Local / Shoreline Management Activities
(listed by increasing order of "complexity")

1. Hand Harvesting and Suction Harvesting

- *Principle*

This is very much akin to weeding your garden. Hand harvesting involves grasping the plant material as close to the sediment layer as possible, even digging into the sediment to grab the root crown, and pulling the intact plant out of the bottom sediment. Plants are pulled slowly to minimize fragmentation, and the entire root system should be removed from the sediment if possible.

If hand harvesting is carried out by a lake resident trying to keep his own shorefront free from plants, plants and roots should be deposited away from the shore to minimize transit back to the lake. This technique is largely restricted to small areas, although only the time, patience and amount of elbow grease prevents a lake resident from keeping a very large area clear. Generally, for large beds of plants, or for plants growing in water greater than a few feet deep (invasive exotics like Eurasian watermilfoil can grow in water up to 20 feet deep), scuba divers will likely be required. In these cases, harvested plant materials, including root systems, stems, leaves, and fruiting structures, are placed in mesh bags and taken away from the lake.

In more extensive diver-operated hand harvesting, a barge on the lake surface with a dredge hose connected to an industrial engine creates suction. The other end of the dredge hose is carried to the lake bottom by a scuba diver. The hose sucks up the plants, roots and top sediments that go into a spoils collection basket on the barge. The basket traps the plants and root fragments, allowing the sediments and water to drain back into the lake. This process is usually referred to as **suction harvesting** or **diver dredging.**

Collected plants can be disposed of at a site away from the lake, or dewatered or dried and used for mulch or fertilizers. Disposal may be confined to small, individual sites, in the case of small dredging operations. Suction harvesting collects a much smaller biomass than does larger-scale mechanical harvesting operations (discussed later), because only small targeted areas are dredged, and because only the nuisance plants are removed, not all of the native and exotic plants.

- *Target Plants and Non-Target Plants*

Hand-harvesting is the ultimate selective plant management technique, since it removes individual plants a single plant at a time. Only those plants that are identified as exotic, invasive, or otherwise contributing to nuisance conditions are removed. Suction harvesting may also remove some nearby plants and sediment, although selective control is still largely achievable.

- *Advantages*

Unlike large scale, lake-wide management techniques, hand harvesting can be conducted on a single plant or a small bed at a minimal expense, if not minimal labor. Anyone can hand-harvest, although only the cautious can hand-harvest well. It targets only those plants that create use impairments or contribute to nuisance conditions. If properly performed (SLOW removal from under the roots or the base of the plant when the plants are still robust), side effects, such as turbidity and bottom disturbance, are minimized and usually temporary. It is also very useful at preventing re-infestations after a larger-scale plant management strategy, particularly when combined with a vigilant surveillance program. For target plants that do not reproduce vegetatively, hand harvesting (as well as mechanical harvesting) can provide some longer-term control of these plants if the plants are removed prior to the formation and fall of the seeds.

Such harvesting can be directed, but not be limited, to clearing swimming areas and opening navigational channels. The technique can be used in open-water and most near-shore areas. Since the diver, and not the barge, controls the operation in suction harvesting, plants can be removed between docks, shallow water, or other areas with physical constraints to boat access. The only limit imposed on the application of suction harvesting is the length of the dredge hose, although multi-diver operations may also have surface air and safety lines linked to the barge.

- *Disadvantages*

Very effective, hand-harvesting is cumbersome and tiring. It is difficult to hand pull large beds of target plants, and inconvenient (from the pullers perspective) to hand pull scattered plants, although this may be the best way to prevent the expansion of single plants into small beds. Efforts to speed up the process, by hand pulling clumps of plants away from the sediment interface at a rapid pace, often results in fragmentation, incomplete plant removal, high turbidity and bottom disturbance. Even when performed properly, hand harvesting frequently results in some fragments and floating bits of root and seed and other plant parts, the vegetative stock for new generations of plants when these materials eventually fall back down to the lake bottom. Moreover, since many nuisance plants spread vegetatively through runners and rhizomes, the inability to remove deeper plants may result in rapid reinfestation from contiguous beds outside the range of shoreline harvesting. It is not very effective on plants that have extensive root systems, such as lily pads, although these plants are usually not (or should usually not be) the target of selective plant control efforts. These limitations effectively result in only local control of nuisance plants with this method.

Suction harvesting operations can have some significant side effects. High turbidity, reduced clarity, and algae blooms from nutrient release can result from either the disturbance of bottom sediments, or the release of the sediment slurry from the on-barge collection basket. This may lead to reduced oxygen conditions, and, ultimately, may affect the ecosystem communities.

Suction harvesting also disrupts the bottom sediments while removing the plants and roots. This control method can have a deleterious effect on the animals living in the sediments and on the plants not dredged but living within the dredged area. Sediments may also contain heavy metals or other potentially hazardous materials. If these materials are present, and proper precautions are not taken, the dredging operation may release these metals into the water, which could have severe repercussions throughout the food web.

Suction harvesting is very costly, as much as two to ten times the cost of mechanical harvesting. While part of the overall cost is incurred at the beginning in capital expenditures, the most significant cost is in operations, due to the slow rate at which

1. Case Study- Hand Harvesting

Lake Setting: Upper Saranac Lake is a 5200 acre lake with more than 44 miles of shoreline found near the northern edge of the Adirondack Park.

The Problem: Eurasian watermilfoil was first discovered in 1996, and local residents and lake users have been concerned that it may take over large portions of the lake.

Response: A locally funded control effort using benthic mats and hand harvesting with four divers was initiated in 1998 by a partnership of organizations, including the Upper Saranac Lake Foundation, the Adirondack Aquatic Institute, Cedar Eden Environmental, and Paul Smiths College. This three-year effort achieved local control of large milfoil beds primary in front of state lands (which nearly 50% of the lake shoreline), and resulted in the annual removal of about 50 acres of milfoil across 3-4 miles of shoreline, at the cost of about $60,000 annually. 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 management efforts for managing extensive milfoil beds. In addition, political considerations prevented the use of some of these management tools, such as aquatic herbicides. As a result, a three year program extensive hand-harvesting and benthic matting program was initiated in May of 2004 to remove and control Eurasian watermilfoil to acceptable levels in the lake.

Based on the experience of other large-scale hand harvesting programs in other NYS lakes, a team of 20 divers was assembled- two divers for approximately every 500 acres of lake area. These divers were trained in a one day training session involving plant identification and safety, followed by in-water training for additional Eurasian watermilfoil identification and removal technique. Each diving team had an experienced dive leader to coordinate diving operations. Divers hand-pulled Eurasian watermilfoil plants in a systematic path around the lake, while other team members tracked locations with Global Positioning System (GPS) units, recorded detailed survey information about the presence of milfoil and native plants, and transported bagged milfoil to a remote location. Additional resources used to support this hand-harvesting effort included 10 “top-water” team members, 4 dive platforms boats, 2 tank dive boats, dinghies, kayaks, and a patrol boat. Divers hand harvested milfoil plants for 5 days a week for 55 days, starting on June 1st and ending by August 15th. Benthic barriers were also placed on the lake bottom in the middle of May.

The project was completed at a cost of approximately $535,000 in 2004, 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 to reduce the extensive overhead (financial and logistic) 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. However, more conventional diving operations (using SCUBA dive tanks) were also needed for more mobile operations to access and removal smaller or more remote beds. Future costs will likely be reduced since capital costs (purchases of boats and other equipment) will be lowered. It is difficult to compare these numbers to costs of other management activities, since the density of plants targeted in hand harvesting (low to moderate) was different than those encountered in other plant management efforts. Based on the number divers, quantity of harvested plants and project costs, this is the most extensive hand-harvesting project to date in New York State.

Results: Long-term evaluation of the effectiveness of the project will not be completed until after the third year of the project in 2006. Preliminary results from 13 transects surveyed around the lake in late 2004 demonstrated milfoil removal ranging from 27 percent to 100 percent of the pre-harvesting plants. The majority of the sites exhibiting greater than 60 percent removal, and removal rates were not closely related to either the plant densities or the number of times plants were hand harvested. Milfoil plants remaining at the end of the growing season resulted from either incomplete hand harvests or regrowth within the growing season; most of this occurred in depths between 8 and 12 feet.

Lessons Learned: This project demonstrates that hand-harvesting can be effective at controlling even large-scale milfoil infestations, but control in large or heavily infested lakes requires significant resources and a well-devised plan of attack.

Source: Martin, M.R. and C. Stiles. 2005. The use of hand-harvesting to control Eurasian milfoil in Upper Saranac Lake, Franklin County, NY. Presentation at the NEAPMS annual conference, Saratoga Springs, NY.

diver dredges can be operated. The operations cost also includes skilled labor. Unlike some control techniques, suction harvesting will probably require at least three specialists; one barge operator and at least two scuba divers, all with some experience in these activities. Even if a lake association can pay for the equipment, it is likely that the harvesting cannot be done without additional outside financial assistance. Thus, suction harvesting is far from a "self-help" control technique.

- *Costs*

By far the most significant expense associated with hand harvesting is labor costs, since this is perhaps the most labor-intensive plant management technique available. For professional control, plants can be hand harvested by scuba divers at a rate of about 90 plants per hour (per diver) for an area first harvested, 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-$1.00 per plant, or upwards of $400-$1000 per acre (Holdren et al, 2001), based on a “typical” density of aquatic plants in a lake with targeted beds of target plants (recognizing that very dense beds are very difficult to control with this method).

The cost of the suction harvesting equipment is about $20,000 to $30,000. The operation requires one or more scuba divers, a dredge operator and a person to assist in the disposal of the plants. This could add an additional $500-1000 per person per day to the cost of the operation. Depending on the size of the weed plots to be harvested, 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*

In most regions of the state, hand harvesting is not a regulated activity, although some NYSDEC Regional Offices may require permits or approval to perform larger-scale hand-harvesting. Within lakes outside of the Adirondack Park that are partially or wholly encompassed within wetlands, a wetland permit may be required.

Larger scale hand harvesting operations require an Adirondack Park Agency (APA) permit within the Adirondack Park. As per recent changes in the APA regulations, hand-harvesting does not requires a permit for control of nuisance plants by individuals in lakes within the Adirondack Park if the hand harvesting:

- is conducted by hand in open water (less than 2 meters deep)
- leaves at least 200 ft^2 of contiguous indigenous wetland 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
- is conducted only on an individual’s property, or with the permission of the property owner
- involves no pesticides or any other form of aquatic plant management, including mechanical plant harvesting methods or matting
- involves no dredging, removal of stumps or rocks, or other disturbance to the bed and banks of the waterbody

The regulations covering suction harvesting are similar to those encountered when proposing a dredging project (see below). A permit will have to be obtained from the NYSDEC and possibly from the Army Corps of Engineers. Inside the Adirondack Park, the APA will also require a permit. As with all dredging project, the process for obtaining a permit can be extensive and very difficult. Projects may require a public notification period; if the local community does not completely support the project, poor publicity can delay and even stop the implementation of the project. While suction harvesting does not usually command the same attention, either good or bad, as the larger-scale sediment removal dredging projects, the potential for public disagreement must still be considered

- *History and Case Studies in NYS*

This strategy has a long history of use in New York State, probably dating back to the first canoe paddle that inadvertently (or maybe not) pulled weeds out of the way and lake. But although it is likely that nearly every lakefront resident has performed hand harvesting, the vast majority of these efforts have gone undocumented. It also cannot be stated with any certainty that these have been successful- while pulling plants clearly remove them, at least from the site on which these offending plants have anchored, it is not clear if the spread of fragmenting plants has been significantly exacerbated by indiscriminate hand harvesting. Hand harvesting has successfully controlled small patches of Eurasian watermilfoil in Lake George, Mountain Lake, and Indian Lake, and larger plant beds in Upper Saranac Lake. Small beds of water chestnut have been controlled by the New York State Canal Corporation in Lake Champlain (although most of this work was done with a mechanical harvester) and by Boy Scout groups and private citizens in Oneida Lake (and surrounding waterways) and Sodus Bay. While most of these efforts have successfully controlled the targeted plants, re-infestation from nearby plant beds and other vectors has required continuing efforts to stem the tide.

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, has precluded the extensive use of this technique in other parts of the state.

- *Is That All?*

Hand harvesting is no doubt the most common management technique used to control nuisance weeds in New York State, particularly if modifications to the "proper" techniques, such as those involving using running boat props or rakes or mattress springs to cut through weed beds, are also included in the count (although these may be more properly identified as "mechanical cutters"). It is increasingly difficult to survey the shoreline of many New York State lakes without finding deposited piles of raked or pulled or cut weeds, although this is probably a greater reflection on the increased use of these lakes and the escalating problem with invasive weeds rather than an accelerating use of this management technique. As perhaps the only plant management strategy that, in general, requires no permits, no significant expertise,

An Insiders Guide to Aquatic Plant Hand-Harvesting

So you wanna pick some weeds? How hard can that be? Well, if you're collecting a bouquet of picturesque aquatic plants to offer to an amour, it may be very similar to gathering wildflowers from an endless meadow. But if you're trying to prevent these pesky plants from returning or spreading, the process is not quite so simple. There are many guides that tell you, in general, how to hand-harvest aquatic plants while minimizing fragmentation and removing most of the plant. This publication provides some of this general guidance. However, there are some tricks of the trade that have proven very successful in effectively controlling the propagation and regrowth of Eurasian watermilfoil and water chestnut, perhaps the two most heavily plucked plants. Below are a few helpful hints from a few of the insiders:

For Eurasian watermilfoil (Martin, 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 (Samuels, 2005)

- Wear old shoes and gloves- the nutlets are <u>very</u> sharp!
- Water chestnut reproduce from the nutlets. If you remove the plants before the nutlets drop, you'll eliminate the seed base for the following year growth, although the nutlets can survive in sediments for up to 20 years. However, if you remove the plants too early, new plants may crop up and produce seeds, and the nutlets are only loosely attached to the plant by late summer. The best window for removing water chestnuts are between mid June and mid August.
- Since infestations start from the outer edge of the plant beds, start removing plants from the outside and work your way into the center of the beds**.**
- Dispose of the plant in the trash or by composting on land away from shore (but watch out for the nutlets!).

Sources: ***Martin, M. 2005. Personal communication***
Eichler, L. 2005. Personal communication
Samuels, A. 2005. Personal communication

and little risk of side effects, it is not surprising that hand harvesting remains the weed control strategy of choice throughout the state. But for many of the New York lakes with pervasive weed problems and active lake associations, hand harvesting frequently occupies the niche of “intermediate” control strategies- used as an interim measure until a larger consensus of tired arms and sore backs supports the use of larger-scale plant management techniques.

Any harvesting operation, while perhaps the easiest of the physical plant removal strategies, create significant fragmentation and a surface “bloom” of cut plants which can migrate around the lake until either sinking to the bottom or depositing on the shoreline of the unfortunate lake resident who is most frequently downwind from his neighbors. Unless rapidly removed, these large piles of cut weeds will decay and create an unseemly mess, although once air dried will condense into a much smaller pile that might be usable as compost. It should be noted that many dried aquatic plants will ultimately be too nutrient poor to be useful as compost.

The slow rate of operation also can prompt some dissatisfaction from residents whose weed beds have not been controlled. Since the funds for operating the dredge will probably come, at least in part, from association fees or directly from the residents, the dissatisfaction resulting from a single year of operation may result in a funding shortfall during future years. Other methods, either faster or less costly, that may have more significant ecological side effects ultimately may be favored over diver dredging.

2. Benthic Barriers

- *Principle*

Benthic barriers, sometimes called benthic screens or bottom barriers, prevent plant growth by blocking out the light required for growth. The barriers also provide a physical barrier to growth by reducing the space available for expansion. Most aquatic plants under theses screens will be controlled if they are light-deprived for at least 30 days (Perkins et al, 1980).

Benthic barriers are made of plastic, fiberglass, nylon, or other non-toxic materials, and are often permeable to gases produced during the degradation of plant material. In some instances, burlap, or materials such as sand or gravel, have also been used as barriers. Most of these materials come in rolls 100ft long, anywhere from 8 to 75 feet wide, and 3-10 mm thick. Some, but not all, materials are heavier than water.

In shallow water, barriers can be installed by two or three people from the shore. The roll can also be placed on a small boat and unwound as the boat is rowed away from shore. Overlapping barriers by four to six inches will allow wider areas to be controlled. Barriers should be securely fastened to the bottom with stakes or anchors. Heavy plant growth can make installation difficult; it may be necessary to time the barrier placement with a low growth period, usually in early spring after ice-out. During the summer, barriers can be applied after a harvester has cleared the area.

Benthic barriers should be limited to areas of either intensive use or significant concern, due to the difficulty of installation and cost of the materials. They are most often used around docks, in swimming areas, or to open and maintain boat access channels. Since barriers can be used to control the growth of specific weed beds or geographical areas, they are effective at maintaining native and controlled plant communities.

The screening materials and anchors should be removed at the end of the growing season so that they can be cleaned off and protected against ice damage during the winter, although some lake residents keep the barriers permanently anchored. In deeper water, or in situations where the barriers are to be kept in place all year, the barriers should be periodically cleaned to remove organic material in order to prevent new plants from growing on top of the barriers. With proper maintenance, the screening materials can last several seasons.

- *Target Plants and Non-Target Plants*

Since all aquatic plants require sunlight, benthic barriers will inhibit photosynthesis and will ultimately control (kill) all plants underneath the barriers; as such, it is a non-selective control strategy. However, proper siting of the barriers will result in selectively controlling only those plants under the barrier, not desirable neighboring plants.

- *Advantages*

While benthic barriers do not selectively control the underlying plants, the placement of the mats can effectively provide selective control by limiting the inhibition of photosynthesis to **monoculture** beds of invasive plants and areas of nuisance plant growth. Ecological side effects can be practically insignificant. 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 quite innocuous. Although cumbersome to place and anchor,

Case Study- Integrated Physical Management Techniques

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

The Problem: Eurasian watermilfoil was first identified at three locations in 1985, and by 1998, the aquatic plant had spread to 127 known sites, 31 of which contain dense growth. Preventing additional spread of the milfoil, and control of existing beds, has been the focus of significant local efforts for many years.

Response: Lakewide aquatic plant surveys and experimental use of selected control strategies were conducted between 1987 and 1992 by a consortium of state and local agencies and the Darrin Freshwater Institute (DFWI). In 1995, physical management efforts were incorporated into an Integrated Aquatic Plant Management Program with management efforts the responsibility of the DFWI. In 2002, Lycott Environmental, Inc. and the Lake George Park Commission conducted the integrated management program at Lake George.

Results: During 2004, a total of 148 milfoil sites were identified throughout the lake. Of these, 64 were cleared through a combination of management techniques and an additional 54 sites were found cleared by the end of 2004 (although, as in previous years, some of these “cleared” sites exhibited milfoil growth by the following summer). “Cleared” refers to no visible milfoil remaining. Six more sites are used by DFWI for research purposes and have not actively been managed. The number of known milfoil sites increased by an average of 8 sites per year from 1987 through 2001, with a total of 141 milfoil sites identified. From 2002 through 2004, there was an increase of only 2-3 sites per year, but whether this represents a slowing of the rate of dispersal of milfoil in Lake George, or simply reflects the limited survey effort to locate new sites of invasion, is unknown. However, in 2004, approximately 40% of previously managed sites remained free of milfoil.

Between 2002 and 2004, 9,300 to 16,400 milfoil plants were removed by hand each year from 64-76 locations. In 2004, approximately 40,000 square feet Palco® pond liner was installed. 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 milfoil were removed by suction harvesting in 2002 and 2003 (approximately 35,000 plants each year) at a single site. 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% in all years, and 97% in some years.

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 milfoil regrowth and recolonization 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.

Source: Lyman, L. and L. Eichler. 2005. Successes and Limits of Hand Harvesting, Suction Harvesting, and Benthic Barriers in Lake George, NY. Presentation at the Northeast Aquatic Plant Management Society annual meeting, Saratoga Springs, NY.

benthic barriers can be applied by laypeople (almost as) well as professionals, although the process is greatly simplified and more effective using specially designed (read: expensive) materials and scuba divers.

- *Disadvantages*

The bottom covering may eliminate some species of benthic invertebrates, and it is possible that the barriers may interfere with some warmwater fish spawning. However, it does not appear that any other components of the food web are adversely affected. Although this strategy can be used throughout the lake (or at least the littoral zone), the cost of the materials and the difficulties in installation can quickly limit the spatial extent of this method, and permitting issues may become more significant. If target plants are intermixed with desirable native plants, it will be difficult to achieve selective control, particularly since the expansion of these desirable plants will greatly enhance the longevity of this management strategy.

- *Costs*

Benthic barriers can be applied “on the cheap”. The bottom materials can be comprised of opaque (usually green or black) garden tarps, while PVC frames can be constructed to hold the tarp in place. Rocks can be used to hold the tarps down as weights, while rebar can be used as stakes. For professional installation, the cost of benthic barriers ranges from $10,000 to $20,000 per acre, depending on the choice of screening material and whether the application involves initial installation or re-employment. This may be much higher than the costs for several other physical control methods. The ability to reuse the materials over several years will help to amortize these costs. Scuba divers will be required to install and secure the barriers, at least in water depths over 6 feet. Plots with steep slopes, natural obstructions, or heavy plant growth may require additional assistance.

- *Regulatory Issues*

In most regions of the state, the use of benthic barriers is not a regulated activity, although some NYSDEC regions may require approval or permits to prevent disruption of fisheries habitat, particularly for large-scale operations covering a large portion of the lake bottom. Within lakes outside of the Adirondack Park that are partially or wholly encompassed within wetlands, a wetland permit is required. Benthic barriers require a general permit for lakes within the Adirondack Park, issued by the Adirondack Park Agency.

- *History and Case Studies in NYS*

Although benthic barriers have been commonly used throughout the state for many years, most of the applications of this method have been by individual lakefront residents who extended the principle from their garden to their lakefront, and most of these practitioners have not reported their findings. The application of benthic barriers in Conesus Lake has been summarized in "*The Conesus Lake Dockside/Near-Shore Lake Weed and Algae Treatment Guide*", while the recolonization of aquatic plants following the removal of benthic barriers in Lake George has been discussed in the Journal of Aquatic Plant Management (Eichler et al, 1995). In both of these lakes, benthic barriers have effectively controlled nuisance plants, albeit in relatively small areas. Other New York

State lakes that have been "treated" with benthic barriers include Brant Lake, Schroon Lake, and Skaneateles Lake.

- *Is That All?*

Benthic barriers are among the safest and most ecologically sound in-lake physical control techniques. They have been effectively used in a wide variety of conditions and for many varieties of nuisance vegetation. Because they can blend in with the natural environment, are usually not noticeable from the shoreline, and don't interfere with many recreational activities, benthic barriers often afford the greatest public satisfaction. The materials and methods are usually effective for several years (since the materials are not subject to significant ultraviolet light while underwater, photodegradation is not a significant problem in practice). Unfortunately, many lake associations cannot afford the cost of professional materials and installation, except perhaps on the most critical weed beds. Control should therefore be limited to small areas with nuisance vegetation, although less expensive alternatives are commonly used by non-professionals.

Installation and maintenance will require significant thought and time. Although the materials may be heavier than water, due to the natural buoyancy of the covered vegetation and water currents, the screening material can easily come undone. Any large application will probably require additional anchoring and reinforcement, such as steel reinforcing rod (rebar). This is especially important when the screens rest on steep slopes, uneven terrain, or heavy plant cover. Buoyancy due to gas formation from degrading plants must be prevented to avoid "ballooning" or screen movement. Should these barriers drift to the surface, they can be difficult and perhaps embarrassing to replace. These problems can be avoided by cutting small slits in the materials; these slits should be sufficiently large to allow gas escape, but not large enough to allow growth through the holes.

Maintenance is critical to minimize plant regrowth due to sediment or silt deposits on top of the screens. Some materials such as burlap easily 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, while other manufacturers recommend that their materials be removed and cleaned yearly. The potential for tearing, and the difficulty of re-installation makes removal of the screen for cleaning impractical for large applications. Screens should be left in-place during cleaning. Great care must be taken if screening materials must be moved or relocated. However, removing individual plants fragments from the barriers underwater can be very tedious, and will almost certainly require the use of scuba divers. The overall cost of installation and maintenance can be great, and must be considered as a necessary expense (or a real hassle) when using benthic barriers as a control technique.

3. Hydroraking / Rotovating

- *Principle*

Rotovating (also called rototilling) is a relatively new form of mechanical control for aquatic vegetation that uses a rototilling machine to cut and dislocate aquatic plants and roots from the sediment, and then removes the cut plants from the lake. Hydroraking is essentially the same technique that uses a mechanical rake, and collects and removes some of the cut material.

A rototilling machine is usually mounted on a barge. The machine has a large rotating head with several protruding tines that churn up the sediments, dislodging the roots and plants. The rotating head can be easily positioned with a hydraulic boom winch and winch cable (as hydroraking). The plants are either brought up on the rotator and disposed of on shore, or the floating vegetation is raked up for proper disposal.

- *Target Plants and Non-Target Plants*

Although rotovating and hydroraking have been used primarily as a means to control Eurasian watermilfoil in New York State, selectivity is limited to targeting only monocultural beds. These techniques are generally non-selective, since the rototillers or hydrorakes cannot be easily maneuvered to selectively remove target plant species within diverse beds, and since the cutting implements can equally cut all plants and root material, from weakly rooted plants to water lilies with thick underground tubers.

- *Advantages*

Rotovating removes the roots as well as the plant, thus providing a longer control strategy than mechanical harvesting (to be discussed later), although new plant growth can easily occur if root stock is not completely macerated or if seeds are readily dispersed. This technique has controlled Eurasian watermilfoil for as long as two years, although the spread of the plants from uncut areas may reduce this longevity. These techniques provide immediate relief and tend to work faster than large scale harvesting operations.

- *Disadvantages*

Many of the side effects described under hand- or mechanical- harvesting apply to rotovating, but are magnified. Rotovating and hydroraking significantly disturb lake bottoms, churning out a brew of sediment, root masses, vegetation, and other debris that may decay on and in the lake. The potential for re-infestation from fragments or seeds of uncollected cut vegetation can be significant for several plant species. Under windy conditions, or in a strong current, plant fragments can easily spread beyond the treatment area unless they are collected immediately.

Plant and animal communities living on the bottom of the lake can be affected significantly by sediment disturbances from rotovating. Non-selective removal of plant species can easily change the plant community and ecosystem balance, often by allowing faster-growing exotic species to re-colonize an area following the rotovating. Disturbing the bottom sediment can destroy the invertebrate and benthic habitats. Sediment disturbances also may result in localized turbidity and transparency problems, as well as providing an ideal habitat for colonization by opportunistic plants, such as exotic macrophytes (rooted aquatic plants).

- *Costs*

The capital costs for a rotovating operation are generally equivalent to the capital costs for mechanical harvesting ($100,000 - $200,000). Operating costs are generally lower, on the order of $200-300 per acre; 1-3 acres can be rotovated per day. If contracted out, the approximate cost of these techniques is on the order of $1500 per acre. This operating cost is slightly lower than for harvesting, though the operation takes 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 the rotovator (or equivalent) will require an Article 15 permit to be issued by the local NYSDEC office. Inside the Adirondack Park, the Adirondack Park Agency (APA) requires a permit for any activity that disrupts the plant community in a wetland. This includes the area within a lake that supports the growth of plants.

- *History and Case Studies in NYS*

There is only a short history of the use of rotovating and hydroraking in New York State, and specific examples have not been reported for any New York State lakes. The most extensive use of these techniques has occurred in British Columbia, with some intermediate-term success in controlling Eurasian watermilfoil.

- *Is That All?*

Rotovating is not a commonly used control technique in New York State. It is a relatively new procedure that has not been used frequently enough to evaluate its effectiveness (Newroth and Soar, 1986). It has the potential to be more effective than mechanical harvesting, since it involves cutting and removing the roots, in addition to the plant. However, it can have much more significant side effects. Unless fragmentation is controlled, the vegetation problem can become worse due to the regrowth and infestation in areas of the lake away from the treatment area. The disturbed sediment may cause excessive turbidity and contribute to nutrient release from either recently exposed sediment (underneath the removed sediment) or suspended rototilled sediment. Unlike the equipment used in several other physical control techniques, the rototiller displaces the plants from the sediment without removing the cut plants and roots from the water. Provisions must be made to remove the cut plants from the surface of the water before they are transported downstream or disperse great distances**.**

Rotovating is primarily used for vegetation control around docks and swimming areas. Larger areas usually are not rototilled due to the increased potential for fragmentation from uncollected cut stems and roots. In areas inaccessible to the rototiller barge, the rototiller boom may be maneuvered between docks and otherwise shallow areas. Any limits to the maximum depth for rotovating are imposed by the height of the rototiller boom and/or winch cable.

This technique may need to be performed several times per year, depending on the density of weed beds, growth rates, and types of vegetation. Regrowth can be somewhat lower for rototilled weed beds, since the root systems have been removed more completely than does hydroraking.

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

4. Dredging

- *Principle*

Sediment removal involves dredging bottom sediment from a lake to increase the depth, control of nuisance aquatic vegetation and nutrient release from sediments, and removal of toxic substances.

Dredging projects take the form of either drawdown excavation or in-lake dredging. During drawdown excavation, water must be pumped or drained from the lake basin and the resulting muds dewatered (dried) sufficiently to accommodate heavy earth-moving equipment. The exposed sediments can then be dredged.

Where it is difficult or impossible to drain a lake, hydraulic and bucket dredges have proved effective in removing nutrient-rich sediments that can promote excessive weed growth. Cutterhead hydraulic pipeline dredges are most commonly used to remove lake sediments as an in-lake dredging operation. These dredges can operate anywhere on the lake, cutting to a depth of 18 meters. The system is operated from a floating steel hull, moved by raising and lowering vertical pipes ("spuds") to "walk" the dredge forward. The cutterhead typically consists of three to six smooth or toothed conical blades, mounted on a movable steel boom or ladder at the bow of the platform. When the cutterhead is lowered to the lake bottom and moved from side to side, the rotating blades loosen the sediments, which are transported to the pickup head by suction from the dredge pump. The sediment slurry (10-20% sediment and 80-90% water) is then pumped through a pipeline for discharge at the disposal site. Such slurries require relatively large disposal sites, designed to allow adequate residence time for the water to evaporate.

Most cutterheads have been designed to loosen sand, silt, clay or even rock. Few, if any, conventional cutterheads have been designed to remove soft, loosely clumped sediments. Although they are effective, most of these machines are not the most efficient means of dredging lakes. However, specialized dredges have been designed specifically for use in lakes, and can be trailered from lake to lake. Some of these use a horizontal auger to move the sediments to the suction pipe, reducing resuspension and turbidity associated with other cutterhead dredges.

Grab-type bucket dredges use a bucket rather than a cutterhead, and remove drier sediments rather than concentrated slurries. They are used only in special situations, most commonly around docks, marinas and shoreline areas. They can be easily transported to different areas within a lake or to different lakes. Their performance is not hampered by stumps and other debris that may impede cutterhead dredges. Bucket dredges have some disadvantages, however. The sediment must be dumped within the radius of the crane arm, onto a barge or into a truck on shore. It is a time-consuming process. The operation also creates turbidity and can leave the bottom "chewed up" and uneven.

Equipment selection will depend upon factors that include availability, cost, time constraints, the distance over which the slurry must be transported, and the characteristics of the dredge spoils. The design of the disposal area depends upon the amount of dredge spoils that must be contained. In addition, the size of sediment grains and the settling characteristics of the dredged materials are important factors to consider if any suspended solids will be discharged in water from the disposal site. The project will need a permit for such discharges.

- *Target Plants and Non-Target Plants*

As with most of the other strategies that mechanically remove plants, selectivity is limited to targeting only monocultural beds. However, selectivity is also affected by the logistic considerations associated with the dredging project- whether it is limited to shallow water, or certain sediment types, or the depth of material removed. Each of these considerations may result in selectively removing only those plants growing in these circumstances.

- *Advantages*

Dredging may help control weed growth in several ways. Plants and the nutrients entrapped within the plants are physically removed by the dredging process. The bottom sediment, which contains the root system of the plant and serves as a nutrient reservoir for plant and algae growth, is also removed. In addition, dredging serves to reduce rooted vegetation growth by increasing the lake depth and reducing the amount of sunlight that reaches the sediment. Since plants require sunlight for growth, reducing the light levels will reduce the plant levels. This will be “permanent” as long as light transmission is limited by water depth, although a shift in aquatic plant communities (from shallow water to deepwater –dominating plants) may change plant growth patterns.

In lakes where nutrient loading from sediments is a major factor affecting nuisance weed and algae growth, sediment removal may improve the overall water quality. Dredging removes the top layer of sediment, which contains the most biologically available nutrients and participates most readily in sediment-water interactions and exchanges. If heavy metals and other toxic materials are present in bottom sediments, dredging these sediments can reduce the concentration of these hazardous substances in the sediments, and ultimately in the overlying water and organisms living in the sediment and water.

Dredging has proven to be an effective control technique for many lakes for increasing mean depth, reducing excessive vegetation levels, controlling nutrient release from sediments, and reducing the concentrations of toxic substances in sediment. It has been used for the entire lake basin in small lakes, or only a small portion of the basin for large lakes.

It is one of the few multi-purpose aquatic plant control strategies. Sediment removal is used to deepen a lake for recreational and navigational purposes. Deepening a lake may be the only recourse when the lake has become too shallow for boat navigation, swimming and fishing. Other control methods such as adding chemicals or installing bottom barriers are of little use when water depth is no longer sufficient for the lake's intended uses.

- *Disadvantages*

If dredging is not done properly, it can actually make lake conditions worse by causing excessive turbidity, fishkills and algal blooms. As a result, dredging projects should be accompanied by an extensive water quality monitoring program. The main problems occur when bottom sediments mix with lake water during the dredging process. This can happen while the sediments are being removed or when return water from a hydraulic dredging settling basin is discharged back into the lake. Nutrients, toxics and other contaminants may be carried back into the lake. Many of the problems of resuspension can be minimized by the proper selection of specialized dredges.

Dredging can harm fish, not only by causing turbidity but also by eliminating the benthic organisms upon which the fish feed. After the dredging of a lake, it could take two or three years for benthic fauna to become re- established. For this reason, it is advisable to leave a portion of the lake undredged.

Disposal areas for dredged sediments ("spoils") should be selected carefully. Because the muck will blanket vegetation and can kill it, disposal is unsuitable in woodlands, floodplains or wetlands. A carefully engineered and diked upland area may be the best option. Any disposal site should be fenced to keep out people and animals. In addition, dredging is usually very expensive, and the permitting process can be quite significant (and may ultimately result in the denial of a dredging permit for a variety of reasons).

- *Costs*

Costs vary depending upon site conditions, desired depth of excavation, available access, nature of the sludge, disposal, transport and monitoring arrangements. Treatment costs per acre of surface area (typically cut to a depth of about 3 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, as may be the case for municipal lakes.

Case Study- Dredging

Lake Setting: Ann Lee Pond, once known as Saw Mill Pond, is a 10 acre pond outside of Albany used for agricultural and commercial operations for the first Shaker settlement in American in the late 1700s. In recent years, it has been used solely for non-contact recreational purposes- fishing and ice skating- and supports wildlife observation and nature walks.

The Problem: By the early 1970s, the lake was highly productive, with a dense surface coverage of submergent, floating, and emergent aquatic plants throughout the lake, primarily water lilies (white and yellow), curly-leafed pondweed, coontail, and common waterweed. The lake was also characterized by algal blooms, and an accelerating sedimentation and filling rate. After evaluating a number of lake management alternatives, the Albany County Environmental Management Council authorized a hydraulic dredging project for the lake to facilitate the reduction of nuisance aquatic plant growth in the lake, 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; the hydraulic dredging removed about 16,500 cubic meters of mostly organic sediment in about 7 acres of the lake in 1980, increasing the average depth of the lake to about 2 meters.

Results: Water quality changes in Ann Lee Pond were not significant during or after the dredging operation. Dissolved oxygen levels increased, whether due to the removal of oxygen demand exerted by the sediment organic matter or the rooted aquatic plants. The density and coverage of water lilies decreased as a result of the dredging project. All of the common submergent plants became re-established after the lake stabilized after the dredging operation was completed in the fall of 1980. The curly-leaf pondweed recolonized at levels comparable to those measured before the dredging. Coontail densities decreased significantly, while the common waterweed levels increased in abundance.

Lessons Learned: Dredging is not likely to reduce submergent aquatic plant coverage unless the final water depth prevents sunlight from reaching large portions of the lake bottom, although there may be a shift in the kinds of plants growing in the lake. However, the density of plants limited by greater water depth- such as lilies- may be reduced as a result of the dredging

Source: Enviromed Associates, 1982. Final report: the monitoring of the restorational dredging of Ann Lee Pond, Colonie, New York. USEPA Phase II final report. Scotia, NY.

- *Regulatory Issues*

Any dredging requires a permit from the regional DEC office. Depending upon various factors, the project could require multiple permits, particularly if all or part of the dredged lake is classified as a wetland. In general, permitting for dredging projects involving less than 400 cubic meters of sediment is somewhat simpler for lakes regulated under Article 24 of the Environmental Conservation law (related to wetlands). The DEC Regional Permit Administrator should be contacted as early as possible when a dredging project is contemplated. In all cases, sediments should be analyzed for toxicity.

Dredging projects have been approved in most regions of the state, although those lakes for which overlapping regulatory agencies, or divisions within single agencies, require permits, such as those in the Adirondacks or whole-lake wetlands, these projects are rarely conducted. US Army Corps of Engineers permits may also be required if the project takes place in a "navigable" waterway.

Case Study- Dredging

Lake Setting: Collins Lake is a 70 acre urban lake in the village of Scotia (Capital District), used primarily for swimming and passive recreation by Village residents.

The Problem: The lake suffered from dense aquatic weed growth. While the lake was perhaps the first in North America with a confirmed identification of the exotic macrophyte water chestnut, which covered most of the lake surface in the early 1990s, aquatic herbicides and hand pulling shifted plant dominance to curly-leafed pondweed, another exotic plant species. The macrophytes beds eventually covered about 60% of the lake surface to a depth of about 10 feet. The significant recreational impacts (bathing and boating) and the high sedimentation rate (1 cm/year) triggered the need to dredge the lake to the depth of the littoral zone (10 feet).

The lake was hydraulically dredged intermittently from 1977 to 1994 (> 50,000 m^3 from about 10% of the lake bottom) as part of a federal Clean Lakes project (after nearly 10 years of resolving permitting issues) for controlling nuisance levels of curly-leafed pondweed.

Results: Prior to dredging, curly-leafed pondweed densities were approximately 170 stems per square meter during the peak of the growing season (mid May). In the portions of the lake not dredged, plant densities by 1988 were similar to measured prior to dredging- about 150 stems per square meter. The dredging dropped pondweed densities to less than 1 stem per square meter in 1979, one year after dredging. Densities were still less than 6 stems per square meter by 1988. By the early 1990s, however, aquatic plant communities in the lake were controlled by Eurasian watermilfoil.

Lessons Learned: While the dredging was successful in dramatically reducing existing plant populations, this ultimately resulted in a shift from curly-leafed pondweed to deeper-dwelling plants (Eurasian watermilfoil). 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 (either trading different kinds of "weeds" or a shift from weeds to algae or vice versa) in response to active management. This also shows that in-lake management without active watershed management may limit the effectiveness of the control measures.

Source: Tobiessen, P., Swart, J. and S. Benjamin. 1992. Dredging to control curly-leafed pondweed: A decade later. J. Aquat. Plant Manage. 30: 71-72.

- *History and Case Studies in NYS*

Small-scale dredging projects, particularly drawdown excavation, are much more common that in-lake or hydraulic dredging projects, although navigational dredging (to deepen a waterway to open or enhance navigation) and dredging to clean up contaminants is more common in river systems and some portions of lakes. These projects including dredging on the Great Lakes and Cumberland Bay in Lake Champlain, and Collins Lake (see box). Excavation dredging was performed at Belmont Lake in Long Island for the control of fanwort in the early 1970s, and a number of lakes in the past (Central Park Lake, Hyde Park Lake and Van Cortlandt Park Lake in New York City, Steinmetz Lake in Schenectady, Delaware Park Lake in Buffalo, Washington Park Lake, Tivoli Lake, Buckingham Lake, and Hampton Manor Lake in the Albany area, Scudders Pond in Long Island, etc.). There have also been proposed dredging projects (Lake Montauk, Glen Lake, Lake George, Cuba Lake, Tannery Pond, Quaker/Red House Lake, etc.) in recent years for navigation or water quality improvement rather than for weed control (NYSDEC, 2002). The removal of sediment as a medium to enhance weed growth (and water deepening) may result in reduction in nuisance weed growth.

- *Is That All?*

Dredging projects are probably the most difficult lake restoration technique to successfully complete. The costs are much higher than practically any other technique, while the potential for negative impacts can be extremely high. While the benefits of dredging can persist for much longer than these other techniques, most lake communities have not been willing to endure the entire environmental review and permitting process.

The public perception of such a drastic control technique is usually unfavorable. If mechanical harvesting can be equated to cosmetic surgery, then sediment removal is akin to a lobotomy. Even if lobotomies are shown to be successful, most people do not favor such radical treatments. Like a lobotomy, dredging can have profound effects on the entire body, in this case the lake ecosystem. Many of these effects are temporary or can be easily predicted, but many cannot be easily determined. Since many of these effects will depend on the specific conditions at a lake, it is extremely difficult to say if dredging is the correct treatment for a lake. It is radical, but it can be very effective.

Since dredging projects will not easily elicit the support of the local community, other management strategies should be considered first. Excessive rooted vegetation may be more simply controlled by mechanical harvesting, herbicides, or diver dredging. Nutrient release can be controlled by phosphorus precipitation and inactivation, and toxic materials may be more easily contained with sand and bottom barriers or chemical inactivation. Unfortunately, there may not be any other feasible management alternative for increasing the lake depth.

If, after considering all other options, dredging is still the preferred control technique, then a number of considerations may ease the process. The most important decisions are those dealing with public acceptance, equipment selection and disposal area design. To avoid future delays and ensure cooperation from all local environmental organizations and officials, it is critical to involve the lake community in the planning process. Residents who feel removed from, or ignored in, the design phase may serve to turn public opinion against the project. Dredging projects, especially those involving toxic materials, will always be confronted by people who attend the NIMBY ("Not In My Back Yard") school. This may become very apparent in the discussions concerning the site for the spoils disposal. Unanimous or near complete approval in any phase of the project may be needed in order to move to the next phase.

5. Biological Control: Herbivorous Insects

- *Principle*

In the 1980s, it was reported that the populations of Eurasian watermilfoil had crashed in the northern end of Cayuga Lake, one of the larger Finger Lakes, resulting in a shift in the plant communities from invasives to desireable native plants (see box below). Such a dramatic change in plant densities could have in theory been attributable to some combination of wishful thinking, illegal herbicide treatments, bad data, or better weather (an observation: when there doesn’t appear to be a logical explanation for a change in the status quo, for better or worse, it is often attributed to “the weather”, and sometimes that is actually correct!). However, in this case, an evaluation by Cornell University determined that the milfoil populations were being significantly preyed upon by an herbivorous aquatic moth, *Acentria ephemerella*, which, while not considered native to the area, was actually found in most nearby New York State lakes. Meanwhile, research on several fronts, including Vermont and Minnesota, found that similar damage was being inflicted on milfoil plants by a native herbivorous weevil, *Euhrychiopsis lecontei* and other insects in lakes and ponds in other locations in North America (Johnson, 2002; Creed, 1998).

The mode of action of these various herbivores varies somewhat. The aquatic moth lays its eggs down near the bottom of Eurasian watermilfoil plants. When the caterpillars hatch, they crawl up the plant and feed on the growing tips (**meristems**) of the plants through various stages of development. Research suggests that nearly one moth per stem of milfoil is necessary to significantly impact the plant populations. Once achieving adulthood (for two days only!), the adult males mate with the mostly wingless females, and then the female swims down to lay her eggs on lower plant leaflets. Two life cycles are generally completed during the summer. The caterpillars overwinter on plants near the lake bottom, and begin feeding in May.

The milfoil weevil adults swim and climb from plant to plant, feeding on leaflets and stem material. Females lay one egg per watermilfoil meristem per stem, usually two stems per day. Once hatched, the larvae first feed on the growing tip, and then mine down into the stem of the plant, consuming internal stem tissue along the way (Sheldon and O'Bryan, 1996). Weevils pupate inside the stem, and adults emerge from the pupal chamber to mate and lay eggs. In the autumn, adults travel to the shore where they over-winter on land. The weevils generally spawn 2 to 4 generations per year.

In recent years, a number of researchers and commercial interests have reared these herbivorous insects in the laboratory and have introduced these organisms through controlled stocking projects in a number of lakes in the northern United States, including several in New York State. The insects are attached to small bundles of Eurasian watermilfoil and placed within a small plot of targeted plant beds. Stocked areas are often quarantined from the rest of the lake, via buoys and signs, to minimize disturbance from boat traffic. It is anticipated that the insects migrate from the bundled plants to the beds and begin their growth cycles.

- *Target Plants and Non-Target Plants*

The milfoil weevil uses Eurasian watermilfoil as its sole host; while historically (as discovered during the earliest research in British Columbia) the weevil utilized northern watermilfoil (*Myriophyllum sibericum*) as its host, it appears to have adapted or evolved to Eurasian watermilfoil. The aquatic moth has been shown to inflict damage on several submergent aquatic plants, but the damage to other plants (besides Eurasian watermilfoil) appears to be superficial.

- *Advantages*

Herbivorous insects appear to be the ideal control agent. They are small and unobtrusive, often invisible to even interested observers. Both the weevil and moth impact the growth of Eurasian watermilfoil, with no or very minimal damage to native plants that might thrive in the absence of the Eurasian watermilfoil, and no apparent damage to other parts of the aquatic ecosystem. This makes this plant management strategy unique among all of the control methods discussed here. The relative slow reduction in plant biomass minimizes the risk of inducing significant oxygen loss through microbial breakdown of the decaying plant matter.

This is a very "low maintenance" control strategy- once the insects are stocked, and buoys or signage sited to minimize disturbance, no work is required to allow the insects to do their work.

Monitoring conducted by Cornell University researchers have found both the milfoil moth and weevil to be either native or **naturalized** in most of the surveyed lakes in New York State. Although the aquatic moth is not considered to be a native herbivore in New York, this naturalized organism appears to have adapted to New York lakes, and thus large-scale stockings or planned introductions are unlikely to create significant disruptions.

Case Study- Herbivorous Insects- Natural Control

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 was first reported in the lake in the 1960s, and grew abundantly after Hurricane Agnes in 1972, dominating the aquatic plant community until the early 1990s.

Findings: Aquatic vegetation surveying conducted from 1987 to the late 1990s identified a crash of Eurasian watermilfoil populations in the early 1990s. While mechanical harvesting (through the state-funded Aquatic Vegetation Control Program) occurred in several locations in the lake at this time, the milfoil decline was attributed to herbivory caused by the milfoil moth, *Acentria ephemerella*. Native plant populations in the lake increased dramatically over the same period, resulting in no measurable change in overall aquatic plant biomass after the onset of moth herbivory (overall plant populations were found at a greater density in the southwest end, and a lower density in the northwest ends of the lake):

Plant Species	% Plant Community Before Onset of Herbivory*	% Plant Community After Onset of Herbivory*
Eurasian watermilfoil	58-95%	<1 – 11%
Eelgrass	24% (northwest end)	54% (northwest end)
Common waterweed	3% (southwest end)	50% (southwest end)
Total Plant Biomass	100%	70% (northwest end) to 300% (southwest end)

*herbivory first reported as significant around 1991

Eurasian watermilfoil populations steadily decreased in the northwest end of the lake, stabilizing at very low densities (< 0.5 grams per square meter) after 1995, while milfoil populations rebounded slightly by the late 1990s in the southwest end of the lake, although milfoil biomass remained < 10% of the overall aquatic plant community throughout this "recovery" period.

Lessons Learned: Although this was not a case involving a planned introduction of herbivorous insects- this reflects native populations and natural control- it does demonstrate the potential for control of Eurasian watermilfoil by these insects

Source: Johnson, R.L, P.J. Van Dusen, J.A. Toner, and N.G. Hairston. 2000. Eurasian watermilfoil biomass associated with aquatic herbivores in New York. J. Aquat. Plant Manage.38: 82-88.

Perhaps most importantly, they are considered a "natural" control mechanism that avoids the introduction of noisy and ungainly machines, plant killing chemicals, or other conspicuous signs of the intensive efforts that often accompany the battle against invasive weeds. These natural populations may have the ability to adapt to small changes in the natural environment (shifts in water quality or temperature) and may be immune to other lake changes that negatively impact other management techniques, such as change in bottom substrate, shifts in native plant communities, or high flow (Solarz and Newman, 1996).

- *Disadvantages*

The practice of rearing, transporting, and stocking herbivorous insects has not successfully replicated what Mother Nature has done in several New York State lakes. Part of this problem has been due to a problem with scale. The lakes that have experienced successful milfoil control via indigenous populations of these herbivorous insects have shown to have upwards of 2 insects per milfoil plant, which can be extrapolated to literally millions of these insects chomping away at these plants, numbers several orders of magnitude larger than what has been “produced” in all of the labs and commercial operations in the business of making bugs. Moreover, even if these bugs could be more readily mass produced (and a lake community would be willing to pay for all those bugs), it could be argued that the reason that many of these lakes do not have naturally high densities of these insects is that these lake environments are simply not hospitable to large populations, either due to competitors, predators, or other impediments to their survival. Moreover, some New York State lakes with naturally high levels of these insects still are overwhelmed with Eurasian watermilfoil beds, suggesting that more than just lots of insects are needed to control milfoil growth.

Lakes experiencing milfoil damage due to weevils have often experienced a rebound in the fall, when regrowth and re-establishment of milfoil beds results from diminished predation from the weevils, and the onset of milfoil damage can be delayed beyond the start of the recreational season.

Herbivory is greatly (negatively) affected by harvesting, since this removes the habitat (and in many cases the actual organisms) for the insects. The same may also be true with extensive boat traffic, although this rarely results in widespread destruction of near-surface plant communities. Since the weevils overwinter along the shoreline, the lack of shoreline substrate (vegetation, leaf litter, etc.), or the use of management techniques that alters either the water level (drawdown) or the makeup of the shoreline (benthic barriers, dredging), threatens their long-term survival.

- *Costs*

The costs for whole lake plant management using these insects cannot be easily determined, since none of the stocking projects have seen either the stocked insects spread to the entire lake or milfoil control beyond the limited stocking area. As a general rule, stocking costs have been approximately $1 per insect (weevil or moth), and about 1000 insects have been stocked per acre of milfoil, translating to about $1000 per acre.

Case Study- Herbivorous Insects- Active Management

Lake Setting: Lincoln Pond is a 600 acre lake along the eastern edge of the Adirondack Park, less than 10 miles from Lake Champlain.

The Problem: Like many Adirondack lakes, Lincoln Pond enjoyed highly favorable water quality conditions for many years, but (also in an increasing number of Adirondack Lakes), by the late 1980s, Eurasian watermilfoil was introduced into the lake through one of the public launch sites. By 1999, detailed surveys of the lake showed that milfoil grew densely (400-1200 grams per square meter) in about 120 acres in water up to 15 feet deep, resulting in impairment of recreational uses of the lake (bathing, boating, and other forms of non-contact recreation). Comparison of these results to historical data suggested that milfoil was taking over the lake at a rate of about 20 acres per year, potentially subjecting another 300 acres of littoral zone to weed infestation. These surveys also found native or naturalized populations of the milfoil weevil (*Euhrychiopsis lecontei*) and the milfoil moth (*Acentria ephemerella*), although both were found in insufficient numbers to significantly impact milfoil populations (generally < 0.2 per stem).

Response: The Lincoln Pond Association expressed strong interest in exploring natural (biological) means for managing the milfoil problem. 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 in the spring of 2000 to release approximately 20,000 second and third instar caterpillars (at a rate of 2 caterpillars per stem) in hopes of building a lakewide population of more than 0.7 moth caterpillars per milfoil tip. Prior to the caterpillar stocking, moth populations increased at some sites in the lake (though not in the stocked areas), as high as 0.4/stem, but they largely disappeared by the end of 2000. The same pattern was observed in 2001. Weevil populations, on the other hand, which were very low prior to the stocking, increased more substantially, to as high as 0.8/stem in several locations in the lake in both 2000 and 2001. It is believed that the weevils were naturally present in higher densities than found in previous surveys, and occupied and impacted the milfoil stems prior to the augmentation of the moths, preventing the moths from propagating on the milfoil 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 pumpkinseeds may have impacted recruitment of future generations of the moths.

Lessons Learned: We still have a lot to learn about augmented biological control (supplementing existing weevil or moth populations to enhance milfoil control), although continued research will ultimately help to improve the application of this promising lake management tool

Source: Lincoln Pond Study Group. 2002. Personal communication.

- *Regulatory Issues*

Herbivorous insects fall under the NYSDEC stocking policy, which requires an Article 11 permit. As of the time of this writing, a single annual permit has been issued for the stocking entity (academic researchers, commercial firm, etc.), with each stocking site (lake) identified on the permit. Although at present there has not been any distinction between stocking native insects (such as the milfoil weevil) and non-native insects (such as the milfoil moth), there may ultimately be some regulatory differences in projects that use these agents.

- *History and Case Studies in NYS*

Although recent surveys have indicated that both the milfoil weevil and moth are found in most surveyed New York State lakes, the history of herbivorous insect stockings in New York State lakes dates back only to the late 1990s. Aquatic weevils have been stocked in small plots in several small New York State lakes, including Lake Moraine in Madison County, Sepasco Lake in Dutchess County, Findley Lake in Chautauqua County, and Millsite Lake in Jefferson County, as well as an experimental stocking in Saratoga Lake. Each of these projects has exhibited some very limited successes, but in no cases have migration out of the treatment plots, or long-term reductions of milfoil beds, been observed. A more significant research project has involved the stocking of the aquatic moth in Lincoln Pond in Essex County (see above). This has been closely monitored for several years, although longer-term successes have also not been observed.

- *Is That All?*

Biological control in general, and herbivorous insect stockings specifically, remain a very promising but thus far elusive aquatic plant control strategy. **While in theory this should be identified as a lakewide control strategy, the limited use stocked insects in New York State lakes has resulted in only limited control of plants in small beds close to the areas where the insects have been stocked.** The potential benefits are substantial, and the promise of a “natural” control method, particularly in light of the very minimal side effects, remain very high. Nonetheless, it cannot be stated with any certainty that this promise will ultimately translated into a viable control strategy. The logistics of producing and distributing the very large quantities of insects required to reach a critical mass necessary to sustain a permanent population of herbivores have not yet been figured. The only limited on-going research has not achieved any significant breakthroughs in recent years, although it is anticipated that greater attention dedicated to invasive plant problems and management in recent years will ultimately translate into more research and funding dedicated to these methods.

So what does that mean for New York lakes? In short, none of the stocking projects in New York have led to milfoil control that can be attributed to the stocking, even in those lakes in which some milfoil control has been achieved through herbivory by indigenous populations. It is not yet known if this is due to inadequate stocking rates, predation on stocked insects by native fish, or premature evaluation of the results. It is hoped that continued research, larger scale stocking projects, and continued evaluation of existing projects will bring reports of successful stockings. Until then, however, it must be stated that herbivorous insect stocking remains at best a means toward plant management rather than an on-going success story.