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THE EFFECTS OF WINTER DRAWDOWN ON MACROPHYTES IN CANDLEWOOD LAKE, CONNECTICUT

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ABSTRACT

Between 1980 and 1983 dense beds of the macrophyte *Myriophyllum spicatum* L. became well established throughout Candlewood Lake, Conn., at the expense of a once diverse native flora. During 1983–84 and 1984–85 winter drawdowns of 2 and 2.7 m, respectively, were attempted to control the densities and further spread of the *M. spicatum*. After the initial drawdown, weed biomass was reduced by more than 90 percent in shallow sites; however, little change in densities occurred in deeper areas. The deeper drawdown resulted in a further reduction in *M. spicatum* densities, although it remained the dominant plant at depths greater than 2.5 m. *Najas minor allioni* became the dominant macrophyte in shallow areas, presumably developing from seeds.

INTRODUCTION

The genus *Myriophyllum* is a member of the Haloragaceae, the watermilfoil family, and is composed of 12 species (Aiken, 1981). *M. spicatum*, Eurasian watermilfoil, overwinters as root crowns, grows to depths of 3 m, has an enlarged stem below the inflorescence with leaves divided into 5 to 24 sections, and has floral bracts equal to or longer than the fruits (Aiken et al. 1979; Aiken, 1981). *M. spicatum* was introduced into North America during the late 19th century in the Chesapeake Bay area and spread rapidly during the 1960s and 1970s, reaching British Columbia, Canada, by 1970 (Aiken et al. 1979). *M. spicatum* succeeded partly because it can outcompete and displace native aquatic macrophytes (Adams and Prentki, 1982). For example, in Lake Wingra, Wis., once Eurasian watermilfoil began to grow, it completely replaced *Vallesneria americana* Michx. and four *Potamogeton* spp. populations (Nichols and Mori, 1971). The ability of *M. spicatum* to outcompete other macrophytes is attributed to its physiology and growth habit. Growth of new *M. spicatum* plants from seeds is rare; milfoil initiates growth from an existing thallus (root crown and/or short evergreen branches) early in the growing season at low temperatures, spreads rapidly (having stored nutrients throughout the winter (Aiken et al. 1979)), and canopies at the surface, effectively cutting down light penetration to macrophytes below it (Adams and Prentki, 1982). *M. spicatum*'s ability to mobilize phosphorus from the sediments may give it another advantage over the native species (Adams and Prentki, 1982).

Candlewood Lake, the largest lake in Connecticut, was built in the 1920s for use as a pump/storage facility by the Connecticut Light and Power Company. Since 1982, dense growths of *Myriophyllum spicatum* have created

extensive recreational and aesthetic problems in the lake. This situation directly contrasted with that which existed between 1978 and 1980 when Connecticut's Department of Environmental Protection reported a rich and diverse community of macrophytes (Dep. Environ. Prot., 1983). No single aquatic vascular plant dominated in the lake and *Myriophyllum spicatum* was, at most, listed as a common weed (Dep. Environ. Prot., 1983). However, by 1983, the density of *M. spicatum* had greatly increased, essentially forming a monoculture in most areas of the lake.

A series of winter drawdowns to freeze the weedbeds were proposed as a possible control mechanism. During the 1983–84 and 1984–85 winters, the lake level was lowered 2 m and 2.7 m, respectively. The present study compared the macrophyte densities (especially of *M. spicatum*) and species diversity before and after each drawdown.

METHODS

The density and distribution of macrophytes were determined along transects at three sites in Candlewood Lake: Lattin's Cove, New Fairfield Bay, and Danbury Bay. During 1983, quantitative measurements were taken (twice) only at the Lattin's Cove site. Qualitative observations were recorded at the New Fairfield and Danbury Bay sites. Each site was surveyed two and three times during 1984 and 1985, respectively.

The plants were harvested via scuba at meter intervals along a 30 m transect positioned perpendicular to the shoreline. All macrophytes along each meter and within 10 cm of the transect were harvested and bagged underwater. In the laboratory, the plants were identified, dried at 100°C for a minimum of 48 hours, and the dry weights determined. The locations of the transects were noted to avoid sampling area overlap. Each transect was parallel to but at least 10 m away from the previous transect. The water depth was measured at 5 m intervals along each transect.

Although the transects were completed to only 18 m from shore in Danbury Bay, weed densities remained approximately the same much farther out into the bay. Sampling was terminated at 18 m because of heavy boating traffic.

SITE DESCRIPTIONS

Lattin's Cove, located at the southeastern end of the lake, was the shallowest of the three sites, with a maximum depth of 5 m. The slope of the bay was very gradual (Fig. 1), especially at the study site, and the sediment was

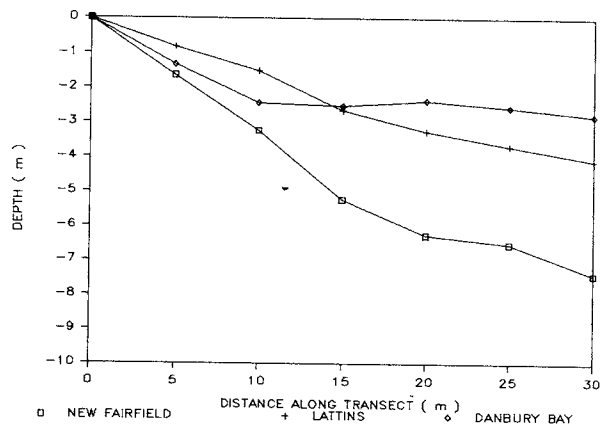


Figure 1.—The mean depth contours along transects in Lattin's Cove, New Fairfield Bay, and Danbury Bay, Candlewood Lake, Conn.

composed of very fine muds and silt.

New Fairfield Bay, located on the western side of the lake midway along its length, was the deepest site, with a maximum depth of 11 m. The slope was relatively steep, reaching 5 m in depth at approximately 15 m from shore (Fig. 1). The sediment was more consolidated than at the other sites.

The Danbury Bay site, located in the southwestern end of the lake, had a low slope similar to that in Lattin's Cove (Fig. 1). The water depth was about 3 m at a distance of 30 m from shore, maintaining that depth past the 30 m mark. Danbury Bay, one of the areas of the lake most used for recreation, had a considerable buildup of fine sediments similar to Lattin's Cove.

RESULTS

Lattin's Cove

During 1983, prior to the first drawdown, the mean biomass (dry weight) of macrophytes along the transects was 44 g/m² (Fig. 2). Over 90 percent of the biomass consisted of *Myriophyllum spicatum*, the dominant plant in the cove. In 1984, after the 2 m drawdown, the mean biomass of macrophytes had significantly decreased to 1.4 g/m², resulting in a 97 percent drop in plant matter (Fig. 2). The large decrease in weed biomass, especially of *M. spicatum*, was widespread throughout the cove. During 1985, after the 2.7 m drawdown, the mean biomass along the July and August transects was 22.7 g/m², significantly

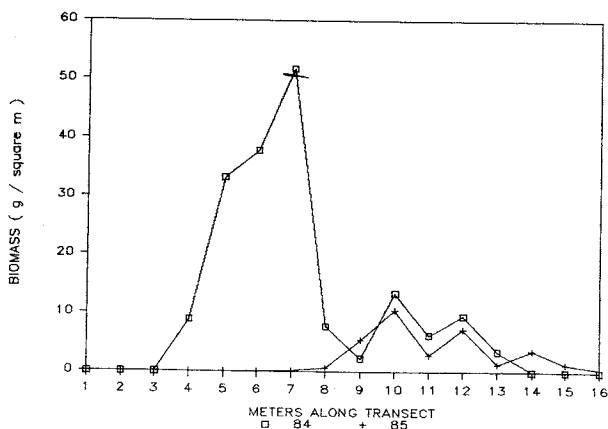


Figure 3.—The mean distribution of macrophyte biomass (g dry weight/m²) along transects in New Fairfield Bay for 1984 and 1985.

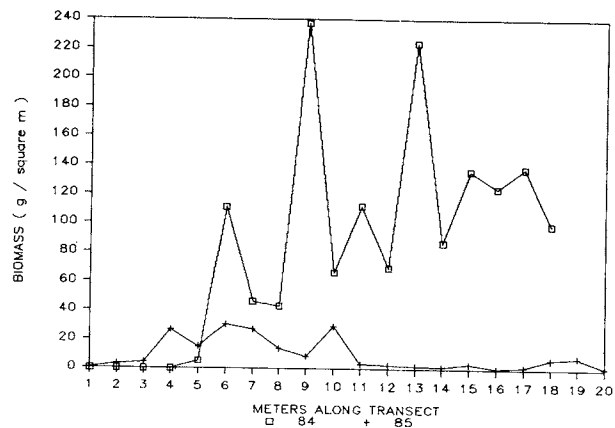


Figure 4.—The mean distribution of macrophyte biomass (g dry weight/m²) along transects in Danbury Bay for 1984 and 1985.

greater than in 1984, but still 48 percent less than the predrawdown level. The increase during 1985, observed throughout the cove, was primarily from the growth of *Najas minor* and, to a lesser extent *N. flexilis* (Willd.) Rostk, and Schdmit. The levels of *M. spicatum* were still considerably reduced. In the zone between 0.5 and 2.5 m in depth (2 to 15 m along the transect), *Najas* spp. accounted for approximately 90 percent of the total plant biomass. At depths greater than 3 m, *M. spicatum* was still the dominant macrophyte. During the early part of the 1985 growing season (May–June), an extensive algal mat consisting of *Cladophora* and *Oedogonium* sp. was found throughout Lattin's Cove; however, it had died back by late July.

During 1983 and 1984, plant densities were extremely low near shore (along the first 8 m of the transects) in water depths less than 0.5 m. However, in 1985 this zone supported some growth of *Najas* spp.

New Fairfield Bay

During 1984, after the first drawdown, the mean biomass of aquatic vascular plants along the transects was 13.4 g/m² with a maximum in a band roughly 4 to 8 m from shore in 1.8 to 2.5 m of water (Fig. 3). Between approximately 8 and 12 m along the transects where the water level increased from 2.5 to 3.5 m, the weed biomass was significantly lower than between the 4 and 8 m band. Beyond 12 to 14 m from shore, there was no macrophyte growth.

In 1985, the mean macrophyte biomass along the July and August transects was 6.7 g/m², a 50 percent decrease compared to 1984 (Fig. 3). The dense band of macrophytes found in 1984 between 4 and 8 m was not found in 1985. Macrophyte densities beyond 8 m from shore were similar for 1984 and 1985.

Myriophyllum spicatum was the dominant macrophyte in New Fairfield Bay during the length of the study. *Vallesneria americanis* and *Potamogeton* spp. were present, but of minor importance; however, unlike at the other sites, *Najas* spp. were not recorded.

Danbury Bay

Weed densities were greatest during the study in Danbury Bay (Fig. 4). In 1983, plant densities were so great that harvesting along the transects via scuba was not possible. In 1984, average weed densities of 83 g/m², substantially greater than at the other sites, were recorded along with transects. The 1984 densities were lower than those observed before the first drawdown in 1983.

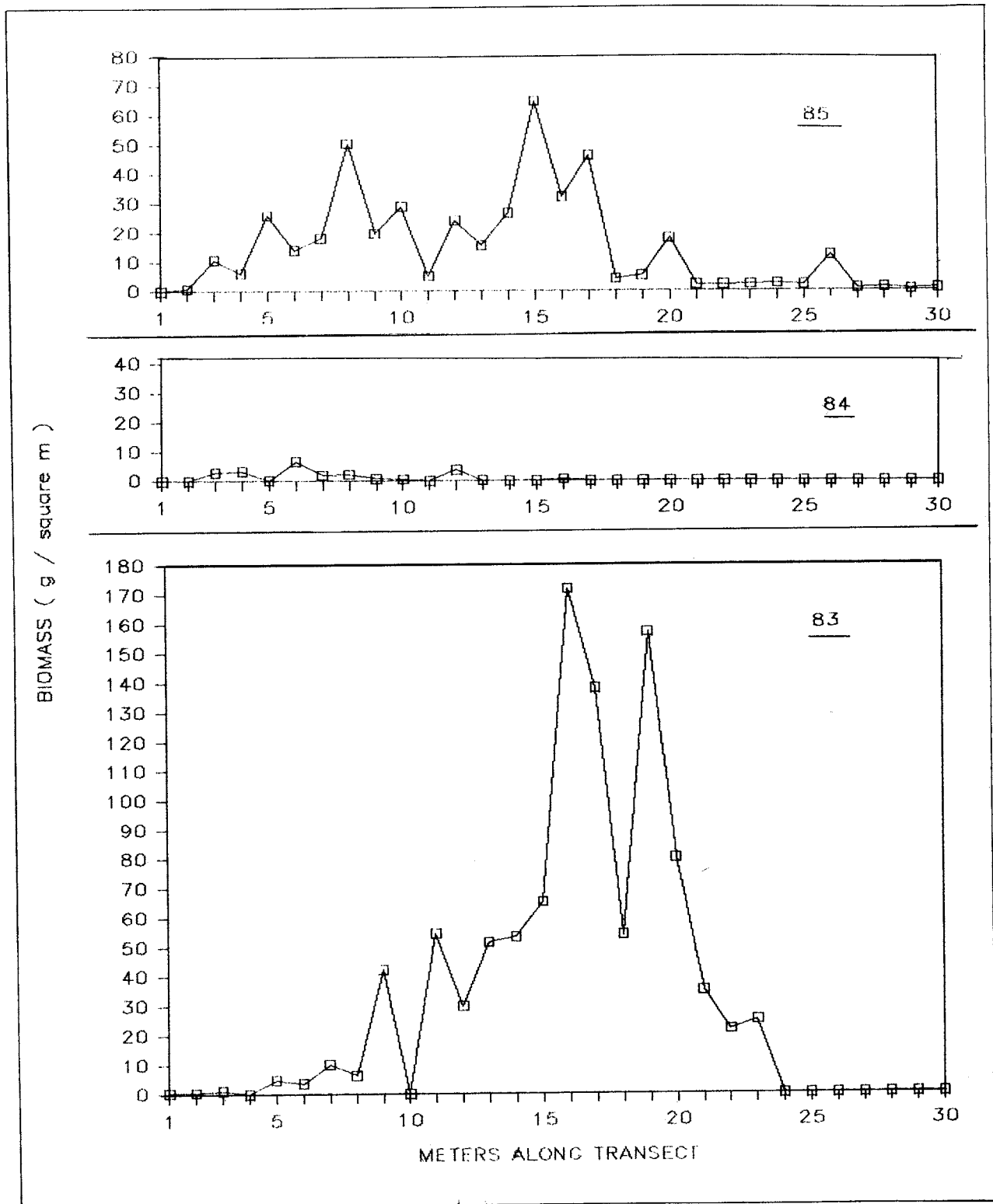


Figure 2.—The mean distribution of macrophyte biomass (g dry weight/m²) along transects in Lattin's Cove for 1983 to 1985.

In 1985, mean macrophyte densities of 13.3 g/m² were found along the transects, an 84 percent reduction compared to 1984 (Fig. 4). As recorded in Lattin's Cove, dense algal beds occurred from May to June, and *Najas minor* and *N. flexilis* populations became established in shallow waters following the second drawdown. *Myriophyllum spicatum* remained the dominant plant in deeper waters.

In Danbury Bay, unlike Lattin's Cove, *M. spicatum* was codominant with *Najas* spp. in shallower waters.

DISCUSSION

Clearly, from the recorded densities in Candlewood Lake during 1983, *Myriophyllum spicatum* was probably more

than just an aesthetic problem and a nuisance to recreational activities. It could have had an important role in cycling nutrients, especially phosphorus, between the water and the sediments. In several surveys, *M. spicatum* has been found to accumulate the majority of its nutrients from the sediments (Barko and Smart, 1980, 1981). The phosphorus is mobilized for plant growth, but a portion can be lost to the water column during active growth (Wetzel, 1983). A large percentage of the phosphorus is released when the plant canopies and sloughs off its lower leaves during the growing season and in the fall as the plants senesce. The released phosphorus could in turn enhance algal blooms (Barko and Smart, 1980). Adams and McCracken (1974) found that in Lake Wingra, Wis., a lake with densities of *M. spicatum* similar to Candlewood Lake, the turnover of phosphorus exceeded the peak seasonal biomass of *M. spicatum*.

Concurrent with the large increase in aquatic weeds in Candlewood Lake since 1980, phosphorus concentrations have increased. Siver (1984) found 75 percent and 35 percent more phosphorus in Danbury Bay and New Fairfield Bay, respectively, than was found in 1978–80 by the Connecticut Department of Environmental Protection (1983). The dense growth of *M. spicatum* could account for the increased phosphorus levels, especially in the shallow bays.

During the 1970s, *Myriophyllum spicatum* was not an abundant plant in Candlewood Lake (Dep. Environ. Prot., 1983). For example, even though *Ceratophyllum demersum* was the most abundant macrophyte in Lattin's Cove during 1979, by 1983 *M. spicatum* had become dominant, and *C. demersum* was absent. Invading and predominating has been *M. spicatum*'s pattern since its introduction and spread throughout North America (Aiken, et al. 1979).

In Candlewood Lake, the 2 m (1983–84) winter drawdown successfully decreased weed biomass in shallow Lattin's Cove (97 percent reduction) and, to a lesser extent, in Danbury Bay, but it had little effect at the deeper New Fairfield Bay site. Bottom topography evidently made the difference. Lattin's Cove, a shallow bay, was extensively drained during the 1983–84 drawdown, exposing the weedbeds to freezing. In addition, many of the exposed weedbeds were far from the lowered lake surface. Because New Fairfield Bay is much steeper, many of the exposed weedbeds were close to the lowered lake surface. Deeper beds, especially in the band between 4 and 8 m, were not exposed. Exposed macrophytes in New Fairfield Bay may not have frozen because water seeped into the sediments under the plants.

The second, deeper drawdown (2.75 m) had an even greater effect on the *Myriophyllum spicatum* populations in Candlewood Lake than did the 1983–84 drawdown. In Lattin's Cove, the 1985 densities of *M. spicatum* were as low in exposed areas as they were in 1984. Macrophyte densities were reduced 84 percent after the 1984–85 drawdown in Danbury Bay (Fig. 4). The reduction in *M. spicatum* plants in Danbury Bay was even greater since this taxon accounted for all the biomass along the transects in 1984, but was codominant with *Najas* spp. in 1985. The thick band of *M. spicatum* plants in New Fairfield Bay observed during 1983 and 1984, fully exposed in the 1984–85 winter, was not found in 1985. At all three sites, *M. spicatum* populations beyond the 2.75 m drawdown point were not affected, and, therefore, the deeper beds remain in the lake.

Based on the reduction in *M. spicatum* plants in Candlewood Lake after the two drawdowns, we believe that drawdowns will effectively control this macrophyte. Consecutive drawdowns, low enough to expose the weedbeds, have effectively controlled aquatic weeds (Richardson, 1975). Submerged aquatic plants generally do not

survive where drawdowns persist for several years or occur frequently during one growing season (Davis and Brinson, 1980). *Myriophyllum spicatum* has been shown to be affected by exposure to freezing temperatures since it overwinters as a mass of roots with short evergreen shoots (Aiken, et al. 1979). Stanley (1976) reported that *Myriophyllum* plants were killed when exposed to freezing temperatures continuously for 96 hours. Even though single drawdowns increased the plant biomass in Lake Miccosukee, Fla., successive drawdowns have effectively controlled *Myriophyllum* (Tarver, 1980). In addition, winter drawdowns have proved to be an excellent means of controlling *Myriophyllum* and other aquatic vascular plants in Connecticut (Dep. Environ. Prot., 1983).

Questions concerning the establishment of *Najas* spp. populations in 1985 are most interesting and perplexing. Not only were *Najas* spp. the most abundant plants in Lattin's Cove and Danbury Bay in 1985, but they were also dominant in many other areas of the lake (Dep. Environ. Prot., 1985; Northeast Utilities, 1985). *Najas flexilis* was found but was not dominant in Candlewood Lake during 1978–80 before any major drawdown (Dep. Environ. Prot., 1983). Neither *N. minor* nor *N. flexilis* was found at the study sites during 1983 and 1984. The possibility of the *Najas* plants invading from other populations is doubtful since no such population existed near either the Lattin's Cove or Danbury Bay sites. In addition, if *M. spicatum* plants were killed by freezing, we would expect the same fate for any vegetative *Najas* plants.

The most logical explanation is that the *Najas* populations developed from seeds in the sediments. Only by this means could the plants have spread in such a short period. *Najas* primarily reproduces from seeds, not from overwintering vegetative organs (Tazik, et al. 1982), but, if the *Najas* beds developed from a seed source, why did seed germination not occur during 1983 or 1984? Perhaps before the first drawdown in 1983, the *Myriophyllum spicatum* plants, which begin growth early in the season from overwintering root crowns, outcompeted the *Najas* spp. and prohibited seed germination. This hypothesis, if correct, still does not explain why the seeds did not germinate in Lattin's Cove during 1984 when macrophyte growth was minimal (Fig. 2). Perhaps the seeds required the more extensive cold period during the 1984–85 winter to germinate. Further investigation is needed to explain the abundance of *Najas* spp.

If the preceding hypothesis is true, yearly drawdowns may promote the growth of *Najas* via seed germination in shallow water while preventing the establishment of *Myriophyllum spicatum* populations by freezing the overwintering root crowns. Such a hypothesis is supported by previous workers who found *Najas flexilis* to be unaffected by drawdowns (Tazik et al. 1982; Nichols, 1975). Tazik, Kodrich, and Moore (1982) believed *Najas flexilis* survived winter drawdowns in a Pennsylvania lake because it re-established itself via seeds. Nichols (1975) actually found enhanced *Najas flexilis* populations after a drawdown.

Without continued drawdowns, *Myriophyllum* plants from the deep populations may re-infest shallow areas, especially since they grow rapidly early in the season. A similar situation was documented in Lake Miccosukee, Fla., where a species of *Myriophyllum* (variable leaf milfoil) rapidly recolonized shallow areas by unaffected *Myriophyllum* plants growing in deeper water (Tarver, 1980).

Although the macrophyte densities were greater in Lattin's Cove in 1985 than in 1984 because of *Najas* spp. growth, they were still significantly less than those in 1983 when *M. spicatum* dominated. Because *Najas* begins growth later in the season, is a submerged bush plant, and does not canopy, it may cause less of a recreational prob-

lem in Candlewood Lake.

We also questioned why *Najas* spp. populations did not become established in New Fairfield Bay. Although further study is needed, the nature of the sediment may be relevant. In Lattin's Cove and Danbury Bay, the sediment is mostly loose, unconsolidated silt; however, at New Fairfield Bay, the bottom is consolidated with more sand and rock. Alternatively, perhaps a *Najas* seed source did not occur in New Fairfield Bay and was therefore exposed to severe freezing because of the bottom topography.

Both chemical treatment and harvesting have successfully controlled *Myriophyllum*. Eurasian watermilfoil is highly susceptible to 2,4 dichlorophenoxy acetic acid (2,4-D) (Aiken et al. 1979). Large-scale and repeated harvesting in Candlewood Lake would not be economically feasible. In summary, since the drawdowns appeared to have no adverse effects on the lake (either on phosphorus or chlorophyll concentrations, phytoplankton levels, or water clarity), they seem the most logical means of controlling *M. spicatum* populations.

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