RAPID RESPONSE PLAN FOR REED GRASS (*Phragmites australis*) IN MASSACHUSETTS

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Species Taxonomy and Identification

Common Reed, *Phragmites australis*, is a large perennial rhizomatous grass, reaching a height of up to 20 ft. The stems are stout, rigid, smooth, and can be up to one inch in diameter. Roots can grow to a depth of 3 ft, and the depth of the rhizome network has been reported to range from 8 inches to over 6 ft (Haslam 1972; Cross and Fleming 1989). Leaves of the common reed are typically 10 to 20 inches in length. Feathery plumes of flowers, known as tassels, are located at the top of the stem, and change from purple-brown in the summer to tan or grey in the autumn. Flowers are surrounded by silky white hairs, while seeds are brown and delicate.

According to Crow and Hellquist 2000, the following taxonomic characteristics are used to identify *Phragmites australis* to species:

1. Plants herbaceous (if appearing woody, then unbranched), flowering regularly, spikelets less than 4 cm long.
2. Florets bisexual, or with 1 bisexual floret along with empty lemmas, or with 1 or 2 staminate florets.
3. Spikelets with two to several bisexual florets.
4. Spikelets pedicellate, not forming simple spikes (some species with spike-like inflorescences, but spikelets not sessile); glumes and lemmas awned or not.
5. Plants large, coarse reeds, 3-20 ft tall; inflorescence plume-like; rachilla bearded, with abundant long silky hairs as long as or longer than lemmas.

Although there are other species of *Phragmites*, most encountered inland *Phragmites* are *P. australis*, and this tall grass is readily identifiable by its strong stems, long thin leaves, and the tassel of downy flowers at the tip of the plant. Some untrained monitors may confuse *Phragmites* with *Zizania*, or wild rice, which is less common and not as robust, aside from detailed taxonomic features that differ.

Figure 1. Phragmites australis pictures and drawings. Photos from: USDA, NRCS. 2004. The PLANTS Database, Version 3.5 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Species Origin and Geography

Phragmites australis is found on every continent except Antarctica and may have the largest range of any flowering plant (Tucker 1990). *P. australis* is found in each of the lower 48 states (except possibly Arkansas), as well as southern Canada. *P. australis* stands are present in Massachusetts in disturbed and coastal areas, and along the margins of ponds, lakes, rivers and wetlands throughout the state (Figure 1). Analysis of peat cores suggested that *Phragmites australis* has been a member of the wetland community in North America for at least 3000 years (Niering et al. 1977), although its distribution was limited. In the late 1900's, *P. australis* began to rapidly colonize fresh and brackish water wetlands. Increased invasiveness of the species led to the suggestion that a more aggressive European strain was introduced (Metzler and Rosza 1987, Tucker 1990), and recent studies have identified two strains of *P. australis* (Saltonstall 2002). The aggressive rhizome network of *P. australis*, coupled with widespread soil disturbance for development, appears responsible for the wave of invasions over the last few decades.

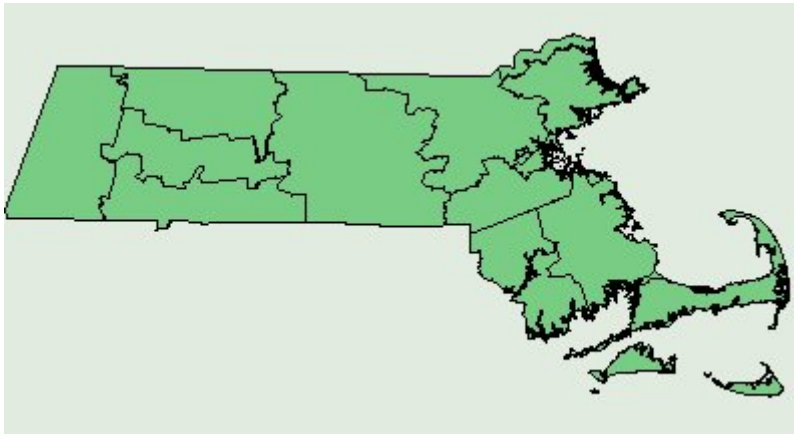


Figure 2 – Distribution map of *Phragmites australis* in Massachusetts. The green areas represent counties where *P. australis* is present, which is all counties in MA. This map was obtained from plants.usda.gov.

Species Ecology

Phragmites australis is common in brackish and alkaline environments (Haslam 1971, 1972; Marks et al. 1993) but also thrives in acidic soils and wetlands (Marks et al. 1993). *P. australis* experiences greater growth in freshwater, but may be outcompeted by other species in these habitats. It is common in coastal areas, disturbed lands, urban areas, lakes, ponds, rivers, riparian zones, and wetlands. It is particularly adapted to areas subjected to human manipulation (Leithead et al. 1971; Ricciuti 1983; Hansen et al. 1988; Swanson and Duebbert 1989; Marks et al. 1993). Areas experiencing disturbances including pollution, dredging or increased sedimentation favor *Phragmites* (Roman et al. 1984). It does not typically initiate growth in areas with permanently standing water, but where it has gained a foothold under dry conditions it proves tenacious and perseverant. It is often found in areas with high water tables or areas that experience seasonal flooding to depths <20 inches (Bolen 1964; Shay and Shay 1986), but it has been found surviving in Massachusetts freshwater ponds in water up to five feet deep.

Soil and water conditions are two factors controlling the distribution of *P. australis*. *P. australis* grows on acidic and alkaline soils of any texture, ranging from fine clays to sandy loams (Shay and Shay 1986; Hansen et al. 1988). It can tolerate a range of salinities, and worldwide maximums have been reported from 12 ppt in Britain to 40 ppt along the Red Sea (Hocking et al. 1983). One New York population is reported to have a maximum salinity tolerance of 29 ppt (Hocking et al. 1983), but high salinity tolerance appears rare. *P. australis* has a low tolerance for wave action, which can break the stems and impede rhizome formation (Haslam 1970).

The majority of reproduction in *P. australis* is vegetative, through growth or rhizomes or dispersal of rhizome fragments (Marks et al. 1993). An extensive network of rhizomes allows for aggressive and rapid expansion, allowing *P. australis* to form dense monospecific stands (Marks et al. 1993). Seed formation occurs between July and September, with seeds being dispersed in the northeast United States between November and January. Seeds and rhizome fragments are transported to new sites via mammals, birds, machinery, wind and currents (Marks et al. 1993). *P. australis* has been used in wetland rehabilitation and remediation projects, further expanding its range (Uchytil 1992). According to Tucker (1990), most seed production results in non-viable seeds, and successful establishment by seeds is rare (Smith and Kadlec 1983; Shay and Shay 1986). However, it is difficult to envision how some of the more remote stands found peripheral to Massachusetts ponds got started if not for wind-blown seeds, so seed production and dispersal should not be ignored in control efforts.

Detection of Invasion

While a substantial stand of *Phragmites* is hard to miss, individual plants are not as noticeable, especially since they tend to occur at the lake periphery or in adjacent wetlands, where other emergent vegetation may obscure them or at least allow plants to blend into the background. The best way to detect *Phragmites* is to move along the edge of the lake, either on land or in shallow water by foot or small boat, focusing on each area of shoreline as it is passed. The inflorescence, or flower/seed head, is obvious when present. Otherwise, look for the stout stems and long, lanceolate leaves, which are an attractive green during much of the growing season. Dead stems from previous years may be tan or grey and look a little like bamboo shoots. Detection in wetlands is more difficult, simply as a function of access, but healthy *Phragmites* is likely to tower over any other non-woody vegetation and even most shrubs. An annual survey is recommended, covering the entire shoreline. If the lake is too large to make a complete survey feasible, focus on disturbed and developed shoreline segments.

Species Confirmation

Unless the invasion is discovered by individuals trained in plant taxonomy, samples should be sent to competent taxonomists for confirmation. In Massachusetts, the Department of Conservation (DCR), the Department of Environmental Protection (DEP), the Massachusetts College of Liberal Arts (North Adams, specifically Dr. Barre Hellquist), and the University of Massachusetts at Amherst (UMASS) have the expertise to assist in plant identification. Many consulting and lake management firms also possess this expertise, but it will be the

responsibility of the DCR to determine where specimens should be sent. Therefore, the DCR at 617-626-1411 or 617-626-1395 should be the first point of contact.

Key steps in confirming an invasion include:

1. Collect complete specimens of the suspected plant; root systems are not needed for identification of this species, but removal of the root system is necessary for plant control, so it is best to extract the entire plant. Specimens can be pressed on a sheet of appropriate (absorbent) paper, covered with wax paper and a stack of books or other suitable weight (an actual herbarium press is useful if available). Alternatively, the plant can be "folded" into a clear plastic ziplock bag; it is likely to be too large to place in such a bag without snapping the stem in several places, but limit mangling of the specimen to the greatest practical extent.
2. Contact the DCR representative at 617-626-1411 or 617-626-1395 and inform him/her that a suspected occurrence of *Phragmites* has been detected in the waterbody. The DCR contact will assess past records for the waterbody and will instruct the caller where to send a sample for confirmation, if warranted.
3. As soon as possible, preferably within 2 days, send specimens to the identified DCR representative for confirmation, or to a taxonomic expert as designated by the DCR contact. Note in writing that the enclosed specimen is believed to be *Phragmites* and include the name of the waterbody, the approximate location in the waterbody (a map is helpful) with water depth and any other site-specific observations, the date and time of collection, and the name, address, phone number and email for the collector or sender.
4. The DCR will confirm the identification or provide an alternative identification either directly or indirectly through a recognized taxonomist, and will be responsible for notifying all appropriate agencies, municipalities and citizen groups either potentially affected or responsible for follow-up actions.

Quantifying the Extent of Invasion

It is not difficult to count the stems of *Phragmites* in new invasions. These are emergent plants of shallow waters to dry land with a shallow groundwater table. Estimates of the number of stems per square foot or meter and the area containing the infestation are useful in planning control efforts, and most new growths will be peripheral and amenable to simple sketch mapping using the outline of the lake as a guide. Once a stand becomes established, the density may be too high to count stems or even to move through the stand. It may be sufficient to delineate *Phragmites* growths as individual plants, sparse groups of stems, or dense stands. An estimate of the area covered and density level with its position on a map is suggested as the basic assessment level, with notation of other species present.

Useful steps in quantifying the invasion include:

1. Using a map of the lake with an accurate representation of shoreline, delineate all areas of *Phragmites* presence.
2. For each area of detection, characterize *Phragmites* growth as individual plants, sparse groups of stems, or dense stands and show the areal extent of coverage. For lower density growths, indicate the average number of stems per square meter or yard.
3. Note all other plant species present within the area delineating the new *Phragmites* growth and in the area forming an approximate circle around the new growth for an additional horizontal distance of 50 to 100 ft from the edge of the new growth. This may involve assessing everything from upland vegetation through emergent wetland assemblages to submergent plant growths.
4. Note water depth all around the edge of the stand and in the additional area surveyed for plants.
5. Note sediment type in the area occupied by *Phragmites* and in the surrounding area surveyed for other plants. If the new growth is more than a single plant or cluster of several plants, attempt to dig into the sediment and determine the approximate depth of rhizomes.
6. Note any animal presence or signs in the vicinity of new growths.

Species Threat Evaluation

The aggressive nature of *P. australis* commonly results in dense, sometimes impenetrable, monospecific stands, leading to decreases in species diversity and habitat quality (Roman et al. 1984). The decrease in biodiversity leads to decreases in food availability for a wide range of species, and eventually impacts the wildlife of invaded ecosystems (Roman et al. 1984). Adult waterfowl occasionally feed on seeds produced by *P. australis*, but the nutritional value is rated as fair to poor. Dense stands of *P. australis* may offer some escape cover for large mammals and molting waterfowl, although only the stand edges are considered useful for nesting. Dry stands of *P. australis* are potential fire hazards, posing a threat to marshes and nearby housing developments (Reimer 1973), and also decreasing aesthetic appeal. *Phragmites* has the ability to reduce the amount of available open water and shade out aquatic vegetation, including rare or endangered species (Marks et al. 1993). Control and monitoring of mosquito populations is nearly impossible in dense stands of *P. australis* (Hellings and Gallagher 1992), representing a human health threat.

Potential spread within the waterbody is governed by the physical features of the waterbody (especially water depth and substrate) and the level of activity of potential vectors of spread for *Phragmites* (especially disturbance by humans and seed dispersal by birds). *Phragmites* grows in almost any sediment under the water or with a water table near the surface. The water depth range for *Phragmites* is from about 2 ft above the water table to nearly 5 ft of water depth, although most dense growths are found in water <2 ft deep. Within a waterbody, spread is strongly a function of rhizome expansion, and is often linked to areas of sediment disturbance (Marks et al. 1994).

Potential spread outside the waterbody is mainly a function of bird and human activities. Birds may transport rhizome fragments, but are more likely to carry seeds, either externally or in their digestive tract. Seeds are considered to be a limited source of new plants (Smith and Kadlec 1983; Shay and

Shay 1986), but even at low viability, this is a potentially important means of invasion, and patterns of *Phragmites* appearance in isolated waterbodies or undisturbed areas of shoreline suggest that dispersal as seeds by birds does occur. Transport by humans is a known threat, with movement of rhizome fragments in soil being of greatest concern (Marks et al. 1993).

These factors combine to create a site-specific level of threat. Of primary interest are how great an infestation may become, how readily it may be transmitted to new areas (both inside and outside the infested waterbody), what resources may be impacted to what degree, and what the potential is for eradication or control through rapid response to detection of an invasion. In evaluating the potential threat from a new *Phragmites* infestation in DCR parks on a case by case basis, the DCR staff will consider the following:

1. What portion of the waterbody could be colonized (estimate as the area with water depth <5 ft and onto shore to a water table depth of about 2 ft)?
2. What is the potential for dense bed formation (estimate as the area with stiff organic to sandy substrate within the potential zone of colonization)?
3. What is the potential for rapid (<3 years) spread of *Phragmites* (estimate as the common area from #1 and #2 above and disturbed or sparsely vegetated)?
4. What is the potential strength of vectors of internal *Phragmites* spread (mainly human disturbance of the shoreline)?
5. What is the potential strength of vectors of external *Phragmites* spread (human soil disturbance or export, daily or seasonally mobile bird populations)?
6. What resources and uses are potentially threatened (water supply, swimming, boating, fishing, aesthetics, sensitive or protected populations)?
7. What is the potential for eradication (based on extent and density of coverage, vectors of spread)?
8. What is the potential for confinement (based on extent and density of coverage, physical isolation of area affected, vectors of spread)?

By answering these questions, one can characterize the threat according to the following matrix, which can then govern the response to detection of an invasion:

FACTOR	YES	NO	THREAT EVALUATION	HIGH	MEDIUM	LOW
A large area could be affected			Extent and speed of possible infestation			
Plant density could be high						
Spread could be rapid						
Water supply may be impacted			Nature of possible impacts			
Swimming may be impacted						
Boating may be impacted						
Fishing may be impacted						
Aesthetics may be impacted						
Sensitive species may be impacted						
Protected species may be impacted						
Spread by water flow likely			Ability to spread			
Spread by birds likely						
Spread by boating likely						
Spread by other human activities likely						
Eradication is possible			Potential success of rapid response			
Confinement is possible						

Communication and Education

Once the presence of *Phragmites* has been confirmed, the Town(s) in which the lake or wetland is situated should be notified, usually through the Conservation Commission, which will have a chairperson or an agent who is reachable through Town Hall. It would also be appropriate to notify all relevant stakeholder groups, but these need to be identified and many will not have a central clearinghouse contact for notification. Groups who should be informed about the infestation include mainly any active lake association and shoreline property owners. Notification through individual contacts is desirable but may be inefficient. Posting a notice in the local paper will help publicize the problem, but the notice may not receive widespread attention. Contacting shoreline property owners is paramount, as it appears that the movement of rhizome-bearing soil by humans is the most common means of dispersal. Some seeds may be viable, but most lake users are not likely to transport seeds or rhizomes. Once a population has been started, expansion is by rhizomes, and property owners should be on the lookout for new growths.

It is desirable to inform property owners even before an invasion, providing a picture or drawing of *Phragmites* and asking people to be on the lookout for this invasive plant. Other lake users may also provide useful information, so it may be advisable to post signs at access points, but these users have not been implicated in the transport of *Phragmites* the way they have for many other invasive species. A local contact (name and phone number) for notification should be supplied, typically either a representative of the property owners association or the town's Conservation Commission, or both.

Responsibility for control of *Phragmites* does not rest with any one entity under the laws of the Commonwealth of Massachusetts. Approval for control actions is governed by the Wetlands Protection Act, which always involves the town's Conservation Commission and the Commonwealth's DEP. Approval for control actions may also involve the Division of Fisheries and Wildlife and/or the Natural Heritage and Endangered Species Program, both agencies of the Commonwealth, depending upon the resources in the lake or wetland (particularly if protected species are known from the lake). Other agencies and approval programs may apply, depending upon the features of the lake (naturally large enough to be a statutory Great Pond), the location of the lake (e.g., in an Area of Critical Environmental Concern), or the uses of the lake (e.g., as a water supply). However, none of these agencies is charged with controlling invasive species, and there is no legislation in Massachusetts that mandates control of *Phragmites*. The DCR has taken the lead in Massachusetts with regard to encouraging control of invasive species, and supports control efforts as its budget allows. However, outside of the state parks and reservations, control is largely a function of local desire to protect and maintain the resource.

For waterbodies within DCR parks, the following notification procedures are to be followed when a new infestation by *Phragmites* has been confirmed:

1. The DCR contact responsible for confirming the *Phragmites* invasion will notify the DCR Regional Director, Park Supervisor and any regional DCR contact charged with managing water resources. A single letter copied to each party is preferred. The letter should briefly state the problem and outline immediate control steps that are needed, indicating an expected date for a follow up visit by Lakes and Ponds Program staff to begin concerted control measures (see posting procedures below).
2. The DCR contact responsible for *Phragmites* invasion confirmation will also notify the DEP, the DFW and the NHESP in writing; a copy of the letter sent to DCR parties is sufficient. If a contact for an associated citizens' lake or watershed organization is known, notification should be given to that group as well.
3. The Regional Director or a designated park contact for local affairs will notify the town(s) in which the park and waterbody are situated. The appropriate parties within the town(s) to be notified may vary by town, but should include the Conservation Commission and either the Selectmen, Town Manager or Mayor, depending upon local government structure.

For waterbodies within DCR parks, the following posting procedures are to be followed when a new infestation by *Phragmites* has been confirmed:

1. All access points to the waterbody (e.g., boat launches, swimming areas, fishing piers or obvious shoreline fishing points) shall be posted with a photograph or drawing of *Phragmites* and a written notice that this invasive plant has been found in the waterbody.
2. Suggested language is as follows: Warning. Common reed (*Phragmites australis*) has been found in this waterbody. This invasive plant represents a threat to this waterbody and its users. Caution should be exercised to avoid the spread of this plant. Do not pick or remove this plant if you encounter it, and be sure that no sediment is transported from this lake with any boats or other equipment used here.
3. Include a contact name and phone number on all postings.

Quarantine Options

Both natural processes and human activities can spread *Phragmites*, both within an invaded lake and to other area lakes. However, the primary vector for *Phragmites* appears to be the movement of rhizome-bearing soil, an activity associated with construction and not common to most recreational lake uses. Some people do use *Phragmites* as an ornamental plant, and such practices should be discouraged through education. However, there is no clear reason to immediately quarantine the lake or even the areas with *Phragmites*, although there may be some protective benefit in roping off new growths to minimize collection or inadvertent transport of seeds or vegetative parts. Although it may be prohibitively expensive, installation of barriers to rhizome expansion (e.g., sheet pile, excavated trench) may be warranted in some cases where rapid response cannot be implemented for some reason.

Where a *Phragmites* invasion is confirmed in a waterbody in a DCR park, the following quarantine steps will be evaluated and implemented as warranted:

1. Post access points with warnings to avoid the plant and/or certain areas of the waterbody; use marker buoys to identify infested areas.
2. Surround smaller infested areas with fencing or other enclosing materials to limit access.
3. Install a barrier below the sediment surface to limit rhizome spread; this might be considered for small but dense stands in an area where permitting for removal may be complicated and protracted.
4. Restrict access to coves or other isolated areas to prevent interaction of people with *Phragmites*.
5. Close any access point (e.g., boat ramp, beach, other points of active contact) in close proximity to *Phragmites*, where the potential for internal or external spread is considered high.
6. Close the waterbody to human use.

Items 4-6 would be unlikely to be implemented except under extreme or extenuating circumstances, as there is minimal threat to human safety or threat of unintentional transport from recreational activities.

Early Eradication Options

Timelines for necessary action with regard to *Phragmites* invasions hinge on stopping the spread of this plant by rhizomes once a new growth has begun. Rhizome expansion occurs throughout the growing season, so the sooner controls are implemented, the smaller the area that must be addressed. Seeds are released in the late fall or winter, but as most appear inviable, it is not clear that action to prevent seed dispersal is critical to control. Once the growing season is over (about October), plants are largely dormant and the above-ground portion dies back until the following spring, when new shoots are sent upward. As the movement of food reserves to the roots and the production of seeds occurs in the second half of the growing season in Massachusetts, actions focusing on limiting rhizome survival and seed output should occur before August wherever possible. Yet the efficiency of controls is such that it should be assumed that at least two successive years of control effort is the minimum required to gain control over a *Phragmites* invasion.

Management options are covered to some extent in The Practical Guide to Lake Management in Massachusetts (Wagner, 2004), a companion guide to the GEIR on Lake Management, available on-line at http://www.mass.gov/dcr/waterSupply/lakepond/lakepond.htm and supplied to all towns in the Commonwealth by the DCR in 2004. However, emphasis in this manual is on techniques for submergent or floating leafed plants, and some potential methods of *Phragmites* control are not covered. The Nature Conservancy has produced a relevant document (Marks et al. 1993), the key elements of which were covered in a later journal article (Marks et al. 1994). A summary of control approaches is provided below, with an evaluation of the potential to eradicate *Phragmites* during the early stages of an invasion.

Hand Harvesting

Mode of action: Plants are removed by hand; removal must include rhizomes, which is no small task. Expect considerable digging, followed by separation of rhizomes from soil and proper disposal, preferably by burning.

Probability of successful control: Where density is very low (literally just one plant or a few plants close together), this approach has merit. However, incomplete collection of rhizomes may allow regrowth, and improper separation from soil could allow spread of this plant. At greater areas of coverage or where standing water is present, this approach becomes ineffective and impractical.

Potential non-target impacts: Limited, unless disturbed soil is placed in a manner that spreads the *Phragmites*. Temporary turbidity increases are expected in an aquatic setting.

Permitting needs: May be approved without an Order of Conditions under the Wetlands Protection Act through a Negative Determination of Applicability (WPA regulations deemed not to apply, as only the invasive plant is removed), but this is rarely attempted.

Monitoring needs: Critical to delineate target area, including the depth to which removal must occur. Follow up monitoring is important to determine effectiveness and the need for further control.

Range of costs: Often done by volunteers, but estimates from professional operations range from $50 to $200 per plant.

Rotovating or Disking

Mode of action: Plants are torn apart by tines of the rotivator or the blade of the disking machine, with a focus on disrupting rhizomes. The approach is analogous to rototilling a garden, and must be very thorough to reduce *Phragmites* growth.

Probability of successful control: A very thorough job must be done to destroy the rhizomes and prevent regrowth, which is often observed unless rhizome-bearing soil is removed. This approach is likely to spread *Phragmites* in a lake environment, and is not recommended in most cases as a primary control means.

Potential non-target impacts: Disrupts everything in the target area, killing plants and most sessile animals. Temporary turbidity increases are expected in the aquatic environment.

Permitting needs: Requires an Order of Conditions under the Wetlands Protection Act.

Monitoring needs: Critical to determine non-target resources in the target area and assess impact to associated populations. Essential to monitor and control rhizome fragment dispersal during rotovation or disking.

Range of costs: On the order of $10,000 per acre.

Hydroraking and Dredging

Mode of action: Plants, roots and associated sediment are removed; plants may need to be cut first for hydraulic dredging; conventional excavation or hydroraking requires no cutting. Removal must include rhizomes to be effective.

Probability of successful control: If all parts of the plant are removed, *Phragmites* can be eliminated. Cost and access to infested areas may limit applicability, however. Hydroraking has been successfully used for infestations in standing water, with fragment control and only limited sediment removal. Multiple years of *Phragmites* control has been obtained in MA (ie Long Pond, Nantucket and Butler Pond, Quincy) with hydroraking. Herbicide treatment preceding hydroraking, such as was performed at Butler Pond, may reduce plant biomass to be removed and increase raking efficacy. Conventional excavation has been successfully applied under dry conditions, with considerably more soil removal. Proper disposal is critical to avoiding the spread of *Phragmites*, and can be a major constraint.

Potential non-target impacts: Any plants and sessile fauna in the target area are likely to be killed. Disposal impacts are possible, including regrowth of *Phragmites* where the sediment is deposited. Substantial turbidity may be generated during the removal operation, but is usually temporary and can be limited by curtain placement.

Permitting needs: Requires an Order of Conditions under the Wetlands Protection Act and possibly other approvals depending upon the amount and quality of sediment to be removed. Permitting of hydroraking may involve only an Order of Conditions under the Wetlands Protection Act. Much information is needed to plan and permit dredging, even on a small scale, and permitting may involve a Chapter 91 Waterways License, Section 404 approval and a Section 401 permit.

Monitoring needs: Critical to delineate target area, including the depth to which removal must occur. Follow up monitoring is important to determine effectiveness.

Range of costs: For small areas, a cost of $50 to $100 per cubic yard of sediment removed can be expected, but the cost of planning, testing, permitting and disposal is likely to be much more than the cost of actual removal on a small scale. Hydroraking typically costs $6000 to $10,000 per acre, while dredging is likely to cost at least $50,000 per acre.

Flooding

Mode of action: Raising the water level to a depth of about three feet above the base of the stem for about four months has been observed to eliminate *Phragmites* in some cases. This process can be aided by cutting the stems first. It may be necessary, however, to flood to a depth of more than 5 feet above the stem base.

Probability of successful control: Where extended duration flooding can be tolerated, increasing the water level may control *Phragmites*, but such situations are rare in the lake environment, and growths of *Phragmites* have been observed to survive in up to 5 ft of water in Massachusetts.

Potential non-target impacts: Flooding can negatively affect non-target plant populations, some fauna, and human property. Consequently, this approach is unlikely to be attempted in typical Massachusetts lakes settings.

Permitting needs: Requires an Order of Conditions under the Wetlands Protection Act, usually entailing a detailed review of the potential for non-target impacts. May also require review under the Federal Emergency Management Act as pertains to flood impacts.

Monitoring needs: Pre- and post-implementation surveys are likely to be required, as well as careful tracking of water levels.

Range of costs: Where flooding is facilitated by existing structures, costs are limited to permitting and monitoring, with potential for mitigation costs if impacts are unacceptable.

Cutting

Mode of action: Plants are physically cut just above the sediment level repeatedly over the growing season. Cut stems and associated leaves must be removed and disposed of in a manner that prevents spread of the plant, as cut stems can sprout root systems.

Probability of successful control: Where cutting occurs before late July, some restriction of food storage in the root system can be achieved. It may take several years to gain control in this manner, and the technique fails about as often as it succeeds. However, this approach can be a valuable augmentation to other controls, especially herbicide application, Dead stems can remain in place for several years, and removal enhances assessment and treatment of any regrowth. Removal of *Phragmites* biomass also facilitates the growth of other plant species. In brackish or saline areas, cut *Phragmites* may be washed out and removed through tidal flushing

Potential non-target impacts: Limited, unless other species are also cut and removed.

Permitting needs: May be approved without an Order of Conditions under the Wetlands Protection Act through a Negative Determination of Applicability (WPA regulations deemed not to apply, as long as only the invasive plant is removed).

Monitoring needs: Critical to delineate target area and to determine what other species are present. Follow up monitoring is important to determine effectiveness and the need for further control.

Range of costs: Typically $1,000 to $2,000 per acre per cutting, but can be done by volunteers for small stands.

Controlled Burning

Mode of action: Plants are consumed by flame in prescribed burn areas. Intense heat may affect shallower rhizomes as well.

Probability of successful control: Complete control is rarely achieved, as some rhizomes invariably survive. Burning does clear areas of old *Phragmites* litter, however, allowing other species to colonize the open area. This option can be a valuable supplement to herbicide treatment.

Potential non-target impacts: Other plants will be burned as well, and may have less ability than *Phragmites* to recolonize. Risk of fire spreading to non-target areas and human habitation areas is a substantial concern. Turbidity increases are expected in nearby waters after burning.

Permitting needs: Requires an Order of Conditions under the Wetlands Protection Act and other permit requirements for burning.

Monitoring needs: Critical to delineate target area and provide means for controlling the spread of fire. Post-burn monitoring to track regrowth is needed.

Range of costs: Highly variable and uncertain, but expected to be on the order of $1000 to $2000 per acre.

Cover Options

Mode of action: The cut area is covered by plastic or mulch, preventing photosynthesis and gas exchange.

Probability of successful control: Where high temperatures are generated under the cover, rhizome die-off has been observed. Experience is limited, however, and variability in results is high. This approach does not appear applicable to lake habitats or other areas of standing water. It may be amendable to application by volunteers for control of small stands after cutting.

Potential non-target impacts: All vegetation and any fauna trapped under the cover are likely to be killed.

Permitting needs: Requires an Order of Conditions under the Wetlands Protection Act.

Monitoring needs: Monitoring during post-cover period is very important to determining success and the need for any follow up. Monitoring of vegetative recovery is likely to be required.

Range of costs: Typically on the order of $1000 to $2000 per acre where plants are cut and mulched in place. Cost may be considerably higher (up to $10,000 per acre) where a synthetic cover is placed by hired contractors

Application of Glyphosate

Mode of action: This systemic herbicide is absorbed by vegetative tissues and translocated throughout the plant with proper application timing, killing susceptible plants. Uptake is fairly rapid, limiting necessary exposure time, but a surfactant and/or sticking agent may be needed to maximize exposure. For larger contiguous stands, broadcast spraying utilizing ammphibious track mounted vehicles or airboats are commonly employed. Typically the boat or vehicle is fitted with an elevated spray platform, in order that the applicator be positioned above the tall *Phragmites* growth for improved visibility and thorough spray coverage. In sparse *Phragmites* growths closely surrounded by valuable native vegetation or state protected species, glyphosate can be hand-wicked or wiped on individual plants or carefully applied with low pressure, back-pack sprayers. Where *Phragmites* growth is extremely sparse, glyphosate may even be injected into individual stems or dripped into cut stems.

Probability of successful control: *Phragmites* is highly susceptible to glyphosate later in the growing season (mid/late August through early/mid-October), when food reserves are being translocated to the root system. Not all plants may be in this stage at once, however, and successful application to all plants in a dense stand is nearly impossible. This approach is most successful with injection or drip application to individual stems, which is restricted to sparse growths but entirely appropriate for new invasions. For spray applications, it is best to cut dead vegetation during the winter after treatment, with follow-up application of glyphosate the following late summer or autumn to surviving plants. Poor access for vehicular cutting machinery and the additional cost may not always justify the need for follow-up cutting, especially on larger sites.

Potential non-target impacts: Many other plants are susceptible to glyphosate, although carefully targeted application may be sufficient to minimize impacts to non-target plants more than a few feet away from the *Phragmites* stand. Fauna are unaffected at typical doses, and there is minimal threat to human health.

Permitting needs: Requires an Order of Conditions under the Wetlands Protection Act and a License to Apply Chemicals from the DEP.

Monitoring needs: Normally the plant community is monitored before and after treatment, including any non-target peripheral vegetation.

Range of costs: Typically $500 to $1000 per acre for spray application, considerably more for individual injection, but this would occur only for scattered plants in a new infestation.

Application of Triclopyr

Mode of action: This systemic herbicide is absorbed by vegetative tissues and translocated throughout the plant, inhibiting synthesis of key enzymes while stimulating growth, resulting in plant death. Uptake is rapid and exposure time can be less than one day. Application techniques are similar to those described above for glyphosate.

Probability of successful control: There is limited experience with this herbicide for *Phragmites* control anywhere, and it was approved for use in Massachusetts in November of 2004. Triclopyr is supposed to target dicotyledonous plants, while *Phragmites* is a monocotyledon. Anectodal information from field trials performed during 2004 in CT, however, indicate that triclopyr may have some efficacy on *Phragmites*, including immature or cut plants. More information and experimentation is needed. .

Potential non-target impacts: Dicotyledonous plants are susceptible to triclopyr, while most monocotyledonous species are minimally affected at label doses. Impacts to fauna or humans have not been observed at applied doses of the aquatic formulation.

Permitting needs: Requires an Order of Conditions under the Wetlands Protection Act and a License to Apply Chemicals from the DEP.

Monitoring needs: Normally the plant community is monitored before and after treatment.

Range of costs: Costs are expected to range from $600 to $1,100 per acre, but there have been too few treatments to date to generalize.

Application of Imazapyr

Mode of action: This systemic herbicide is absorbed by vegetative tissues and translocated throughout the plant, inhibiting the synthesis amino acids necessary for building proteins and causing death in plants by structural failure. It does not require active movement of food reserves to the rhizomes to reach this critical area of control, allowing for application earlier in the growing season and possible follow up treatment within the same growing season. It also requires a lower dose than glyphosate-based herbicides, measured as active ingredient. Plot treatments performed in CT in 2004 suggest good efficacy and the potential for treating immature plants or *Phragmites* regrowth.

Probability of successful control: Applied at 64 to 96 ounces per acre with an anionic surfactant added, 80 to 95% removal of *Phragmites* has been observed in tests conducted in five states with imazapyr.

Potential non-target impacts: Susceptibility of other plants to imazapyr varies, but localized application and avoiding spray drift or runoff can limit non-target impacts. It has limited potential toxicity to fauna or humans at typical application rates. Re-planting areas treated with Imazapyr may require an extended waiting time, due to its extended activity period.

Permitting needs: Would require an Order of Conditions under the Wetlands Protection Act and a License to Apply Chemicals from the DEP, but this herbicide was not registered for use in Massachusetts as of June 2005.

Monitoring needs: Normally the plant community is monitored before and after treatment. Other requirements are uncertain, as this herbicide is not yet approved for use in Massachusetts.

Range of costs: Costs are expected to be comparable to triclopyr.

Other Options

Other management options are not listed for one or more of the following reasons:

- impractical on a small scale
- not able to control *Phragmites*
- could cause *Phragmites* to spread
- not approved for use in Massachusetts

In particular, there are no current biological controls considered specific and effective. Additionally, most of the methods described above have the potential to spread the plant and most methods are unlikely to eradicate it. The probability of eradication is definitely increased by early action, when only a limited number of plants must be attacked and before an extensive rhizome system has been developed. Eradication potential is also enhanced by the combination of two or more methods, with repeated application.

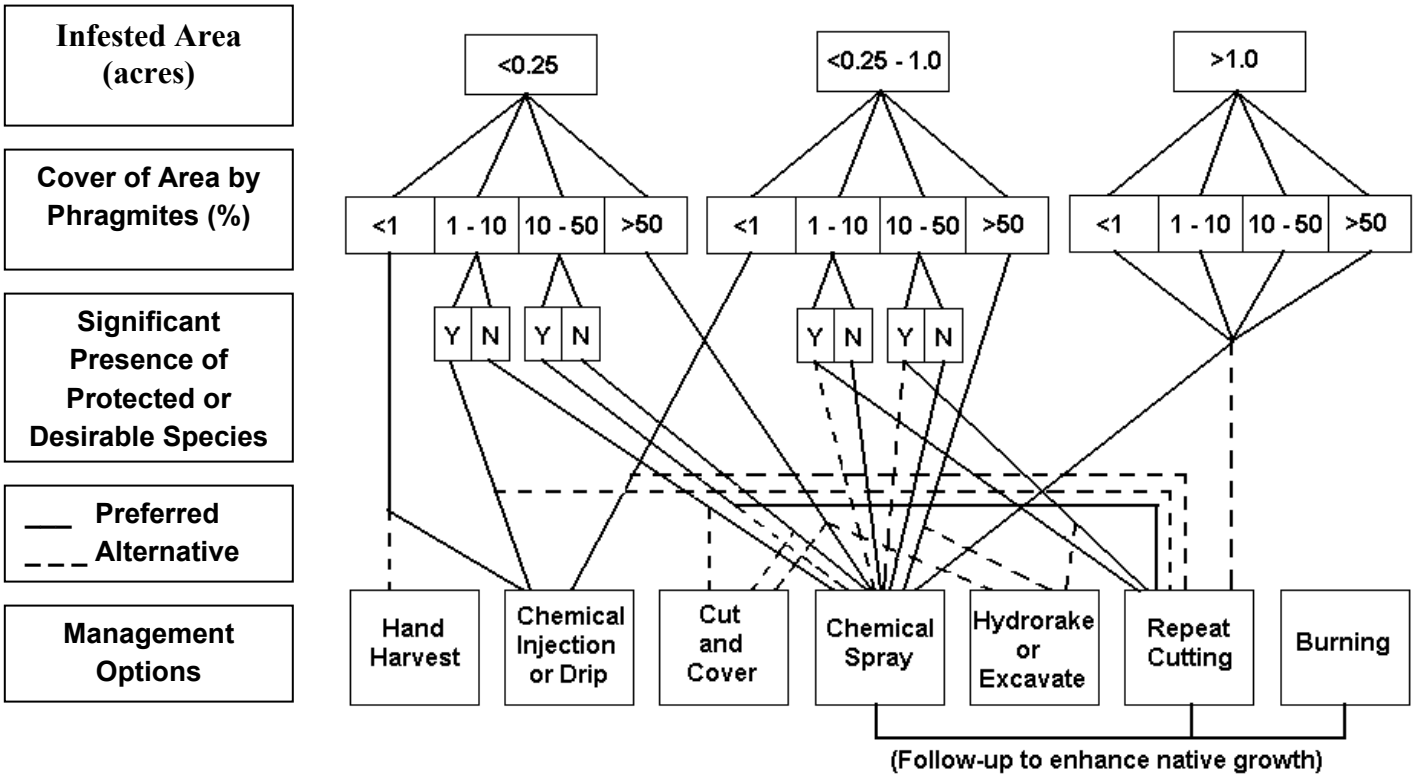
Recommended Options for Early Eradication

The most recommended early actions are the herbicides glyphosate and imazapyr, although the latter is not yet registered for use in Massachusetts. Applied to individual plants comprising early infestations, these herbicides have a high potential to eliminate the entire *Phragmites* plant and could lead to eradication. Hand harvesting of the entire plant, including the root system, is practical only on the smallest of scales, and then with great difficulty in the lake environment. Dredging may be possible, but is prohibitively expensive and may be difficult to permit. Hydroraking is more commonly practiced in standing water than dredging, and can be effective if done very thoroughly and where a fragment collection system is applied. Cutting and mulching approaches appear well suited as precursors or supplements to other techniques, most notably herbicide use, but have limited potential for success by themselves and may not be particularly useful in a lake setting. Burning and flooding have limited potential to eradicate *Phragmites* and pose definite threats to the environment and humans, creating limited opportunity for effective application. However, burning *Phragmites* biomass collected by other means, such as cutting or hydroraking, is a preferred method of disposal. Rotovating and disking have a poor track record of success in the lake environment. Experience with triclopyr is insufficient to make any definitive recommendation at this time.

Deciding Which Technique to Apply

The following decision tree is provided as an aid to evaluating control options. Thresholds for application are given as general guidelines, not rigid rules. Individual circumstances may affect the choice of approach and outcome. The use of this decision tree is not a substitute for a site specific evaluation performed by an experienced lake management professional familiar with invasive plant management techniques. Follow up monitoring is considered essential, and follow up control after an initial application is considered likely to be necessary.

Figure 3. Decision Tree for Control of Common Reed (*Phragmites australis*)



Notes: This decision tree represents a guideline, not a set of absolute choices. For treatment areas >1 acre where significant other species are present and another option is desired, subdivide area and reconsider based on the above decision tree. Chemical spray has been restricted to glyphosate in MA; triclopyr is now an option and imazapyr may be a future option. Cover options generally practiced on land only, not in lakes.

Control of Established Infestations

This document deals mainly with early invasion and the new infestations that result, but it is important to note that older infestations, where the *Phragmites* has become dominant over a larger area, can and should be addressed if continued invasion in the region is to be curtailed. The techniques reviewed above remain the primary suite of options, and the preferred order is not appreciably different. Unfortunately, the effectiveness of most techniques is reduced at larger scales, as a function of the increased probability of survival of some rhizomes. Repeated application of any technique, over a period of two years and more likely for five or more years, is to be expected.

Prevention of Re-Infestation

Once an invasion has been repulsed through any of the above methods, it should be apparent that the lake is susceptible to *Phragmites*. As the cost of prevention is much less than the cost of rehabilitation of an infested lake, steps should be taken to reduce the risk of re-introduction of *Phragmites*. As *Phragmites* most often comes from contaminated soils, control activity is encouraged on a watershed, multi-municipal or regional level. Use of *Phragmites* as an ornamental plant should also be discouraged. Seed dispersal will be very hard to control, with the best defense associated with limiting existing infestations in the area. Working across political boundaries with limited funding is difficult, but represents the most sweeping opportunity to limit future invasions. Alternatively, and almost essential as a back-up, steps need to be taken at the individual lake to reduce the risk of re-introduction. Key steps may include:

- Education through the lake association or town for shoreline property owners. Emphasize avoiding the placement of fill in or near the lake and avoiding use of *Phragmites* as an ornamental plant. Education should also cover how to identify *Phragmites* and who to contact if it is found.
- Monitoring of the plant community to detect *Phragmites*, with a focus on boat ramps and inlets.

Summary

1. Common Reed, *Phragmites australis*, is a large perennial rhizomatous grass, reaching a height of up to 20 ft. Its long, strong stems, long, lanceolate leaves, and tassels of flowers/seeds make it distinctive.
2. *Phragmites* is found on most continents and has been in the USA for many years. However, invasive populations appear to be a European strain, with invasions increasing dramatically over the last several decades in Massachusetts.
3. *Phragmites* appears to be dispersed mainly in rhizome-bearing soil during construction activities, with some rhizome transport by animals possible. It becomes locally abundant by rhizome expansion. Some transport as ornamental plants also occurs. Seeds are of limited importance in dispersal, but may cause new infestations via transport by wind or birds.
4. *Phragmites* creates tall, dense stands of vegetation that shade out other plant species. At high density it provides poor habitat for water-dependent fauna and eliminates recreational uses.
5. *Phragmites* is easily recognized once it forms dense stands, but may be less obvious as individual or scattered plants around a lake periphery. The tassels at the top of the plant are

distinctive, and plants can be found emerging from water up to about five feet deep. Confirm identification through contact with the designated DCR representative.

6. When detected, map *Phragmites* coverage with notation of density as beds, sparsely scattered plants, or solitary stems. Record all other species present and their relative abundance. Map an area that extends 50 to 100 ft outside the infested area. Include information on water depth and sediment type, and determine the depth at which rhizomes are growing if possible.
7. Educate lake users by whatever means practical about the threat and presence of *Phragmites*. Emphasize the role of disturbed sediments in *Phragmites* transport and discourage use as an ornamental plant.
8. There is little benefit to quarantining the lake or infested areas until removal can be attempted, although discouraging access to infested areas will raise awareness. Barriers to minimize rhizome spread may be appropriate where rapid response might be delayed.
9. *Phragmites* is extremely difficult to eradicate once it has developed a rhizome system, as that rhizome system may be far below the sediment surface and can start new plants when cut. Unless rhizomes can be removed by an expensive dredging operation or physically disturbed to the point where new shoots do not develop from them, they must either be chemically killed or starved to the point where food reserves are depleted, usually by timely and repeated cutting.
10. Eradication of *Phragmites* detected early in an invasion can best be accomplished with a glyphosate-based herbicide applied to individual plants. Imazapyr application may be equally or more effective, if and when this herbicide is approved for use in Massachusetts. Triclopyr may be effective on younger or cut plants, and is now approved for use in Massachusetts, but there is only a very limited track record for this herbicide.
11. Hand harvesting may be possible where the invasion involves only a few plants. Cutting may be an aid to herbicide treatments. Covering following cutting is only practical for very small sites that have no standing water at any time throughout the year. Hydroraking can be effective if done thoroughly and with a fragment control system in place. Long-term benefit may be extended if herbicide treatment precedes the raking process. Burning is a preferred disposal means for cut or raked *Phragmites* biomass. Other techniques may have some utility under specific circumstances, but potentially detrimental aspects of each method limit applicability in lake settings.
12. Options to combat later stage invasions are not appreciably different than those reviewed for applicability to new invasions, and herbicide application is the most effective control over the greatest range of circumstances. Additional techniques may enhance control by herbicides, but effectiveness is usually reduced at larger scales, and repeated control effort is usually necessary.

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