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Investigations into Eurasian Watermilfoil Management by Deep Drawdown at Candlewood Lake

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Introduction

In 1985, a biennial deep (10 foot) drawdown was instituted to manage the aquatic invasive plant *Myriophyllum spicatum* (Eurasian watermilfoil) established in Candlewood Lake. This approach resulted from collaborations of a technical committee comprised of representatives from Connecticut Light & Power (CL&P), the Connecticut Department of Environmental Protection (CT DEP), and the Candlewood Lake Authority (CLA). Management strategies were also supported by studies conducted by Western Connecticut State University researchers (Siver et. al., 1986) as well as scientists from Connecticut Light & Power (CL&P; unpublished data) which was the owner of the hydro facilities at that time.

Every other year from 1985 through the mid 1990s, the lake level was lowered to a minimum of 420 feet above sea level (CL&P datum) by early January and generally kept there for approximately 60 days or longer (Table 1). During that time it was common for the level to be lower than 419 feet above sea level. On occasion lake level was lower than 418 feet above sea level. Normally, in late February or early March CL&P, who owned and operated the lake as part of a hydroelectric facility, began refilling Candlewood to its summer recreation level which falls between 427 and 428.5 feet above sea level (CL&P datum).

This technique, implemented biennially, was conducted in a fairly consistent manner up through and including 1995 (Table 1). Starting in the later part of the 1990s the characteristics of the deep drawdown changed, starting with the duration at or below 420 feet being reduced (1997 and 1999).

Table 1. Summary of historical lake levels from 1980 thru 2007. No. Days ≤ 420 denotes number of days that the lake level was at or below 420 feet above sea level (CL&P datum) from January 1st thru December 31st. No. Days ≤ 419 is a subset of No. Days ≤ 420. Normal recreation levels at Candlewood are approximately 427.5 to 429 feet above sea level (CL&P datum). Lake level data provided by CL&P, Northeast Generation Services, and FirstLight Power Resources.

Year	No. Days ≤ 420	No. Days ≤ 419	Notes
1985	62	34	Down past 420 all of Jan & Feb
1986	11	0	All December - really part of '87 drawdown
1987	64	0	
1988	0	0	
1989	77	53	Were 31 days ≤ 418
1990	0	0	
1991	68	44	Jan, Feb, into March
1992	57	0	
1993			No data for 93
1994	0	0	
1995	67	61	Jan, Feb, into March; 21 days ≤ 418
1996	0	0	
1997	21	0	
1998	22	17	All days were in Dec of 98
1999	25	18	All in January; nothing in February
2000	0	0	
2001	2	0	There were 69 days ≤ 421
2002	1	0	In December
2003	61	47	Start mid Jan & well into March
2004	0	0	
2005	3	0	Only 23 days ≤ 421; 3 days ≤ 420 in Dec
2006	5	3	All in December
2007	61	2	All Jan, Feb and early March

The lake has seen notably fewer days below the 420 foot level in the current decade with the exception of the 2003 and 2007 deep drawdowns which did have 60+ days duration below a depth of 420 feet above sea level. In 2003, the 419 foot elevation was exceeded 47 days. The 2009 drawdown will also fall below 420 feet above sea level, but probably well short of a 60 day duration.

Beginning in 2005, three consecutive years of deep drawdown were thought to have been implemented by the power company. The second and third of the three came about, in part, because of the perceived ineffectiveness of each preceding year's deep drawdown with the 2007 event finally yielding more effective milfoil control in the following recreation season. However, a closer examination of lake level data revealed that of the three consecutive years only 2007 was similar to the more traditional deep drawdowns of the mid 1980s through mid 1990s (Fig. 1).

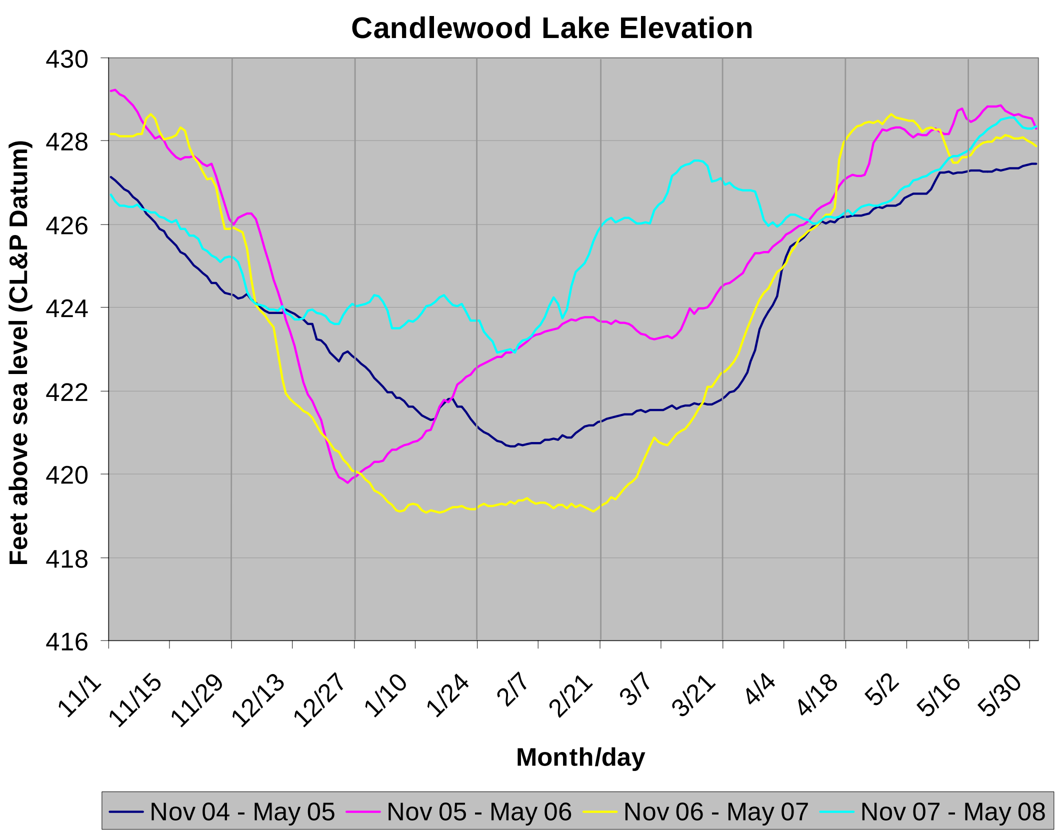

Figure 1. Elevations of Candlewood Lake from November 1st through May 30th for 2004 to 2008.

Good years – Bad years: Anecdotal Data

Quantitative data on the efficacy of the deep drawdown at Candlewood Lake is limited; anecdotal data is plentiful. Anecdotally, there was little concern about weed densities among the lake community from the mid 1980s through the mid 1990s. It appeared that the deep drawdowns provided the lake community an acceptable level of weed management and assurance that all that could be done was being done in the best interest of meeting the needs of weed control and of the protection of lake ecosystems. In contrast, the community expressed great concern regarding the invasiveness of *M. spicatum* for much of the current decade with the exception of 2003 and 2007, and to a lesser extent during the latter part of the 1990s. Their concerns may have weighed into decisions by the power company to consider yearly deep drawdowns in consecutive years of 2005, 2006 and 2007.

In the winter of 2008, a shallow drawdown was performed (see Nov 07 – May 08 data in Fig. 1). In the following summer, many in the community characterized milfoil densities as being as high as any observed in recent memory and expressed great concern.

Good years – Bad years: Quantitative Data

From 1985 through 2000, CL&P collected annual quantitative data on weed densities at several locations in Candlewood Lake. Although a much more thorough analysis of the CL&P data is warranted, it does appear that a correlation exists between deep drawdowns and weed densities from 1985 through 2000. Zone III weed densities at the Lynn Deming site, for example, were much lower following deep drawdowns in contrast to densities in the same zone following a shallow drawdown (Fig. 2). It is important to note that based on the weed density data in 1997 and 1999 from all three of CL&P's sampling sites, deep winter drawdowns of shorter duration (between 21 and 25 days) seemed to be effective. However, weed densities in 1998 that followed a shallow drawdown were, in general, higher than observed in many of the previous years, regardless of whether a deep or shallow drawdown was performed.

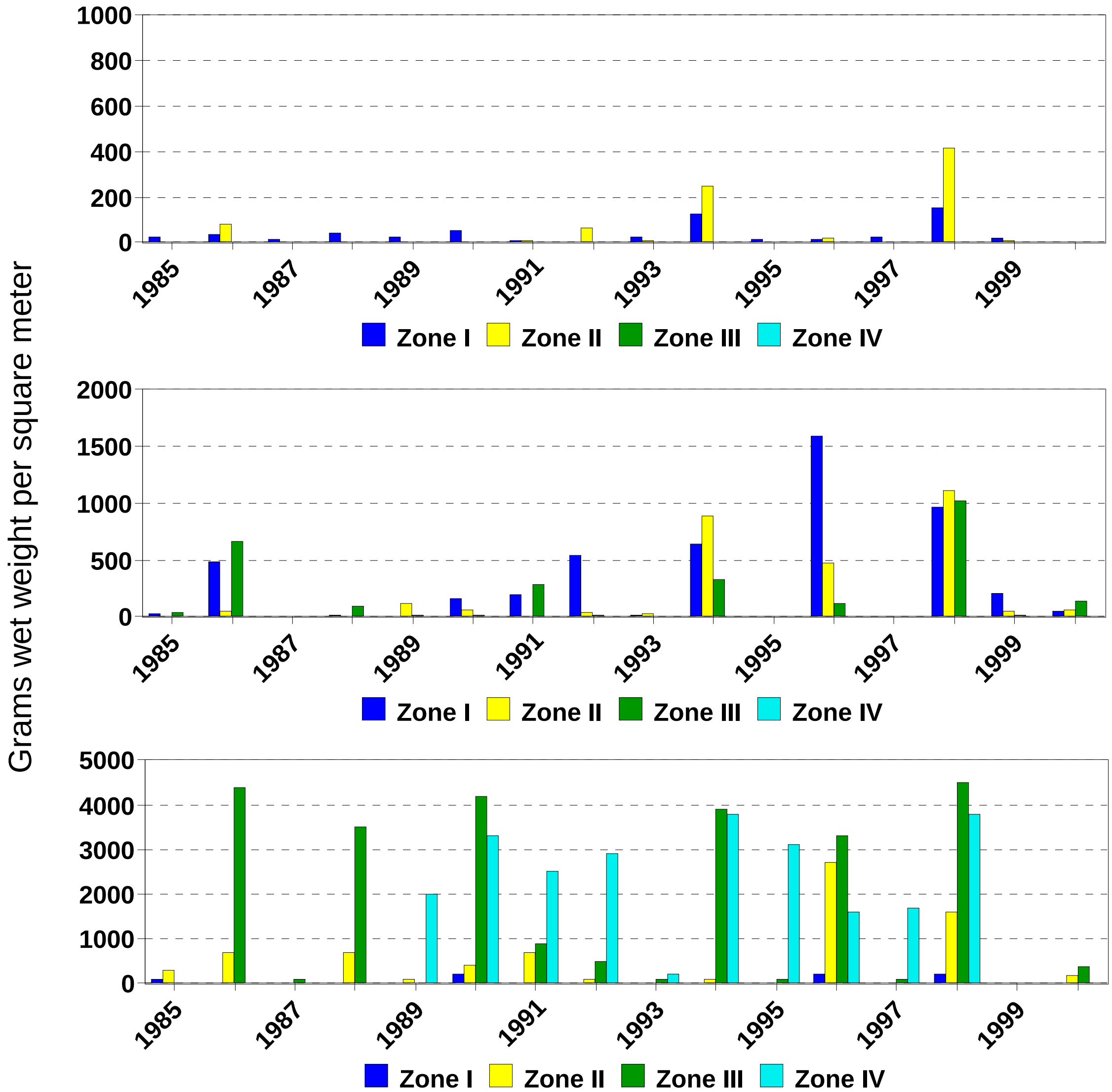

Figure 2. Weed density data collected by CL&P from 1985 through 2000. The top panel is data collected at a site in Squantz Cove, New Fairfield; the middle panel is data collected at a site in New Milford; and the bottom panel is data collected from the Lynn Deming site in New Milford. Note that the scale for grams wet weight per square meter is different in each panel. Zone I elevation range = 423' above sea level and above. Zone II elevation range = 421' to 423' above sea level. Zone III and IV elevation ranges = 419' to 421' and 418' to 419' above sea level, respectively.

Candlewood Lake is a pumped-storage reservoir built in the late 1920s for hydroelectricity production. As such, an important management plan required in the operating license issued by Federal Energy Regulatory Commission to the power company in 2004 was the Nuisance Plant Monitoring Plan. As approved by FERC, the licensee of the hydro project (currently FirstLight Power Resources or FLPR) is required to have *M. spicatum* mapped and quantified annually on Candlewood and in alternate years at Lakes Lillinonah and Zoar.

In 2005, a private consulting company who utilized four days of field reconnaissance and a modeling method based on water depth and substrate was contracted to map weeds in Lakes Candlewood, Zoar, and Lillinonah. While providing maps and descriptive statistics on milfoil stand properties, no actual total coverage of milfoil was provided (Kleinschmidt, 2006). In 2005 and 2006, the Invasive Aquatic Plant Program (IAPP) at the Connecticut Agricultural Experiment Station (CAES) also mapped aquatic vegetation in Candlewood Lake for the CLA as part of their statewide program (CAES, 2009). Starting in 2007, the CAES began conducting the weed mapping for FLPR as part of the FERC license requirement. CAES performed Trimble GPS-aided mapping over several weeks on Candlewood alone in their assessments. In addition to maps of weed beds, data on total area coverage of invasive and native plants species was provided. From surveys conducted in 2005/2006, 2007, and 2008 CAES reported total acres of *M. spicatum* as 275, 221 (Bugbee et. al., 2007), and 451 acres (Bugbee, 2009), respectively.

Characteristics of Effective Drawdown

A survey of some of the literature on drawdowns for weed management was conducted to develop some understanding of the optimal conditions for effective control. Literature surveyed included peer-reviewed scientific papers and text, power company websites, municipal websites, websites of state environmental agencies, reports from environmental consultants, and national environmental agency websites.

From this survey surfaced several important characteristics of effective control of *M. spicatum* by drawdown. First, to kill milfoil during a lake drawdown requires that the plant is exposed to the freezing air temperatures for a prolonged duration; that the plant and root crown must not be insulated by snow, water, leaves or collapsed milfoil plants; that the plant and the soil surrounding the root crown are de-watered or desiccated; that a prolonged drawdown duration increases the probability of exposure to adequate periods of freezing air (Goldsby et. al., 1978; Cooke, 1980; Harvard, 2000; Mattson et. al., 2003; Entergy, 2004a,b; WA DOE, 2009a,b).

Desiccation of the plant and plant roots is compromised by rain or water runoff and the ability of lake sediments to retain water and therefore Mattson et. al. (2003) recommended that after reaching the targeted drawdown depth, the water level be maintained there to prevent re-watering of the milfoil.

Cooke (1980) suggested that the duration at target depth should be one to two months. At one location duration was for three months (Entergy, 2004a). The greater duration period increases the probability of a four to five day period of both freezing and dry conditions to occur, which reportedly kills the root crown of the plant (Environment Canada, 2003).

Lastly, it was reported that in Massachusetts only one in three winter seasons had all the environmental factors simultaneously for a successful milfoil kill during their deep drawdowns (MA DCR, 2004). Other lake locations have decided to have deep drawdowns annually or two to three years in a row (Harvard, 2000; Mattson et. al. 2003; Entergy, 2004, WA DOE, 2009a,b).

Local Winter Climatic Conditions

The review above prompted an examination of local climatic conditions in conjunction with lake level, from November 1st through May 30th between 2004 and 2007. Lake levels were compared to temperature, rainfall, and snowfall for those periods (Figs. 3, 4, 5). Some notable observations included the following. Temperatures during the 2004/2005 drawdown were below freezing from mid January to early February and then again from mid February to early March. During the 2005/2006 winter shorter periods of sub freezing temperatures were observed. In 2007 a prolonged stretch of freezing temperatures were observed starting in mid January and lasting through mid February. There appeared to be more small (< 1 inch) rain events during the 2004/2005 and

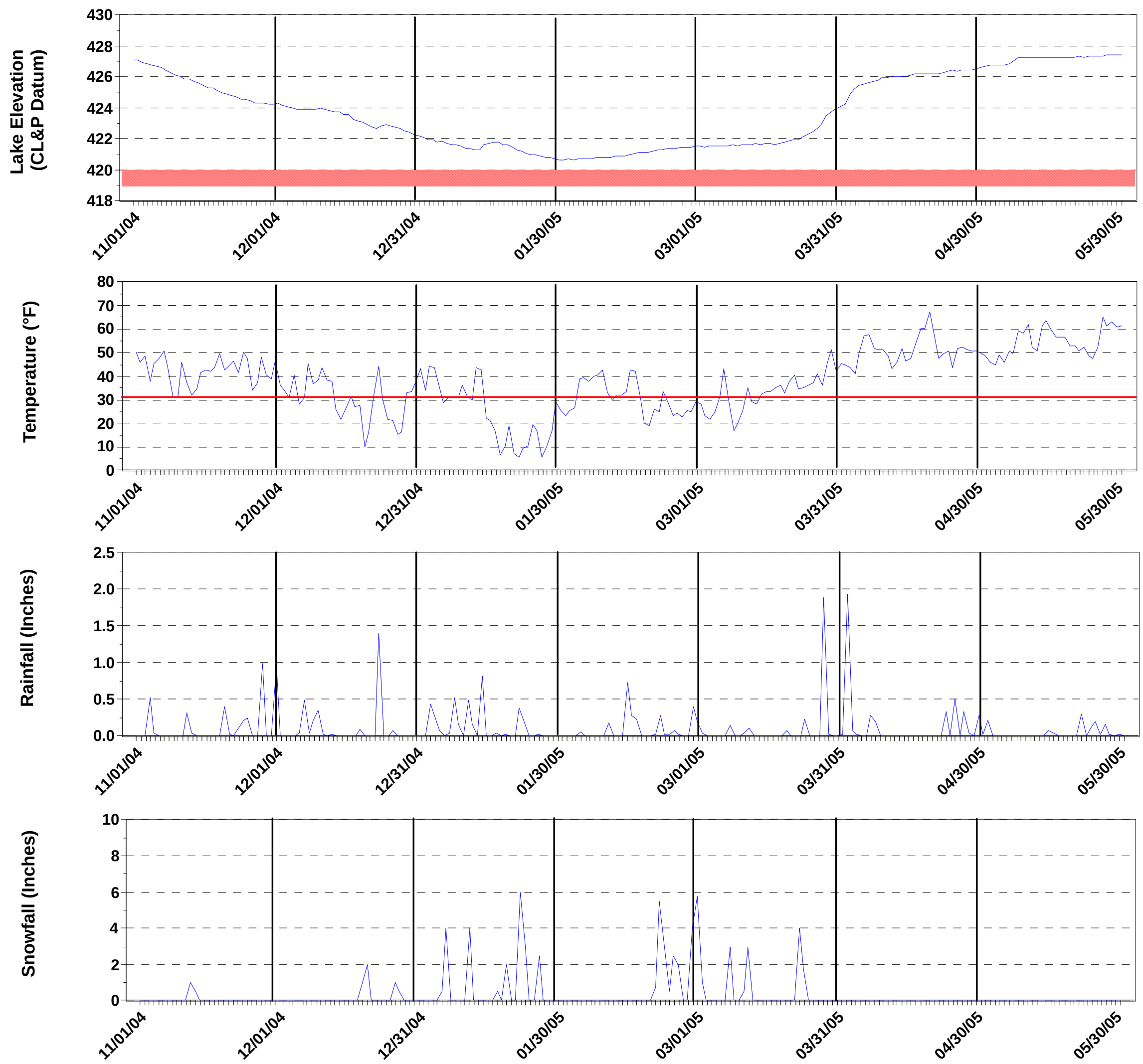

Figure 3. Climate and lake level from November 1, 1004 to May 30, 2005. The red-shaded area in the lake level panel represents the targeted depth. The red line in the temperature panel indicates a temperature of 32 °F or freezing. Climate data provided by Western Connecticut State University.

2005/2006 drawdowns. The 2006/2007 winter was generally dryer but also experienced the only large scale (2+ inches) rain event of the three season period occurring in early March of 2007. Also worth noting are the differences in snowfall events from year to year. The 2004/2005 winter had more events of lesser magnitude. The 2006/2007 winter had the fewest events. The 2005/2006 winter had more snow events than the 2006/2007 winter but fewer than the 2004/2005 winter, as well as the only storm delivering greater than 10 inches. The February 12, 2006 storm delivered 19.8 inches of snow.

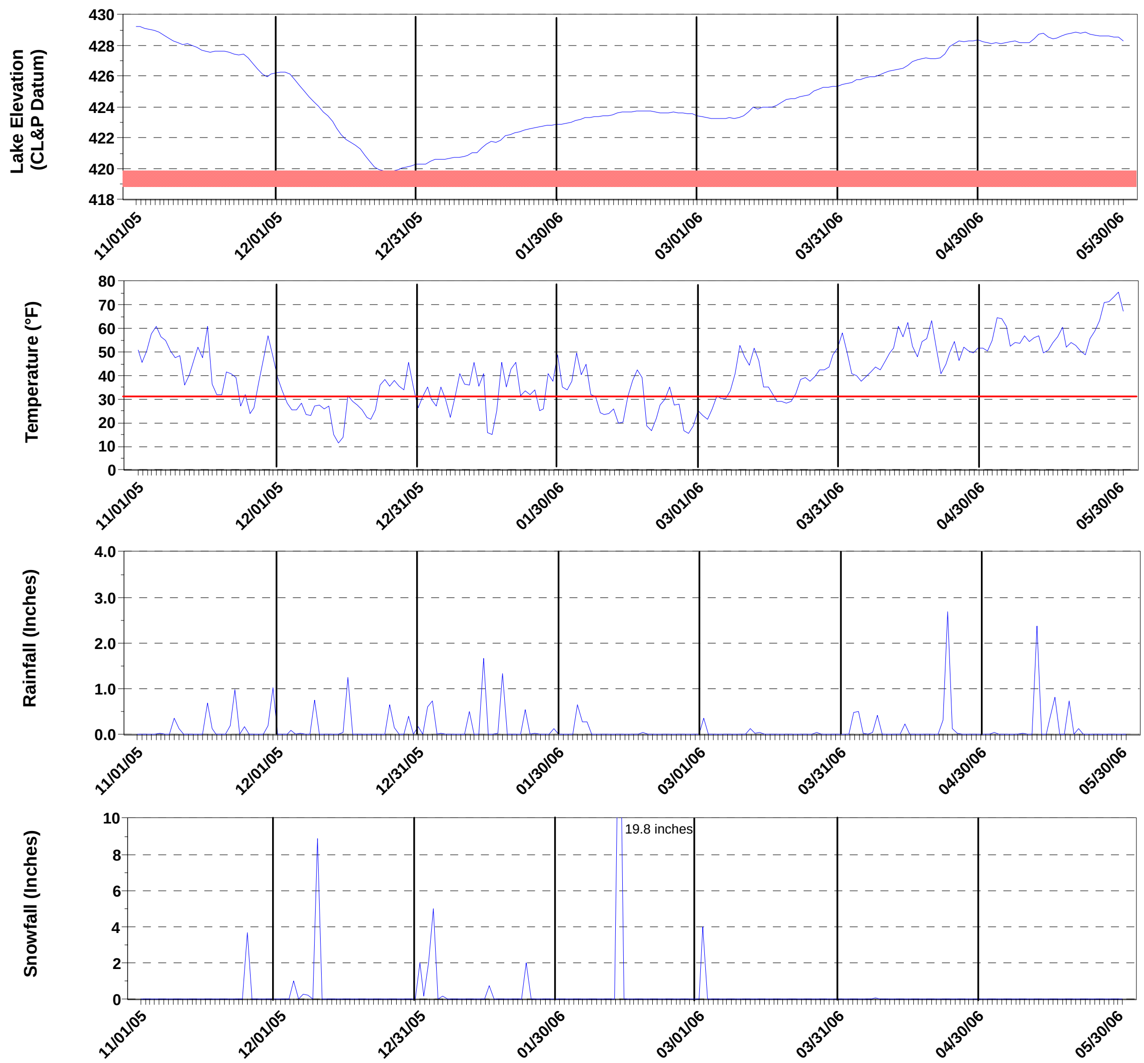

Figure 4. Climate and lake level from November 1, 2005 to May 30, 2006. The red-shaded area in the lake level panel represents the targeted depth. The red line in the temperature panel indicates a temperature of 32 °F or freezing. Climate data provided by Western Connecticut State University.

It appears from a cursory assessment that the 2006/2007 deep drawdown may have been the only one of the three back-to-back-to-back deep drawdowns that had the required climatic conditions. This observation supports the findings of the Massachusetts research that indicates that only one in three years have the conditions necessary for successful weed management via deep drawdown (MA DCR, 2004). A more thorough examination of this data and additional historical local climate data is warranted.

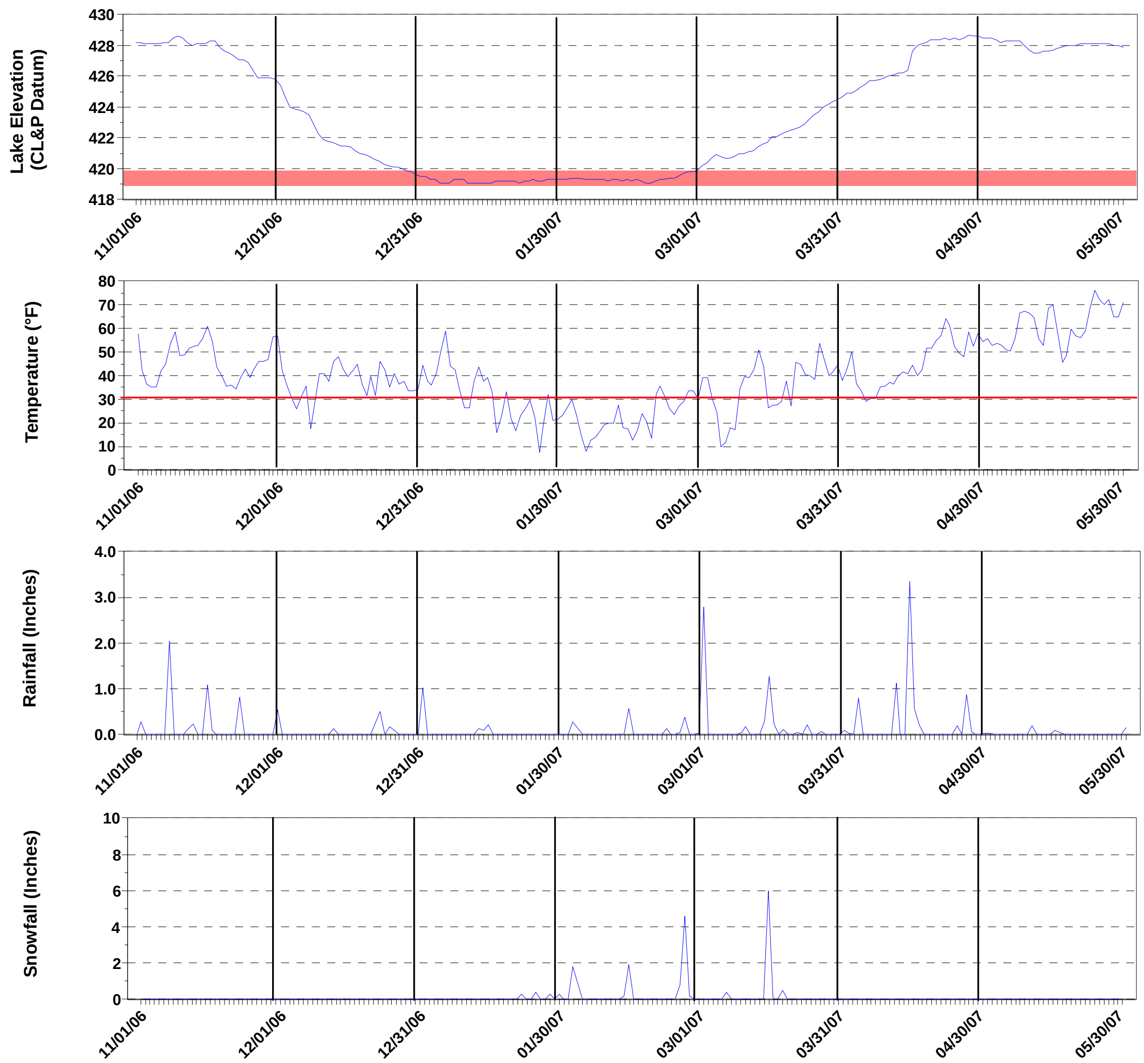

Figure 5. Climate and lake level from November 1, 2006 to May 30, 2007. The red-shaded area in the lake level panel represents the targeted depth. The red line in the temperature panel indicates a temperature of 32 °F or freezing. Climate data provided by Western Connecticut State University.

Adverse Impacts from Drawdowns: Literature Review

There is a substantive body of scientific literature reporting on the potential adverse impacts of water level fluctuations (WLF) in lakes. A 2008 volume of Hydrobiologia, a well-respected – peer reviewed scientific journal on aquatic biology, provided an excellent accounting of many of those impacts. In Leira's (2008) annotated bibliography on the effects of water-level fluctuation, impacts included those on aquatic habitat and feeding or breeding grounds, on littoral zone invertebrates, on phytoplankton and zooplankton, on fish communities, on aquatic plant communities, on lake morphometry, on sedimentation zones, on light penetration in the water column, and on other water chemistry.

The CT DEP has also assembled an extensive bibliography on impacts of water level fluctuations or drawdowns. The CT DEP also collects fisheries data on many of the lakes in Connecticut, including Candlewood. Their data indicate a change in the fisheries of the lake that corresponds with the history of the drawdown. The CT DEP is also currently conducting research on impacts of drawdowns and will be sharing that study in the future.

Shoreline erosion is an issue at Candlewood that has both ecological and economic impacts. It is quite probable that the deep drawdown program at Candlewood contributes to erosion forces impacting the shoreline and littoral zone to some degree. In summary, while the deep drawdown is a cost effective tool for controlling the invasive aquatic plants, it can have some adverse impacts on the lake's ecology.

Discussion and Recommendations

There are still many unknowns regarding the deep drawdown technique and the *M. spicatum* infestation problems at Candlewood Lake. Unexplored in this report, for example, are any relationships between historical drawdown efficacy and climate change. Do changes in ice and snow cover on lakes impact the growth of aquatic plants? Has Candlewood experienced limnological change related to climate? There are reports that lakes in New England are experiencing ice cover later in the year and ice-off earlier in the year (USGS, 2005). Does that impact aquatic plant growth? These questions warrant additional study including an examination of historical drawdowns as compared to local historical climate since 1985.

There are other factors that go into the decision of when to lower and raise the lake. Clearly precipitation plays an important role in lowering the lake down. Under flood conditions, water can actually be pumped up into Candlewood to reduce flood pressures on the Housatonic River, particularly in New Milford. Other factors include regional snowpack and the ability to return the lake to recreational levels by the start of Connecticut's fishing season in mid April.

There are also economic factors. FirstLight Power Resources participates in the Forward Capacity Market which commits power companies to meet regional electricity needs in exchange for market-priced capacity payments (ISO NE, 2007). Participation in this market can influence the timing and depth of the drawdown. All of the factors, environmental and economic, need to be communicated and understood by all stakeholders so that no one is surprised by variations in the drawdown program.

This report suggests that biennial deep drawdowns were effective between 1985 and 1995. The program since 1995 seems to be less effective. Changes in the technique between those two periods of time include 1) the timing and duration of exposure of the milfoil to winter elements and 2) the frequency of the deep drawdown. Early on, the program was clearly biennial. Today it seems more triennial. Another important question is will a return to the drawdown program of 1985 through 1995 provide better control? It is the position of the CLA that it may and that the option should be given due consideration.

A deep drawdown was implemented this winter and it is hoped that will translate into better management of the invasive aquatic plants in the summer of 2009. However, the lake only reached the target level in the latter half of January, due in part to precipitation incurred in December. But before the target depth could be reached, the lake began to freeze so by the time the target depth was reached, a four to six inch covering of ice lay on top of the would be exposed lake sediments. While snow is known to insulate *M. spicatum* from freezing and desiccation, it is unknown if an ice cover will do the same. The 2009 mapping of milfoil will provide some insight into this question. The CLA believes that in the future, every effort should be made to mirror drawdowns between

1985 and 1995, including getting the lake level to target depth by early January and keeping the lake at the target level for 60 days.

There are those in the community that believe an annual deep drawdown, as well as a deeper (12 to 15 foot) drawdown approach, should be implemented at Candlewood Lake. There is considerable debate on the impact that an annual and deeper approach would have on the lake ecosystem as a whole despite the scientific literature on this. Environmental professionals will need to continue to sift through the literature, and if practical, continue to conduct research to provide more insights. Public seminars should also be considered to disseminate factual information regarding drawdowns and management strategies.

The Nuisance Plant Monitoring Plan called for the establishment of a technical to evaluate the results of annual monitoring. As it continues to meet and discuss Candlewood's *M. spicatum* problems, the technical committee should look to bring a balanced management approach to controlling *M. spicatum* while conserving the ecological values Candlewood Lake provides. The initial biennial approach was seen as a measure to provide that balance. Despite the possible impacts of the drawdown since 1985, Candlewood Lake still provides great ecological values. If the program is to dramatically change (e.g. annual deep drawdowns, deeper drawdowns, etc.) then it will be important to show that those values are not additionally compromised.

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