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Control of Variable Watermilfoil in Bashan Lake, CT with 2,4-D: Monitoring of Lake and Well Water

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ABSTRACT

Variable watermilfoil (*Myriophyllum heterophyllum* Michx.) has recently become a problem in Bashan Lake, East Haddam, CT, USA. By 1998, approximately 4 ha of the 110 ha lake was covered with variable watermilfoil. In 1999, the milfoil was spot treated with Aquacide®, an 18% active ingredient of the sodium salt of 2,4-D [(2,4-dichlorophenoxy) acetic acid], applied at a rate of 114 kg/ha. Aquacide® was used because labeling regarding domestic water intakes and irrigation limitations prevented the use of Navigate® or AquaKleen®, a 19% active ingredient of the butoxyethyl ester of 2,4-D. Variable watermilfoil was partially controlled in shallow protected coves but little control occurred in deeper more exposed locations. 2,4-D levels in the treatment sites were lower than desired and offsite dilution was rapid. In 2000, the United States Environmental Protection Agency (USEPA) issued a special local need (SLN) registration to allow the use of Navigate® or AquaKleen® in lakes with potable and irrigation water intakes. Navigate® was applied at a rate of 227 kg/ha to the same areas as treated in 1999. An additional 2 ha of variable watermilfoil was treated with Navigate® in 2001, and 0.4 ha was treated in mid-September. Dilution of the 2,4-D ester formulation to untreated areas was slower than with the salt formulation. Concentrations of 2,4-D exceeded 1000 µg/L in several lake water samples in 2000 but not 2001. Nearly all of the treated variable watermilfoil was controlled in both years. The mid-September treatment appeared as effective as the spring and early summer treatments. Testing of homeowner wells in all 3 years found no detectable levels of 2,4-D.

Key words: *Myriophyllum heterophyllum*, 2,4-D, Nonnative invasive weeds, Aquatic herbicide residues.

INTRODUCTION

Invasive aquatic weeds can restrict recreational opportunities, interfere with water supplies, and displace native vegetation (Madsen et al. 1991). Variable watermilfoil is considered not native to Connecticut (CT) and was first reported in the state in the 1940's (Muenscher 1944). Until recently reports of it being a weed problem were few. Variable watermilfoil is known to be locally aggressive (Crow and Hellquist 2000) and like Eurasian watermilfoil (*Myriophyllum spicatum* L.) spreads primarily by fragmentation (Madsen 1988). Unlike Eurasian watermilfoil where studies on control with herbicides (Westerdahl and Hall 1983), insects (Johnson et al. 2000), microbes (Smith et al.1989), and other means are abundant, few studies are available on the control of variable watermilfoil. Variable watermilfoil was first detected in Bashan Lake, East Haddam, CT, in the early 1990's. Bashan Lake is 110 ha and noted for its clear water, low alkalinity and olig-

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otrophic nutrient status (Frink and Norvell 1984, Canavan and Siver 1995). Large areas of variable watermilfoil in nutrient poor lake water may be explained by plant uptake of nutrients from the bottom sediment (Bristow and Whitcombe 1971). Attempts to control the milfoil in the early to mid 1990's by harvesting and applications of Reward®, diquat dibromide (6,7-dihydrodipyrido[1,2-α:2',1'-c]pyrazinediium ion, failed. Herbicide formulations containing 2,4-D offer a greater chance for control because their systemic activity destroys plant roots and prevents regrowth. 2,4-D also has the advantage of being suitable for spot applications and is selective to most dicotyledonous plants. This favors regrowth with less obtrusive monocotyledonous plants such as native *Potamogeton* spp. (Sprecher et al. 1998). Obstacles for utilizing 2,4-D include: USEPA restrictions on using the ester formulations of 2,4-D such as Navigate® and AquaKleen® in lakes with potable and irrigation water intakes, public perception that 2,4-D poses health risks (Sagan 1991), and lack of evidence that 2,4-D is effective on variable watermilfoil. The label for the herbicide Aquacide® did not state a restriction regarding water intakes. In 2000, the USEPA granted a SLN registration to Connecticut for Navigate® and AquaKleen®. The registration required that treated water not be used for drinking and irrigation until an approved assay found 2,4-D levels in treatment sites were below 70 and 100 µg/L respectively. The Connecticut Department of Environmental Protection (CTDEP) further restricted the use of 2,4-D ester products by requiring testing of nearby groundwater wells for 2,4-D and notification of lakefront homes that the lake water is not considered potable.

MATERIALS AND METHODS

Surveys for variable milfoil were performed from 1996 to 2001 by traversing parts of the lake with depths of less than 5 m, visually locating the vegetation, and marking the locations on a bathymetric map. Diving and obtaining plant samples with a drop line garnered further information. Local divers and shoreline residents frequently reported sightings of variable watermilfoil and this information was followed up by visits to the sites. Because the variable watermilfoil was in localized patches, detecting every patch was restricted by water clarity and wave action. From 1999 to 2001 variable watermilfoil surveys were performed before and after treatment on May 27 and October 8 in 1999, May 30 and September 8 in 2000, and June 13 and September 27 in 2001 (Figures 1, 2, and 3). Additional surveys were performed each summer to

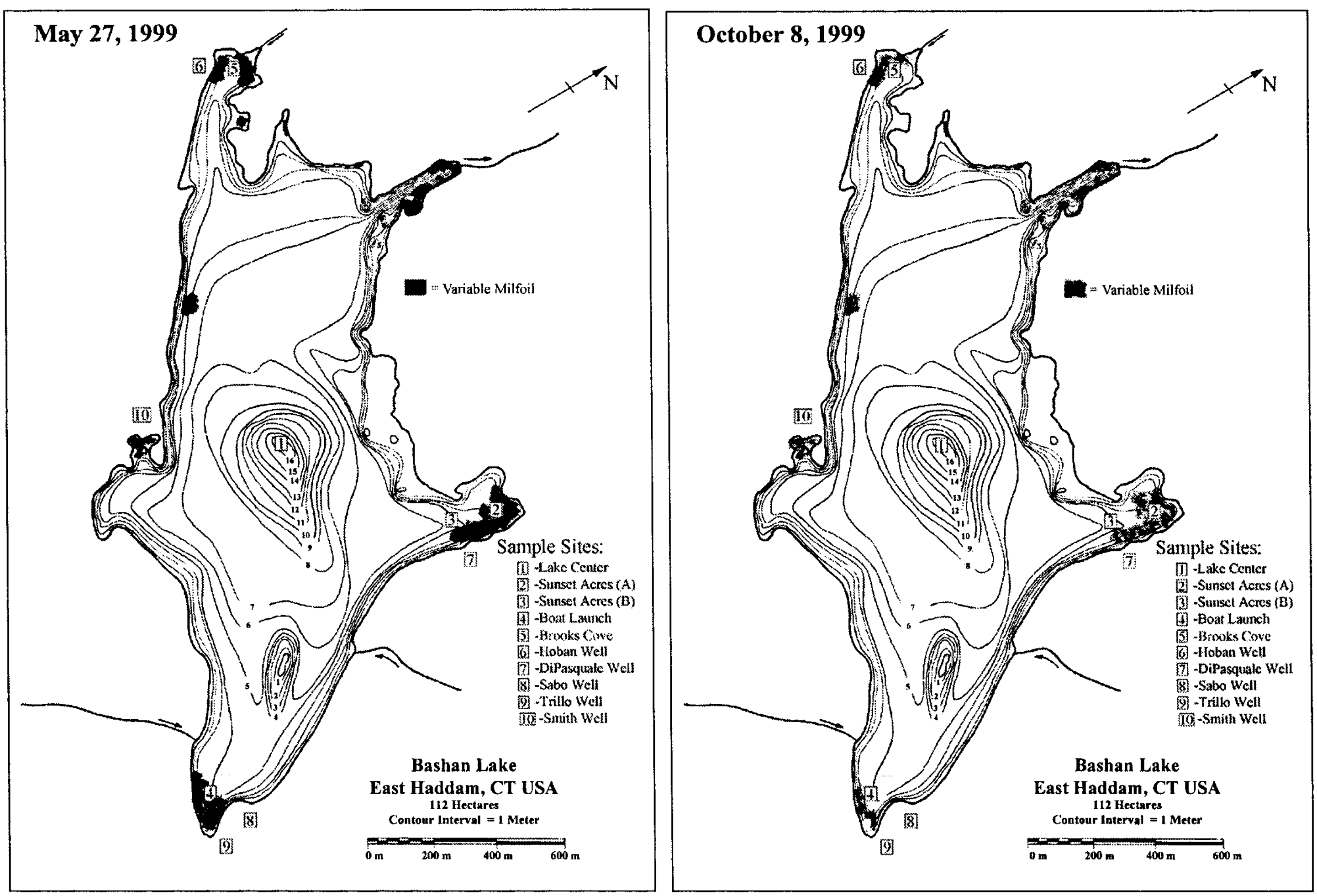

Figure 1. Observed location and estimated density of variable watermilfoil in Bashan Lake in 1999.

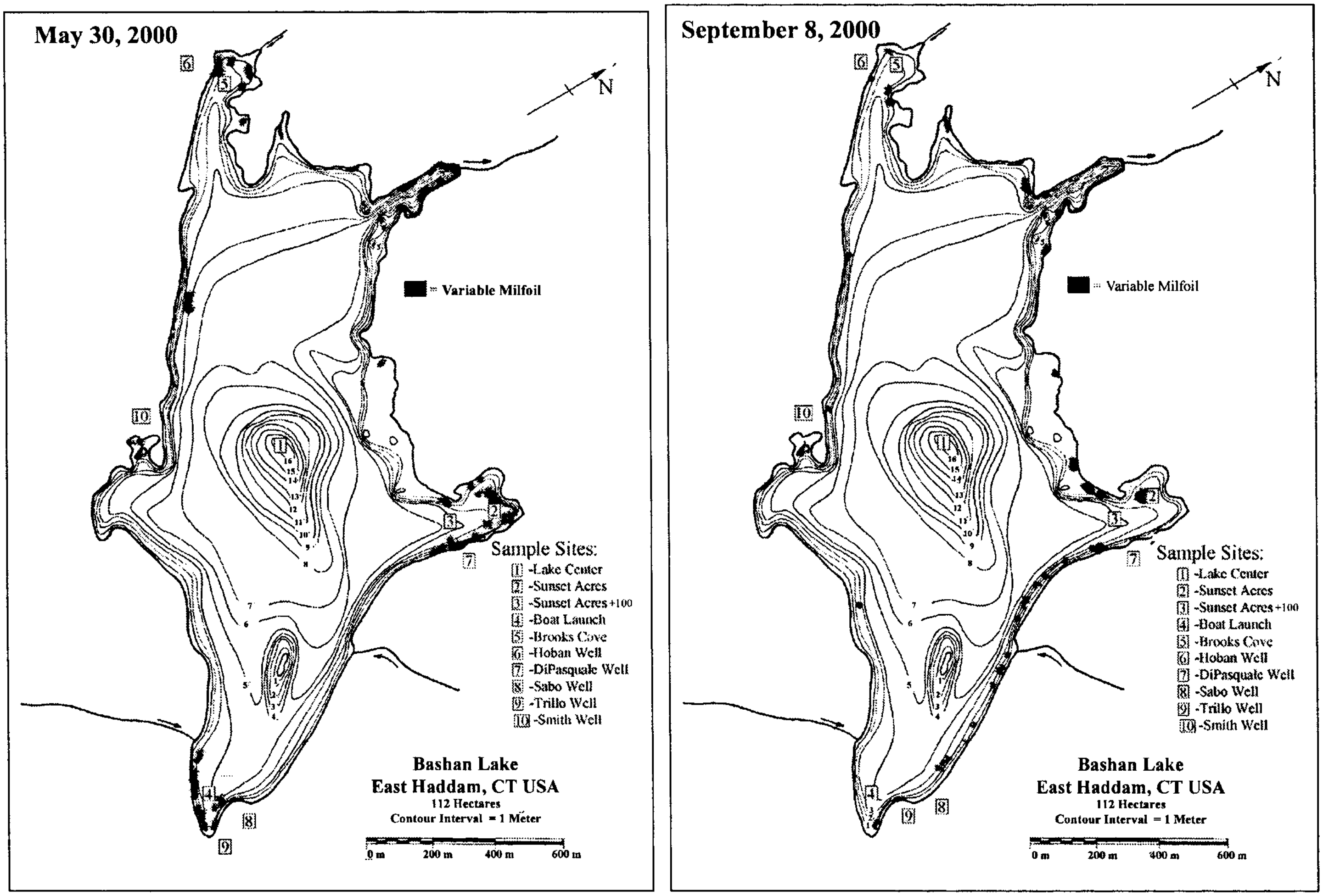

Figure 2. Observed location and estimated density of variable watermilfoil in Bashan Lake in 2000.

assess the speed and degree of control and to determine if follow-up treatments were necessary.

In each year of this study, all areas indicated as having variable watermilfoil on the pretreatment surveys (Figures 1, 2, and 3) were treated with 2,4-D. In 1999, the town of East Haddam, CT, applied for and received a permit from the CT-DEP to apply Aquacide®. The permit specified an application rate of 114 kg/ha to a total of 4 ha and required monitoring for 2,4-D in shallow drinking water wells near the treatment areas. A restriction on using the lake-water for irrigation was mandated until 2,4-D concentrations fell below 100 µg/L in treatment sites. Aquacide was applied on July 6, 1999, using an electric spreader modified with oversized openings to facilitate the passage of large pellets.

In 2000 and 2001, CTDEP approved a permit to apply Navigate® or AquaKleen® to Bashan Lake based on the conditions of the SLN registration and the CTDEP restrictions mentioned previously. In 2000 and 2001, Navigate® was applied at the greatest allowable rate of 227 kg/ha at the times and amounts shown in Table 1. The highest allowable rates of Navigate® were used to increase the chances for variable watermilfoil control and to test the movement of 2,4-D to wells and throughout the lake under extreme conditions. Rates of AquaKleen® as low as 113 kg/ha have been shown to be effective against Eurasian milfoil (Parsons et al. 2001) and may be more appropriate for variable milfoil. To test the effectiveness of late season treatments, 0.4 ha was treated in mid-September 2001. Before and at designated intervals after application (Tables 2, 3 and 4), a 2-L surface and subsurface lake-water sample was obtained from the main treatment sites, 30 m from the Sunset Acres treatment site an, in the center of the lake, approximately 200 m from all treatment sites (Figures 1, 2 and 3). In 1999 and 2000 water samples were obtained from the surface at a depth of 0.5 m and from the subsurface within 1 m of the bottom. The subsurface sample in the lake center was taken from a depth of 9 m. Only subsurface samples were taken in 2001 because previously these samples contained the highest concentrations of 2,4-D. Surface samples were taken by lowering the collection bottle by hand and the subsurface samples were collected with a 12 volt submersible pump attached to the end of flexible Teflon lined tube. Well water samples were collected before and after treatment (Tables 2, 3 and 4) from the faucets of five homes close to the treatment sites. The locations of the wells are shown in Figures 1, 2 and 3. All water samples were refrigerated after collection. Wells were encased arte-

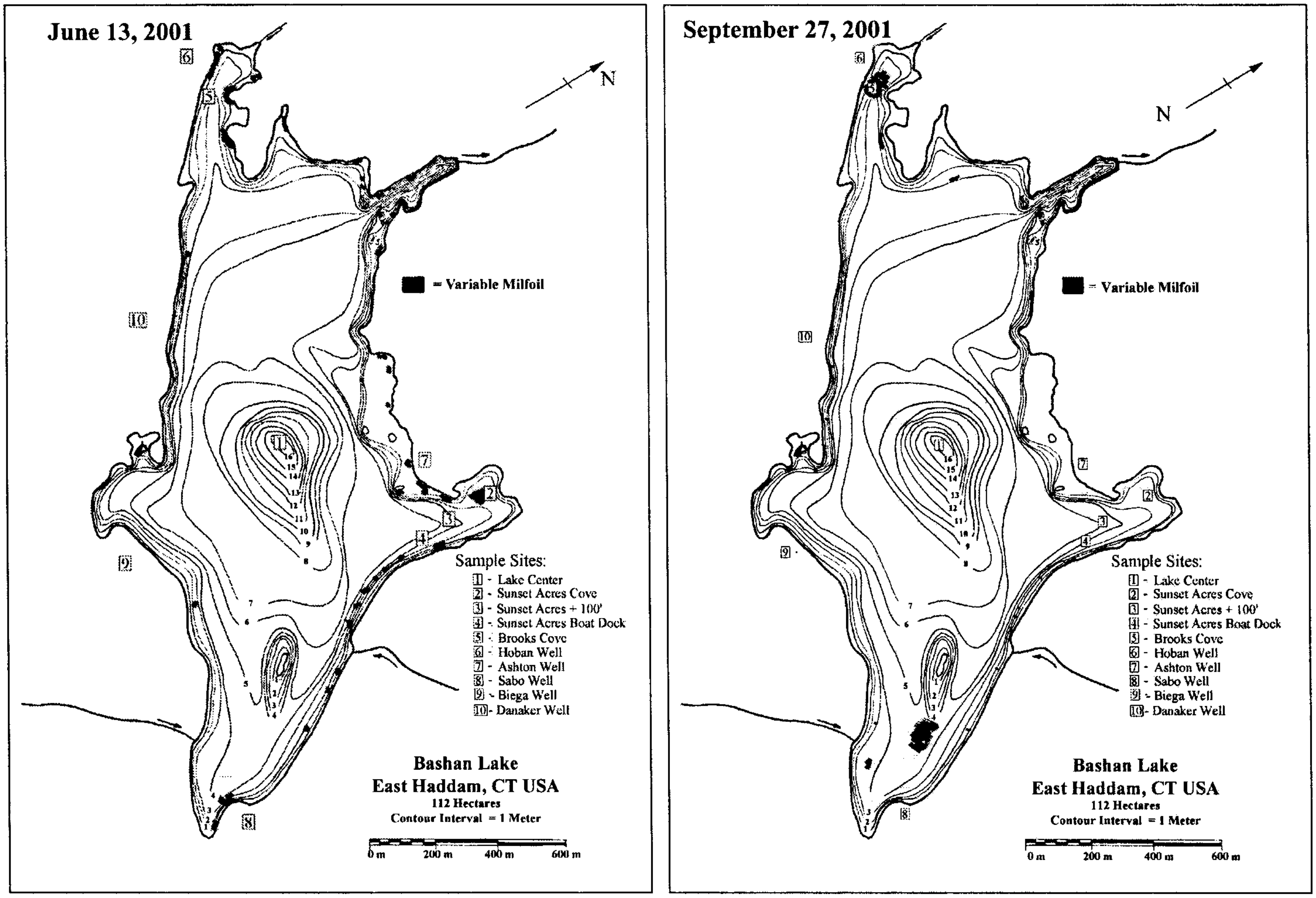

Figure 3. Observed location and estimated density of variable watermilfoil in Bashan Lake in 2001.

sian wells less than 5 m deep. Well water levels were slightly above the level of the lake. The distance of the wells from the lake varied from less than 5 m for the Hoban, Sabo, and Trillo wells to approximately 30 m for the Ashton and Danaker wells.

Because of the different 2,4-D formulations used, water testing protocol differed in 1999, from 2000 and 2001. In 1999, water samples were acidified in the field to a pH 2 with 6 M HCL, and then subjected to solid phase extraction (SPE) through C18 cartridges that had been conditioned with methanol and distilled water. Samples of 200 mL each were drawn through the SPE cartridges at 5 psi. Air was then drawn over the cartridges for 30 minutes to facilitate drying and the C18 was extracted with 2.8 ml of methanol. 2,4-D was analyzed by High Pressure Liquid Chromatography (Agilent 1100 series, Palo Alto, CA USA) utilizing a Supelco Discovery column (5 µ C18, 4.6 by 250 mm) with a mobile phase of 3:2 methanol/1% glacial acetic acid at 1 ml/min and ultraviolet diode array detection (280 nm). The detection limit was approximately 2 µg/L. Recovery of spiked 2,4-D sodium salt was 93% + 2.5. Water samples containing the ester formulation for herbicide treatments in 2000 and 2001 were treated with 6 M NaOH to bring the pH to 12 for 24 hours, thereby cleaving the ester group. The samples were then acidified to pH 2 with 6 M HCL, extracted, and analyzed as above. The efficiency of the ester cleavage was determined to be only 15% so a correction factor was applied to all samples. The Connecticut Department of Public Health (CTDPH) independently analyzed one set of well-water samples each year. Lake water was tested for alkalinity using titration with 0.16N H_2SO_4 to an endpoint of pH 4.5. Conductivity was determined by electrode and water clarity by Secchi disk. Alkalinity, conductivity, and clarity measurements were obtained at the same times as the lake 2,4-D samples and occasionally more often.

Table 1. Date, formulation, amount, area and rate of 2,4-D applied to Bashan Lake.

Date	Formulation	Amount kg	Area ha	Rate kg/ha
July 6, 1999	Aquacide	455	4.0	114
May 30, 2000	Navigate	818	3.6	227
July 13, 2000	Navigate	91	0.5	227
June 13, 2001	Navigate	227	1.0	227
June 26, 2001	Navigate	91	0.5	227
September 13, 2001	Navigate	136	0.6	227

Table 2. Concentrations of 2,4-D in lake and well water samples collected from Bashan Lake in 1999.

Location	Depth (m)	PTRT[a] (7/1)[a]	2 HAT[b] (7/6)	1 DAT[c] (7/7)	3 DAT (7/9)	6 DAT (7/12)	9 DAT (7/15)	16 DAT (7/22)	27 DAT (8/2)	55 DAT (8/30)	94 DAT (10/8)
1999						2,4-D (μg/L)					
Brooks Cove	0.2	<2[d]	6	48	48	12	22	11	13	2	<2
Brooks Cove	2.0	*	1200	120	51	15	41	18	13	3	<2
Boat Launch	0.2	<2	2	15	120	13	13	14	14	<2	2
Boat Launch	2.0	*	7	12	110	14	11	17	13	3	2
Sunset Acres	0.2	<2	9	17	85	11	11	10	7	4	<2
Sunset Acres	3.0	*	57	45	89	15	18	11	12	2	2
Sunset A. +100	0.2	*	<2	39	28	10	14	12	12	3	<2
Sunset A. +100	3.0	*	<2	9	30	37	22	12	28	2	<2
Center	0.2	*	<2	<2	4	7	9	14	14	2	<2
Center	6.0	*	<2	<2	4	10	12	12	28	2	<2
All Wells[d]	*	*	<2	<2	<2	<2	<2	<2	<2	<2	<2

[a]Pretreatment.
Hours after treatment.
[c]Days after treatment.
[d]Below detection limit of 2 μg/L.
*Not Tested.

RESULTS AND DISCUSSION

The May 27, 1999, pretreatment aquatic plant survey (Figure 1) found approximately 4 ha of variable watermilfoil. Most of the variable watermilfoil occurred in shallow protected areas less than 3 m deep in areas near the outlet dam, the boat launch, Sunset Acres, Brooks Cove and adjacent to the Smith well in Laurel Cove. In Brooks Cove, Sunset Acres, and Laurel Cove the variable watermilfoil frequently reached the surface. In the cove near the boat launch the variable watermilfoil had largely been chopped below the surface by outboard motors.

Variable Watermilfoil Control 1999 to 2001

In 1999, the first signs of variable watermilfoil control were visible 16 days after treatment (DAT) on July 22, when large mats of variable watermilfoil began floating to the surface. By July 28, 22 DAT, severe browning of the variable watermilfoil was evident in Laurel Cove while moderate browning occurred at sites in the boat launch, Sunset Acres and near the dam. Because outflow at the dam was minimal substantial losses of 2,4-D downstream were unlikely. About 75% of the total variable watermilfoil in other areas of the lake appeared relatively unaffected.

Table 3. Concentrations of 2,4-D in lake and well water samples collected from Bashan Lake in 2000.

Location	Depth (m)	PTRT (5/25)	2 HAT (5/30)	1 DAT (5/31)	2 DAT (6/1)	6 DAT (6/5)	9 DAT (6/8)	16 DAT (6/15)	23 DAT (6/22)	30 DAT (6/29)	48 DAT 7/11	73 DAT (8/11)
2000						2,4-D (μg/L)						
Brooks Cove	0.2	<2[d]	<2	170	48	160	150	130	110	62	23	<2
Brooks Cove	2.0	<2	2000	640	310	360	290	150	88	61	37	<2
Boat Launch	0.2	<2	<2	490	250	88	92	220	120	55	17	<2
Boat Launch	2.0	<2	1400	3900	4800	110	2500	160	100	<2	17	<2
Sunset Acres	0.2	<2	<2	250	310	260	150	130	88	78	<2	<2
Sunset Acres	3.0	<2	2000	910	960	97	360	130	88	76	14	<2
Sunset A. +100	0.2	<2	<2	<2	100	150	180	150	83	83	13	<2
Sunset A. +100	3.0	<2	<2	<2	69	170	230	160	95	95	15	<2
Center	0.2	<2	<2	<2	<2	100	90	150	95	79	<2	<2
Center	6.0	<2	<2	<2	<2	60	91	170	<2	70	18	<2
All Wells[d]	*	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

[a]Pretreatment.
[b]Hours after treatment.
[c]Days after treatment.
[d]Below detection limit of 2 μg/L.
*Not Tested.

TABLE 4. CONCENTRATIONS OF 2,4-D IN LAKE AND WELL WATER SAMPLES COLLECTED FROM BASHAN LAKE IN 2001.

Location	Depth (m)	PTRT (6/11)	3 DAT (6/16)	7 DAT (6/20)	15 DAT (6/28)	22 DAT (7/5)	29 DAT (7/12)	35 DAT (7/18)	43 DAT (7/26)	57 DAT (8/9)	70 DAT 8/22
2001	2,4-D (µg/L)										
Brooks Cove	2.0	<2	163	36	15	11	<2	10	6	4	6
Sunset Acres	3.0	<2	12	25	23	13	5	6	5	4	6
Sunset A. Dock	3.0	<2	35	490	17	26	<2	4	7	5	6
Sunset A. +100	3.0	<2	*	26	15	12	4	7	5	4	6
Center	6.0	<2	<2	<2	<2	<2	6	8	<2	6	6
All Wells	*	<2	*	*	*	<2	*	*	*	*	*

[a]Pretreatment.
[b]Hours after treatment.
[c]Days after treatment.
[d]Below detection limit of 2 µg/L.
*Not Tested.

By August 25, 56 DAT, those areas observed as browning on July 28, 22 DAT, had largely disappeared. Close inspection of the bottom by diving indicated a small amount of rerooting of previously damaged but not controlled plants. On September 20, 82 DAT, no further decline in variable watermilfoil was observed and a slight recovery of the previously browned variable watermilfoil was evident. Near complete control was present in the area by the dam and the north side of Brooks Cove. Variable watermilfoil in the north and east side of Sunset Acres cove, the south side of the boat launch cove, and Brooks cove appeared very healthy. Some regrowth had occurred in Laurel Cove. The final survey in 1999 (Figure 1) on October 8, 100 DAT, found about 50% of the variable watermilfoil in treated areas had been eliminated. This includes about 25% where the bottom was now clear of variable watermilfoil and 25% from a thinning out of dense patches.

In 2000, virtually all the variable watermilfoil treated with the ester formulation of 2,4-D Navigate® on May 30 had disappeared by July 6, 36 DAT. Occasionally pieces of healthy looking variable watermilfoil were observed floating in the lake. This indicated that variable watermilfoil was still present in untreated areas. Closer inspection found sporadic patches of variable watermilfoil not observed in previous surveys. These patches were mainly along the south shore from Laurel Cove to Brooks Cove and the north shore from Sunset acres to the mouth of the cove by the dam. It was likely that these patches were not new but had not been located in previous surveys. A follow-up application of Navigate was made on July 13 (Table 1) to these newly found patches. Some patches were <2 m in diameter and treatment covered only about 4 m diameter. Inspection on August 8 found all variable watermilfoil treated with the follow-up application had been eliminated. No regrowth was evident in areas treated on May 30. The final weed survey performed in 2000, on September 8 (Figure 2), found all areas previously treated were virtually free of variable watermilfoil with the exception of one or two plants near the boat launch. These secondary plants could have been missed in previous treatments or may represent plants that had drifted in and taken root. Several more areas not previously known to have variable watermilfoil were also identified, particularly along the shore between the boat launch and Sunset Acres.

In 2001, the pretreatment survey performed on June 13 (Figure 3) found areas treated in 2000 largely free of variable watermilfoil. Exceptions included small sporadic areas on the north side of the boat launch cove and the south side of Brooks Cove. On June 26 13 DAT the treated milfoil was either no longer visible or was seriously damaged. Visual inspection on August 8 71 DAT found all treated variable watermilfoil had disappeared but a 0.5-ha untreated patch was found towards the mouth of Brooks Cove. This patch was dense and nearly reached the surface. It may have been missed in previous surveys because the water was 3 to 4 m deep and may have had limited visibility.

The variable watermilfoil survey performed on September 5, 2001, 99 DAT, confirmed all treated areas were free of variable watermilfoil (Figure 3). New variable watermilfoil patches were found, however, in untreated areas between the boat launch and the nearby island, at the mouth of Brooks Cove, and along the east shore of Sunset Acres cove. Other isolated patches were found, most notably in Laurel Cove. The Brooks and Laurel Cove patches were treated in 2000 but not 2001. Variable watermilfoil on the east shore of Sunset Acres Cove was in <1 m of water and probably had been exposed by a shallow draw down the preceding winter. Navigate applied on September 13 (Table 1) to areas of variable watermilfoil in Brooks Cove, Laurel Cove, Sunset Acres, and the cove by the dam resulted in elimination of the variable watermilfoil by September 27. This successful use of Navigate® during the late summer or fall could be a valuable tool for controlling variable watermilfoil when lake use is minimal andthree are many months before major lake use resumes. Where variable watermilfoil was eliminated by the June treatment, the bottom was often colonized by bladderwort (*Ultricularia* sp.). In small shallow areas of Laurel Cove the bladderwort reached the surface. In most other areas it remained close to the bottom and was not considered a problem.

Testing of Lake and Well Water

Lake-and well-water testing for 2,4-D in 1999 (Table 2) indicated that 2,4-D concentrations in the treatment areas remained low. 2,4-D levels peaked near 100 µg/L, 3 DAT, and dropped to below the 2 µg/L detection limit within 55 to 94

DAT. 2,4-D was detected 30 m outside the Sunset Acres treatment area 1 DAT and in the central portion of the lake, >200 m from treatment sites, 3 DAT. Green and Westerdahl (1990) observed that under controlled laboratory conditions, a concentration of 1000 µg/L for a 24-hour period was required to eliminate Eurasian watermilfoil. In 1999, only one sample taken 2 hours after treatment (HAT) exceeded 1000 µg/L. Given the low concentrations in the remainder of the treatment sites and that the sample was obtained close to the sediment, it is likely that the high 2,4-D concentration may have resulted from close contact between the sampling tube and an herbicide pellet. Rapid migration and dilution of the salt formulation out of the treatment sites probably caused the overall low levels of 2,4-D. Levels of 2,4-D in all lake samples fell below the potable restriction of 70 µg/L and irrigation limit of 100 µg/L in samples taken 6 DAT. No 2,4-D was detected in water collected from the five drinking water wells tested.

In 2000, the concentrations of 2,4-D in the treatment areas (Table 3) were significantly greater than those in 1999. Water samples taken 2 HAT, 1 DAT, and 2 DAT exhibited subsurface stratification of 2,4-D. Levels of 2,4-D peaked in subsurface water from treatment sites 2 DAT with concentrations ranging from 310 to 4800 µg/L. These levels are approximately half that found by Parsons et al. (2001) in plots of Eurasian milfoil treated with half the rate of AquaKleen® used in this study (114 kg/ha). All lake water concentrations of 2,4-D fell below the allowable irrigation level of 100 µg/L 30 DAT and the allowable potable level of 70 µg/L 48 DAT. Migration of 2,4-D out of the treatment sites appeared slower with the ester formulation compared with the sodium salt formulation used in 1999. 2,4-D was detected 30 m from the Sunset Acres treatment site 2 DAT and in the center of the lake 6 DAT. Within the treatment areas, 2,4-D concentrations exceeded the critical level of 1000 µg/L proposed by Green and Westerdahl (1990) for at least 2 days. The slower migration of the ester formulation out of the treatment sites and the higher initial application rate probably caused the higher concentrations of 2,4-D in 2000 compared with 1999. Water obtained from the four groundwater wells after treatment contained no detectable levels of 2,4-D.

In 2001, 2,4-D levels in treatment sites peaked between 25 and 490 µg/L 7 DAT and rapidly dropped to low or non-detectable levels (Table 4). No levels of 2,4-D approached the critical concentration of 1000 µg/L (Green and Westerdahl, 1990) probably because the treatment sites were smaller and more dispersed throughout the lake. Trace concentrations of 2,4-D were found 30 m from the Sunset Acres treatment sites 7 DAT and in samples in the center of the lake 29 DAT. All levels of 2,4-D were below the irrigation standard of 100 µg/L and the potable water standard of 70 µg/L 15 DAT. 2,4-D levels in all sites fell below 10 µg/L 29 DAT. From this time until the end of sampling on August 22, 2,4-D concentrations in the lake center generally ranged from 5 to 10 µg/L and were similar to the treated sites. The Navigate application on June 26 did not increase 2,4-D in the lake samples. This was probably because of the small amount of Navigate® used and the distance of the sampling sites from the treated areas.

Bashan Lake's pH ranged between 5.0 and 7.0 with most levels 6.0 to 6.5 (Figure 4). Of particular note is the very low

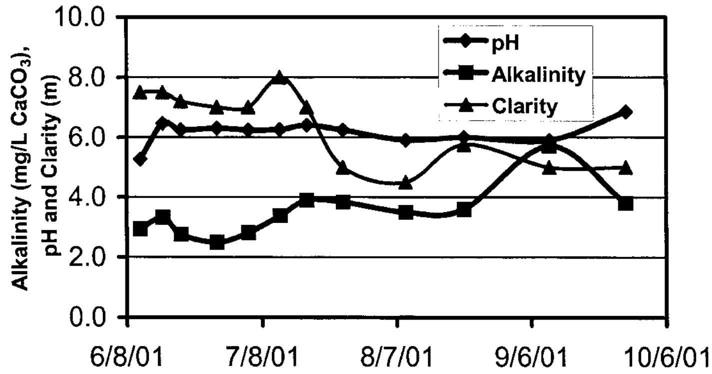

Figure 4. Alkalinity, pH and Clarity in Bashan Lake in 2001.

buffering capacity of the lake-water, with alkalinity values ranging from 2-6 mg/l CaCO3. Because Navigate® is less effective in water with a pH >8 (Navigate® label), it is possible that the low pH and low alkalinity have caused the rapid variable watermilfoil control. Water clarity varied between 4 and 8 m, which is extremely clear for Connecticut lake, (Canavan and Siver 1995). Surface viewing of variable watermilfoil was limited to shallower depths because the variable watermilfoil's brownish color blended in with bottom. This apparently caused significant areas of variable watermilfoil to be missed during surveys.

Granular ester formulations of 2,4-D were extremely effective in controlling variable watermilfoil in Bashan Lake. Timing of applications was not critical as control was achieved in May, June, July, and September. September applications hold promise for treating variable watermilfoil outside the season of major lake use. Control of small patches < 6 m diameter was also achieved, suggesting that once major areas of variable watermilfoil are eliminated, routine spot treatments could prevent large-scale regrowth. 2,4-D levels fell below levels allowable for irrigation less than 30 DAT and allowable for potable use less than 48 DAT. No traces of 2,4-D were detected in shallow groundwater wells near the treatment sites.

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LITERATURE CITED

Bristow, J. M. and M. Whitcombe. 1971. The role of roots in the nutrition of aquatic vascular plants. Amer. J. Bot. 58:8-13.

Canavan IV, R. W. and P. A. Siver. 1995. Connecticut Lakes: A study of the chemical and physical properties of fifty-six Connecticut Lakes. Connecticut College Arboretum. New London, CT.

Crow, G. E. and C. B. Hellquist. 2000. Aquatic and wetland plants of northeastern North America. The University of Wisconsin Press, Madison, WI.

Frink, C. R. and W. A. Norvell. 1984. Chemical and physical properties of Connecticut lakes. Conn. Agric. Exp. Sta. Bull. 817.

Green, W. R. and H. E. Westerdahl. 1990. Response of Eurasian water watermilfoil to 2,4-D concentrations and exposure time. J. Aquat. Plant Manage. 28:27-32.

Johnson, R. L., P. J. Van Dusen, J. A. Toner and N. G. Hairston, Jr. 2000. Eurasian watermilfoil biomass associated with insect herbivores in New York. J. Aquat. Plant Manage. 30:82-88.

Madsen, J. D, L. W. Eichler and C. W. Boylen. 1988. Vegetative spread of Eurasian watermilfoil in Lake George, New York. J. Aquat. Plant Manage. 26:47-50

Madsen, J. D., J. W. Sutherland, J. A. Bloomfield, L.W. Eichler and C. W. Boylen. 1991. The decline of native vegetation under dense Eurasian watermilfoil canopies. J. Aquat. Plant Manage. 29:94-99.

Muenscher, W. C. 1944. Aquatic Plants of the United States, Ithaca, New York, USA. Comstock Publishing Company Inc. Cornell University.

Parsons, J. K., K. S. Hamel, J. D. Madsen and K. D. Getsinger. 2001. The use of 2,4-D for selective control of an early infestation of Eurasian milfoil in Loon Lake, Washington. J. Aquat. Plant Manage. 39:117-125.

Sagan, K. V. 1991. Poison in your backyard: The pesticide scandal. Family Circle. 4(2):59-111

Smith, C. S., T. Chand, R. F. Harris and J. H. Andrews. 1989. Colonization of a submersed aquatic plant, Eurasian watermilfoil (*Myriophyllum spicatum*), by fungi under controlled conditions. Appl. Environ. Microbiol. 55(9):2326-2332.

Sprecher, S. L., K. D. Getsinger and A. B. Stewart. 1998. Selective effects of aquatic herbicides on sago pondweed. J. Aquat. Plant Manage. 36:64-66.

Westerdahl, H. E. and J. F. Hall. 1983. Threshold 2,4-D concentrations for control of Eurasian water-watermilfoil (*Myriophyllum spicatum*) and Sago pondweed (*Potamogeton pectinatus*). J. Aquat. Plant Manage. 21:22-25.