Plant Control Rules to Live By

1. In lighted areas with suitable sediments, plants will grow

- ♦ Light and substrate quality are the critical factors in plant growth
- ♦ All lakes and ponds will normally have some amount of aquatic vegetation and it is important for lake ecology in many ways
- ♦ Management for a diverse native plant community that does not minimize open water is an appropriate goal for a healthy lake ecosystem
- ♦ Complete elimination of plants to facilitate water dependent uses is only practicable on a localized basis (e.g., in a swim area or at a boat launch)
- ♦ Maintenance will always be required to keep even small areas relatively free of aquatic vegetation

2. Understanding plant biology and ecology is essential to control

- ♦ The ecology of plant species varies and not all approaches work on all species
- ♦ Light needs and nutrient uptake vary substantially among species and may affect control
- ♦ Reproduction by seeds vs. vegetative propagation is important to duration of control
- ♦ Monocotyledon vs. dicotyledon biology can affect results of herbicide use

3. There is no "One Size Fits All" solution to plant problems

- ♦ Each situation is to some extent unique
- ♦ Adaptive strategies of plants require adaptive management for control and maintenance of a balance of native plants and open water
- ♦ Techniques can be applied in a wide range of levels and combinations
- ♦ Management plans and related permitting should incorporate multiple control options that support defined goals with thresholds for when each method would be applied

4. It is unusual to successfully manage all plants in a lake with one technique

- ♦ Variation in lake and plant features usually calls for multiple techniques
- ♦ Initial control and follow-up maintenance often require different approaches

5. Watershed management is unlikely solve problems of excessive rooted plant density

- ♦ Very few rooted aquatic plants can be controlled by clean water
- ♦ Increased water clarity may extend the depth of plant growth
- ♦ Watershed management complements in-lake management and should be part of a long-term lake management plan, but watershed management cannot address most rooted plant problems

6. Prevention is far less expensive than rehabilitation but is not easy

- ♦ Prevention costs are mainly associated with monitoring, regulation, and small-scale action

- ♦ Vigilance is essential and requires coordination among participating stakeholders
- ♦ Rapid response to a new infestation is essential, has limited cost, and is best supported by pre-existing plans
- ♦ Delays in permitting can be detrimental to rapid response; it is important to work with all permitting authorities where an invasion is underway to expedite approval processes to take prompt action
- ♦ Rehabilitation costs typically involve expansive and repeated control efforts; it is very difficult to eliminate an established infestation
- ♦ If rehabilitation is achieved, additional prevention costs then apply to maintain the desired native plant community

7. A regional focus is needed to protect the investment made in control

- ♦ Re-infestation from nearby lakes can reduce control longevity or allow introduction of new species
- ♦ Control of invasive plant species on a larger scale can be more efficient and economical
- ♦ Prevention measures are more effective on a regional scale

Management Options for Control of Aquatic Vascular Plants

Option	Mode of Action	Advantages	Disadvantages
PHYSICAL CONTROLS			
1) Benthic barriers	♦ Mat of variable composition laid on bottom of target area, suppressing growth ♦ Can cover area for as little as a month or permanently ♦ Maintenance improves results ♦ Usually applied around docks, in swim areas or boating lanes	♦ Highly flexible control ♦ Reduces turbidity from soft bottom sediments ♦ Can cover undesirable substrate ♦ Can improve fish habitat by creating edge effects	♦ May cause anoxia at sediment-water interface ♦ May limit benthic invertebrates ♦ Non-selective interference with plants in target area ♦ May inhibit spawning/feeding by some fish species ♦ Non-maintained barriers can fail
1a) Porous or loose-weave synthetic materials	♦ Laid on bottom and usually anchored by weights or stakes ♦ Removed and cleaned or flipped and repositioned at least once per year	♦ Allows some escape of gases which may be generated underneath ♦ Panels may be flipped in place or removed for relatively easy cleaning or repositioning	♦ Allows some plant growth through pores ♦ Gas may still build up underneath in some cases, lifting barrier from bottom
1b) Non-porous or sheet synthetic materials	♦ Laid on bottom and anchored by stakes, anchors or weights, or by layer of sand ♦ Removed or cleaned in place periodically	♦ Prevents all plant growth until sediment accumulates ♦ Minimizes interaction of sediment and water column	♦ Gas build-up may cause barrier to float if not vented ♦ Strong anchoring may make removal difficult
1c) Altering sediment composition	♦ Sediments added on top of existing sediments and plants ♦ Can limit plant growths and alter sediment-water interactions. ♦ Sediments can be applied from the surface or suction dredged from below muck layer (reverse layering technique)	♦ Plant biomass can be buried ♦ Seed banks can be buried deeper ♦ Sediment can be made less hospitable to plant growths ♦ Nutrient release from sediments may be reduced ♦ Increased surface sediment appeal to human users	♦ Lake depth may decline ♦ Sediments may sink into or mix with underlying muck ♦ Permitting for added sediment difficult ♦ New sediment may contain nutrients or other contaminants ♦ Usually too expensive for large scale application

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
2) Dredging	♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering/disposal ♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system ♦ Plants and seed beds are removed, and re-growth can be limited by light and/or substrate limitation	♦ Plant removal with some flexibility ♦ Increases water depth ♦ Can reduce pollutants including nutrients ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows major renovation of aquatic ecosystem ♦ May allow for growth of desirable species.	♦ Temporarily removes benthic invertebrates ♦ May create turbidity ♦ May eliminate fish community (complete dry dredging only) ♦ Possible impacts from containment area discharge ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging ♦ Usually very expensive
2a) "Dry" excavation	♦ Lake drained or lowered to maximum extent practical ♦ Target material dried to maximum extent possible ♦ Conventional excavation equipment used to remove sediments	♦ Tends to facilitate a very thorough effort ♦ May allow drying of sediments prior to removal ♦ Allows use of less specialized equipment ♦ Greater ability to remove target sediment reliably	♦ Eliminates most aquatic biota unless a portion of lake is left undrained ♦ Eliminates lake use during dredging
2b) "Wet" excavation	♦ Lake level may be lowered, but sediments not substantially dewatered ♦ Draglines, bucket dredges, or long-reach backhoes used to remove sediment	♦ Requires least preparation time or effort, tends to be least cost dredging approach ♦ May allow use of easily acquired equipment ♦ May preserve most aquatic biota	♦ Usually creates turbidity concerns ♦ May not remove all target sediment ♦ Containment area often needed to dry sediments prior to hauling ♦ May cause severe ecological disruption ♦ Impairs most lake uses during dredging

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
2c) Hydraulic (or pneumatic) removal	♦ No lake lowering ♦ Suction/cutterhead dredges create slurry which is hydraulically pumped to containment area ♦ Slurry dewatered, sediment retained, water discharged	♦ Creates minimal turbidity and limits impact on biota ♦ Can allow some lake uses during dredging ♦ Allows removal with limited access or shoreline disturbance	♦ Often leaves some sediment behind ♦ Cannot handle extremely coarse or debris-laden materials ♦ Requires advanced and more expensive containment area ♦ Water discharge needed
3) Dyes and surface covers	♦ Water-soluble dye is mixed with lake water, limiting light penetration and inhibiting plant growth ♦ Dyes remain in solution until washed out of system. ♦ Opaque sheet material applied to water surface	♦ Light limit on plant growth without high turbidity or great depth ♦ May achieve some control of algae as well ♦ May achieve some selectivity for species tolerant of low light	♦ May not control peripheral or shallow water rooted plants ♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at shallower depth ♦ Covers inhibit gas exchange with atmosphere and restrict recreation ♦ Dyes not used in water bodies with an active outlet
4) Mechanical removal (“harvesting”)	♦ Plants reduced by mechanical means, possibly with disturbance of soils ♦ Collected plants may be placed on shore for composting or hauled for disposal ♦ Wide range of techniques employed, from manual to highly mechanized	♦ Highly flexible control ♦ May remove other debris ♦ Can balance habitat and recreational needs	♦ Possible impacts on aquatic fauna ♦ Possible non-selective removal of plants ♦ Possible spread of undesirable species by fragmentation ♦ Possible generation of turbidity
4a) Hand pulling	♦ Plants uprooted by hand (“weeding”) and removed	♦ Highly selective technique ♦ No specialized equipment requirement	♦ Labor intensive ♦ Difficult to perform in dense stands ♦ Usually requires divers

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
4b) Cutting (without collection)	♦ Plants cut in place above roots without being harvested	♦ Generally efficient and less expensive than complete harvesting	♦ Leaves root systems and part of plant for possible re-growth ♦ Leaves cut vegetation to decay or to re-root ♦ Not selective within applied area
4c) Harvesting (with collection)	♦ Plants cut up to depth of 10 ft and collected for removal from lake ♦ May involve one machine or two, one for cutting and one for collection	♦ Allows plant removal on greater scale ♦ Can create lanes and ecological edge habitat	♦ Limited depth of operation ♦ Often leaves fragments which may re-root and spread infestation ♦ May impact lake fauna ♦ Limited selectivity within applied area
4d) Rototilling	♦ Plants, root systems, and surrounding sediment disturbed with mechanical blades	♦ Can thoroughly disrupt entire plant	♦ Usually leaves fragments which may re-root and spread ♦ May impact lake fauna ♦ Not selective within applied area ♦ Creates substantial turbidity
4e) Hydroraking	♦ Plants, root systems and surrounding sediment and debris disturbed with mechanical rake, material collected by rake removed from lake ♦ Usually performed near lake edge where mechanical harvesters cannot easily operate	♦ Can thoroughly disrupt entire plant ♦ Also allows removal of stumps or other obstructions ♦ Some sediment likely to be removed with plants and debris ♦ Can grade bottom in swim areas or boat launches	♦ Usually leaves fragments which may re-root and spread ♦ May impact lake fauna ♦ Not selective within applied area ♦ Creates substantial localized turbidity ♦ May be treated as dredging under MA regulations

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
5) Water level control	♦ Lowering or raising the water level to create an inhospitable environment for some or all aquatic plants ♦ Disrupts plant life cycle by desiccation, freezing, or light limitation	♦ Requires only outlet control to affect large area ♦ Provides widespread control in increments of water depth ♦ Complements certain other techniques (dredging, flushing)	♦ Potential issues with water supply ♦ Potential issues with flooding ♦ Potential impacts to non-target flora and fauna
5a) Drawdown	♦ Lowering of water allows desiccation, freezing in winter, physical disruption of plants and habitat ♦ Timing and duration of exposure and degree of dewatering are critical aspects ♦ Variable species tolerance to drawdown; emergent species and seed-bearers less affected ♦ Most effective on annual basis	♦ Control with some flexibility ♦ Opportunity for shoreline clean-up/structure repair ♦ Flood control utility ♦ Protects shoreline from ice damage ♦ Impacts vegetative propagation species with limited impact to seed producing populations ♦ Develops coarser sediment in drawdown area	♦ Possible impairment of well production ♦ Reduction in water supply availability ♦ Alteration of downstream flows ♦ Possible impacts on emergent wetlands and water dependent wildlife ♦ Possible fish impacts ♦ Possible shoreline erosion and slumping ♦ May result in greater nutrient availability for algae
5b) Flooding	♦ Higher water level in the spring can inhibit seed germination and plant growth ♦ Higher flows which are normally associated with elevated water levels can flush seed and plant fragments from system	♦ Where water is available and dam control exists, this can be an inexpensive technique ♦ Plant growth need not be eliminated, merely retarded or delayed ♦ Timing of water level control can selectively favor certain desirable species	♦ Potential peripheral property flooding ♦ Possible downstream impacts ♦ Many species may not be affected, and some may benefit ♦ May increase nutrient and organic loading, increasing algae growth

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
CHEMICAL CONTROLS			
6) Herbicides	♦ Liquid or pelletized herbicides applied to target area or to plants directly ♦ Contact or systemic chemicals kill plants or limit growth ♦ Typically requires application every 1-5 years	♦ Wide range of control is possible ♦ May be able to selectively eliminate species ♦ May achieve temporary algae control ♦ May allow for more desirable plant growth	♦ Possible toxicity to non-target species ♦ Possible downstream impacts ♦ Restrictions of water use after treatment ♦ Increased oxygen demand from decaying vegetation ♦ Possible recycling of nutrients to allow other growths
6a) Forms of copper or peroxide	♦ Contact herbicides ♦ Cellular toxicants, membrane disruption ♦ Applied as wide variety of liquid or granular forms, usually for control of algae on plants to improve results of other herbicide applications	♦ Control of some submersed plant species but applied mostly as an aid to control by other herbicides ♦ More often an algal control agent	♦ Potentially toxic to aquatic fauna as a function of concentration, formulation, and ambient water chemistry ♦ Ineffective at colder temperatures ♦ Copper ion persistent in system sediment
6b) Forms of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid)	♦ Contact herbicide with limited translocation potential ♦ Membrane-active chemical which inhibits protein synthesis ♦ Causes structural deterioration ♦ Applied as liquid or granules	♦ Moderate control of some emersed plant species, moderately to highly effective control of floating and submersed species ♦ Limited toxicity to fish at typical MA dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Potentially toxic to aquatic fauna (varying degrees by formulation) ♦ Time delays on use for water supply, agriculture and recreation

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
6c) Forms of diquat (6,7-dihydropyrido [1,2-2',1'-c] pyrazinediium dibromide)	♦ Contact herbicide with limited translocation potential ♦ Absorbed by foliage but not roots ♦ Strong oxidant; disrupts most cellular functions ♦ Applied as a liquid, sometimes in conjunction with copper	♦ Moderate control of some emersed plant species, moderately to highly effective control of floating or submersed species ♦ Limited toxicity to fish at recommended dosages, low toxicity at typical MA doses ♦ Rapid action	♦ Non-selective in treated area ♦ Potentially toxic to zooplankton at high application rates ♦ Inactivated by suspended particles; ineffective in muddy waters
6d) Forms of flumioxazin (N-(7-fluoro-3,4-dihydro-3-oxo-4-prop-2-ynyl-2H-1,4benzoxazin-6-yl)-cyclohex-1-ene-1,2-dicarboxamide)	♦ Contact herbicide with limited translocation potential ♦ Blocks biosynthesis in several metabolic pathways, toxic porphyrins build up ♦ Damages cell membranes, physical plant structure	♦ Moderately to highly effective control of a variety of submersed and floating leaved species ♦ More effective on algae mats than many herbicides ♦ Fairly fast action	♦ Potential toxicity to aquatic fauna, depending upon formulation and ambient water chemistry ♦ Limited selectivity ♦ Time delays for use of treated water for agriculture and turf management
6e) Forms of glyphosate (N-[phosphonomethyl glycine)	♦ Systemic herbicide ♦ Absorbed through foliage, disrupts enzyme formation and function in uncertain manner ♦ Applied as liquid spray	♦ Moderately to highly effective control of emergent and floating leaved plant species ♦ Can be used selectively, based on application to individual plants ♦ Rapid action ♦ Low toxicity to aquatic fauna at usual dosages ♦ No time delays for use of treated water	♦ Non-selective in treated area ♦ Inactivation by suspended particles; ineffective in muddy waters ♦ Not for use within 0.5 miles of potable surface water intakes ♦ Terrestrial formulations have caused public concern over human health impacts

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
6f) Forms of imazapyr (2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl)-nicotinic acid)	♦ Systemic herbicide ♦ Inhibits acetolactate synthase (ALS), an enzyme involved in the synthesis of essential amino acids ♦ Applied as liquid spray to emergent or floating leaved vegetation ♦ Causes slow death by structural deficiency	♦ Moderately to highly effective control of emergent and floating leaved plant species ♦ Can be used selectively, based on application to individual plants ♦ Low toxicity to animals, which do not have ALS	♦ Non-selective in treated area ♦ Not for use within 0.5 miles of potable surface water intakes ♦ Long time delay for agricultural use after treatment unless residue testing reveals values below set threshold
6g) Forms of imazamox ((±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1Himidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid)	♦ Systemic herbicide ♦ Inhibits acetolactate synthase (ALS), an enzyme involved in the synthesis of essential amino acids ♦ Applied as liquid to emergent, floating leaved, or submerged plants, especially monocotyledons ♦ Causes slow death by structural deficiency	♦ Moderately effective control of aquatic vegetation ♦ Extends control to submergent plants unlike the similar imazapyr ♦ Limited exposure time needed ♦ Low toxicity to animals, which do not have ALS	♦ Low selectivity in treated area ♦ Not for use within 0.5 miles of potable surface water intakes ♦ Long time delay for agricultural use after treatment unless residue testing reveals values below set threshold
6h) Forms of 2,4-D (2,4-dichlorophenoxyl acetic acid)	♦ Systemic herbicide ♦ Inhibits cell division in new tissue, stimulates growth in older tissue, resulting in gradual cell disruption ♦ Applied as liquid or granules, frequently as part of more complex formulas, preferably during early growth phase of plants	♦ Moderately to highly effective control of a variety of emergent, floating, and submersed plant species ♦ Can achieve some selectivity through application timing and concentration ♦ Limited exposure time needed	♦ Potential toxicity to aquatic fauna, depending upon formulation and water chemistry ♦ Time delays for use of treated water for agriculture and recreation ♦ Not for use in potable water supplies; including lakes with nearby wells in sandy soils

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
6i) Forms of fluridone (1-methyl-3-phenyl-5-[-3-{trifluoromethyl} phenyl]-4[IH]-pyridinone)	♦ Systemic herbicide ♦ Inhibits carotenoid pigment synthesis and impacts photosynthesis ♦ Best applied as liquid or granules during early growth phase of plants	♦ Can be used selectively, based on concentration ♦ Gradual deterioration of affected plants limits impact on oxygen level ♦ Effective against several difficult-to-control species ♦ Low toxicity to aquatic fauna	♦ Impacts on non-target plant species possible at higher doses ♦ Extremely soluble and mixable; difficult to perform partial lake treatments ♦ Requires extended contact time
6j Forms of triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid)	♦ Systemic herbicide ♦ Disrupts enzyme systems specific to plants ♦ Applied as liquid spray or subsurface injected liquid	♦ Effectively controls many floating and submersed plant species ♦ Can be used selectively, more effective against dicotyledon plant species ♦ Effective against several difficult-to-control species ♦ Low toxicity to aquatic fauna ♦ Limited exposure time needed	♦ Impacts on non-target plant species possible at higher doses ♦ Restrictions on use of treated water for supply or recreation ♦ Not as effective on certain invasive species as other applicable herbicides
6k Forms of florpyrauxifen-benzyl (2-pyridinecarboxylic acid, 4-amino-3chloro-6-(4-chloro-2-fluoro-3-methoxy-phenyl)-5-fluoro-, phenyl methyl ester)	♦ Systemic herbicide ♦ Synthetic auxin, alters cell wall elasticity and gene expression, disrupts tissue formation, causes slow death ♦ Liquid sprayed on emergent/floating plants or injected into water column	♦ Effectively controls several invasive species ♦ Can be used selectively, more effective against dicotyledon plant species ♦ Low toxicity to aquatic fauna ♦ Limited exposure time needed	♦ Limited target species, higher doses limited by solubility ♦ Time delays on use of treated water for irrigation ♦ Limited track record (new in MA as of 2019)

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
BIOLOGICAL CONTROLS			
7) Biological introductions	♦ Fish, invertebrates or pathogens which feed on or parasitize plants are added to system to affect control ♦ The most commonly used organism outside MA is the grass carp, but the larvae of several insects have been used, and viruses have been tested	♦ Provides potentially continuing control with one treatment ♦ Harnesses biological interactions to produce desired conditions ♦ May produce potentially useful fish biomass as an end product	♦ Typically involves introduction of non-native species ♦ Effects may not be controllable ♦ Plant selectivity may not match desired target species ♦ May adversely affect indigenous species
7a) Herbivorous fish	♦ Sterile juveniles stocked at density which allows control over multiple years ♦ Growth of individuals offsets losses, increases herbivorous pressure ♦ Grass carp are illegal in Massachusetts.	♦ May greatly reduce plant biomass in <2 years ♦ May provide multiple years of control from single stocking ♦ Sterility intended to prevent population perpetuation and allow later adjustments	♦ May eliminate all plant biomass ♦ Likely to impact non-target species ♦ Funnels energy and nutrients into algae ♦ Alters habitat ♦ May escape upstream or downstream ♦ Difficult to manage population
7b) Herbivorous invertebrates	♦ Larvae or adults stocked at density intended to foster control ♦ Usually intended to selectively control target species ♦ May yield broader plant control in some cases	♦ May involve species native to region, or even targeted lake ♦ Some species have no negative effect on non-target species ♦ May facilitate longer term control with limited management	♦ Some utilized species are non-native ♦ Population ecology suggests incomplete control likely ♦ Oscillating cycle of control and re-growth expected ♦ Predation by fish may complicate control ♦ Possible interference from other lake management actions that impact some life stages

Plant Control Table - continued

Option	Mode of Action	Advantages	Disadvantages
7c) Fungal/bacterial/viral pathogens	♦ Inoculum used to seed lake or target plant patch ♦ Growth of pathogen population expected to achieve control over target species ♦ Very few products available, largely experimental	♦ May be highly species specific ♦ May provide substantial control after minimal inoculation effort	♦ Effectiveness and longevity of control not well known ♦ Infection ecology suggests incomplete control likely
7d) Selective plantings	♦ Establishment of plant assemblage resistant to undesirable species ♦ Plants introduced as seeds, cuttings or whole plants	♦ Can restore native assemblage ♦ Can encourage assemblage most suitable to lake uses ♦ Supplements targeted species removal effort	♦ Largely experimental ♦ Nuisance species may eventually return to dominate assemblage ♦ Introduced species may become nuisances ♦ Very limited track record in MA, but a logical follow up to invasive species control where large areas are without plants