Twin Lakes – Salisbury, CT

Long-Term Aquatic Vegetation Management Plan

DRAFT Report
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Prepared for:

Town of Salisbury
Twin Lakes Association

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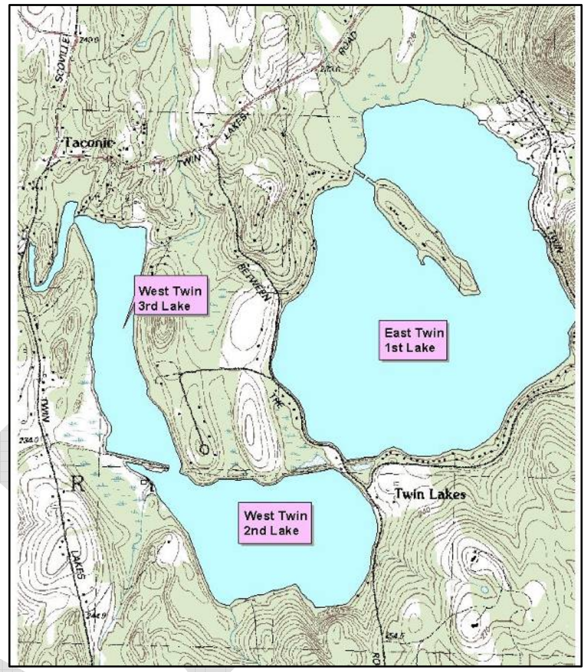
INTRODUCTION AND PROBLEM STATEMENT

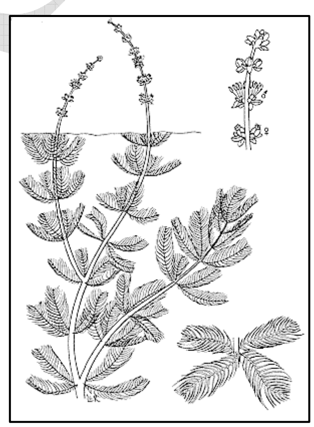
The Twin Lakes of Salisbury, Connecticut, otherwise knownas Lakes Washining (East Twin) and Washinee (West Twin), serve as an important freshwater resource for the state of Connecticut. The Twin Lakes are regarded as one of the State's best fisheries supporting both warmwater and coldwater gamefish. They have excellent water quality and support a diverse assemblage of aquatic plants including several State Protected species. The ample amount of wooded shoreline and large adjacent wetlands provide hospice for an array of wildlife. There is low to moderate density residential development around the lake shorelines. The lakes are a recreational resource for the area, supporting a variety of water-based activities including fishing, paddling, swimming and water skiing.



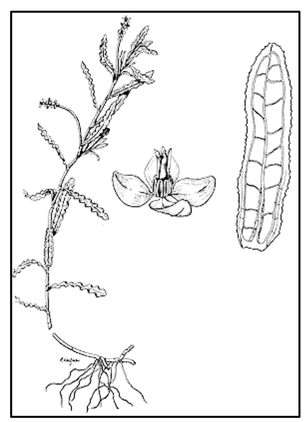
West Twin Lake is a 280-acre waterbody with two distinct basins generally referred to Second Lake (175 acres) and Third Lake (105 acres). East Twin Lake, on the other hand, is a considerably larger (562-acre), round lake with significantly deeper water depths.

For years lakeside residents, and visitors alike, have been faced with the problem of nuisance aquatic plant growth. Although the fairly deep nature of East Twin Lake has confined much of the growth to the shallow (littoral zone) along the edge of the lake, West Twin is shallower and supports plant growth throughout most of the two basins. Eurasian watermilfoil (*Myriophyllum spicatum*), and more recently curlyleaf pondweed (*Potamogeton crispus*), have become the primary focus of vegetation management efforts in the Twin Lakes.

Both Eurasian watermilfoil and curlyleaf pondweed are recognized throughout North America as highly invasive, non-native plants with the capability to out compete native species; often threatening plant diversity through the establishment of monocultures. Eurasian watermilfoil is a fast growing plant (up to 1" per day) that often forms a vegetative canopy, not only blocking out light for other plants, but also inhibiting boating and creating a safety hazard for swimmers. By the late 1990's Eurasian watermilfoil was inhabiting a majority of East Twin Lake's shoreline, and was found throughout most of West Twin Lake.



Eurasian watermilfoil



Curlyleaf Pondweed

For years the Town of Salisbury funded mechanical harvesting of the milfoil to maintain shoreline access to the lake, however, as the milfoil continued to spread, harvesting efforts became incapable of providing acceptable control of this highly invasive plant. Alternative approaches were investigated and some were tried without success (i.e. weevil stocking). Within the past few years significant progress has been made towards controlling the milfoil and curlyleaf pondweed populations in the Twin Lakes. Herbicide treatments, starting with a demonstration Sonar herbicide application in West Twin Lake in 2001 and followed by spot-treatments with Reward herbicide each year from 2003 to 2006, have managed to reduce the density and distribution of these nuisance plants in the Twin Lakes.

The current program is currently providing effective seasonal control of milfoil and curlyleaf pondweed. Efforts to manage these nuisance plants must continue for the foreseeable future to maintain control of these particularly invasive species and to prevent the lakes from resorting to pre-management conditions. The balance of this report will review the recent history of aquatic vegetation management in Twin Lakes; summarize available options for continued aquatic plant maintenance; and, provide direction towards the establishment of a fluid, long-term aquatic vegetation management plan which can be used and tailored to address future aquatic vegetation management needs at Twin Lakes.

MANAGEMENT HISTORY

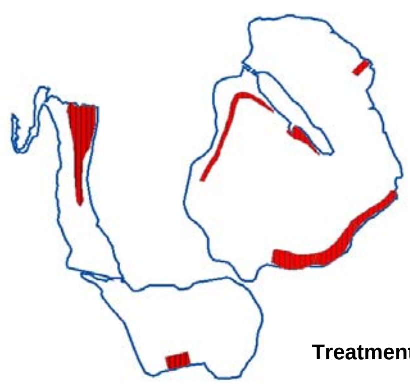
The initial method utilized for Eurasian watermilfoil control in Twin Lakes was mechanical harvesting. One or two cuttings per year were performed in portions of all three basins to improve recreational access to the lake. Once harvesting was unable to provided acceptable control of the expanding milfoil population, alternative methods of aquatic plant control were investigated. Stocking of the herbaceous milfoil weevil (*E. lecontei*) occurred in 1999 or 2000, but no appreciable reduction in milfoil was observed.

After much consideration, and concern regarding endangered aquatic plants, a demonstrational aquatic herbicide application was planned and performed in West Twin Lake in the summer of 2001. The treatment, conducted by Aquatic Control Technology, Inc., consisted of a low-dose application of Sonar AS (fluridone) herbicide in Third Lake. The treatment provided excellent control (>99%) of the target milfoil throughout the 2001 and 2002 seasons. However, there was impact to native plants the year of and year after treatment, including the State Protected species water marigold (*Megalodonta beckii*). Ultimately, it was determined that State Protected species could not be adequately protected to warrant additional treatment with Sonar herbicide in the Twin Lakes system.

Based on the outcome of the demonstrational Sonar application in 2001, and the associated concerns regarding its further use in future partial or whole-lake herbicide applications, it was determined that a management plan must be initiated that would control milfoil without threatening the existing beds of diverse native growth, or any area harboring State Protected species. After several meetings and coordination with DEP, it was determined that a partial lake treatments with Reward (active ingredient diquat) would be an acceptable management strategy. Starting in 2003, Aquatic Control Technology, Inc. began an herbicidal maintenance plan aimed at controlling Eurasian watermilfoil on a site specific basis, avoiding treatment in any areas known to harbor growth of State Protected species. Reward herbicide was used in 2003 and in each subsequent year to control of nuisance milfoil growth. Although Reward is a contact herbicide and it does not offer the multi-year control possible with a systemic herbicide that kills the root structures such as Sonar, the early season Reward treatments have effectively controlled milfoil growth for the past four summers (2003-2006), and reductions in milfoil density and distribution have been documented.

Milfoil Treated

Year	East Twin	West Twin
2006	40 ac	25 ac
2005	40 ac	15 ac
2004	75 ac	30 ac
2003	60 ac	15 ac



2006 Treatment Map

Between 2003 and 2005, Reward treatments were limited to designated management areas in East Twin and in the Third Lake. Treatment acreage has varied from year to year in these two basins, but reductions in milfoil density and distribution have been documented by the comprehensive monitoring that has accompanied the treatment program. In 2006, the same areas on East Twin and Third Lake were treated and DEP granted permission to treat a 5-acre demonstration area on Second Lake near the Salisbury School docks. Results of the 2006 treatment were favorable in all three basins, achieving summer-long milfoil control while avoiding impacts to native plants, including State Protected species.

EVALUATION OF MANAGEMENT OPTIONS

The following section aims to outline and discuss a variety of available aquatic plant management options. Each management tool is discussed in reference to the situation facing Twin Lakes, spelling out both advantages and disadvantages of the particular technique. The first part of this section reviews non-chemical aquatic vegetation management techniques. This discussion is followed by review of mechanical and chemical treatment options. Together these three sections provide a comprehensive outline of the aquatic vegetation management tools available for aquatic plant control in the state of Connecticut.

NON-CHEMICAL OPTIONS

Manual Removal and Benthic Barriers

Hand-pulling, suction harvesting (or hand pulling with suction removal) and benthic barrier installations are the principal manual plant control strategies used for submersed aquatic plant growth. These three approaches are generally used to control small localized patches of dense plant growth, however hand-pulling and suction harvesting can be useful in controlling widely scattered aquatic growth. The limitations of these control measures often restricts their application to newly discovered, pioneer infestations or as follow-up to a larger scale management strategy such as chemical treatment or drawdown. It is usually ineffective and often counter-productive to apply these strategies to large-scale control efforts.

Presently, most of the nuisance milfoil and curlyleaf pondweed growth that is being managed is beyond levels where these strategies can be effectively used at Twin Lakes. Review of these techniques is provided in the event that these strategies are utilized as part of an integrated management program at some point in the future, or if they are considered for small scale control around individual shorefronts.

Hand-Pulling

Hand-pulling of submersed plants like milfoil involves dislodging plants from the bottom sediments and placing the entire plant in mesh collection bags. A person in a support boat is usually needed to empty the mesh collection bags and to collect plant fragments missed by the hand-pullers. The actual hand-pulling work can be accomplished by an individual equipped with a mask and snorkel in shallow water areas, but often SCUBA divers are required if water depths exceed 4 feet. Other factors that may complicate a hand-pulling effort include limited water clarity, highly flocculent or muddy or contaminated sediments that are easily suspended and reduce clarity, firm bottom substrate that prevents complete root removal, and dense cover of native species.

At Twin Lakes, hand-pulling is presently not a realistic strategy for large-scale plant control since there are several acres of fairly abundant milfoil and curlyleaf pondweed growth, and the infestation is widely distributed. However, hand-pulling could prove to be a useful tool for managing small colonizations of low density growth (less than one percent) or less than 500 plants per acre (Wagner 2003). It may also be applicable for moderate density (less than 10 percent cover) in some of the smaller, localized patches. Cost will likely vary depending on milfoil density, area of infestation and staff being utilized.

Suction Harvesters

Suction harvesters typically involve the use of a pump on a boat or barge and with two SCUBA divers to operate a pair of suction lines. Plants are dislodged from the sediment by hand, fed into the suction line and discharged into a mesh collection basket on the boat or barge. Suction harvesting essentially makes hand-pulling more efficient. It is best suited for controlling just small areas with sparse to moderate growth that would require a considerable hand-pulling effort. Due to the potential turbidity generated with this technique, floating fragment barriers are sometimes used to isolate the area where the barge and divers are working to capture fragments. This limits the mobility of the unit, making it less efficient and substantially more costly to cover large areas with widely scattered plant growth. Typical suction harvesting operations require a crew of 3-4 personnel with per acre costs between $5000-$14,500.

Aside from high unit costs and the amount of labor required, suction harvesting can present some non-target impacts. It is somewhat less selective than hand-pulling, especially after the turbidity increases as the operation gets underway. Other plants besides milfoil will inadvertently be harvested. Macroinvertebrates either attached to plants or dislodged from the sediment during uprooting will be removed. The turbidity and suspended sediments produced using this approach is also more significant than hand-pulling (VT DEC 2004). Benthic organisms may be also smothered when the sediment settles-out. For these reasons, it is impractical for suction harvesting to be considered a suitable strategy for large-scale milfoil control efforts at Twin Lakes. Use of this technique will likely be limited to control of moderate to dense infestations in small areas after substantial control of the milfoil has been attained.

Benthic/Bottom Barriers

Several materials have been commercially manufactured to serve as benthic or bottom barriers in lakes. Typically, barriers are weighted to the lake bottom and kill plants through compression and blockage of sunlight. They are most effective for use in small areas around docks and swim areas. Large installations can become cost-prohibitive, with material and installation costs exceeding $40,000 per acre, and may interfere with the utilization of bottom sediments by aquatic organisms. They are also non-selective, killing all plants that are covered and affecting macroinvertebrates as well. Plants are usually effectively controlled within 1-2 months of installation, so they could be moved to control plants in multiple locations within the same year. However, the labor required for installation and removal makes annual retrieval and redeployment impractical. Barriers must be routinely checked to insure that excess billowing/uplifting does not occur that could endanger swimmers or entangle boat props. Other routine maintenance typically involves removal, cleaning and redeployment to discourage plant growth on the barrier. Maintenance efforts and cost can be substantial, especially for larger installations. Observations at Twin Lakes also indicate that fisherman can hook the net and damage it.

Benthic barriers can be cost limiting on any area of scale, and should not be considered for use on large areas of growth like those in Twin Lakes. Generally, benthic barriers are only recommended for areas less than one-quarter acre in size. Bottom barrier installations will likely be limited to infestations of dense growth around private docks and swimming areas or in high use areas of the lake.

Table 1 - Comparison of Hand-Pulling, Suction Harvesting and Benthic Barriers

Approach	Typical Application	Advantages	Limitations	Approximate Unit Cost
Hand-Pulling	Widely scattered plants <500 stems per acre	Highly selective Can utilize trained volunteers in some cases	Impractical for large areas with milfoil coverage greater than ~1-5%. Reduced visibility from poor water clarity or suspended sediments from a mucky bottom	<$500 acre
Suction Harvesting	Small scattered to moderate infestations (< 1 acre in size)	More efficient than hand pulling for higher plant densities	Equipment difficult to relocate Additional staff require Increased turbidity Very high cost	$5000 - $14,500 acre
Benthic Barriers	Small dense patches (< 0.25 acres)	Quick control for small areas Prevents reinfestation Barriers can be reused	Non-selective, kills all plants and may impact macroinvertebrates and other non-target organisms Barriers require routine maintenance Very high cost per acre	>$25,000 - $50,000 /acre

Biological Controls

The introduction of herbivorous insects and fish is often considered to be a natural and potentially long-term management strategy to control excessive aquatic vegetation.

<u>Grass Carp</u>

Sterile or triploid grass carp (*Ctenopharyngidon idella*) that consume aquatic plants are regularly used as a management strategy in southern tier states, and are used in Connecticut waterbodies by special permit. They have been stocked in Ball Pond in New Fairfield, CT and some other fairly large lakes in nearby New York, but nothing approaching the size of Twin Lakes. They reportedly do not show a feeding preference for milfoil and are therefore not recommended for use in a productive lake with a diverse native plant community like Twin Lakes. Non-selective vegetation removal on a large scale would have serious impacts on fish habitat and the overall lake ecology.

Milfoil Weevil

Most of the work with herbaceous aquatic insects in the region has focused on the control of Eurasian watermilfoil. A native aquatic weevil (*Euhrychiopsis lecontei*) that developed a preference for Eurasian watermilfoil over its native host species (*Myriophyllum sibiricum*) was first identified in Vermont after natural milfoil declines were observed in several lakes. The weevil generated a considerable amount of interest and study over the past decade. It is now being commercially reared and stocked as a milfoil control strategy. The weevil does not eradicate milfoil, but instead destroys apical meristems or growth points on the plant and reduces the buoyancy of the stems, causing the plants to collapse towards the bottom. A number of milfoil infested lakes in the northeast have attempted weevil stocking programs. Some significant milfoil reductions have been reported, but there have been oscillations between the milfoil and weevil densities, resulting in unpredictable levels of milfoil control. Limitations include availability of shoreline cover for overwintering weevils and fish predation.

Weevils were stocked in the Twin Lakes in 1999 and 2000. No perceivable milfoil control was reported following the weevil stocking program.

Weevil stocking remains unproven as a dependable milfoil management strategy. It is probably unreasonable to expect lake users to wait for several years, without using other strategies to control nuisance milfoil, to see if a weevil stocking program would be effective. At this time, weevil introduction is not viewed as an effective milfoil control technique for Twin Lakes.

Physical Controls

Drawdown

Lowering water levels during the winter months to expose aquatic plants to freezing and desiccation (drying) is a commonly used management approach in northern climates. Although drawdown can be relatively effective it is limited by the constraints of the lake and its control structure. There can also be adverse impacts to some aquatic flora and fauna in the lake and in hydraulically connected wetlands.

Drawdown is not a recommended option in Twin Lakes for several reasons. Milfoil and curlyleaf pondweed are growing at nuisance densities to water depths in excess of 12 feet, and lowering the lake that far could have serious impacts to non-target species. The existing outlet control structure in addition to the shallow water depth of Third Lake and the very shallow "connector channel" between East Twin and Second Lake would not allow for significant water level manipulation.

Mechanical Removal

Several different approaches have been used to mechanically remove aquatic vegetation. The most commonly employed strategies in the northeast include dredging, harvesting and hydro-raking. Other mechanical techniques like rotovating/rototilling have been used on a limited basis elsewhere across the country with anecdotal if any demonstrated project experience in the northeast.

Mechanical control of Eurasian watermilfoil is generally not recommended in large waterbodies like Twin Lakes because of the potential for plant segmentation and further spread of milfoil. Brief reviews of the potential applicability of hydro-raking, harvesting and dredging are provided.

Hydro-Raking

Mechanical hydro-raking involves the removal of aquatic plants and their attached root structures. Hydro-rakes are best described as floating backhoes. The barge is powered by paddle wheels similar to a harvester, and it is equipped with a hydraulic arm that is fitted with a York Rake attachment. The rake tines dig through the bottom sediments, dislodging the plants in water depths up to approximately 12 ft. Many hydro-rakes do not have on-board storage, so each rake full needs to be deposited directly on-shore or else onto a separate transport barge.

Plants with large, well-defined root structures like waterlilies and emergent species are most efficiently removed through hydro-raking. In some cases, control of these and similar species can be attained for 2-3 years or longer. Hydro-raking is also sometimes favored for annual weed maintenance of public and private beach and swim areas, because removing the plant root structures often provides summer long control of submersed species. It is not well suited for large-scale submersed plant control. Hydro-raking is best suited for removal of perennial plants with large, well defined root structures like waterlilies. Plant removal efficiency is considerably lower than with harvesting, requiring 10 or more operating hours to clear a one-acre area compared to the 3-4 hours typically needed for a harvester. Raking the bottom sediments may also affect plant recolonization and favor species that thrive in disturbed sediments like milfoil.

Hydro-raking has historically been used in the Twin Lakes to clear privately owned access points and swim areas. This technique has merit for these uses and may continue to be a beneficial strategy for controlling native aquatic plant growth (e.g. waterlilies) that are growing to nuisance densities in sections of West Twin Lake. Hydro-raking should not be used in areas were significant, viable growth of milfoil is present.

Mechanical Harvesting

As previously mentioned, a sizeable, annual harvesting operation was conducted at the Twin Lakes for many years, and was the primary control strategy for controlling milfoil, Although aggressive harvesting can achieve seasonal control of milfoil, it greatly increases the risk of milfoil spread through the fragmentation that is inherent in the cutting of aquatic plants. Throughout the country, waterbodies infested with Eurasian watermilfoil were controlled with harvesting, and in many cases the historically harvesting operations are blamed for the rapid spread of milfoil throughout the harvested systems. .

Where milfoil density and distribution in the Twin Lakes has been considerably reduced over the past four years by the chemical treatment program, mechanical harvesting is no longer a recommended management strategy. Cutting the milfoil plants stimulates growth and is believed to result in multiple branched plants, rather than the single stem plants that now regrow throughout most of East Twin and the Third Lake. It would also be nearly impossible to avoid plant fragments from escaping. These fragments develop adventitious roots and are capable or settling to the bottom and becoming reestablished in previously uninfested areas. Additionally, the water flow patterns in the Twin Lakes system will carry escaping plant fragments into the Third Lake, which is the shallowest of the three basins and the most susceptible to rapid reinfestation by milfoil.

Some discussion was raised in recent years about the possibility of performing early season harvests to specifically target curlyleaf pondweed growth. While this may be feasible, it would be logistically challenging. Researchers at the Connecticut Agricultural Experiment Station reported seeing turion production on curlyleaf pondweed plants in early May at Crystal Lake in Middletown, CT in 2006. This would leave a very limited “window” of time to effectively harvest curlyleaf pondweed, without fragmenting milfoil and risking further spread. Milfoil is actively growing by early May.

Dredging

Dredging involves the removal of bottom sediment to add water depth. It controls aquatic vegetation through physical removal of the plant and root structures and nutrient-rich sediments, and by leaving nutrient-poor sediments less suitable for plant growth. There can also be the added benefit of increasing water depth below the photic zone or the depth that light can penetrate to support plant growth. This can be accomplished by various means. Dry-dredging involves draining the lake and using conventional excavation equipment. Wet-dredging, performed without lowering the water levels, uses drag-line equipment from shore or excavation equipment on floating barges. Hydraulic or suction dredging involves the use of a floating barge equipped with an auger cutting head that pumps a water and sediment slurry to nearby containment basins for dewatering. Dredging projects carry a high cost relative to other management techniques, and seldom is a cost-effective means of controlling rooted aquatic plants. Detailed planning and complicated, local, state and federal permits will also be required for most dredging projects. The permitting, data collection and planning process prior to implementation can take several months or longer.

Dredging is not a suitable strategy for wide scale aquatic vegetation control at the Twin Lakes. Operationally, the lakes are too large, without ample access sites to stage a major dredging operation. Deepening the shoreline littoral zone beyond the photic zone is also impractical. Milfoil was regularly found growing to 8-12 feet. Achieving sufficient depth to discourage milfoil growth would leave steeply sloped shorelines that would be subject to erosion, create difficult access for recreation and would drastically alter the existing fish spawning and wildlife habitat. Dredging areas to depths less than 10-12 feet would leave them subject for rapid recolonization by milfoil and other opportunistic exotic plants. Milfoil is often one of the first plants to become reestablished in disturbed sediments. .

HERBICIDE TREATMENT

The use of chemicals to control nuisance aquatic plant and algae growth is probably the most widely used and recommended management strategy for lakes with submersed aquatic plant infestations that are beyond effective control with non-chemical techniques like hand-pulling, suction harvesting or bottom barriers. Registered herbicides must meet strict federal guidelines and demonstrate that there is not an "unreasonable risk" to humans and the environment when applied in accordance with their product label. According to Madsen (Madsen 2000), "currently no product can be labeled for aquatic use if it poses more than a one in a million chance of causing significant damage to human health, the environment, or wildlife resources. In addition, it may not show evidence of biomagnification, bioavailability or persistence in the environment".

Aquatic herbicides and algaecides are also subject to periodic re-registration with the Environmental Protection Agency (EPA) where the latest technology and scientific studies are used to evaluate the potential impacts of these products. Most of the commonly used products have recently completed EPA's more stringent re-registration process. Aquatic herbicides and algaecides must also be registered for use in Connecticut ponds and lakes by the Department of Environmental Protection.

When properly used, aquatic herbicides are capable of providing area and, to some extent, species selective plant control, often with less temporary disturbance than comparative mechanical or other non-chemical techniques. Herbicides are generally described as having either "contact action", meaning that only the actively growing portions of the plants that the chemical comes into contact with are controlled; or "systemic action", where the herbicide is internally translocated throughout the plant effectively killing the stem, foliage and root structures. Systemic herbicides are usually preferred for control of perennial nuisance weeds like Eurasian watermilfoil, since multiple year plant control can be achieved. This reduces the frequency of amount of chemicals that are applied. Systemic herbicides do not have the same benefits for control of curlyleaf pondweed or other annual plants that propagate from seed each year. These types of plants can be just as effectively controlled with contact herbicides. Several consecutive years of treatment with contact herbicides before turions (seed structures) are produced are usually needed to achieve appreciable reductions in the amount of curlyleaf pondweed regrowth.

Species-selective control is also desired when targeting non-native and invasive species like Eurasian watermilfoil. Treatment programs can be tailored to limit impacts to non-target native species through treatment timing, treatment location, use of different herbicide formulations, and manipulation of the herbicide concentration or dose rate. Achieving species-selectivity is often challenging considering the limitations of the available herbicide formulations and the variability of response seen from lake to lake. Water chemistry, lake morphology, bottom sediment type and plant composition all potentially influence herbicidal activity and the results are often not completely predictable.

Summaries of aquatic herbicides that could potentially be used for nuisance plant control at Twin Lakes are provided below. The mode of action and anticipated efficacy for each herbicide is provided, along with highlights on toxicity and non-target impacts. More detailed summaries of each herbicide are provided in Appendix B.

The principal contact-acting herbicides include diquat (Reward), endothall (Aquathol) and copper (various forms of copper-carbonate and copper-ethylenediamine complexes). These products target and disrupt different pathways, but are similar in that they only control portions of the plant that are directly contacted. Contact-acting herbicides are relatively fast acting, with most plant uptake usually occurring over a 1-3 day period. Susceptible plants generally die-back within 1-2 weeks of exposure. Contact-acting herbicides will usually provide summer long control of target species. Since the root structures are not controlled, regrowth usually occurs the following year. Systemic herbicides include 2,4-D granular (Navigate), fluridone (Sonar) and Triclopyr (Renovate). These herbicides are absorbed and translocated within the plant, effectively controlling the entire plant including the roots. Typically multiple years of control is attained with systemic herbicides.

Reward (diquat)

Reward is probably the most commonly used contact herbicide for milfoil control in the Northeast. We estimate that over 150 Connecticut ponds and lakes are treated annually with Reward and more than 400 waterbodies throughout New England. It is a rapid acting contact herbicide that disrupts the leaf cuticle of plants and acts by interfering with photosynthesis. Good selectivity for Eurasian watermilfoil control has been seen in some large lake systems in the Northeast, as demonstrated at Twin Lakes between 2003-2006. Seasonal control of milfoil and curlyleaf pond has been achieved, while most broad-leaved pondweeds (*Potamogeton spp.*) and other native species have largely been preserved.

The concentration of Reward in treated water after application at the maximum allowable 2 gallon/surface acre use rate is approximately 0.37 ppm ion immediately after application. Residual levels of Reward in water decline very rapidly, and their reduction is due to the uptake by the weeds and adsorption to suspended soil particles in the water or to the bottom sediment. Reward is practically immobile in sediment and does not pose a significant risk for contamination of wells or ground water. Photochemical degradation accounts for some loss under conditions of high sunlight and clear water. Usually residues decline to 0.01 ppm or below with 3-14 days after treatment.

Application Rate – Reward is usually applied at 1-2 gallons per acre depending on water depth, plant density, water clarity and treatment area configuration. The maximum application rate in water less than two feet deep is one gallon per acre.

Efficacy on Milfoil and Curlyleaf Pondweed – Eurasian watermilfoil and curlyleaf pondweed are controlled by Reward. Treatment typically occurs when the plants are in their most active phase of growth, but before peak biomass is reached. This usually falls between late May and early July. Plants die-back completely within 2-3 weeks of treatment and are usually controlled for the remainder of the summer season. Regrowth of milfoil in the year following treatment with Reward can range from no regrowth up to 100 percent regrowth with no discernible pattern among the treated lakes. The amount of regrowth is likely determined by several factors including plant density, bottom sediment type, water clarity, and abundance of non-target plant growth that is not impacted by the treatment. A typical level of milfoil regrowth seen the year after treatment in the northeast is 75 percent.

Water Use Restrictions – Reward went through the Re-registration Eligibility Determination process with EPA in the mid 1990's. Following that review the temporary water use restrictions were lowered considerably. The current EPA label lists the following restrictions on using treated water:

- Drinking – 3 days
- Livestock Consumption – 1 day
- Irrigation for Turf and Ornamentals – 3 days
- Irrigation for Food Crops – 5 days
- Swimming and Fishing – no restriction

Advantages – The principal benefits of Reward are its rapid action, effectiveness for partial lake or shoreline applications, and its low cost as compared to other available aquatic herbicides.

Disadvantages – Its contact action and inability to provide multiple years of nuisance plant control are the primary limitations of Reward. It has reduced efficacy in highly colored or turbid water, but this is rarely encountered on large lake systems in the Northeast and is certainly not a limiting factor at the Twin Lakes where water clarity is excellent. Reward is considered a broad-spectrum herbicide and it will impact some non-target, native plants; although, selectivity for milfoil has been good at the Twin Lakes.

Aquathol (endothall)

Aquathol is another contact herbicide available for control of milfoil and curlyleaf pondweed. Similar to Reward, Aquathol can be used in area specific partial or whole-lake applications, however, typically provides the same results of Reward applications at a higher unit cost.

Endothall, the active ingredient in Aquathol, reacts with the cell structure to inhibit protein synthesis. The chemical is absorbed into the plant within 12-24 hours after application. Chemical that is not absorbed by the plants is either broken down very quickly or chemically bound up in the sediment where it undergoes further degradation. Endothall is biodegradable, and it normally disappears from water in 1-10 days after application and from the soil in one to three weeks.

Application Rate – Aquathol is available in two formulations – Aquathol K is a concentrated liquid and Aquathol Super K is a granular formulation. Dose calculations for both formulations are determined on a volumetric basis. Application rates of 2.0-3.0 ppm are recommended for whole lake or large treatment areas, while rates of 3.0-4.0 are recommended for spot or lake margin treatments targeting milfoil.

Efficacy on Milfoil and Curlyleaf Pondweed – Again, both Eurasian watermilfoil and curlyleaf pondweed are controlled by Aquathol K. Treatment typically occurs when the plants are in their most active phase of growth, but before peak biomass is reached. This usually falls between late May and early July. Plants die-back completely within 2-3 weeks of treatment and are usually controlled for the remainder of the summer season. Variable levels of Eurasian watermilfoil regrowth are reported in the year following treatment. Limited reduction in regrowth is anticipated the year after treatment.

Water Use Restrictions – The current EPA label lists the following restrictions on using water treated with Aquathol formulations:

- Livestock Watering, Agricultural Food Sprays, Irrigation, or Domestic Purposes – 7-25 days (depending on concentration applied)
- Swimming and Fishing – no restriction

Advantages – Its rapid action and effectiveness for partial lake or shoreline applications. Aquathol can be used early season in colder water temperatures than Reward. It also could be used for area selective control of broad-leaved pondweeds.

Disadvantages – Again, being a contact herbicide the potential for multiple years of control is limited. The broad-spectrum activity of Aquathol will also impact some non-target, native plants.

Cerexagri-Nisso LLC, the manufacturer of Aquathol, claims that recent early season treatment work being performed in the Midwest by the U.S. Army Corps of Engineers targeting curlyleaf pondweed control is also showing good efficacy on Eurasian watermilfoil. Treatments are being performed early in the growing season (late April – early May) when the water temperatures reach 50° F and the plants are only a few feet tall. Treatment protocol has been to treat the lower four feet of the water column at a dose of 1.5 ppm. Aquathol K liquid is being applied using weighted hoses or Aquathol Super K granular is being used. These lower dose rates have provided effective, season-long control of curlyleaf pondweed and Eurasian watermilfoil. Applying a lower concentration provides significant cost savings over higher dose rates. The early season applications have the added benefit of reducing impact to non-target species that have not entered active growth phases so early in the season. If experimental low-dose, early-season Aquathol applications continue to show effective control of curlyleaf pondweed and Eurasian watermilfoil, some consideration of Aquathol applications on Twin Lakes should be considered.

Copper-Based Herbicides (Komeen/Nautique)

Several copper complexes (various forms of copper-carbonate and copper-ethylenediamine) are marketed as contact herbicides. Used alone, these compounds provide typically seasonal control of vascular plants, at best. When used in combination with other herbicides like Fluridone (Sonar) or Reward, they can sometimes enhance their effectiveness. Copper compounds tank-mixed with other herbicides often improve treatment efficacy where the target plants are heavily coated with filamentous algae.

Due to their limited effectiveness, copper-based herbicides are not applicable for the current aquatic vegetation problem at Twin Lakes. These copper compounds typically have no temporary water use restrictions post-treatment when applied to ponds, lakes and even drinking water reservoirs.

Navigate (2,4-D granular)

Having been used for well over four decades 2,4-D is the oldest and most extensively researched systemic herbicide in the aquatics industry. Granular formulations of 2,4-D ester (Aqua-Kleen & Navigate) are used almost exclusively in the northeast. The granules sink to the bottom where the active ingredient is released over a period of hours to a few days. Plant uptake occurs at the leaves, shoots and root structures. It mimics plant auxins, promoting cell elongation without new cell production. Essentially plants grow themselves to death. Epinasty or the bending and twisting of leaves and stems are the visible signs associated with 2,4-D exposure. 2,4-D is highly selective since it is most effective on dicot, or broad-leafed, species. Commonly managed aquatic dicots include watermilfoils, water chestnut and occasionally water lilies. Most monocot or narrow-leafed species, are only marginally impacted or tolerant of 2,4-D applications. This allows for larger-scale applications to be performed that are fairly species selective. Selective control of milfoil can be achieved with application rates between 75-100 pounds per surface acre, which is less than half the maximum permissible label rate of 200 pounds per acre. The granular formulation also facilitates fairly successful partial lake or shoreline applications.

Application Rate – 2,4-D is available as a granular ester formulation and as a liquid amine formulation. The granular ester formulation is primarily used in the Northeast. The labeled application rate is 100-200 pounds per surface acre. Eurasian watermilfoil is usually highly susceptible to 2,4-D granular and application rates between 75-100 pounds per acre usually provide sufficient control.

Efficacy on Milfoil and Curlyleaf Pondweed – Eurasian watermilfoil is effectively controlled by 2,4-D. It primarily targets dicot plants, so less effective control of curlyleaf pondweed is anticipated following treatment. Treatment typically occurs when the plants are in their most active phase of growth, but before peak biomass is reached. This usually falls between late May and early July. Plants die-back completely within 2-3 weeks of treatment. The systemic action of 2,4-D usually provides multiple years of effective Eurasian watermilfoil control. Two or three years of nuisance level milfoil control is typical for whole lake or large area treatments.

Water Use Restrictions – The current EPA label lists the following restrictions on using water treated with 2,4-D granular formulations:

- Do not drink treated water until the in-lake concentration drops below 70 ppb
- Do not use treated water for irrigation until the in-lake concentration drops below 100 ppb
- Swimming and Fishing – no restriction

It typically takes 3-4 weeks for 2,4-D concentrations to drop below the reuse thresholds.

Advantages – Selectivity for dicot plants, effectiveness for partial lake or shoreline applications, and systemic action that provides multiple years of effective control make 2,4-D especially effective for Eurasian watermilfoil control.

Disadvantages – Extended water use restrictions limit where 2,4-D can be used. It also carries a negative public perception for use in water, despite being one of the most widely used terrestrial herbicides.

Sonar (fluridone)

Sonar has often become the herbicide of choice for managing lake-wide infestations Eurasian watermilfoil. It has demonstrated the ability to provide fairly selective control of Eurasian watermilfoil at low doses and its systemic action typically yields multiple years of effective control. Sonar also has a favorable toxicology profile with regulators and the general public. It is even labeled for use directly in potable (drinking) water reservoirs at low doses (<20 ppb) with no restrictions on using the treated lake water for drinking or domestic purposes.

Application Rate – Available Sonar formulations include the liquid Sonar AS (Aqueous Suspension) and three pellets Sonar SRP (Slow Release Pellet) Sonar PR (Precision Release) and Sonar Q (Quick Release). All formulations are labeled for a maximum application rate of 150 ppb. Effective control of Eurasian watermilfoil has been achieved with doses as low as 5 ppb, but doses in the 8-10 ppb are generally preferred for increased duration (2-3 years) of control. Pellets are usually applied at higher application rates, due to the time delayed release of fluridone off of the pellets.

Efficacy on Milfoil and Curlyleaf Pondweed – Eurasian watermilfoil and curlyleaf pondweed are highly susceptible to low dose (5-10 ppb) concentrations of Sonar. Provided that adequate contact time can be maintained for 60-90 days, the systemic action of fluridone typically provided multiple year control of Eurasian watermilfoil.

Water Use Restrictions – The current EPA label lists the following restrictions on using water treated with Sonar:

- Do not use treated water for irrigation for 7-30 days following treatment or until the in-lake concentration drops below 10 ppb or 5 ppb for known sensitive species.
- Do not apply Sonar within ¼ mile of an active potable water intake.
- Swimming and Fishing – no restriction

Advantages – Major advantages include low cost for whole-lake applications, potential selectivity for sensitive species with low dose (<10 ppb) applications, systemic action that provides multiple years of effective Eurasian watermilfoil control, and a favorable toxicology profile.

Disadvantages – The high solubility of Sonar makes it difficult to achieve effective control with spot or shoreline applications. Even low dose (<10 ppb) applications can have adverse impacts non-target, native species as was seen at Third Lake in 2001.

The 2001 "low dose" Sonar application on the Third Lake demonstrated that Sonar can be used to effectively control Eurasian watermilfoil on Twin Lakes. The results of that demonstration treatment clearly indicate that Sonar is capable of providing effective multi-season control of milfoil, however, it also demonstrated the susceptibility of the endangered *Megalodonta beckii* to the activity of the herbicide. The presence of *Megalodonta beckii* and other State Protected species in all three basins of the Twin Lakes likely will prohibit the use of Sonar.

Renovate (triclopyr)

EPA granted full aquatic registration for Triclopyr (trade name Renovate 3) in the fall of 2002. Triclopyr has been used in the turf, forestry and right-of-way industries to control terrestrial plants for many years under the trade name Garlon 3A. Triclopyr is an auxin mimic systemic herbicide that targets dicot or broad-leafed plants, with a mode of action similar to that of phenoxy herbicides like 2,4-D. It is translocated throughout the entire plant killing the stem, foliage and roots. It only requires a short contact time with targeted plants, so it should be effective for partial lake treatments. Presently, it is formulated as a concentrated liquid. Dosing is based on the volume of water being treated. Demonstration treatments performed under an Experimental Use Permit (EUP) issued by the EPA showed that species-selective control of submersed Eurasian watermilfoil and emergent purple loosestrife could be achieved. While Renovate cannot be currently used at Twin Lakes, it could prove to be an potential management tool for partial lake treatments of milfoil in future years.

Application Rate – Renovate is available as a liquid (Renovate 3) or newly released flake (Renovate OTF) amine formulation. The labeled application rate is based on water volume, target species and anticipated contact time. The dose rate ranges from 0.75-2.5 ppm. Anticipated recommended application rates for large area treatments are between 1.5-2.0 ppm.

Efficacy on Milfoil and Curlyleaf Pondweed – Eurasian watermilfoil is effectively controlled by Renovate. Like 2,4-D, it primarily targets dicot plants, so less effective control of curlyleaf pondweed is anticipated following treatment. Treatment typically occurs when the plants are in their most active phase of growth, but before peak biomass is reached. This usually falls between late May and early July. Plants should die-back completely within 2-3 weeks of treatment. The systemic action of Renovate promises to provide multiple years of effective Eurasian watermilfoil control. Two or three years of nuisance level milfoil control is expected for large area treatments. Curlyleaf pondweed is not effectively controlled by Renovate.

Water Use Restrictions – The current EPA label lists the following restrictions on using water treated with Renovate:

- Do not use treated water for irrigation for 120 days or until the in-lake concentration drops below detectable limits.

Advantages – Anticipated benefits include selectivity for dicot plants, effectiveness for partial lake or shoreline applications, and systemic action that provides multiple years of effective Eurasian watermilfoil control.

Disadvantages – Renovate carries a considerably higher unit cost than other herbicides that are effective for partial-lake treatment (i.e. Reward, Aquathol and Navigate). There are not many lakes that have been treated with Renovate in the Northeast. The potential impact to some native species, in particular State Protected species, is not yet as well documented as it is for most other aquatic herbicides.

Rodeo (glyphosate)

Rodeo or its generic equivalents (active ingredient glyphosate) is registered for aquatic use. It has no effect on submersed aquatic plants because it is rapidly degraded by hydrolysis, but it can be used to treat the dry/exposed vegetation of floating-leaved and emergent species.

Application Rate – Glyphosate is typically applied in a ¾-1 ½ % solution. It is usually mixed with an aquatic surfactant (sticking agent).

Efficacy on Milfoil and Curlyleaf Pondweed – None. This product is only effective on floating-leafed and emergent species. It should be applied directly to the dry/exposed vegetation of mature plants.

Water Use Restrictions – The current EPA label lists the following restrictions on using water treated with glyphosate:

- Do not apply with ½ mile of an active potable water intake.

Advantages – This product could be an effective means of selectively controlling nuisance waterlily growth. Unlike mechanical techniques, it will not disturb submersed vegetation or the bottom sediments, which can favor recolonization by invasive species like milfoil or curlyleaf pondweed.

Disadvantages – Broad-spectrum action requires care during application.

NO ACTION ALTERNATIVE

Taking no action to control and prevent further infestation of the Twin Lakes with milfoil or other non-native species would be inconsistent with the current and future management objectives of the Town of Salisbury and the Twin Lakes Association, and the uses of the lake by abutters and visitors. No action to control the invasive aquatic plants would significantly alter the recreational and ecological values of the lake, and therefore, is not an acceptable alternative. Some "natural" milfoil crashes have been documented, but they are relatively infrequent and the causes are uncertain. Increases in milfoil cover within a lake are usually the norm.

Allowing milfoil to grow unabated will enable it to out-compete more desirable native plants. This would likely result in the regrowth of large, dense stands of milfoil that were present when the lakes were being harvested in the 1990's. Resulting monocultures decrease fish and wildlife habitat, can greatly impair recreation and reduce property values. Lakes with dense milfoil beds throughout the littoral zones often develop filamentous algal growth on top of the milfoil, which further restricts access and degrades water quality. Dense floating mats of milfoil fragments often develop in lakes where recreational boating pressure is significant. Ultimately, increased milfoil cover would cause more biomass deposition each year and accelerate the eutrophication of the entire lake.

AQUATIC VEGETATION MANAGEMENT RECOMMENDATIONS

MANAGEMENT OBJECTIVES

The most challenging aspect of preparing any long-term vegetation management plan is formulating realistic and attainable objectives. Based on the experiences between 2003 and 2006, it would appear that Eurasian watermilfoil and curlyleaf pondweed can be effectively and selectively managed in the Twin Lakes through spot-treatments with aquatic herbicides. Considering the size of the lakes and the amount of area being currently managed (60-100 acres each year), herbicide treatment will continue to be an essential management tool. However, if conditions change or the management-focus increases to include control of native species, then non-chemical strategies should be considered. Ultimately, a fluid plan should be adopted that integrates the most appropriate strategy for each specific objective.

Based on the current conditions at Twin Lakes, it would appear to be reasonable to adopt the following principals in a long-term vegetation management plan. The challenge will be to develop a program that adequately addresses all of these stated needs.

1. Target control of the dense Eurasian watermilfoil curlyleaf pondweed beds
2. Prevent the establishment of other non-native and potentially invasive species
3. Preserve a diverse native plant assemblage for fish and wildlife habitat
4. Avoid any adverse impacts to State Protected species
5. Avoid any adverse impacts on water quality
6. Improve recreation for the multiple user groups, including: fishing, rowing, sailing, power boating and swimming.

RECOMMENDED MANAGEMENT PROGRAM

Preparing a Long-Term Aquatic Vegetation Management Plan for the Twin Lakes requires current and potential future issues to be addressed. Presently, there are two distinct aquatic plant management needs at the Twin Lakes:

Maintain control over non-native Eurasian watermilfoil and curlyleaf pondweed

Provide area-selective control of excessive native plant growth along developed shorelines and access points

These may change in the future, if new invasive species are discovered or other issues supplant the need for or importance of aquatic plant management. The management plan must remain fluid to account for such changes.

Eurasian Watermilfoil and Curlyleaf Pondweed Control

For the immediate future, continuation of the current Eurasian watermilfoil and curlyleaf pondweed management program is recommended. The Reward herbicide treatment program performed between 2003 and 2006 has provided exceptional seasonal control of milfoil and curlyleaf pondweed, with minor impacts to non-target species.

Continue Current Program - Reward (Diquat) Herbicide

Specific elements that should be included in future Reward (diquat) herbicide treatments follow:

Treatment Area	Treatment should be limited to controlling areas with common to dense cover of milfoil and curlyleaf pondweed. Actual treatment areas should be finalized following pre-treatment inspections performed in late May and early June of each year. East Twin – Primary treatment areas should continue to include the western and southern developed shorelines, swim area on south side of Isola Bella Island, and a boating access lane to O'Hara's Marina. Possible areas for expansion include the developed portion of northeast shoreline immediately north of O'Hara's, if adequate protection of State Protected species at the northern end of the lake can be maintained. Third Lake – Continue managing nuisance growth throughout Third Lake. Possible expansion into the outlet canal may be warranted. Second Lake – The 2006 demonstration treatment provided fairly selective control of milfoil. Measured expansion of treatment acreage should be pursued in 2007. Priority areas remain the Salisbury School dock, access around other property owners' docks and creating a boating lane to Third Lake. Expansion of the treatment area should proceed cautiously to guard against impacts to State Protected species.

Treatment Timing	Between late May and mid June This time frame is preferred because the milfoil and curlyleaf pondweed plants will be mature enough to accurately identify treatment areas, many of the native species will not have started their most active phase of growth, and the water temperatures will just be reaching 65 F, which is recommended to optimize the efficacy of Reward (diquat).
Treatment Approach	Herbicide applications should be guided by DGPS navigation to insure that the pre-determined treatment areas are being treated and that the herbicide is being evenly applied. Deeper water (8-15 feet) treatment areas on East Twin and Second Lake should be treated using a deep-water injection technique. This should help to limit dilution and herbicide movement away from the targeted area, and help limit the total acreage requiring treatment. Avoiding direct application of herbicide in the shallow margins of the littoral zone should further limit impact on non-target native species that are principally established in these areas.

Alternative Aquatic Herbicides for Future Use

At some point, it may be worthwhile or perhaps necessary to consider the use of alternate herbicides. This may be required if the targeted nuisance species change, if impacts to native species are identified, if new research suggests that a more effective and more selective product is available, and to avoid the possibility of selecting for herbicide tolerant milfoil. The recent discovery of Sonar (fluridone) tolerant Hydrilla in Florida has brought nationwide awareness to the possibility of herbicide tolerance in aquatics. To date, tolerance of aquatic plants to herbicides has not been reported in the Northeast, where the frequency of treatment and application rates are lower than in southern climates. Alternate herbicides to consider for management of the current milfoil and curlyleaf pondweed infestations include:

Renovate (Triclopyr) – Renovate would be effective for area-selective control of milfoil. It is not expected to control curlyleaf pondweed. Multiple-year milfoil control and greater selectivity are the potential advantages of using Renovate over Reward. The systemic mode of action of Renovate kills the entire plant including the root structures. This should provide multiple years of effective milfoil control and potentially reduce treatment frequency. Dicot or broad-leaved plants like milfoil and waterlilies are much more susceptible to Renovate than monocot or narrow-leaved species like many of the native pondweeds. This should facilitate selective milfoil control; however, the selectivity seen following the Reward treatments at the Twin Lakes has been quite good.

Renovate is still fairly new to the aquatic market. The liquid formulation (Renovate 3) that has been available for the past several years has proven to be effective, but it is very expensive when treating water deeper than 6 feet. A solid or flake formulation (Renovate OTF) just received its federal registration (EPA label) in November 2006. This formulation will reportedly facilitate treatment of deeper water at a lower cost, because the treatment dose is based on the lower 4 feet of the water column.

Several applications of Renovate OTF in the Northeast are being planned and permitted for the 2007 season. Once more information is available on the efficacy of this product in the Northeast region, it should be reevaluated for use at the Twin Lakes.

Aquathol (endothall) – Early season applications of Aquathol may be worthwhile for consideration at the Twin Lakes, if they can demonstrate season-long control of both milfoil and curlyleaf pondweed. Aquathol has greater activity in colder water temperatures, which would enable the treatment to occur approximately one-month earlier than the current early-mid June schedule with Reward. The advantages of treating earlier are 1) the potential for less impact to native species and 2) the potential to control curlyleaf pondweed before any turion (reproductive structure) production occurs. The chemical cost will likely be 2-4 fold higher than a comparative Reward treatment.

An early season Aquathol treatment program was initiated at Copake Lake in Copake, NY in 2006 and is expected to continue in 2007. A similar treatment program is tentatively planned for Lake Waramaug in CT, where a pioneer infestation of curlyleaf pondweed was discovered in 2006. Results of these treatments should help evaluate the potential for using Aquathol at the Twin Lakes.

Non-Chemical Control Strategies

Proven non-chemical control strategies used to control large-scale submersed plant infestations (i.e. mechanical harvesting and drawdown) are not appropriate for the Twin Lakes for a variety of reasons. However, diver hand-pulling and possibly the use of bottom barriers could be considered to control low density or small, isolated patches of milfoil or curlyleaf pondweed. Presently the infestation remains too widespread and the plant density is still too high for these strategies to be used cost-effectively. There inclusion into an integrated management program may be warranted, if continued reduction of milfoil and curlyleaf pondweed is realized over the next several years. Lake residents should also be trained and encouraged to carefully remove widely scattered milfoil and curlyleaf pondweed plants.

Native Plant Control

Presently, the primary concerns with native plant growth appear to be in the Third Lake, which is the shallowest of the three basins. Floating-leaved waterlilies and broad-leaved pondweeds appear to be the species reaching problematic densities.

Waterlily Control

Waterlilies do form dense surface mats of vegetation and much of the growth is close to shore and directly adjacent to individual docks and swim areas. These plants were being partially controlled when the lake was being mechanically harvested. There was also considerable thinning of the waterlily growth following the 2001 Sonar herbicide treatment. Over the past several years considerable re-growth has occurred because Reward herbicide does not impact waterlilies. Area-selective management of waterlilies could be performed to improve access for shoreline residents.

Rodeo (glyphosate) – Topical applications of glyphosate herbicide could be performed to provide area selective control of waterlily growth. Treatment should be performed once the plants have matured, typically in July and August. This is when the plants are actively trying to build up the starch reserves and it helps translocate the herbicide to their root structures. Typically, one or two applications are required to effectively control the targeted plants. Glyphosate is systemic-acting and carryover control into a second and possibly third season would be anticipated. However, only spot-treatments are recommended, so some level on ongoing maintenance will be required.

Mechanical Hydro-Raking – Reportedly, many of the shoreline property owners, particularly in the Third Lake, have utilized mechanical hydro-raking around their individual dock and swim areas. This is an effective means of selectively controlling waterlily growth because the plants have large root structures. Hydro-raking is also effective at removing accumulated leaf-litter and other organic debris. Care should be taken to avoid hydro-raking in areas where there is active milfoil or curlyleaf pondweed growth, because the resulting fragmentation could spread the infestation.

Broad-Leaved Pondweed Control

Portions of the Third Lake harbor fairly robust growth of broad-leaved pondweeds. These plants are capable of matting to the surface in moderate water depths (typically less than 8 feet). Seasonal variations in the density of these plants are anticipated. If they truly reach problematic densities that interfere with recreational use of the lake, then spot-treatment with Aquathol (endothall) herbicide could be considered. If these species begin to encroach on dock and swim areas, residents should try to manually remove the plants through raking or hand-pulling. Broad-leaved pondweeds grow much more slowly than milfoil or curlyleaf pondweed, and physically removing the plants can often provide several seasons of effective control. The broad-leaved pondweeds have high fish and wildlife value, so large-scale control of these species is not recommended.

APPENDIX

Herbicide Toxicology Summaries

HERBICIDE TOXICOLOGY & ENVIRONMENTAL FATE SUMMARIES

The following toxicology and environmental fate summaries were adapted from Appendix III of “Eutrophication and Aquatic Plant Management in Massashusetts; Final Generic Environmental Impact Report.” This section was compiled by the Massachusetts Department of Environmental Protection, Office of Research and Standards.

Reference:

Mattson, M.D., P.J. Godfrey., R.A. Barletta and A. Aiello. 2004. Eutrophication and Aquatic Plant Management in Massachusetts. Final Generic Environmental Impact Report. Edited by Kenneth J. Wagner. Department of Environmental Protection and Department of Conservation and Recreation, EOEA, Commonwealth of Massachusetts.

Diquat (Reward)

Diquat dibromide (6,7 –dihydrodipyridol [1,2-ά:2’,’-c] pyrazinediium ion)

Distributing Company- Syngenta Group Greensboro, NC
EPA Registration Number- 100-1091
Percent of Active Ingredient- 35.3%
General- a water soluble contact type, nonselective herbicide
Aquatic Uses- used to control both submerged and floating weeds
Submersed Plants Controlled by Diquat- Bladderwort (*Utricularia*), Coontail (*Ceratophyllum demersum*), Elodea (*Elodea spp.*), Naiad (*Najas spp.*), Watermilfoil (*Myriophyllum spp.*), Hydrilla (*Hydrilla verticillata*), Pondweeds (*Potamogeton spp.*)
Mode of Action- Diquat is absorbed readily by foliage through the cuticle of the leaf. Absorption is rapid, resulting in concentrations in plant tissue well above that in surrounding water. Diquat’s herbicidal activity is dependant on the diquat cation.
Environmental Fate- Following application dissipation of diquat is very rapid. At the maximum label rate of 4lbs/acre (in four feet of water) yields a concentration of 0.37ppm, falling to 0.10ppm within 24 hours and 0.01ppm within 14 days. Once diquat reaches the sediment it is irreversibly bound and becomes biologically unavailable.
Toxicity- As a result of Diquat’s rapid dissipation acute effects on organisms in the field are unlikely at rates used for vegetation control. Studies have found that *Daphnia* and *Hyallella* are the most sensitive invertebrates with 24-hour LD50s of 1-2ppm, and 0.6ppm respectively. Diquat has shown no adverse effect on oysters, shrimp or fish. Toxicity of Diquat varies with the size and type of fish as well as the softness or hardness of water. One study reports LD50 values ranging from 12-90ppm for 24-hour exposures, 6-44ppm for 48-hour exposures and 4-36ppm for 96-hour exposures. The results of 13 experiments conducted with diquat indicate that diquat did not cause any direct mortality to any fish species at 1.0ppm and below. The highest concentration allowed by the manufacturer’s label would equal an initial in-water concentration of 1.5ppm. When diquat concentrations diminish in the water, diquat concentrations in fish tissue clear.
Water Use Restrictions (at maximum label rate of 1.5ppm)-

- Drinking – 3 days
- Fishing and Swimming – 0 days
- Livestock Consumption – 1 day
- Irrigation for turf and ornamentals – 3 days
- Irrigation for food crops – 5 days

Fluridone (Sonar)

(1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone)

Distributing Company- SePRO Corporation, Carmel IN
EPA Registration Number- 67690-4, 67690-12, 67690-3
Percent of Active Ingredient- 41.7%
General- a selective systemic aquatic herbicide
Aquatic Uses- used to control broad-leafed aquatic macrophyte species
Submersed Plants Controlled by Fluridone- American Lotus (*Nelumbo lutea*), Bladderwort (*Utricularia*), Coontail (*Ceratophyllum demersum*), Duckweed (*Lemna minor*), Elodea (*Elodea spp.*), Fanwort (Cabomba caroliniana), Hydrilla (*Hydrilla verticillata*), Naiad (*Najas spp.*), Watermilfoil (*Myriophyllum spp.*), Pondweeds (except Illinois) (*Potamogeton spp.*), Spatterdock (Nuphar luteum), Waterlily (*Nymphaea spp.*), Waterprimrose (including *Waterpurlane*) (*Ludwigia spp.* including *Ludwigia palustris*), Watershield (*Brasenia schreberi*)
Mode of Action- Fluridone produces its toxic effect in plants by inhibiting carotenes (pigments that protect chlorophyll molecules from photodegredation)
Environmental Fate- Following application the major fate process affecting fluridone in aqueous environments is photolysis. Secondary fate processes include microbial degradation, absorption to soil and suspended colloids and plant uptake. Fluridone that has adhered to sediment particles/organics in sediment will eventually desorb and photodegrade.
Toxicity- At maximum label concentrations fluridone has no acute effects on aquatic organisms. At twice the maximum label rate (0.30ppm) fluridone has been shown to cause a reduction in certain zooplankton, however, populations recover quickly. Fish toxicology studies have found that Rainbow Trout are most sensitive to fluridone with 96-hour LD50 values of 11.7ppm, nearly eighty times the maximum label rate.
Water Use Restrictions (at maximum label rate of 150ppb)-
Drinking – 0 days
Fishing and Swimming – 0 days
Livestock Consumption – 1 day
Irrigation – 7-30 days

2,4-D (BEE - butoxyethonol esters) (Navigate)

(2,4-dichlorophenoxyacetic acid)

Distributing Company- Applied Biochemists Milwaukee, WI (Navigate)
EPA Registration Number- 713668-4-8959 (Navigate)
Percent of Active Ingredient- 27.6%
General- a somewhat selective systemic broadleaf aquatic herbicide
Aquatic Uses- used to control a variety of submersed, emersed and floating aquatic plants
Submersed Plants Controlled by Fluridone- Arrowhead (*Sagittaria spp.*), Bladderwort (*Utricularia*), Bullrush (Scirpus spp.), Burreed (Sparganium spp.), Coontail (*Ceratophyllum demersum*), Creeping Waterprimrose (*Jussiaea repens*), Pickerelweed (*Pontederia spp.*), Spatterdock, Cow Lily, Yellow waterlily (*Nuphar spp.*), Waterweed (*Elodea spp. or Anacharis*), Waterchestnut (*Trapas natans*), Naiad (*Najasflexilis.*), Watermilfoil (*Myriophyllum spp.*), Pondweeds (*Potamogeton spp.*), Waterlily (*Nymphaea spp.*), Water Smartweed (*Polygonum spp.*), Watershield (*Brasenia schreberi*)
Mode of Action- 2,4-D is readily translocated throughout the plant phloem (the food-conducting tissue of vascular plants). It is a somewhat selective, systemic growth regulator with hormone-like activity. 2,4-D inhibits cell division of new tissue and stimulates cell division of some mature plant tissue, resulting in inhibition of growth, necrosis (death of cells) of apical growth and eventual total cell disruption and plant death.
Environmental Fate- The primary fate process of 2,4-D (BEE) in water is microbial biodegeneration and hydrolysis (decomposition of a chemical compound by reaction with water). Degradation of 2,4-D in aquatic sediment is rapid, generally occurring in less than one day through microbial biodegeneration.
Toxicity- 2,4-D (BEE), is toxic to fish with LD50s starting below 1ppm (0.78ppm for Cutthroat fingerlings). In-water concentrations following application of 2,4-D rarely exceed 0.3ppm and are generally much lower around 0.1-0.15ppm. Bioconcentration factors (BCF) values for 2,4-D (BEE) are very low. The ester formulation of 2,4-D is quickly hydrolyzed by organisms to its acid form and rapidly excreted. Applied at maximum label rate, 2,4-D poses little treat to aquatic organisms from either acute or chronic poisoning.

Water Use Restrictions (at maximum label rate of 200lbs/acre)-

Drinking – <0.07ppm*
Irrigation – <0.1ppm*
*concentrations to be determined by approved assay

Endothall (Aquathol)

Dipotassium salt of endothall (7-oxabicyclo [2.2.1]heptane-2,3-dicarboxylic acid)

Distributing Company- Cerexagri, Inc. Philadelphia, PA
EPA Registration Number- 4581-204-82695, 4581-388-82695
Percent of Active Ingredient- 40.3%
General- a relatively water soluble contact herbicide
Aquatic Uses- used to control submersed aquatic macrophyte species
Submersed Plants Controlled by Endothall- Largeleaf pondweed (Bass Weed) (Potamogeton amplifolius), Burreed (Sparganium spp.), Coontail (*Ceratophyllum demersum*), Watermilfoil (*Myriophyllum spp.*), Bushy pondweed (Najas spp.), Curly-leaf pondweed (*Potamogeton crispus*), Flat-stemmed pondweed (*Potamogeton zosteriformis*), Floating-weed pondweed, (*Potamogeton natans*), Horned pondweed (*Zannichellia spp.*), Sago pondweed (*Potamogeton pectinatus*), *Potamogeton nodosus, Potamogeton diversifolius, Potamogeton filiformis, Potamogeton pusillus,* Water Star Grass (*Heteranthera spp.*)
Mode of Action- Not clear – Knowns: Endothall interferes with plant protein synthesis; affects lipid synthesis and dipeptidase and proteinase activities. Postulations: 1. Endothall produces a number of cell membrane changes that cause drying and wilting of leaf tissue and an increased respiratory rate in plants; 2. endothall acts to inhibit respiration; 3. endothall interferes with metabolism of molecules involved in genetic coding.
Environmental Fate- Following application the major fate process affecting endothall in aqueous environments is biotransformation and biodegeneration via microbial action. In aerobic conditions, endothall has a half-live of a week or less. In anoxic conditions this half-life is increased to about 10 days. Endothall applied to a waterbody at a rate of 0.3-1.4ppm has a half-life between 2.5-12 days. In general endothall usually undergoes compete degradation 30-60 days in aquatic systems depending on application rate and trophic conditions. Endothall does not adsorb to sediments nor does it bioconcentrate in organisms to any appreciable degree.
Toxicity- At maximum label concentrations endothall (in dipotassium salt formulation) has no acute effects on aquatic organisms. The maximum allowable application rate of endothall (as Aquathol K) is 5ppm. Studies have shown that typical 96-hour LC50 values for most aquatic organisms are greater than 150ppm, but rage from 39-740ppm. Toxicology studies have found that mysid shrimp are most sensitive to the Aquathol formulation of endothall with an LC50 value of 39ppm, nearly nine times the maximum label rate.
Water Use Restrictions (at maximum label rate of 5ppm)-

Drinking – 25 days
Fish Consumption – 3 days
Livestock watering – 25 days
Irrigation – 25 days

Triclopyr (Renovate)

(3,5,6-trichloro-2pyridinyloxyacetate acid, trithylamine salt)

Distributing Company- SePRO Corporation, Carmel, IN
EPA Registration Number- 62719-37-67690, 67690-42
Percent of Active Ingredient- 44.4%
General- Triclopyr is a systemic herbicide with selective control of woody and broadleaf species.
Aquatic Uses- Renovate 3 is labeled for control of submerged weeds, such as watermilfoil (*Myriophyllum spicatum*) in lakes, reservoirs or ponds, and in non-irrigation canals or ditches that have little or no continuous outflow. Triclopyr the ability to remove milfoil and allow non-invasive native monocots and tolerant dicots to proliferate.
Submersed Plants Controlled by Triclopyr-, Watermilfoil (*Myriophyllum spp.*), Spatterdock (*Nuphar spp.*), American Lotus (*Nelumbo lutea*), American frogbit (*Limnobium spongia*), Aquatic sodaapple (*Solanum viarum*), Parrotfeather (*Myriophyllum aquaticum*), Pickerelweed (*Pontederia spp.*), Pennywort (*Hydrocotyle leucocephala*), Purple

loosestrife (*Lythrum salicaria*), Waterhyacinth (*Eichhornia crassipe ; Mart*), Waterlily (*Nymphaea spp.*), Waterprimrose (*Jussiaea repens*)

Mode of Action- Although not completely understood, the primary action of this compound is thought to be like that of the naturally occurring auxin (Any of several plant hormones that regulate various functions, including cell elongation), Indole Acetic Acid (IAA). The action appears to involve cell plasticity and nucleic acid metabolism. The symptoms typical of auxin-type herbicides include epinastic3 bending and twisting of stems and petioles, stem swelling (particularly at nodes) and elongation, and leaf cupping and curling.

Environmental Fate- Triclopyr triethylamine salt (TEA) is highly soluble in water and dissociates within one minute to the weak acid, triclopyr. Aquatic photolysis and microbial breakdown are significant degradation pathways for triclopyr. Dissipation half lives of triclopyr in water range from 0.5 days to 7.5 days. In sediment, triclopyr dissipation rates ranged from 2.8 to 5.8 days in field studies. Triclopyr is, however, persistent under anaerobic aquatic conditions. It is highly water soluble and is not expected to bind with organic material

Toxicity- Triclopyr acid is practically non-toxic to freshwater invertebrates. Based on the waterflea (*Daphnia magna*) life-cycle toxicity study using triclopyr TEA formulation, the calculated 48-hr LC50 value based on nominal concentrations, was 1,170 ppm and the 21-day chronic toxicity LC50 value, based on analyzed concentrations, was 1,140 ppm. Triclopyr TEA is practically non-toxic to freshwater fish on an acute basis. Triclopyr TEA has fish 96-hr LC5O values of 552 and 891 ppm for rainbow trout and bluegills respectively. The corresponding values for triclopyr acid are 117 and 148 ppm for rainbow trout and bluegill respectively. No toxicological effects were seen at the maximum label rate of 2.5ppm.

Water Use Restrictions (at maximum label rate of 2.5ppm)-

Drinking – Setback distances from potable water intakes determined by size of area treated and herbicide concentration levels. Setback distances are on the herbicide label.
Swimming – 0 days
Fish Consumption – 0 days
Livestock watering – 0 days
Irrigation – 120 days*
*safe irrigation concentrations can be determined before 120 days with an approved ELISA test.

A Review of the Toxicity and Environmental Fate of Triclopyr
Submitted to the Massachusetts Pesticide Board Subcommittee
By Steven E. Antunes-Kenyon and Gerard Kennedy
Massachusetts Department of Agricultural Resources
November 12, 2004
http://www.mass.gov/agr/pesticides/water/Aquatic/triclopyr_final.pdf

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Glyphosate (Rodeo – and generic equivalents)

(Glyphosate ((N-phosphonomethyl)glycine)

Distributing Company- Dow AgroSciences, Inc.
EPA Registration Number- 62719-324
Percent of Active Ingredient- 53.8%

General- Glyphosate is a systemic herbicide with broad-spectrum control of woody and herbaceous species; it is only active on dry or exposed vegetation.

Aquatic Uses- Glyphosate is primarily used for management of floating-leafed or emergent species.

Common Aquatic Plants Controlled by Glphyosate-, Spatterdock (*Nuphar spp.*), American Lotus (*Nelumbo lutea*), Pickerelweed (*Pontederia spp.*), Purple loosestrife (*Lythrum salicaria*), Waterhyacinth (*Eichhornia crassipe ; Mart*), Waterlily (*Nymphaea spp.*), Watershield (*Brasenia schreberi*), Water Chestnut (*Trapa natans)* partial control.

Mode of Action- Glyphosate penetrates leaf cuticle and migrates to the phloem from which it is translocated throughout the plants. Glyphosate blocks synthesis of aromatic amino acids and the metabolism of phenolic compounds by disrupting the plant's shikimic acid metabolic pathyway, leading to the inability of the plant to synthesize protein and produce new plant tissue. Secondary mode of action affects the photosynthetic process, synthesis, respiration and synthesis of nucleic acids by interacting with a complex series of enzymes which control synthesis of important molecules such as chlorophyll.

Environmental Fate- Major fate process is biodegradation, which occurs under both aerobic and anaerobic conditions. The average half-life of Glyphosate in soil is 60 days, and in natural waters half-lives range from 1.5-14 days.

Toxicity- Glyphosate has very low toxicity in fish and invertebrates. A range of 96-hr LC50 values idenfied for fish exposed to Rodeo were reported to greater than 1000 mg/l. The EPA classifies Glyphosate as a E carcinogen (indicating that there is evidence of noncarcinogenicity in humans).

Water Use Restrictions (at maximum label rate of 2.5ppm)-

Drinking – ½ mile setback distance from potable water intakes
Swimming – 0 days
Fish Consumption – 0 days
Livestock watering – 0 days
Irrigation – 0 days