Lakewide / Whole Lake Management Activities

1. Mechanical Harvesting

- *Principle*

Mechanical harvesting is the physical removal of rooted aquatic plants (macrophytes) from the lake using a mechanical machine to cut and transport the vegetation to shore for proper disposal. This is one of the most common methods of aquatic vegetation control in New York State.

The physical removal of macrophytes serves to eliminate the symptom of excessive vegetation growth.. Immediately after harvesting, swimming and boating conditions are improved. . Harvesting also serves to remove the nutrients, primarily phosphorus, stored in the plant structure thereby addressing one contributor to the cause of excessive rooted vegetation growth.

There are two different types of mechanical harvesting operations, single-stage harvesting and multistage harvesting. Typically single-stage mechanical harvester cuts a swath of aquatic plants from six to ten feet in width and from six to eight feet in depth. The harvester usually has two upright cutting bars and a vertical cutting bar. The cut vegetation is transported up a 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 via a shore conveyer to a truck for disposal.

The multistage harvester refers to two or more specialized pieces of equipment. The first machine moves through the lake with cutting bars similar to the single stage harvester, cutting the vegetation and allowing the plant's natural buoyancy to bring it to the surface. A second machine follows the cutter and rakes up the cut fragments for disposal. The cutting capabilities for the multistage harvester can be greater than the single-stage harvester; the depth can extend as far as ten feet and the width can be up to twelve feet.

With either harvesting method, the growth rates of some species of aquatic plants may require two or more harvests during the recreational season. This increases the costs and, especially when outside contractors are involved, can create scheduling challenges.

- *Target Plants and Non-Target Plants*

These techniques are generally non-selective since the mechanical harvesters cut most to all plants contacting the cutting bar. The machines cannot be easily maneuvered to selectively remove target plant species within diverse beds, particularly near the lake shoreline. Selectivity is limited to targeting only plant beds comprised of a single plant species. . In recent years, most mechanical harvesting operations in New York State have targeted Eurasian watermilfoil. Historically a wide range of native plants, from submergent plant species such as *Potamogeton amplifolius* (large-leafed pondweed), and floating leaf plants such as water lilies, have been the target of harvesting efforts.

- *Advantages*

Simply stated, mechanical harvesting works to remove excess vegetation. Management of macrophytes can be limited to boat channels, launch sites, swimming areas, other high use areas or areas where weeds cause safety concerns.

Case Study- Mechanical Harvesting

Lake Setting: Saratoga Lake is a 4000 acre, heavily used recreational lake in Saratoga County, at the foothills of the Adirondack Park.

The Problem: High 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. At the time, more than 50% of recreational users of the lake objected to the algae levels and water clarity (Koojoomjian and Clesari, 1973), and water clarity had dropped from about 5 meters in 1932 (with fully oxygenated conditions throughout the lake) to about 1.5 meters in 1967, with oxygen deficits beginning at a depth of about 6 meters.

In the 1970s, water quality improvements resulted from the diversion of municipal wastewater out of the watershed (one of the inflows was locally called "Gas Brook" due to the persistent sewage smell), the implementation of non-point source control measures on agricultural lands, and nutrient inactivation- these activities were funded in part by a federal Clean Lakes Project. However, in response to the increased water clarity, nuisance growth of Eurasian watermilfoil and curly-leafed pondweed dominated the littoral zone to a depth of about 4 meters. This resulted in a shift from an algae- to a macrophyte-dominated system, without significant improvement in recreational conditions (although walleye and bass fisheries may have improved). However, 75% of the lake residents indicated that the lake was "somewhat" to "much" clearer (Boylen et al., 1995). Water clarity improved from about 1.5 meters in 1967 to more than 3 meters by the mid-1990s (and higher in the late 1990s due to the introduction of zebra mussels).

Response: The Saratoga Lake Protection and Improvement District (SLPID), a local management and taxing authority authorized by the NYS Legislature in 1986, oversaw the use of two mechanical weed harvesters purchased in 1984 that cut from 500-750 acres of nuisance vegetation per year, operating 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:

Species:	Range of Biomass, 1982	Range of Biomass, 1994
Eurasian watermilfoil	40-1000 g/m^2	0-700 g/m^2
Curlyleaf pondweed	0-170 g/m^2	0-250 g/m^2
Southern naiad	10-400 g/m^2	0-450 g/m^2
Eelgrass	0-40 g/m^2	0-600 g/m^2
Water stargrass	0-140 g/m^2	0-30 g/m^2

Although mechanical harvesters are slow-moving beasts, they provide immediate relief from surface canopies and dense underwater growth of nuisance plants. The tops of the aquatic plants are cut, removing the growing leaves, nutlets and flowering parts of strongly rooted plants. Weakly rooted plants may be uprooted. For aquatic plants that propagate primarily from seed banks or nutlets, such as water chestnut, removing the top of the plant (which usually carries the seeds) prior to the maturation of the seeds can eliminate the following year of growth. Multiple years of harvesting may serve will gradually deplete the bank of seeds in the sediments. Harvesting operations, as opposed to cutting, will remove the nutrients stored within the plant material. It has been estimated that this may comprise as much as 50% of the internal (sediment-bound) load of nutrients that might otherwise migrate into the overlying water and become available for algae growth.

Harvesting will usually result in continued blanketing of the lake floor by the lower portion of standing aquatic plants. This will provide continued cover and habitat for fish and other aquatic life at the same time that recreational uses are supported by the reduction or loss of the plant canopy.

- *Disadvantages*

The most significant side effect of mechanical harvesting is fragmentation. Fragments of cut plants that are not picked up and removed can move from the treatment area by wind or currents, spreading the plant to other portions of the lake or to downstream water bodies. This can result in enhanced propagation of those plants that spread primarily from fragmentation, such as milfoil.

Case Study- Mechanical Harvesting (cont)

Some species were more abundant in 1982, while others were more abundant in 1994. Eurasian watermilfoil populations were substantially reduced in shallower water- up to depths of about 1 meter- but this was probably due to the winter drawdown 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% of the lake residents identified rooted aquatic plants as at least a minor problem. This included impacts due to weed decomposition and floating weeds cut by boats or harvesters. 40% identified this problem as significant. However, about 60% viewed the harvesting program as successful (versus about 70% for the sewering and drawdown conducted through the Clean Lakes Program).

The harvesters were replaced by larger, more efficient machines in the late 1990s, and the SLPID has been investigating an integrated approach to aquatic plant management, conducting small-scale experiments since 2000 on the use of aquatic herbicides and herbivorous insects (while continuing the use of the mechanical harvesters).

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 palatable alternatives. For a lake this size, however, it is an expensive operation.

Sources: Boylen, C.W., L.W. Eichler, and T.B. Clear. 1995. An aquatic plant assessment of Saratoga Lake. RPI publication. Troy, NY.

Hardt, F.W., G. Hodgson, and G.F. Mikol. 1983. Saratoga Lake Phase I Diagnostic-Feasibility Study and Management Plan. USEPA Clean Lakes Program. 236pp

Kooyoomjian, K.J. and N.L Clesari. 1973. Perception of water quality by selected groupings in inland water-based recreational environments. Rensselaer Polytechnic Institute report 73-7. Troy, NY.

Plant communities may be altered by harvesting. If both native and fast-growing exotic plants are cut to the same degree, the exotic plants, often the original target for harvesting, may grow faster and dominate the plant community. This is especially true for plants that propogate by fragmentation.

An improperly designed or executed harvest can have other unnecessary side efforts. Small, slowmoving fish may be trapped in the cutting blades or removed by the conveyer. If all cut vegetation is not removed, oxygen levels may temporarily fall and nutrient levels, such as phosphorus, may rise. Turbidity resulting from the harvesting process is also usually short-term.

The logistics involved with harvesting result in some disadvantages to the use of this technique. Many lakefront property owners are frustrated with the inability of the harvesting equipment to operate in shallow areas near docks and shorelines. 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 far away from the areas to be harvested, a lot of time is spent traveling between the sites.

Mechanical harvesting is not universally accepted. Many lake residents recognize that it is, for the most part, a cosmetic treatment, treating only the symptoms of a more pervasive water quality problem. An appropriate analogy to mechanical harvesting is mowing the lawn. Neither harvesting nor mowing will prevent re-growth, or even provide any significant long-term control. Both methods are used to provide a cosmetic control of excessive growth and sustain popular recreational uses. The long-term benefits derived from harvesting do not approach the benefits of other cause-, or source-based management strategies.

Due to the slow cutting rates and relatively narrow cutting band, the harvester may need to be on the lake throughout the summer during most daylight hours. The perpetual presence of the machine is objectionable to some residents and may be an obstacle to jet skiers and water skiers. Others may become frustrated over the time required to get local weed beds harvested. This problem is exacerbated by the limited areas available for harvesting due to shallow water or confined navigational corridors, unfavorable weather conditions, and down-time for mechanical repairs. 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. Leasing a harvester can reduce the overall costs; however, since harvesting may be required at least once yearly, leasing costs will quickly overtake purchasing costs.

- *Costs*

The cost at time of printing for the equipment averages between $100,000 and $200,000 for the harvester and shore conveyer. The harvester can cut approximately one acre of aquatic plants every 4-8 hours, depending on the size of the harvester and density of plants, and costs about $200-300 per acre to operate. The time and costs will vary greatly depending upon the type and densities of the aquatic plants being harvested. The numbers shown here are averages for North American lakes infested predominately with Eurasian watermilfoil.

Mechanical harvesters can also be leased. A typical leasing price in New York State is approximately $150-300 per hour, usually with an additional set-up, transport, and sitting fee of about $300.

- *Regulatory Issues*

The regulations governing mechanical harvesting vary within the state. Inside the Adirondack Park, the Adirondack Park Agency (APA) requires a permit for any activity that disrupts the plant community in a wetland, including the area within a lake that supports the growth of plants. Harvesting outside of the Adirondack Park is not regulated except in cases where the harvesting is within or adjacent to classified wetlands. In these circumstances, a permit from the local NYSDEC regional office may be necessary. Contact the Environmental Permits staff at the local DEC office for further information.

- *History and Case Studies in NYS*

Mechanical harvesters have been seen on lakes large and small throughout the state for many years, although in recent years the use of herbicides has largely superseded harvesting as the most common means for “whole lake” control of nuisance plants. While the use of harvesters in New York State dates back at least to the 1950s, the most significant regional activities originated with the advent of the Aquatic Vegetation Control Program in the Finger Lakes region in the late 1980s. In this program, state (member item) funds were provided to several counties in the Finger Lakes Region to conduct a variety of lake management activities. In some counties, this included the purchase of mechanical weed harvesters or harvesting services for several Finger Lakes, embayments to Lake Ontario, and some smaller waterbodies in these counties. The harvesting program at Chautauqua Lake has been used to evaluate nutrient removal from harvesting operations. Large lakes outside of the Finger Lakes region that have been harvested include Lake Champlain and Oneida Lake (for water chestnut) and Saratoga Lake and Greenwood Lake (for Eurasian watermilfoil). A statewide inventory of lakes that utilize mechanical harvesters has not been compiled, in large part due to the lack of regulatory oversight (and therefore a paper trail of permits) in most parts of the state.

- *Is That All?*

In summary, harvesting is one of the most common and publicly-acceptable methods for controlling rooted aquatic vegetation. Harvesting opens most recreational areas and navigation channels, and removes unwanted vegetation covering the surface of the lake. The few ecological side effects are considered minor relative to the overall benefits, activities in other portions of the lake are not greatly affected, and in many communities, the harvested plants are dried and used as compost and lawn fertilizers.

Since an aquatic harvesting program is aimed at controlling nuisance levels of vegetation, the species of plants and their growth patterns should be identified before harvesting. This will help target the areas that should be controlled, with an approximate date when the aquatic plants will begin to cause some impairment to use. When a harvesting schedule is set up, the lake shore property owners should be informed of where and approximately when harvesting will take place. Several criteria should be examined before establishing this schedule.

Initially, harvesting should involve the areas where the greatest public use is impaired. The type of use will determine the extent and type of harvesting. Fishing areas only need open lanes, but swimming and most boating activities will require large areas free from plants at or near the surface. Areas with significant weed beds will take longer to harvest due to time lost in unloading the conveyer away from the treatment area.

Certain areas should be restricted from harvesting either because they are important as a fishery or wetland area or because they receive little or no use. These areas should be identified before the harvesting program begins each year. The regional DEC office can help determine the location of any important fisheries or wetland areas.

The location of unloading sites should be identified and mapped before the harvesting season begins. If a site is located on private property, it may be prudent to sign a contract with the owner to protect against liability claims. These sites should have suitable conditions to enable the harvester to get close to shore and allow a truck access to load the harvested weeds for disposal. The selection of these sites may dictate where you can or cannot efficiently harvest on the waterbody.

2. Drawdown (Water Level Manipulation)

- *Principle*

Drawdown involves manipulating the water level of a lake to expose rooted aquatic vegetation and sediments to freezing and drying conditions, which serves to affect the growth of the plants. When the lake level is lowered in winter, some species of rooted plants and their seeds can be severely damaged or killed by two to four weeks of freezing and drying. However, other species that are resistant to freezing are unaffected, and some species may actually be enhanced by this technique, either through increased growth rates, or decreased competition from other species. Drawdown is best used once or twice every three years to discourage the establishment of resistant plant species, which are often the non-native or exotic plants that were originally the target of the drawdown.

In New York State, drawdown usually occurs between December and April. For drawdown to have any significant effect, the water level must be lowered at least three feet, exposing the plants to winter conditions for at least four weeks and exposing the sediments to the freezing and drying action of cold air. The bottom sediments must freeze to a depth of at least four inches. In mild winters, snow cover may insulate the sediments and prevent freezing.

Ice may help control weeds by loosening roots and loose organic material on the exposed lake bottom. The drying action may also serve to limit the availability of nutrients, particularly under low oxygen conditions, by compacting the loose upper layer of sediment. This reduces the potential for resuspension of this sediment and the nutrients adhering to the sediment.,.

- *Target Plants and Non-Target Plants*

Since this mode of control involves freezing and desiccation, seed producing plants, in general are not as strongly impacted as those that reproduce vegetatively (fragments and rhizomes). Some seed-dependent (seed-abundant?) plants may increase in density or coverage during and after the drawdown. The following is an incomplete list of common submergent aquatic plants in New York State and the impact of winter drawdown on their populations:

- *Advantages*

Drawdown is a fairly simple management strategy, particularly for residents of relatively small lakes with full control over water level. This method creates an unfavorable environment for many of the nuisance aquatic plant species, such as Eurasian watermilfoil and fanwort, and selects for beneficial plants. 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 wildlife.

The water level can be (re-) manipulated as frequently as needed, by adding or removing boards or controlling the value, although the lake response time will almost certainly not be immediate. This also allows time for other lake management activities, such as cleaning up the shoreline, repairing docks or retaining walls, and cleaning or otherwise maintaining erosion control structures.

Case Study- Drawdown

Lake Setting: Galway Lake is a 500 acre lake in the Capital District region of New York, represented by a lake association of approximately 500 members in mostly seasonal dwellings. The maximum depth of the lake is about 25 feet, and a good portion of the lake is comprised of areas flooded by a dam constructed in the 1850s to provide power and water for the downstream textile mills.

The Problem: Extensive milfoil beds took over large portions of the littoral zone, within a band between 7 and 14 feet deep, in the late 1980s, impacting recreational uses of the lake (despite the lack of motorized boat traffic). The formation of surface canopies in much of the littoral zone resulted in an infestation of more than 100 acres lakewide.

Response: Based on an evaluation that milfoil was light limited at depths greater than 14 feet and frozen out at depths below 7 feet, the lake association elected to draw the water level down to a depth of about 16 feet in 1989 (this was also conducted to repair the dam). Deep drawdowns were relatively common in the lake prior to the 1940s, and engineering studies concluded that the likelihood of the lake refilling to full capacity by the following spring was greater than 50%. Channels were cut by volunteers to prevent ponding.

Results: By the summer of 1990, milfoil densities had substantially dropped throughout the lake, limited to a very small number of isolated plants. The lake association did not receive any reports of fishkills (fishing was thought to be normal), and native plant populations (coontail, common waterweed, clasping-leaf pondweed, and macroalgae) were growing in the areas previously occupied by the milfoil. By the late 1990s, aquatic plant populations had steadily increased, reaching the lake surface during much of the summer. An additional deep lake drawdown in 2000 resulted in a substantial drop in aquatic plant densities and coverage for the next several years, based on information collected at Galway Lake through the NY Citizens Statewide Lake Assessment Program (CSLAP).

Lessons Learned: Drawdown effectively controlled Eurasian watermilfoil populations, and there may have been some selective control, but the effect only lasted for a few years after the drawdown. However, even deep drawdowns (not practical in many lakes) will not prevent recolonization of milfoil, particularly if the target plants are found in neighboring lakes or otherwise continue to enter the lake.

Source: Aronstein, J. 1998. Personal communication.

- *Disadvantages*

Drawdown is limited to lakes that have either a dam structure, or some other mechanism for controlling lake level.

Drawdown can result in the loss of a substantial volume of lake water when the deeper portions of the littoral zone are exposed, especially in shallow to moderately deep lakes with large littoral zones. This can also result in substantial impacts to adjacent wetlands or other areas with desirable vegetation, although the impacts to many traditional wetland plant species can be variable.

Effect of Winter Drawdown on Common NYS Macrophytes*

Decrease After Drawdown	**No Change or Variable**	**Increase After Drawdown**
Cabomba caroliniana (fanwort)	**Typha latifolia** (cattail)	**Potamogeton spp.** (most pondweeds)
Myriophyllum spp. (milfoils)	**Vallisneria americanum** (eelgrass)	**Najas spp.** (naiads) **except Najas quadalupensis** (southern naiad)
Potamogeton robbinsii (Robbins pondweed)	**Chara spp.** (muskgrass)	
Nuphar spp. (yellow water lily)	**Elodea canadensis** (common waterweed)	
Utricularia spp. (bladderwort)	**Brasenia schreberi** (water shield)	
Ceratophyllum demersum (coontail)	**Trapa natans** (water chestnut**)**	

*- adapted from Holdren et al, 2001

If the lake is shallow and the sediments and inflow have a high oxygen demand, winter drawdown can deplete oxygen, and fishkills may result. Nutrient release may also be enhanced, causing algal blooms. In such cases, hypolimnetic [define] aeration may be necessary.

The removal of macrophytes along the shore may increase turbidity due to wind-induced erosion and/or re-suspension of sediments. Some lakes with complete drawdown can experience algae blooms after refilling. Another problem could be the emergence of new, or previously unnoticed, plant species that are enhanced or unaffected by drawdown. These plant species may prevent the regrowth of native plants, and without competing species, may grow to levels greater than those prior to drawdown.

Drawdown that does not result in timely refilling of the lake may leave water intake pipes exposed to the same elements as the targeted plants. This might result in the pipes freezing or not being below the water level during the winter and spring (and perhaps later).

- *Costs*

If the lake has means for controlling lake level, such as a dam or controllable spillway, costs are negligible unless pumping is needed to reduce the lake level, or if aeration is necessary.

- *Regulatory Issues*

Article 15, Title 8 of the Environmental Conservation Law defines regulations relating to the volume, timing, and rate of change of reservoir releases. These specifications are designed to ensure that an adequate supply of water is available for public and personal use and for power production, and to provide for the health and safety of local residents in the event of drought or emergency conditions. Title 8 also specifies requirements in monitoring, inspection, and maintenance of records, in addition to reporting and investigations by NYSDEC. When drawdown significantly affects navigability of these waters, the NYS Navigation Law may also apply. These regulations may be appropriate for either drawdown or hypolimnetic withdrawal [what is there, not previously covered in this chapter – if not relevant here delete sentence..

In addition, wetlands regulations require a permit for the use of this technology, particularly since in many cases drawdown may be incompatible with the benefits derived from wetlands. [when wetlands nearby but not contiguous with the lake are affected by the change in water level? Shoreline wetlands?]

- *History and Case Studies in NYS*

Drawdown has been commonly utilized at many New York State lakes, most often for benefits not associated (or directly geared toward) aquatic plant control. The NYS lakes for which drawdown was used as a weed control method include Galway Lake (Saratoga County), Saratoga Lake, and Greenwood Lake (on the New Jersey/New York border), and some of the lakes in the Fulton Chain of Lakes (interior Adirondacks) for controlling Eurasian watermilfoil, Forest Lake in the southern Adirondacks to control Elodea and pondweed, and Minerva Lake (southern Adirondacks) for the control of native plants. Most of these have been fairly successful, although immediately after drawndown a different mix of invasive plants have often colonized and dominated the aquatic plant community before the lakes reached equilibrium after a few years. For example, the dominant plants in Robinson Pond (Columbia County) shifted from Eurasian watermilfoil to bushy pondweed after the lake was regularly drawn down (for maintaining fisheries habitat downstream rather than for weed control), although this shift reversed several years later.

- *Is That All?*

In summary, water level manipulation is one of the most common lake management techniques, not only for the control of nuisance aquatic vegetation, but also for repairing dams and docks, and as part of dredging and bottom screening techniques. It is a simple and readily acceptable control technique, due to the low cost and the timing (corresponding to the winter, not the summer recreational season). Since most nuisance vegetation problems occur in the shallow littoral zone these area can be managed by drawdown without having a significant effect on the open water portion of the lake. Since no chemicals or significant mechanical equipment is used, there may be no visible changes in the lake besides the changes in vegetation levels.

In periods of normal or high precipitation, the potential side effects of drawdown are usually overridden by the benefits. However, if the lake is drawn too low, or during periods of drought,, water levels may take a long time to return to acceptable levels.It is critical to plan for a low precipitation summer when devising a drawdown schedule, for the residents and lake users may otherwise be denied use of the lake for much of the summer. This can reduce resident acceptance of this technique, and summer revenues from recreation and tourism. The concerns over "putting in another board" to raise the summer level will often dominate lake association meetings, and any management decisions to lower lake levels may be second-guessed if not ultimately rewarded by decreased weed growth <u>and</u> restored water levels.

3. Biological Control- Grass Carp

- *Principle*

Grass carp (*Ctenopharyngodon idella*, or white amur) physically remove vegetation from lakes. Beyond removing the nutrients entrapped within the plant, the grass carp does not reduce nutrient levels, or afford any control of the source of these nutrients. These are essentially "biomanipulation" tools- as a general class of lake management tools, biomanipulation is discussed in greater detail in Chapter 7.

Originally, they were imported to Arkansas and Alabama from Malaysia in 1962. The carp, less than one pound in weight and two feet in length (less than one foot may be preyed upon by largemouth bass), are stocked at a rate of about 15-40 per acre of surface area. They can grow up to 6 pounds per year, and may ultimately consume 20-100% of their body weight each day in vegetation. Carp can grow to several hundred pounds.

The fish will selectively feed on particular types of plants; although the carp are reported to have particular favorites among the plant species, these preferences may be a function of specific lake conditions, and eating habits may not be reproducible from lake to lake.

Only sterile grass carp (called triploid) are presently allowed for stocking in New York state, as in 14 other states (15 states allow both sterile and fertile carp, and 19 states do not allow importation of these fish). Grass carp have the potential to reproduce and eradicate all vegetation in lakes, and can escape downstream to other waterbodies and induce unwanted vegetation control or eradication. Grass carp have a strong tendency to follow flowing water, such as inlet and outlet streams. Unless these streams are adequately screened, the fish are likely to move out of the lake. Not only is the investment in fish lost, but the nuisance weeds remain in the lake, and the carp may destroy desirable aquatic plants in the streams.

In most of the 35 or so states that allow their use, grass carp are restricted to lakes with no sustainable outflow, to reduce the possibility of escape, and to maximize the control of vegetation within the target lake. However, fish cannot be expected to control weeds at a specific part of a lake, such as a beach or an individual dock. Since fish have access to the entire lake, grass carp treatment is necessarily a full-lake treatment.

Vegetation control with grass carp is necessarily slow, but could be effective over a long period of time. If only sterile carp are used, the time required for the carp to effectively control vegetation will depend on the density of vegetation, stocking rate, and growth rate of the carp. Projects using non-sterile carp will have to consider the reproduction rate, and the ultimate carrying capacity of the lake.

- *Target Plants and Non-Target Plants*

In general, most grass carp prefer most species of *Hydrilla*, *Potamogeton*, *Ceratophyllum*, *Najas*, *Elodea* and some filamentous algae, while some specific plants, such as *Myriophyllum spicatum* and *Potamogeton natans*, are considered less palatable (Cooke and Kennedy, 1989). However, in many cases, the grass carp will consume these less desired plant species in the absence of their favorites. Grass carp stockings in most New York State lakes have been directed toward control of Eurasian watermilfoil, in spite of the plant preferences indicated by the carp (perhaps this is akin to using children to reduce the world's supply of liver and onions).

Case Study- Grass Carp

Background: The majority of the grass carp treatments in New York State have occurred in the downstate region between New York City and the mid-Hudson. This is due in part to the proximity of these lakes to areas (Long Island and Orange County) where the work was conducted by the NYSDEC to evaluate the use (and permitting requirements) of these fish. However, this also reflects the higher degree of comfort lake residents in this area seem to exhibit for the use of this management tool. As such, the case studies evaluated here all come from this region.

Lake Setting: Walton Lake, a 120 acre lake in Orange County in the Lower Hudson River region of New York.

The Problem: Excessive growth of Eurasian watermilfoil

Response: in 1987, 400 grass carp were introduced at a rate of 10 fish per vegetated acre as an experimental project to evaluate the use of grass carp. The objective of the stocking was to reduce the vegetation biomass by 75%. Rooted aquatic vegetation levels, water clarity, and fish populations were monitored after the introduction, and stocking rates were varied to evaluate lake response to increasing predation by the grass carp.

Results: The initial stocking, and a supplemental stocking in 1989, resulted in an estimated abundance of 15 to 19 fish per vegetated acre and a biomass reduction of about 30% within two years. Selective grazing on preferred species increased Eurasian watermilfoil coverage on established transects by about 30% and resulted in a virtual monoculture of Eurasian watermilfoil. A third stocking increased the density of fish to 21-27 fish per vegetated acre and resulted in the complete removal of the remaining milfoil. Floating and submergent plants, such as water lily and spadderdock, were less dense than prior to stocking. In comparison, grass carp nearly eradicated rooted aquatic vegetation when stocked at 15 fish per acre in at least five nearby lakes and ponds. Rooted aquatic plant coverage had not substantially recovered more than ten years later.

During the initial study period, water clarity readings generally remained between 9 and 11 feet, suggesting macrophytes reduction did not result in increased algal blooms. Filamentous algae were also virtually absent. The take of largemouth bass (measured as catch per unit effort, or CPUE) declined from 1986 to 2001, for both large (greater than 12 inch) and small fish. Bluegill catch also decreased over this period, while the percentage of sunfish as part of the overall fish catch increased.

Lessons Learned: Grass carp stocking at lower rates (<15-20 fish per vegetated acre) results in initial submergent plant reductions, but milfoil and other less preferred species may actually increase in response to the greater available substrate. Higher stocking rates may result in eradication, with little long-term recovery. Fish densities and the makeup of the fish community may also change.

Source: NYSDEC. 2001. Experiences with using grass carp for aquatic vegetation control in DEC Region 3 with emphasis on Walton Lake.

- *Advantages*

Grass carp are perceived as a “natural” aquatic plant control agent (and are certainly among the “less visible” plant control strategies), even if they are not native to a lake, and as such this plant control method avoids some of the opposition to other more invasive or controversial control strategies. If stocked at a high enough rate, grass carp can significantly reduce weed populations within a year, although most acceptable (i.e. permittable) stocking rates in New York State are not high enough to result in significant first season control. In fact, 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, particularly in lakes with stocking rates kept fairly low to prevent eradication of all plants. As long as grass carp populations, particularly voracious younger fish, remain high, multiple years of control can be expected. Population dynamics can be well controlled due to the sterilization required for fish stocked in New York State lakes.

- *Disadvantages*

Grass carp do not meet any of the criteria for an "ideal" candidate for introduction to an aquatic system: they do not co-adapt with other aquatic species, do not have a narrow niche, are not easily controlled after escape, and are not free from exotic diseases and parasites.

The most significant drawback of using grass carp is the potential for complete eradication of vegetation. A complete removal of all types of vegetation may occur after the grass carp have exhausted the supply of target plants, and would have severe detrimental effects on the plant community and entire ecosystem. This is a distinct possibility in the event of overstocking; however, excessive growth of smaller populations of fish could cause the same problem. At the other extreme, understocking or insufficient consumption of vegetation may result in the control or eradication of non-target plants, since the eating habits of grass carp are not completely predictable. In the absence of competitive native species, this could allow the exotic target plants to dominate the plant community. Destruction of either native or exotic species could also have significant effects on the aquatic animals whose habitat (niche) is based on these plants. Altering fish habitats could have severe effects on zooplankton and phytoplankton populations.

Eutrophic conditions could be enhanced through a number of mechanisms. More than 50% of the ingested plant material could be reintroduced through excretion by the carp, primarily as particulate organic matter and urinary nitrogen. This nutrient recycling could stimulate algae blooms and oxygen depletion. Algae blooms may also result from the actual removal of rooted plants, since these plants may compete with algae for available nutrients. Even if the nutrient levels remain constant, algae populations may be enhanced due to the greater availability of these nutrients.

As an exotic, non-native fish species, grass carp may also introduce exotic diseases or parasites to a lake. *Cestodes*, a type of parasitic tapeworm, or flatworm, has been found in lakes in which grass carp were introduced. However, infestation can be minimized with the use of praziquantel ($C_{19}H_{24}N_2O_2$).

Grass carp can also escape downstream, particularly given their propensity to migrate to moving water, although permits are only issued in larger New York State lakes with inlets or outlets if steps are taken to prevent movement of the fish out of the lake (through screening or other means).

Case Study- Grass Carp: 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: Excessive growth of Eurasian watermilfoil. Lake Mahopac had a dense monoculture of Eurasian watermilfoil inhabiting most of the lake shoreline to a depth of 12-15 feet. Lake Carmel suffered water quality problems related to excessive nutrient and algae levels and poor water clarity for many years, and by the early 1990s, nuisance weed growth (primarily common waterweed and coontail) also plagued use of the lake. The lake was dredged in the last 1980s, and mechanical plant harvesting after 1986 enjoyed some success. Residents of the town served by the lake were opposed to the use of aquatic herbicides. Plant biomass surveys by the mid 1990s found biomass of 150-400 g/m^2 throughout 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% 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, typical of historical readings for the lake.

Results: *Lake Mahopac*: A private consulting biologist monitoring the results of the treatment report that, by 1995, the biomass of aquatic vegetation (including filamentous algae) had been reduced by 73% from pre-stocking levels. By 1996, vegetation had been reduced by 86% from baseline. In addition, reports through the NY 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.

NYSDEC fisheries surveys of the lake in the late 1990s revealed virtually no submerged rooted aquatic vegetation. Catch rates for largemouth bass (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% for bass over 15 inches. It is not known if this decline can be attributed to the grass carp, although many local anglers blame the decline to the loss of aquatic vegetation.

Lake Carmel: By 2002, 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 algae blooms (*Coelosphaerium* and *Microcystis*). Although largemouth bass continued to be the dominant fish species, about 15% of the fish were greater than 6” long; this suggests that the loss of refuge habitat for the young fish may affect future age classes of the fish.

Lessons Learned: Moderate stocking rates (10-15 fish per vegetated acre) can be effective at removing nuisance vegetation, but near total eradication of plants can occur at the higher end of this range. Water quality changes and fisheries impacts may also occur, although the few studies of the affects of grass carp have not been adequate to attribute observed changes solely to the loss of vegetation (and conversion of rooted plants to nutrients).

Source: NYSDEC Bureau of Fisheries 1999/2000 Annual Report-Warmwater Lakes and Ponds.

Grim, J. Personal communications. 2003.

Case Study- Antidotal Reports

The effectiveness of lake management activities are best evaluated through well-designed scientific studies that compare documented conditions prior to the treatment to conditions after the "treatment" has stabilized, particularly relative to conditions in nearby control lakes. That doesn't happen much. Most water quality problems or impairments to lake uses are well known but not well documented before locals decide to do something about it, and few control measures are supplemented with sufficient funds to analyze whether they worked (particularly given, or perhaps despite, the high cost of lake management). At some level, while this is understandable, it is also unacceptable, since without information about what worked and what didn't, it is difficult for the next generation of lake managers to make informed decisions about planned management activities.

Simple surveys can provide at least some of the information future managers need to evaluate the success and failure of a particular management strategy. One such survey is provided below, used by local residents of Plymouth Reservoir, an 80 acre impoundment in the Southern Tier (Central) region of New York with excessive weed growth (primarily Eurasian watermilfoil), to evaluate the use of grass carp one year after stocking, in 1994. This was followed up by the same survey, completed by the same lake residents, in 2004- the 1994 answers are reported as A1994, while the 2004 answers are reported as A2004:

Q. Did the carp adapt to their settings?
A1994. ***The carp appear to have adapted to their surroundings, as. only 1-2 dead fish were found***
A2004. ***Yes, the carp seem to adapt well. They have been observed at approx. 3+ feet in length feeding along the shorelines***

Q. Did you notice a preference for any food type (plant), and was this the target species?
A1994. ***We did observe (that) 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. Certain sections of the lake where milfoil had been dense, there was an obvious decrease in density. 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 2 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 1000 + 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. ***The aquatic plant populations were people swim and boat were noticeably less dense and thick.***
A2004. ***The weeds are noticeably less dense and thick. Hopefully, this is due to our weed control efforts but we have had heavier snowfalls in recent years, reducing the winter greenhouse effect on our shallow lake. Also with the darker color and particulates in the lake this may be diminishing the amount of sunlight filtering through to the plants***

- *Costs*

Grass carp offer one of the least expensive lake management techniques for controlling nuisance aquatic vegetation. Costs are a function of vegetation density and stocking rate, and usually run from $50 to $100 per acre, based on a "standard" allowable New York State stocking rate of about 10-15 fish per vegetated acre. These costs can be amortized over several years, since the grass carp application requires only capital expenses.

- *Regulatory Issues*

The New York State DEC regulates the stocking of grass carp through Article 11 of the Environmental Conservation Law. The NYSDEC maintains the existing policy of using sterile grass carp only for projects approved through a complete and thorough State Environmental Quality Review Act (SEQRA) process.

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 the Department of Environmental Conservation.
- 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 must be supported by a complete EIS (Environmental Impact Statement). Within the EIS review process, DEC could deny a permit to stock grass carp.
- In NY, DEC policy is to limit stocking rates to no more than 15 fish per surface acre for those ponds of 5 acres or less and size and when contained wholly

Case Study- Antidotal Reports- Grass Carp in Plymouth Reservoir (cont)

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 effects 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***

within the boundaries of land privately owned or leased by the applicant and the following conditions are met;

- Aquatic plants must significantly impair the intended use of the pond (and should
- 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 NYS regulated wetland.
- The lake/pond is not a natural or manmade impoundment on a permanent streams shown on USGS topographic maps.
- At least two years have elapsed from the date of the last stocking unless demonstrated that previous stocking had high mortality.

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 warn an association beforehand of any major obstacles to a project on any specific lake.

- *History and Case Studies in NYS*

There have been literally thousands of permits issued by the NYSDEC for the use of grass carp since 1991; the vast majority of these are for very small (< 1 acre "farm") ponds with no inlet or outlet and a single landowner. The majority of the stockings appear to be in Finger Lakes region and western New York (nearly 1000 every year), and in the downstate region (nearly 500 per year). The effectiveness of these stockings has not been documented. The grass carp stocking and aquatic plant response of Walton Lake in Orange County, one of the original (experimental) stockings in the state, has been documented by the NYSDEC Division of Fish and Wildlife. Information about other stockings is largely antidotal.

- *Is That All?*

Biological control methods are not well understood. They are relatively new, have not been studied often in the field, and have not been applied to a wide variety of lake conditions. The most significant reason for the lack of understanding about biological controls, however, is in the nature of biological manipulation. Ecosystems are at once dynamic and extremely fragile; a change in one component in the ecosystem can have dramatic effects in other components within the ecosystem. Unlike physical control methods, and, to a lesser extent, chemical techniques, the results from biological manipulation studies either in theory or in the laboratory cannot be easily reproduced in the field, in actual lakes.

Grass carp may offer an excellent vegetation control option for some situations. There is a great deal of interest in using this species for biological control of nuisance aquatic plants rather than chemical and/or mechanical means. Unfortunately, grass carp are not the instant solution to all aquatic vegetation problems in every lake. Even where they have been effective, there have been undesirable side effects. For many lakes, the potential side effects inherent in grass carp treatments will more than outweigh the benefits.

The experiences in New York State have been somewhat variable. In nearly all cases when stocking rates are high, grass carp effectively remove submergent aquatic plants, such as in Lake Mahopac (southern New York). In other locations, long-term eradication of nearly all plant material has accompanied grass carp introduction, to the detriment of the long-term integrity of the aquatic ecosystem, particularly as habitat for fish spawning and survival. In some cases, this has also resulted in short-term water quality impacts- primarily increasing turbidity and decreasing water clarity.

At lower stocking rates, non-target aquatic plants have often been most heavily controlled, particularly when the target plant is Eurasian watermilfoil, a plant not generally near the top of the menu for grass carp. For example, the initial stocking in Walton Lake (10 fish/vegetative acre) had only limited impact on plant densities. while a higher stocking rate two years later (15-19 fish/vegetative acre), resulted in removal of about 30% of the plants[,] and a selective removal of all but the Eurasian watermilfoil (which increased in some areas). Subsequent higher stocking rates (to 20-27 fish/acre) removed these exotics, resulting in a paucity of plants throughout the lake (although emerging plants generally were much less affected). This did not have any measurable impact on water clarity, but did result in a drop in fish catch rates as plant populations dropped.

Until moose can be harnessed and stocked in lakes, grass carp are the only "biomanipulation" tool that has worked successfully in controlling excessive levels of nuisance aquatic plants.

4. Aquatic Herbicides

- *Principle*

Aquatic herbicides (pesticides) are chemical compounds used to kill undesired macrophytes and restrict further vegetation growth. Herbicides are used primarily to kill specifically-targeted aquatic vegetation species, whether floating, emergent, or submerged. They also provide short-term clearance for recreational areas and navigational channels. As with other in-lake weed management strategies, herbicides address neither the cause nor the source of the problem.,

Herbicides are applied in either liquid or granular form. In most cases, the chemicals are applied to the water directly overlying the problem area. Most granular herbicides are activated through photodegradation of the granular structure, releasing the active chemical. These chemicals either elicit direct toxicity reactions or affect the photosynthetic ability of the target plant. The plants die and degrade within the lake. Some herbicide residuals sink to the lake sediment, providing some additional temporary control of vegetation. For some herbicides, however, once the granules sink to the bottom and out of the **photic zone** (area penetrated by light), photodegradation ceases, and the chemical is no longer effective. .

There are generally two classes of aquatic herbicides. **Contact herbicides** affect only those portions of the plant contacted by the herbicide, usually through (plant) toxicity. **Systemic herbicides** affect metabolic or growing processes within most or all of the plant, often translocating from the leaves to the root system. In general, systemic herbicides tend to take longer to work, but are often more effective at controlling plants for a longer period. Contact herbicides generally work more quickly but have less longevity. However, individual herbicides within these classes have different modes of action for either inhibiting plant growth or destroying the plant itself.

Both classes of herbicides are registered for use in NYS and since many herbicides contain toxic chemicals, only licensed applicators should place herbicides in lakes. Most herbicides can be used in most lakes, but some lakes used for a domestic drinking water source may have restricted uses for certain herbicides.

Correct timing of the chemical application is important, since seeds can germinate and roots can sprout even when the parent plants are killed off. The specific time for the application will depend on the specific target weed, required dosage rate, water temperature, water chemistry characteristics of the lake, weather conditions, water movement and retention time, and recreational use of the lake. Curly-leaf pondweed has a growing season from mid-fall through early summer, while Eurasian watermilfoil usually grows from early spring through the end of the summer. Herbicide applications must consider the timing of the growing season relative to the algae levels (since photodegradation of herbicides may be slower when algae reduces lake clarity), ice cover, and the effect the chemical application will have on the recreational use of the lake. Most herbicides have restrictions on the use of the water body immediately after treatment, lasting up to 30 days, depending on the dose rate or use of the lake.

Case Study- Aquatic Herbicides

Lake Setting: Snyders Lake is a 110 acre lake found in the Capital District region of New York State, used primarily by local residents for swimming and boating.

The Problem: While more than 20% bottom coverage of rooted aquatic plants had been reported in the lake from the time of the biological surveys of the 1930s through at least the late 1980s, water quality issues, particularly winter and spring blooms of the red alga *Oscillatoria rubescens* and complaints of turbidity by nearby development had dominated discussions about the management of the lake. Weeds had not been sufficiently dense to warrant active management until the late 1990s, but at that time, dense aquatic plant beds were dominated by Eurasian watermilfoil throughout the littoral zone.

Response: After significant public debate about the need for management and the available alternatives, the Lake Association of Snyders Lake voted to apply fluridone to the entirety of the lake in the spring of 1998. A combination of private funds and state local assistance grants were used to offset the appx. $25,000 cost for the treatment.

Fluridone was applied at a rate of approximately 13-18 (parts per billion, or ppb), and was tracked by the lake association at several locations and depths for about 5 months. Fluridone residuals remained above 6ppb for at least 55 days, above 4ppb for more than 115 days, and were still above 2ppb for at least 155 days. The greater-than-expected longevity was due to a combination of factors, including a dry spring and summer resulting in little outflow (through a small sand-bagged outlet), a slow drop of the thermocline, and a lower rate of photodegradation.

Results: By the end of the summer in the year of treatment, there was no evidence of any submergent aquatic plants in the lake. Scattered submergent plant growth returned the following summer, although this was limited primarily to macroalgae (*Chara* spp.) and isolated single stems of Eurasian watermilfoil, mostly in thin sediments. In 2000 and 2001, however, extensive billowing beds of brittle naiad (*Najas minor*) were found in the areas where sediment was thick and organic, and small quantities of other native plants (large-leaf pondweed, leafy pondweed, macroalgae) were found in isolation throughout the littoral zone. Eurasian watermilfoil was still largely limited to small patches, mostly in the thinner sediments. Maps showing aquatic plants in the lake prior to treatment and in 2000 look very similar, with the brittle naiad replacing the milfoil. However, while the brittle naiad grew very bushy below the surface, unlike the milfoil, it did not form dense canopies at the surface.

Follow-up monitoring should track the fate of the applied chemical, and changes in the plant communities, water quality conditions, and impaired uses. The effectiveness for any given herbicide treatment varies with the treatment design, and the conditions of the lake and treatment site listed above (Westerdahl and Getsinger, 1988). In general, for contact herbicides the effectiveness of an herbicide treatment will last anywhere from several weeks to several months, usually corresponding to a single growing season. Since seeds and roots frequently are not affected by treatment, once the chemicals have degraded or washed out of the system, plant growth will resume, and reapplication may be necessary. Effectiveness rarely carries over to the next growing season. For systemic herbicides, treatment effectiveness is often not observed for at least three to four weeks (and often up to six to eight weeks), although plant control with these herbicides have been observed to last for several years.

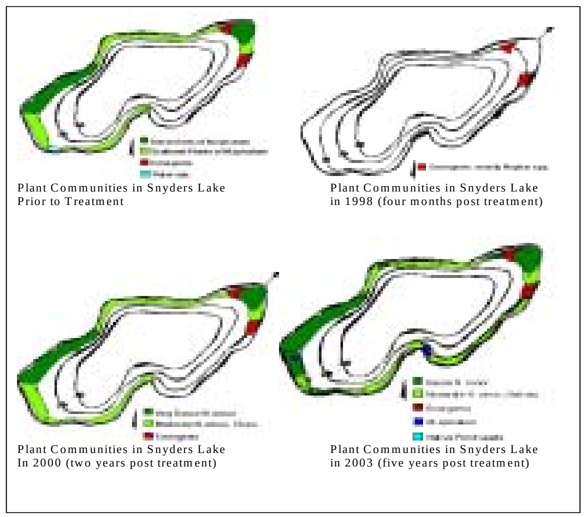
- *Target Plants and Non-Target Plants*

At the dosage rates allowed in New York State lakes, most aquatic herbicides are not selective. If applied when plants are actively growing, at concentrations allowed by the label, most plants within the treatment zone will be removed by these herbicides. Selectively can be increased by timing the applications to when the target plants are preferentially growing. To a lesser extent lower dosage rates appear to exert some selectivity.

Case Study- Aquatic Herbicides (cont)

Results (cont): After 2001, milfoil recolonized large patches of the littoral zone, although it was still much less dominant than prior to treatment, due to the well-established brittle naiad beds. The milfoil spread to some areas not previously occupied by any macrophytes. The coverage and density of the milfoil/brittle naiad beds were significant enough to trigger a spot treatment with endothal in the summer of 2004 in the areas of the lake with the highest macrophytes coverage (and, perhaps not coincidentally, the highest sedimentation rate).

Most antidotal information from lake residents and visitors indicate a general satisfaction with the results of the initial treatment, with few reported complaints from anglers about the lack of a fishing edge or loss of any year-classes. Water quality conditions were relatively stable throughout the treatment and subsequent response period, and reports of blue-green algal blooms or other water quality complaints were less common than in most previous five-year periods, despite the potential available of nutrients not taken up by the rooted plants. However, this may have been more a function of more favorable weather conditions.


Plant Communities in Snyders Lake Prior to Treatment

Plant Communities in Snyders Lake in 1998 (four months post treatment)

Plant Communities in Snyders Lake In 2000 (two years post treatment)

Plant Communities in Snyders Lake in 2003 (five years post treatment)

Lessons Learned: Aquatic plants appear to recover (or get re-introduced) after a long

Source: Kishbaugh, S.A. 2002. Assessment of Eurasian watermilfoil control with Sonar at Snyders Lake, NY: 1998-2001. Presentation to the NEAPMS annual conference, Suffern, NY.

In New York State, the most frequently used aquatic herbicides are diquat, 2,4-D, endothol, glyphosate, and fluridone.

- Diquat is a contact herbicide used to control emergent species such as cattail; floating species such as duckweed; and submerged species such as coontail, milfoil, nitella; and some varieties of pondweed. It is often used with chelated copper sulfate for algae control.
- 2,4-D is a systemic herbicide used for controlling a wide variety of emergent, floating, and submerged species, primarily Eurasian milfoil, coontail, and water hyacinth. Like diquat, it remains in the sediment for several months.

- Endothol is a contact herbicide used primarily for control of coontail and most pondweeds, including curly-leafed pondweed. It stays in the water column longer than either diquat or 2,4-D.
- Glyphosate is a contact herbicide used almost exclusively on emergent and floating plants, especially cattail and waterlily.
- Fluridone is a systemic herbicide used extensively in recent years 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.

The table below indicates the susceptibility of common New York State submergent, floating, or emergent plants to these herbicides.

- *Advantages*

Unlike many other in-lake management techniques, aquatic herbicides can be applied directly to the problem plants, although many of the herbicides registered in New York State are so water soluble that they do move somewhat out of the treated areas. Aquatic herbicides are available for immediate or long-term control of nuisance plants, and some of these herbicides have been shown to be somewhat selective if applied at the right time (usually very early or very late in the growing season, corresponding to when target plants, such as invasive exotic weeds, are preferentially growing) and at the right dosage rate.

Aquatic herbicides have been effective at providing at least temporary control of Eurasian watermilfoil in some New York State lakes. This pernicious exotic weed has not been consistently (or at least somewhat selectively) controlled by any of the other whole-lake treatment strategies. While generally cost-prohibitive for treatments of very large areas or very large lakes, aquatic herbicides are often less expensive than other large-scale plant control methods.

- *Disadvantages*

Chemically-treated lakes may experience some significant side effects. Because herbicides kill plants primarily through toxic response, the toxicity of the herbicide to non-target plants and animals can be of great concern. Short-term impacts of aquatic herbicides have been fairly well studied for most of the inhabitants of lakes and the surrounding environment, and have been deemed to be an "acceptable risk" if applied in the appropriate manner**.** In general, humans and most animals have high tolerance to the toxic effects of herbicides presently approved for use in lakes. This is especially true of the newer generation herbicides that have been formulated to impact metabolic processes specific to chlorophyll-producing plants. However, the long-term impact of herbicides on humans and other plants and animals in the environment continues to be poorly studied. High herbicide dosages can elicit toxic response for the applicator and protective gear must be worn.

Non-target plants may not be resistant to the herbicide. If a wide variety of plant species are eradicated by herbicide treatment, the fast-growing ("opportunistic") exotic species that were the original target plants may recolonize the treatment area and grow to levels greater than before treatment. There are only very limited data on the effect of specific herbicides on plant species in New York State lakes. It is not clear if the target plant species listed on the herbicide labels can be completely controlled without adversely affecting non- target species at any given lake.

Impact of NYS Registered Herbicides on Common Nuisance Aquatic Plants

Susceptibility to Herbicide:					
Aquatic Plant	**Diquat**	**2,4-D**	**Endothal**	**Glyphosate**	**Fluridone**
Emergent Species					
Lythrum salicaria (purple loosestrife)	low	low	low	high	low
Phragmites spp (reed grass)	low	low	medium	high	low
Pontederia cordata (pickerelweed)	low	medium	low	medium	low
Sagittaria spp (arrowhead)	low	high	low	high	low
Scirpus spp (water bulrush)	medium	high	low	high	low
Typha spp (cattails)	medium	medium	low	high	medium
Floating Leaf Species					
Brasenia schreberi (water shield)	medium	medium	medium	low	medium
Lemna spp. (duckweed)	high	medium	medium	low	high
Nuphar spp (yellow water lily)	low	medium	medium	high	medium
Nymphaea spp (white water lily)	low	medium	medium	high	medium
Trapa natans (water chestnut)	low	medium	low	low	low
Submergent Species					
Ceratophyllum demersum (coontail)	high	medium	high	low	high
Cabomba caroliniana (fanwort)	medium	medium	high	low	high
Chara spp. (muskgrass)	low	low	low	low	low
Elodea canadensis (common waterweed)	high	medium	low	low	high
Heteranthera dubia (water stargrass)	high	high	medium	low	medium
Myriophyllum spicatum (Eurasian watermilfoil)	high	high	high	low	high
Najas flexilis (bushy pondweed)	high	medium	high	low	medium
Potamogeton amplifolius (largeleaf pondweed)	low	low	medium	low	medium
Potamogeton crispus (curly-leafed pondweed)	high	low	high	low	high
Potamogeton robbinsii (Robbins pondweed)	low	low	medium	low	high
Stuckenia pectinatus (Sago pondweed)	high	low	medium	low	medium
Utricularia spp (bladderwort)	high	medium	low	low	high
Vallisneria americanum (eelgrass)	low	low	medium	low	medium

*- adapted from Holdren et al., 2001 and others

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

Case Study- Aquatic Herbicides

Lake Setting: Waneta Lake is an 800 acre lake in the western Finger Lakes region that is part of a two-lake chain with Lamoka Lake (downstream to the south); the Waneta-Lamoka Lakes Association was formed in 1938 to address a variety of lake management issues. The lake is also a valued local fishery for largemouth- and smallmouth-bass and a secondary source for muskellunge brood stock throughout the state, and thus the lake fisheries 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 nuisance weed growth. The latter has been exacerbated by the introduction and spread of Eurasian watermilfoil throughout both Waneta and Lamoka Lakes since at least the mid-1980s. By the late 1990s, Eurasian watermilfoil comprised just over 50% of the biomass of aquatic plants in Waneta Lake. Mechanical weed harvesting was conducted during the mid-1980s, with funds provided through the Aquatic Vegetation Control Program (AVCP, the predecessor to the Finger Lakes-Lake Ontario Watershed Protection Alliance). This was marginally successful, but the funds for this activity dissipated over time.

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 Waneta and Lamoka Lakes. After much discussion and "negotiation", the NYSDEC issued a permit for the whole-lake application of fluridone only in Waneta Lake at an initial concentration of 12-14 ppb in the summer of 2003, with provisions for a bump application as needed to restore fluridone residuals back to 6ppb within 60 days. Due to very low dilution (probably due to relatively low inflow and low photodegradation), however, fluridone residuals remained above 6ppb, without supplemental applications, for more than 60 days, and remained above 3ppb for nearly 175 days.

Performance standards were devised to evaluate herbicidal impacts to Waneta Lake and proposals for follow-up treatments in Lamoka Lake. Native and exotic plant recovery were monitored as part of an extensive survey program conducted by Cornell University, and results were evaluated by the lake consultant and NYSDEC to determine if "sufficient" recovery existed to maintain cover and refuge in the event of a downstream (Lamoka Lake) treatment. This corresponded to < 25% loss of native plant cover and overall aquatic plant biomass, and > 90% milfoil removal, within the year of treatment, and return to pre-treatment plant densities the following year.

Results: As a result of the herbicide treatment, Eurasian watermilfoil disappeared from the lake, and there was no evidence of milfoil anywhere in the lake through at least the summer of 2004. Traces of native plants were found in 54 of the 91 sites with some evidence of plant growth prior to treatment in 2003, and in 50 sites in 2004, with native plant biomass reduced to about 5% of the pre-treatment native biomass. No significant water quality changes or fisheries impacts were reported (or attributable to the herbicide treatment), and it is expected that native plant recovery will accelerate beginning in 2005, as was found in other lakes with similar initial recovery patterns. Due to delays in the plant recovery in Waneta Lake, however, large-scale treatment of Lamoka Lake was not approved. It is anticipated that the strategies used to evaluate the Waneta Lake treatment will be utilized in assessing the impacts (positive and negative) of other herbicide treatments throughout the state.

of nutrients could have detrimental effects on the health or survival of fish and other aquatic life as well as stimulating new plant growth.

The effectiveness of systemic herbicides is often delayed. Given that the most effective treatment windows correspond to periods bounded by the onset of thermal stratification in the beginning of the year (to avoid treating the entire lake rather than the upper warmer waters where plants tend to grow) and by the onset of fish spawning and native plant uptake (when surface waters warm to > 50°F), plant dieoff may often not occur until early to mid summer. This means that plant control from systemic herbicides might not be "enjoyed" by lake residents until much of the recreational season has passed.

- *Costs*

Herbicide costs will vary with the chemical brand and form (liquid or granular), required dose rate, applicator fees, and frequency of application. Typical costs for using herbicides are approximately $200-400 per acre of treated area per treatment, with the majority of these costs associated with the raw materials.

- *Regulatory Issues*

Herbicide use in New York State requires a permit from the DEC regional environmental permits office, in compliance with the Environmental Conservation Law. If all or part of the lake contains a regulated wetland, an additional wetland permit may be required. For those lakes for which the generic Environmental Impact Statement (EIS) prepared by the manufacturers of these herbicides is deemed insufficient to address the myriad of permitting issues that might be appropriate in the lake, a site-specific EIS may be required to issue these permits. The Adirondack Park Agency will require a separate permit for herbicide use within the boundaries of the park.

> **Case Study- Aquatic Herbicides: Waneta Lake (cont)**
>
> 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, and it is unlikely that all parties involved will agree that the process and the results were adequate. However, the dialogue accompanying the application process 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.
>
> *Sources: Lord, P.H., R.L. Johnson, and K. Wagner. 2005. Effective aquatic plant monitoring: data and issues from Waneta Lake. Presentation at the NEAPMS annual conference, Saratoga Springs, NY.*
>
> *Lord, P.H., R.L. Johnson and M.E. Miller. 2004. Waneta Lake 2003 and 2004 plant community structure research subsequent to 2003 fluridone treatment for control of Eurasian watermilfoil. Cornell University report. Ithaca, NY.*
>
> *ENSR International. 2001. Draft supplemental environmental impact statement for the control of Eurasian watermilfoil in Lamoka and Waneta Lakes with fluridone. Document No. 8734-352-03. Willington, CT.*

Nearly all of the aquatic herbicides registered for use in New York State carry at least one water use restriction, ranging from 24 hour restrictions on bathing to 30 day prohibition of the use of the lake water for irrigation of established row crops. These restrictions are clearly identified on the label governing the use of each of product formulations registered in New York State

Herbicide applicators must also be licensed by New York State. A list of licensed applicators is available from the NYSDEC Bureau of Pesticides in Albany. Applicators may also need to carry an insurance policy.

Permits have been issued for aquatic herbicides in nearly every part of New York StateIn fact, upwards of 500 permits are issued annually, not including purchase permits for small farm ponds. However, in some regions of the state, such as the Adirondacks no aquatic herbicide permits are being issued. The myriad of reasons include overlapping regulatory authority (the NYSDEC and the Adirondack Park Agency), strong sentiments about the use of herbicides, the presence of and concern for protecting rare and endangered species, and the lack of historical precedent in the use of many aquatic plant control strategies (due in part to the historical lack of problems with invasive plants). . A paucity of permits is also the case for lakes in other regions of the state used for potable water intake or encompassing wetland areas, since the permitting rigor is often more significant in these waterbodies. On the other hand, many lakes in the downstate region have been treated with aquatic herbicides.

Copper-based herbicides (for rooted plant control) have been registered for use in New York State, but since they can kill some fish species at the label application rate, these require extensive review and environmental assessment by the NYSDEC.

- *History and Case Studies in NYS*

Aquatic herbicides have been used in New York State for many years. Federal regulation began by at least the early 1900s, although the "modern" pesticides regulations largely stem from the passage of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in 1947. However, federal and state attention to pesticides, including aquatic herbicides, was significantly heightened by the publication of Silent Spring by Rachael Carson in 1962. Since then the aquatic herbicides used in lakes have been subject to more stringent testing and regulations, resulting in amendments to FIFRA starting in 1972.

However, most of the lakes treated with aquatic herbicides have not been closely studied either before or after treatment. The most closely monitored lakes include Waneta Lake in Schuyler County and Snyders Lake in Rensselaer County.

- *Is That All?*

Perhaps no other lake-related issue causes as much heated discussion as chemical controls. At many lake association meeting, large or small, there will likely be two factions, both convinced that the other could ruin the lake. One faction may claim that there are absolutely no conditions or situations that call for chemical treatments. The other group may insist that if herbicides are not applied immediately, weeds will take over the entire lake, destroying recreational use and slicing property values. And neither group is likely to listen to the other.

There have been few, if any, documented cases of an herbicide treatment gone completely awry. Any health problems associated with contact with herbicide-treated lakes may be perceived and based on an expected threat. While toxicological studies indicate that short-term human health effects or impacts to non-targeted organisms in the lake ecosystem are probably very small when herbicides are applied according to the permitted label, long-term monitoring of ecological or human health has not occurred. An herbicide treatment may also be ineffective due to poorly timed applications, unusual weather conditions, eradication of non- target plants, reinfestation by exotic species, or by simply using the wrong herbicide to control a particular species. Even when successful, treatments will have to be repeated at least every growing season, as is the case with nearly all symptom- based vegetation control techniques. These limitations and concerns need to be balanced against the ecological damage that may occur when invasive plants spread through a lake ecosystem, creating “biological pollution” and drastically altering the ecological balance.

Although herbicide use requires a permit in New York State, the decision whether to use chemical treatment usually rests with the lake association, residents, or lake management team. As much information as possible should be obtained about the particular species of nuisance plant, proposed herbicide, existing water chemistry conditions on the lake, and the benefits and drawbacks of using this particular herbicide on this particular lake to control this particular plant. It is important to use discretion when extrapolating information from a different lake to the conditions at your lake. Differing weather conditions, recreational uses, water chemistry characteristics, and vegetation types could yield dramatically different results from one lake to another. The DEC regional office may be able to provide some assistance in obtaining information about the lake and proposed herbicide.

5. Shading

- *Principle*

Shading involves the use of chemical dyes to inhibit light penetration to the lake bottom, ultimately controlling the growth of nuisance aquatic vegetation in areas greater than two to four feet deep. These non- toxic vegetable dyes work by reducing light penetration in the water ("shading"), and by the absorption of wavelengths within the photosynthetically active region of light. Absorbing these wavelengths prevents the plants from photosynthesizing and growing.

The dyes treat the entire waterbody and are usually not used on large lakes due to cost limitations. Dyes are most effective in small waterbodies with little or no flow where the appropriate concentration can be maintained. .The duration for treatment for either large or small lakes is a function of water retention time. Dyes will be significantly and quickly diluted or washed downstream in lakes with inflow and outflow.

The use of shading dye is prohibited in potable water supplies; however, there are no use restrictions associated with the use of water treated with shading dye immediately after the application

The most common chemical dye used in shading is Aquashade®, an inert blue liquid vegetable dye made primarily of food colors. However, in recent years, many other products that perform the same function have been advertised as "landscaping tools", "colorants" or to improve the "aesthetic quality" of the water, thus avoiding claims of any herbicidal impacts that require permits and compliance with regulatory restrictions outlined in FIFRA. Some of the products, particularly those registered as having herbicidal impacts, are often combined with copper formulations to enhance control of algae.

Case Study- Shading to Grass Carp: 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 rebuilt by the Civilian Conservation Corps in the 1930s. The lake is characterized by a group of floating peat bogs, which have been managed by a variety of strategies over time, presently corralled by a log boom.

The Problem: Rooted aquatic plant growth has been the subject of complaints since 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.

The Adirondack Lake Association utilized a number of lake management tools, from water level drawdown (from 3 to 9 feet), mechanical harvesting, and aquatic herbicides (2,4-D), during the late 1970s and early 1980s.

Response and Results: In 1984, Aquashade, an inert vegetable dye, was applied at a rate of 1 part per million (500 gallons), in combination with a relatively deep lake drawdown. As a result, 90% of the aquatic plant beds (large-leaf pondweed beds comprised 95% of the biomass) were cleared from the lake for two years, with aquatic plant growth limited to shallow water by early 1986. However, by later that year, the APA estimated aquatic plant growth to be "moderate" to "abundant". By the following year, after a deep winter drawdown, Aquashade was applied again to control primarily large-leafed pondweed beds covering 80% of the shoreline to a depth of 7 feet. This resulted in a shift in the aquatic plant communities from large-leafed pondweed to brittle naiads (*Najas minor*) and common waterweed (*Elodea canadensis*) by the following year, although, after a year of no control, the large-leafed pondweed returned to abundance. As aquatic plant growth increased, Aquashade was applied a third time in 1991, again after a (lower) winter drawdown, and a fourth time in 1994, at a total cost (for the four treatments) of about $54,000.

By 1996, the lake association shifted the agent of control from Aquashade to grass carp, in part due to the lower costs (an expected cost of $35,000 for 10 year grass carp control versus about $54,000 for 10 years of shading agents). The effectiveness of the carp have been evaluated through aquatic plant surveys conducted on the lake since 1999. It appears that the plant communities have shifted from dominated by large-leaf pondweed (*Potamogeton amplifolius*) to a mixed community with a brittle naiad and a multitude of native milfoils and other submergent and floating-leaf plants. Overall plant coverage and densities have decreased slightly over the last several years.

Lessons Learned: It was believed that the repeated Aquashade treatments reduced plant populations in the deeper water, but had less impact in the shallow water. although the extent of the impact, and whether the shift from one dominant plant to another was acceptable, is not clear. The grass carp were generally effective at reducing the population of a plant (large-leaf pondweed) that is often considered to be a nuisance, although it is not known if the overall reduction in plant biomass adversely affected the fisheries or overall lake ecology.

Source: Grim, J. 1996. Supplement to Adirondack EAF: Environmental Impacts of Stocking Triploid Grass Carp. Unpublished report, Rhinebeck, NY.

Kishbaugh, S. 2004. Aquatic plant survey of Adirondack Lake. Unpublished report submitted to the Hamilton County SWCD. Albany, NY.

• *Target Plants and Non-Target Plants*

Shading dyes have been shown to be somewhat effective for several nuisance plants including *Elodea (common waterweed), Potamogeton (pondweed), Najas (naiad), Myriophyllum* (milfoil) and some filamentous algae. However, shading dyes are usually generalist agents. Since dyes reduce the transmission of light into a lake, all submergent plants tend to get affected by this process. Specific weed beds or sections of a lake cannot be isolated for treatment unless flow between this area and the rest of the lake can be restricted

- *Advantages*

Lake dyes are non-toxic to humans and most aquatic organisms, including the invertebrate species likely to be exposed to the dye during treatment. They are relatively inexpensive for small lake and pond applications, although these costs may become prohibitive for larger-scale treatments.

- *Disadvantages*

Since the field research on the dyes has been rather sparse, it is not clear which aquatic plant species, including algae, are affected by the treatments. Some shallow water or light-insensitive plants, such as the opportunistic Eurasian watermilfoil, may actually be selected for with this technique. Since the dyes are so soluble, they tend to migrate throughout the lake, minimizing opportunities for control in selected areas of the lake. Non-target plants may be adversely affected by the dyes, including some providing fish habitat.

These dyes can frequently and rapidly wash out of a lake, so repeated applications may be required in lakes with very low residence times (high flushing rates) or during periods of rapid water movement into and out of a lake, such as major storm events.

- *Costs*

The cost of the chemical dyes is about $50 per gallon, which is sufficient to treat four acre-feet of water at the recommended concentration of 1 ppm (one acre-foot equals one acre of surface area treated to a depth of one foot).

- *Regulatory Issues*

Chemical dyes require a pesticides permit from the NYSDEC and the APA if the label on the dye promotes plant control (acts as an herbicide), since the use of herbicidal agents is governed under FIFRA (see the secton on the use of Aquatic Herbicides in this chapter). For those products that provide “landscaping” or “colorant” to lakes or ponds, permits are not required.

- *History and Case Studies in NYS*

There is little historical information on the use of shading agents in New York State lakes, although they have been commonly used on ponds, particularly golf course and ornamental ponds, for many years. The only large-lake experiment with the use of lake dyes was in Adirondack Lake in the late 1980s.

- *Is That All?*

There have been few attempts to use chemical dyes in New York State. Although chemical dyes use physical light inhibition and not toxicity as the mode of action, pesticide permits are required (from the regional DEC office and the APA) to apply the dye to a lake. The public may perceive the technique to be another herbicide with the potential of eliciting toxic reactions in non-target organisms. The dyes also impart a