RAPID RESPONSE PLAN FOR FANWORT (*Cabomba caroliniana*) IN MASSACHUSETTS

Prepared for the
Massachusetts Department of
Conservation and Recreation
251 Causeway Street, Suite 700
Boston, MA 02114-2104

dcr

Prepared by
ENSR
2 Technology Park Drive
Westford, MA 01886

ENSR INTERNATIONAL

June 2005

RAPID RESPONSE PLAN FOR FANWORT (*Cabomba caroliniana)* IN MASSACHUSETTS

Species Taxonomy and Identification

Fanwort, *Cabomba caroliniana* is a submerged perennial aquatic plant. Fanwort is fully submerged except for occasional floating leaves when the plant grows to the waters surface. The vertical shoots or stems of fanwort are actually extensions of the fragile, horizontal rhizomes. The stems are branched, can reach a length of 10 meters, and are covered with white or reddish-brown hairs. Submerged leaves are finely divided and arranged around the stem in pairs. The submerged leaves are about 5 centimeters across and fan-shaped. Floating leaves are small, diamond-shaped, and arranged alternately on flowering branches. Flowers are solitary, less than 2 cm across, float on the surface of the water, and are usually white (sometimes yellow or pink). The fruit is a leathery, indehiscent, 3-seeded follicle (Crow and Hellquist 2000).

According to Crow and Hellquist 2000, the following taxonomic characteristics are used to identify Cabomba:

- Submersed leaves opposite, dissected into linear segments; floating leaves small, insconspicuous, oblong to linear-elliptic, peltate, less than 2 cm long, subtending flowers; submersed portions of the plants lacking mucilaginous coating; flowers white to pinkish; stamens 3-6.

Figure 1. A photograph and diagram of fanwort. The photo was taken from http://www.adkinvasives.com and the diagram was taken from www.fish.washington.edu.

Species Origin and Geography

Fanwort is native to the subtropic-temperate regions of eastern North and South America. Today, it is naturalized in the southeastern United States, and has been introduced throughout the world via the aquarium trade (Orgaard 1991). Within the U.S. it ranges from Florida to Texas in the south, up the east coast to New Hampshire and west to Oklahoma. In the western U.S. it is present in Washington and Oregon (Figure 2). Fanwort is highly capable of transport to new water bodies due to vegetative growth and reproduction. Plant fragments transported to new waterbodies can become rooted and form new shoots. Plant fragments are easily transported to new waterbodies by boats, trailers, fishing gear, wind, animals and currents. In one study, Minnesota authorities found aquatic plants on 23% of all boats inspected (Bratager et al. 1996). In Massachusetts, is it largely a plant of the eastern coastal plain and the granite belt bordering New Hampshire, both areas with acidic waters, and is absent from the more alkaline Berkshire lakes. It often co-occurs and competes with variable watermilfoil (*Myriophyllum heterophyllum*) another invasive plant.

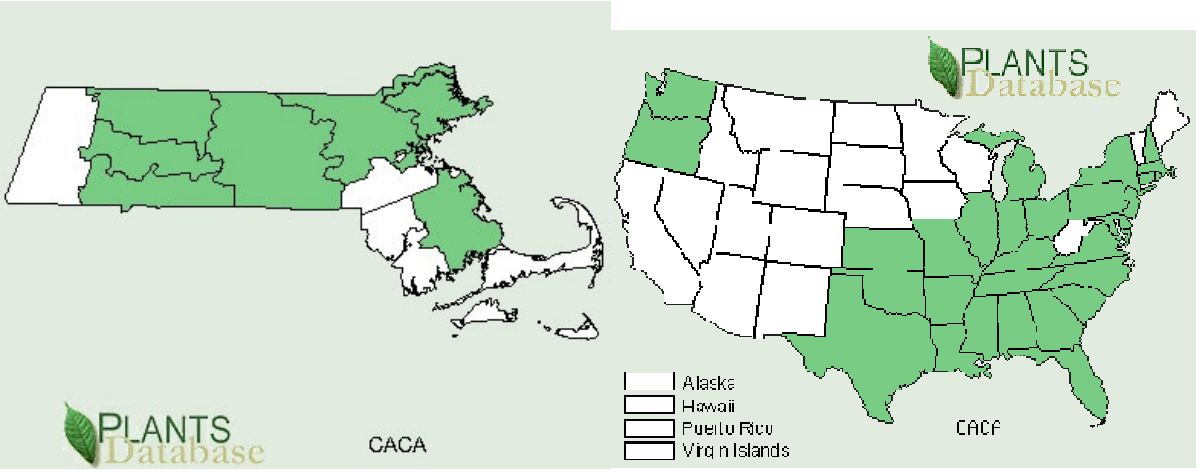


Figure 2. Map indicating the present range of *Cabomba caroliniana* in the United States, and Massachusetts. This map was taken from The USDA Plant Data Base. http://plants.usda.gov/cgi_bin/topics.cgi

Species Ecology

Fanwort grows rooted in the mud of stagnant to slow flowing water, and is found in streams, small rivers, lakes, ponds, reservoirs, sloughs, ditches and canals. Fanwort can grow on a range of substrates, but prefers organic silts, and experiences reduced growth on harder substrates. Fanwort grows well in waters with low pH; the stems begin to defoliate above pH 8. Growth is also hindered in waters with high calcium levels, coincident with high pH in Massachusetts. While fanwort may survive temperatures as low as the freezing point for water, it prefers warm temperatures ranging from 13-27°C. Fanwort is sensitive to drying, and requires permanent water. Typically it grows in less than 10 feet of water, but can grow at depths of up to 30 ft. Fanwort reproduces primarily through plant fragmentation and rhizomes, but it produces flowers and seeds that may have a limited role in dispersal.

Detection of Invasion

As fanwort enters lakes with flow, boats and birds in the vast majority of cases, the logical places to look first are the mouths of tributaries, boat ramps and areas of higher bird concentrations. While mature fanwort growths may reach the surface and form a canopy, new infestations may be less obvious and often require underwater examination for early detection. Although fanwort can grow in water as deep as 30 ft, it typically gets its start in shallow waters (<10 ft deep) and is likely to be visible from a boat with a viewing tube or by snorkeling. Use of an underwater video system (Aqua-Vu or equivalent) can be very helpful in scanning large areas of variable depth, but is more expensive and not usually necessary for detecting early invasion.

Sources may not be obvious, but the pattern of occurrence observed during early detection may provide useful clues. Appearance near boat ramps suggests boats as vectors, while appearance in more remote areas with no direct access or inflows suggests birds as the source. Where growths are detected near the mouth of a tributary, it would be appropriate to check the next upstream waterbody or the stream bed itself if conditions are suitable for rooted plant growth.

There are multiple methods of plant survey, and no truly standardized technique. The object is to be as thorough as time and trained manpower allow, to maximize detection probability. To detect a suspected invasion, or simply to monitor for possible invasion, consider the following steps:

1. Acquire a suitable map of the waterbody, showing shoreline features and reference points, and preferably with water depth contours.
2. Use the taxonomic information supplied here, or supplementary information from taxonomic guides, plant keys, or herbarium sheets to identify fanwort.
3. As fanwort overwinters in a vegetative state, it can be surveyed any time, but is most easily detected and identified in spring as one of the earliest plants to begin growth or in late summer when it may reach the surface.
4. Ideally, space transects around the waterbody, extending from shore to the end of plant growth, with one transect per defined shoreline segment, determining transect location with GPS or readily identified shoreline features. Segments should be of roughly equal length, but this can be based on actual shoreline, straight distance across the water, land use or other features of concern or interest, or encompassed waterbody area. Be sure to cover all boat launch, swimming, inlet, bird congregation, key habitat and intake areas, and any other key access points.
5. Priority can be given to transects of key concern, either based on likely invasion points (access points) or potentially threatened resources (intakes, swimming areas, key habitat) if the number of transects is too great for the manpower and time resources available, but recognize the limitations this will impose on invasion detection.
6. Using a boat with a viewing tube or underwater videocamera, or employing snorkeling or SCUBA gear, examine the plant community along transects between the shore and the maximum depth of plant growth (typically <20 ft, usually <10 ft). Note presence/absence of fanwort and extent of coverage and density where fanwort is encountered. Record observations for 2 ft water depth intervals, with each observation representing either a defined area within the depth range or the

length of the transect between depth intervals (typically 0-2 ft, 2-4 ft, 4-6 ft, and so on). GPS is particularly useful for both transect and point location for future reference.

7. Tabulate all data in a manner that facilitates future comparisons, normally in a spreadsheet or GIS format. Evaluate presence of any fanwort, extent of coverage and density, and pattern of occurrence. Map the distribution of fanwort in the waterbody for visual reference.
8. Repeat the survey at least once every 3 years (about the time for an invasion to have a detectable impact), and preferably every year to allow the earliest possible detection.

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 fanwort; root systems are less critical for this species, but it is helpful to know that the whole stem has been harvested, and removal of the root crown is necessary for plant control. Place the specimen in a clear container with water for easy viewing (clear 2-L soda bottles without labels work well); keep chilled. Alternatively, 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).
2. Contact the DCR representative at 617-626-1411 or 617-626-1395 and inform him/her that a suspected occurrence of fanwort 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 fanwort 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

Gaining effective control of fanwort depends on detecting all growths, as this species can expand rapidly. The initial discovery may be made during a routine mapping exercise, but mapping approaches suitable for overall plant assemblage characterization (e.g., point intercepts on a grid or transects) may not be appropriate for thorough coverage of recent invasions. Where a growth is detected, it is likely that expansion in the first growing season will be by root crowns, so viewing each discovered growth in concentric circles moving outward from the apparent center will best facilitate mapping of the growth. Detection of additional growths is best accomplished by a thorough visual inspection of the newly infested area, either using tightly spaced transects radiating out from the first discovered growth or focused in the direction of likely current or wind transport.

If the waterbody is large, effort may have to be limited to the most likely locations for invasion. In this regard, examination of any existing plant maps may be helpful. Look for areas of suitable depth (<30 ft, with emphasis on areas 2-10 ft deep) and substrate (moderately organic and silty), known plant and bottom disturbance (marinas, boating lanes, windswept shallows), and plant assemblages of lower density and/or lesser canopy formation.

Evaluation of recent fanwort growths should focus on extent of coverage and degree of dominance. Biovolume or biomass measures are useful but time consuming and are not critical to combating new infestations. Careful stem counts are helpful in assessing the efficacy of possible controls, but are also time consuming. An estimate of stems per unit area and the area covered is more valuable in assessing potential controls for new growths. With regard to dominance, it is important to note other species present, as the presence of protected species and the relative abundance of seed producers vs. vegetative propagators are important to planning management actions. A list of plant species with an approximation of the percent of the community each represents is appropriate.

Assessing the rate of expansion may not be necessary if the invasion is detected early and prompt control actions are implemented. However, where fanwort has been present for more than a single growing season, information on the rate of expansion may be helpful in planning a control strategy and in garnering support for rapid action. Isolated plants are likely to signal the first year of growth, while scattered plants are likely to represent the second year of growth and well established beds will normally be more than two growing seasons old.

Useful steps in quantifying the invasion include:

1. Use the data generated by the transect method in the section on Detection of Invasion to get a first impression of the extent of invasion, preferably in mapped format. Where fanwort is discovered in multiple locations, look for spatial patterns that suggest either transport from the earliest infestation or invasion from multiple sources.
2. If a discovered growth is in a definable cove, examine the entire cove, or at least that portion with a water depth <20 ft.
3. If a discovered growth is associated with a boat ramp, check a suitable area (typically 1-2 acres) associated with that ramp, and check other ramps if present.

4. Where growths occur near a tributary mouth, check area maps for upstream ponds or impoundments on the offending stream and any other tributary and investigate where possible fanwort sources seem most likely.
5. When the new growth appears associated with areas of bird congregation, check all such areas in the waterbody.
6. In all cases, note which areas have established beds vs. scattered plants vs. a single plant or just a few stems.
7. Identify all other plants in association with fanwort growths, to the limit of areas likely to be targeted for control. Follow the protocols for species confirmation where specimens of unknown identity are encountered, paying particular attention to possible protected species or other invasive species.

Species Threat Evaluation

Threats associated with fanwort are the same as those associated with variable watermilfoil (*Myriophyllum heterophyllum*), which occurs in the same habitats and occupies a similar niche. New shoots grow rapidly in the spring and branch repeatedly as they approach the surface of the water. Leaf canopies created by fast growing shoots shade out the germinating seeds or vegetative propagules of understory plants, eventually replacing the native plants and reducing species diversity. Dense and extensive growths of fanwort can affect water quality, including oxygen, pH and organic content. Monospecific stands of fanwort can negatively affect wildlife, and can alter the predator/prey relationship among fish as well as the overall ecology of an aquatic ecosystem. Human uses can be severely impacted by fanwort.

Dense mats of fanwort limit human uses of the waterbody, as dense mats choke channels, clog water intakes, and restrict aquatic activities such as fishing, swimming and boating. Limitations on water uses can negatively impact real estate values (Christie and Varney 2003). The mass of large mats can cause flooding in some waterbodies (www.ecy.wa.gov 2004), and increase sedimentation by trapping detritus (Adams and Prentki 1982).

Oxygen levels can be reduced underneath large fanwort growths due to a decrease in wind mixing, and decaying plants decrease oxygen and increase the nutrient load to the waterbody (Honnell et al. 1992; Engel 1995; www.ecy.wa.gov 2004). High levels of photosynthesis elevate pH and day-night variation causes potentially deleterious pH fluctuations at high fanwort biomass. Decay of large plant masses puts elevated levels of dissolved and suspended organic matter into the water column.

Aquatic macrophytes can provide food, shelter and spawning habitat for a wide variety of fishes (Lillie and Bud 1992). Intermediate densities of aquatic macrophytes, including fanwort, may enhance fish diversity, feeding, growth and reproduction (Dibble et al. 1996). Yet fanwort tends to replace native macrophytes in areas where it is introduced, creating food shortages for fishes (Engel 1995). Dense beds of fanwort can also impede predation, shelter panfishes, and cover spawning areas, leading to potential decreases in sportfish abundance (Engel 1995). Large piscivorous fishes spend more time foraging for prey as density increases, thus reducing growth rates (Savino and Stein 1982). Fanwort beds are believed to decrease fish abundance compared to native vegetation,

and Keast (1983) found that beds of native vegetation supported up to four times as many fish, and up to seven times as many macroinvertebrates as some invasive species. Decreases in macroinvertebrate abundance are expected, based on work on Eurasian milfoil coverage (Cheruvelil et al. 2001). The depletion of oxygen in waterbodies with dense fanwort coverage can also result in fish avoidance, and in extreme cases could cause fish kills (Holland and Huston 1984, Lillie and Bud 1992, Engel 1995).

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 fanwort (especially boats, birds, flow and currents). Fanwort grows mostly on organic substrates, sometimes only thinly covering sandy sediment. Rocky to gravelly substrates support much lesser densities of fanwort. The depth range for fanwort is from shore to about 30 ft, but in the vast majority of cases, nuisance growths are observed only to 10 ft of water depth. Boats and birds can actively transport fanwort within a waterbody, but fanwort fragments or dislodged plants also drift with currents.

Potential spread outside the waterbody is mainly a function of surface outflow, birds and human activities. Overflow can carry viable fragments downstream to additional waterbodies. Birds may transport fragments, and may also carry seeds, either externally or in their digestive tract. Seeds are considered to be a limited source of new plants, but even at low viability, this is a potentially important means of invasion. Transport by humans is a known threat, with movement of fragments in or on boats and trailers well documented (Johnstone et al. 1985, Bratager et al. 1996).

All of 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 fanwort 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 <15 ft)?
2. What is the potential for dense bed formation (estimate as the area with fine sediments with high organic content, usually in water <10 ft deep)?
3. What is the potential for rapid (<3 years) spread of fanwort (estimate as the common area from #1 and #2 above and not densely covered by native plants)?
4. What is the potential strength of vectors of internal fanwort spread (boat traffic, flow, currents, open expanses vs. isolated coves)?
5. What is the potential strength of vectors of external fanwort spread (trailered day-use boats, daily or seasonally mobile bird populations, outlets without screening)?
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 fanwort has been confirmed, the town(s) in which the waterbody 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 any active lake association, shoreline property owners, boaters, anglers, swimmers, birdwatchers, and water suppliers. 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. Posting the waterbody at access points is perhaps the most effective approach, as it is the actual users that should be informed and warned to avoid spreading fanwort.

It is desirable to post access points with warning signs even before an invasion, displaying a picture or drawing of fanwort and asking waterbody users to be on the lookout for this invasive plant. Users,

particularly boaters, should be asked to inspect their boats and any trailers prior to launching, and to remove any discovered plants with proper disposal in a manner that prevents the plant from reaching the waterbody. A local contact (name and phone number) for notification should be given, typically either a representative of the lake association or the town's Conservation Commission, or both. Users should be advised to mark the location where the plant was observed if at all possible, but not to pull it out unless they can get the whole plant, including the roots. As most users will not be diving or snorkeling, immediate, effective hand harvesting is probably not a realistic expectation.

After an invasion has been discovered, access points should be posted with a warning to users to avoid any action that could spread fanwort. Again, a picture or drawing of fanwort should be provided, and any known locations of the plant should be shown on a map of the waterbody. Users should be asked to notify a local contact if fanwort is found in other areas not shown on the map, and to avoid motorized boating in areas with fanwort. All boats, trailers, fishing equipment, bait buckets or other possible means of transport should be inspected and cleaned prior to leaving the waterbody.

Responsibility for control of fanwort 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 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 waterbody (particularly if protected species are known from the waterbody). Other agencies and approval programs may apply, depending upon the features of the waterbody (naturally large enough to be a statutory Great Pond), the location of the waterbody (e.g., in an Area of Critical Environmental Concern), or the uses of the waterbody (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 fanwort. 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 fanwort has been confirmed:

1. The DCR contact responsible for confirming the fanwort 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 fanwort 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 fanwort 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 fanwort and a written notice that this invasive plant has been found in the waterbody.
2. Suggested language is as follows: Warning. Fanwort (*Cabomba caroliniana*) 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 all equipment brought to this waterbody is clean before leaving.
3. Include a contact name and phone number on all postings.

Quarantine Options

Both natural processes and human activities can spread fanwort, both within an invaded waterbody and to other area lakes. Minimizing the spread of fanwort may require some form of quarantine. Making the waterbody off limits to all users is an extreme action not typically justified for new growths that are likely to be limited in areal coverage. However, keeping people out of infested areas may be a valid option. This may be done by signage, buoys, or an actual sequestration curtain, with cost increasing dramatically in the listed progression.

Where the invasion is occurring at a boat ramp, closure of the ramp may be justified; this will both limit the spread of fanwort and generate public awareness of the problem and a desire to take action against the fanwort. A town may take such an action where the public welfare is deemed to be at stake for a boat ramp owned by the town, but it is not clear that such action is legal for private boat ramps, and towns do not have the authority to close ramps owned by the Commonwealth. Consult with private owners or the Public Access Board of Massachusetts when considering closure of a ramp not owned by the town.

Where the invasion is occurring in a swimming area, closure of that area will have much the same effect and limitations as for boat ramps. If the fanwort growths are localized, it may be possible to partition off the infested area by moving the buoyed ropes that usually delimit swimming areas. If the growths are extensive, it may be appropriate to close the swimming area on the basis of public safety; people can get tangled in dense macrophyte infestations and drown.

The use of sequestering curtains or screens can both restrict access to an infested area and limit the spread of fanwort by vegetative fragmentation. This approach, while often expensive, has been very effective in a number of cases, especially for small areas or coves with a narrow connection to the main body of the waterbody.

Possible expansion routes should be considered and addressed to the extent possible. Sequestration, as noted above, can be highly effective if the infested area is localized and amenable to curtains or screens. Outlets from the waterbody should also be screened to minimize the export of fanwort fragments with outflow. This may be problematic where leaves or other debris are abundant enough to clog such screens, necessitating frequent cleaning. Rotating screens or other automated outflow restrictors are effective but expensive. Drawdown may also limit fanwort escape, if an appropriate subsurface outlet exists and fanwort can be prevented from passing through it. It may be advisable to implement bird controls to limit bird contact with infested areas; scare tactics (e.g., flags or pinwheels on buoys, noisemakers) can be effective for short time periods, which may be all that is necessary for lakes with migratory populations. Greater effort may be needed for lakes with substantial resident bird populations. If boating is allowed, it is advisable to set up a temporary wash station at any ramp; it may be necessary to staff it to maximize use compliance. At the very least, boats and trailers leaving the waterbody should be inspected and cleaned.

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

1. Screen the surface outlet of the waterbody to minimize downstream movement of fanwort, maintaining the screen as necessary to facilitate outflow.
2. Lower the water level to prevent surface outflow; a subsurface drain may be used to continue outflow, but fanwort may escape through this exit if not screened, and such screening will require cleaning.
3. Post access points with warnings to avoid the plant and/or certain areas of the waterbody; use marker buoys to identify infested areas.
4. Surround smaller infested areas with sequestration curtain or other enclosing materials that prevent spread and limit access.
5. Curtain off coves or other isolated areas to prevent fanwort spread and limit access.
6. Use scare tactics or other approaches to limit bird use of the waterbody.
7. Set up a washing station and inspection point for boats taken out of the waterbody; require inspection and cleaning where needed.
8. Close any access point (e.g., boat ramp, beach, other points of active contact) in close proximity to fanwort, where the potential for internal or external spread is considered high.
9. Close the waterbody to human use.

Early Eradication Options

Timelines for necessary action with regard to fanwort invasions hinge on stopping the spread of this plant. Root crown expansion occurs throughout the growing season, so the sooner controls are implemented, the smaller the area that must be addressed. Once the growing season is over (about October), plants are largely dormant and many collapse or otherwise be reduced in biovolume until the following spring. Detecting and effectively removing fanwort plants by physical means will therefore be more difficult outside the growing season.

Management options that can be applied to fanwort are covered 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. A summary of control approaches with the potential to eradicate fanwort during the early stages of an invasion is provided below.

Hand Harvesting

Mode of action: Plants are removed by divers by hand; removal includes root crowns.

Probability of successful control: Where density is <500 plants per acre over a small number of acres, control can be complete. At higher densities or area of coverage, risk of incomplete harvest or spread by fragment escape increases dramatically.

Potential non-target impacts: Limited; with training, divers recognize fanwort and avoid other plants; risk to non-target plants increases as density of plant community increases. Temporary turbidity increases are expected.

Permitting needs: Can be approved without 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).

Monitoring needs: Critical to delineate target area and provide means for divers to stay on course with complete coverage. Monitoring during harvesting to detect and collect fragments is also very important to successful elimination of fanwort.

Range of costs: Often done by volunteers, but estimates from professional operations range from $100 to $500 per acre.

Other considerations: Use of a fragment barrier around all harvesting areas is highly recommended. Effective hand harvesting requires careful planning and is more difficult that it may appear.

Suction Harvesting

Mode of action: Plants can be pulled directly into the suction apparatus, but for best effect this is a suction aided hand harvesting operation, whereby hand harvested plants are fed into the suction tube and filtered out in an above-water chamber. This speeds up the operation and limits fragment dispersal.

Probability of successful control: High potential for eradication at low to moderate densities of fanwort; complete removal probability declines at higher densities.

Potential non-target impacts: May pull in non-target plants and plankton by suction, but effects localized and limited. Turbidity plume at surface from filtering chamber may be substantial.

Permitting needs: Generally requires an Order of Conditions under the Wetlands Protection Act, but may be issued a Negative Determination of Applicability where risk to other species and turbidity are expected to be low.

Monitoring needs: Critical to delineate target area and provide means for divers to stay on course with complete coverage.

Range of costs: $5,000 to $15,000 per acre, depending upon equipment features, contractor mobilization, fanwort density, and total area to be harvested.

Other considerations: Turbidity may be unacceptable where a large area is suction harvested.

Benthic Barriers

Mode of action: Covers target area with a porous or non-porous blanket, limiting light and physically stressing plants.

Probability of successful control: Usually completely eliminates live vegetation from covered area in 30 to 60 days.

Potential non-target impacts: All plants under the barrier will be killed. Some invertebrates are also killed, but many relocate. Fish find the barriers attractive for cover and foraging area, mainly a function of "edge effect" (creation of edges between plants and open water).

Permitting needs: Often approved through a Negative Determination of Applicability (provisions of WPA do not apply) where fanwort is the main plant affected. Otherwise permitted with an Order of Conditions with possible restrictions where other species are at significant risk.

Monitoring needs: Careful delineation of areas to be covered is needed. Condition of plant community, especially root crowns of fanwort, should be assessed prior to removal.

Range of costs: Materials typically cost $0.50 to $1.00 per square foot. With application and maintenance costs, expect $30,000 to $50,000 per acre. However, material can be re-used indefinitely, so costs are greatly reduced for subsequent applications.

Other considerations: To enhance performance, benthic barriers should be carefully anchored and periodically cleaned. To minimize hooks and lures getting caught in benthic barriers, mark location with labeled buoys. Barriers may present a safety hazard in swimming areas.

Water Level Drawdown

Mode of action: Lowered water level exposes plants and substrate to drying and freezing action. Ice damage may also be a factor. Where plants can be dried, frozen, or ripped up by ice action, fanwort can be greatly reduced in abundance or eliminated. With many years of repeated drawdown, exposed substrate tends to be dominated by coarse sediment less hospitable to fanwort invasion.

Probability of successful control: Very high where drying, freezing and/or ice damage occurs. As this is a function of the weather pattern, uncertainty is high; about one out of three years provides effective drawdown conditions in Massachusetts. Where thick organic sediments, spring activity, or other factors limit freezing and drying, success will be lower.

Potential non-target impacts: Other plants that overwinter in vegetative forms are also likely to be harmed. Seed-producing plants may be stimulated. Some invertebrates (especially mollusks), amphibians (most likely frogs), reptiles (particularly wood turtles) and mammals (most probably beaver and muskrat) could be negatively affected. Effects on fish vary, depending upon timing and duration of drawdown and the interaction with feeding and reproduction. Direct water supply and water level in wells may be affected.

Permitting needs: Requires an Order of Conditions under the Wetlands Protection Act, usually entailing a detailed review of the potential for non-target impacts.

Monitoring needs: Can be extensive. Pre- and post-implementation surveys are needed. Aside from effects on the plant community, effects on susceptible fauna may be required. Water supply must be monitored and a contingency plan is needed if supply is impaired. It should be assumed that at least three years of implementation will be needed to conduct a valid assessment of success and non-target impacts.

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

Other considerations: A very detailed evaluation of potential drawdown impacts is needed before attempting this technique. Issues of downstream flooding, refill time, and impacts on water supply and non-target organisms must be addressed.

Application of Fluridone

Mode of action: This systemic herbicide is absorbed by vegetative tissues and translocated throughout the plant, inhibiting the synthesis of carotenoid pigments. Lack of these auxiliary (protective) photosynthetic pigments causes susceptible plants to die slowly through reduced food production and damage by sunlight. Uptake must be nearly continuous over an extended period (>60 days preferred), necessitating extended exposure time.

Probability of successful control: Where adequate dose (>10 ppb for fanwort) and exposure time (60-120 days) are maintained, fanwort can be eradicated. This has proven difficult to achieve, however, particularly in partial lake treatments. Use of slow release pellet formulations or sequestration of the target area with impervious curtains maximizes exposure time and limits dilution of the dose. Follow up actions, such as hand harvesting, are often necessary, and re-treatment the next year may enhance control. Despite limitations, fluridone is a preferred chemical for fanwort control.

Potential non-target impacts: Susceptibility of other plants to fluridone varies widely, and much of the native community may survive at doses <6 ppb. However, doses <6 ppb are unlikely to control fanwort, and complete control is not typically achieved at <10 ppb. At doses >10 ppb, impact on some non-target plants are expected. Slow die-off of affected plants limits oxygen reduction. No impacts to fauna or humans are expected at applied doses.

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. The concentration of fluridone is also commonly tracked on a weekly to monthly basis with an Enzyme Limited Immuno-Sorbent Assay (ELISA).

Range of costs: Costs range from $500 to $2,000 per acre, depending upon the form of fluridone applied, any necessary re-treatment to maintain dose, and any sequestration of the target area.

Other considerations: The combination of dose and exposure time is critical to success; the combination of achievable detention time and degree to which non-target plants must be protected will determine the potential for eradication or extended control.

Application of Triclopyr

Mode of action: This systemic herbicide is absorbed by vegetative tissues of dicot plants 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 to three days. Plants sink from the surface within a week and die within three weeks.

Probability of successful control: Where adequate dose (0.75 to 2.5 ppm, usually about 1.5 ppm) and exposure time (6-12 hours up to 3 days) are maintained, impact on fanwort is possible but not consistently obtained in limited trials. As this herbicide was approved in November of 2004

for use in Massachusetts, there is only limited experience under experimental use permits to guide treatment.

Potential non-target impacts: Dicotyledonous plants, including fanwort, are susceptible to triclopyr, while monocotyledonous species, such as naiad and pondweed, are minimally affected at label doses. Impacts to fauna or humans have not been observed at applied doses. No threat to humans has been indicated at label doses.

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 $800 per acre, but there have been too few treatments to date to generalize.

Other considerations: As triclopyr was only registered for use in Massachusetts in 2004, evaluation of its potential is based on experimental use only, and those results are not encouraging. However, lower required exposure times make it an attractive choice with short detention time.

Other Options

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

- impractical on a small scale
- not able to eradicate fanwort
- could cause fanwort to spread
- not approved for use in Massachusetts

Recommended Options for Early Eradication

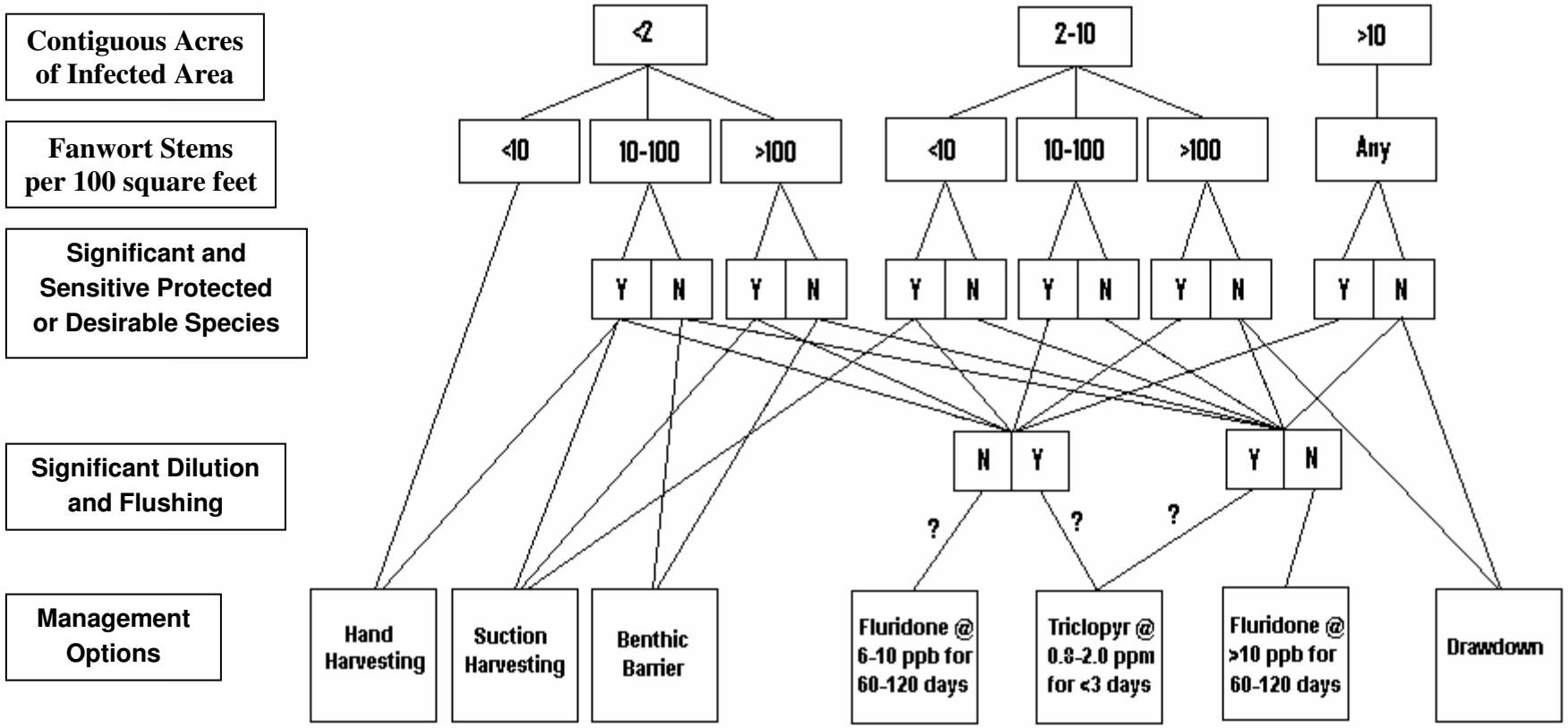
The most commonly recommended early actions are hand harvesting and bottom barriers, each of which has a high potential for success, low cost on a localized basis, and limited permitting needs. Where growths are too dense for effective hand harvesting and too extensive for cost-effective bottom barrier placement, suction harvesting should be considered. Drawdown, where applicable, is perhaps the most widely effective preventive control in cases where repeated invasion is expected or documented, but is not applicable in all cases. Where detention time can be maximized, either on a whole lake basis or with sequestration of a target area, fluridone can eliminate fanwort. On a localized basis, the herbicide triclopyr may have potential for control of fanwort where exposure times are limited and with limited impacts on other native species; more experience is needed to make a more definitive recommendation, however.

A graphic summary of rapid response actions is provided in Figure 3. Most rapid responses will involve sparse growths over a limited area or small, dense beds in a confined area. While the listed techniques may still be applicable after growths have become widespread, addressing them may not qualify as a rapid response, and additional considerations (e.g., impacts to non-target organisms on a lakewide basis) are likely to become more important in the permitting process. It is extremely important to detect an invasion early and act quickly to eliminate the infestation. The selection pathways shown in Figure 3 represent logical choices based on general features of the aquatic system, and are not intended to provide infallible rules or inflexible options. Practitioners should use a careful process of option review based on site specific data when selecting a rapid response.

Deciding Which Technique to Apply

The following decision tree is provided as an aid to evaluating control options. Thresholds for application are given as guidelines, not rigid rules. Individual circumstances may affect the choice of approach and outcome. 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 the Control of Fanwort (*Cabomba caroliniana*)



Notes: Hand harvesting and suction harvesting must include root system removal. Benthic barrier should remain in place for 30 to 60 days. Fluridone is effective at >10 ppb with >60 days exposure; lesser doses and exposure time may yield some control. Triclopyr approved for use in MA in late 2004; experience is limited in MA. Drawdown use is dependent on many factors, including hydrology and use as a water supply. Moderate to dense growth over an extensive area (>10 acres) may not be appropriate for rapid response consideration.

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 fanwort has moved throughout the waterbody into all suitable habitats and probably become the dominant plant, can and should be addressed if continued invasion in the region is to be curtailed. The Practical Guide to Lake Management in Massachusetts (Wagner, 2004), a companion guide to the GEIR on Lake Management, provides a review of all available techniques for combating fanwort (*Cabomba caroliniana*) infestations. On a whole lake basis, herbicide treatment is the most cost-effective means for reducing fanwort coverage and density to levels that can be controlled by physical techniques like hand harvesting or bottom barriers. However, only fluridone is applicable at this scale, and effectiveness is highly dependent on both dose and exposure time. Drawdown will reduce fanwort in the drawdown zone, but it is rare that a waterbody can be drawn down enough to eliminate fanwort without unacceptable impacts to non-target species. Techniques suitable for combating new growths are seldom practical or effective on a whole lake scale (e.g., hand harvesting, bottom barriers).

Maintenance techniques that limit the impact of fanwort on waterbody uses, but do not typically result in elimination of fanwort, include mainly mechanical harvesting, hydroraking and rotovation. These physical methods may actually spread fanwort if it is not already everywhere in the waterbody, after which these methods are analogous to mowing a lawn.

Dredging can remove fanwort along with all other plants and any remaining seeds or other propagules associated with the dredged sediment. The cost is extremely high, however, and resulting substrate conditions may still be hospitable to fanwort growth. With much bare area to be colonized, invasive species such as fanwort are likely to become dominant if more desirable species are not actively introduced. Only if dredging results in a water depth too great for effective colonization by fanwort is it likely to be the only method needed to control fanwort in the target area.

Grass carp can eliminate fanwort (and indeed all other submersed plants) when stocked at sufficient density, but are not approved for use in Massachusetts at this time. There are no known invertebrate herbivores that attack fanwort to an extent that might facilitate control.

Prevention of Re-Infestation

Once an invasion has been repulsed through any of the above methods, it should be apparent that the waterbody is susceptible to fanwort. As the cost of prevention is much less than the cost of rehabilitation of an infested waterbody, steps should be taken to reduce the risk of re-introduction of fanwort. As fanwort most often comes from a local source, control activity is encouraged on a watershed, multi-municipal or regional level. 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 waterbody to reduce the risk of re-introduction. Key steps may include:

- Education through the lake association or town for all users about the threat of fanwort, how to avoid introducing it to the waterbody, how to identify it, and who to contact if it is found. See the other sections in this document for relevant information to be provided.

- Posting of all access points with signs warning of the threat, showing how to identify fanwort, and urging that boats, fishing gear and other recreational equipment be cleaned before and after use in the waterbody. See the section on Communication and Education in this document.
- Provision of wash stations at boat ramps, and/or staffing of ramps with inspectors.
- Drawdown where applicable and permitted to minimize overwintering of introduced fanwort.
- Monitoring of the plant community to detect fanwort, with a focus on boat ramps and inlets.

Summary

1. Fanwort (*Cabomba caroliniana*) is an invasive plant normally identified by fan-shaped submerged leaves arranged around the stem in pairs.
2. Fanwort is native to the subtropic-temperate regions of eastern North and South America. It is most often transported on boats or trailers, by birds, and with water flow.
3. Fanwort can be transported great distances by fragments that can root and grow. It becomes locally abundant by root crown expansion. Seeds are of limited importance in dispersal, but cannot be ignored completely in evaluating routes of new infestations or regrowth from seemingly eradicated populations.
4. Fanwort creates canopies that shade out other plant species. At high density it provides poor habitat for most water-dependent fauna, impairs recreational uses, and can have negative impacts on water supply and flood control.
5. Fanwort is most often detected in the early stages of infestation in water <10 ft deep by visual examination (viewing tube from boat or mask and snorkel). Look first in the vicinity of boat ramps, inlets, and areas of bird congregation. One effective long-term monitoring strategy involves setting up transects representing areas of the lake and searching at discrete depth intervals from shore to the maximum depth of plant growth.
6. When detected, map fanwort coverage with notation of density as beds, scattered plants, or solitary stems. Be thorough with visual coverage of potentially infested areas. Record all other species present and their relative abundance. Confirm identification through the DCR.
7. Educate waterbody users by whatever means practical about the threat and presence of fanwort. Posting of access points is useful in all cases. Signs should show how to identify fanwort, urge that all boats, trailers and other recreational equipment be cleaned before and after use in the waterbody, and provide a contact name and phone number for reporting or correspondence.
8. It is advantageous to quarantine infested areas until removal can be attempted. Closing beaches and boat ramps can be problematic, legally and practically, but can promote greater awareness and support for prompt action. Use of curtains or screens both to keep people out of an infested area and to keep fanwort inside is desirable but expensive.
9. Eradication of fanwort detected early in an invasion can be accomplished with hand harvesting, suction harvesting, benthic barriers, drawdown, or the herbicide fluridone. The herbicide triclopyr may be effective, but was approved for use in Massachusetts in late 2004 and experience is limited. Hand harvesting and benthic barriers are often allowable without an Order of Conditions under the WPA, and can therefore be implemented most rapidly. Each method has benefits and drawbacks, and the specific circumstances will affect which option(s) can be applied.

10. A range of additional options are available to combat later stage invasions. Those not mentioned as eradication options for new infestations have some feature that prevents effective, rapid use, but these techniques may have applicability under special circumstances.
11. Drawdown, where feasible, can act as a deterrent to invasion on an annual basis at a relatively low cost, through direct impact on invading fanwort and by gradually altering the peripheral sediment features to make them less hospitable, but has many possible impacts on aquatic resources and requires a thorough evaluation in each case.
12. Once fanwort has been removed after an invasion event, steps are necessary to prevent re-infestation. Education of waterbody users, with a focus on boating, and ongoing monitoring to detect new fanwort plants are critical components. It should be assumed that fanwort will return, but it is far easier to address new growths than to combat a full infestation.

References

Adams, M. S., and R. T. Prentki. 1982. Biology, metabolism and functions of littoral submersed weedbeds of Lake Wingra, Wisconsin, U.S.A.: a summary and review. Arch. Hydrobiol./Suppl. 62:333-409.

Adirondack Park Invasive Plant Program website. 2004. www.adkinvasives.com.

Bratager, M., W. Cromwell, S. Enger, G. Montz, D. Perleberg, W. J. Rendall, L. Skinner, C. H. Welling, and D. Wright. 1996. Harmful Exotic Species of Aquatic Plants and Wild Animals in Minnesota. Annual Report. Minnesota Department of Natural Resources, St. Paul. 99 pp.

Cheruvelil, K. S., P. A. Soranno, and J. D. Madsen. 2001. Epiphytic macroinvertebrates along a gradient of Eurasian watermilfoil cover. Journal of Aquatic Plant Management 39:67-72.

Crow, G. E., and C. B. Hellquist. 2000. Aquatic and wetland plants of northeastern North America. Volume One: pteridophytes, gymnosperms, and angiosperms: dicotyledons. University of Wisconsin Press, Wisconsin.

Dibble, E. D., K. J. Killgore, and S. L. Harrel. 1996. Assessment of fish-plant interactions. Transactions of the American Fisheries Society 16:357-372.

Engel, S. 1995. Eurasian watermilfoil as a fishery management tool. Fisheries 20(3):20-27.

Holland, L. E., and M. L. Huston. 1984. Relationship of young-of-the-year northern pike to aquatic vegetation types in backwaters of the Upper Mississippi River. North American Journal of Fisheries Management 19:18-27.

Honnell, D., J.D. Madsen, and R.M. Smart. 1992. Effects of aquatic plants on water quality in pond ecosystems. Proceedings: 26th Annual Meeting, Aquatic Plant Control Research Program. Report A-92-2. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Johnstone, I.M., B.T. Coffey, and C. Howard-Williams. 1985. The role of recreational boat traffic in interlake dispersal of macrophytes: a New Zealand case study. J. Environ. Manage. 20:263-279.

Keast, A. 1983. The introduced aquatic macrophyte, *Myriophyllum spicatum*, as habitat for fish and their invertebrate prey, Department of Biology, Queens University, Kingston, Ontario, Canada.

Lillie, R. A., and J. Budd. 1992. Habitat architecture of *Myriophyllum spicatum* L. as an index to habitat quality for fish and macroinvertebrates. Journal of Freshwater Ecology 7(2):113-125.

Orgaard, M. 1991. The genus Cabomba (Cabombaceae) – a taxonomic study. Noridc Journal of Botany 11:179-203.

Savino, J. F., and R. A. Stein. 1982. Predator-Prey interaction between largemouth bass and bluegills as influenced by simulated, submersed vegetation. Transactions of the American Fisheries Society 11:255-266.

University of Washington website. 2004. www.fish.washington.edu.

Varney, R. and N. Christie, N. 2003. Fighting the spread of invasive species in New Hampshire. www.epa.gov/newengland/ra/column/archive/invasivespecies_nh_20030909.html.

Wagner, K.J. 2004. The Practical Guide to Lake Management in Massachusetts. Commonwealth of Massachusetts, Executive Office of Environmental Affairs, Boston, MA.

Washington Department of Ecology website. 2004. www.ecy.wa.gov.