset. 416 pp., keys and line drawings (available from University of Wisconsin Press, 114 N. Murray St., Madison, WI 53715-1199; 800/829-9559; cost: $25.50 + $3.00 shipping; order code: MAAQ cl.).

**Attributes of Wisconsin Lake Plants**. Information Circular 73. 1991. Stanley Nichols, James Vennie. 18 pp. (available from Wisconsin Geological and Natural History Survey, Map and Publications Office, 3817 Mineral Point Rd., Madison, WI 53705-5100; 608/263-7389; cost: $4.00 + $2.50 postage and handling).

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**Aquatic Plant Management in Lakes and Reservoirs**. 1997. North American Lake Management Society and Aquatic Plant Management Society. 103pp. (available from North American Lake Management Society, PO Box 5443, Madison, WI 53705-5443; 608/233-2836; WebSite: http:\\www.nalms.org ; cost: $25.00 [40% discount for NALMS members]).

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**Common Marsh, Underwater, and Floating-Leaved Plants of the United States and Canada**. 1970 reissue. Neil Hotchkiss. 223 pp., line drawings (available from Dover Publications, Inc., 31 East 2nd Street, Mineola, NY 11501-3582; cost: $9.95 + $4.00 postage and handling; order code: 22810-X).

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**Lake Smarts: The First Lake Maintenance Handbook**. 1993. Steve McComas. 215 pp., 400 photos (available from Lake Smarts, c/o 550 Snelling Ave. South, Suite 105, St. Paul, MN 55116; 612/690-9602; cost: $21.95 + $4.00 shipping).

**The Lake and Reservoir Restoration Guidance Manual**. EPA-440/4-90-006. 1990. 2nd ed. 326 pp. (available from North American Lake Management Society, PO Box 5443, Madison, WI 53705-5443; 608/233-2836; WebSite: http:\\www.nalms.org ; cost: $25.00 [40% discount for NALMS members]).

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**Water Plants for Missouri Ponds**. 1990. J.R. Whitley, B. Bassett, J.G. Dillard, R.A. Haefner. 151 pp., line drawings, color photos (available from Missouri Dept. of Conservation, PO Box 180, Jefferson City, MO 65102; 573/751-4115, ext. 335; cost: $7.50 + $2.00 shipping and handling).

muskgrass (Chara spp.)

Aquatic Plant Management Notes:

arrowhead
(Sagittaria spp.)

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Appreciation is extended to the University of Wisconsin-Extension and the Wisc. Dept. of Natural Resources for illustrations from their "Water Quality Digitized Clip Art Collection" and other publications, and to the Illinois State Museum for their aquatic plant illustrations. Mention of trade names and commercial products does not constitute endorsement of their use.

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