4.2 DRAWDOWN

4.2.1 Water Level Lowering

Drawdown is a multipurpose lake management tool that can be used for aquatic plant control. The water level is lowered by pumping, siphoning, or opening a pipe or gate in the dam. Historically, water level drawdown has been used in waterfowl impoundments and wetlands for periods of a year or more, including the growing season, to improve the quality of wetlands for waterfowl breeding and feeding habitat (Kadlec, 1962; Harris and Marshall, 1963). It has also been a common fishery management method. Until a few decades ago, drawdowns of recreational lakes were primarily for the purpose of flood control and allowing access for near-shore clean ups and repairs to structures, with macrophyte control as an auxiliary benefit. While this technique is not effective on all submergent species, it does decrease the abundance of some of the chief nuisance species, particularly those that rely on vegetative propagules for overwintering and expansion (Cooke et al., 1993a). If there is an existing drawdown capability, lowering the water level provides an inexpensive means to control some macrophytes. Additional benefits may include opportunities for shoreline maintenance and oxidation or removal of nutrient-rich sediments.

The ability to control the water level in a lake is affected by area precipitation pattern, system hydrology, lake morphometry, and the outlet structure. The base elevation of the outlet or associated subsurface pipe(s) will usually set the maximum drawdown level, while the capacity of the outlet to pass water and the pattern of water inflow to the lake will determine if that base elevation can be achieved and maintained. In some cases, sedimentation of an outlet channel or other obstructions may control the maximum drawdown level.

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

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

Desirable side effects associated with drawdowns include the opportunity to clean up the shoreline, repair previous erosion damage, repair docks and retaining walls, and search for septic system breakouts. (Nichols and Shaw, 1983; Cooke et al., 1993a; WDNR, 1989). Some authors (Cooke 1980) have reported that game fishing often improves after a drawdown, but this is not the case in Massachusetts or New England. Since emergent shoreline vegetation tends to be favored by drawdowns, populations of furbearers are expected to benefit (WDNR 1989), although direct negative impacts may be caused if lodges and food caches are exposed. The consolidation of loose sediments and sloughing of soft sediment deposits into deeper water is perceived as a benefit by shoreline homeowners (Cooke et al., 1993a; WDNR 1989).

The actual conduct of a drawdown involves facilitating more outflow than inflow for a sustained period on the order of several weeks or months. After the target water level is reached, outflow is roughly matched to inflow to maintain the drawdown for the desired period, usually at least a month and often up to 3 months, usually over the winter. At a time picked to allow refill before any undesirable spring impacts can occur, outflow is reduced (although it should not be eliminated) and "excess" inflow causes the water level to rise. In some cases, refill is commenced after an inch or two of ice forms, ripping up plants and bottom material. This "extreme disturbance" approach may be a preferable alternative where sediments will not dewater sufficiently to provide the level of freezing and desiccation desired. It also should be noted that this approach may disturb overwintering organisms. Impacts and effectiveness have not been documented, although observations by practitioners seem to favor this approach as more effective than just freezing.

4.2.2 Effectiveness

4.2.2.1 Short-Term

The factors that determine the effectiveness of a drawdown for rooted plant control include:

1. Sensitivity of species to dehydration (Nichols, 1975); see Table 4-2 for sample tolerance listings.
2. Sediment composition and slope. Clay or muck soils will dry out much slower than sandy soil. The rate and degree of desiccation achieved will limit effectiveness (Pieterse and Murphy, 1990). Steeper slopes allow movement of finer sediment out of the area, leaving a less hospitable substrate for growth of plants.
3. The depth of the drawdown; in lakes that have macrophyte beds at varying depths, greater effectiveness is achieved on macrophyte beds that are completely exposed during the drawdown (Siver et al., 1985).
4. Weather during drawdown. Some species, such as *Nuphar*, may require a prolonged period of frost in order for the drawdown to be effective (Cooke et al., 1993a). Repeated rain will offset dewatering. Mild winter temperatures will limit freezing effects. Snowfall can insulate plants, preventing adequate freezing and desiccation.
5. Pattern and rate of groundwater seepage into lake sediments (Cooke, 1980). Groundwater inputs can offset dewatering.
6. Plant density at the time of drawdown. When the canopy dries out it can form a covering over other plants and root systems and prevent dehydration (Pieterse and Murphy, 1990).

To reduce impacts to non-target plants and animals during the growing season, drawdowns in Massachusetts are normally conducted in fall and winter. Most of these factors act upon success over several months, with successful drawdowns resulting in reduced plant density the following growing season. Consequently, short-term impacts are not readily noticeable in most cases. If the following growing season is considered to represent "short-term" effects, then drawdown has variable effectiveness in accordance with the above-listed factors.

The effectiveness of drawdown as an aquatic plant control technique depends foremost on the susceptibility of the target species to drawdown. Some species are sensitive to drawdown, while others are resistant or even stimulated by it (Table 4-2). Species that depend upon vegetative propagation and overwintering strategies (most perennials) will likely to be impacted, while species that depend upon seed reproduction (annuals) may not be impacted. Seeds are not adversely impacted, and germination may be stimulated. If the root systems of perennials can be dried and frozen, density reductions can be striking.

Drawdown has been applied for many years in lake management and tends to reduce rooted plant density in the drawdown zone, even if not always intended as a plant control technique (Dunst et al., 1974; Wlosinski and Koljord, 1996). Winter drawdowns of Candlewood Lake in Connecticut (Siver et al., 1986) reduced nuisance species by as much as 90% after initial drawdown. Drawdowns in Wisconsin lakes have resulted in reductions in plant coverage and biomass of 40 to 92% in targeted areas (Dunst et al., 1974). In one Wisconsin case, Beard (1973) reported that winter drawdown of Murphy Flowage opened 64 out of 75 acres to recreation and improved fishing.

The effect of drawdown on plants is not always predictable or desirable, however. Reductions in plant biomass of 44% to 57% were observed in Blue Lake in Oregon (Geiger, 1983) following drawdown, but certain nuisance species actually increased and herbicides were eventually applied to regain control. Drawdown of Lake Bomoseen in Vermont (VANR, 1990) caused a major reduction in many species, many of which were not targeted for biomass reductions. The Lake Bomoseen drawdown was effective at reducing Eurasian watermilfoil in the areas exposed (down to four feet), but most of the milfoil was present in deeper areas and quickly recolonized. A slow refill of Indian Lake in Worcester in the spring (refill started in May) allowed plants at deeper depths to grow and reach the surface, hindering recreational use (G. Gonyea, MDEP, pers. comm., 1996). Reviewing drawdown effectiveness in a variety of lakes, Nichols and Shaw (1983) noted the species-specific effects of drawdown, with a number of possible benefits and drawbacks. A system-specific review of likely and potential impacts is highly advisable prior to conducting a drawdown.

Algal control by drawdown is dependent upon oxidation of sediments to reduce the potential for internal recycling in subsequent growing seasons. Unfortunately, increases in available nutrients have been as common as decreases, as decomposition makes nutrients more readily available. Where flushing is high, the released nutrients may be out of the lake by the next growing season, but highly flushed systems usually have problems with external loading and may have reduced algal biomass just by virtue of the flushing activity. Short-term impacts of drawdown on algae are therefore not reliably predictable.

Table 4-2 Anticipated response off some aquatic plants to winter drawdown. (After Cooke et al., 1993a)

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

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

4.2.2.2 Long-Term

The intended overall effect of a drawdown is a change in the composition of the plant community and a reduction in assemblage biomass. The former goal is usually achieved if the target species are sensitive to drawdown. Achieving the latter goal is partly a function of sediment type and slope, but can be achieved with careful drawdown management in many cases. Annual drawdowns maximize long term effectiveness, although repeated drawdowns may result in dominance of drawdown resistant species which could limit the long term effectiveness of this control method (Nichols, 1975). Nuisance conditions caused by drawdown resistant species usually occur in shallow, minimally sloped areas where the substrate is hospitable.

Lake Garfield in Monterey is a good example of the switch from drawdown sensitive to drawdown tolerant species. An 8 ft drawdown limits Eurasian watermilfoil growth but promotes dense stands of the seed-producing, annual, broad-leaf pondweed (*Potamogeton amplifolius*) in that lake (BEC, 1992b). In Candlewood Lake, CT, however, two species of the seed producing, annual, naiad (*Najas*) increased following drawdown, but have not impeded lake uses. After two winter drawdowns during 1983-84 and 1984-85 the biomass of *Myriophyllum spicatum* (Eurasian watermilfoil) was significantly reduced (Siver et al., 1985) and remains an effective control method for milfoil in Candlewood Lake (R. Larsen, NE Utilities, pers. comm., 1995).

Drawdowns at Lake Lashaway (East and North Brookfield, Massachusetts) in the mid-1980s were successful at reducing plant growth for six sequential growing seasons (Haynes, 1990). Previous attempts to control fanwort (*Cabomba caroliniana*) and naiad (*Najas flexilis*) with chemicals had been inadequate in Lake Lashaway, while the drawdowns controlled both species (Haynes, 1990). Drawdown has been applied to many lakes in the Berkshire region since the 1960s or earlier, and plant composition and density in the drawdown zone clearly indicates that species such as Eurasian watermilfoil can be controlled at the lake periphery by this technique. In Stockbridge Bowl there is little milfoil out to a water depth of 3 to 4 ft, owing to an 18-inch drawdown and about 2 ft of ice contact (ENSR, 2002b). Drawdown kept areas of Richmond Pond <6 ft deep largely free of milfoil for over 30 years (BEC, 1990a). Lake Buel, by comparison, has no water level controls and has dense milfoil growth right to the shoreline. It is also true, however, that milfoil grows at depths much greater than drawdown can typically reach, so recolonization after cessation of drawdown may only take a few years.

Otis Reservoir was studied in detail in 2000 (ENSR, 2001c). It has experienced a drawdown of 8 ft, 3 inches on an annual basis for several decades. The drawdown is conducted by the MDCR with a primary goal of protecting structures around the lake from ice damage, but the plant control effect is striking. Where the slope is more than about 1:4 (at least 1 ft of vertical change for every 4 ft of horizontal change), there is almost no soft sediment in the drawdown zone, and the habitat is rock, sand and gravel with few plants. Where the slope is lower, muck sediments are present and seed-producing annual plants native to the area are abundant but not overly dense, creating excellent habitat for fish and invertebrates. Below the drawdown zone, a band of plants encircles the lake, again providing desirable habitat but not interfering with recreation. No invasive species of aquatic plants were found in the lake, despite high levels of boating by visitors.

Indian Lake in Becket has been the subject of six years of study, three pre-drawdown and three post-drawdown (ENSR, 2001d). This drawdown targeted a number of native species that were perceived as expanding toward nuisance levels. The first winter drawdown in 1999-2000 stimulated seed producers but failed to kill vegetative propagators, given the mild winter. The second drawdown in the better suited winter of 2000-2001 greatly reduced the biomass of the plant assemblage, but left areal coverage similar to past years. No species were lost, and overall diversity was higher. Recreation and habitat value were both considered to have been enhanced, based on fewer impediments to sailing and swimming by lower plant growths that had expanded coverage and added species in this lake.

From the data available, it can be concluded that sensitive species (i.e., those overwintering and reproducing by vegetative means) can be controlled within the drawdown zone by exposure over a period of at least a month to drying and freezing conditions. To maintain control, a successful drawdown is needed every other to every third year. However, as success is partly weather dependent, it is generally desirable to plan for annual drawdown and to abort plans when conditions have been acceptable for the previous year or when weather conditions suggest little benefit. When first using drawdown as a management technique, it may be necessary to apply it for several consecutive years, and use of drawdown for certain other purposes (e.g., protection of structures from ice damage, flood prevention) may dictate annual drawdown. The ability of drawdown to reduce overall assemblage density is largely a function of sediment features and regrowth rates. Where a coarse substrate is maintained by drawdown, plant growth is likely to be limited. Where soft sediment is abundant, drawdown-resistant plants can be expected to grow. Whether those resistant plants create nuisance conditions will be a function of which species become dominant.

Long-term control of algae by drawdown depends on reduced release of nutrients from the sediment to the water column. This is only likely when the sediment in the drawdown zone is converted from nutrient-rich muck to sand or coarser substrates. This is sometimes accomplished by focusing of sediments into deeper areas, but only where the slope is adequate. There have been claims that this focusing has negative water quality impacts, but this is unlikely; oxidized sediment arriving in deep waters buries other sediment that was interacting with the water column, and the area of sediment-water interaction is largely unchanged. However, unless a major drawdown is conducted, one in which most of the lake sediment is exposed and altered, it seems unlikely that this approach will yield major algal benefits.

4.2.3 Impacts to Non-Target Organisms

4.2.3.1 Short-Term

Undesirable possible side effects of drawdown include loss or reduction of desirable plant species, facilitation of invasion by drawdown-resistant, undesirable plants, reduced attractiveness to waterfowl (considered an advantage by some), possible fish kills if oxygen demand exceeds re-aeration during a prolonged drawdown, altered littoral habitat for fish and invertebrates, mortality among hibernating reptiles and amphibians, impacts to connected wetlands, shoreline erosion during drawdown, loss of aesthetic appeal during drawdown, more frequent algal blooms after refill in some cases, reduction in water supply, impairment of recreational access during the drawdown, and downstream flow impacts (Nichols and Shaw, 1983; Cooke et al., 1993a).

Careful planning can often avoid at least some of these negative side effects, but managers should be aware of the potential consequences of reduced water level.

Non-target species of plants that depend on vegetative means of overwintering or reproducing may indeed be reduced in abundance along with the targeted species. Resistant species, mainly those overwintering by seed, or species abundant below the drawdown zone, may become more abundant in the drawdown zone. Open substrate created through drawdown may be colonized by invasive species, although most of the problematic nuisance species are sensitive to drawdown. Drawdown for nuisance plant control is intended to cause shifts in plant assemblage composition and abundance, but not all shifts will necessarily be desirable.

The impact of drawdowns on wetlands that are hydraulically connected to the lake is often a major concern of environmental agencies. Available data do not suggest major effects, positive or negative, from winter drawdowns (Van der Valk and Davis, 1980; ENSR, 2002c; 2001d). This is believed to be a result of dormancy by most plants and frozen soil conditions is some areas; wetlands are generally adapted to fluctuating water levels and fluctuations in the winter are of least concern.

Hydrology is generally considered the master variable of wetland ecosystems (Carter, 1986), controlling recruitment, growth and succession of wetland species (Conner et al., 1981). It is apparent that the depth, timing, duration and frequency of water level fluctuations are important with regard to severity of impacts to adjacent wetlands (Kusler and Brooks, 1988). It is also apparent that the specific composition of a wetland plant community prior to drawdown plays a role in determining impacts.

The naturally-occurring hydrologic regime is probably the single most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes. Hydroperiod is the seasonal pattern of water levels in a wetland and is like a hydrologic signature of each wetland type. It is unique to each type of wetland and its constancy from year to year ensures reasonable stability for that wetland (Mitsch and Gosselink, 1986). Significant changes in hydroperiod can produce significant changes in vegetative species zonation in non-forested wetlands (Brinson et al., 1981). However, most drawdowns for lake management purposes constitute only a temporary influence on hydrologic regime, and will not necessarily have a detectable, widespread effect as evidenced in recent studies (ENSR, 2000c; 2000d).

Duration and timing of the drawdown are important factors in limiting impacts to associated wetlands. Drawdown of the water level in summer, if more than a week or two in duration, leads to desiccation and stress of wetland species in most cases. In contrast, a similar drawdown practiced during late fall or early winter is expected to have little impact on dormant emergent plants, but should have a destructive effect on exposed littoral zone.

Most wetland plants are very well adapted for existence during conditions of fluctuating water level. In fact, a prolonged stable water level is known to lead towards dominance by single species in emergent wetland communities; nearly pure stands of common cattail or sedges/grasses are the most common manifestations of this phenomenon (Van der Valk and Davis, 1980). Some water level fluctuation is required for elevated species diversity.

The nature of the wetland soils will influence wetland response to a drawdown. Generally the water table in a peat or muck soil is within one or two feet of the average ground surface (Bay, 1966). The upper layer of a peat soil has been termed the active layer, the layer in which plant roots exist and the layer with the greatest water level fluctuation (Romanov, 1968). The total porosity of the undecomposed raw peat moss horizon exceeds 95%, but the porosity of decomposed peat is only 83%. While this may not seem to be a major difference, lowering the water table in loose, porous, undecomposed peat removes 60 to 80% of the water in a given horizon, but an equal lowering in a decomposed peat removes only approximately 10% of the water (Bay, 1966). Where a substantial layer of decomposing organic matter underlies the wetland, as is expected in most wetlands associated with Massachusetts lakes, dewatering will be very slow and impacts from winter drawdown will be minimized.

In the lake itself, lowering of the water level results in a temporary loss of habitat and possible impacts to fish, invertebrates and algae (Manuel, 1994). Frogs, turtles, beavers and other vertebrates may also be impacted, but there is little scientific documentation. One study of Lake Sebasticook, Maine, found that a large population of freshwater mussels largely disappeared after a lake drawdown (Samad and Stanley, 1986). After a second drawdown in the same lake the only area with live mussels was a small area near the inlet. Although the movement rate of mussels of 1 to 16 mm/min would have allowed escape as the water receded, the direction of movement of mussels was random (Samad and Stanley, 1986). Similar impacts on mollusks (clams and snails) were observed in the Lake Bomoseen drawdown in Vermont (VANR, 1990). Paterson and Fernando (1969) reported that much of the benthic fauna (mostly oligochaete worms, nematodes and chironomid fly larva) was destroyed following drawdown of the Laurel Creek Reservoir in Ontario. Drawdown has been reported to alter the movement and behavior of predatory fish such as northern pike and largemouth bass (Rogers and Bergersen, 1995), and the range of possible impacts on spawning success is wide. Muskrat houses left exposed during drawdowns may also lead to increased predation on muskrats. Likewise, exposure of beaver lodges and food caches cannot be interpreted as a benefit to the beavers.

Post-refill algal blooms, lowered dissolved oxygen, poor access to spawning areas, desiccation of eggs, sedimentation impacts on eggs, and lowered food resources have all been cited as possible causes of damage to fishery resources from drawdowns (R. Hartley, L. Daley and R. Keller, MDFG, pers. comm., 1995). However, no scientific studies have been conducted in Massachusetts, and the literature for other states suggests mixed benefits and detriments (Wlosinski and Koljord, 1996).

Observations by L. Daley suggest that Richmond Pond in Richmond suffered a loss of rainbow smelt and depletions of largemouth bass, brown trout and crayfish populations coincident with drawdowns in the 1970's (MDFG, pers. comm., 1995). Smelt runs were noticeably absent in both Goose Pond in Lee and Greenwater Pond in Becket following drawdowns. Drawdown could indeed have caused such effects, especially since these drawdowns have a flood control component and were held as long as possible in the spring, but scientific study to document cause and effect has been lacking.

It is certainly possible to cause negative impacts to lake fauna through drawdown if the program is not carefully planned and implemented, and it is true that some impacts may occur even with the best of planning, given the dependency of the technique on weather conditions. The timing of the drawdown and refill is critical to the ability of fish to spawn successfully, but cannot be tightly controlled in most cases. Loss of fish through unscreened outlets is possible, and the MDFG recommends half-inch grates at the outflow during drawdowns to minimize fish escape. Minimally mobile invertebrates such as molluscs would seem to be susceptible to drawdowns initiated while they are in shallow water. However, many invertebrates (particularly snails) move offshore for the winter (Jokinen, 1992), limiting impacts if drawdown is delayed. There are few scientific studies that document impacts from later drawdowns, so it is essential to consider each aspect of the ecology of the targeted lake when planning a drawdown.

There may be impacts downstream as a result of increased flows during drawdown, but a properly conducted drawdown should not involve flows outside the normal range for the stream channel. Of greater concern are reduced spring flows during refill, although a properly conducted drawdown should allow for continued downstream flow during refill. Changes in streamflow can have an impact on fish populations as different species habitats are dictated by depth, current velocity and area, as well as stability of flow (Bain et al., 1988; Lewis, 1969). Obviously, a lack of flow during spring could be very detrimental.

Impairment of water supply during a drawdown is a primary concern. Processing or cooling water intakes may be exposed, reducing or eliminating intake capacity. The water level in wells with hydraulic connections to the lake will decline, with the potential for reduced yield, altered water quality and pumping difficulties. Drawdowns of Cedar Lake and Forge Pond in Massachusetts in the late 1980s resulted in impairment of well water supplies (K. Wagner, ENSR, pers. obs.1987-1989), but there is little mention of impairment of well production in the reviewed literature.

Recreational facilities and pursuits may be adversely impacted during a drawdown. Swimming areas will shrink and beach areas will enlarge during a drawdown. Boating may be restricted both by available lake area and by access to the lake. Winter drawdown will avoid most of these disadvantages, although lack of control over winter water levels can make ice conditions unsafe for fishing or skating. Additionally, outlet structures, docks and retaining walls may be subject to damage from freeze/thaw processes during overwinter drawdowns, if the water level is not lowered beyond all contact with structures.

4.2.3.2 Long-Term

Although there have been claims of devastating effects following a single drawdown (e.g., VANR, 1990), aquatic biota tend to be very resilient and impacts from any one drawdown are usually only temporary (Wlosinski and Koljord, 1996). Even complete loss of a year class of fish or elimination of molluscs from part of a lake will have little impact on overall lake ecology on a one-time basis. However, repetition of such impacts on an annual basis could alter biological communities in an undesirable and more prolonged manner, and for drawdown to be effective, it must be applied on a repetitive basis. Short-term impacts may therefore result in long-term impacts if drawdown is conducted on an annual or regular basis.

Fish populations can suffer from a loss of plant cover, changes in plant species composition, a loss of invertebrate food sources, and by a loss of annual recruitment if the timing of the drawdown overlaps and impacts spawning. Non-target organisms from the lake, downstream and adjacent wetlands could be impacted if there is difficulty refilling the lake in the spring (Haynes, 1990; Cooke et al., 1993a). Impacts may be highly system-specific, necessitating evaluation of possible impacts during the planning stage and follow-up monitoring to document any impacts.

Very few studies have been conducted over an extended period of time on lakes in Massachusetts that have experienced drawdown over multiple years. Three years of post-drawdown evaluation of Indian Lake in Becket, coupled with three years of pre-drawdown assessment (ENSR, 2002c) is the best available example of an extended study, but it does not cover all possible impacts. The ability of drawdown to control certain nuisance species in the drawdown zone has been well documented through multiple studies at individual lakes (e.g., Onota Lake in Pittsfield, Lake Lashaway in Brookfield). However, avoidance or prevention of impacts to non-target species has not been documented in a scientific fashion. Lakes such as Richmond Pond in Richmond and Otis Reservoir in Tolland have thriving fish, reptile, amphibian, avian and mammal communities, based on observations included in the D/F studies for these lakes (BEC, 1990a; ENSR, 2001c) but it cannot be definitively stated that there have been no negative impacts to the fauna from drawdown. The overall effect of drawdown appears positive in many cases, but negative impacts to specific components of system biology are plausible and probable.

In summary, there are a variety of possible negative consequences of drawdown for non-target species. Potential adverse impacts of an individual drawdown may not be manifest or may be temporary, yet repetitive application of drawdown could induce long-term impacts if temporary impacts are caused repeatedly. Therefore, drawdown should be preceded by an evaluation of possible impacts. If drawdown appears feasible under regulatory constraints, an appropriate monitoring plan should be developed that will signal adverse impacts if they occur and facilitate mitigative action. Assumption of impacts without a system-specific evaluation is unjustified, but prevention of unacceptable impacts is likely to require careful planning, implementation and monitoring, and may be difficult in some situations.

4.2.4 Impacts to Water Quality

4.2.4.1 Short-Term

Drawdown may affect water quality, particularly the parameters of clarity and dissolved oxygen concentration. Clarity will be a function of algal production and suspension of non-living particles. Algal production is most often related to phosphorus availability. By oxidizing exposed sediments, later release of phosphorus may be reduced through binding under oxic conditions, although post-drawdown algal blooms suggest that this mechanism may not be effective for all lakes. Decomposition during drawdown could make nutrients more available for release, but this is not a routinely observed phenomenon (Cooke et al., 1993a). It is likely that binding of iron and phosphorus influences phosphorus availability after drawdown, and the interplay between oxygen and levels of iron, sulfur and phosphorus is likely to vary among aquatic systems, resulting in variable nutrient availability. Calcium may also play a role in variable phosphorus availability in Berkshire lakes. Furthermore, the degree of flushing in the spring may be an important variable; lakes that require most of the spring flow to refill after drawdown have a higher probability of experiencing an increase in nutrient levels than those that flush once or more after spring refill.

Turbidity induced by sediment resuspension is likely during refill at rapid rates, but in many lakes the rise in water level is not fast enough to resuspend sediments by itself. Wind action in shallow waters (previously exposed areas) could promote increased short-term turbidity, if sediments are not consolidated after drawdown. Compaction of sediment during drawdown varies with sediment type and dewatering potential, but any resulting compaction tends to last after refilling, reducing resuspension potential and post-drawdown turbidity (Kadlec, 1962; Bay, 1966; Cooke et al., 1993a).

Interaction between unexposed sediments and the lesser volume of water in the lake during drawdown can lead to depressed oxygen levels if oxygen demand exceeds aeration and sources of inflow are slight (Cooke et al., 1993a; WDNR, 1989). Under ice, this can lead to fish kills, but such occurrences appear rare in Massachusetts, based on fish kill reports on file with the MDFG. Decreased detention time in response to lower lake volume and colder water temperatures may be countering the potentially elevated impact of sediment oxygen demand on a smaller lake volume.

4.2.4.2 Long-Term

Impacts to water quality are likely to be temporary, unless drawdown causes an actual change in sediment features. Drawdown may consolidate sediments or cause fine sediment to move into deeper water, thereby reducing turbidity in response to wind action (Cooke et al., 1993a). Such sediment changes may also reduce internal recycling, as flux is related to the area of nutrient-rich sediment interacting with the overlying water column. To achieve such benefits, however, a large portion of the lake area must be exposed, and this may lead to detrimental impacts that are likely to limit the application of drawdown. However, detailed studies of long-term water quality changes that might be linked to drawdown of lakes in Massachusetts have not been conducted.

4.2.5 Applicability to Saltwater Ponds

Drawdown is generally not applicable to saltwater ponds due to the low elevation relative to the ocean and the need to use pumps to remove water from the pond. Shellfish may be destroyed in a saltwater pond drawdown.

4.2.6 Implementation Guidance

4.2.6.1 Key Data Requirements

The listing of key considerations provided in Table 4-3 indicates the extensive data needs for proper implementation of this technique. Maps should be produced to show the areas affected and the present distribution of aquatic macrophytes. Expected ice depth should also be considered when determining the volume of water in the lake during drawdown. Biological surveys will undoubtedly be needed where non-target populations are perceived to be at risk from drawdown. Drawdown should not be conducted unless there is sufficient inflow to fill the lake by early spring, necessitating a thorough hydrologic evaluation. Correct identification of plant species is essential, as some species are reduced by lake drawdown, while others are unaffected or can increase. A carefully crafted monitoring program is critical to overall project success.

4.2.6.2 Factors that Favor this Approach

The following considerations are indicative of appropriate application of drawdown for the control of plants in lakes:

1. The lake periphery is dominated by undesirable species that are susceptible to drying and freezing.
2. Drawdown can be achieved by gravity outflow via an existing outlet structure, or such a structure can be established for a reasonable cost.
3. Drawdown can reach a depth that impacts enough of the targeted plants to detectably improve recreation (e.g., allow more access, increase safety) and enhance habitat (provide nearshore open water, reduce density of invasive species of limited habitat value).
4. Areas to be exposed have sediments and slopes that facilitate proper draining and freezing.
5. Drawdown and refill can be accomplished within a few weeks under typical flow conditions and without causing downstream flows outside the natural range.
6. Drawdown can be timed to avoid key migration and spawning periods for non-target organisms.
7. Populations of molluscs or other nearshore-dwelling organisms of limited mobility are not significant.
8. The lake is not used for water supply, and nearby wells are deep.
9. Flood storage capacity generated by drawdown prevents downstream flood impacts.

Table 4-3 Key Considerations for Drawdown

Reasons for Drawdown

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

Necessary Drawdown Planning Information

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

In-Lake and Downstream Water Quality

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

Water Supply

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

Sediments

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

Flood Control

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

Table 4-3 (continued) Key considerations for drawdown

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

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

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

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

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

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

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

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

4.2.6.3 Performance Guidelines

Planning and Implementation

Drawdown is a relatively simple technique, but there are many considerations that must be addressed before it can occur. Table 4-3 lists a range of issues to be addressed. Logistics of drawdown will vary somewhat from lake to lake, but the basic pattern involves increasing the outflow during the fall to a level greater than the inflow within the constraints of what the downstream system can handle. This elevated outflow is held until the target water level is reached, with a target rate of water level decline typically of no more than about 2-3 inches per day. Ideally, the drawdown process will take 2 weeks to a month. Once the target level is reached, outflow is matched to inflow to the maximum extent practical for at least one month of freezing conditions. Holding the drawdown until spring ice-out may be an option, as might refill after an inch or two of ice has formed, depending upon project goals and constraints. Refill by early April is usually desired. Refill is accomplished by restricting outflow to a level lower than inflow, but not so low as to impact downstream resources. Restricted outflow continues until full lake level is achieved, ideally several weeks to 2 months later.

Water fluctuations generally are greater in man-made impoundments, thus permitting restrictions can be more relaxed for these water bodies, as biotic communities are somewhat adapted to water level variations. The relatively stable lakes (particularly natural lakes) should be more protected from unnatural drawdowns so as to protect endemic species which may be less tolerant of water level fluctuations.

The MDFG has offered the following guidelines to meet fish and wildlife management goals where drawdowns have been determined to have desired benefits:

- Limit drawdown to 3 ft or contact the MDFG for assistance in evaluating impacts of greater drawdown; however, exceeding this level may meet DFG guidelines if justified in the NOI or lake management plan. The DFG policy is to review drawdowns in excess of three feet.
- Commence drawdown after the beginning of November.
- Achieve the target drawdown depth by the beginning of December.
- Achieve full lake level by the beginning of April.
- Keep outflow during drawdown below a discharge equivalent to 4 cfs per square mile of watershed. Once the target water level is achieved, match outflow to inflow to the greatest extent possible, maintaining a stable water level.
- Keep outflow during refill above a discharge equivalent to 0.5 cfs per square mile of watershed.

Monitoring and Maintenance

Monitoring of lake level is required to maintain effectiveness and minimize impacts. Any potential water supply impairment needs to be monitored and addressed quickly. Additional monitoring requirements will vary with the lake, but would be expected to include a quantitative pre- and post-drawdown plant community survey and similar assessment of representative populations considered at risk from the drawdown. Certain populations of fish, aquatic benthic invertebrates (especially molluscs), reptiles, amphibians, birds and mammals (especially beaver and muskrat) may be at risk. Some water quality monitoring might also be required, most often involving summer nutrient concentrations and winter oxygen levels. There is a need for detailed scientific investigation of possible drawdown impacts, and a need to develop inexpensive monitoring techniques that can signal impending impacts before they become too severe.

Drinking water wells around the lake should be evaluated to predict whether drawdown will limit water supply, as this is an impact that may halt a drawdown immediately. The threat of drawdown to water supplies has restricted the depth of drawdown in many systems and eliminated drawdown as a viable option in several cases (e.g., Forge Pond in Westford, Lower Chandler Mill Pond in Duxbury and Pembroke). Very shallow wells that may go dry should be replaced by deeper wells for health reasons, but there is little regulatory impetus to force such changes at the homeowner's expense. Slightly deeper wells will not go dry, but may have reduced production capacity as a function of a shorter water column in the well. If the well pump is sized for the original water depth, it may pump the well to the point at which the water level drops below the intake depth, causing an interruption of service until the water level in the well recovers. If the residence has a large enough storage tank, no supply limitation may be felt. However, where the residence is served by a small tank or no tank at all, elevated or even normal water use may result in a temporary water shortage. Provisions for water supply will be necessary in such cases, if drawdown is to be applied.

Maintenance needs are variable and generally limited for this technique. Dams (including berms, concrete walls and outlet structures) should be kept in good repair (see Office of Dam Safety regulations). Any areas of shoreline erosion should be stabilized.

<u>Mitigation</u>
Mitigation measures to minimize undesirable environmental impact from this method focus on maintaining the water level in non-target areas where feasible and adjusting the timing and duration of drawdown to minimize impacts on sensitive organisms. Water level can be maintained in inlet streams and along emergent wetland interfaces with temporary dams (e.g., sandbags, jersey barriers) if necessary, but blocking access by fish and wildlife may be an issue in such cases. Starting and ending the drawdown at times that minimize interference with migration and spawning activities is desirable, but not all biota will move or mate at the same time, creating possible conflicts. The MDFG suggests that many impacts can be lessened by controlling the timing and rate of drawdown and refill to permit spawning, or staggering drawdowns every other year or more to lessen impacts on fish recruitment. Restricting drawdown to late fall and winter will minimize impacts to many species. Maintenance of an adequate pool with sufficient oxygen will be critical to successful overwintering by most organisms. Water can be provided to anyone whose well is impaired during the drawdown, but ultimately a deeper well will be needed if drawdown is to be applied repeatedly.

4.2.7 Regulations

4.2.7.1 Applicable Statutes

In addition to the standard check for site restrictions or endangered species (Appendix II.), a Notice of Intent must be sent to the Conservation Commission with a copy to the Department of Environmental Protection Regional Office. If the proposed project occurs within an Estimated Habitat of Rare Wildlife in the most recent version of the Natural Heritage Atlas, a copy of the Notice of Intent must be submitted to the Natural Heritage and Endangered Species Program

(NHESP) within the MDFG for review (Appendix II). If the proposed project occurs within a Priority Habitat of Rare Species in the most recent version of the Natural Heritage Atlas, the project proponent must submit project plans to the NHESP for an impact determination. An Order of Conditions must be obtained prior to work.

The Department of Environmental Protection has issued a document (DEP, 2004) entitled "Guidance for Aquatic Plant Management in Lakes and Ponds as it relates to the Wetlands Protection Act" (Policy/SOP/Guideline# BRP/DWM/WW/GO4-1, effective April 8, 2004). This document provides guidance on preparation and review of Notices of Intent and includes information about projects subject to Wetlands Protection Act regulations, a description of limited projects and estimated habitats of rare wildlife. In addition it provides:

- Information required to evaluate impacts for all projects
- Additional information required for draw down projects
- Additional information required for herbicide/algaecide projects
- Additional information required for harvesting projects
- Additional information required for dredging projects
- Managing pioneer infestations of invasive plants
- Other related permits/licenses/certifications

Appendices provide sample conditions that conservation commissions can use in approving projects subject to the Wetlands Protection Act, guidance for complying with a wildlife habitat evaluation, and protocols for application of the herbicide 2,4-D to lakes and ponds. For further information on all permits see Appendix II.

4.2.7.2 Impacts Specific to Wetlands Protection Act

The following overall impact classification is offered as a generalization of impacts, with clarifying notes and caveats as warranted:

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

4.2.8 Costs

Drawdown is a relatively inexpensive lake management technique, if the means to conduct a drawdown are present. Where an outlet structure facilitates drawdown, the cost may be as little as what is required to obtain permits, open and close the discharge structure, and monitor. If pumps are required to lower the water level, the drawdown will be more expensive. The total project cost for the restoration of Lake Lashaway was $397,600, covering mainly the construction of an outflow structure (Haynes, 1990). The cost of a new outlet structure to facilitate drawdown of Forge Pond in Westford was about $80,000, including engineering and permitting costs (Turner, Westford CC, pers. comm., 1995). It is unusual to alter a dam these days for less than $100,000, but if the structure already supports water level control, costs of $3,000 to $10,000 per year would be a reasonable expectation for permitting and monitoring. Drawdowns of the past few decades had no monitoring requirement, but Conservation Commissions, the MDEP and the MDFG are requesting pre- and post-drawdown monitoring more often now. Where protected species are present, permitting may be difficult and monitoring and mitigation costs can escalate.

4.2.9 Future Research Needs

Evaluation of drawdown impacts on non-target species is a serious shortcoming in drawdown planning and permitting, and requires a major effort involving many species in multiple lakes over multiple drawdowns. A major program of study is needed at the state level. All referenced data from the MDFG on negative or positive impacts should be put in a report format and reviewed. Additional field studies should be sponsored by the Executive Office of Environmental Affairs as part of its Lake and Pond Initiative.

4.2.10 Summary

Drawdown is an effective and relatively inexpensive method to control susceptible rooted plants, and many lakes in Massachusetts have been lowered annually for decades. However, it also has substantial potential to cause adverse impacts to non-target organisms. Although it may need to be implemented on an annual or biennial basis in order to maintain effectiveness, the cost is limited to permitting and monitoring expenses, provided there is an existing outflow structure in place. Where the outflow structure must be altered, siphons installed, or pumps deployed, the cost will rise but may still be tolerable. Regulatory acceptance depends on identifying and minimizing potential impacts to a wide variety of aquatic resources and uses.

Drawdown can be an advantageous method for aquatic plant control where the target plants depend upon vegetative structures for reproduction and overwintering. It is not labor intensive and when performed in the winter will not interrupt most recreational lake uses or interfere with most ecological functions. Drawdown presents an opportunity for repairing docks and boat ramps, or employing other methods of lake management such as dredging or benthic barriers.

The disadvantages of drawdown are linked to reduced areal coverage by water and lowered water volume. Water supply from the lake or wells may be impaired, and species that depend upon the exposed area may be affected. Changes in exposed sediment features may affect water quality after refill. Downstream resources may be impacted as well. Repeated drawdown may result in the invasion of plants that are resistant to drawdowns, some of which may be nuisance species. Failure to refill the lake in time for spring spawning may affect fish populations. None of these impacts may be manifest, and various mitigative means may avoid or minimize them. However, it is difficult to predict the ecological impact to many non-target organisms, due largely to the lack of published information and site-specificity of many possible impacts. As the Wetlands Protection Act requires assurance that resources will not be significantly and adversely impacted, applicants must learn much about the targeted lake system. Monitoring can indicate impending impacts, but more scientific research is needed to answer long-standing questions about drawdown effects.

4.3 HARVESTING

4.3.1 Overview

Harvesting of nuisance aquatic plants includes a suite of techniques that vary in sophistication and cost from simply hand pulling of weeds to large-scale mechanical cutting and collection of plants. Harvesting can be an effective short-term treatment to control the growth of aquatic plants. With repeated application at appropriate intervals, it can produce long-term shifts in the plant community, but it is unlikely to reduce long-term plant density substantially. Harvesting is generally used seasonally to remove vegetation that limits lake uses such as boating and swimming. A significant nutrient reduction resulting from macrophyte harvest is rare (Engel, 1990, Cooke et al., 1993a). Harvesting is occasionally used to remove algal mats from water, but this is usually a very short-term method and is not practical on a large scale (McComas, 1993).

There are many variations on mechanical removal of macrophytes. Table 4-1 breaks these varied techniques into hand pulling, suction harvesting, cutting without collection, harvesting with collection, rototilling, and hydroraking. These techniques are often cited as being analogous to mowing the lawn (cutting or harvesting), weeding the garden (hand pulling), or tilling the soil (rototilling or hydroraking), and these are reasonable comparisons. Mechanical management of aquatic plants is not much different from managing terrestrial plants, except for the complications imposed by the water.

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

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