# 6 Aquatic Plants: Not Just Weeds

## Introduction

For a frustrated lake resident, rooted aquatic plants may all be called seaweeds, while a scientist may call them macrophytes and extol their virtues. Still others hold each name in shrouded reverence, marveling at the gentle swell of the purple bladderwort or the primitive majesty of the horsetail. Yet although each person may view the plant kingdom with unequal parts idolatry and contempt, all those who spend time around lakes share a core set of reasons for understanding aquatic plants.

This chapter focuses on strategies to minimize the impacts of excessive aquatic plants. The term "minimize" is appropriate because eradicating water weeds is neither practical nor wise. Aquatic plants will grow wherever light reaches the lake bottom. Most have reproductive structures (seeds, roots, rhizomes, etc.) that cannot be fully exterminated. The goal of management is to minimize the impacts of invasive plant populations, and the impacts of nuisance growth.

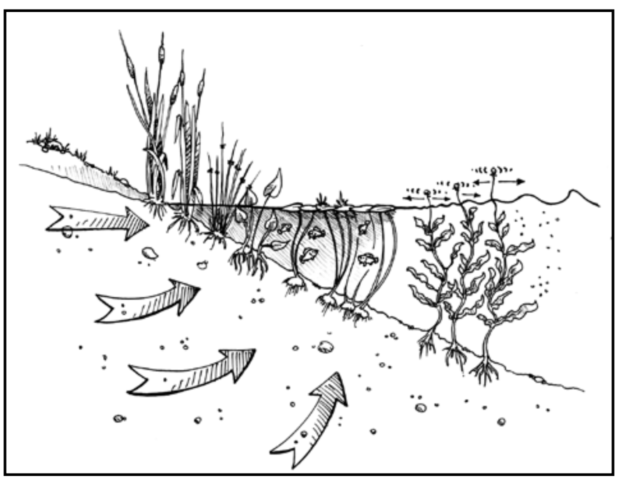

*Fig. 6–1. Rooted aquatic plants, called macrophytes, reduce erosion by dampening wave action, sheltering young fish, supplying food for ducks and providing homes for creatures at the base of the food chain.* (Credit: Chris Cooley)

## Aquatic plants in the ecosystem

All aquatic plants should not be removed, even if that were possible. They play an essential role in a healthy lake ecosystem. Boaters with clogged props may consider all aquatic plants to be "weeds" and curse their existence, but lakes devoid of aquatic plants might as well be swimming pools. They may be recreationally pleasing, but functionally and aesthetically they are bleak. Wetland and aquatic plants provide many benefits and ecosystem services:

- forests of plant stems and leaves provide protective nursery areas for small fish, tadpoles and other aquatic organisms;
- networks of roots help bind the sediment and prevent erosion;
- leaves shade and help cool the water;
- plant stems absorb the energy of waves, translating it into movement of stems and leaves, and reduce erosive power at the shoreline;
- roots throughout the shoreline sediments intercept groundwater flowing from upland areas and filter out nutrients and other contaminants; and
- plants produce oxygen which keeps the water healthy for fish and other animals.

Removal of plants may have undesirable consequences. Some uses of the lake, such as fishing, require a healthy population of plants. Weed-free lakes may not support potable water usage since aquatic plants filter pollutants out of the water. Efforts to drastically reduce plant populations frequently cause conflicts among lake users, even when anglers, swimmers and property owners all agree there are too many weeds. Part of plant management consists of balancing differing needs.

## Preparing for action

### Developing a plan

An aquatic plant management plan first defines the goals and the steps required to achieve those goals. Ideally, it is set within the context of broader lake management planning, including water-quality improvement, fisheries management, and a multitude of other objectives. In many New York State lakes, nuisance aquatic plant growth is often the trigger for the development of a lake and watershed management plan (see Chapter eleven, "Management plan development").

Aquatic plant management plans can be developed in different ways. Some lake groups consult experts to properly identify the offending plant(s), present strategies to effectively control them, and lay out a process for implementation. Other lake groups take on these tasks from within, sometimes assigning the task to a single (very unlucky) person.

Regardless of the means to the end, experience demonstrates that all affected parties need to be actively involved. Building consensus about "How much is too much?" is an important step in setting aquatic plant-management goals and choosing strategies. Though not always easy, building consensus for a plan of action is crucial for success. Consensus building is not necessarily about getting everyone to agree. It is about getting everyone to work together toward a common goal despite strongly varying opinions about how to get there.

### Aquatic plant identification

To manage plants, it important to know what plants are there. Identification is critical because many strategies for controlling nuisance weeds only work for specific aquatic plants. The seed banks of naiads and some varieties of pondweeds (*Potamogeton sp.)* can tolerate the arid and icy conditions associated with winter water-level drawdown. The populations of these plants may actually increase after a drawdown at the expense of other plants that reproduce vegetatively. Grass carp *(Ctenopharyngodon idella)* like the taste and texture of some plants but not

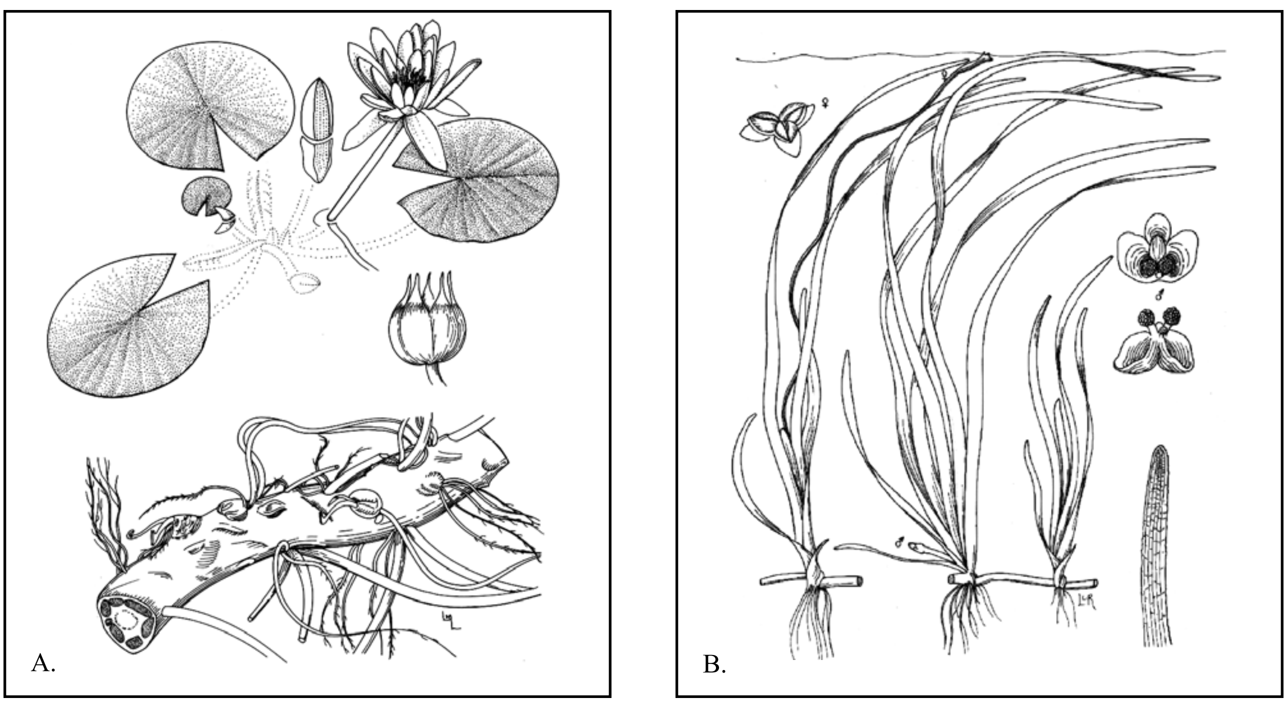


*Fig. 6–2. Different plants require different management strategies. A. Water lilies (Nymphaea sp.) and other plants with extensive root systems are not easily removed by hand harvesting. B. Eel grass (Vallisneria sp.) is an example of a plant with weak roots that can easily be removed.* (Credit: Univ. of Florida)

others, and their preferences are unpredictable and inconsistent. Plants that are strongly rooted, such as water lilies (*Nymphaea sp.)* and hardy Eurasian watermilfoil *(Myriophyllum spicatum)*, derive the majority of their nutrition from the bottom sediments, and respond to treatments differently than plants such as coontail, bladderwort and eel grass that are weakly rooted and absorb nutrients from the surrounding water. These examples illustrate the importance of carefully identifying the nuisance plants so that appropriate management strategies can be selected. Plant identification skills are also needed to conduct an aquatic plant survey of the lake, a topic discussed in Chapter four, "Problem diagnosis."

## *Who's in charge?*

It is important to identify the regulatory oversight and to recognize the regional variability that occurs in both regulation and environmental sensitivity to different plant management strategies. Don't waste time selecting plant control techniques that are not likely to be permitted.

The New York State Department of Environmental Conservation (DEC) maintains responsibility in most of the state for regulating aquatic plant management under various articles within the state Environmental Conservation Law (ECL). Permits obtained through DEC are required for some, but not all aquatic plant-management tools and situations. Some tools also require the evaluation of potential environmental impact. A permit is likely to be required if a portion of a lake is classified as a wetland under ECL Article 24. The DEC regional offices can assist in determining if any portion of a lake is classified as a regulated wetland. If it is, most activities in water less than two meters (m) deep are regulated and require a permit.

Aquatic plant-management permit applications are evaluated on a case-by-case basis in each region of the state. Some regional patterns have emerged, because regulatory requirements and environmental constraints dictate some variation within the review process. This is especially true for proposals involving aquatic herbicides and herbivorous fish (grass carp). By statutory law, aquatic herbicides can be legally used on lakes within the Adirondack Park, for example, but to date no permits have been issued. This is partially due to the stronger regulatory framework protecting wetlands within the Park. On Long Island, aquatic herbicide use is also very limited, though not due to regulatory restrictions. Both regions have historically had lower incidences of aquatic plant problems and have experienced stronger public opposition to aquatic herbicide use than other regions of the state. Permit approval for grass carp also varies widely by region. Grass carp are often stocked in Long Island lakes, but less so in the Adirondack Park where wetlands protection has greater significance.

Restrictions on use of aquatic herbicides and grass carp exist in other regions as well. This includes the large number of wetland lakes in the eastern portion of Central New York, the relatively short retention, time lakes or wide rivers in the southwestern Adirondacks, and water-supply reservoirs throughout the state. In contrast, a very large number of both aquatic herbicide and grass carp permits are issued downstate. This can be attributed to the large number of weed-infested lakes and the large population base affected by excessive weed growth. In most other regions of the state, the proclivity toward issuing permits for aquatic herbicides and grass carp is neither high nor low.

Some lakes have oversight by additional agencies. For lakes where the bottom is owned by the state of New York, plant-management activities that might significantly impact the lake bottom are administered by the Office of General Services (OGS). (see Appendix C, "Who owns New York State lakes?") The Adirondack Park Agency (APA) maintains regulating authority on waterbodies within the Adirondack Park, primarily authorized under wetland regulations (specifically 9 NYCRR 578.3(n)(2)(ii) and ECL Article 24) that govern the APA and activities that could affect the region's water resources. The regulatory definition of a wetland in the Adirondack Park differs from state and federal wetland definitions. Within the Adirondacks, the shallow portion of all lakes that have emergent, submergent, floating leaf or deep-water marsh wetland plant communities in less than two meters of water are classified as wetlands. Any activity that could substantially impair the functions served by, or the benefits derived from, freshwater wetlands is a regulated activity and requires a permit from the APA. This basically encompasses all shallow-water plant-management activities on lakes within the Adirondack Park. In deeper waters, APA jurisdiction is much more limited.

Other entities may have authority over some aquatic plant-management activities. Authorities that regulate water level in the state, such as the New York State Canal Corporation and the Hudson River-Black River Regulating District, may dictate whether water level in feeders to the canals or larger river systems can be manipulated for aquatic plant management. Such authorities have control of water levels in many New York State lakes. Other government agencies that possess regulating authority include the:

- U.S. Army Corps of Engineers for "navigable" waters, and for the upstate reservoirs designated as feeder lakes for the Erie/Barge Canal;
- New York State Department of State for "wetland" lakes with direct connections to designated coastal areas;
- Lake George Park Commission, Saratoga Lake Protection and Improvement District, and local government agencies with delegated responsibilities from DEC for regulating wetlands;
- New York State Office of Parks, Recreation, and Historic Preservation (OPRHP) for those lakes and ponds that have state park land; and
- Departments of Health (statewide and county) often provide input on permit applications for projects that may affect potable water, such as some aquatic herbicides.

The local or regional office of these agencies should always be contacted to determine whether they have regulatory authority over a proposed lake-management activity and whether a permit is required.

## *An ounce of prevention*

There remain many unanswered questions about how, why, and where aquatic plants will grow, but it is quite clear that exotic plant problems start from a single plant, seed or fragment from a distant plant bed. The best control strategy for non-native nuisance plants is prevention. If the plant isn't in a lake, there is no need to develop control methods. Even in lakes that are already weed-infested, the arrival of new or hardier exotic plant species might cause worse problems.

New introductions of plants are often found near boat launch sites. Propellers, hitches, and trailers frequently get entangled with weeds and weed fragments. Boats not cleared of exotic fragments after leaving a lake may introduce plants to another lake. Bilge or bait-bucket water may contain traces of exotic plants or animals. They should always be emptied and washed before moving from one lake to another. Bait buckets should be emptied in the trash, not in the lake.

Boater education and inspection programs are useful and have been utilized at boat-launch sites in several locations in the state. Lake associations provide handouts to boaters about the link between boats and the movement of invasive exotic plants. Signs posted at boat launches by DEC and advocacy groups encourage boaters to do self-inspections and remove any hitchhikers. These signs provide pictures of the most significant invaders, most often water chestnuts, zebra mussels, and Eurasian watermilfoil. They also highlight hot spots on boat props and trailers where straggling plants may cling, and the proper methods for removing and disposing of them. Volunteers may be trained to conduct inspections of boats and trailers entering or leaving the lake to make sure all plant fragments are removed. Lake stewards have been posted at boat launch sites in Lake Champlain, Lake George, Lake Placid and at several locations through stewardship programs led by Paul Smiths College and the Adirondack Student Conservation Association (SCA).The most extensive programs add boat-wash stations, ranging from simple hoses to pressurized hot washes, to remove both nuisance plants and **veligers**, the larval stage of the zebra mussel.

Invasive species can be introduced in other ways. Ducks and other waterfowl often unwittingly transport plants from lake to lake. Since they more often encounter canopy-forming plants such as watermilfoil and water chestnut, the fragments and seeds from these exotic plants are common hitchhikers. So feeding the ducks can effectively feed invasive plants to the lake. Many exotic plant species can be readily purchased for household fish tanks or water gardens. Prevention depends on education programs, in the absence of stricter federal or state laws that ban or restrict the sale of these plants. At present, only the planting or transit of water chestnut *(Trapa natans)* plants and seeds is prohibited within New York State. The New York Invasive Species Council, however, is developing a four-tier classification list of exotic plants and animals that will ultimately provide a framework for prohibiting or restricting the introduction of potentially invasive organisms, including those provided through the nursery trade.

## Rapid response

The best chance for control of exotic plants is when they are first detected and then removed before becoming established. Complete eradication is rarely possible even when the plant exists as a small isolated patch. Once the population is extensive, limiting its expansion becomes more difficult. Where invaders have thrived for decades, nuisance plant communities will probably remain forever, and will require ongoing management. But in some lakes, and even in a few regions of the state, some invasive species have not yet established footholds. The early detection and rapid response to pioneering invasions of exotic aquatic plants can prevent the unwanted spread of these plants and the ecological and recreational problems associated with their domineering presence.

Early-detection networks of trained volunteers can be very effective in identifying newly introduced aquatic plants and implementing a rapid response plan to remove the offenders. Early detection and rapid response works best in areas where invasive species have not yet established firm footholds. Many lakes in the interior of the Adirondack Park, for example,


*Fig. 6–3. Informational signs about exotic invasive plants can be posted at boat launches to educate boaters. It is important for boats, trailers and equipment to be inspected and cleaned before launching.* (Credit: DEC)

remain free from invasive exotic plants, and neither Eurasian watermilfoil *(Myriophyllum spicatum)* nor water chestnut *(Trapa natans)* have established a significant presence in Long Island. Water chestnut is mostly restricted to the corridors associated with the Hudson and Mohawk Rivers and Lake Champlain.

Accurate plant identification is critical for effective early detection and rapid response. Some invasive plants, such as water chestnut, can be readily identified with minimal training. Some invasive plants are more difficult to identify in their early stages. Some plants, such as curly-leafed pondweed *(Potamogeton crispus)*, have early growing seasons that do not correspond to the recreational season in New York State, or the plants grow in deepwater habitats and are less readily detected. Eurasian watermilfoil is notoriously difficult to correctly identify due to its similarity to several other plants. It is often first observed in beds rather than as isolated plants. Even this pernicious invader, however, can be identified through careful early-detection networks.

There are problems associated with using rapid response to control plants in New York State lakes. Some management techniques simply do not work rapidly. Regulatory requirements often dictate a permitting timetable measured in months or even years, rather than days or weeks. Other techniques require significant capital expenditures. When new exotic animals such as snakehead are introduced into New York, the DEC holds statutory authority to intervene in rapid response control efforts, even in private waterbodies. This authority may not exist for exotic plants, impeding the use of state funds or enacting the emergency provisions of the State Environmental Quality Review (SEQR) Act to streamline the regulatory process. It is anticipated that a rapid response protocol will eventually be established for pioneering introductions of at least some invasive exotic plants, particularly those new to or not yet established in the state.

The discussion of each aquatic plant-management technique presented in this chapter outlines the expected implementation timetables for securing permits and grants, other necessary actions, and the best timing for the treatment to be effective. When all of these tools are considered, the "simplest" strategies, such as hand harvesting, tend to be the most effective rapid-response tools in the plant-management toolbox. Model rapid response plans have been developed to dispatch new invasions in the Adirondacks and within Lake Champlain as part of the Adirondack Aquatic Nuisance Species (ANS) plan.

## Plant management techniques: What works?

Weed problems have plagued New York State lakes for decades. During that time much has been learned from successes and failures, but no silver bullet has been developed. Every management strategy has some risks associated with its use in the dynamic and unpredictable biological settings of lakes. "Management" sometimes even makes the problem worse.

When choosing the most effective management techniques, the plant manager must keep in mind the factors that most influence weed growth. First and foremost, exotic species cannot grow in a lake unless they are introduced. Aquatic plants have physical requirements, including the proper sediment characteristics and water depth, adequate light transmission, and space. Some plants do not grow well in certain bottom substrates. Water depth and clarity are important because plants cannot grow if sunlight is inadequate. Management actions that decrease water depth or increase water clarity allow plants to grow in areas where they did not grow before. Management actions that increase water depth or decrease water clarity may select for plants that are light insensitive.

Space is needed since plants cannot grow on top of other plants. Some invasive species gain more space by forming dense canopies that out-compete native plants by blocking sunlight. Invasive plants then take over the vacant areas no longer occupied by their predecessors. Perhaps most importantly, invasive plants grow very well in "disturbed" environments where the sediment characteristics have been altered for a variety of reasons.

All plants, aquatic and terrestrial, need nutrients for vigorous growth. These nutrients are generally obtained from the sediments rather than the water column. Increased nutrient concentrations in the water, through leaching septic systems, fertilizer, stormwater, and other sources, will influence weed growth only when they are deposited in the sediments. Prior to sediment deposition, however, nutrients are often absorbed by algae, resulting in reduced water clarity. This gives an edge to invasive plants such as Eurasian watermilfoil and water chestnut that thrive in more turbid water. The connection between nutrients and algae is far stronger than the connection between nutrients and macrophytes. Most rooted aquatic plants are nitrogen limited; their growth may be limited by shortages of nitrogen. Algae are usually phosphorus-limited in New York State lakes. While both nutrients are provided by many pollution sources, such as stormwater or soil erosion, watershed management actions focusing on phosphorus control are more likely to reduce excessive algae than control nuisance weeds.

The core group of aquatic plant-management strategies that have been used in New York State lakes can be categorized by their mode of action:

- *physical* control strategies that impact the physical growth patterns of the weeds by disturbing the sediment, altering light transmission through the water or to the plants, or water-level manipulation;
- *mechanical* control strategies that remove the plants and root systems, such as cutting, harvesting, and rotovating;
- c*hemical* control strategies, such as herbicides that are toxic to all or selected aquatic plants; and
- *biological* control strategies, such as herbivorous fish and insects that are predators consuming enough plant matter to reduce growth below nuisance levels.

Alternatively, plant-management control strategies can be categorized as "local" or "lakewide." Local strategies can be used by an individual lakefront owner. Lakewide strategies impact most or all of a lake. Lakewide strategies require a greater consensus among lake residents and are more likely to require a permit. These categories are used to organize the remainder of this chapter, since weed sufferers are likely to find this distinction valuable in selecting a mode of action. Other factors described for each aquatic plant-management technique include the advantages and disadvantages of each method and its cost. Because prices vary with place, time and circumstance, the cost listings are relative at the time of publication of this book.

Local strategies are discussed first, because anyone can use them without a consultant, an army of permit writers, and a truckload of cash. The chapter then discusses the high tech, multi-permit, big ticket items such as mechanical, biological or chemical strategies. These more complex management activities are briefly introduced because they should only be attempted after extensive research. Unexpected consequences are noted under each management technique, at least as much as the unexpected can be predicted.

The techniques described are not specifically endorsed by New York State Federation of Lake Associations (NYSFOLA) or by regulatory agencies. This is simply a list of recognized methods for addressing specific aquatic plant problems. Additional information about each of these techniques can be found from a variety of sources, including Holdren et al., (2001); Cooke et al. (1993); and Baker et al. (1993). (see Appendix G, "References cited" and Appendix H, "Additional readings")

## Local management activities

### *Hand harvesting*

#### *Principle*

Hand harvesting is the most common plant-management technique used to control nuisance weeds in New York State. It is the only strategy that generally requires no permits in most parts of the state, no significant expertise, and little risk of side effects. It is used first, before the harvester is overwhelmed by the work, or used last after permits cannot be secured or consensus can't be reached for larger scale techniques. It is used as an interim measure until a consensus of tired arms and sore backs supports the use of large-scale techniques. It is perhaps most effective when used in concert with whole-lake control strategies, as a follow-up to prevent re-infestation or re-establishment of large beds of weeds. It is ineffective for plants with extensive root systems, such as water lilies.

Anyone can hand harvest, although only the cautious can do it well. It is comparable to weeding a garden. The entire root system must be removed by grasping the plant material from under the roots of the plant as close as possible to the sediment layer. Digging into the sediment may be needed to grasp the root crown and free the intact plant from the sediment. Side-effects, such as fragmentation, turbidity and bottom disturbance, are reduced by pulling plants slowly, and harvesting while the plants are still robust. Plants and roots should be deposited away from the shore to minimize re-infestation of the lake.

## *Advantages and disadvantages*

Hand harvesting is an effective rapid-response tool, particularly for controlling exotic plant species such as water chestnut or Eurasian watermilfoil. It is also a useful way to prevent re-infestations following a large-scale plant-management strategy. In both situations, it is most effective when combined with a vigilant surveillance program. For target plants that do not reproduce vegetatively, hand harvesting can provide long-term control if the plants are removed prior to the formation and fall of seeds.

Hand harvesting can be conducted on a single plant or a small bed at a minimal expense, if not minimal labor. In theory, only time, patience and the amount of available elbow grease limit the area cleared by hand harvesting. In reality, it is restricted to small areas because it is so labor intensive. It is difficult to hand pull large or deep beds of plants, and inconvenient to hand pull scattered plants, although this may be the best way to prevent the expansion of single plants into small beds.

Efforts to rush the process often result in fragmentation, incomplete plant removal, and bottom

### Insider's guide to hand harvesting weeds

So you wanna pick some weeds? How hard can that be? Well, if collecting a bouquet of picturesque aquatic plants, it may be very similar to gathering wildflowers from an endless meadow. If trying to prevent these pesky plants from returning or spreading, however, the process is not quite so simple. Here are some tricks of the trade that have proven successful in effectively controlling the propagation and re-growth of Eurasian watermilfoil and water chestnut, perhaps the two most heavily plucked plants.

For Eurasian watermilfoil *(Myriophyllum spicatum)* (Martin and Stiles, 2005 and Eichler, 2005):

- Each sediment type creates unique challenges for hand harvesters. Muckier sediments are easily disturbed, resulting in turbidity that can inhibit divers abilities to locate plants. Harder sediments can be rough on the divers hands.
- Beds are generally best harvested by working in from the outside edge, usually moving from greater to lesser depth to minimize disturbance of milfoil beds by boats (assuming they migrate to the harvesting site from the open water.)
- Plant stems should be removed by prying the root crown out of the sediments, rather than pulling or tugging on the stems. Divers should insert their fingers into the sediments around the root crown, which may be the size of a tennis ball for mature milfoil plants, and should exert a steady pull. It has been described as similar to pulling an onion out of the soil, although the milfoil plants have more fine roots.

For Water Chestnut *(Trapa natans)* (Samuels, 2005)

- Water chestnuts reproduce from the nutlets. The nutlets are very sharp so wear old shoes and gloves when harvesting.
- The best window for removing water chestnuts is between mid-June and mid-August.
- Plants should be flipped upside down once picked to prevent seeds from dropping. If nutlets are removed before they drop, the plants will be eliminated as a seed base for future growth. The nutlets can survive in sediments for up to 20 years so any dropped in previous years are likely to be viable. Do not remove the plants too early; new plants may crop up and produce seeds, unless re-harvested. If plants are removed later than August, some nutlets may drop off during the harvesting process since they are loosely attached to the plant by late summer.
- Since infestations spread outward from the edge of the plant beds, start removing plants from the outside and work into the center of the beds.
- Kayaks are effective for removing chestnuts due to their maneuverability through dense beds, but canoes carry more chestnut cargo.
- Plastic laundry baskets work well for holding chestnuts in kayaks. Leaf tip (self-standing) bags work well for transporting plants out of canoes or pontoons.
- Dispose of the plant in the trash or by composting on land away from shore (but watch out for the nutlets!)

disturbance resulting in high turbidity. Harvesting can create significant fragmentation and a surface "bloom" of cut plants that can migrate around the lake. Unless rapidly removed, these plant masses will migrate to the shoreline of an unappreciative downwind neighbor.

Even when performed properly, hand harvesting frequently results in the release of some plant fragments, roots or seed. These drift back down to the lake bottom and become the vegetative stock for new generations of plants. Since many nuisance plants spread vegetatively through runners and rhizomes, the inability to remove these parts can result in rapid re-infestation from beds outside the shallow range of hand harvesting. This is not an effective way to remove plants that have extensive root systems, such as water lilies.

The hand harvesters are also responsible for disposal of the weeds. Large piles of water weeds will create an unseemly, smelly mess as they decay, although deposited mounds of plants will dry into much smaller piles. Composting is a common disposal strategy, although aquatic plants are usually nitrogen poor and are not particularly beneficial gardening supplements.

### Target and non-target plants

Hand-harvesting is the ultimate selective plant-management technique. It removes plants one at a time, and removes only those plants that are identified as exotic, invasive, or otherwise contributing to nuisance conditions.

### Costs

The advantage to hand harvesting is that it can be done at minimal or no cost. If someone is hired to hand pull, however, the cost can exceed $1,000 per acre.

### Regulatory issues

Hand harvesting is not a regulated activity in most regions of the state, although some DEC Regional Offices may require permits or approval to perform large-scale hand-harvesting. This would take the form of a Protection of Waters permit governed under ECL Article 15.

An ECL Article 24 wetland permit may be required for lakes outside of the Adirondack Park and partially or wholly encompassed within wetlands. Large-scale hand-harvesting operations within the Adirondack Park require an APA permit. A wetlands permit is not required if the hand harvesting:

- is conducted only on an individual's property, or with the permission of the property owner, or is done by individual shore land owners adjacent to their shoreline;
- is conducted by hand in open water;
- leaves at least 200 square feet ($ft^2$) of contiguous, indigenous wetland vegetation in the immediate vicinity of the owners shoreline;
- does not involve more than 1000 $ft^2$ of native freshwater wetland plants;
- does not involve rare or endangered species;
- involves no **pesticides** or any other form of aquatic plant management, including mechanical plant harvesting methods or benthic barriers;
- involves no dredging, removal of stumps or rocks, or other disturbance to the bed and banks of the water body; and
- the activities are not a part of a lakewide harvesting program by individuals or groups.

### History and case studies in New York State

Hand harvesting has a long history of use in New York State. It is likely that nearly every lakefront resident has performed hand harvesting, though not necessarily with the care and thoroughness needed to be effective. Hand harvesting has successfully controlled small patches of Eurasian watermilfoil in Lake George, Mountain Lake, Indian Lake and Lake Colby. Studies conducted in Chautauqua Lake have shown a long-term reduction in Eurasian watermilfoil beds in small areas after uprooting of plants through hand harvesting. Small beds of water chestnut have been controlled by Boy Scout groups and private citizens in Oneida Lake and Sodus Bay. Most of these efforts have successfully controlled the targeted plants, but continued efforts have been necessary to prevent re-infestation.

## *Diver harvesting*

### *Principle*

Scuba divers will be required for hand harvesting large plant beds, or for plants growing in water greater than a few feet deep. As with all hand harvesting, divers also need to pull out the roots. When done properly, this should not significantly disturb the substrate. If done incorrectly, it can create sediment clouds and cause water-quality problems.

In the simplest situations, diver-harvested plant materials are placed in mesh bags and taken away from the lake. More extensive diver harvesting uses a suction hose in a process referred to as **suction harvesting** or **diver dredging.** A barge with a large engine powers a dredge hose that sucks the diver-pulled and fed plant materials, rather than using the hose like a vacuum cleaner to ingest plants and sediment. The dislodged plants go into a spoils-collection basket on the barge. The basket traps the plant matter, allowing water to drain back into the lake.

Diver harvesting collects a much smaller biomass than does the large-scale mechanical harvesting operations discussed later. Only small targeted areas are harvested, and only the nuisance plants are removed. Plants can be disposed of at a site away from the lake, or dried and used for mulch or fertilizers. Disposal may be confined to small, individual sites.

### *Advantages and disadvantages*

Divers can remove plants from between docks, in shallow water or in open water, even when a suction hose is used since the diver, and not the barge,

*(Continued on page 128)*

**Case study:**
**Hand harvesting by divers in Upper Saranac Lake**

**Lake setting**: Upper Saranac Lake is a 5,200-acre lake with more than 44 miles of shoreline found near the northern edge of the Adirondack Park.

**The problem**: Eurasian watermilfoil *(Myriophyllum spicatum)* was first discovered in 1996, and local residents and lake users have been concerned that it may invade large portions of the lake.

**Response**: A privately funded control effort using benthic mats and suction harvesting with four divers was initiated in 1998 by a partnership of organizations, including the:

- Upper Saranac Lake Foundation (USLF);
- Adirondack Aquatic Institute (AAI), and Adirondack Watershed Institute (AWI) at Paul Smith's College; and
- Cedar Eden Environmental, LLC.

This three-year effort achieved local control of large Eurasian watermilfoil beds primarily in front of state lands, which comprise nearly 50 percent of the lake shoreline. It resulted in the annual removal of about 50 acres of Eurasian watermilfoil across three to four miles of shoreline, at an annual cost of about $60,000. This level of effort was insufficient to prevent the spread or re-establishment of the plant. The benthic barriers and harvesting kept plant densities from being high enough to consider other control options for managing extensive Eurasian watermilfoil beds. In addition, political considerations prevented the use of some techniques, such as aquatic herbicides.

A more extensive, three-year harvesting and benthic matting program was initiated by USLF in May of 2004 to reduce Eurasian watermilfoil to acceptable levels, although additional work continued into at least 2008. Benthic barriers were placed on the lake bottom in the middle of May. Based on the experience of other large-scale, diver-assisted harvesting programs in other New York State lakes, a crew of 20 divers was assembled two divers for approximately every 500 acres of lake area. All were experienced and certified divers who were trained in a one-day session involving plant identification and safety. Additional in-water training covered advanced Eurasian watermilfoil identification and removal techniques. Divers were divided into four teams, each with an experienced dive leader to coordinate diving operations. Day-to-day direction and decision making was conducted by Crew Chief Tim LaDue, with additional volunteer resources provided by the Upper Saranac Lake Association and USLF. Additional resources used to support this hand-harvesting effort included 10 "top-water" team members, four dive platforms boats, two tank dive boats, dinghies, kayaks, and a patrol boat.

Divers harvested Eurasian watermilfoil plants five days a week for 55 days, starting on June 1st and ending August 15th. The divers hand-pulled plants in a systematic path based on wind direction, traffic patterns, existing growth and anticipated flow and control of fragments. Team members tracked locations with global positioning system (GPS) units, recorded detailed survey information about the presence and density of Eurasian watermilfoil and native plants, and transported bagged Eurasian watermilfoil to a remote location.

The project costs for 2004 were approximately $535,000, or approximately $200-per-acre of infestation. Labor costs were about $1,000 per hour, and constituted about 75 percent of the overall project cost. The project managers devised a unique compressed air-distribution system. It was used to reduce the extensive financial and logistic overhead cost associated with supplying and replenishing air tanks to such a large team of divers. This also provided a more effective means for mass plant removal in large beds. Conventional diving operations, using scuba tanks, provided greater mobility to access and remove smaller or more remote beds.

Future costs will likely be reduced since the capital costs for purchases of boats and other equipment will be lowered. It is difficult to compare these numbers to costs of other management activities, since the low to moderate density of plants targeted in hand harvesting was different than those encountered in other plant management efforts. Based on the number of divers, quantity of harvested plants and project costs, this is the most extensive hand-harvesting project to date in New York State.

**Results:** A three-year evaluation was completed by the Adirondack Watershed Institute at Paul Smiths College. (Martin and Stiles, 2005) Results from 13 transects surveyed around the lake in late 2004 demonstrated re Eurasian watermilfoil removal ranging from 27 percent to 100 percent of the pre-harvest plants. The majority of the sites exhibited greater than 60 percent removal. Removal rates were not closely related to either the plant densities or the number of times an area was hand harvested. Eurasian watermilfoil plants remaining at the end of the growing season resulted from either incomplete hand harvests or regrowth within the growing season. Most of this regrowth occurred in water depths between 8 and 12 feet. By 2008, the average Eurasian milfoil plant densities were less than 20 stems per acre in 15 surveyed areas, compared to densities exceeding 400 stems per acre in some parts of the lake prior to hand harvesting. August milfoil densities increased from about 120 to more than 500 stems per acre from 2007 to 2008 in an unmanaged area of the lake.

**Lessons learned**: This project demonstrates that hand harvesting can be effective for controlling even large-scale, Eurasian watermilfoil infestations, but control in large or heavily infested lakes requires significant resources and a well-devised plan of attack with consistent year-to-year follow up.

controls the operation. The main limit to suction harvesting is the length of the dredge hose and the length of any barge-attached surface air and safety lines for the divers.

Suction harvesting can have significant, although usually temporary, side effects. High turbidity, reduced clarity, and algal blooms can result from either the disturbance of bottom sediments, or the release of sediment slurry from the on-barge collection basket. This may reduce dissolved oxygen and impact the lake ecosystem. Sediment disturbance or removal, therefore, should be very minimal. Some less discriminating harvesters use the suction hoses to remove plants and roots by scouring the bottom, blurring the practical distinction between suction harvesting and dredging, despite the significant regulatory differences between the two techniques.

Disruption of the bottom sediments can have a deleterious effect on the animals living in the sediments and on the non-target plants living in the vicinity of the harvested area. Sediments may also contain heavy metals or other potentially hazardous materials that can be released into the water if proper precautions are not taken.

Lakeshore owner dissatisfaction may result from a slow rate of diver harvesting that fails to control their weed beds during the first year. This dissatisfaction may result in funding shortfall during subsequent years, since some of the operating funds for diver harvesting will probably come from these same lakeshore residents. They may prefer faster or less costly methods that may have more significant ecological side effects.

### *Target and non-target plants*

Diver harvesting can achieve selective control, although some nearby non-target plants and sediment may be removed. Some heavily rooted plants with extensive root systems, such as water lilies, are difficult to control with this method.

### *Costs*

Diver harvesting, without the added suction dredge, is among the most labor-intensive plant management techniques available. Plants can be hand harvested by professional, experienced scuba divers at a rate of about 90 plants per hour (per diver) for an area's first harvest, and about 40 plants per hour for a re-harvested area. This includes diving time, finding and removing only targeted plants, bagging, and disposal. The entire operation costs about $0.25 to $1.00 per plant, or upwards of $400 to $1,000 per acre, based on a "typical" density of aquatic plants in a lake.

The cost greatly increases when suction harvesting equipment is added, since the machinery costs about $20,000 to $30,000. The most significant cost is labor due to the slow rate at which diver dredges operate and the skilled labor required. Suction harvesting often requires at least three experienced specialists; one barge operator and at least two scuba divers. This adds an additional $500 to $1,000 per-person-per-day to the cost of the operation. Depending on the plant density, a one-acre site could take from 2 to 40 days to dredge or from $1,000 to $25,000 per acre, exclusive of the equipment costs.

### *Regulatory issues*

Permits are not required for small-scale hand harvesting by divers working without a suction dredge. If suction is used only for plants and not sediment, some DEC regions will not require permits. Suction harvesting involving sediment is considered dredging projects and is discussed elsewhere in this chapter. The regulations that cover suction harvesting are similar to those encountered when proposing a lakewide dredging project. A permit must be obtained from the DEC and from the U.S. Army Corps of Engineers if the lake is a "navigable" waterway. Within the Adirondack Park, the APA may also require a permit.

The process for obtaining permits can be extensive and difficult. Projects often require a public notification period. If the local community does not completely support the project, it can be delayed or even terminated. While suction harvesting does not usually command the same attention as the large-scale sediment removal dredging projects, the potential for public disagreement must still be considered.

### History and case studies in New York State

Suction harvesting projects have occurred with some success in Lake George, East Caroga Lake, and Saratoga Lake. The higher cost and more significant permit issues encountered in many regions of the state, as well as the need for highly trained personnel to operate the hoses and the boat, have precluded the extensive use of this technique in other parts of the state. The largest example of hand harvesting by divers without the use of suction equipment is Upper Saranac Lake (see case study page 126).

## Benthic barriers

### Principle

Benthic barriers, sometimes called benthic screens or bottom barriers, prevent plant growth by blocking the light required for growth. The barriers also provide a physical barrier to growth by reducing the space available for expansion and by preventing plants from germinating. Most aquatic plants under these barriers will be controlled if they are deprived of light for at least 30 days.

Barriers should be installed during low-growth periods, usually in early spring after ice-out, since dense plant growth can make installation difficult. During the summer, barriers can be applied after physical removal of the plants. Barriers are most often used around docks, in swimming areas, or to open and maintain boat-access channels.

Benthic barriers can be commercially purchased or homemade. They are usually made of materials that are heavier than water and are permeable to gases produced during the degradation of plant material. Commercial benthic barriers are made of plastic, fiberglass, nylon, or other non-toxic materials. Typical barriers from commercial vendors in New York State cover between 150 and 250 square feet. The narrow dimension ranges from 7 to 12 feet for installation in small spaces such as between docks. Homemade barriers can be opaque garden tarps with PVC pipe frames constructed to hold them in place. Barriers should be securely fastened to the bottom with stakes or anchors. Rocks can be used as weights to hold the tarps down, and steel reinforcing rebar rod can be used to stake the mat in place. Wide areas can be controlled if barriers are overlapped by four to six inches.

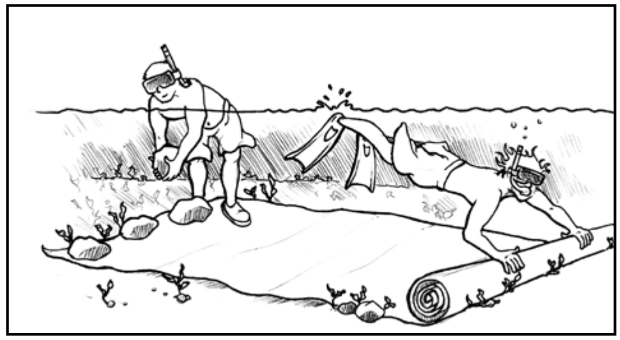

*Fig. 6–4. Benthic barriers clear small areas by blocking sunlight and eliminating space where weeds can grow.* (CREDIT: CHRIS COOLEY)

Barriers can be installed from the shore in shallow water by two or four people. The roll can also be placed on a small boat and unwound as the boat is rowed away from shore. Scuba divers are often required to install and secure the barriers in water depths greater than six feet. Plots with steep slopes, natural obstructions, or heavy plant growth may require additional assistance.

The screening materials and anchors should be removed at the end of the growing season so they can be cleaned off and protected against ice damage during the winter. Some lake residents keep the barriers permanently anchored. In these situations, or in deeper water areas, the barriers should be periodically cleaned to remove organic material. This will prevent new plants from growing on top of the barriers. With proper maintenance, the screening materials can last several seasons.

### Advantages and disadvantages

Benthic barriers can be among the safest and least detrimental in-lake physical control technique and often afford the greatest public satisfaction. They have been effectively used for many varieties of nuisance vegetation and in a wide variety of lake conditions. They can be used in any portion of the lake where rooted weeds can grow. Benthic barriers do not introduce toxic or hazardous chemicals and do not involve extensive machinery. Some materials are said to photodegrade in ultraviolet light, but the degradation products are usually innocuous.

Barriers may eliminate some species of benthic invertebrates, especially if the barriers are permanently installed on the lake bottom. It is possible that they also interfere with some warmwater fish spawning. Most other components of the food web are not adversely affected, and the ecological side-effects are insignificant outside of the treated areas, but long-term ecological impacts from benthic barriers have not been well studied.

Benthic barriers are cumbersome to place and anchor, but can be sited by laypeople almost as well as professionals. Installation and maintenance will require significant thought and time. The materials may be heavier than water, but currents and the natural buoyancy of the covered vegetation can cause the screening material to move or deteriorate. Should these barriers drift to the surface, they can be difficult to replace. Any large application will probably require additional anchoring and reinforcement. This is especially important when the screens rest on steep slopes, uneven terrain, or thick plant cover.

Buoyancy due to gas formation from degrading plants must be prevented to avoid ballooning or screen movement. These problems can be avoided by cutting small slits in the materials, large enough to allow gas escape, but not large enough to allow plant growth through the holes.

Maintenance is critical to minimizing plant regrowth due to sediment or silt deposits on top of the screens. Materials used in some benthic barriers allow root structures from deposited plant fragments to take hold. Some manufacturers claim that any new growths can be easily removed from the screen surface. Removing individual plants fragments from the barriers underwater, however, can be very tedious and will almost certainly require the use of scuba divers in deeper water. Other manufacturers recommend that their materials be removed and cleaned annually. This is not practical for large applications because of the potential for tearing, the weight of the water and sediment on the barriers, and the difficulty of re-installation. Even for small applications this can be tedious, since barriers are difficult to remove once they accumulate sediment, falling debris, newly rooted plants and any zebra mussels present in the waterbody.

The benefits of benthic barriers are thus counterbalanced by the difficulty of installation and maintenance and the overall cost. These considerations usually limit the use of benthic barriers to areas of either intensive recreational activities or strong aesthetic concern. For large areas, permitting issues may become more significant.

### *Target and non-target plants*

It is possible to site benthic barriers to provide selective control over **monoculture,** or single-species beds of exotic or nuisance plants. If carefully sited, they can be effective for selectively suppressing an area of undesirable plants and maintaining native and controlled plant communities. Without proper use, however, this is a non-selective control strategy. If target plants are intermixed with desirable native plants, it is difficult to achieve selective plant control. Blocking sunlight and photosynthesis will kill all of the plants beneath the barriers, not just the nuisance plants.

### *Costs*

For professional installation, the cost of benthic barriers ranges from $10,000 to $20,000 per-acre, depending on the choice of screening material. The price can vary depending on whether the application involves an initial or repeat installation. The ability to reuse the materials for several years will help to amortize these costs. Unfortunately, many lake associations cannot afford the cost of professional materials and installation, except perhaps on the most critical weed beds. Control, therefore, should be limited to small areas with nuisance vegetation, although less expensive alternatives are commonly used by non-professionals.

## An insider's guide to benthic barriers

**Before Installation Tips:**

- When possible, plan ahead for a spring installation.
- Map areas where barriers will be installed, including dimensions of beds, bottom conditions, and slope.
- Take a photograph just in case, but DEC does not currently require permits for benthic barriers.

**Construction Tips:**

- Newer systems use a breathable, webbed tarp that allows gases to escape, usually available in 6 foot x 30 foot rolls. Alternatively, landscape fabrics or geotextiles are suitable for blocking sunlight and venting gases. Burlap will deteriorate more rapidly. Tarps should be vented with one inch cuts in regular intervals.
- Tarps are held to the bottom by a frame made of sun-resistant PVC pipe that has been slotted lengthwise and concrete-reinforcing rebar.
- A loop of the tarp is inserted into the slot in the PVC pipe and is held in place with the inserted rebar. The PVC pipe is then closed at both ends with glued-on caps. These bars are placed 18 or 20 inches apart, making the system quite heavy even in water.
- Alternatively, the PVC-rebar pipes can be made separately and simply laid as weights on top of the breathable tarp material.
- Wooden frames (2x2 inch boards) are another method, provided the wood is not pressure treated. Frames can be constructed 12x12 inches square, made of 2x2 inch boards. Plywood triangles are screwed to each corner and to a center brace. (Fig. 6–6) Once the tarp is stapled to the frame, another set of plywood triangles are screwed in the corners to create a sandwich that secures the tarp to the wood frame.
- For larger areas, construct multiple 12x12 inch frames that can be installed adjacent to one another. Larger frames are too difficult to install and maneuver.

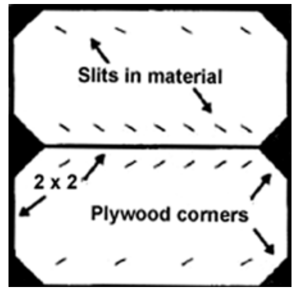


*Fig. 6–5. Homemade 12x12 inch square benthic barrier constructed of 2x2 inch, non-pressure-treated wood.* (ADAPTED FROM CORNELL COOPERATIVE EXTENSION ONONDAGA COUNTY)

**Installation Tips:**

- Barriers should be installed as soon as possible after spring spawning and removed in four to six weeks, but no later than Labor Day.
- Barriers should not be installed within 50 feet of any public or private water intakes.
- Any sticks or large stones should be removed from the barrier site prior to installation.
- It takes four strong people to place these mats in position over the weeds. Bags of stone may also be needed to submerge the barrier frames during installation.
- Wood-frame barriers should be anchored with native lake cobbles placed in polypropylene sand bags. Ropes should be used to tie the bags shut and attach them to the frame.
- A diver may be needed to position tarp and weight bags over the center brace.
- Barriers installed in less than six feet of water should be marked with buoys to protect boaters, swimmers and weed harvesters.
- Warning signs should be posted in areas with heavy boat traffic to keep boaters and their anchors away from the barrier site.

**Post-installation tips:**

- The barrier materials and frame should be periodically inspected and maintained to prevent the barriers from becoming a navigation hazard.
- The tarp needs to be "burped" with additional vent cuts if there is any evidence of air bubbles underneath it.
- Mats can be relocated to a new area after two or three weeks to extend the area of weed-growth suppression. Weeds in the original area will grow back slowly, similar to their start-up growth in the spring. (Somerlot, 2005)

## Regulatory issues

In most regions of the state, the use of benthic barriers has not been a regulated activity. There are situations, however, where approval or permits may be necessary. The U.S. Army Corps of Engineers considers benthic barriers to be “fill”, and thus require permits on navigable waters. DEC has increasingly required permits if the barriers are not removed at the end of the growing season. Regional DEC offices may require permits for benthic barriers if boulders or gravel are used and when they are placed as contiguous barriers by multiple neighbors. When a large portion of the lake bottom will be covered, approval or permits may be required to prevent disruption of fisheries habitat. The regulatory framework for this permit would be a Protection of Waters permit issued under Article 15 of the ECL.

Outside the Adirondack Park, benthic barriers are considered regulated activities within 100 feet of wetlands and adjacent areas under Article 24 of the ECL. Within the Adirondack Park, a wetland permit is required by the APA to “smother” aquatic habitats, and by extension the overlying plants (9 NYCRR Part 578 Special Provisions Relating to Freshwater Wetlands).

## History and case studies in New York State

Benthic barriers have been commonly used throughout the state for many years. Most applications have been by individual lakefront residents and are frequently not documented. The application of benthic barriers in Conesus Lake has been summarized by the Conesus Lake Association (2002). The recolonization of aquatic plants following the removal of benthic barriers in Lake George is discussed in the Journal of Aquatic Plant Management (Eichler et al, 1995). In both lakes, benthic barriers have effectively controlled nuisance plants, although in relatively small areas. Other New York State lakes that have been “treated” with benthic barriers include Brant Lake, Schroon Lake, Eagle Lake, Upper Saranac Lake, and Skaneateles Lake. This technique is no doubt used in many more lakes.

# Rotovating / Hydroraking

## Principle

**Rotovating** or rototilling is a relatively new form of mechanical control for aquatic vegetation. It uses a rototilling machine to cut aquatic plant roots from the sediment and remove them from the lake. **Hydroraking** is essentially the same technique, but it uses a mechanical rake to collect and remove some of the cut material. Neither is common in New York State, although this technique has been used more frequently in recent years.

Rotovating is primarily used for vegetation control around docks and swimming areas. The machine is usually mounted on a barge and has a large rotating head. Protruding tines churn up the sediment and dislodge the roots and plants. The rotating head can be easily positioned with a hydraulic boom winch and winch cable. This is also true for hydroraking. Plants are brought up on the rotator and disposed of on shore, or the floating vegetation is raked up for proper disposal.

In areas inaccessible to the rototiller barge, the rototiller boom may be maneuvered between docks and other shallow areas. The height of the rototiller boom and winch cable determines the maximum depth for rotovating.

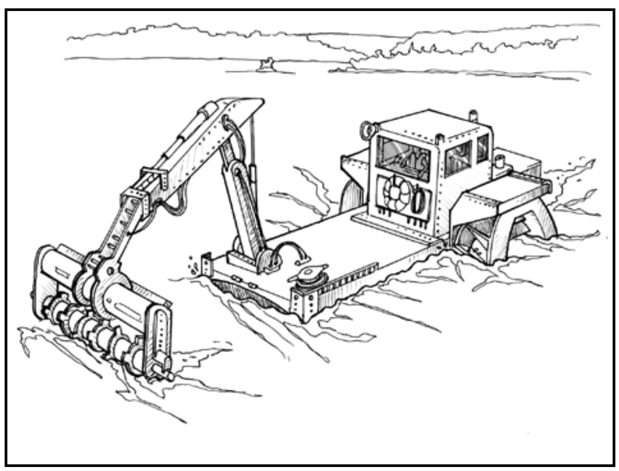

*Fig. 6–6. Rotovating equipment uses large cutters to remove aquatic plants and their roots from lake sediments.*

(Credit: Chris Cooley)

### Advantages and disadvantages

Rotovating and hydroraking have the potential to be more effective than mechanical harvesting. Both techniques can provide immediate relief and tend to work faster than mechanical harvesting. Since the roots, as well as the plant, are removed they provide a longer duration control strategy than mechanical harvesting.

This technique has controlled Eurasian watermilfoil *(Myriophyllum spicatum)* for as long as two years, but the introduction of plants from uncut areas may reduce this longevity. Hydroraking is more effective at controlling very strongly rooted plants, such as water lilies, and it can also remove small stumps common to artificial lakes.

These techniques usually need to be performed several times per year, depending on the density of weed beds, growth rates, and types of vegetation. New plant growth can easily occur if root stock is not completely macerated or if seeds are dispersed. There is less regrowth after rotovating than after hydroraking because of the greater removal or disturbance of root systems.

Side effects described under hand or mechanical harvesting apply to rotovating, but are greatly magnified. Provisions must be made to minimize turbidity and to remove the floating cut plants before they are dispersed downstream**.** Significant lake sediment disturbance can destroy the invertebrate and benthic habitats, and may result in localized turbidity and water-transparency problems. Freshly disturbed sediment provides an ideal habitat for colonization by fast-growing exotic species, and can skew the plant community towards invasives that actually make plant problems worse. Rotovating churns up a brew of root masses, vegetation, and other organic debris that decay in the lake. Under windy conditions or strong currents, plant fragments can spread beyond the treatment area unless they are collected immediately. This increases the potential for re-infestation of the plant species that reproduce vegetatively.

Negatives aspects associated with mechanical control of vegetation, such as heavy machinery, potentially high cost, and slow results, will contribute to potential public dissatisfaction. Floating weeds and high turbidity may be more noticeable than with other techniques. Unless the cut weeds are removed quickly, the public may perceive rotovating as a management technique that detracts from the aesthetic appeal of the lake. Even if this distraction is only temporary, it may be either untimely or be embedded in the memories of lake residents whose support is critical for the success of any lake-management strategy.

Hydroraking has many of the advantages of rotovating without as many of the drawbacks. The disturbances of bottom sediments are less significant, since the method involves less intense cutting and removal of the plants. Problems with excessive fragmentation, bottom disturbance, and impacts to bottom fauna may be less common, but still occur.

### Target and non-target plants

Rotovating and hydroraking are essentially non-selective since the machinery cannot be easily maneuvered to cut individual plants. The blades cut all plants and their root material within beds of diverse plant species. These techniques have been used in New York State primarily to control dense beds of Eurasian watermilfoil where other plants are not likely to exist.

### Costs

The capital costs for a rotovating operation $100,000 to $200,000. Operating costs range from $200 to $300 per-acre. One to three acres can be rotovated each day. If hydroraking or rotovating services are contracted out, the cost is approximately $1,000 per-acre. This operating cost is slightly lower than for mechanical harvesting, but the operation can take twice as long. These costs and time estimates do not consider retrieval and disposal of cut plants.

### Regulatory issues

Due to the disruption of the bottom sediments during operation, the use of a rotovator or hydrorake requires an ECL Article 15 permit issued by the local DEC office. Few permits have been obtained in New York State, although it is likely that much small scale rotovating occurs under the regulatory radar screen. This may be because lake residents, and perhaps rotovator and hydrorake operators, have not always been aware of permit requirements, or they may have been negligent in applying for necessary permits. Use of these techniques is brought to the attention of regulatory agencies only through the vigilance of concerned neighbors. The APA considers rotovating to be a regulated activity if the activity could substantially impair the functions served by or the benefits derived from freshwater wetlands.

### *History and case studies in New York State*

Rotovating and hydroraking have a limited history in New York State, and specific examples have not been documented. Rotovating is being used at an increasing frequency in small areas of much larger lakes, particularly in the Finger Lakes region and in western New York State. As these actions become more widespread and "supervised" within a regulatory context, case studies will no doubt be better documented.

## Lakewide or whole lake management activities

### *Mechanical harvesting*

#### *Principle*

Mechanical harvesting physically removes the upper portion of rooted aquatic plants, using a machine to cut and transport the vegetation to shore for proper disposal. It is often described as underwater lawn mowing. This common method of aquatic vegetation control can be used for clearing boat channels, launch sites, swimming areas, and other high use areas where weeds pose the greatest nuisance. It is often done to improve recreational use, which can be resumed immediately after harvesting. Harvesting also removes the nutrients, primarily phosphorus, stored in the plant structure, thus controlling one contributor that causes excessive rooted vegetation growth.

The two different types of mechanical harvesting operations are single-stage harvesting and multistage harvesting. A single-stage mechanical harvester cuts a swath of aquatic plants from six to eight feet in depth and from six to ten feet in width. Cut vegetation is transported by conveyer belt and stored on the harvester. The maximum capacity of the harvesting barge is usually between 6,000 to 8,000 pounds wet weight of aquatic plants. The harvester transports the plants to shore where they are unloaded to a truck for disposal.

The multistage harvester refers to two or more specialized pieces of equipment. The first machine cuts the vegetation and utilizes the plant's natural buoyancy to bring it to the surface. The cutting capabilities for the multistage harvester are usually greater than for the single-stage harvester. The cutting depth can extend as far as 10 feet, and the cutting width can be up to 12 feet. A second machine follows the cutter and rakes up the floating cut fragments for disposal.

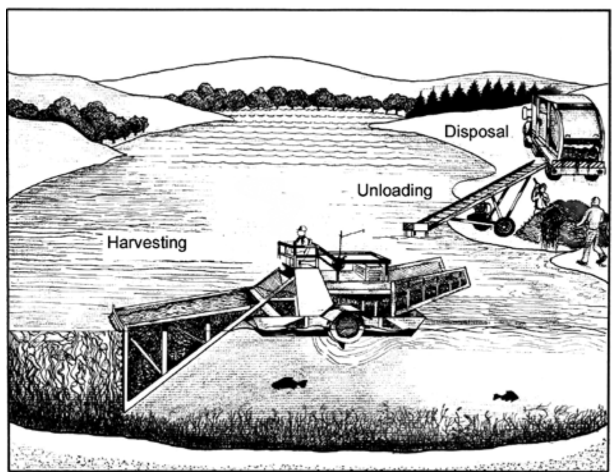


*Fig. 6–7. Mechanical harvesting removes the cut weeds from the lake. Some harvesters dump the collected weeds on the shore where they are manually loaded into a dump truck. Newer, larger harvesters can offload weeds directly into a dump truck.* (Credit: DEC)

#### *Advantages and disadvantages*

Harvesting provides immediate relief by removing the surface canopies of the dense, underwater, rooted plants that most interfere with recreational uses. Public support for harvesting can be strong because the plant canopy is the most conspicuous feature of nuisance plants and often defines the need for management.

The growing leaves, nutlets and flowering parts of strongly rooted plants are removed when the tops of the aquatic plants are cut. Weakly rooted plants may be completely uprooted. For aquatic plants that propagate primarily from seed banks or nutlets, such as water chestnut, removing the top of the plant prior to the maturation of the seeds can eliminate their growth the following year. Multiple years of harvesting may gradually deplete the bank of seeds in the sediments. Harvesting does not remove the lower portion of standing aquatic plants, which continue to provide cover and habitat for fish and other aquatic life.

Harvesting removes the nutrients stored within the plant material. It has been estimated that this may comprise as much as 50 percent of the internal (sediment-bound) load of nutrients that might otherwise become available for plant growth. In most lakes the macrophyte-bound portion of the sediment nutrient load is probably much lower.

The most significant side effect of mechanical harvesting is plant fragmentation. Plant fragments that are not picked up and removed from the lake can spread to other parts of the lake or to downstream waterbodies. The result is increased propagation of plants that spread primarily from fragments, such as Eurasian watermilfoil.

Plant communities may be altered by harvesting. If both native and fast-growing exotic plants are cut equally, the exotic plants may grow back faster and dominate the plant community. This is especially true for plants that propagate by fragmentation, and these are usually the plants originally targeted for removal. Stressed plant communities often favor the selective growth of exotic plants. As with the backyard lawn, cut plants often rebound with more luxuriant growth.

There may be negative environmental consequences of an improperly designed or executed harvest. Small, slow-moving fish can be trapped in the cutting blades or removed by the conveyer belt. If all cut vegetation is not removed, its decay may cause oxygen levels to temporarily fall, nutrient levels to rise, and short-term turbidity to occur. Even well-designed harvesting plans impact macroinvertebrates and other benthic organisms and may remove herbivorous insects that might otherwise help control aquatic plants.

The logistics of harvesting can frustrate lakefront property owners. Mechanical harvesters cannot be operated in shallow areas near docks and shorelines, but these are the very areas most residents want cleared of vegetation. Due to the slow cutting rates and relatively narrow cutting band, the harvester may need to be on the lake during most daylight hours throughout the summer. The perpetual presence of the machine is objectionable to some residents and may be an obstacle to jet skiers and water skiers.

Suitable launch sites for the harvester, or locations to park the conveyor, can be hard to locate in very shallow lakes or lakes with steep banks. If the conveyor is located away from the areas to be harvested, time is wasted traveling between the sites. Time is also lost loading and unloading the conveyer, especially when shoreline conditions prevent it from being close to the harvested area. The slowness of getting weed beds harvested can be exacerbated by unfavorable weather conditions, and mechanical breakdowns.

Many lake scientists, and an increasing number of lakeshore residents, believe that harvesters are simply very large riding mowers. Neither harvesting nor mowing will prevent re-growth, or even provide any significant long-term control. Harvesting is used to provide cosmetic control of excessive growth and to sustain popular recreational uses. The long-term benefits derived from harvesting do not approach the benefits of other cause-, or source-based management strategies. Harvesters can spread invasive weeds to places not yet colonized and create problems where none previously existed.

Harvesting remains the plant management tool of choice in many very large New York State lakes even though there are significant drawbacks. It is one of the few large-scale options for controlling weeds in lakes where herbicides are taboo, drawdown and dredging are heavily regulated, and other options are too costly.

## Target and non-target plants

These techniques are generally non-selective since the mechanical harvesters cut nearly all of the plants contacting the cutting bar. The machines cannot be easily maneuvered to selectively remove target plant species within diverse beds, and they cannot be operated in very shallow water. Selectivity is limited to targeting only plant beds comprised of a single plant species.

## Costs

Both capital and operating costs can be quite high due to the large equipment expenditures and the technical expertise necessary to run or repair the machinery. The purchase cost for a harvester and shore conveyor averages between $100,000 and $200,000. Some single-stage harvesters can be purchased for closer to $50,000. Leasing a harvester can reduce the overall costs unless frequent harvesting is needed, in which case, leasing costs quickly overtake purchasing cost. A typical leasing price in New York State is approximately $150 to $300 per hour. Additional set-up, transport, and sitting fees of about $300 are usually added.

A harvester can cut approximately one acre of aquatic plants every four to eight hours depending on the size of the harvester and the type and density of the plants. Acceptable control of aquatic plants may require two or more harvests during the recreational season. This increases the costs and can create scheduling challenges when outside contractors are involved.

## Regulatory issues

The regulations governing mechanical harvesting vary within the State. APA requires a permit for any activity in the Adirondack Park that disrupts the plant community in a wetland, including the area within a lake that supports the growth of plants. This includes mechanical harvesting. Outside of the Adirondack Park, harvesting is not regulated except where it is conducted within or adjacent to classified wetlands. In these circumstances, an ECL Article 24 permit from the local DEC regional office is usually necessary. Certain areas should be restricted from harvesting because they are important as a fishery or because they receive little or no use. The Environmental Permits staff at the local DEC office should be contacted for further information.

## History and case studies in New York State

The use of harvesters in New York State dates back at least to the 1950s. Historically a wide range of native plants, from submergent plant species such as large-leafed pondweed (*Potamogeton amplifolius*), and floating leaf plants such as water lilies, have been the target of harvesting efforts. Recently, however, most mechanical harvesting operations in New York State have targeted Eurasian watermilfoil *(Myriophyllum spicatum)*.

*Fig. 6–8. Large-leafed pondweed (Potamogeton amplifolius) is a native plant once commonly targeted by harvesting operations.* (CREDIT: CROW AND HELLQUIST)

## Case study: Mechanical harvesting in Saratoga Lake

**Lake setting**: Saratoga Lake is a 4,000 acre, heavily used recreational lake in Saratoga County in the foothills of the Adirondack Park.

**The problem**: Increased development pressure and recreational use in the 1960s and 1970s resulted in degraded water quality and impaired use of the lake for most recreational activities. More than 50 percent of the recreational users objected to the algae levels and water clarity. (Kooyoomjian and Clesari, 1973) In 1932, water clarity was about 5 meters and the lake was fully oxygenated throughout. By 1967, water clarity had dropped to about 1.5 meters and oxygen deficits began at a depth of about 6 meters. One of the inflows was locally called "Gas Brook" due to the persistent sewage smell.

In the 1970s, water-quality improvements resulted from the diversion of municipal wastewater out of the watershed, nutrient inactivation and the implementation of nonpoint source control measures on agricultural lands. These activities were funded in part by a federal Clean Lakes Project. (Hardt, et al, 1983) In response to the increased water clarity, nuisance growth of Eurasian watermilfoil *(Myriophyllum spicatum)* and curly-leafed pondweed *(Potamogeton crispus)* dominated the littoral zone to a depth of about four meters. This resulted in a shift from algae- to macrophyte-dominated system, without significant improvement in recreational conditions. However, 75 percent of the lake residents indicated that the lake was "somewhat" to "much" clearer. Water clarity did improve from about 1.5 meters in 1967 to more than 3 meters by the mid-1990s.

**Response**: The Saratoga Lake Protection and Improvement District (SLPID), a local management and taxing authority, oversaw the use of two mechanical weed harvesters purchased in 1984 that cut from 500 to 750 acres of nuisance vegetation per year. They operated daily from May through September. The biomass of the major macrophyte species in the lake did not experience significant change between 1982 and 1994, when an aquatic-plant survey was conducted by Darrin Freshwater Institute (DFI). (Boylen, et al, 1995) Some species were more abundant in 1982, while others were more abundant in 1994. (Table 6–1) Eurasian watermilfoil populations were substantially reduced in water depths less than about one meter but this was probably due to the winter drawdown that was regularly conducted each year.

By the early 1990s, in the midst of the harvesting program and supplemental work in shallower areas with a suction harvester, more than 90 percent of the lake residents identified rooted aquatic plants as a minor problem. This included effects due to weed decomposition and floating weeds cut by boats or harvesters. This problem was identified as significant by 40 percent of residents. About 60 percent viewed the harvesting program as successful, versus about 70 percent who viewed the sewering and drawdown conducted through the Clean Lakes Program as successful.

| Plant Species | Range of Biomass, 1982 | Range of Biomass, 1994 |
|---|---|---|
| Eurasian watermilfoil | 40-1000 g/m2 | 0-700 g/m2 |
| Curly-leafed pondweed | 0-170 g/m2 | 0-250 g/m2 |
| Southern naiad | 10-400 g/m2 | 0-450 g/m2 |
| Eelgrass | 0-40 g/m2 | 0-600 g/m2 |
| Water stargrass | 0-140 g/m2 | 0-30 g/m2 |

*Table 6–1. Biomass of plant species in Saratoga Lake in 1982 and 1994.*

The harvesters were replaced by larger, more efficient machines in the late 1990s. SLPID has been investigating an integrated approach to aquatic plant management. They have been conducting small-scale experiments since 2000 on the use of aquatic herbicides and herbivorous insects, while continuing the use of the mechanical harvesters. By 2007, large scale aquatic herbicide use was adopted as the management tool of choice.

**Lessons learned**: Mechanical harvesting may not result in a significant reduction in aquatic plant density or coverage, but it may be viewed favorably by many lake residents, particularly in light of what may be perceived as less desirable alternatives. For a lake this size, however, it is expensive.

In the late 1980s, the advent of the Aquatic Vegetation Control Program in the Finger Lakes region enabled many counties to purchase mechanical weed harvesters or harvesting services for use on the Finger Lakes, embayments to Lake Ontario, and some smaller waterbodies. Outside of the Finger Lakes region, harvesting has been conducted on Lake Champlain and Oneida Lake to remove water chestnut, and on Saratoga Lake, Greenwood Lake and many smaller lakes to remove Eurasian watermilfoil. (see Case study) A statewide inventory of lakes that utilize mechanical harvesters has not been compiled, largely due to the lack of regulatory oversight in most parts of the state, and therefore no paper trail of permits exists.

## Dredging

### Principle

**Dredging** removes the top layer of sediments that hold biologically available nutrients involved in exchanges and interactions with the water column. Sediment removal may improve the overall water quality in lakes where nutrient loading from sediments is a major factor affecting nuisance weed and algae growth. When the top layer of sediment is removed, so are the plants, plant roots, the nutrients they contain, and at least some of the accumulated seed bank. Dredging also serves to reduce rooted vegetation growth by increasing the lake depth, thereby reducing the amount of sunlight that reaches the bottom.

There are two basic dredging methods, drawdown excavation and in-lake dredging. During drawdown excavation, water is pumped or drained from the lake basin. The exposed mud is then dewatered (dried) sufficiently to accommodate the heavy earth-moving equipment that does the dredging.

In-lake dredging is used where it is difficult or impossible to drain a lake. Cutterhead hydraulic pipeline dredges are most commonly used. These dredges can operate anywhere on the lake, cutting to a depth of 60 feet. When the cutterhead is lowered to the lake bottom and moved from side-to-side, the rotating blades loosen the sediments, which are then transported by a dredge pump through a pipeline for discharge at the disposal site. The discharge is slurry that is 10 to 20 percent sediment and 80 to 90 percent water. The slurry requires a relatively large disposal site, designed to allow adequate residence time for the water to evaporate.

The other common type of in-lake dredge uses a grab-type bucket instead of a cutterhead. They are commonly used around docks, marinas and shoreline areas. Bucket-dredge performance is not hampered by stumps and other debris that may impede cutterhead dredges. They can be easily transported to different areas within a lake. This method removes sediment that is drier rather than as slurry. The sediment must be dumped within the radius of the crane arm, however, onto a barge or into a truck on shore. Sediment resuspension, and its associated ecological impacts, can be minimized by the proper selection of specialized dredges. Equipment selection is important because it influences the environmental impacts.

### Advantages and disadvantages

Dredging has proven to be an effective control technique for many lakes to increase water depth, reduce excessive vegetation levels, and control nutrient release from sediments. It has been used for small lakes, or for only a small portion of a basin in large lakes.

Dredging is one of the few multi-purpose aquatic plant-control strategies. Sediment removal deepens a lake for recreational and navigational purposes. It can reduce hazardous substances such as heavy metals and other toxic materials in bottom sediments and ultimately in the overlying water. It can also reduce the number of organisms living in the sediment and water.

Although the benefits of dredging can persist for a relatively long time, it is probably the most difficult lake restoration technique to successfully complete. Most lake communities have not been willing to endure the extensive environmental review and permitting process. If plant management is the primary goal, other strategies should be considered first, but other feasible management alternatives for increasing the lake depth may not exist.

Dredging can have profound effects on the entire lake ecosystem. Some of these effects are temporary or predictable, but many are not. Results depend on specific lake conditions, which make it extremely difficult to predict whether this is the correct treatment for a lake. If dredging is not done properly, it can actually make lake conditions worse by causing excessive turbidity, fishkills and algal blooms. Dredging projects should be accompanied by an extensive water-quality and sediment-toxicity monitoring program.

Dredging can harm fish, not only by causing turbidity but also by eliminating the benthic organisms upon which they feed. After a lake has been dredged, it can take two or three years for benthic fauna to re-establish. It is advisable, therefore, to dredge only a portion of a lake and leave a portion in its natural state.

Disposal areas for dredged sediments spoils should be selected carefully. Disposal is not suitable in woodlands, floodplains or wetlands because the muck will blanket and kill terrestrial vegetation. A carefully engineered and diked upland area may be the best option. Disposal sites should be fenced to keep out people and animals.

Public perception of dredging is often unfavorable because it is such a drastic control technique. It is critical to involve the lake community early in the planning process. Residents who feel removed from or ignored in the design phase may turn public opinion against the project, prompt reduced cooperation from officials and cause project delays.

### *Target and non-target plants*

Dredging removes all plants in the dredged area. Some selectivity can be achieved by limiting the depth of material to be removed, the type of sediment and the area of the lake to be dredged.

### *Costs*

Dredging costs depend on site conditions, desired depth of excavation, available access, nature of the spoils, and disposal, transport and monitoring requirements. Treatment costs per acre of surface area cut to

#### Case study: Dredging in Collins Lake

**Lake setting**: Collins Lake is a 70-acre urban lake, in the village of Scotia within the Capital District of New York State. It is used primarily for swimming and passive recreation by village residents.

**The problem**: Collins Lake is considered to be the first in North America with a confirmed identification of the exotic macrophyte, water chestnut *(Trapa natans)*. The plant covered most of the lake surface in the early 1970s. Hand pulling and the use of aquatic herbicides shifted plant dominance to curly-leafed pondweed *(Potamogeton crsipus)*, another exotic plant species. The macrophyte beds eventually covered about 60 percent of the lake surface to a depth of about 10 feet. The significant recreational impacts to swimming and boating and the high sedimentation rate of one centimeter-per-year (cm/year) triggered the need to dredge the lake to the 10-foot depth of the littoral zone.

After nearly 10 years of permitting issues, the lake was hydraulically dredged intermittently from 1977 to 1994 to control nuisance levels of curly-leafed pondweed as part of a federal Clean Lakes project. Ten percent of the lake bottom was dredged, yielding over 50,000 cubic meters ($m^3$) of sediment.

**Results:** Prior to dredging, curly-leafed pondweed densities were approximately 170 stems per-square-meter ($m^2$) during the peak of the growing season in mid-May. Dredging reduced pondweed densities to less than one stem per $m^2$ in 1979. Densities were still less than six stems per $m^2$ by 1988. In the portions of the lake not dredged, plant densities by 1988 were about 150 stems per $m^2$, similar to those measured prior to dredging. By the early 1990s, Eurasian watermilfoil dominated the aquatic plant communities. (Tobiessen and Benjamin, 1992)

**Lessons learned**: While the dredging was successful in dramatically reducing existing plant populations, this ultimately resulted in a shift from curly-leafed pondweed to the deeper-dwelling Eurasian watermilfoil *(Myriophyllum spicatum)*. This is one of many examples of how unintended and often undesired consequences result from even well-designed projects. Lakefront residents and recreational users should be aware of the potential for a shift from one type of plant (or algae) to another in response to active management. This also shows that in-lake management, without active watershed management, may limit the effectiveness of the control measures.

### Case study: Dredging in Ann Lee Pond

**Lake setting**: Ann Lee Pond, once known as Saw Mill Pond, is a 10-acre pond near Albany. In the late 1700s, it was used by America's first Shaker settlement for agricultural and commercial operations. In recent years, it has been used solely for non-contact recreational purposes, including fishing, ice skating, nature walks and wildlife observation.

**The problem**: By the early 1970s, the lake was highly productive. It had a dense surface coverage of submergent, floating, and emergent aquatic plants, including water lilies (white and yellow), curly-leafed pondweed, coontail, and common waterweed. The lake was also characterized by algal blooms and an accelerating sedimentation rate. After evaluating a number of aquatic plant management alternatives, the Albany County Environmental Management Council (EMC) authorized a hydraulic dredging project to be supplemented by a mechanical harvesting program after the dredging was completed.

Immediately prior to dredging, the typical water depth of the lake was about 0.7 meters. In 1980, about 16,500 cubic meters ($m^3$) of mostly organic sediment was removed from about seven acres of the lake. This increased the average depth of the lake to around two meters.

**Results**: Water-quality changes in Ann Lee Pond were not significant during or after the dredging operation. Dissolved oxygen levels increased, due to the removal of oxygen demand from decaying organic materials in the sediment. The density and aerial extent of water lilies decreased, but the common submergent plants became re-established after the dredging operation was completed in the fall of 1980. Curly-leaf pondweed *(Potamogeton crispus)* recolonized at levels comparable to those measured before the dredging. Coontail *(Ceratophyllum demersum)* densities decreased significantly, and common waterweed *(Elodea canadensis)* levels increased in abundance.

**Lessons learned**: Dredging is not likely to reduce the extent of submergent aquatic plant coverage unless the final water depth prevents sunlight from reaching large portions of the lake bottom. Dredging may shift the kinds of plants growing in a lake by reducing the density of plants, such as water lilies, that are limited by greater water depth. (Enviromed, 1982)

the typical depth of about three feet range from about $1,000 to $40,000. The latter figure represents a situation in which sediment spoils must be transported out of the area, which may be required for lakes in heavily developed areas.

## *Regulatory issues*

The permitting process is usually lengthy and detailed. The DEC Regional Permit Administrator should be contacted as early as possible when a dredging project is contemplated. Often, the process results in the denial of a dredging permit for a variety of reasons.

Any dredging requires at least an ECL Article 15 Protection of Waters permit from the regional DEC office. APA requires a freshwater wetland permit within the Adirondack Park. Outside of the Park, the project could require additional permits if part of the dredged lake is classified as a wetland, or if sediment testing uncovers hazardous materials. In general, the permitting process under ECL Article 24 is somewhat simpler if the project removes less than 400 cubic meters of sediment. U.S. Army Corps of Engineers permits may also be required if the project takes place in a "navigable" waterway.

## *History and case studies in New York State*

There have been a few dredging projects conducted for aquatic plant control, including Belmont Lake in Long Island for the control of fanwort *(Cabomba caroliniana)* in the early 1970s, and more recently Collins Lake in the Capital District for controlling curly-leafed pondweed *(Potamogeton crispus)* (see case study). A dredging project on Glen Lake was designed to improve water quality rather than for weed control. In river systems and shallow portions of lakes, it is most common to dredge to simultaneously clean up contaminants and improve navigation, as was done in the Great Lakes and in Cumberland Bay in Lake Champlain. Many of the original Clean Lakes projects in New York State in the 1970s involved dredging, but few of these were implemented to reduce weed populations.

## Water-level drawdown

### Principle

Drawdown involves winter manipulation of lake level to expose rooted aquatic vegetation and sediments to the freezing and drying action of cold air. The water level must be lowered at least three feet and the sediment must freeze to a depth of at least four inches. Snow cover may insulate the sediment and prevent freezing in mild winters. Freezing can help control weeds by loosening roots and loose organic material on the exposed lake bottom. Drawdown usually occurs between December and April in New York State.

Some species of rooted plants can be severely damaged or killed after four weeks of lowered lake levels. Some plant species are resistant to freezing and others may actually be enhanced by this technique (see Table 6–2). In general, plants that reproduce by seeds, such as naiads and many pondweeds, are less susceptible to drawdown than those plants that reproduce by rhizomes and other vegetation means. The latter includes Eurasian watermilfoil *(Myriophyllum spicatum)* and fanwort *(Cabomba caroliniana)*. Drawdown should be used every other year or twice every three years to discourage the establishment of resistant plant species. These resistant species are often the non-native or exotic plants that originally caused the nuisance conditions.

Substrate drying can limit the availability of nutrients, particularly under low oxygen conditions. Compaction of the loose, upper layer of sediment provides weed control by reducing the potential for re-suspension of the sediment and the nutrients adhering to it.

### Advantages and disadvantages

Water-level manipulation is one of the most common lake management techniques. It is used not only for the control of nuisance aquatic vegetation but also for repairing dams and docks, maintaining retaining walls and erosion control structures, cleaning up the shoreline, altering downstream flow, and as part of dredging and benthic barrier techniques. Drawdown

| Decrease After Drawdown | No Change or Variable | Increase After Drawdown |
|---|---|---|
| Brazilian elodea *(Egeria densa)* | Bladderworts *(Utricularia sp.)* | Duckweed *(Lemna minor)* |
| Coontail *(Ceratophyllum demersum)* | Cattail *(Typha latifolia)* | Naiads *(Najas sp.)* |
| Fanwort *(Cabomba caroliniana)* | Common waterweed *(Elodea canadensis)* | Pondweeds *(Potamogeton sp.)* |
| Hydrilla *(Hydrilla verticillatum)* | Eelgrass *(Vallisneria americanum)* | Water bulrush *(Scripus sp.)* |
| Milfoils *(Myriophyllum sp.)* | Muskgrass *(Chara vulgaris)* | |
| Robbins pondweed *(Potamogeton robbinsii)* | Water chestnut *(Trapa natans)* | |
| Southern naiad *(Najas quadalupensis)* | White water lily *(Nymphaea sp.)* | |
| Water shield *(Brasenia schreberi)* | | |
| Yellow waterlily *(Nuphar sp.)* | | |

*Table 6–2. An incomplete list of common submergent aquatic plants in New York State and the response of their populations to winter drawdown.* (ADAPTED FROM HOLDREN, ET AL, 2001)

is a fairly simple management strategy for relatively small lakes for which water levels can be fully controlled. Public response is generally favorable due to the low cost and the winter timing that does not interfere with summer recreation.

Drawdown creates an unfavorable environment for many nuisance aquatic plant species, such as Eurasian watermilfoil and fanwort, and encourages beneficial plants. Most nuisance vegetation problems occur in the shallow littoral zone. Depending on the slope of the lake and the depth of the littoral zone, drawdown only impacts the near-shore area while maintaining sufficient volume of water to support fish and wildlife. Since no chemicals or significant mechanical equipment is used, once water levels return to normal there may be no visible changes in the lake besides the changes in vegetation densities and plant community structure.

Drawdown can negatively affect adjacent wetlands or other areas with desirable vegetation. This impact is greater on lakes with large littoral zones. The impact of drawdown on many traditional wetland plant species is variable.

The potential impacts to benthic communities can be substantial since drawdown essentially shifts their habitat temporarily from aquatic to terrestrial. While some water-level variability occurs naturally within many lakes, anthropogenic manipulation of this marginal habitat can exert significant stress on frogs, turtles and other winter mud-dwellers. For this reason, proposals for water-level drawdown will often be closely evaluated by DEC, particularly in those lakes classified as wetlands, or those that possess sensitive or highly valued shoreline or marginal habitat. Removal of shallow water vegetation used for fish spawning or shelter may affect some fish species. See Chapter eight, “User conflicts,” for other potential negative effects on flora and fauna when water level is altered.

The removal of sediment-anchoring macrophytes along the shoreline has the potential to increase turbidity caused by waves, wind-induced erosion or re-suspension of sediments. Lakes with complete drawdown sometimes experience algal blooms after refilling. Sometimes new, or previously unnoticed plant species emerge that are unaffected, or even enhanced, by drawdown. Without competing species, non-native plants can flourish to the point of preventing the re-growth of native plants.

Winter drawdown can deplete oxygen, and fishkills may result, if a lake is shallow, and the sediments and inflow have a high oxygen demand. Nutrient release can also be enhanced and cause algal blooms. Hypolimnetic aeration may be necessary to mitigate these impacts.

If too much water is removed, or drawdown is followed by a period of drought, water levels may take a long time to return to normal levels. Domestic or fire-protection water-intake pipes may be exposed to the elements resulting in frozen pipes, or water levels below the intake levels. If the lake level does not recover sufficiently, recreational use of the lake could be limited for much of the summer. This can reduce both residents’ acceptance of drawdown and summer revenues from recreation and tourism. When devising a drawdown schedule, it is critical to prepare for the possibility of a low-precipitation summer. Conversely, the potential side effects of drawdown may be overridden in periods of normal or high precipitation. Heavy groundwater inflow in lakes near low water tables, such as those commonly found in Long Island and in wetlands within the Adirondacks and western New York, may prevent the winter desiccation needed to impact rhizomes and other plant reproductive structures.

Concerns over water level will often dominate lake association meetings, and any discussions regarding lowering the lake level may be hotly debated. With a well-conceived plan, and some luck from Mother Nature, lake users can be rewarded by decreased weed growth and restored water levels.

### *Target and non-target plants*

Seed producing plants are usually not as severely affected as those that reproduce vegetatively since seeds generally remain viable after freezing and thawing. Plants that reproduce by seeds sometimes increase in density or coverage after the drawdown. The effects of drawdown on specific plant species common to New York lakes is summarized in Table 6–2.

### Costs

If a lake has a dam or controllable spillway, drawdown costs are negligible. If pumping is needed to further reduce the lake level, or other impact mitigation is necessary, costs will increase. The costs for initially building a dam or water-level control structure are not factored in, since such activity is not generally undertaken primarily for weed control.

### Regulatory issues

ECL Article 15, Title 8 defines regulations relating to the volume, timing, and rate of change of reservoir releases. Title 8 also specifies other requirements such as monitoring, inspection, and maintenance of records. It is under this authority that the DEC issues permits for drawdown. When drawdown significantly affects navigability of a waterbody, the New York State *Navigation Law* may also apply. In addition, wetlands regulations require an ECL Article 24 permit for the use of this technology because drawdown often impacts adjacent wetlands.

Drawdown is a regulated activity in lakes within the Adirondack Park. It requires a permit from the APA if it could substantially impair the functions served by or the benefits derived from freshwater wetlands.

### History and case studies in New York State

Drawdown has been commonly used on many New York State lakes, often for reasons unrelated to aquatic plant control. Drawdown for the purpose of controlling Eurasian watermilfoil has been undertaken at Galway and Saratoga Lakes in Saratoga County, Greenwood Lake on the New Jersey/New York border, and some Adirondack lakes in the Fulton Chain of Lakes. Forest Lake, in the southern Adirondacks, was drawn down to control common waterweed and native pondweeds. Lake levels in Minerva Lake, also in the southern Adirondacks, were lowered for the control of native plants. Most of these have been fairly successful, although immediate effects included colonization by a different mix of invasive plants that dominated the aquatic plant community for a few years. The dominant plants in Robinson Pond in Columbia County, for example, shifted from Eurasian watermilfoil *(Myriophyllum spicatum)* to brittle naiad *(Najas minor)* after the lake was drawn down for the benefit of fisheries habitat downstream. The shift in plant dominance reversed several years later.

## Biological control

### Herbivorous insects

#### Principle

In the early 1990s, the populations of Eurasian watermilfoil crashed in the northern end of Cayuga Lake, the longest Finger Lake. Plant community structure dramatically shifted from invasives to desirable native plants (see case study). Researchers at Cornell University determined that the Eurasian watermilfoil populations were being significantly preyed upon by an herbivorous milfoil moth, *Acentria ephemerella.* The moth is considered a **naturalized** organism, one introduced some time ago that has adapted to New York State lakes. Similar damage is inflicted on Eurasian watermilfoil plants by a native herbivorous milfoil weevil, *Euhrychiopsis lecontei,* which is present in many New York State lakes. At least 25 herbivorous insect species have been found that feed on Eurasian watermilfoil including chironomid larvae (*Cricotopus* sp.) and a genus of caddisflies (*Triaenodes tarda*). The milfoil moth and the milfoil weevil are the most studied, and perhaps the most promising, for induced Eurasian watermilfoil control in New York State.

The mode of action of these various herbivores varies somewhat. The milfoil moth lays its eggs on the Eurasian watermilfoil plants near its base. When the caterpillars hatch, they crawl up the plant and feed on the growing tips (meristems). Research suggests that one moth per stem of Eurasian watermilfoil is necessary to significantly impact plant populations. The adult moth life stage lasts a mere two days, during which the males mate with the mostly wingless females. The female then swims down to lay her eggs on the lower plant leaflets. Two life cycles are

### Case study: Herbivorous insects— Natural control in Cayuga Lake

**Lake setting**: The 43,000 acre Cayuga Lake is one of the largest lakes in the state and is the largest Finger Lake by surface area.

**The problem**: Eurasian watermilfoil *(Myriophyllum spicatum)* was first reported in the lake in the 1960s, grew abundantly after Hurricane Agnes in 1972, and dominated the aquatic plant community until the early 1990s.

**Response**: Aquatic vegetation surveying conducted from 1987 to the late 1990s identified a crash of Eurasian watermilfoil populations in the early 1990s. While mechanical harvesting supported by the state-funded Aquatic Vegetation Control Program occurred in several locations in the lake during this time, the Eurasian watermilfoil decline was attributed to herbivory caused by the milfoil moth, *Acentria ephemerella*. Native plant populations in the lake increased dramatically over the same period. No measurable change in overall aquatic plant biomass resulted after the onset of milfoil moth herbivory. After the insects arrived, the total biomass dropped in the northwest end of the lake to 70 percent of the original biomass, but tripled in the southwest end. Overall plant populations were found at a greater density in the southwest end, and a lower density in the northwest end of the lake. (Table 6–3)

Eurasian watermilfoil populations steadily decreased in the northwest end of the lake and stabilized at very low densities (less than 0.5 grams per square meter) after 1995. Eurasian watermilfoil populations in the southwest end of the lake rebounded slightly by the late 1990s, but biomass remained less than 10 percent of the overall aquatic plant community throughout this "recovery" period.

**Lessons learned**: This case demonstrates the potential for control of Eurasian watermilfoil by these insects. (Johnson, et al, 2000)

generally completed during the summer. The caterpillars over-winter on plants near the lake bottom and begin actively feeding the next May.

The milfoil weevil feeds on more of the plant than the meristem. Adult weevils swim and climb from plant to plant, feeding on leaflets and stem material. Females lay two eggs per day, depositing each on a different Eurasian watermilfoil meristem. Once hatched, the larvae first feed on the growing tip. They then mine down into the stem of the plant and consume internal stem tissue. Weevils pupate inside the stem, and adults emerge from the pupal chamber to mate and lay eggs. Adults travel to the shore in autumn where they over-winter on land. The weevils generally spawn two to four generations-per-year, and two to four weevils per stem are required to significantly damage the Eurasian watermilfoil plants.

There are differences between the effects caused by milfoil weevils and moths. Weevils appear to start controlling plants in early summer. They reduce the height of plants in the manner of a mechanical harvester. Plants often return after the weevils depart the lake in the fall for wintering sites along the shoreline. Moths appear to produce a more permanent control, but may be more susceptible to predation or competition from weevils. The most critical period for lake residents concerned about invasive weed growth is the three-month window between Memorial Day and Labor Day. This corresponds to peak recreational use and the most active period for insect **herbivory** (consumption of plants) by both weevils and moths. Both milfoil weevils and moths, therefore, could prove to be effective in New York State.

| Plant Species | % Plant Community Before Onset of Herbivory* | % Plant Community After Onset of Herbivory* |
|---|---|---|
| Eurasian watermilfoil | 58-95% | Less than 1-11% |
| Eelgrass | 24% (NW end) | 54% (NW end) |
| Common waterweed | 3% (SW end) | 50% (SW end) |
| Total Plant Biomass | 100% | 70% (NW end) to 300% (SW end) |

*Table 6–3. Percentage of plant community in Cayuga Lake before and after onset of the herbivory.*

**Herbivory first reported as significant about 1991.*

In recent years, a number of researchers and commercial interests have reared these two herbivorous insects in the laboratory and have introduced them through controlled stocking projects. The insects are attached to small bundles of Eurasian watermilfoil and placed in a small plot of targeted plant beds. Stocked areas are often quarantined from the rest of the lake by buoys and signs to minimize disturbance from boat traffic. It is believed that the insects migrate from the bundled plants to nearby beds to continue their growth and reproductive cycles. In lakes stocked to date, insects have not spread or controlled Eurasian watermilfoil beyond the limited stocking area.

### *Advantages and disadvantages*

Many aspects of herbivorous insects make them ideal control agents. Both the milfoil weevil and moth damage the growth of Eurasian watermilfoil and cause only minimal damage to native plants. Plant biomass is reduced slowly, which minimizes the risk of inducing significant oxygen loss due to microbial breakdown of the decaying plant matter.

No impacts to other parts of the aquatic ecosystem have been observed. Since these insects are either native or naturalized in New York State, large-scale stockings or planned introductions are unlikely to create significant disruptions. That makes this plant-management strategy unique among all the control methods discussed here. The aquatic insects are living organisms that may have the ability to adapt to small changes in the natural environment, such as shifts in water quality or temperature. They are more immune to lake changes that are disadvantageous to other management techniques, such as high flow that flushes out chemicals.

Use of herbivorous insects is a very “low maintenance” and unobtrusive control strategy. Once the insects are stocked, and buoys or signage are sited to minimize disturbance, the insects do their work without the need for other assistance. They are inconspicuous, differing from noisy and ungainly machines, plant killing chemicals, or other clear signs of the intensive efforts that often accompany the battle against invasive weeds.

Are these insects the perfect weed control, a silver bullet? Unfortunately not. Some New York State lakes with naturally high levels of these insects are still overwhelmed with Eurasian watermilfoil. None of the stocking projects in New York State have resulted in control that can be completely attributed to the stocking. This is true even in lakes where control stocking augmented indigenous insect populations. Obviously, something other than a large insect population is needed to control Eurasian watermilfoil growth. It is not yet known if poor results are due to inadequate stocking rates, predation on stocked insects by native fish, or premature evaluation of the results. Research conducted by Cornell University and SUNY Oneonta in several Madison County lakes suggests that bluegills *(Lepomis macrochirus)* or pumpkinseed sunfish *(Lepomis gibbosus)* may be feeding on milfoil weevils, preventing herbivorous activity and keeping Eurasian watermilfoil densities high (Lord, 2004). This suggests that a top-down biocontrol approach may be preferred. One such approach would be to stock walleye or other top predators to feed on the fish that prevent milfoil weevils or moths from mowing down the Eurasian watermilfoil.

There is some evidence that the stocking method plays an important role in the success of a program. Stocking adult insects at a moderately low density, on widely separated bundled stems, often results in greater reproductive success for the next generation of eggs and larvae. This improves the migration of herbivores from bundled stems to peripheral plants and beyond. Such “selective” stocking, however, is very difficult to make commercially viable. It is anticipated that continued research, larger scale stocking projects, and continued evaluation of existing projects will bring reports of successful stockings.

There are other difficulties that make herbivorous insects at best a glimmer of hope rather than an on-going success story. The logistical difficulties associated with producing and distributing the very large quantities of insects have yet to be overcome. Part of this problem has to do with scale. Lakes that have experienced successful Eurasian watermilfoil control by indigenous milfoil moths or weevils have upwards of two insects-per-plant. This can be extrapolated to literally millions of these insects per lake. It is several orders of magnitude larger than what has been "produced" in all of the labs and commercial operations in the business. Even if the insects could be more readily mass-produced, they might not be affordable to some lake communities. Other lake environments are simply not hospitable to large insect populations.

Another disadvantage to biological control is that the life cycle of the insects does not always correlate with the needs of lake users. Eurasian watermilfoil that has been stressed by weevils often rebounds in the fall when the predation from the weevils is diminished. In the spring, it takes the weevils awhile to knock back the fall regrowth, sometimes extending into the early part of the recreational season. This may be less of an issue with the aquatic moth and other herbivores such as caddisflies and midges, although widespread effects from the latter have not yet been demonstrated in New York lakes.

Other lake management techniques can negatively impact biological control. Herbivory is greatly affected by harvesting because both insects and their habitat can be removed. Since weevils over-winter along the shoreline, the lack of shoreline substrate (vegetation, leaf litter, etc.), or the use of management techniques that alter either the water level (drawdown) or the makeup of the shoreline (benthic barriers, dredging), threatens their long-term survival.

Herbivorous insect stockings remain a promising, but thus far elusive aquatic plant control strategy. In theory, this should be identified as a lakewide control strategy, but insect use in New York State lakes has so far yielded only limited control of plants, in small beds, close to the insect release areas. The potential benefits are substantial, and the promise of a "natural" control method with very minimal side effects, remains very high. It cannot be stated with any certainty, however, that this promise will ultimately translate into a viable control strategy. The limited on-going research has not achieved any significant breakthroughs in recent years. It is hoped that greater attention dedicated to invasive plant problems and management will translate into more research and funding for the methodology, followed by greater success. Until then, herbivorous insect stocking remains at best a glimmer of hope rather than an on-going success story.

### Target and non-target plants

The milfoil moth and weevil are very selective in their feeding preferences. The milfoil moth inflicts significant damage only on Eurasian watermilfoil. The leaves of some other submergent aquatic plants may have superficial teeth marks from the moth, but the plants are otherwise unaffected by the munching. The milfoil weevil uses Eurasian watermilfoil as its sole host. Research in British Columbia indicates that the weevil previously utilized northern watermilfoil (*Myriophyllum sibericum*) as its host and adapted or evolved to use Eurasian watermilfoil *(Myriophyllum spicatum)* (Kangasniemi, 1993). On-going research at Cornell University is looking at herbivory and potential use of several species of leaf beetle (*Galerucella sp.*) on water chestnut *(Trapa natans)* and several native plant species, including water lilies.

### Costs

The costs for whole-lake plant management using insects cannot be easily determined. As a general rule, stocking costs have been approximately $1 per milfoil weevil or moth. About 1,000 insects have been stocked per-acre of Eurasian watermilfoil, translating to about $1,000 per acre.

### Regulatory issues

Stocking herbivorous insects requires a Fish and Wildlife ECL Article 11 permit from the DEC. To date, a single annual permit is issued to the stocking entity, such as academic researchers or a commercial firm. Each lake to be stocked is identified on the permit. At the present time, there is no permitting distinction between stocking native insects (such as the milfoil weevil) and non-native insects (such as the milfoil moth). In the future, there could be some regulatory differences. Insect stockings also require a Freshwater Wetlands Permit (ECL Article 24) by the APA for lakes within the Adirondack Park.

## History and case studies in New York State

Both the milfoil weevil and moth are found in most of the New York State lakes surveyed, but the history of herbivorous insect stockings in New York State lakes dates only from the late 1990s. Milfoil weevils have been stocked in small areas in several small New York State lakes, including Lake Moraine in Madison County, Sepasco Lake in Dutchess County, Findley Lake in Chautauqua County, Lake Bonaparte in Lewis County, and Millsite Lake in Jefferson County. An experimental stocking was also performed in Saratoga Lake. Each of these projects has exhibited limited successes, since neither insect migration from the treatment plots nor long-term reduction of Eurasian watermilfoil has been observed. A more significant research project involved the stocking of the aquatic moth in Lincoln Pond in Essex County (see case study). This has been closely monitored for several years. Long-term success has not been shown.

### Case study: Herbivorous insects—Active management

**Lake setting**: Lincoln Pond is a 600-acre lake in Essex County, along the eastern edge of the Adirondack Park.

**The problem**: Like many Adirondack lakes, Lincoln Pond enjoyed highly favorable water-quality conditions for many years. In the late 1980s, Eurasian watermilfoil *(Myriophyllum spicatum)* was introduced into the lake at one of the public launch sites. By 1999, detailed surveys of the lake showed that Eurasian watermilfoil grew densely (400 to 1,200 grams per $m^2$) on 120 acres in waters up to 15 feet deep, which limited recreational use of the lake. Comparison with historical plant community data suggested that Eurasian watermilfoil was colonizing the lake at a rate of about 20 acres per year. It had the potential to infest another 300 acres of the littoral zone. Surveys also found native or naturalized populations of the milfoil weevil (*Euhrychiopsis lecontei*) and the milfoil moth (*Acentria ephemerella*). Both generally averaged less then 0.2 insects per stem, an insufficient number to significantly influence Eurasian watermilfoil populations.

**Response**: The Lincoln Pond Association expressed strong interest in using biological control to manage the Eurasian watermilfoil problem. In the spring of 2000, The lake association, the Natural Resources Department at Cornell University, Cornell Cooperative Extension in Essex County, the Lake Champlain Basin Program and other partners collaborated on a project. Approximately 20,000 second and third instar moth caterpillars were stocked at a rate of two caterpillars per stem. An instar is the immature insect between molts, or shedding of the outer shell

Prior to the caterpillar stocking, moth populations increased at some sites in the lake (although not in the stocked areas), to as high as 0.4 moths per stem, but they had largely disappeared by the end of 2000. The same pattern was observed in 2001. On the other hand, weevil populations, which were very low prior to the stocking, increased substantially. Populations rose to 0.8 weevils per stem in several locations in both 2000 and 2001. It is believed that the weevils were naturally present in higher densities than previously believed, and that they occupied and affected the Eurasian watermilfoil stems prior to the augmentation of the moths. This prevented the moths from propagating on the Eurasian watermilfoil host. There also appeared to be some difficulties in the moths surviving and "evolving" after the augmentation, perhaps due to problems in transit to the lake bottom. Other research, conducted by Cornell University, suggests that predation by pumpkinseed fish may have impacted future generations of the moths. (Lincoln Pond Study Group, 2002)

**Lessons learned**: We still have a lot to learn about augmented biological control. Continued research will ultimately improve the application of this promising lake management tool.

## Grass carp

### Principle

*Fig. 6–9. Grass carp (Ctenopharyngodon idella) eat vegetation at a rate of 20 to 100 percent of their body weight each day.* (Credit: Eric Engbretson)

Grass carp (*Ctenopharyngodon idella),* also known as white amur, remove vegetation in a lake by consuming it at a rate of 20 to 100 percent of their body weight each day. This physical removal of vegetation is a type of **biomanipulation,** altering the food web in order to change lake conditions or give advantage to a desired species. Use of grass carp is one of the few biomanipulation tools shown to control excess levels of nuisance aquatic plants. More uses of biomanipulation are discussed in Chapter seven, "Algae and other undesirables."

The grass carp is the most extensively studied and most frequently stocked fish used for aquatic plant management in North America. They were originally imported to Arkansas and Alabama from Malaysia in 1962. The common carp, rudd, tilapia, and silver dollar fish are other fish that feed on or disturb aquatic plants, but these haven't been stocked to manage nuisance plants.

Only sterile **grass carp**, called **triploid carp**, are presently allowed for stocking in New York State. The fish have been stocked at a rate of about 10 to 40 per acre of lake surface, with lower rates more acceptable in recent years. Fish used for stocking are approximately two feet in length, too large to be preyed on by largemouth bass. When stocked, they weigh less than one pound, but they can increase by up to six pounds per year. They can achieve several hundred pounds, although this is rare in northern temperate climates.

In most states that allow their use, grass carp are restricted to lakes with no permanent outflow. This reduces the possibility of escape and maximizes the control of vegetation within the target lake. New York State allows stocking in larger lakes with an outflow only when migration out of the lake can be prevented.

### Advantages and disadvantages

There is a great deal of interest in using these fish to control nuisance aquatic plants. Grass carp are perceived as a "natural" plant control agent even if they are not native. This technique gains some of its public support because it appears to be devoid of the more conspicuous, disruptive or controversial aspects of other control strategies.

Biological control methods are relatively new and not well understood. They have not been widely studied in the field, and have not been applied to a wide variety of lake conditions. The results from biological manipulation experiments, either in theory or in laboratory studies, are not easily reproduced in actual lakes. Since lakes are both dynamic and fragile, a change in one component of a lake ecosystem can have dramatic effects on other components. The potential side-effects of a particular technique may outweigh the benefits for many lakes.

While these eating machines may be an excellent option in some situations, the use of grass carp is not a panacea. One undesirable side-effect that has been observed is an increase rather than decrease in the plant species being targeted. Grass carp are reported to favor particular plant species, but these preferences may be a function of the conditions in individual lakes. While carp will selectively feed on particular types of plants, their choice of plants is not predictable and varies from lake to lake. Once the preferred plants have been removed, less palatable plants can grow explosively, or grass carp can completely eradicate all aquatic vegetation. This may be bad for the plant community and the entire ecosystem in a lake, but may be acceptable in small, self-contained ponds. It is unrealistic to expect that these fish will remove weeds from a specific part of a lake, such as by an individual dock or swimming area since fish have access to the entire lake.

Grass carp do not meet the criteria for an "ideal" candidate to be introduced into an aquatic system, due to the potential eradication of the entire plant community and the associated repercussions. The absence of aquatic plants will have significant effects on the aquatic animals whose habitat has been destroyed. Subsequent declines in fish populations could ripple down the food chain, affecting zooplankton and phytoplankton abundance. Grass carp do not co-adapt with other aquatic species, do not have a narrow niche, are not easily controlled if they escape, and are not free from exotic diseases and parasites.

Grass carp can also enhance eutrophic conditions. More than 50 percent of the nutrients in the ingested plant material could be reintroduced to the lake system through carp excretion. This nutrient recycling could stimulate algal blooms and oxygen depletion. The removal of rooted plants by the carp may mean less competition for available nutrients, further feeding algal blooms, although this may be limited to lakes with poorly rooted plant communities such as those dominated by coontail or bladderwort.

The risk of ecosystem disruption makes the containment of grass carp imperative. They have a propensity for flowing water and can escape unless inlets and outlets are screened. Escaped carp may destroy desirable aquatic plants in tributaries and outflow streams. The escaped fish also equal a lost investment as nuisance weeds remain in the lake.

Though grass carp have voracious appetites, in New York State most permitted stocking rates are not high enough to result in significant first-season control. Many of the less successful experiments with grass carp have resulted from not waiting long enough for the carp to effectively control excessive weed growth. This is particularly true in lakes where

| High | High to Moderate | Moderate | Moderate to Low | Low |
|---|---|---|---|---|
| Brazilian elodea *(Egeria densa)* | Curly-leafed pondweed *(Potamogeton crispus)* | Bladderwort *(Utricularia sp.)* | Eelgrass *(Vallisneria americanum)* | Cattail *(Typha sp.)* |
| Common waterweed *(Elodea canadensis)* | Duckweed *(Lemna sp.)* | Coontail *(Ceratophyllum demersum)* | Floating leaf pondweed *(Potamogeton natans)* | Common reed *(Phragmites australis)* |
| Hydrilla *(Hydrilla verticillatum)* | Fanwort *(Cabomba caroliniana)* | Filamentous algae | Slender spikerush *(Eleocharis acicularis)* | European frog-bit *(Hydrocharis morsus-ranae)* |
| Large-leaf pondweed *(Potamogeton amplifolius)* | Illinois pondweed *(Potamogeton illinoensis)* | Pondweed (most) *(Potamogeton sp.)* | Watermilfoils (most) *(Myriophyllum sp.)* | Variable watermilfoil *(Myriophyllum heterophyllum)* |
| Musk grass *(Chara sp.)* | Naiads (most) *(Najas sp.)* | Stonewort *(Nitella sp.)* | Water primrose *(Ludwigia sp.)* | Water chestnut *(Trapa natans)* |
| Southern naiad *(Najas quadalupensis)* | Sago pondweed *(Stuckenia pectinatus)* | Watermeal *(Wolffia sp.)* | | Water lily *(Nuphar sp. & Nymphaea sp.)* |
| | | | | Water shield *(Brasenia schreberi)* |

*Table 6–4. Grass carp (Ctenopharyngodon idella) feeding preferences for common nuisance aquatic plants.*

stocking rates were kept fairly low to prevent eradication of all plants. Grass carp can live 10 to 12 years, providing multiple years of plant control, although most stocking projects require substantial restocking in narrower intervals of four to six years due to loss by predation and other factors. Due to the sterilization required for fish stocked in New York State, the number of fish does not increase.

## Target and non-target plants

Using grass carp to remove Eurasian watermilfoil or water chestnut is akin to using children to reduce the world's supply of brussel sprouts. Though grass carp are most often stocked in New York State lakes to control Eurasian watermilfoil, grass carp generally prefer softer or more ribbon-leafed pondweeds, coontail, naiads, common waterweed and some filamentous algae. Two increasingly common exotic plants, Brazilian elodea *(Egeria densa)* and hydrilla *(Hydrila verticillatum),* are highly favored by these herbivorous fish. Grass carp palates are somewhat unpredictable, and can change with water hardness, the age and lake-specific texture of the plants and even the proximity of target plants to heavily used shorelines, since these fish also avoid contact with humans. Unusually hungry grass carp have been observed feeding on grass clippings and low hanging tree leaves. In the absence of their preferred food, the grass carp will consume the less desired, problem plant species. Preferential munching on a non-target plant species can reduce plant competition, allowing more aggressive plants to dominate the plant community.

## Costs

Grass carp offer one of the least expensive, lakewide techniques for controlling nuisance aquatic vegetation. Prices range from $50 to $100 per acre, based on a "standard" allowable New York State stocking rate of about 10 to 15 fish-per-vegetated-acre. These costs can be amortized, since the carp live for 10 to 20 years, although restocking rates of up to 35-50 percent may be required every four to six years.

## Regulatory issues

DEC regulates the stocking of grass carp through ECL Article 11. Stocking of sterile grass carp is only approved after a complete and thorough State Environmental Quality Review (SEQR) process.

Any proposed plans for using grass carp should be discussed with the DEC Regional Fisheries Manager. The manager is responsible for issuing the stocking permit and may be able to advise lake residents about any major obstacles. Grass carp stocking that requires any modifications to a dam, such as screening to prevent escape, will also require a permit from the DEC Dam Safety Unit. For lakes within the Adirondack Park, the APA requires a wetland permit for the stocking of grass carp. For these projects, the DEC and APA cooperate on a coordinated review of proposals.

New York State's present policy indicates the following:

- No person or organization shall possess or introduce any grass carp into waters of the state without having obtained a stocking permit from DEC.
- Only sterile, triploid grass carp will be considered for introduction into the waters of the state. All fish must be certified as triploids by competent taxonomists retained by the applicant before being released.
- All proposed introductions of sterile, triploid grass carp into New York State must be supported by a complete Environmental Impact Statement (EIS). Within the EIS review process, DEC could deny a permit to stock grass carp.
- In New York, DEC policy is to limit stocking rates to no more than 15 fish per surface acre for those ponds of five acres or less.

When the lake/pond is contained wholly within the boundaries of land privately owned or leased by the applicant, the following conditions must be met:

- Aquatic plants must significantly impair the intended use of the pond;

- No endangered, threatened or species of special concern shall be present in the proposed stocking area;
- The lake/pond is not contiguous to part of a New York State regulated wetland;
- The lake/pond is not a natural or manmade impoundment on a permanent stream as shown on USGS topographic maps; and
- At least two years have elapsed from the date of the last stocking unless it is demonstrated that previous stocking had high fish mortality.

### *History and case studies in New York State*

Since 1991, there have been thousands of permits issued by DEC for the use of grass carp. The vast majority of these are for less-than-one-acre "farm" ponds with no inlet or outlet and a single landowner. Most of the permits have been issued in the Finger Lakes, western New York, and the Downstate region. The effectiveness of these stockings has not been well documented. Some experimental stockings have been evaluated by the DEC Division of Fish and Wildlife, but most information is anecdotal.

#### Case study: Grass carp *(Ctenopharyngodon idella)* in Lake Mahopac and Lake Carmel

**Lake setting**: Lake Mahopac is a 560-acre lake in Putnam County, north of New York City. Lake Carmel is a 200-acre lake in the same area. Both lakes are heavily used for swimming and other recreational activities

**The problem**: Lake Mahopac had dense, homogenous beds of Eurasian watermilfoil *(Myriophyllum spicatum)* inhabiting most of the lake shoreline to depths of 12 to15 feet. Lake Carmel suffered water-quality problems related to excessive nutrient and algae levels and poor water clarity for many years. By the early 1990s, nuisance weed growth, primarily common waterweed and coontail, also plagued Lake Carmel. The lake was dredged in the late1980s, and mechanical plant harvesting after 1986 achieved some success. Residents of the town served by Lake Carmel were opposed to the use of aquatic herbicides. By the mid-1990s, surveys of plant biomass reported 150 to 400 grams-per-square-meter (g/$m^{2)}$ for about 100 acres of lake bottom.

**Response**: In October, 1994, 2565 triploid grass carp were privately stocked in Lake Mahopac at a rate of 15 fish per-vegetated-acre. The objective of the treatment was to provide 70 percent control of the vegetation. In 1999, 10 grass carp per-vegetated-acre were stocked in Lake Carmel. At the time of stocking, water clarity was about 3.5 feet, historically typical for this lake.

**Results**: *Lake Mahopac*: A private consulting biologist monitored the results of the treatment. By 1995, he reported that the biomass of aquatic vegetation, including filamentous algae, had been reduced by 73 percent from pre-stocking levels. By 1996, vegetation had been reduced by 86 percent from baseline levels. Reports through the New York Citizens Statewide Lake Assessment Program (CSLAP) indicated that aquatic plant coverage had dropped from "dense" at the lake surface in the mid-1990s to "not visible" from the lake surface. This continued through at least 2001.

DEC fisheries surveys of the lake in the late 1990s revealed virtually no submergent rooted aquatic vegetation. Catch rates for largemouth bass *(Micopterus salmoides*), the lake's principal gamefish, were high compared to most neighboring lakes before and after treatment, although by 1999 there was a decline of almost 50 percent for bass over 15 inches. It is not known if this decline can be attributed to the grass carp, but many local anglers blame the decline on the loss of aquatic vegetation. (NYSDEC, 2000)

*Lake Carmel*: By 2002, plant biomass dropped under 50 g/$m^2$ in the northeast cove (which had less pre-treatment biomass) and under 100 g/$m^2$ in the southern cove. Water clarity dropped to about 2.5 feet, due to more frequent blue-green algal blooms. Although large-mouth bass continued to be the dominant fish species, only about 15 percent of the fish were greater than 6 inches long. (Grim, 2003) This suggests that the loss of refuge habitat for the young fish may affect future age-classes of the fish. (See Chapter five, "Fisheries management" for discussion about age-classes)

**Lessons learned**: Moderate stocking rates of 10 to 15 fish per-vegetated-acre can be effective at removing nuisance vegetation. At the higher end of this range, near total eradication of plants can occur. Water-quality changes and fisheries impacts may also occur, although studies to date have not been adequate to attribute observed changes solely to the use of grass carp.

### Case Study: Anecdotal reports regarding the use of grass carp *(Ctenopharyngodon idella)* in Plymouth Reservoir

The effectiveness of any lake management activity is best evaluated through a well-designed scientific study. Unfortunately, this is rarely done since design of controls and data collection takes away from already precious funds. While this is understandable, given the high costs of lake-management tools, quantification of their effectiveness would help the next generation of lake managers make informed decisions.

Simple surveys can provide some of the information needed to evaluate the success or failure of a particular management strategy. In 1994, homeowners on Plymouth Reservoir, an 80-acre impoundment in Chenango County, used a survey to evaluate the use of grass carp the previous year. In 2004 the survey was repeated with the same respondents. A summary of the survey answers are reported below as A1994 and A2004 respectively. (Doing, 2005)

*Q. Did the carp adapt to their settings?*

A1994. The carp seem to have adapted to their surroundings. Only one to two dead fish were found.

A2004. The carp seem to be well adapted. Fish approximately 3 feet in length have been observed feeding along the shorelines.

*Q. Did you notice a preference for any food type (plant), and was this the target species?*

A1994. In areas where curly and floating pondweed had been abundant, the weeds were not as concentrated. Previously the weed growth had been dense and floating on the surface. In sections of the lake where Eurasian watermilfoil had been dense, there was an obvious decrease. Grasses were found floating that appeared to have been pulled out by the roots.

A2004. There appears to be a decrease in pondweed (various species), eel grass and elodea.

*Q. Was the physical condition of the lake…notably clearer, about the same, or not as clear…?*

A1994. The physical condition of the lake was about the same as in previous summers.

A2004. The lake was not clear, with considerable more brownness. Our lake has a natural brown color. The increased amount of rain and snow the past two years may have contributed to this. We have had a problem with an excessive amount of nutrient flow into the lake since the 1998 tornado destroyed 1,000 plus acres of state forest adjacent to our lake.

*Q. Were the (overall) aquatic plant populations, in the areas where people swim and boat … denser, about the same, or less dense?*

A1994. Aquatic plant populations in these areas were noticeably less dense and thick.

A2004. The weeds are noticeably less dense and thick. It is hoped this is due to our weed control efforts, but we have had heavier snowfalls in recent years. Also the darker color and particulates in the lake may be diminishing the amount of sunlight filtering through to the plants.

*Q. Was the recreational condition of the lake… improved, unchanged, or degraded?*

A1994. Overall, the ability to use the lake improved… Fishing and boating were greatly improved.

A2004. In 2003 and 2004 the lake did not improve or degrade.

*Q. In retrospect, was there any unanticipated lake effect from the stocking, and were they positive or negative?*

A1994. Too early to make any determinations, but we were pleased with the water quality and aesthetics of our lake.

A2004. The general consensus has been the carp have had a positive impact on the lake. We have maintained moderate stocking of the carp. It is difficult to determine the number remaining in the lake.

*Q. Would you say the carp provide effective control, provide no noticeable control, make the problem worse, or it is too early to gauge effectiveness?*

A1994. Too early to gauge effectiveness.

A2004. We feel the carp have provided effective control.

The experiences with grass carp in New York State have been somewhat variable. When stocking rates are high, grass carp effectively remove submergent aquatic plants. In many instances, long-term eradication of nearly all plant material has occurred. This poses a threat to the long-term integrity of the aquatic ecosystem since plants provide habitat for fish spawning and survival, as well as other benefits. In some lakes, short-term water-quality impairment, including increased turbidity, has also resulted.

Walton Lake is an example of poor results from use of grass carp. The initial stocking of 10 fish-per-vegetative-acre had only limited effect on plant densities. A higher stocking rate two years later of 15 to 19 fish-per-vegetative-acre resulted in removal of about 30 percent of the plants. The carp selectively removed every plant species except Eurasian watermilfoil, which actually increased in some areas. Subsequent higher stocking rates of 20 to 27 fish-per-acre removed the Eurasian watermilfoil, leaving a scarcity of plants throughout the lake. No measurable impact on water clarity occurred, but fish catch rates declined as plant populations were reduced.

## *Aquatic herbicides*

### *Principle*

Aquatic **herbicides** are chemicals that kill macrophytes or inhibit their normal growth through direct toxic reactions or by hampering their photosynthetic ability. Some chemicals are species-specific and others affect a broad spectrum of plants. The herbicide is usually applied to the water directly above the nuisance weed bed and the plants are left to die and degrade within the lake.

Herbicide applications must be properly timed to correlate with lake conditions, plant life cycles and recreational uses of a lake. To be most effective, herbicides should be applied between the onset of thermal stratification (usually late spring) and the onset of fish spawning and native plant uptake (usually early summer), although some fall treatments take advantage of selective plant growth by some invasive exotic plants.

Most herbicides contain toxic chemicals designed to kill plants. Through a registration process overseen by DEC and the U.S. Environmental Protection Agency (EPA), half a dozen aquatic herbicides can be used in New York State. Several other aquatic herbicides are also registered for use by the EPA and can be used in other states, but New York is among the few states that has a separate registration process. This provides both enhanced environmental protection and regulatory oversight, an additional regulatory layer applauded by some and unwanted by others. Only licensed professionals can legally apply herbicides in lakes, except in very small, private waterbodies, as discussed in the *Regulatory Issues* section below. Applicators are licensed by the State of New York. A list of licensed applicators is available from the DEC Bureau of Pesticides in Albany (see Appendix F, “Internet resources”).

Nearly all of the aquatic herbicides registered for use in New York State carry at least one water-use restriction for a time period after the application. Use restriction range from 24-hour restrictions on bathing to 30-day prohibition of the use of the lake water for irrigation of established row crops. Certain herbicides may be restricted in lakes that are used for domestic drinking-water supplies. Restrictions are clearly identified on the labels governing the use of the products.

There are two main classes of aquatic herbicides. Contact herbicides are toxic to only those parts of the plant contacted by the herbicide. The treatments tend to work quickly and will usually be effective from several weeks to several months. Effectiveness is usually limited to a single growing season because seeds and roots are not normally affected. Once the chemicals have degraded or flushed out of the system, plant growth will resume, and reapplication may be necessary.

Systemic herbicides affect the plant’s metabolic or growing processes. Systemic herbicides often move from the application site to the root system and affect the entire plant. A treatment usually takes from three to eight weeks to be effective, but plant control with these herbicides can last for several years. With some systemic herbicides, plant die off may not occur until early- to mid-summer. The benefits of herbicide application, therefore, might be delayed until much of the recreational season has passed.

Approved herbicides are available in either liquid or granular form. Most granular herbicides are activated through **photodegradation.** When the granules sink to the lake bottom and out of the photic zone, photodegradation ceases, and the chemical is no longer effective. For some other herbicides, residuals sink to the lake sediment and may provide some additional, temporary vegetation control through uptake by plant roots.

### *Advantages and disadvantages*

No documented cases exist of an herbicide treatment gone awry in New York State, but few lake issues cause as much heated discussion as the planned use of chemical control. There will inevitably be two factions in lake associations and the community. The first group will claim that there are absolutely no conditions or situations that justify chemical treatment. The other group will insist that if herbicides are not immediately applied the weeds will invade the entire lake, destroy all recreational enjoyment and cause property values to plummet. They are not likely to listen to each other, and both groups are convinced that the other could ruin the lake. The decision whether or not to use chemical treatment often rests on these human dynamics rather than ecological factors.

Concerns about the use of herbicides should be balanced against the ecological damage caused when invasive plants spread through a lake ecosystem, creating "biological pollution" and drastically altering the ecological balance. Aquatic herbicides can provide at least temporary control of Eurasian watermilfoil *(Myriophyllum spicatum).* This pernicious, exotic weed has not been consistently controlled by any other whole-lake strategies.

To facilitate a decision, as much information as possible should be obtained about the nuisance plant, proposed herbicide, existing water chemistry of the lake, and all the pros and cons of using a particular herbicide on a particular lake. Discretion is vital when extrapolating information from one lake to the conditions of another. Differing weather conditions, recreational uses, water chemistry, and vegetation types could yield dramatically different. The DEC regional office can provide assistance in obtaining necessary information.

Chemically treated lakes may experience some significant side effects. When herbicides are applied in a lake environment, the affected plants drop to the bottom of the lake, die, and decompose. The resulting depletion of dissolved oxygen and release of nutrients can have detrimental effects on the health or survival of fish and other aquatic life, particularly in small, shallow lakes and ponds.

The toxicity of the herbicide to non-target plants can be of great concern. Data are very limited on the effect of specific herbicides on plant species in New York State lakes. It is unclear whether target-plant species listed on herbicide labels can be completely controlled without adversely affecting non-target species in a given lake. If a wide variety of plant species are eradicated by an herbicide treatment, fast-growing, opportunistic exotics may re-colonize the treatment area. Lake residents may find that beds of the original nuisance plant are even greater than before.

Short-term effects of aquatic herbicides have been fairly well studied for most aquatic organisms and their surrounding environment. Studies to date indicate that humans and most animals have high tolerance to the short-term toxic effects of currently approved aquatic herbicides. This is especially true of "newer generation" herbicides that are formulated to disrupt the metabolic processes specific to chlorophyll-producing plants. Any negative impacts have been deemed to be an "acceptable risk" if the herbicide is applied in the appropriate manner.

The long-term effect of herbicides on humans and other organisms is not well studied. High herbicide dosages can elicit toxic response for the applicator, and protective gear must be worn. The pesticide labels and permitted conditions are designed to protect applicators and others using treated lakes.

Newer formulations and greater experience by applicators will continue to improve the effectiveness of this management strategy. Recent herbicide treatments have effectively controlled the target plant, sometimes for many years. An herbicide treatment might be ineffective due to poorly timed application, unusual weather conditions, eradication of non-target plants, re-infestation by exotic species, or by simply using the wrong herbicide to control a particular species.

### *Target and non-target plants*

At the dosage rates allowed in New York State lakes, most aquatic herbicides are not truly selective, although some herbicides are partially selective when applied at the proper time and dosage rate. If applied when plants are actively growing, these chemicals will remove most plants within the treatment zone. Selectivity can be increased by choosing the proper herbicide, correlating the application to the growth period of target plants and by lowering dosage rates to protect non-target plants. For example, 2,4-D and triclopyr can selectively control dicots (flowering plants with opposite seed leaves), while fluridone can be both selective or broad spectrum depending on concentration, exposure time and the plant species.

In New York State, the most frequently used aquatic herbicides are diquat, 2,4-D, endothol, glyphosate, fluridone, and triclopyr. Table 6–5 lists the susceptibility of common New York State submergent, floating, or emergent plants to these most common herbicides.

*Diquat* is a contact herbicide that controls emergent species such as cattail; floating species such as duckweed; and submerged species such as coontail, milfoil, nitella and some varieties of pondweed. It must be applied in water less than six feet deep or closer than 200 feet from shore, whichever provides the greater distance from shore, and maybe limited in lakes with stressed bass, walleye, or muskellunge populations.

*2,4-D* is a systemic herbicide used for controlling a wide variety of emergent, floating and submerged species, primarily Eurasian watermilfoil, water chestnut, coontail, and water hyacinth. It remains in the sediment for several months and cannot be used in waters used for potable water supplies when the concentrations of the chemical exceed 70 ppb.

*Endothol* is a contact herbicide often used to control coontail, Eurasian milfoil, and most pondweeds. It stays in the water column longer than either diquat or 2,4-D, but its breakdown products (carbon, hydrogen and oxygen) are of less concern than those from these other herbicides. The Aquathol® K formulation is preferred in New York state lakes to minimize toxicity.

*Glyphosate* is a systemic herbicide used almost exclusively on emergent and floating plants, notably cattail and water lily. It has not been commonly used for submergent plant control in New York State, and requires significant setbacks from potable water intakes.

*Fluridone* is a systemic herbicide. In New York State it is used extensively for the control of Eurasian watermilfoil and curly-leafed pondweed. It has been used at low dosage rates to attempt to manage target plants while preserving non-target plants.

*Triclopyr* was registered for use in New York State in 2007. It is a systemic herbicide that targets Eurasian watermilfoil and purple loosestrife *(Lythrum salicaria).* Data from other states, and initial data from New York State in 2008, indicate that this is a fairly selective herbicide that can be applied at higher dosage rates than fluridone.

*Copper-based herbicides* have been registered for rooted plant control in New York State, but since they can affect some aquatic organisms at the label application rate, they require extensive review and environmental assessment by the DEC. Copper-herbicide mixtures are commonly used when both algae and rooted plant control is desired. The dosage rate of copper required to control most macrophytes is much higher than would normally be allowed for algae control. Copper may be applicable in those rare instances in which a macroalgae, such as *Chara,* inhibits lake use. *Chara*, also known as muskgrass, is a weakly rooted algae that superficially resembles larger aquatic plants. Copper is a common algacide and is discussed in greater detail in Chapter seven, “Algae and other undesirables.”

| Herbicide: | Diquat | 2,4-D | Endothal | Glyphosate | Fluridone | Triclopyr |
|---|---|---|---|---|---|---|
| **Emergent Plants** | | | | | | |
| Arrowhead *(Sagittaria sp.)* | Low | High | Low | High | Low | Medium |
| Cattail *(Typha sp.)* | Medium | Medium | Low | High | Medium | Low |
| Pickerelweed *(Pontederia cordata)* | Low | Medium | Low | Medium | Low | High |
| Purple loosestrife *(Lythrum salicaria)* | Low | Low | Low | High | Low | High |
| Reed grass *(Phragmites sp.)* | Low | Low | Medium | High | Low | Medium |
| Water bulrush *(Scirpus sp.)* | Medium | High | Low | High | Low | Low |
| **Floating Leaf Plants** | | | | | | |
| Duckweed *(Lemna sp.)* | High | Medium | Medium | Low | High | Low |
| Water chestnut *(Trapa natans)* | Low | Medium | Low | Medium (foliar only) | Low | Medium |
| Water shield *(Brasenia schreberi)* | Medium | Medium | Medium | Low | Medium | Medium |
| White water lily *(Nymphaea sp.)* | Low | Medium | Medium | High | Medium | Medium |
| Yellow water lily *(Nuphar sp.)* | Low | Medium | Medium | High | Medium | Medium |
| **Submergent Plants** | | | | | | |
| Bladderwort *(Utricularia sp.)* | High | Medium | Low | Low | Medium | Low |
| Brazilian elodea *(Egeria densa)* | High | Low | Low | Low | High | Low |
| Bushy pondweed *(Najas flexilis)* | High | Medium | High | Low | Medium | Low |
| Common waterweed *(Elodea canadensis)* | High | Medium | Low | Low | High | Low |
| Coontail *(Ceratophyllum demersum)* | High | Medium | High | Low | High | Low |
| Curly-leafed pondweed *(Potamogeton crispus)* | High | Low | High | Low | High | Low |
| Eelgrass, tapegrass *(Vallisneria americanum)* | Low | Low | Medium | Low | Medium | Low |
| Eurasian watermilfoil *(Myriophyllum spicatum)* | High | High | High | Low | High | High |
| Fanwort *(Cabomba caroliniana)* | Medium | Medium | High | Low | High | Low |
| Hydrilla *(Hydrilla verticillatum)* | High | Low | High | Medium | High | Medium |
| Large-leaf pondweed *(Potamogeton amplifolius)* | Low | Low | Medium | Low | Medium | Low |
| Muskgrass *(Chara sp.)* | Low | Low | Low | Low | Low | Low |
| Robbins pondweed *(Potamogeton robbinsii)* | Low | Low | Medium | Low | High | Low |
| Sago pondweed *(Stuckenia pectinatus)* | High | Low | Medium | Low | Medium | Low |
| Variable watermilfoil *(Myriophyllum heterophyllum)* | Medium | High | Medium | Low | Medium | High |
| Water stargrass *(Zosterella dubia)* | High | High | Medium | Low | Medium | Medium |

*Table 6–5. Impact of New York State registered herbicides on common aquatic plants.*

(ADAPTED FROM HOLDREN ET AL, 2001)

## Costs

Aquatic herbicide treatments are generally less expensive than other large-scale plant-control methods except for very large areas. Typical costs range from $200 to $1500 per-acre of treated area per-application. Some treatments will have to be repeated on a regular basis. Most of the cost is associated with the chemical itself. Costs will vary with the chemical brand and form (liquid or granular), required dose rate, frequency of application and applicator fees. The costs have generally been lower when local applicators were used.

## Regulatory issues

Herbicide use in New York State requires a permit from the DEC regional Environmental Permits office, in compliance with ECL Article 15 and Part 326 of the NYCRR. If all or part of the lake contains a regulated wetland, an additional wetland permit will be required. If the outlet flow needs to be controlled with the use of sandbags to assure herbicide contact time or keep the chemical out of downstream waterbodies, dam safety permits may be required. For some lakes, the generic EIS prepared by the manufacturers of these herbicides will be deemed insufficient to address all of the permitting issues. In this case, a site-specific EIS may be required. Additionally, aquatic plant monitoring and the development of a plant-management plan is required by DEC for most of the state's "high profile" lakes. A list of the waterbodies for which these requirements exist is available on the DEC website. The Adirondack Park Agency requires a separate permit for herbicide use within the boundaries of the Park, under the purview of the aquatic wetland program. A compelling public benefit needs to be demonstrated to allow the use of herbicides in most wetlands, since there are stringent regulations governing activities within wetlands, particularly within the Adirondack Park.

No aquatic herbicide permits have been issued in some regions of the state, such as the Adirondacks. Reasons include the overlapping regulatory authority of DEC and the APA, strong sentiments about the use of herbicides, the presence of and concern for protecting rare and endangered species, the abundance of pesticides alternatives, and the lack of historical precedent for the use of many aquatic plant-control strategies. Few permits are issued in other regions of the state where lakes are used for potable water intake or encompass wetland areas, due to a more rigorous permitting process for these waterbodies. Pesticide use in Suffolk County (Long Island) has also been restricted by legislative initiative to protect groundwater.

Aquatic herbicides can be applied by a homeowner, after securing a purchase permit from the DEC, for lakes and ponds smaller than one acre, solely on private land and with no outlet leaving the property. This permit is valid for a year and involves a fairly simple application form to be submitted to regional DEC pesticides offices.

## History and case studies in New York State

Federal regulation of herbicides began in the early 1900s. "Modern" pesticide regulations developed from the passage of the **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** in 1947. Both federal and state attention to pesticides, including aquatic herbicides, was greatly increased by the publication of *Silent Spring* by Rachael Carson (1962).

Aquatic herbicides have been used in New York State for many years. In fact, nearly 500 permits are issued annually, not including purchase permits for small farm ponds. Aquatic herbicides permits have been issued in nearly every part of New York State. Most lakes treated with aquatic herbicides have not been closely studied either before or after treatment. The most thoroughly monitored lakes have been Waneta and Lamoka Lakes in Schuyler County and Snyders Lake in Rensselaer County (see case studies and Fig. 6–10).

## Case study: Aquatic herbicides in Waneta and Lamoka Lakes

**Lake setting**: Waneta Lake is an 800-acre lake that is part of a two-lake chain with its downstream, similarly-sized southern neighbor Lamoka Lake. They are located in the western Finger Lakes region. The Waneta-Lamoka Lakes Association was formed in 1938 to address a variety of lake management issues. The lake is a valued local fishery for largemouth bass *(Micropterus salmoides)* and smallmouth-bass *(Micropterus dolomieui*), and a secondary source for muskellunge *(Esox lucius cross Esoc masquinongy)* brood stock throughout the state. The lake fisheries, therefore, have enjoyed a high level of protection.

**The problem**: Waneta Lake has a long history of recreational use impacts associated with both nuisance algae and weeds. Weed problems have been exacerbated by the introduction and spread of Eurasian watermilfoil *(Myriophyllum spicatum)* throughout both Waneta and Lamoka Lakes since the mid-1980s. By the late 1990s, Eurasian watermilfoil comprised just over 50 percent of the biomass of aquatic plants in Waneta Lake, and was identified at 80 sites in the lake during 2000. Mechanical weed harvesting was conducted during the mid-1980s, with funds provided through the Aquatic Vegetation Control Program, the predecessor to the Finger Lakes-Lake Ontario Watershed Protection Alliance (FL-LOWPA). This was marginally successful, but the funds for this activity were not maintained.

**Response**: The lake association proposed the use of fluridone to reduce the coverage and density of Eurasian watermilfoil, while maintaining sufficient cover of native plants to protect the valuable fisheries resource in both Lakes. (ENSR, 2001) Funding was provided through the creation of a special taxing district. After much discussion, the DEC issued a permit only for Waneta Lake for the whole-lake application of fluridone at an initial concentration of 12–14 parts-per-billion (ppb) in the summer of 2003, with provisions for a bump application as needed to restore fluridone residuals back up to 6 ppb within 60 days. There was very low dilution, probably due to relatively low inflow and low photodegradation. Fluridone residuals remained above 6 ppb for more than 60 days, without supplemental applications. Fluridone remained above 3 ppb for nearly 175 days.

Performance standards were developed and adopted to evaluate herbicidal impacts to Waneta Lake. Recovery of native and exotic plants was monitored as part of an extensive survey program conducted by Cornell University. Results were evaluated by the lake consultant and DEC to determine if "sufficient" recovery existed to maintain cover and fish refuge if treatment was permitted in the downstream Lamoka Lake. The performance standards required less than 25 percent loss of native plant cover and overall aquatic plant biomass, and greater than 90 percent Eurasian watermilfoil removal within the year of treatment, and return to pre-treatment native plant densities the following year. (Lord, Johnson and Miller, 2004)

**Results**: As a result of the herbicide treatment, Eurasian watermilfoil disappeared from Waneta Lake, and there was no evidence of it anywhere in the lake through the summer of 2004. Eurasian watermilfoil first returned in 2005, and began regrowing extensively along the northern and southern shores of the lake in 2006. Prior to treatment, traces of native plants were found in 54 of the 64 survey sites in 2003. Post-treatment, native plants were found in 50 sites during 2004, and in 37 sites during 2005. After treatment, native plant biomass was initially reduced to about five percent of the pre-treatment biomass. No significant water-quality changes or fisheries impacts were reported or attributable to the herbicide treatment. Large-scale treatment of Lamoka Lake was not approved, however, due to delays in the plant recovery in Waneta Lake. An experimental control of a small part of Lamoka Lake was allowed in 2005. By 2008, Eurasian watermilfoil was sufficiently re-established to justify partial lake treatments of both Waneta and Lamoka Lakes with triclopyr, with additional treatments in other parts of both lakes contingent upon both target plant loss and native plant survival or recovery to protect the lake fisheries. The strategies developed to evaluate the Waneta Lake treatment have been used in assessing the positive and negative impacts of other herbicide treatments throughout the state.

**Lessons learned**: The controversies over the proposed treatment in Waneta Lake are a microcosm of the issues surrounding the use of aquatic herbicides in New York State. It is unlikely that all parties involved will agree that the process and the results were adequate. The dialogue accompanying the application process, however, was insightful and open, and the compromise reached by the advocates for, the opponents of, and the mediators in the permitting and evaluation process may serve as a template for future contentious aquatic plant-management proposals. It is also hoped that the results from the well-designed monitoring plan will provide sorely needed answers to continuing questions about the use of aquatic herbicides in New York State lakes. (Lord, Johnson and Wagner, 2005)

## Case study: Aquatic herbicides in Snyders Lake

**Lake setting**: Snyders Lake is a 110-acre lake in the Capital District region of New York State. It is used primarily by local residents for recreation.

**The problem**: For many years, water-quality issues dominated lake management discussions. Resident complained about increased turbidity attributed to nearby development, and about blooms of the red alga *Oscillatoria rubescens* in winter and spring. Weeds were not dense enough to warrant active management until the late 1980s. Biological surveys, conducted on the lake from the 1930s through the late 1980s, reported that plants covered about 20 percent of the lake bottom. By the late 1990s, dense aquatic plant beds existed throughout the littoral zone and were dominated by Eurasian watermilfoil *(Myriophyllum spicatum)*.

**Response**: After significant public debate, the Lake Association of Snyders Lake voted to conduct a whole-lake application of fluridone in the spring of 1998. A combination of private funds and state grants were used to offset the approximately $25,000 treatment cost.

Fluridone was applied at a rate of approximately 11 to13 ppb. Herbicide levels were tracked by the lake association at several locations and depths for about 5 months. Fluridone residuals remained above 6 ppb for at least 55 days, above 4 ppb for more than 115 days, and were still above 2 ppb for at least 155 days. This greater-than-expected longevity was caused by less dilution due to dry conditions and an inactive outlet for the duration of the treatment.

**Results**: By the end of summer 1998, there were no observable submergent aquatic plants in the lake. Scattered submergent plant growth returned the following summer, but this was limited primarily to macroalgae (*Chara* spp.) and isolated single stems of Eurasian watermilfoil. In 2000 and 2001, however, extensive beds of brittle naiad (*Najas minor*) were found in areas where sediment was thick and organic-rich. Isolated, small quantities of other native plants (large-leaf pondweed, leafy pondweed, macroalgae) were found throughout the littoral zone. Eurasian watermilfoil was largely limited to small patches in thinner sediments. Aquatic plants survey maps drawn prior to the fluridone treatment and again in 2000 look very similar except that brittle naiad *(Najas minor)* largely replaced Eurasian watermilfoil. (Fig. 6–10)

After 2001, Eurasian watermilfoil recolonized large patches of the littoral zone. It was less dominant due to the well-established brittle naiad beds, but it spread to some areas not previously "weed free." The coverage and density of the Eurasian watermilfoil/brittle naiad beds prompted a spot treatment with endothal in the summer of 2004 in a small portion of the lake.

Anecdotal information indicated a general satisfaction with the results of the initial treatment. Most lake residents were satisfied with the transition from Eurasian watermilfoil to brittle naiad, although the latter is also an exotic, invasive species. Although Eurasian watermilfoil returned to the lake, the densities in most regions of the lake were significantly lower than prior to treatment and for at least ten years after treatment. There were few reported complaints from anglers. Water-quality conditions were relatively stable throughout the treatment and subsequent response period. Reports of blue-green algal blooms or other water-quality complaints were less frequent than in most previous five-year periods. Annual aquatic plant monitoring continues to track the extent of exotic and native plants in the lake.

**Lessons learned**: Aquatic plants have the ability to recover, or to be re-introduced after an herbicide treatment. Native plants may be the initial re-colonizers if the dosage rate is high enough to control root systems, and if new invasive plants are not re-introduced,. Too high a dosage, however, can render a lake susceptible to invasive re-infestation or ecological impacts from a barren lake bottom. (Kishbaugh, 2002)

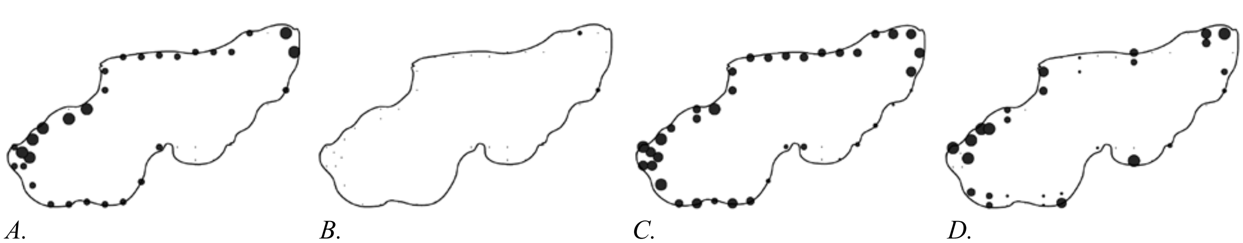

*Fig. 6–10. Plant communities in Snyder Lake: A. Pre-treatment B. 1998 C. 2000 D. 2003*

## Shading

### Principle

Shading involves the use of non-toxic, vegetable dyes to inhibit light penetration throughout the water column. This limits the growth of nuisance aquatic vegetation in water depths greater than two to four feet. The dye absorbs certain wavelengths of light, which further limits plant photosynthesis. Shading is used to treat an entire waterbody and is most often used in farm ponds. It is rarely used on large lakes, due in large part to cost considerations (see case study "Multiple strategies for invasive species control in Adirondack Lake").

The treatment duration is a function of water-retention time. When applied to lakes with significant inflow or outflow, dyes will quickly dilute or be flushed downstream. These dyes may persist throughout much of the recreational season, depending on the flushing rate of the lake.

The use of shading dye is prohibited in potable water supplies, but there are no restrictions associated with the immediate use of dye-treated water, although most lake residents will be deterred from swimming in a lake so artificially colored. The dyes impart a rather unnatural color to the water, despite efforts by dye manufacturers to mimic the natural appearance of lake water.

The most common chemical dye used in shading is Aquashade®, an inert, blue liquid, vegetable dye. Many shading products that are registered as having herbicidal impacts are combined with copper formulations to enhance algae control. In recent years, many similar products have been advertised as "landscaping tools" or "colorants" that improve the "aesthetic quality" of the water. This marketing technique steers clear of any claim of herbicidal impact and is done to avoid regulatory restrictions outlined in FIFRA.

### Advantages and disadvantages

Lake dyes are non-toxic to humans and most aquatic organisms. Disruption of lake ecology can occur, since the non-selective reduction of the plant community can influence fish habitat. Dyes can frequently and rapidly wash out of a lake. Repeated applications are needed in lakes with very low residence times, or after spring runoff or storm events.

This control strategy is less expensive than others, and may result in some limited success in controlling nuisance vegetation with only minor side effects. Nonetheless, the public may perceive the technique to be another "toxic chemical." Anyone proposing to use chemical dyes should enlist public support prior to application.

### Target and non-target plants

Shading dyes have been shown to be somewhat effective for several nuisance plants including common waterweed (*Elodea*), pondweeds (*Potamogeton*), naiad (*Najas*), watermilfoil (*Myriophyllum*) and some filamentous algae. Since dyes reduce the transmission of light through the water column of a lake, however, all submergent plants are affected. Specific lake areas or individual weed beds cannot be isolated for treatment unless water flow is somehow restricted

### Costs

Shading dyes are relatively inexpensive for small lake and pond applications, but costs can become prohibitive for large-scale treatments. The cost of the chemical dyes is about $50-per-gallon. Applied at the recommended concentration of one part per million (ppm) each gallon will treat four acre-feet of water (one acre of surface area at a depth of one foot).

### Regulatory issues

The use of herbicidal agents is governed under FIFRA. If the label on the dye promotes plant control, use of the chemical requires a pesticides permit from the DEC. This applies to lakes or ponds greater than one acre in size, waterbodies owned by multiple residents, or those that drain beyond the property lines of a single landowner. Permits are not required for products that make only "landscaping" or "colorant" claims. The DEC Regional Office should be consulted, however, prior the use of any shading agent.

The use of chemical dyes or other shading agents in lakes within the Adirondack Park is a regulated activity. It requires a permit from the APA if the activity could substantially impair the functions served by or the benefits derived from freshwater wetlands.

### *History and case studies in New York State*

Shading has been commonly used on ponds, particularly golf course and ornamental ponds, for many years. There is little historical information on the use of shading agents in larger New York State lakes. Field research on the dyes has been rather sparse, though one large-lake experiment took place in Adirondack Lake in the late 1980s (see case study).

## Integrated plant management (IPM)

Integrated Pest Management, commonly known as IPM, is the process of using multiple management actions to achieve long-term control of pests. This approach improves effectiveness by extending the benefits of each technique. This concept can also apply to plants. **Integrated plant management**, a form of IPM, points to the need for plant managers to avoid focusing on only a single management tool.

In general, IPM involves the use of a whole-lake control strategy, such as an aquatic herbicide, in concert with at least one other control strategy, such as hand harvesting. This is comparable to painting a room using both a roller and a brush. The roller is best for the broad expanses of wall and the paint

### Case study: Multiple strategies for invasive species control in Adirondack Lake

**Lake setting:** Adirondack Lake is a 200-acre lake in the town of Indian Lake in the middle of the Adirondack Park. It was formed by a stone dam originally built in 1910 to create a recreational lake, and was rebuilt by the Civilian Conservation Corps (CCC) in the 1930s. The lake is characterized by a group of floating peat bogs, which have historically been managed by a variety of strategies, and are currently corralled by a log boom. The lake flushes, completely exchanges the volume of water in the lake, about every 10 months.

**The problem:** Rooted aquatic plant growth has been the subject of complaints from the late 1960s to early 1970s. By the late 1970s, the aquatic plant populations in the lake were dominated by beds of large-leafed pondweed, although other native species were well represented.

**Response**: The Adirondack Lake Association utilized a number of lake-management tools during the late 1970s and early 1980s. They included water-level drawdown from three to nine feet, mechanical harvesting, and the aquatic herbicide 2,4-D. In 1984, 500 gallons of Aquashade® were applied at a rate of one part-per-million (ppm). In combination with a relatively deep lake drawdown, 90 percent of the aquatic plant beds were cleared from the lake for two years, with aquatic plant growth limited to shallow water by early 1986. By later that year, however, the APA estimated aquatic plant growth to be "moderate" to "abundant". By 1987, after another deep winter drawdown, Aquashade® was applied again, primarily to control large-leafed pondweed beds covering 80 percentage of the shallow, shoreline areas to a depth of seven feet. Aquatic plant communities shifted from large-leafed pondweed to brittle naiads (*Najas minor*) and common waterweed (*Elodea canadensis*) by 1988. By 1990, after a year of no control, e large-leafed pondweed returned in abundance. As aquatic plant growth increased, Aquashade® was applied a third time in 1991, again after a deep winter drawdown, and a fourth time in 1994. Total cost for the four treatments was approximately $54,000.

**Result:** It was believed that the repeated Aquashade® treatments reduced plant populations in the deeper water, but had less impact in the shallow water. By 1996, the lake association shifted the agent of control from Aquashade® to grass carp *((Ctenopharyngodon idella)*, in part due to the lower costs. There was an expected cost of $35,000 for a 10-year grass-carp control versus about $54,000 for 10 years of shading agents. (Grim, 1996)

**Lessons learned:** In a relatively large lake, even without a rapid flushing rate, the benefits from an application of shading dye can be relatively short-lived. The alteration in the plant community demonstrated that these agents may be less effective in shallow water portions of lakes where plant growth is limited by factors other than light transmission. (Kishbaugh, 2004)

## Case study: Integrated Plant Management Techniques in Lake George

**Lake setting**: Lake George is a 28,000 acre lake located in the southeast corner of the Adirondack Park.

**The problem**: Eurasian watermilfoil *(Myriophyllum spicatum)* was first identified at three locations in 1985. By 1998, the plant had spread to 127 known sites, 31 of which contained dense growth. Preventing additional spread of the Eurasian watermilfoil, and controlling existing beds, has been the focus of considerable local efforts for many years.

**Response**: A consortium of state and local agencies, and the Darrin Freshwater Institute (DFI) used lakewide aquatic plant surveys and selected experimental control strategies from 1987 to1992. (Darrin Freshwater Institute, 1991) In 1995, physical management efforts were incorporated into an Integrated Aquatic Plant Management Program under the auspices of the DFI. In 2002, Lycott Environmental, Inc. and the Lake George Park Commission implemented the program on Lake George. (Eichler and Boylen, 2002)

**Results**: As of 2005, a total of 149 Eurasian watermilfoil sites were identified throughout the lake. Since 2002, most of the new infestations have been identified by volunteers. A combination of management techniques has cleared 72 of them. An additional 43 sites were found cleared by the end of 2004. "Cleared" refers to no visible Eurasian watermilfoil remaining. Six more sites are used by DFI for research purposes and have not been actively managed. The number of known Eurasian watermilfoil sites increased by an average of eight sites per-year from 1987 through 2001, with a total of 141 sites identified. From 2002 through 2004, there was an increase of only two to three sites per year. It is not clear whether this represents reduced Eurasian watermilfoil dispersal rate in Lake George or a limitation in the progress to locate new invasion sites. Approximately 40 percent of previously managed sites remained free of Eurasian watermilfoil. The annual cost for the management program is about $150,000. (Lycott, 2006)

Between 2002 and 2005, 7,000 to 16,400 Eurasian watermilfoil plants were removed by hand each year from 64 to76 locations. About 40,000 square feet of Palco® pond liner, in 7 foot x 50 foot sections, was installed in both 2004 and 2005. 1,500 square feet of pond liner was also reclaimed and relocated in 2004 from a site managed in 2003. In addition, 45 to 50, 30-gallon barrels of Eurasian watermilfoil were removed by suction harvesting in 2002 and 2003 at a single site at the rate of approximately 35,000 plants each year. In 2004, no suction harvesting took place, since it was decided that the possible negative impacts and efficiency of suction harvesting, relative to barrier methods, was not cost effective. Hand harvesting efficiency, as estimated by repeat harvesting, exceeded 85 percent in all years, and 97 percent in some years. (Lyman and Eichler, 2005)

**Lessons learned**: Benthic barriers can be an effective management strategy, particularly when plant densities are low. When integrated with hand harvesting, these efforts can clear significant portions of the lake bottom. Active annual maintenance is necessary to prevent recolonization of Eurasian watermilfoil in these areas. While these methods have been successful under certain circumstances, there are many considerations for implementation including water clarity, substrate conditions, species and density of the aquatic plant growth, and depth of the plant growth.

brush best for the corners and details. The herbicide broadly controls most plants, while hand harvesting removes any remaining solitary plants. Mechanical harvesting used in tandem with benthic barriers is a similar useful pairing. Harvesting controls plants in deeper water and benthic barriers control the shoreline plants. The installation of benthic barriers can also be expedited using drawdown, adding another management tool. Not all techniques can be paired. Mechanical harvesting and herbivorous insects, for example, are an unsuccessful pair, since harvesting removes the tips of the plants where the insects thrive.

In any plant-management program, preventive measures should always be coupled with any in-lake, aquatic plant-management actions. Strategies include preventing the introduction of invasive plants, and keeping excess nutrients and sediments from entering the lake. This is discussed in greater detail in Chapter nine, “Watershed management.”

## Other management activities

There are other techniques that are experimental, part of the folklore of weed management, or used in other regions of the country. The most common ones are noted below.

*Surface covers* are light-inhibiting agents that are usually constructed from the same material as benthic barriers. They float on the water instead of being anchored on the lake bottom. Surface covers interfere with recreation and safe boating, and can be aesthetically unpleasing. They have not been regularly used in New York State lakes.

*Weed rollers and sweepers* are patented devices that are connected to docks and travel across plant beds in an arc centered at the dock edge. The devices typically use a roller to compress plants or a sweep a bar that dangles chains over the top of plants. Both contraptions weaken plants over a period of several days to weeks, causing the plants to dislodge and degrade. Some DEC regional offices have determined that permits are required if lake sediments are disturbed and some regions have limited their use to post-fish spawning periods. These devices are not widely used, but there are vendors in New York State.

*Use of plant pathogens*, such as fungi, as a possible aquatic weed control has been researched for many years. In Maryland, pathogens referred to as ”Northern Disease” were implicated in a Eurasian watermilfoil *(Myriophyllum spicatum)* population crash. This led to significant laboratory research on the plant pathogen *Mycoleptodiscus terrestris* by the U.S. Army Corps of Engineers and the Republic of China, where Eurasian watermilfoil is indigenous. This has not evolved into a viable plant management technique.

*Altering sediment chemistry* to affect nutrient uptake in rooted aquatic plants has shown limited success in other parts of the country. The work is still very experimental and none of the substances under investigation are presently registered as aquatic herbicides in New York State. Their full impacts are unknown, and they cannot be legally applied for aquatic plant control in New York State lakes.

*Scattering corn* on lake bottoms is recommended by some lake residents to attract common carp (*Cyprinus carpio*). These bottom-scouring fish then supposedly disturb the lake bottom and disrupt the growth of rooted plants. No corn-chumming projects have been documented in a New York State waterbody, although some officials residing at bays along Lake Ontario have pushed for this rather than many of the techniques described above. It is not known how many fish it would take to roil up the bottom enough to dislodge plants, not to mention the turbidity and spectacle of such rubble-rousing.

The use of *ultrasonic devices* is discussed in detail in chapter seven, “Algae and other desirables” as a means for controlling nuisance algae. Some limited experimental ultrasonic treatments of water chestnut *(Trapa natans)* in Lake Champlain in 2005 demonstrated water chestnut mortality without any apparent effects on fish after 10 seconds of 20 kHz ultrasound waves. On-going research is focused on scaling up the procedure to treating one acre plots per day, at a cost under $1000 per acre. Additional data will be required to determine if this is a safe and viable control option (Wu and Wu, 2007).

## Decision trees for controlling Eurasian watermilfoil and water chestnut

Management does not start with the choice of a particular control method but rather with the problem plants. Eurasian watermilfoil and water chestnut are currently the most significant invasive plant species found in New York State. A decision tree for each of these species is provided to help determine the most appropriate management techniques for a particular typical lake (see Figs. 6–11 and 6–12). If different plants are the object of concern, lake associations may want to make their own customized decision tree to aid in making choices and communicating those choices.

## Putting it all together: The art of aquatic plant management

This chapter has described many methods used to combat nuisance aquatic plants. None is a panacea for weed problems, however, and aquatic plant management remains extremely complex. There are many considerations that make plant management as much an art as a science.

### *The convergence of timing, longevity, and public perception*

Each management strategy has its own timetable of effectiveness and longevity. There are also other milestones during a project that can impact public perceptions and expectations. Immediately after a mechanical harvester cuts a swath of nuisance Eurasian watermilfoil, for example, plant fragments and turbidity clouds may follow the harvester much as the rats followed the Pied Piper. This is often a temporary phenomenon, but this detritus may make people unhappy when it ultimately lands on their shoreline. Some herbicides cause marginally susceptible plants to temporarily turn a white or pinkish color. Mats of filamentous algae may form on the tips of plants treated with a systemic aquatic herbicide, and the rooted plants themselves may become increasingly denuded ("poodled") prior to falling out of the water column. Such unsightly consequences can cause a public perception that these side-effects are worse than the weeds.

### *Sacrificing the wrong plants*

Some plant control methods remove beneficial native plants along with the target nuisance species. Aquatic herbicide permits have been denied in New York for this reason, especially when the beneficial plants support fish habitat. Drawdown has some effect on unwanted Eurasian watermilfoil *(Myriophyllum spicatum*), but it can also kill native plants. This gives the more aggressive Eurasian watermilfoil an extra niche to fill upon its recovery. There are also a large number of protected plants identified as rare, threatened, or endangered in New York State, and there are nearly 600 federally protected terrestrial and aquatic species. Many of the techniques described in this chapter can also affect these protected plants, so the state permitting process involves a level of review necessary to afford adequate protection to them. The more than 6500 non-indigenous species in the country, however, are among the greatest threats to these protected plants, so managing nuisance plants in lakes with protected species becomes a necessary balancing act. This provides yet another reason for identifying and controlling exotic plants before they turn into an invasion.

### *All are equal, but some are more equal*

Although New York State regulatory agencies permit the use of each of the aquatic plant-management techniques discussed in this chapter, some techniques are more favored than others. Some of this bias originates in the funding sources used to pay for aquatic plant control. Historically, some grant programs have not included certain management techniques. In some regions of the state, such as Long Island and the Adirondacks, aquatic herbicide treatments are uncommon to non-existent. Some of this is due to strict regulations governing land use, water quality, and

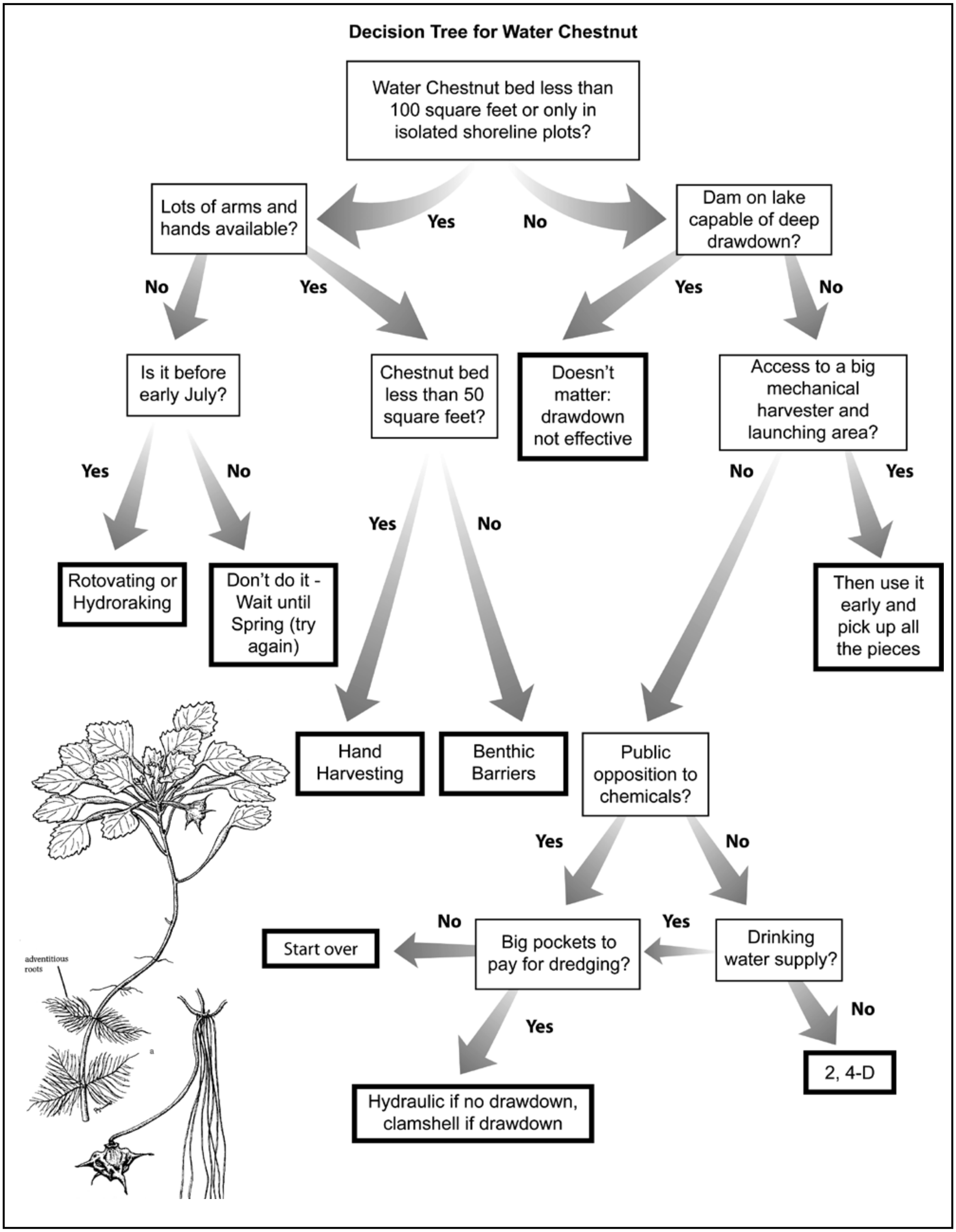


*Fig. 6–12. Decision tree for controlling Water chestnut (Trapa natans).*

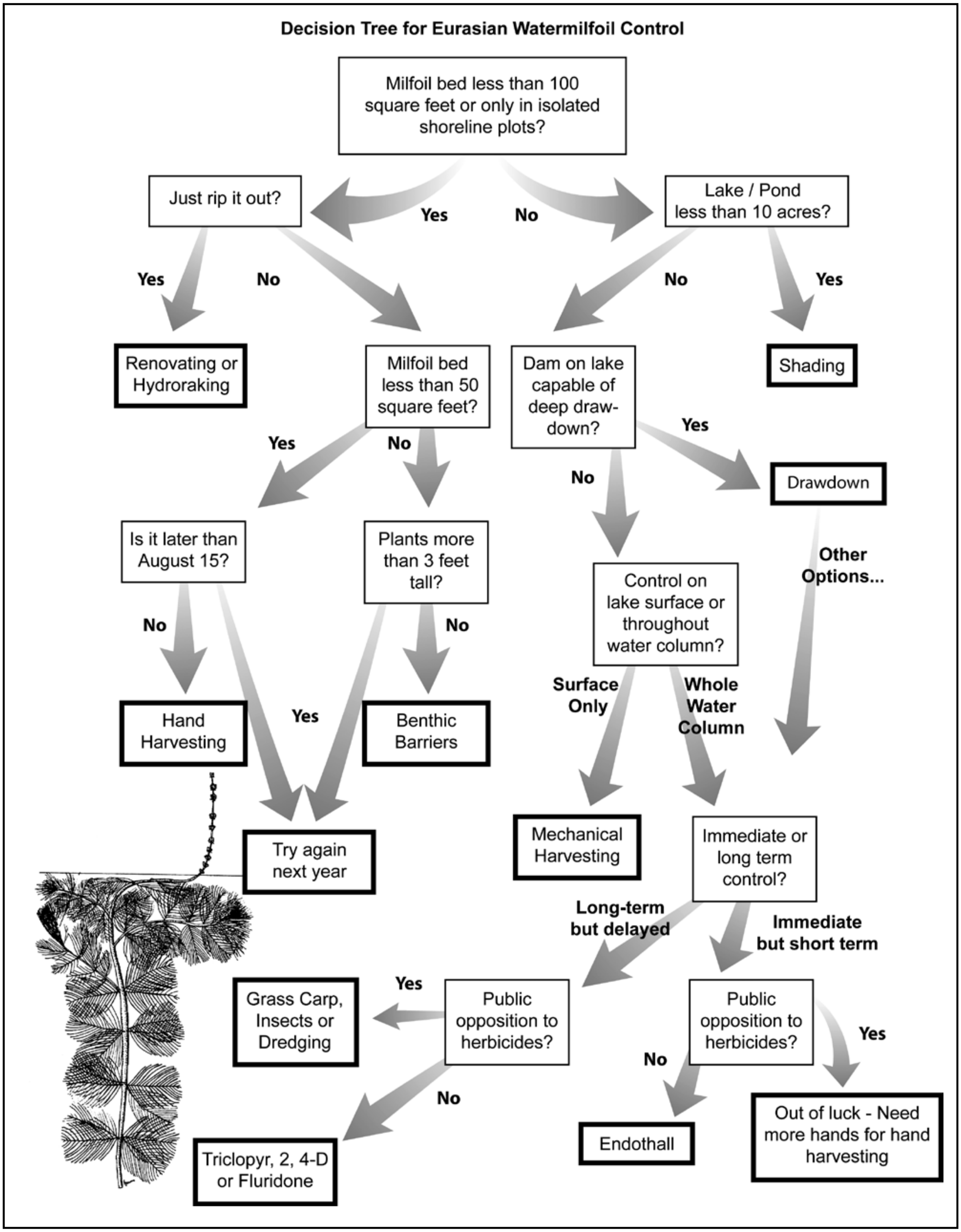


*Fig. 6–12. Decision tree for controlling Eurasian watermilfoil (Myriophyllum spicatum).*

especially wetlands in these regions. It is important to remember that the primary role of the permitting agencies is environmental protection. Invasive or exotic plants have only recently been recognized as biological pollution capable of causing great ecological harm. Surrendering expanses of beneficial native plants for the sake of invasive plant removal has met regulatory skepticism. Some of this partiality is philosophical, since the political and social environment in some regions of the state strongly influences management decisions. Sociopolitical influences are likely to change as circumstances change, but for now, most aquatic plant-management activities will continue to be closely scrutinized within the Adirondacks and on Long Island. It is also worth noting that regulatory agencies evaluate the actions for invasive exotic plant control much more favorably than they evaluate actions for native plant control.

### *There is no such thing as eradication*

Eradication of invasive exotic plants is a prime goal of plant-management actions, but in reality, eradication is but an illusory dream. No method completely removes all nuisance plants or their means of reproduction. Drawdown rarely exposes plants lurking in the deepest part of the lake. Some aquatic plants are developing resistance to the few herbicides capable of controlling them. Hand harvesting does not always remove the entire root system. If a plant appears to have been exterminated from a lake, new plants or their means of reproduction can be introduced to become the next generation of invaders. The good news is that water chestnut *(Trapa natans)* can be controlled and perhaps even extirpated from a lake. The bad news is that if there is a reservoir of nutlets skulking in the lake sediments, these seeds can remain viable for up to twenty years. Water chestnut is unique among invasive exotic plants in that it is:

- visible and apparent very early in its colonization;
- a seed producer, and thus controllable if removed prior to seed formation; and is
- easily distinguishable among aquatic plants found in New York State.

Other seedy invaders, if so easily bulls-eyed, could also be candidates for eradication, but it must be stated that a reasonable goal for aquatic plant management is not eradication. For lakes with a monoculture of a single exotic plant species, a targeted control project will essentially eliminate all plants in the lake, rendering the lake susceptible to re-invasion from either the same or a different invasive exotic plant. For lakes with a mix of exotic and native plants, even a successfully selective removal of just the exotic plants may still leave some lake residents unhappy with the remaining lush plant growth, despite the better residual ecological balance. Successful plant management must be accompanied by reasonable expectations.

## Summing it up

Plant management starts with the identification of the nuisance plant and progresses to the most appropriate control method for that particular plant in a given New York State lake. The most important lesson is that there is no magic bullet, no single tool that will work on all aquatic plant problems in all New York State lakes. Aquatic plant control, like the larger goal of lake and watershed management, involves the delicate process of choosing the right management tools, building consensus toward the use of those tools, and sometimes getting lucky when it works right.

While nuisance weeds are usually the most prominent part of a lake-management plan, they are not the only plague on a lake. Chapter seven, "Algae and other undesirables", and Chapter eight, "User conflicts" will discuss the most common strategies for dealing with the myriad of other lake and watershed management issues confronted by those who live for the beauty and protection of New York State lakes.