APPENDIX E

INFORMATION ON SELECTED VEGETATION CONTROL METHODS

The Practical Guide to Lake Management in Massachusetts

A Companion to the Final Generic Environmental Impact Report on Eutrophication and Aquatic Plant Management in Massachusetts

Prepared for the

Department of Environmental Protection
and
Department of Conservation and Recreation

Executive Office of Environmental Affairs,
Commonwealth of Massachusetts

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2004

DRAWDOWN

How it Works

Drawdown is a process whereby the water level is lowered by gravity, pumping or siphoning and held at that reduced level for some period of time, typically several months and usually over the winter. Drawdown can provide control of plant species that overwinter in a vegetative state, and oxidation of sediments may result in lower nutrient levels with adequate flushing. Drawdowns also provide flood control and allow access for nearshore clean ups and repairs to structures. The ability to control the water level in a lake is affected by area precipitation pattern, system hydrology, lake morphometry, and the outlet structure. The base elevation of the outlet or associated subsurface pipe(s) will usually set the maximum drawdown level, while the capacity of the outlet to pass water and the pattern of water inflow to the lake will determine if that base elevation can be achieved and maintained. In some cases, sedimentation of an outlet channel or other obstructions may control the maximum drawdown level.

Several factors affect the success of drawdown with respect to plant control. While drying of plants during drawdowns may provide some control, the additional impact of freezing is substantial, making drawdown a more effective strategy during late fall and winter. However, a mild winter or one with early and persistent snow may not provide the necessary level of drying and freezing. The presence of high levels of groundwater seepage into the lake may mitigate or negate destructive effects on target submergent species by keeping the area moist and unfrozen. The presence of extensive seed beds may result in rapid re-establishment of previously occurring plant species, some of which may be undesirable. Recolonization from nearby areas may be rapid, and the response of macrophyte species to drawdown is quite variable.

Aside from direct impact on target plants, drawdown can also indirectly and gradually affect the plant community by changing the substrate composition in the drawdown zone. If there is sufficient slope, finer sediments will be transported to deeper waters, leaving behind a coarser substrate. If there is a thick muck layer present in the drawdown zone, there is probably not adequate slope to allow its movement. However, where light sediment has accumulated over sand, gravel or rock, repetitive drawdowns can restore the coarse substrate and limit plant growths.

The actual conduct of a drawdown involves facilitating more outflow than inflow for several weeks or months. After the target water level is reached, outflow is roughly matched to inflow to maintain the drawdown for the desired period, usually at least a month and often up to 3 months, usually over the winter. At a time picked to allow refill before any undesirable spring impacts can occur, outflow is reduced (although it should not be eliminated) and "excess" inflow causes the water level to rise. In some cases, refill is commenced after an inch or two of ice forms, ripping up plants and bottom material. This "extreme disturbance" approach has been applied where sediments will not dewater sufficiently to provide the level of freezing and desiccation desired, but impacts have not been studied extensively.

Despite the apparent simplicity of the concept of drawdown, proper conduct of a drawdown to maximize effectiveness and minimize adverse side effects necessitates that many considerations be addressed (Table 5). Expected response of target species (Table 6) is of particular importance when plant control is the major goal.

Benefits

- Kills vegetative portions of plants by drying, freezing, or physical disturbance
- Increases plant species richness in many cases
- Allows sediment oxidation and compaction, with potential reduction of sediment oxygen demand, sediment volume, and available nutrient content
- May reduce fine sediments in drawdown zone, creating coarser peripheral substrate and enhancing plant control and habitat for some organisms
- Provides protection from ice damage to shoreline and associated structures
- Facilitates access for shoreline clean–up, sediment removal, and structural maintenance
- Provides flood storage capacity

Drawdown

Drawdown: after many years, rocks have become the dominant nearshore substrate

Detriments

- Will not kill seeds or other non-vegetative overwintering propagules, and may stimulate increased seed germination
- Nutrient release during exposed sediment oxidation may fuel increased algal production if not flushed from system before next growing season
- Will reduce available water for supplies, and may impair nearby shallow well production
- May strand and harm minimally mobile aquatic fauna (such as molluscs)
- Concentration of fish in smaller volume may harm some populations through predation or oxygen stress particularly in warmer months
- Fish may not be able to reach spawning areas during drawdown
- May expose and harm hibernating reptiles and amphibians
- May restrict access and cover for aquatic mammals and birds
- Limits human access where peripheral sediments are soft
- Although largely dormant in winter, hydrologically connected wetlands may experience some changes in species composition and relative abundance if dewatering occurs

Drawdown: refill at this stage may rip plants and stumps from the bottom

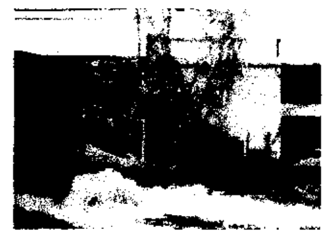
Drawdown: access provided for swimming area maintenance

The disadvantages of drawdown are linked to reduced areal coverage by water and lowered water volume and elevation. Water supply from the lake or wells may be impaired, and species that depend upon the exposed area may be harmed. Changes in exposed sediment features may affect water quality after refill. Downstream resources may be impacted as well. Repeated drawdown may result in the invasion of plants that are resistant to drawdowns, some of which may be nuisance species. Failure to refill the lake in time for spring spawning may affect fish populations. None of these impacts may be manifest, and various mitigative means may avoid or minimize them. However, it is difficult to predict the ecological impact to many non-target organisms, due largely to the lack of published information and site-specificity of many possible impacts.

Information for Proper Application

The listing of key considerations provided in Table 5 indicates the extensive data needs for proper implementation of this technique. Key needs include:

- Detailed hydrology and lake morphometry to allow estimates of drawdown and refill times under the range of potential conditions
- Knowledge of outlet features essential to releasing and holding water
- Maps of aquatic macrophytes and expected area of exposure
- Evaluation of sediment types and slopes in expected drawdown zone
- Biological surveys of populations perceived to be at risk from drawdown
- Assessment of downstream channel configuration and resources, to facilitate planning to minimize adverse impacts
- Local well depths or water supply intake elevations
- A carefully crafted monitoring program to track water levels and outflow, and to assess potential impacts, positive and negative



Drawdown pipe (left) usurps flow from normal outlet (right)

Excessive downstream flow from a discharge to achieve drawdown

Inadequate downstream flow during refill after drawdown

Factors Favoring the Use of this Technique

- The lake periphery is dominated by undesirable species that are susceptible to drying and freezing
- Drawdown can be achieved by gravity outflow via an existing outlet structure, or such a structure can be established for a reasonable cost
- Drawdown can reach a depth that impacts enough of the targeted plants to make a difference for recreational interests and habitat enhancement
- Areas to be exposed have sediments and slopes that promote dewatering
- Drawdown and refill can be accomplished within a few weeks under typical flow conditions and without causing downstream flows outside the natural range
- Drawdown can be timed to avoid key migration and spawning periods for non-target organisms
- Populations of molluscs or other nearshore-dwelling organisms of limited mobility are not significant
- The lake is not used for water supply and nearby wells are deep
- Flood storage capacity generated by drawdown prevents downstream flood impacts
- The downstream channel and associated resources will not be impacted by fluctuating flows expected during drawdown and refill periods
- Shoreline structures are prone to ice damage

Performance Guidelines

- Determine susceptibility of target plants to drawdown
- Evaluate potential risks to non-target flora and fauna
- Limit drawdown to 3 ft or contact the MDFG for assistance in evaluating impacts of greater drawdown
- Commence drawdown after the beginning of November

- Achieve the target drawdown depth by the beginning of December; target a drawdown rate of <3 inches/day
- Achieve full lake status by the beginning of April
- Keep outflow during drawdown below a discharge equivalent to 4 cfs per square mile of watershed; once the target water level is achieved, match outflow to inflow to the greatest extent possible, maintaining a stable water level
- Keep outflow during refill above a discharge equivalent to 0.5 cfs per square mile of watershed
- Conduct a monitoring program that includes water level, flow, water clarity, winter oxygen, the plant community, and representative sensitive faunal populations
- After target species are controlled, evaluate the potential to move to an every other or every third year drawdown schedule

Possible Permits

- WPA permit through local Conservation Commission/DEP
- Review by NHESP (further action if protected species are present)

Impacts Specific to the Wetlands Protection Act

- Protection of public and private water supply – Potential detriment (if adequate water for supply is not maintained), but can be neutral in some cases with proper management
- Protection of groundwater supply – Potential detriment (if lowered lake level lowers groundwater), but can be neutral (if adequate groundwater level is maintained or there is no significant interaction)
- Flood control – Benefit (flood storage potential increased)
- Storm damage prevention – Benefit (flood storage potential increased), but possible detriment as exposed areas may be subject to potentially damaging storm impacts
- Prevention of pollution – May provide benefit (water quality enhancement) or detriment (water quality deterioration), but impacts generally limited
- Protection of land containing shellfish – Detriment (shellfish potentially exposed), but impacts may be neutral in some cases, and shellfish habitat may be improved overall
- Protection of fisheries - Potential detriment by temporary habitat loss, potential benefit by habitat improvement (may have benefit and detriment to different species in same lake from same drawdown)
- Protection of wildlife habitat - Potential detriment by temporary habitat loss for completely aquatic species and impact on muskrat and beaver lodges, potential benefit by habitat improvement (may have benefit and detriment to different species in same lake from same drawdown)

Cost Considerations

Drawdown is a relatively inexpensive lake management technique, if the means to conduct a drawdown are present. Where an outlet structure facilitates drawdown, the cost may be as little as what is required to obtain permits, open and close the discharge structure, and monitor. If pumps are required to lower the water level, the drawdown will be more expensive. It is unusual to alter a dam for less than $100,000, but if the structure already supports water level control, costs of $3,000 to $10,000 per year would be a reasonable expectation for permitting and monitoring. Where protected species are present, permitting may be difficult and monitoring and mitigation costs can escalate.

Table 5. Key Considerations for Drawdown

Reasons for Drawdown
Access to structures for maintenance or construction – note that other permits may apply
Access to sediments for removal (dredging) – additional permits apply
Flood control – a major late winter benefit, but minimally available in spring with regulatory refill date
Prevention of ice damage to shoreline and structures – control of late winter water level needed
Sediment compaction – only if sediments dewater sufficiently
Rooted plant control – for species that rely on vegetative forms to overwinter

Necessary Drawdown Planning Information
Target level of drawdown – depth of water lost
Pond bathymetry – detailed contours for calculation exposed area
Area to be exposed – area of sediment at water depth < target depth, plus ice contact zone
Volume to remain – quantity of water available for habitat and supply during drawdown
Timing and frequency of drawdown – initiation/duration and whether annual or less frequent event
Outlet control features – method for controlling outflow
Climatological data – frequency of sub-freezing weather, precipitation and snow cover data
Normal range of outflow – maximum, minimum and average over expected time of drawdown
Outflow during drawdown and refill – provisions for downstream flow control (high and low)
Time to drawdown or refill – rate of water level change, number of days to achieve target level

In-Lake and Downstream Water Quality
Possible change in nutrient levels – any expected increases due to oxidation of sediments
Possible change in oxygen levels – any expected increase through oxidation or decrease under ice
Possible change in pH levels – any expected shift due to interactions with smaller volume
Other water quality issues – any expected changes as a function of drawdown

Water Supply
Use of lake water as a supply – dependence on water availability and impact of drawdown
Presence/depths of supply wells – potential for supply impairment
Alternative water supplies – options or supplying water to impacted parties
Emergency response system – ability to detect and address supply problems during drawdown
Downstream flow restrictions – maintenance of appropriate flows for downstream habitat and uses

Sediments
Particle size distribution (or general sediment type) – dewatering potential
Solids and organic content – dewatering potential, nutrient content
Potential for sloughing – potential for coarse sediment to be exposed in drawdown zone
Potential for shoreline erosion – threat of erosive impacts to bank resources
Potential for dewatering and compaction – possibility of sediment alteration and depth increase
Potential for odors – emissions from exposed area
Access and safety considerations – issues for use of lake during drawdown

Flood Control
Anticipated storage needs – ability to meet needs with target drawdown
Flood storage gained – volume available to hold incoming runoff
Effects on peak flows – dampening effect on downstream velocities and discharge

Table 5 (continued). Key Considerations for Drawdown

Protected Species
Presence of protected species – NHESP designated species may require special protection
Potential for impact – assessment of possible damage to protected populations
Possible mitigative measures – options for avoiding adverse impacts

In-lake Vegetation
Composition of plant community – details of species present and susceptibility to drawdown
Areal distribution of plants – mapping of plant locations relative to drawdown impact zone
Plant density – quantity of plants present
Seed-bearing vs. vegetative propagation – drawdown will only control vegetative propagators
Impacts to target and non-target species – analysis of which species will be impacted

Vegetation of Connected Wetlands
Composition of plant community – details of species present and susceptibility to drawdown
Areal distribution of plants – mapping of plant locations relative to drawdown impact zone
Plant density – quantity of plants present
Temporal dormancy of key species – potential for seasonal impacts
Anticipated impacts – analysis of likely effects of drawdown

Macroinvertebrates, Fish and Wildlife
Composition of fauna – types of animals present
Association with areas to be exposed – when and how drawdown zone is used on a regular basis
Breeding and feeding considerations – use of drawdown for breeding or food on intermittent basis
Expected effects on target and non-target species – analysis of likely faunal impacts

Downstream Resources
Erosion or flooding potential – susceptibility to impacts from varying flow
Possible habitat alterations – potential for impacts
Water quality impacts – potential for alteration
Direct biotic impacts – possible scour or low flow effects on biota
Recreational impacts – effects on downstream recreational uses
Supply impacts – effects on downstream supply uses

Access to the Pond
Alteration of normal accessibility – issues for seasonal use of pond by humans and wildlife
Possible mitigation measures – options for minimizing impacts

Associated Costs
Structural alteration to facilitate drawdown by gravity – expense for any needed changes to outlet
Pumping or alternative technology – operational expense for pumped or siphoned outflow
Monitoring program – cost of adequate tracking of drawdown and assessment of impacts

Other Mitigating Factors
Monitoring program elements – may be very lake specific and vary over years
Watershed management needs – additional actions beyond drawdown may be warranted
Ancillary project plans (dredging, shoreline stabilization) – additional actions may require separate planning and permitting

Table 6. Anticipated Response of Some Aquatic Plants to Winter Drawdown (After Cooke et al., 1993).

	Change in Relative Abundance		
	Increase	No Change	Decrease
Acorus calamus (sweet flag)	E		
Alternanthera philoxeroides (alligator weed)	E		
Asclepias incarnata (swamp milkweed)			E
Brasenia schreberi (watershield)			S
Cabomba caroliniana (fanwort)			S
Cephalanthus occidentalis (buttonbush)	E		
Ceratophyllum demersum (coontail)			S
Egeria densa (Brazilian Elodea)			S
Eichhornia crassipes (water hyacinth)		E/S	
Eleocharis acicularis (needle spikerush)	S	S	S
Elodea canadensis (waterweed)	S	S	S
Glyceria borealis (mannagrass)	E		
Hydrilla verticllata (hydrilla)	S		
Leersia oryzoides (rice cutgrass)	E		
Myrica gale (sweetgale)		E	
Myriophyllum spp. (milfoil)			S
Najas flexilis (bushy pondweed)	S		
Najas guadalupensis (southern naiad)			S
Nuphar spp. (yellow water lily)			E/S
Nymphaea odorata (water lily)			S
Polygonum amphibium (water smartweed)		E/S	
Polygonum coccineum (smartweed)	E		
Potamogeton epihydrus (leafy pondweed)	S		
Potamogeton robbinsii (Robbins' pondweed)			S
Potentilla palustris (marsh cinquefoil)			E/S
Scirpus americanus (three square rush)	E		
Scirpus cyperinus (wooly grass)	E		
Scirpus validus (great bulrush)	E		
Sium suave (water parsnip)	E		
Typha latifolia (common cattail)	E	E	
Zizania aquatic (wild rice)		E	

E=emergent growth form; S=submergent growth form (includes rooted species with floating leaves); E/S=emergent and submergent forms

BENTHIC BARRIERS

How it Works

The use of benthic barriers, or bottom covers, is predicated upon the principles that rooted plants require light and cannot grow through physical barriers. Applications of clay, silt, sand, and gravel have been used for many years, although plants often root in these covers eventually, and current environmental regulations make it difficult to gain approval for such deposition of fill. Artificial sediment covering materials, including polyethylene, polypropylene, fiberglass, and nylon, have been developed over the last three decades. A variety of solid and porous forms have been used. Manufactured benthic barriers are negatively buoyant materials, usually in sheet form, which can be applied on top of plants to limit light, physically disrupt growth, and allow unfavorable chemical reactions to interfere with further development of plants. Various plastics and burlap have also been used, but are not nearly as durable or effective in most cases.

In theory, benthic barriers should be a highly effective plant control technique, at least on a localized, area-selective scale. In practice, however, there have been difficulties with the deployment and maintenance of benthic barriers, limiting their utility over the broad range of field conditions. Benthic barriers can be effectively used in small areas such as dock spaces and swimming beaches to completely terminate plant growth. The creation of access lanes and structural habitat diversity is also practical. Large areas are not often treated, however, because the cost of materials, application and maintenance is high.

Benthic barrier problems of prime concern include long-term integrity of the barrier, billowing caused by trapped gases, accumulation of sediment on top of barriers, and growth of plants on porous barriers. Successful use is related to selection of materials and the quality of the installation. As a result of field experience with benthic barriers, several guidelines can be offered:

- Porous barriers will be subject to less billowing, but will allow settling plant fragments to root and grow; annual maintenance is therefore essential
- Solid barriers will generally prevent rooting in the absence of sediment accumulations, but will billow after enough gases accumulate; venting and strong anchoring are essential in most cases
- Plants under the barrier will usually die completely after one to two months, with solid barriers more effective than porous ones in killing the whole plant; barriers of sufficient tensile strength can then be moved to a new location, although continued presence of solid barriers restricts recolonization

Proper application requires that the screens be placed on the sediment surface and staked or securely anchored. This may be difficult to accomplish over dense plant growth, and a winter drawdown can provide an ideal opportunity for application in exposed areas. Late spring application has also been effective, despite the presence of plant growths at that time, and barriers applied in early May have been removed in mid-June with no substantial plant growth through the summer. Scuba divers normally apply the covers in deeper water, which greatly increases labor costs. Bottom barriers will accumulate sediment deposits in most cases, which allow plant fragments to root. Barriers must then be cleaned, necessitating either removal or laborious in-place maintenance. Despite application and maintenance issues, a benthic barrier can be a very effective tool. Benthic barriers are capable of providing control of rooted plants on at least a localized basis, and have such desirable side benefits as creating more edge habitat within dense plant assemblages and minimizing turbidity generation from fine bottom sediments.

Considerations for the installation of benthic barriers include the size of the area to be treated, bottom features and possible obstructions, the cost of the product, application and maintenance costs, and possible impacts to non-target organisms in the installation area. Sheeting materials come in a variety of dimensions, from about 20 ft by 50 ft to 7 ft by 100 ft, although custom sizes of a wider range are possible. Deployment is therefore a function of manpower and cleverness by the installer. Careful consideration of site conditions is essential to maximizing effectiveness, as barriers must remain in place for at least a month and possibly two months to kill the target plants.

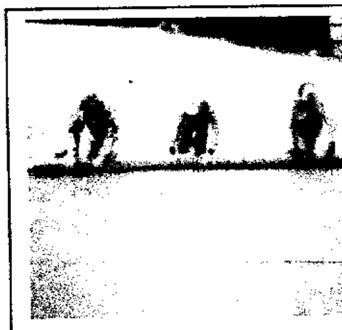
There are many ways to install barriers, ranging from spreading them out with the lake drawn down to underwater positioning by divers. In water less than about 10 ft. deep, snorkeling may be sufficient to get the barrier properly positioned. One aid to application involves rolling the barrier onto PVC pipe with a slightly longer wooden or metal pole inside the PVC pipe, allowing the barrier to be rolled out like paper towels. Anchoring systems vary with barrier type, but most forms do require staking or weighting. Sleeves can be sewn into sheet materials to allow rebar to be inserted, pieces of chain can be attached to edges, or patio blocks can be dropped onto the barrier to hold it in place. Burial under sandy sediments has been tried, but may allow more rapid plant recolonization. Where removal at a later date is desired, the weighting system should be simple and reversible (patio block weights are very convenient in this regard).

One way to extend the benefits of benthic barrier involves flipping the barrier over into the adjacent area after one to two months. Plants are killed over that time period, and the barrier can be re-deployed to the adjacent plot as part of normal maintenance. In this manner, two or three times the area of the benthic barrier can be treated in a single growing season. If plant elimination is not necessary, and simply reducing plant biomass is acceptable, it may be possible to move the barrier on a biweekly schedule. This could allow a linear band of nuisance vegetation to be managed over the first few months of the growing season, creating acceptable conditions over a larger area with a smaller barrier. Manpower is the primary limiting factor in this approach, although not all barriers can be moved once installed.

Porous weave benthic barrier

Benefits

- Complete elimination of plants in target area with proper application and maintenance
- Some barrier materials are re-useable, allowing coverage of multiple areas over time with the same material
- Creates edge effect and habitat enhancement when portions of dense assemblages are covered
- May foster improved assemblage after removal, by seeds or selective planting



Preparing benthic barrier for easier installation

Detriments

- Non-selective technique; all plants under barrier will be killed
- Effectiveness declines without labor-intensive maintenance

Information for Proper Application

- Mapping of area to be covered by barrier, with information on plant types and density
- Knowledge of sediment features, along with any obstructions or other interference factors
- Inventory of biological features of the target area, especially the presence of any protected species
- Plan for installation and maintenance

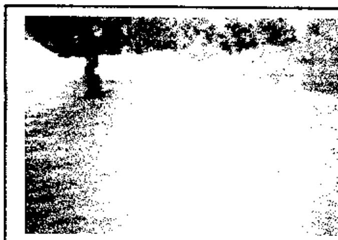
Factors Favoring the Use of this Technique

- The target area has dense plant growths of undesirable species
- The target area is small (<1 acre) and relatively free of obstructions (stumps, logs, boulders, pilings and moorings)
- The target area represents only a small portion of the whole lake (<10%)

- Long-term control is sought over a small area with recognition of necessary maintenance needs
- Inexpensive labor is available
- No significant shellfish resources are present in the target area
- A favorable plant assemblage is expected to develop (or can be encouraged by planting) after barrier removal

Performance Guidelines

- Map the vegetation and other resources in the target area; avoid barrier use on protected species
- Select a benthic barrier with properties consistent with project goals and site features
- Avoid installation over >10% of lake littoral zone
- Lay out and anchor barrier in a manner that maximizes stability in response to wave action or other influences
- Post the area to inform potential users of barrier presence
- Leave barrier in place for at least one month
- Develop a maintenance program that monitors and maximizes barrier effectiveness; avoid discontinuous coverage, sediment accumulation, and rooting of plants through porous barriers
- Monitor the plant community before and after barrier application
- Monitor water quality near the barrier and in the lake in general if the installation is large (>1 acre)



Installed benthic barrier in a swimming area

Possible Permits

- WPA permit through local Conservation Commission/DEP
- Review by NHESP (further action if protected species are present)

Impacts Specific to the Wetlands Protection Act

- Protection of public and private water supply – Generally neutral (no significant interaction), although reduced plant density may benefit taste and odor control
- Protection of groundwater supply – Neutral (no significant interaction)
- Flood control – Neutral (no significant interaction)
- Storm damage prevention – Neutral (no significant interaction)
- Prevention of pollution – Neutral (no significant interaction), but could be a detriment if nutrient cycling promotes algal blooms
- Protection of land containing shellfish – Generally neutral (no significant interaction), but covering of significant shellfish resources must be avoided
- Protection of fisheries – Possible benefit (habitat enhancement) and possible detriment (food source alteration, loss of cover), but over a relatively small area no lakewide effects are expected
- Protection of wildlife habitat - Potential benefit by habitat improvement, but may have benefit and detriment to different species in the same relatively small area

Cost Considerations

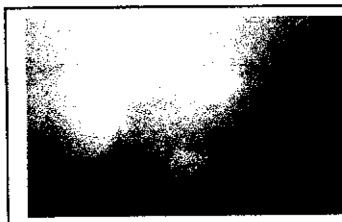
The most commonly used materials for benthic barriers and the cost (material only) include Texel at $0.25/sq.ft, Palco at $0.40/sq.ft, and Aquatic Weed Net at $0.60/sq.ft. Less expensive substitutes can be found, but usually lack the properties that make these barriers as effective as they are. Such substitution will save initial material costs, but may require more material over the long-term and may increase labor costs to achieve the same effectiveness. Cost per acre is estimated at $20,000 to $50,000 for benthic barrier installation, including design, permitting, materials and labor for a year. The initial capital cost is substantial, but the annual cost diminishes greatly after original installation, as material costs are minimal after initial purchase.

HAND HARVESTING

How it Works

Hand pulling is exactly what it sounds like; a snorkeler or diver surveys an area and selectively pulls out unwanted plants on an individual basis. This is a highly selective technique, and a labor intensive one. It is well suited to vigilant efforts to keep out invasive species that have not yet become established in the lake or area of concern. Hand pulling can also effectively address non-dominant growths of undesirable species in mixed assemblages, or small patches of plants targeted for removal. This technique is not well suited to large-scale efforts, especially when the target species or assemblage occurs in dense or expansive beds.

Hand pulling can be augmented by various tools, including a wide assortment of rakes, cutting tools, water jetting devices, nets and other collection devices. McComas (1993) provides an extensive and enjoyable review of options. Suction dredging is also used to augment hand pulling, allowing a higher rate of pulling in a targeted area, as the diver/snorkeler does not have to carry pulled plants to a disposal point. Use of these tools transitions into more mechanized forms of harvesting.



Hand harvesting

Benefits

- Highly selective plant control
- Limited impact to non-target organisms
- Can prevent infestations before they become problems

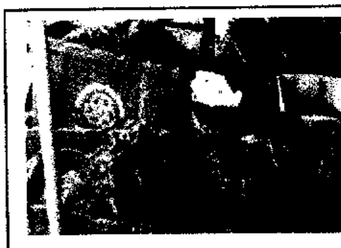
Hand harvesting bags being ferried to shore

Detriments

- Incomplete harvesting may foster regrowth or dispersal of plants
- Turbidity generation may be substantial

Information for Proper Application

- Knowledge of plant assemblage – types, distribution, density
- Careful identification of target species
- Planning for collection and disposal of hand harvested plants
- Pre- and post-harvesting monitoring of plant assemblage to assess results



Hand harvested Eurasian watermilfoil and curly leaf pondweed

Factors Favoring the Use of this Technique

- Nuisance species are not yet established; target plant density is low (<500 stems/acre)
- Target species are in shallow water, or dive crew is readily available
- Target species are not strongly rooted or prone to fragmentation

Performance Guidelines

- Map the distribution of the target species and any protected non-target species in the lake
- Train all harvesting personnel to recognize the target species and any non-target species of concern
- Restrict hand harvesting to areas of sparse density of the target species (<500 stems/acre in most cases)
- Provide fragment barrier around areas to be harvested and bags in which harvested plants are to be placed
- Harvest entire plants; pull out root systems to the greatest extent possible

- Observe safety precautions in areas where boat traffic may be encountered or other risks exist; provide spotters on the surface for all divers
- Monitor turbidity in the harvest area before, during and after harvest
- Monitor pre- and post-harvest density of target plants
- Plan for follow-up inspection and harvesting within the same growing season and in the following growing season

Possible Permits

- WPA permit through local Conservation Commission/DEP
- Review by NHESP (further action if protected species are present)

Note that some Conservation Commissions have issued a negative Determination of Applicability for hand pulling efforts under the WPA

Impacts Specific to the Wetlands Protection Act

- Protection of public and private water supply – Generally neutral (no significant interaction)
- Protection of groundwater supply – Generally neutral (no significant interaction)
- Flood control – Generally neutral (no significant interaction)
- Storm damage prevention – Generally neutral (no significant interaction)
- Prevention of pollution – Generally neutral (no significant interaction), but could be a detriment if sediment disruption and resultant turbidity are high
- Protection of land containing shellfish – Generally neutral (no significant interaction)
- Protection of fisheries – Generally neutral (no significant interaction), unless a very large effort is undertaken, in which case there may be benefits and detriments
- Protection of wildlife habitat – Generally neutral at expected scale of operation, but may have benefit and detriment to different species in same lake from same effort

Cost Considerations

Many hand harvesting efforts are volunteer programs, so costs are difficult to estimate. For programs where cost accounting is possible, the cost of hand harvesting when targeted plant density is sparse is estimated at $150-$300/acre, with most of these representing control of new and sparse milfoil growths. A range of $100 to $500/acre for sparse to moderate growths is suggested; the cost for hand harvesting dense stands would be much higher.

Costs for augmentation of hand pulling through suction harvesting are estimated at >$5,000/acre, with some estimates approaching $15,000/acre. This may be worthwhile for small areas, but will limit the utility of this technique on a lake-wide basis.

Fragment barrier used during hand harvesting to prevent the spread of target plants

MECHANICAL HARVESTING

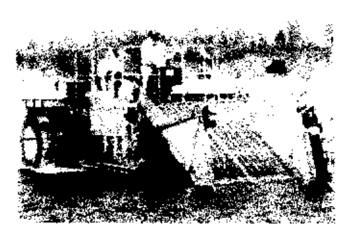
How it Works

Mechanical harvesting is most often associated with large machines on pontoons that cut and collect vegetation, but encompasses a range of techniques from simply cutting the vegetation in place to cutting, collecting, and grinding the plants, to collection and disposal outside the lake. In its simplest form, cutting, a blade of some kind is applied to plants, severing the active apical meristem (location of growth) and possibly much more of the plant from the remaining rooted portion. Regrowth is expected, and in some species that regrowth is so rapid that it negates the benefits of the cutting in only a few weeks. If the plant can be cut close enough to the bottom, or repeatedly, it will sometimes die, but this is more the exception than the rule. Cutting is defined here as an operation that does not involve collecting the plants once they are cut, so impacts to dissolved oxygen and nutrient release are possible in large-scale cutting operations.

Hand held rake

Towed cutting bar

Advanced technology cutting techniques involve the use of mechanized barges normally associated with harvesting operations, in which plants are collected for out-of-lake disposal. In its use as a cutting technology, the "harvester" cuts the plants but does not collect them. A modification in this technique employs a grinding apparatus that ensures that viable plant fragments are minimized after processing. There is a distinct potential for dissolved oxygen impacts and nutrient release as the plant biomass decays, much like what would be expected from many herbicide treatments.



Mechanized harvester (provided by J. Dauffenbach, Aquarius Systems)

Harvesting may involve collection in nets or small boats towed by the person cutting the weeds, or can employ smaller boat-mounted cutting tools that haul the cut biomass into the boat for eventual disposal on land. It can also be accomplished with larger, commercial machines with numerous blades, a conveyor system, and a substantial storage area for cut plants. Offloading accessories are available, allowing easy transfer of weeds from the harvester to trucks that haul the weeds to a composting area. Choice of equipment is really a question of scale, with larger harvesting operations usually employing commercially manufactured machines built to specifications suited to the job. Some lake associations choose to purchase and operate harvesters, while others prefer to contract harvesting services to a firm that specializes in lake management efforts.

Mechanized harvester with offloading conveyor (provided by J. Dauffenbach, Aquarius Systems)

Cutting rates for commercial harvesters tend to range from about 0.2 to 0.6 acres per hour, depending on machine size and operator ability, but the range of possible rates is larger and is often dependent upon distance to the offloading location when out-of-lake disposal is planned. Even at the highest conceivable rate, harvesting is a slow process that may leave some lake users dissatisfied with progress in controlling aquatic plants. Weed disposal is not usually a problem, in part because lakeshore residents and farmers often will use the weeds as mulch and fertilizer. Also, since aquatic plants are more than 90 percent water, their dry bulk is comparatively small. Key issues in choosing a harvester include depth of operation, volume and weight of plants that can be stored, reliability and ease of maintenance, along with a host of details regarding the hydraulic system and other mechanical design features.

Benefits

- Clears target area of plant biomass to selected depth (usually up to 7 ft)
- Does not kill most plants through single cutting
- Repeated harvest may reduce abundance of seed-producing species
- Harvesting at the sediment level may disrupt plants and provide greater longevity of results or shift to more desirable species

Mechanical harvesting of species prone to viable fragmentation has been demonstrated to promote the spread of those species and is not desirable when such species are present at low densities or in only a localized portion of the waterbody. However, if such species are already abundant, harvesting may be a useful maintenance strategy.

Detriments

- Minimally selective; only depth of harvest is controlled, Although this may be adequate to favor desirable low-growing plants, it may also open areas for colonization by invasive species
- Will rarely control species that propagate vegetatively, and may help expand their populations
- Regrowth may overrun ability of harvester to keep target area clear of plants in larger operations
- Harvesting with collection tends to collect many small fish and other aquatic life forms
- Cutting without collection may affect water quality through plant decay

Information for Proper Application

- General plant mapping and knowledge of any sensitive areas, especially where protected species are involved
- For large or repeated efforts, more detailed mapping with estimates of cover or biomass that aid planning
- Fragment control plan, where species that expand by this process are not yet dominant or where downstream movement must be prevented
- Harvesting plan to include areas to be harvested, timing and pattern of harvest, and means to dispose of the plant material
- Information on underwater obstructions, shallow areas, and other possible interference factors
- Monitoring plan for assessing results, including impact on plant types and abundance, regrowth rates, achieved cutting rate, and any impacts to non-target organisms of concern

Harvesting repeatedly at the sediment-water interface may be sufficiently disruptive to lower plant biomass for a prolonged period of time. In most cases, however, regrowth to pre-harvest densities is expected within two growing seasons.

Factors Favoring the Use of this Technique

- The lake is dominated by undesirable annual species that propagate by seeds
- Overall density of macrophytes is excessive throughout the littoral zone
- Surficial and underwater obstructions in targeted areas are minimal
- Suspended sediments resettle quickly and leave minimal residual turbidity
- Convenient access for equipment and trucks and a nearby location for plant disposal are available

Harvesting before seed-producing species such as pondweeds and water chestnut can generate and disperse seeds can reduce the abundance of those species once the existing seed bed has been depleted.

Performance Guidelines

- Map the distribution of the target species and any protected non-target species in the lake

- Develop a harvesting plan that divides the lake into zones and addresses which zones will be harvested in what order, designated offloading sites, and any protected (no harvest) areas
- Select equipment consistent with goals; cutting depth and hopper capacity are important features, and auxiliary barges and offloading equipment may improve efficiency
- Inspect and clean all equipment before entering or leaving a lake
- Avoid areas of known sensitive habitat during active use
- Avoid harvesting of plants that spread by vegetative fragmentation when present at low densities unless the collection system is very effective
- When cutting dense and extensive assemblages of plants that spread by vegetative fragmentation, collect the cut plants or kill them by grinding or other methods; fragment control may be needed
- When harvesting annual (seed-producing) plants, harvest before seeds are formed and dispersed for greatest longevity of results
- Harvest as close to the bottom as equipment allows for maximum effect; actually disturbing the root systems in soft sediment may prolong control, but may also produce excessive turbidity
- Monitor pre- and post-harvest density of target plants and the plant community in general
- Monitor collection of non-target fauna (e.g., fish, turtles) and avoid excessive collection
- Develop a harvester maintenance plan; routine repairs are essential to keeping a harvesting program on schedule

Possible Permits

- WPA permit through local Conservation Commission/DEP
- Review by NHESP (further action if protected species are present)

Impacts Specific to the Wetlands Protection Act

- Protection of public and private water supply – Generally neutral (no significant interaction), although reduced plant density may benefit taste and odor control and minimize clogging of intakes
- Protection of groundwater supply – Generally neutral (no significant interaction)
- Flood control – Generally neutral (no significant interaction)
- Storm damage prevention – Generally neutral (no significant interaction)
- Prevention of pollution – Generally neutral (no significant interaction), but could be a detriment if sediment disruption and resultant turbidity are high, or if cut vegetation is left in the lake to decay
- Protection of land containing shellfish – Generally neutral (no significant interaction)
- Protection of fisheries – Detriment from mechanical harvesting (direct fish removal), but with potential benefit by habitat improvement (may have benefit and detriment to different species in same lake from same effort)
- Protection of wildlife habitat - Potential benefit by habitat improvement, but may have benefit and detriment to different species in same lake from same effort

Cost Considerations

Commercial harvesting costs vary depending on the target plant(s), the density of growth, travel distance for disposal of harvested plants and the number of obstructions present. The harvesting cost per acre usually ranges from $350 to $550, including trucking and disposal. An exception to this range is very dense growths, such as water chestnut (*Trapa natans*), where costs have ranged from $1,000 to $1,500/acre. Lower costs are possible where cut vegetation is left in the lake. Where a lake association owns its own harvesting equipment and has substantial experience with operation and maintenance, cost may also be lower. The cost per acre of harvesting is inversely proportional to the size of the area harvested; there is an efficiency of scale for larger projects. A cost range of $200 to $600 per acre for mechanical harvesting at typical densities and $1,000 to $2,000 per acre for very high densities of plants is suggested.

Wisconsin Department of Natural Resources

January 2012

Diquat Chemical Fact Sheet

Formulations

Diquat, or diquat dibromide, is the common name of the chemical 6,7-dihydrodipyrido (1,2-a:2',1'-c) pyrazinediium dibromide. Originally registered by the EPA in 1986, diquat was reregistered in 1995 and is currently being reviewed again. It is sold for agricultural and household uses as well as for use on certain floating-leaf and submersed aquatic plants and some algae. The aquatic formulations are liquids: two of the more commonly used in Wisconsin are Reward™ and Weedtrine-D™ (product names are provided solely for your reference and should not be considered endorsements).

Aquatic Use and Considerations

Diquat is a fast-acting herbicide that works by disrupting cell membranes and interfering with photosynthesis. It is a non-selective herbicide and will kill a wide variety of plants on contact. It does not move throughout the plants, so will only kill parts of the plants that it contacts. Following treatment, plants will die within a week.

Diquat will not be effective in lakes or ponds with muddy water or where plants are covered with silt because it is strongly attracted to silt and clay particles in the water. Therefore, bottom sediments must not be disturbed during treatment, such as may occur with an outboard motor. Only partial treatments of ponds or bays should be conducted (1/2 to 1/3 of the water body). If the entire pond were to be treated, the decomposing vegetation may result in very low oxygen levels in the water. This can be lethal to fish and other aquatic organisms. Untreated areas can be treated 10-14 days after the first treatment.

Diquat is used to treat duckweed (*Lemna* spp.), which are tiny native plants. They are a food source for waterfowl but can grow thickly and become a nuisance. Navigation lanes through cattails (*Typha* spp.) are also maintained with diquat. Diquat is labeled for use on the invasive Eurasian watermilfoil (*Myriophyllum spicatum*) but in practice is not frequently used to control it because other herbicide options are more selective.

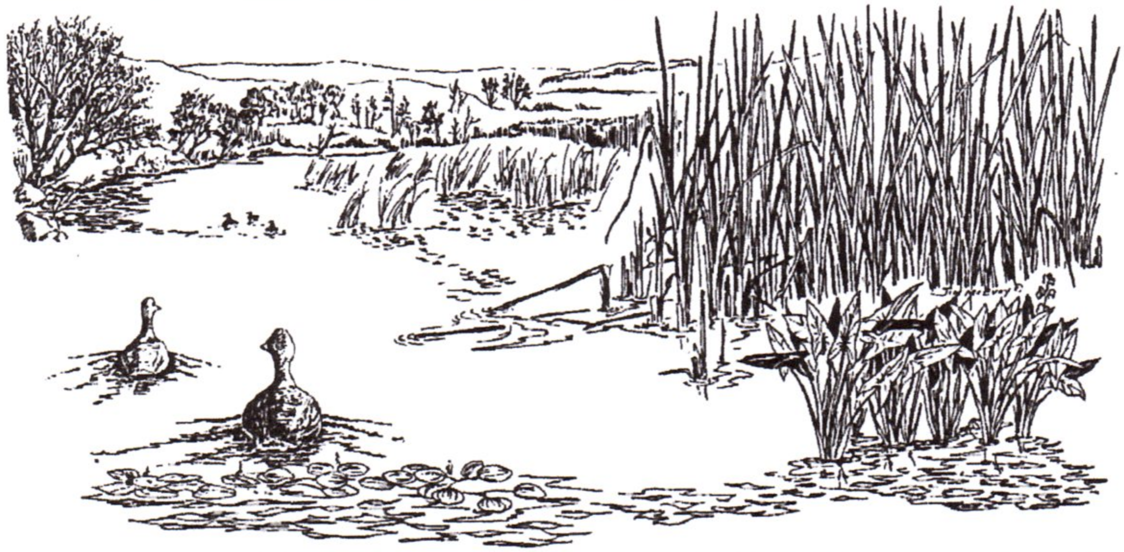
Post-Treatment Water Use Restrictions

There are no restrictions on swimming or eating fish from water bodies treated with diquat. Treated water should not be used for drinking water for one to three days, depending on the concentration used in the treatment. Do not use treated water for pet or livestock drinking water for one day following treatment. The irrigation restriction for food crops is five days, and for ornamental plants or lawn/turf, it varies from one to three days depending on the concentration used.

Herbicide Degradation, Persistence and Trace Contaminants

Diquat is not degraded by microbes. When applied to a waterbody, diquat binds with the organic matter in the sediment indefinitely. It does not degrade and will accumulate in the sediments. Diquat is usually detectable in the water column for less than a day to ~35 days after treatment. Diquat will remain in the water column longer when treating a waterbody with sandy soils due to the low organic matter and clay content. Because of its persistence and very high affinity for the soil, diquat does not leach into groundwater.

Ethylene dibromide (EDB) is a trace contaminant in diquat products. It originates from the manufacturing process. EDB is a carcinogen, and the EPA has evaluated the health risk of its presence in formulated diquat products. The maximum level of EDB in diquat dibromide is 10 ppb (parts per billion), it degrades over time, and it does not persist as an impurity.



Impacts on Fish and Other Aquatic Organisms

At application rates, diquat does not have any apparent short-term effects on most of the aquatic organisms that have been tested. However, certain species of important aquatic food chain organisms such as amphipods and Daphnia (water fleas) can be adversely affected at label application rates. Direct toxicity and loss of habitat are believed to be the causes. Tests on snails have shown that reproductive success may be affected, as well. These organisms only recolonize the treated area as vegetation becomes re-established.

Laboratory tests indicate walleye are the fish most sensitive to diquat, displaying toxic symptoms when confined in water treated with diquat at label application rates. Other game and panfish (e.g. northern pike, bass, and bluegills) are apparently not affected at these application rates. Limited field studies to date have not identified significant short or long-term impacts on fish and other aquatic organisms in lakes or ponds treated with diquat.

The bioconcentration factors measured for diquat in fish tissues is low. Therefore, bioconcentration is not expected to be a concern with diquat.

Human Health

The risk of acute exposure to diquat would be primarily to chemical applicators. Diquat causes severe skin and eye irritation and is toxic or fatal if absorbed through the skin, inhaled or swallowed. Wearing skin and eye protection (e.g. rubber gloves, apron, and goggles) to minimize eye and skin irritation is required when applying diquat.

The risk to water users of serious health impacts (e.g. birth defects and cancer) is not believed to be significant according to the EPA. Some risk of allergic reactions or skin irritation is present for sensitive individuals.

For Additional Information

Environmental Protection Agency
Office of Pesticide Programs
www.epa.gov/pesticides

Wisconsin Department of Agriculture, Trade, and Consumer Protection
http://datcp.wi.gov/Plants/Pesticides/

Wisconsin Department of Natural Resources
608-266-2621
http://dnr.wi.gov/lakes/plants/

Wisconsin Department of Health Services
http://www.dhs.wisconsin.gov/

National Pesticide Information Center
1-800-858-7378
http://npic.orst.edu/

TREATMENT WITH DIQUAT

How it Works

Diquat is a fast acting contact herbicide, producing results within 2 weeks of application through disruption of photosynthesis. It is a broad-spectrum herbicide with potential risks to aquatic fauna, but laboratory indications of invertebrate toxicity have not been clearly documented in the field. A domestic water use restriction of 3 days is normally applied. Irrigation restrictions of 2 to 5 days are applied, depending on dose and crop to be irrigated. Regrowth of some species has been rapid (often within the same year) after treatment with diquat, but two years of control have been achieved in some instances. Concentrations in treated water should not exceed 2 mg/L, and are usually no more than half that dose in Massachusetts.

Diquat is used as a general purpose aquatic herbicide, both as a primary control agent for a broad range of macrophytes and as a follow-up treatment chemical for control of plants (especially milfoil) missed by other herbicides or physical control techniques. Treatment with diquat is recommended early in the season to impact early growth stages, but can be applied any time. Usage in Massachusetts has shown that the effects of diquat are generally visible after 2-3 days and plants are controlled within 7-10 days. Diquat is less effective in turbid, muddy water due to adsorbance onto sediments and other particles.

Since diquat is a broad spectrum herbicide, it can be expected to impact non-target plants when they are present. Loss of vegetative cover may have some impact on aquatic animals, but short-term effects are not expected. The acute toxicity of diquat for fish is highly variable depending on species, age, and hardness of water. Young fish are more sensitive than older fish. Toxicity is decreased as water hardness increases. Toxicity is rare at doses applied in Massachusetts.

Field concentrations of diquat are hard to maintain because diquat rapidly sorbs to the sediments. Maximum concentrations based on the Reward brand label are currently 0.72 ppm as the cation, based on the maximum rate of 2 gallons per acre in areas deeper than 2 feet. For water less than or equal to 2 feet in average depth, a maximum of 1 gallon of Reward per acre is allowed. Normally Reward is used at a rate of 1 gallon per surface area in Massachusetts waters with an average depth of 4 feet. This typically renders a concentration of 0.1 ppm of active ingredient. Treatment doses are therefore not expected to exceed thresholds for potential toxicity. Other formulations of diquat may have different dose restrictions, but concentrations tend to be low relative to maximum allowable rates.

As a contact herbicide, diquat is relatively non-selective and will leave root systems that may generate regrowth. It is often used for spot treatment of limited areas as a follow-up to more selective lakewide treatment with another herbicide, but is also used where other herbicides are less effective.

Benefits

- Effective against a wide variety of species
- Relatively rapid kill of targeted vegetation
- Can be used for spot treatments; limited drift or impact outside target area

Detriments

- Not very selective; kills most species contacted
- Does not damage portions of plants with which it does not contact; regrowth from roots is common
- Potential for toxicity to fauna, but uncommon in practice

Information for Proper Application

- Knowledge of lake and downstream water uses
- Inventory of aquatic biota with emphasis on sensitive species
- Mapping of aquatic vegetation with accurate identification of all species and general appraisal of relative abundance and overall cover/biomass

- Water quality data that facilitate dose planning and evaluation of effectiveness and impacts; suspended solids/water clarity, hardness, dissolved oxygen and temperature should be included at a minimum
- Treatment plan to include dose, areas treated, expected alteration of plant community, and follow-up activities
- Knowledge of use restrictions after treatment
- Monitoring program for assessing effectiveness and impacts

Factors Favoring the Use of this Technique

- An invasive plant species has been detected as patches of dense growth but is not amenable to physical control techniques
- Overall vegetative density is excessive over a large portion of the lake, negatively affects habitat and water uses, and is not amenable to alternative control methods
- Localized control of plants is needed either to support localized use (e.g., swimming area) or as follow-up to alternative controls

Performance Guidelines

- Map plant community and note density and distribution of target and non-target species; presence of protected species may prevent treatment
- Application must be performed by licensed applicators
- Apply diquat product in accordance with label instructions and restrictions; justify dose, location and timing of treatment
- Where a large portion of the lake is treated, apply diquat in strips or zones to provide faunal refuges
- Monitor water quality before and after treatment, with emphasis on oxygen and nutrient levels, if more than 10% of lake is treated
- Monitor plant community features before and after treatment

Possible Permits

- WPA permit through local Conservation Commission/DEP
- Review by NHESP (further action if protected species are present)
- License to Apply Chemicals from DEP

Impacts Specific to the Wetlands Protection Act

- Protection of public and private water supply – Neutral
- Protection of groundwater supply – Neutral no interaction as diquat is adsorbed to soil particles
- Storm damage prevention – Neutral (no significant interaction)
- Prevention of pollution – Generally neutral (no significant interaction), but could be a detriment if plant die-off causes low oxygen at the lake bottom
- Protection of land containing shellfish – Generally neutral (no significant interaction), but reduced algae might reduce food resources for shellfish, and direct toxicity is possible under unusual circumstances
- Protection of fisheries – Possible benefit (habitat enhancement) and possible detriment (food source alteration, loss of cover)
- Protection of wildlife habitat – Possible benefit (habitat enhancement) and possible detriment (food source alteration, loss of cover)

Cost Considerations

Diquat treatments typically cost $200 to $500 per acre.

Wisconsin Department of Natural Resources

January 2012

Endothall Chemical Fact Sheet

Formulations

Endothall is the common name of the active ingredient endothal acid (7-oxabicyclo[2,2,1] heptane-2,3-dicarboxylic acid). Endothall products are used to control a wide range of terrestrial and aquatic plants. Both granular and liquid formulations of endothall are available for aquatic use in Wisconsin. Two types of endothall are available: dipotassium salt (such as Aquathol®) and monoamine salts (such as Hydrothol 191). Trade names are provided for your reference only and are neither exhaustive nor endorsements of one product over another.

Aquatic Use and Considerations

Endothall is a contact herbicide that prevents certain plants from making the proteins they need. Factors such as density and size of the plants present, water movement, and water temperature determine how quickly endothall works. Under favorable conditions, plants begin to weaken and die within a few days after application.

Endothall products vary somewhat in the target species they control, so it is important to always check the product label for the list of species that may be affected. Endothall products are effective on Eurasian watermilfoil (*Myriophyllum spicatum*) and also kill desirable native species such as pondweeds (*Potamogeton* spp.) and coontail (*Ceratophyllum* spp.). In addition, Hydrothol 191 formulations can also kill wild celery (*Vallisneria americana*) and some species of algae (*Chara, Cladophora, Spirogyra, and Pithophora*).

Endothall will kill several high value species of aquatic plants (especially *Potamogeton* spp.) in addition to nuisance species. The plants that offer important values to aquatic ecosystems often resemble, and may be growing with those plants targeted for treatment. Careful identification of plants and application of endothall products is necessary to avoid unintended harm to valuable native species.

For effective control, endothall should be applied when plants are actively growing. Most submersed weeds are susceptible to Aquathol formulations. The choice of liquid or granular formulations depends on the size of the area requiring treatment. Granular is more suited to small areas or spot treatments, while liquid is more suitable for large areas.

If endothall is applied to a pond or enclosed bay with abundant vegetation, no more than 1/3 to ½ of the surface should be treated at one time because excessive decaying vegetation may deplete the oxygen content of the water and kill fish. Untreated areas should not be treated until the vegetation exposed to the initial application decomposes.

Post-Treatment Water Use Restrictions

Due to the many formulations of this chemical the post-treatment water use restrictions vary. Each product label must be followed. For all products there is a drinking water standard of 0.1 ppm and can not be applied within 600 feet of a potable water intake. Use restrictions for Hyrdtohol products have irrigation and animal water restrictions.

Herbicide Degradation, Persistence and Trace Contaminants

Endothall disperses with water movement and is broken down by microorganisms into carbon, hydrogen, and oxygen. Field studies show that low concentrations of endothall persist in water for several days to several weeks depending on environmental conditions. The half-life (the time it takes for half of the active ingredient to degrade) averages five to ten days. Complete degradation by microbial action is 30-60 days. The initial breakdown product of endothall is an amino acid, glutamic acid, which is rapidly consumed by bacteria.

Impacts on Fish and Other Aquatic Organisms

At recommended rates, the dipotassium salts (Aquathol and Aquathol K) do not have any apparent short-term effects on the fish species that have been tested. In addition, numerous studies have shown the dipotassium salts induce no significant adverse effects in aquatic invertebrates (such as snails, aquatic insects, and crayfish) when used at label application rates. However, as with other herbicide use, some plant-dwelling populations of aquatic organisms may be adversely affected by application of endothall formulations due to habitat loss.

In contrast to the low toxicity of the dipotassium salt formulations, laboratory studies have shown the monoamine salts (Hydrothol 191 formulations) are toxic to fish at dosages above 0.3 parts per million (ppm). In particular, the liquid formulation will readily kill fish present in a treatment site. By comparison, EPA approved label rates for plant control range from 0.05 to 2.5 ppm. In recognition of the extreme toxicity of the monoamine salt, product labels recommend no treatment with Hydrothol 191 where fish are an important resource.

Other aquatic organisms can also be adversely affected by Hydrothol 191 formulations depending upon the concentration used and duration of exposure. Tadpoles and freshwater scuds have demonstrated sensitivity to Hydrothol 191 at levels ranging from 0.5 to 1.8 ppm.

Findings from field and laboratory studies with bluegills suggest that bioaccumulation of dipotassium salt formulations by fish from water treated with the herbicide is unlikely. Tissue sampling has shown residue levels become undetectable a few days after treatment.

Human Health

Most concerns about adverse health effects revolve around applicator exposure. Liquid endothall formulations in concentrated form are highly toxic. Because endothall can cause eye damage and skin irritation, users should minimize exposure by wearing suitable eye and skin protection.

At this time, the EPA believes endothall poses no unacceptable risks to water users if water use restrictions are followed. EPA has determined that endothall is not a neurotoxicant or mutagen, nor is it likely to be a human carcinogen.

For Additional Information

Environmental Protection Agency
Office of Pesticide Programs
www.epa.gov/pesticides

Wisconsin Department of Agriculture, Trade, and Consumer Protection
http://datcp.wi.gov/Plants/Pesticides/

Wisconsin Department of Natural Resources
608-266-2621
http://dnr.wi.gov/lakes/plants/

Wisconsin Department of Health Services
http://www.dhs.wisconsin.gov/

National Pesticide Information Center
1-800-858-7378
http://npic.orst.edu/

TREATMENT WITH ENDOTHALL

How it Works

Endothall is a contact herbicide, attacking a wide range of plants. The method of action of endothall is suspected to inhibit the use of oxygen for respiration. Only portions of the plant with which the herbicide can come into contact are killed. There are two forms of the active ingredient; the inorganic potassium salt that is found in the products Aquathol® Granular and Aquathol® K and the alkylamine salt formulations of Hydrothol® 191 Granular and Hydrothol® 191. Effective control can range from weeks to months. Most endothall compounds break down readily and are not persistent in the aquatic environment, disappearing from the water column in under 10 days and from the sediments in under 3 weeks.

Endothall acts quickly on susceptible plants, but does not kill roots with which it cannot come into contact, and recovery of many plants occurs. Rapid death of susceptible plants can cause oxygen depletion if decomposition exceeds re-aeration in the treated area, but this can be mitigated by conducting successive partial treatments. Toxicity to invertebrates, fish or humans is possible but not expected at typical doses, but endothall is not used in drinking water supplies.

Endothall is primarily a broad spectrum vascular plant control chemical. The Massachusetts experience is that endothall has not been very effective against milfoil, but works well on most species of pondweeds, coontail and naiads. It is used less than most other herbicides in Massachusetts, mainly due to dose limits that are observed to avoid impacts to non-target fauna.

Hydrothol 191 is an alkylamine salt formulation of endothall. This formulation is effective against algae as well as macrophytes, but is much more toxic to fish than Aquathol K. The environmental hazards listed on the Hydrothol 191 (Dimethylalkylamine endothall granular and liquid) labels warn that fish may be killed by dosages in excess of 0.3 ppm. Hydrothol 191 is less toxic to fish in cool water (<65°F). However, Hydrothol 191 granular is rarely used in Massachusetts because of potential dust problems and possible toxicity to the applicator. Aquathol K is much less toxic and is used more frequently in Massachusetts than Hydrothol 191. Aquathol K application rates vary with water depth. Although usually applied at lower rates, the maximum rate of 269 lbs per 2 acre feet or 6.4 gallons per 2 acre-feet for spot treatment would result in a maximum concentration of 5 ppm according to the product labels. Average concentrations in Massachusetts are <1 mg/L from the Aquathol K form.

As a contact herbicide, endothall is relatively non-selective, although dose and timing may limit impacts to non-target vegetation in some cases. Endothall is used much like diquat, for spot treatment of limited areas. It is preferred where diquat is expected to be less effective, but is used less than diquat in Massachusetts.

Benefits

- Effective against a wide variety of species
- Relatively rapid kill of targeted vegetation
- Areally selective; limited drift or impact outside target area

Detriments

- Not very selective; kills most species contacted
- Does not damage portions of plants with which it does not contact; regrowth from roots is common
- Potential for toxicity to fauna, but uncommon in practice

Information for Proper Application

- Knowledge of lake and downstream water uses; endothall cannot be used in all cases
- Mapping of aquatic vegetation with accurate identification of all species and general appraisal of relative abundance and overall cover/biomass
- Inventory of aquatic biota with emphasis on sensitive species

- Water quality data that facilitates dose planning and evaluation of effectiveness and impacts; suspended solids/water clarity, hardness, dissolved oxygen and temperature should be included at a minimum
- Treatment plan to include dose, areas treated, expected alteration of plant community, and follow-up activities
- Knowledge of use restrictions after treatment
- Monitoring program for assessing effectiveness and impacts

Factors Favoring the Use of this Technique

- An invasive plant species has been detected as patches of dense growth but is not amenable to physical control techniques
- Plant density is excessive over a large portion of the lake, negatively affects habitat and water uses, and is not amenable to alternative control methods
- Localized control of plants is needed either to support localized use (e.g., swimming area) or as follow-up to alternative controls

Performance Guidelines

- Map plant community and note density and distribution of target and non-target species; presence of protected species may prevent treatment
- Application must be performed by licensed applicators
- Apply endothall product in accordance with label instructions and restrictions; justify dose, location and timing of treatment
- Where a large portion of the lake is treated, apply endothall in strips or zones to provide faunal refuges
- Monitor water quality before and after treatment, with emphasis on oxygen and nutrient levels, if more than 10% of lake is treated
- Monitor plant community features before and after treatment

Possible Permits

- WPA permit through local Conservation Commission/DEP
- Review by NHESP (further action if protected species are present)
- License to Apply Chemicals from DEP

The Aquathol formulation is less toxic than the Hydrothol form and is therefore used more often.

Impacts Specific to the Wetlands Protection Act

- Protection of public and private water supply – Neutral
- Protection of groundwater supply–Neutral (no interaction as endothall is adsorbed to soil particles)
- Storm damage prevention – Neutral (no significant interaction)
- Prevention of pollution – Generally neutral (no significant interaction), but could be a detriment if plant die-off causes low oxygen at the lake bottom
- Protection of land containing shellfish – Generally neutral (no significant interaction), but reduced algae might reduce food resources for shellfish, and direct toxicity is possible under unusual circumstances
- Protection of fisheries – Possible benefit (habitat enhancement) and possible detriment (food source alteration, loss of cover)
- Protection of wildlife habitat – Possible benefit (habitat enhancement) and possible detriment (food source alteration, loss of cover)

Cost Considerations

Endothall treatments typically cost $400 to $700 per acre