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Aquatic Plant Control Research Program

Use of Whole-Lake Fluridone Treatments to Selectively Control Eurasian Watermilfoil in Burr Pond and Lake Hortonia, Vermont

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Final report

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Preface

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP). The APCRP is sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Research and Development Center (ERDC) under the purview of the Environmental Laboratory (EL), Vicksburg, MS. Funding was provided under Department of the Army Appropriation No. 96X3122, Construction General. Support was also provided by the Vermont Department of Environmental Conservation (VTDEC), Waterbury, VT, coordinated through Ms. Holly A. Crosson, VTDEC. The APCRP is managed under the Center for Aquatic Plant Research and Technology (CAPRT), Dr. John W. Barko, Director. Mr. Robert C. Gunkel, Jr., was Assistant Director, CAPRT. Program monitor during the study was Mr. Timothy R. Toplisek, HQUSACE.

The Principal Investigator of this work was Dr. Kurt D. Getsinger, Environmental Processes Branch (EPB), Environmental Processes and Engineering Division (EPED), EL, ERDC. This work was conducted and report prepared by Dr. Getsinger and Mr. R. Michael Stewart, Aquatic Ecology and Invasive Species Branch (AEISB), Ecosystem Evaluation and Engineering Division, EL, ERDC; Dr. John D. Madsen, Minnesota State University, Mankato, MN; Mr. Adam S. Way, Dyntel Corporation, Vicksburg, MS; Ms. Chetta S. Owens, ASI Corporation, Lewisville, TX; Ms. Crosson, VTDEC; and Mr. Alan J. Burns, SePRO Corporation, Carmel, IN.

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This work was performed under the general supervision of Dr. Terrance Sobecki, Chief, EPB; Dr. Richard E. Price, Chief, EPED; and Dr. Edwin A. Theriot, Director, EL.

At the time of publication of this report, Director of ERDC was Dr. James R. Houston; Commander and Executive Director was COL John W. Morris III, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acre-feet	1,233.489	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers
yards	0.9144	meters

1 Introduction

Background

The aquatic herbicide fluridone (1-methyl-3-phenyl-5-[3-(trifluromethyl) phenyl]-4(1H)-pyridinone) is being used to control the submersed exotic weed *Myriophyllum spicatum* L. (Eurasian watermilfoil) in water bodies across the northern tier states. Limiting the growth of *M. spicatum* is important because nuisance levels of this plant enable it to out compete most native submersed species and become the dominant component of the plant community (Grace and Wetzel 1978; Aiken, Newroth, and Wile 1979; Madsen, Eichler, and Boylen 1988; Smith and Barko 1990). These weedy infestations also negatively impact fish and wildlife habitat, water quality, and recreational uses of water bodies (Hansen, Oliver, and Otto 1983; Newroth 1985; Ross and Lembi 1985; Nichols and Shaw 1986).

The objective of most fluridone treatments is to selectively remove *M. spicatum*, while minimizing impacts on the native vegetation. A liquid aqueous suspension (AS) of fluridone is being used in many of these selective-control applications. In these cases, fluridone is being used in a unique manner, in that the entire water body is being treated with a herbicide to selectively remove an exotic pest species, rather than relying on a more traditional approach of spot-treating smaller sections of a lake to reduce the weed infestation.

Although the maximum legal concentration of fluridone in water can be up to 150 $\mu g\ L^{-1}$ (parts per billion), laboratory research has indicated that fluridone can render various levels of *M. spicatum* control at initial treatment rates as low as 4 to 15 $\mu g\ L^{-1}$, provided that an adequate herbicide exposure period ($\geq$60 days) is maintained (Netherland et al. 1993; Netherland and Getsinger 1995a, 1995b). These concentration and exposure time (CET) studies have clearly shown that to provide effective control, a target plant must be exposed to some threshold level of fluridone in the initial period of exposure, and then be exposed to lower levels of fluridone for an extended time period. Furthermore, results of outdoor mesocosm CET evaluations on mixed submersed plant communities have suggested that fluridone rates between 5 and 10 $\mu g\ L^{-1}$, concomitant with an adequate exposure period (>60 days) with residues remaining above 2 $\mu g\ L^{-1}$, can effectively control *M. spicatum*, while effects on nontarget species, such as *Elodea canadensis* L. (elodea), *Potamogeton nodosus* Poiret (American pondweed), *Stukenia pectinata* (L) Borner (formerly *Potamogeton pectinatus)* (sago pondweed), and *Vallisneria americana* Michaux (wild celery), are minimal in the year of treatment (Netherland, Getsinger, and Turner 1997). Finally, results of these small-scale studies revealed two important points: (a) there was a significant difference in the species-selective properties of fluridone between 5 and 10 µg L^{-1}; and (b) early season applications of fluridone provided better control of *M. spicatum* and enhanced selectivity.

Currently, there is some debate among the lake management community concerning the selective plant control properties of fluridone when used in whole-lake treatment scenarios (Kenaga 1993, 1995). Although cover and diversity of native species has usually recovered by 1 to 3 years posttreatment following a whole-lake fluridone application, even at rates $\geq$20 µg L^{-1} (Getsinger 1993; Smith and Pullman 1997), much of the concern has focused on potential impacts to game fish populations following the removal of a portion of vegetation throughout the lake in the year of treatment. Field observations and reports indicate that when fluridone is applied at water concentrations $\geq$10 µg L^{-1}, some nontarget plant species may survive the year of treatment while others do not (Kenaga 1993, 1995; Welling, Crowell, and Perleberg 1997; Smith and Pullman 1997).

In a 1997-98 evaluation, four lakes in Michigan (55 to 220 ha in size) were treated with low doses of fluridone (Getsinger et al. 2001). The formulation Sonar® AS was used to provide initial whole-lake concentrations of 5 µg L^{-1} fluridone, followed by a "booster" or "bump" application at 16 to 21 days following the initial treatment. This treatment strategy resulted in good to excellent control of *M. spicatum* in three of the four lakes. Although some native species were impacted, the treatment strategy allowed for >70-percent coverage of native plants to remain in all of the water bodies, even during the year of treatment. At the time of these studies, Michigan regulations would not allow depths of >3.3 m (10 ft) to be used in water volume calculations in whole-lake fluridone treatments. This restriction affected the ability to properly utilize the influence of water temperatures and thermoclines as factors in lake mixing processes and made it difficult to achieve the initial target rate of 5 µg L^{-1} fluridone. In addition, *M. spicatum* was poorly controlled in one of the lakes; thus, investigators recommended that higher initial and booster application rates (e.g., 6 µg L^{-1}) should be considered for future low-dose, whole-lake treatments. This modified application strategy should assist in achieving previously established fluridone CET requirements for selective control of *M. spicatum*.

Objectives

Since reliable quantitative information linking changes in submersed plant species diversity with fluridone treatments is limited, particularly with respect to water residue records, a study was conducted in which a prescription low-dose fluridone treatment was applied to two lakes in Vermont. The primary objective of this study was to determine whether submersed plant diversity and frequency were impacted by whole lake, low-dose fluridone applications in the year of treatment, and beyond, when targeting for control of *M. spicatum*. A secondary objective was to verify laboratory results of fluridone concentration and exposure time relationships with respect to efficacy against *M. spicatum*.

2 Fluridone Treatments

Development of Treatment Strategy

Personnel from the U.S. Army Engineer Research and Development Center (ERDC) assisted the Vermont Department of Environmental Conservation (VTDEC) in developing a strategy for selectively managing *M. spicatum* using the aquatic herbicide Sonar AS (fluridone) in Burr Pond and Lake Hortonia. Considerable input for developing this treatment strategy was also provided by personnel at SePRO Corporation (manufacturer of Sonar AS), and by individuals of the Lake Hortonia Property Owner's Association and the Burr Pond Association (LHPOA/BPA). The strategy was based upon the use of lake-specific factors such as bathymetry, water volume, temperature, and thermocline data, as well as upon previously developed fluridone concentration and exposure time relationships against *M. spicatum* and nontarget aquatic vegetation, and results from previous small-scale fluridone CET evaluations and field studies. By using these factors, a low-dose, whole-lake prescription application method was employed on each water body to selectively remove the invasive plant, *M. spicatum*, using fluridone. The LHPOA/BPA was the applicant for the aquatic pesticide permit issued by the VTDEC for the fluridone treatments.

Description of Lakes

Burr Pond

Burr Pond is a 34.5-ha (85-acre) impounded water body located in west-central Vermont in Rutland County (Figure 1). The lake's shoreline has a regular shape, with a dam located in the southwest quadrant (Figure 2). An outlet stream flows from the dam, forming the major inflow into Lake Hortonia. An inflow stream, originating from Hinkum Pond Brook, flows into the southeast quadrant of Burr Pond. Based on water depth measurements taken during the plant assessment portion of this study, the average depth of the lake was calculated to be 3.6 m (11.7 ft), with a maximum depth of ~6 m (~20 ft). Historically, at least 44 species of aquatic plants have been identified in Burr Pond, with *M. spicatum* first confirmed in 1991 and becoming the dominant plant in the lake by the mid 1990's (LHPOA/BPA 1999). A 1998 survey by VTDEC personnel reported 23 species of aquatic plants in the lake, with *M. spicatum* being very abundant (LHPOA/BPA 1999). The 1999 and 2000 pretreatment vegetative communities for Burr Pond are described in Chapter 3.

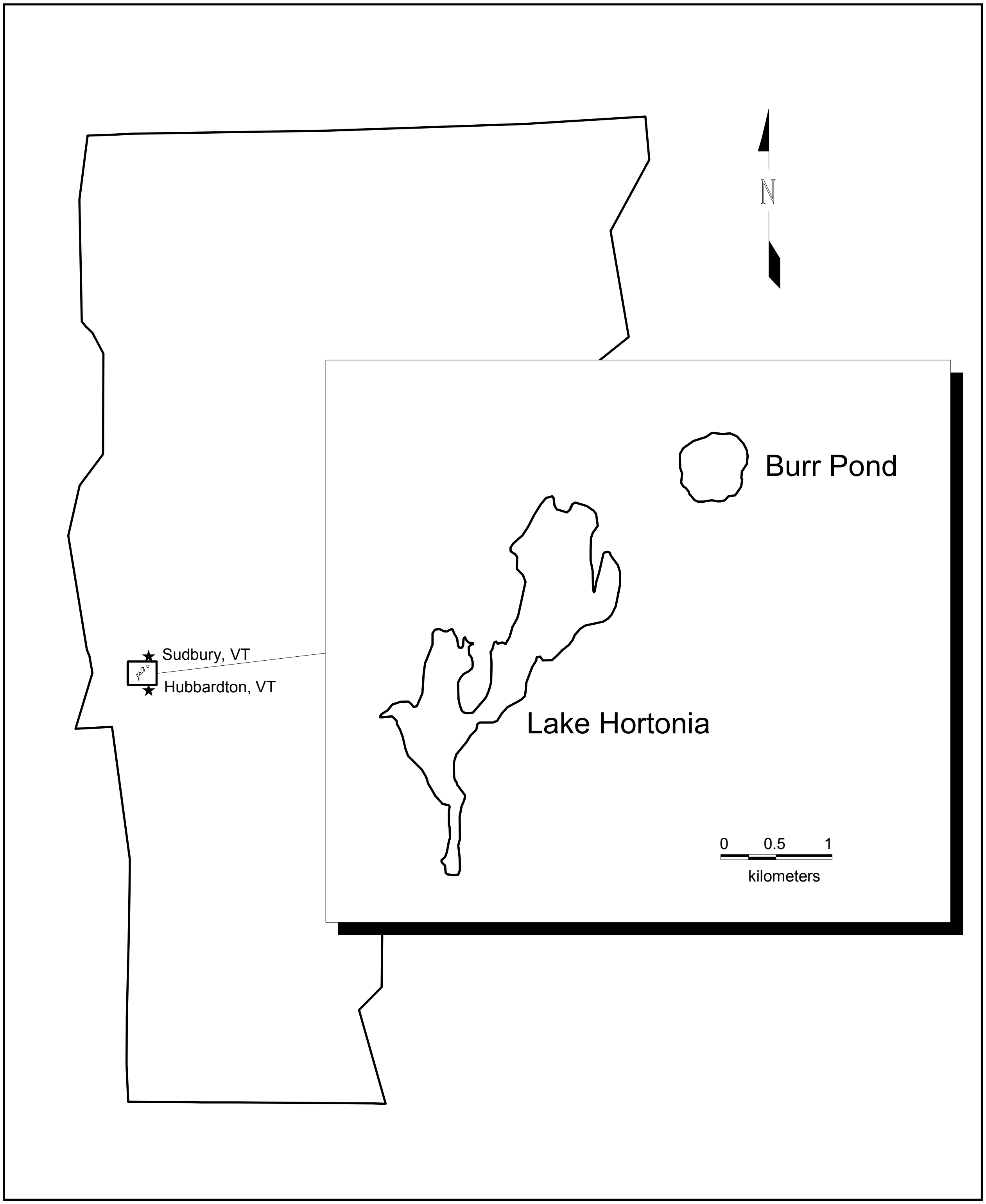

Figure 1. Map of Vermont showing approximate locations of Burr Pond and Lake Hortonia

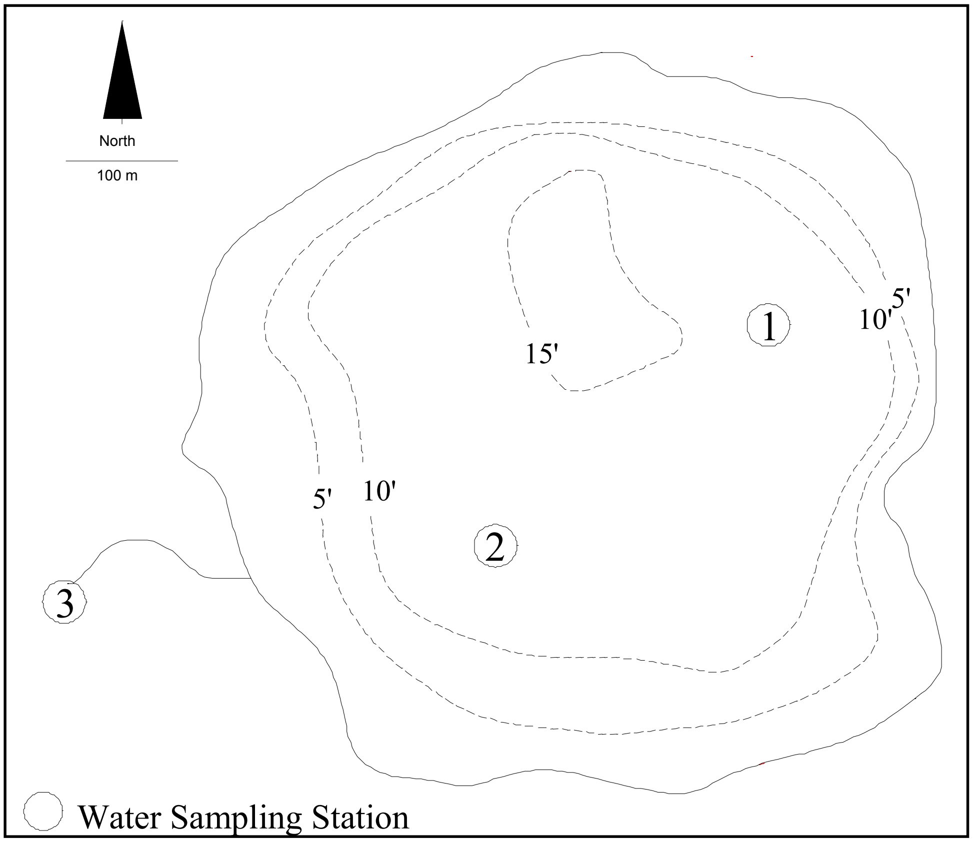

Figure 2. Water sampling stations (June – September 2000) on Burr Pond, Vermont

Lake Hortonia

Lake Hortonia is a 194-ha (480-acre) impounded water body also located in west-central Vermont in Rutland County (Figure 1). The shoreline of the lake is irregular in shape (Figure 3) with a constriction connecting a deep northeastern basin (average depth of 4.94 m (16.2 ft)) to a shallow southwestern basin (average depth of 2.35 m (7.7 ft)). The lake has a maximum depth of 19 m (62 ft), which occurs in the northeastern basin. Based on water depth measurements taken during the plant assessment portion of this study, the average depth of the lake was calculated to be 5.85 m (19.2 ft). Most of the lake's 17.9-km^2 (6.9-sq-mile) drainage basin is forested (64 percent) with 11 percent grassland, 6 percent residential, and 3 percent cropland. The primary inlet stream on Hortonia is a drain from Burr Pond, entering the lake from the northeastern shore. The outlet from the lake flows from a concrete dam (owned by the Vermont Department of Fish and Wildlife) on the western shore into the Hubbarton River, and finally into Lake Champlain. The lake shoreline is developed with private dwellings (some 240 camps). Historically, at least 48 species of aquatic plants have been identified in Lake Hortonia, with *M. spicatum* first confirmed in 1984, and becoming the dominant plant in the lake by the mid 1990's (LHPOA/BPA 1999). A 1998 survey by VTDEC personnel

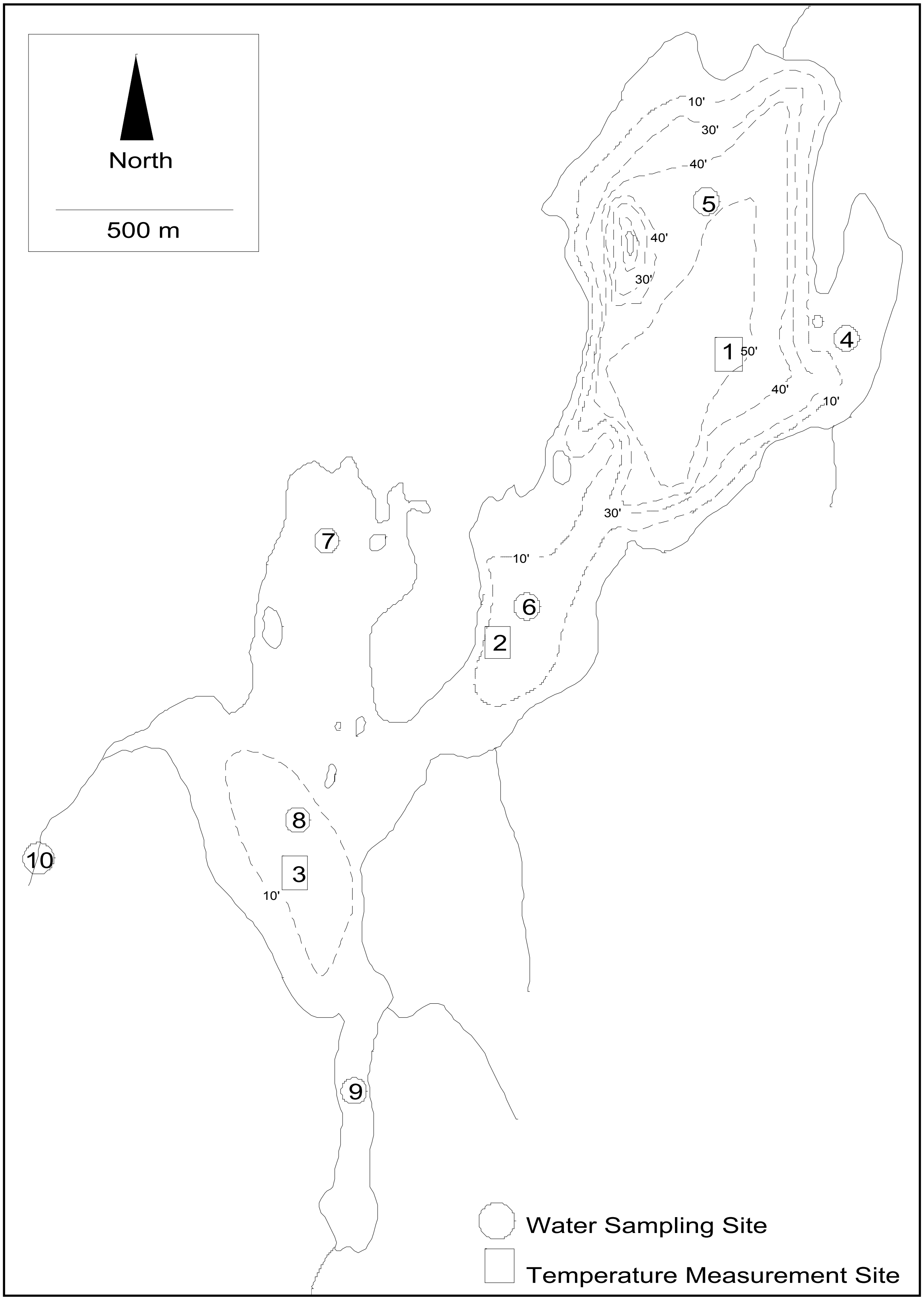

Figure 3. Water temperature measurement sites (29 May 2000) and water sampling stations (June – September 2000) on Lake Hortonia, Vermont

reported 32 species of aquatic plants in the lake, with *M. spicatum* being very abundant (LHPOA/BPA 1999). The 1999 and 2000 pretreatment vegetative communities for Lake Hortonia are described in Chapter 3.

Methods and Materials

Lake bathymetry and calculated water volumes

A key factor for establishing and maintaining an adequate concentration of fluridone is to document the volume of water contained in the lake to be treated. In Burr and Hortonia, this was accomplished by systematically collecting bathymetric data, using a fathometer (Raytheon V850 Echosounder) and a global positioning system (GPS) receiver, to develop depth contours (bathymetric maps) for each lake (ReMetrix LLC, Carmel, IN). This information was then used to determine water volumes (in acre-feet) for each depth layer (surface to 3 ft, 3 ft to 6 ft, etc.).[1] Using this method, the entire volume of each lake (or lake basin) was calculated, and these data were used to determine the amount of Sonar AS needed to provide the desired aqueous concentration of fluridone.

Because of its regular morphology, Burr Pond was treated as a single basin with respect to the calculated water volume required for herbicide application. However, analyses of the water volume data from Lake Hortonia indicated that this lake should be divided into six distinct basins (1, 1A, 2, 3, 3A, and 3B) for herbicide applications (Figure 4). Specific details for measuring, recording, analyzing, and mapping the bathymetry of each lake, used in the herbicide treatment process, are provided in Appendix A.

Water temperatures and lake thermoclines

Another factor that can influence distribution and accuracy of aqueous fluridone levels is the depth of the thermocline at the time of herbicide treatment. As reported in previous field studies (Getsinger et al. 2001), fluridone will mix to the thermocline level in a lake following application. Moreover, fluridone residues can become locked into the depth zone above the thermocline until a lake turnover event occurs. By measuring the thermocline just prior to fluridone application, this information can be used to predict the mixing potential of the product with respect to depth contours. Thus, the water volumes of the metalimnion and hypolimnion can be determined — information critical for calculating the amount of herbicide required to accurately treat the depth zones where most of the plants would grow. When real-time lake temperature measurements are coupled with accurate lake bathymetry, a precision application of fluridone (± 1 μg L^{-1}) in targeted depth zones should be achievable.

Water temperature on Lake Hortonia was measured using a calibrated therister (YSI Model 95) on 29 May 2000 (Table 1) at these locations (Figure 3) 5 days prior to fluridone application. These data showed that temperatures were

[1] A table of factors for converting U.S. customary units of measurement to metric (SI) is presented on page xiv.

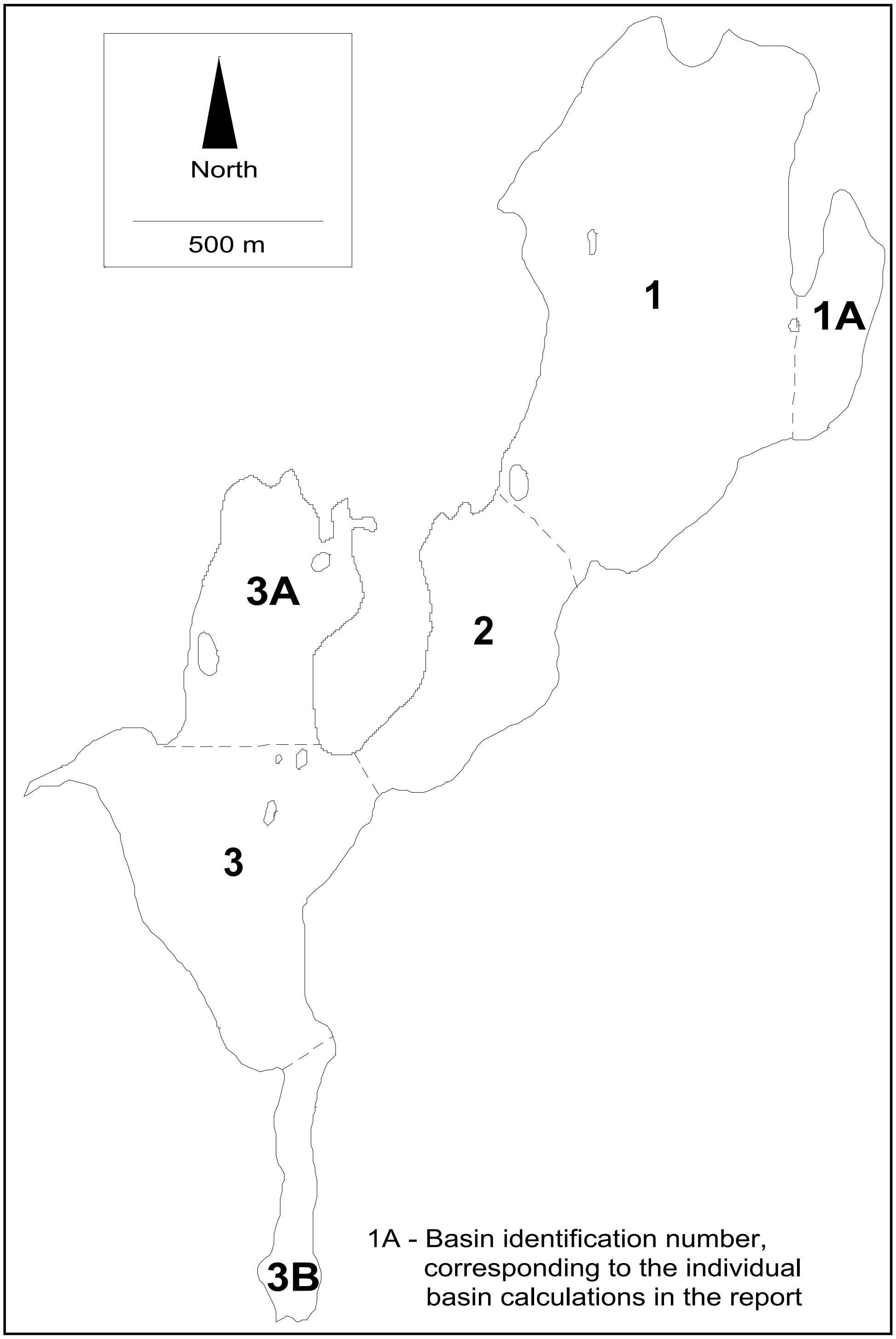

Figure 4. Water basin map of Lake Hortonia, Vermont

Table 1
Water Temperature Profiles for Lake Hortonia Taken on 29 May 2000 at 1700 hr

Depth m	Site 1 Temp,°C	Site 2 Temp,°C	Site 3 Temp,°C
0	16.7	16.9	16.1
-1	16.7	17	17.1
-2	16.7	17	17.3
-3	16.7	16.9	17.3
-4	16.7	16	16.9
-5	16.7	14.5	
-6	13.1	12.7	
-7	11		
-8	10.2		
-9	9.6		
-10	9.1		
-11	8.4		
-12	8.1		
-13	7.9		
-14	7.8		
-15	7.7		

essentially isothermal (16.5 to 17.0 °C) in the upper 4 to 5 m (13 to 16 ft) of the water column, indicating that fluridone would only mix through that depth. With one exception (Basin 1), all of the other basins in the lake had an average water depth of less than the measured thermocline (i.e., Basins 1A and 3B, average depth = 1.9 m; Basin 2, average depth = 3.9 m; Basin 3, average depth = 3.5 m; and Basin 3A, average depth = 1.6 m). Therefore, these average depths were used to calculate the water volumes used for determining the amount of herbicide applied in each of those basins. Since Basin 1 had an average depth of 9 m, the thermocline depth was used to calculate water volume to be treated in that basin.

Since the average water depth of Burr Pond was 4.4 m (as calculated by methods used in Appendix A), and that lake was not divided into basins, the whole lake average depth was used to calculate water volume for fluridone application to the lake. In addition, pretreatment water temperature profiles were not taken on Burr Pond.

Fluridone applications

Burr Pond. Water volumes used for the prescription treatment on Burr Pond were based on the average depth of the lake, 4.4 m (Appendix A), in order to achieve an aqueous fluridone concentration of 6 $\mu g\ L^{-1}$ throughout the lake. However, there are discrepancies in the average depths reported for Burr Pond. Historical information (LHPOA/BPA 1999) indicates an average depth of 2.7 m (39 percent less than the 4.4-m average depth from Appendix A), while data collected for the plant assessment portion of this study and summarized in Table 2 indicate an average depth of 3.6 m (18 percent less than the 4.4-m mean depth from Appendix A). These discrepancies suggest that the water volume used (as calculated in Appendix A) for determining the amount of Sonar AS required to achieve an initial whole-lake concentration of 6 $\mu g\ L^{-1}$ fluridone might be an overestimation and therefore cause the targeted herbicide dose to be exceeded.

The herbicide was mixed in a 190-L (50-gal) tank with lake water and injected just below the surface using a diaphragm pump and boom system. The boom was mounted on the stern of an airboat and equipped with four weighted drop hoses (0.6 to 1.2 m in length), evenly spaced at 0.6-m intervals. The airboat was piloted across the lake in a pattern that provided an even application of the

Table 2
Average Water Depth and Estimated Lake Volumes for Burr Pond[1]

Date	Average Depth ft	Estimated Volume acre-feet
June 1999	11.2	834
August 1999	11.2	834
June 2000	12.6	942
August 2000	12.0	895
June 2001	11.9	891
August 2001	11.4	850
Average	11.7	874

[1] Based on water depth measurements at the 191 point-intercept sampling points used in the aquatic plant assessments.

herbicide. This procedure represented a typical and recommended type of fluridone application method for whole-lake scenarios. A total of 18.9 L (5 gal) of Sonar AS was applied to the lake on 4 June 2000 (1110 to 1230 hr). In order to extend the contact time of fluridone in the lake, a booster application was performed on 9 July 2000 (1215 to 1230 hr) using a total of 5.6 L (1.5 gal) of Sonar AS to reestablish a 6-μg L^{-1} level of fluridone in the lake. To reduce possible herbicide injury to the nontarget emergent and floating-leaved vegetation growing in nearshore areas around the lake, the application boat avoided direct treatment to those regions.

Lake Hortonia. Calculated water volumes from each basin on Lake Hortonia (Appendix A) were used to determine the amount of product required to achieve an initial aqueous fluridone concentration of 6 μg L^{-1} in each basin, and thus the whole lake. Unlike the situation at Burr Pond, there were no significant discrepancies between historical (LHPOA/BPA 1999) and recently measured water depths (Table 3 and Appendix A) on Lake Hortonia. A total of 91.8 L (24.25 gal) of Sonar AS was applied to the lake on 4 June 2000. Using water volume data, the following amounts of Sonar AS were applied to each basin during this initial treatment: Basin 1, 53 L (14 gal); Basin 1A, 2.8 L (0.75 gal); Basin 2, 11.4 L (3 gal); Basin 3, 16.1 L (4.25 gal); Basin 3A, 6.6 L (1.75 gal); and Basin 3B, 1.9 L (0.5 gal). The application commenced at 0830 hr and was completed by 1100 hr, with the weather conditions being sunny and calm.

Table 3
Average Water Depth and Estimated Lake Volumes for Lake Hortonia[1]

Date	Average Depth ft	Estimated Volume acre-feet
June 1999	18.3	8,765
August 1999	18.3	8,765
June 2000	21.9	10,522
August 2000	19.4	9,312
June 2001	19.6	9,408
August 2001	17.8	8,544
Average	19.2	9,216

[1] Based on water depth measurements at the 299 point-intercept sampling points used in the aquatic plant assessments.

In order to extend the contact time of fluridone in the lake, a whole-lake booster treatment was applied on 9 July 2000. This booster application occurred 35 days following the first application and was designed to add another 2 $\mu g\ L^{-1}$ of fluridone to the system, reestablishing the aqueous fluridone concentration in the lake to the initial target level of 6 $\mu g\ L^{-1}$. To achieve that goal, a total of 29.1 L (7.7 gal) of Sonar AS was applied to the lake using the same water volume calculations and apportionment to the six lake basins as utilized on the initial treatment of 4 June. The application methods employed for the initial and booster treatments were identical to those described for Burr Pond. The application commenced at 1245 hr and was completed at 1500 hr, with the weather conditions being sunny and calm.

Monitoring of leaf and shoot *M. spicatum* pigment levels (data not shown) indicated that *M. spicatum* in Basin 3A was not responding to the fluridone in a manner that would result in plant death. Therefore, to ensure a fluridone CET that should provide adequate *M. spicatum* control, a second booster treatment was conducted in that basin of the lake on 19 September 2000, using previously described application methods. Approximately 20 ha (52 acres) of the basin were treated with 7.6 L (2 gal) of Sonar AS using previously described methods. This treatment was designed to reestablish a concentration of 6 $\mu g\ L^{-1}$ fluridone in that portion of the basin. The second booster application commenced at 1030 hr and was completed at 1130 hr, with the weather being sunny and a southerly breeze at 16 kph (10 mph).

To reduce possible herbicide injury to the nontarget emergent vegetation growing in large stands occurring in certain sections of the lake (i.e., north end of Basins 1A and 3A, and south end of Basin 3B), the application boat remained at least 100 m away from the edge of these wetland stands. This 100-m buffer zone was maintained during the initial and booster treatments.

Fluridone residue sampling and analysis

In order to monitor aqueous herbicide levels following the fluridone applications, sampling stations were established on Burr Pond (Stations 1 and 2) and on Lake Hortonia (Stations 4 through 9), as well as at a downstream location (Stations 3 and 10) from each lake (Figures 2 and 3). These stations were selected to provide an even coverage of residue data in the lake basins. Water samples were taken at 1, 5, 10, 15, 22, 29, 37, 50, 57, 71, 85, 95, 102, 108, and 116 days after treatment (DAT). Samples were collected at a depth of approximately 0.5 m below the surface, stored on ice in opaque 125-mL polyethylene bottles, and shipped to the laboratory for analysis within 24 hr. Fluridone was analyzed using an immunoassay technique, which has shown a statistically significant correlation with standard high performance liquid chromatography (HPLC) methods (Netherland et al. 2002). Results of residue analyses were used to determine if initial target levels of fluridone were achieved and to calculate the amount of Sonar AS needed to reestablish fluridone levels via booster applications.

Results and Discussion

Burr Pond

Aqueous fluridone residues for Burr Pond from 1 through 103 DAT are shown as discrete sample values in Table 4, and as mean values (±SE) in Table 5 and Figure 5. Initial measurements in Burr Pond indicated that a whole-lake level of 9.9 $\mu g\ L^{-1}$ fluridone was achieved at 1 DAT, which was somewhat higher than the target dose of 6 $\mu g\ L^{-1}$ fluridone. Although levels declined to 7.4 $\mu g\ L^{-1}$ fluridone on 5 DAT, whole-lake herbicide residues did not approach the intended target level of 6 $\mu g\ L^{-1}$ fluridone until 10 DAT (14 June), when aqueous concentrations averaged 6.3 $\mu g\ L^{-1}$.

Several factors may have played a role in causing the higher-than-expected initial fluridone concentrations. These factors included overall hydraulic mixing processes in the lake, temperature stratification patterns at time of treatment, and overestimation of calculated water volume used to yield the targeted fluridone dose.

For undetermined reasons, the waters in Burr Pond may not have mixed well until several days after the initial treatment. This delayed mixing could have resulted in elevating the aqueous fluridone concentration in the near-surface waters, where the samples were collected (~0.5 m in depth). In a related manner, the incomplete mixing could have been caused by the occurrence of a thermocline, resulting in elevated fluridone concentrations in the "mixed" zone that would persist until the thermocline disappeared. Unfortunately, a record of water temperature profiles in the lake just prior to treatment is unavailable, so the presence of a thermocline in Burr Pond cannot be confirmed.

As noted earlier, inaccurate water depth measurements may have also contributed to an overestimation of herbicide required to produce the targeted initial dose (6 $\mu g\ L^{-1}$ fluridone). Historical (LHPOA/BPA 1999) water depth records and measurements from the plant assessment portion of this study (Table 2) suggest that the water volume from Appendix A, which was used to calculate the amount of herbicide required for the targeted dose, was 22 to 63 percent greater than that calculated using the water volumes derived from the other sources. Therefore, using the overestimated water volume could have resulted in initial fluridone doses of from 7.4 to 9.8 $\mu g\ L^{-1}$. In fact, the measured fluridone concentration in Burr Pond was 9.9 $\mu g\ L^{-1}$ on 1 DAT and 7.4 $\mu g\ L^{-1}$ on 5 DAT.

The suspected inaccuracy of the depth measurements (and corresponding depth zone volumes) from Appendix A is further supported by observations of the lake bottom, and by hydroacoustic measurements taken by a SAVEWS system (Sabol and Melton 1995; Sabol and Burczynski 1998). As with many shallow, bowl-shaped northern tier lakes, the bottom of Burr Pond has become filled over time with fine sediments. These sediments have most likely originated from the runoff of mineral silts and the accumulation of decomposed aquatic plant tissues. The sediments can be >1 m deep and are not well consolidated, especially in the center of the lake. A hydroacoustic printout (Figure 6)

Table 4
Sample Sites and Concentration of Aqueous Fluridone in Burr Pond and Outlet Stream, 5 June through 15 September 2000

Date	Sample Site	Fluridone, $\mu g\ L^{-1}$
5 Jun 00	1 - north side 13 ft inlet side	9.4
	2 - south side 13 ft outlet side	10.5
	3 - outlet stream 100 yd from dam	9.1
9 Jun 00	1 - north side 13 ft inlet side	7.8
	2 - south side 13 ft outlet side	7.1
	3 - outlet stream 100 yd from dam	6.55
14 Jun 00	1 - north side 13 ft inlet side	6.7
	2 - south side 13 ft outlet side	5.9
	3 - outlet stream 100 yd from dam	4.6
19 Jun 00	1 - north side 13 ft inlet side	6.1
	2 - south side 13 ft outlet side	5.9
	3 - outlet stream 100 yd from dam	6.45
26 Jun 00	1 - north side 13 ft inlet side	4.35
	2 - south side 13 ft outlet side	4.25
	3 - outlet stream 100 yd from dam	4.75
3 Jul 00	1 - north side 13 ft inlet side	4
	2 - south side 13 ft outlet side	4.1
	3 - outlet stream 100 yd from dam	3.7
11 Jul 00	1 - north side 13 ft inlet side	5.8
	2 - south side 13 ft outlet side	5.45
	3 - outlet stream 100 yd from dam	5.6
24 Jul 00	1 - north side 13 ft inlet side	3.85
	2 - south side 13 ft outlet side	3.7
	3 - outlet stream 100 yd from dam	3.85
31 Jul 00	1 - north side 13 ft inlet side	2.9
	2 - south side 13 ft outlet side	3.6
	3 - outlet stream 100 yd from dam	3.35
14 Aug 00	1 - north side 13 ft inlet side	3.25
	2 - south side 13 ft outlet side	3.55
	3 - outlet stream 100 yd from dam	3.05
28 Aug 00	1 - north side 13 ft inlet side	2.7
	1a - north side swamp near access	0.99
	2 - south side 13 ft outlet side	2.65
	3 - outlet stream 100 yd from dam	2.75
15 Sep 00	1 - north side 13 ft inlet side	2.3
	2 - south side 13 ft outlet side	2.65
	3 - outlet stream 100 yd from dam	---

Table 5
Mean (±SE) Fluridone Residues in Burr Pond for 5 June through 15 September 2000

Date	Days After Treatment	Fluridone, µg L^{-1}, mean ±SE
4 Jun 00	0	Initial treatment
5 Jun 00	1	9.950 ± 0.550
9 Jun 00	5	7.450 ± 0.350
14 Jun 00	10	6.300 ± 0.400
19 Jun 00	15	6.000 ± 0.100
26 Jun 00	22	4.300 ± 0.050
3 Jul 00	29	4.050 ± 0.050
9 Jul 00	35	Booster
11 Jul 00	37	5.625 ± 0.175
24 Jul 00	50	3.775 ± 0.075
31 Jul 00	57	3.250 ± 0.350
14 Aug 00	71	3.400 ± 0.150
28 Aug 00	85	2.113 ± 0.562
15 Sep 00	102	2.475 ± 0.175

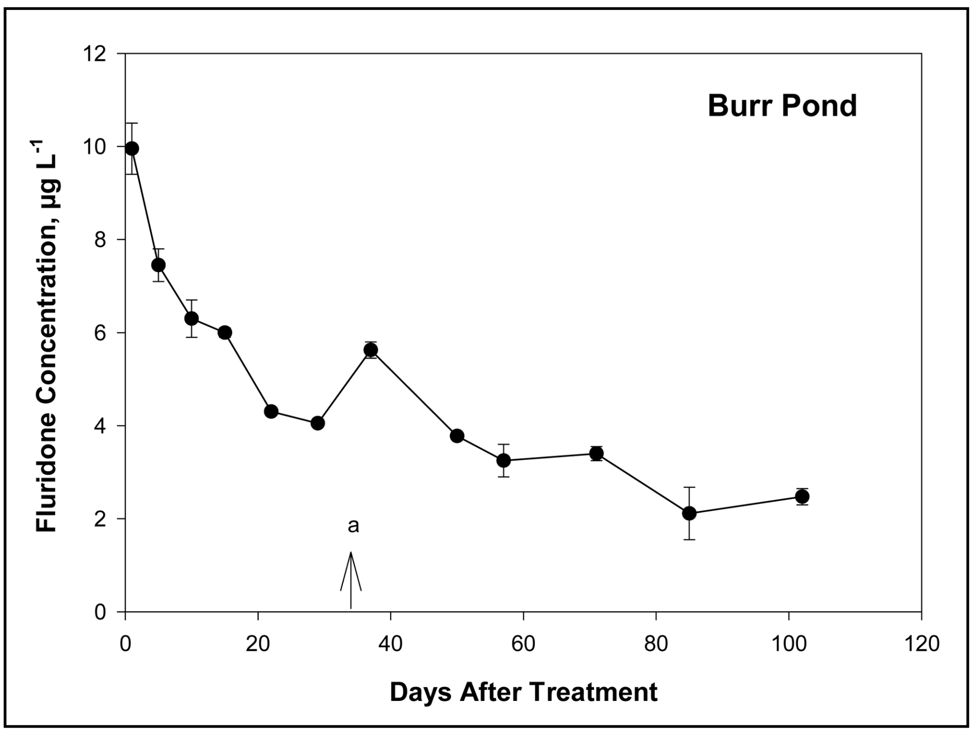

Figure 5. Mean (±SE) fluridone residues in Burr Pond for 5 June through 15 September 2000. Booster application occurred on 9 July 2000, as indicated by arrow (a)

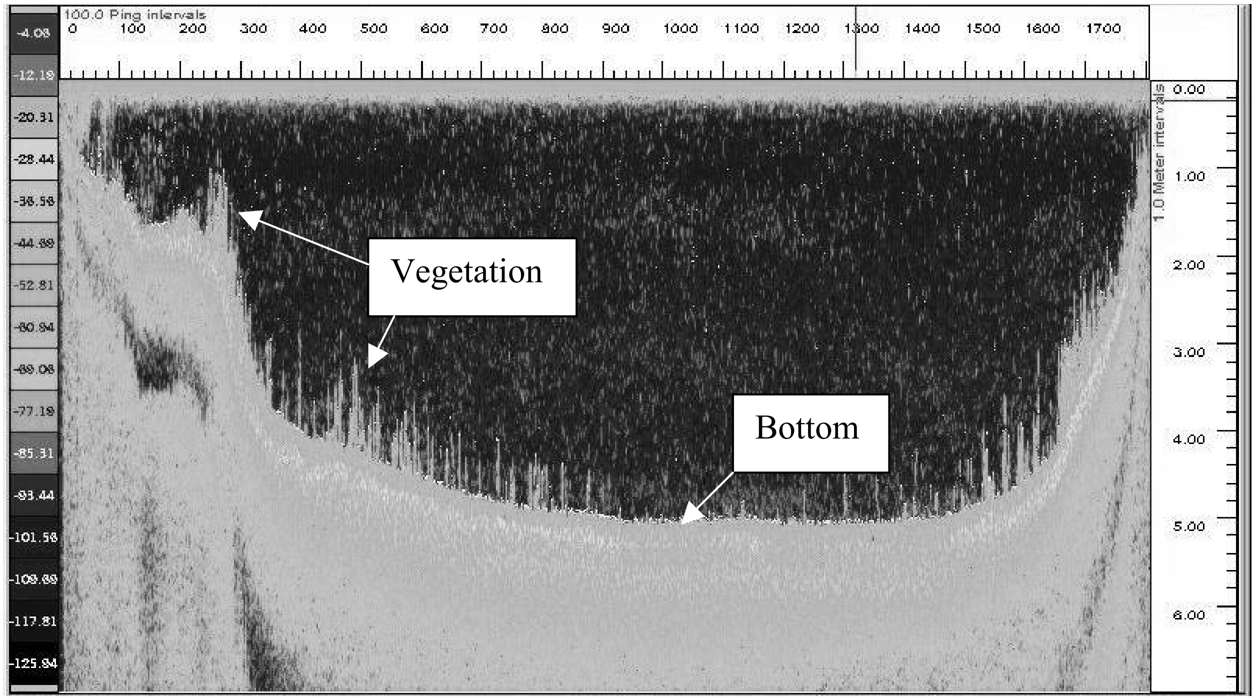

Figure 6. Illustration of hydroacoustic tracing generated by SAVEWS along a transect in Burr Pond during August 2000. Approximate location of the transect in Burr Pond is illustrated in Figure 7

from August 2000, obtained from a SAVEWS transect located along the center region of Burr Pond (Figure 7), clearly shows that phenomenon. The nature of these "soft" or "muck-type" sediments makes it difficult to obtain accurate depth measurement with fathometers. When using a fathometer, such as the one used to obtain depth data presented in Appendix A, a signal strong enough to pulse through submersed vegetation must be maintained. However, such a signal has a tendency to penetrate "soft" sediments before recognizing a "hard" bottom, and thus an overestimation of actual depth can occur. It is likely that this process of penetrating the "soft" bottom in Burr Pond did occur (personal communication, D. Hendricks, ReMetrix LLC, Carmel, IN). To prevent inaccurate bottom readings where "soft" sediments may exist, it is suggested that a more sensitive fathometer, such as the BioSonics DT Series Digital Scientific Echosounder, be used for bathymetric measurements.

While fluridone residues reached levels above the target dose, these elevated concentrations only lasted for a few days. Regardless of the greater-than-intended initial dose of fluridone measured in Burr Pond, or the reason(s) for the higher levels, the anticipated outcome of treatment effectiveness (i.e., selective control *M. spicatum*) was still expected to occur.

By 29 DAT, water residues had declined to 4 $\mu g\ L^{-1}$ fluridone, but had rebounded to a level of 5.6 $\mu g\ L^{-1}$ 2 days after the 9 July booster application, or 37 days after the initial fluridone treatment. These data indicated that a reestablishment of the initial fluridone dose of 6 $\mu g\ L^{-1}$ was essentially achieved. Unlike

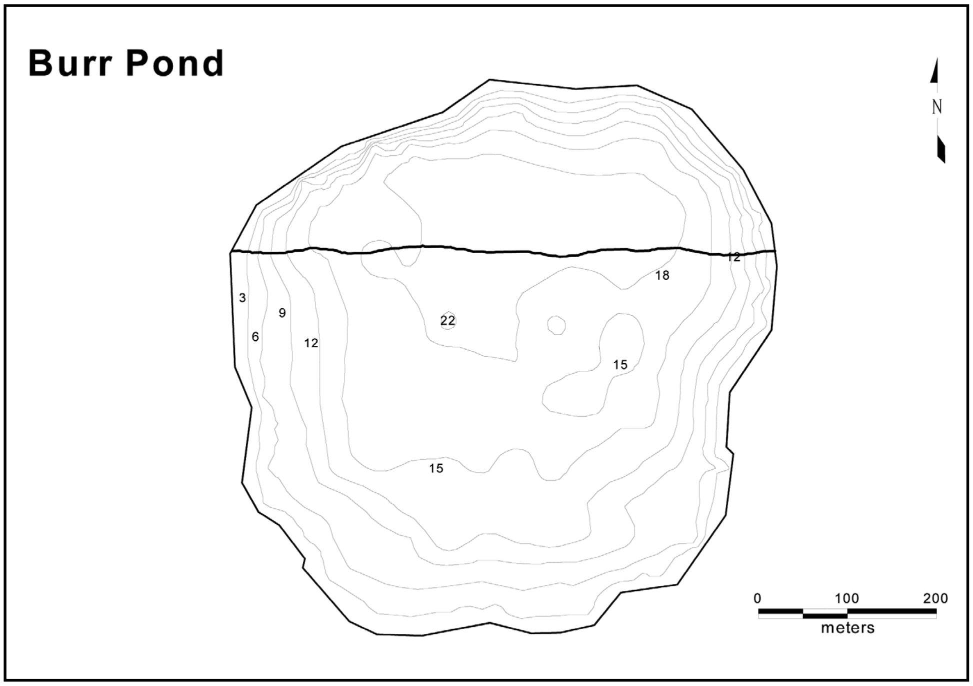

Figure 7. Depth contour map of Burr Pond generated from water depths collected during point-intercept sampling for aquatic plant assessments. The horizontal line indicates the approximate location of west-to-east hydroacoustic survey transect illustrated in Figure 6

the initial application, this booster treatment did not exceed the intended application level. Since the same calculated water volumes (based on an average depth of 4.4 m, as provided in Appendix A) were used for the initial and booster applications, this suggests that a water mixing problem immediately following the initial application (4 June), rather than an overestimation of water volume, may have been responsible for the higher-than-intended fluridone levels measured in the lake at 1 and 5 DAT.

Fluridone residues slowly declined to a level of 2.5 $\mu g\ L^{-1}$ by 15 September, 108 days after the initial herbicide application or 68 days after the booster application. However, based on results from previous small-scale and field evaluations (Getsinger et al. 2001; Netherland, Getsinger, and Turner 1993; Netherland and Getsinger 1995a, 1995b), the fluridone CET relationship maintained in Burr Pond was expected to provide acceptable control of *M. spicatum*, while minimizing injury to nontarget vegetation. Fluridone residues measured at Station 3, on the outlet stream approximately 100 m from the dam, ranged from 9.1 $\mu g\ L^{-1}$ fluridone on 5 June (1 DAT) to 2.7 $\mu g\ L^{-1}$ fluridone on 28 August (85 DAT).

Lake Hortonia

Aqueous fluridone residues for Lake Hortonia from 1 through 116 DAT are shown as discrete sample values in Table 6, and as mean values ($\pm$SE) in Table 7 and Figure 8. In contrast to residues in Burr Pond, initial measurements indicated that a whole-lake level of 6.3 $\mu g\ L^{-1}$ fluridone was achieved at 1 DAT, well

Table 6
Sample Sites and Concentration of Aqueous Fluridone in Lake Hortonia and Outlet Stream, 5 June through 15 September 2000

Date	Sample Site	Fluridone $\mu g\ L^{-1}$
5 Jun 00	4 - near inflow from Burr Pond	8
	5 - middle north 60 ft	6.2
	6 - middle center 24 ft	4.5
	7 - north bay swamp <6 ft	1.65
	8 - middle south 15 ft	6.85
	9 - south bay swamp <9 ft	10.5
	10 - outlet stream 1 mile from dam	0
9 Jun 00	4 - near inflow from Burr Pond	5.95
	5 - middle north 60 ft	5.85
	6 - middle center 24 ft	5.3
	7 - north bay swamp <6 ft	3.65
	8 - middle south 15 ft	8.85
	9 - south bay swamp <9 ft	8.1
	10 - outlet stream 1 mile from dam	3.3
14 Jun 00	4 - near inflow from Burr Pond	5.25
	5 - middle north 60 ft	5.25
	6 - middle center 24 ft	5.5
	7 - north bay swamp <6 ft	5.1
	8 - middle south 15 ft	5.85
	9 - south bay swamp <9 ft	6.9
	10 - outlet stream 1 mile from dam	5.1
19 Jun 00	4 - near inflow from Burr Pond	4.9
	5 - middle north 60 ft	5.75
	6 - middle center 24 ft	5.1
	7 - north bay swamp <6 ft	4.4
	8 - middle south 15 ft	5.35
	9 - south bay swamp <9 ft	5.65
	10 - outlet stream 1 mile from dam	4.3
26 Jun 00	4 - near inflow from Burr Pond	4.25
	5 - middle north 60 ft	4.65
	6 - middle center 24 ft	4.9
	7 - north bay swamp <6 ft	4.1
	8 - middle south 15 ft	4.2
	9 - south bay swamp <9 ft	4.4
	10 - outlet stream 1 mile from dam	4.3
3 Jul 00	4 - near inflow from Burr Pond	4
	5 - middle north 60 ft	4.25
	6 - middle center 24 ft	4
	7 - north bay swamp <6 ft	3.5

(Sheet 1 of 3)

Table 6 (Continued)		
Date	**Sample Site**	**Fluridone µg L^{-1}**
3 Jul 00 (Cont)	8 - middle south 15 ft	4.15
	9 - south bay swamp <9 ft	2.8
	10 - outlet stream 1 mile from dam	2.5
11 Jul 00	4 - near inflow from Burr Pond	5.5
	5 - middle north 60 ft	6.3
	6 - middle center 24 ft	5.1
	7 - north bay swamp <6 ft	5.3
	8 - middle south 15 ft	6.25
	9 - south bay swamp <9 ft	8.2
	10 - outlet stream 1 mile from dam	1.6
24 Jul 00	4 - near inflow from Burr Pond	4.65
	5 - middle north 60 ft	4.7
	6 - middle center 24 ft	4.7
	7 - north bay swamp <6 ft	4.35
	8 - middle south 15 ft	4.5
	9 - south bay swamp <9 ft	4.5
	10 - outlet stream 1 mile from dam	3.65
31 Jul 00	4 - near inflow from Burr Pond	3.95
	5 - middle north 60 ft	5.45
	6 - middle center 24 ft	4.35
	7 - north bay swamp <6 ft	4.05
	8 - middle south 15 ft	4.3
	9 - south bay swamp <9 ft	4.6
	10 - outlet stream 1 mile from dam	1.2
14 Aug 00	4 - near inflow from Burr Pond	3.9
	5 - middle north 60 ft	4.2
	6 - middle center 24 ft	4.25
	7 - north bay swamp <6 ft	3.5
	8 - middle south 15 ft	4
	9 - south bay swamp <9 ft	2.85
	10 - outlet stream 1 mile from dam	3.05
28 Aug 00	4 - near inflow from Burr Pond	3.5
	4a - NE bay near inlet	3.05
	5 - middle north 60 ft	3.75
	6 - middle center 24 ft	3.5
	7 - north bay swamp <6 ft	3
	7a - west side of main swamp 9 ft	2.85
	8 - middle south 15 ft	3.25
	9 - south bay swamp <9 ft	2.85
	10 - outlet stream 1 mile from dam	2.25
7 Sep 00	4 - near inflow from Burr Pond	3.15
	5 - middle north 60 ft	2.9
	6 - middle center 24 ft	3.35
	7 - north bay swamp <6 ft	2.95
		(Sheet 2 of 3)

Table 6 (Concluded)		
Date	**Sample Site**	**Fluridone $\mu g\ L^{-1}$**
7 Sep 00 (Cont)	8 - middle south 15 ft	3.2
	9 - south bay swamp <9 ft	2.65
	10 - outlet stream 1 mile from dam	---
15 Sep 00	4 - near inflow from Burr Pond	3.6
	5 - middle north 60 ft	3.1
	6 - middle center 24 ft	3.4
	7 - north bay swamp <6 ft	3.05
	8 - middle south 15 ft	5.2
	9 - south bay swamp <9 ft	2.3
	10 - outlet stream 1 mile from dam	---
20 Sep 00	7 - NW swamp 9 ft only booster	8.2
28 Sep 00	4 - near inflow from Burr Pond	2.05
	5 - middle north 60 ft	2.2
	6 - middle center 24 ft	2.75
	7 - north bay swamp <6 ft	4.85
	8 - middle south 15 ft	3.95
	9 - south bay swamp <9 ft	3.15
	10 - outlet stream 1 mile from dam	---
		(Sheet 3 of 3)

Table 7
Mean (±SE) Fluridone Residues in Lake Hortonia for 5 June through 28 September 2000

Date	Days After Treatment	Fluridone, $\mu g\ L^{-1}$, mean ±SE
4 Jun 00	0	Initial treatment
5 Jun 00	1	6.283 ± 1.234
9 Jun 00	5	6.283 ± 0.776
14 Jun 00	10	5.642 ± 0.274
19 Jun 00	15	5.192 ± 0.206
26 Jun 00	22	4.417 ± 0.124
3 Jul 00	29	3.783 ± 0.223
9 Jul 00	35	1st booster
11 Jul 00	37	6.108 ± 0.464
24 Jul 00	50	4.567 ± 0.057
31 Jul 00	57	4.450 ± 0.221
14 Aug 00	71	3.783 ± 0.216
28 Aug 00	85	3.219 ± 0.119
7 Sep 00	95	3.033 ± 0.102
15 Sep 00	102	3.442 ± 0.395
19 Sep 00	106	2nd booster[1]
28 Sep 00	116	2.820 ± 0.344

[1] Basin 3 only.

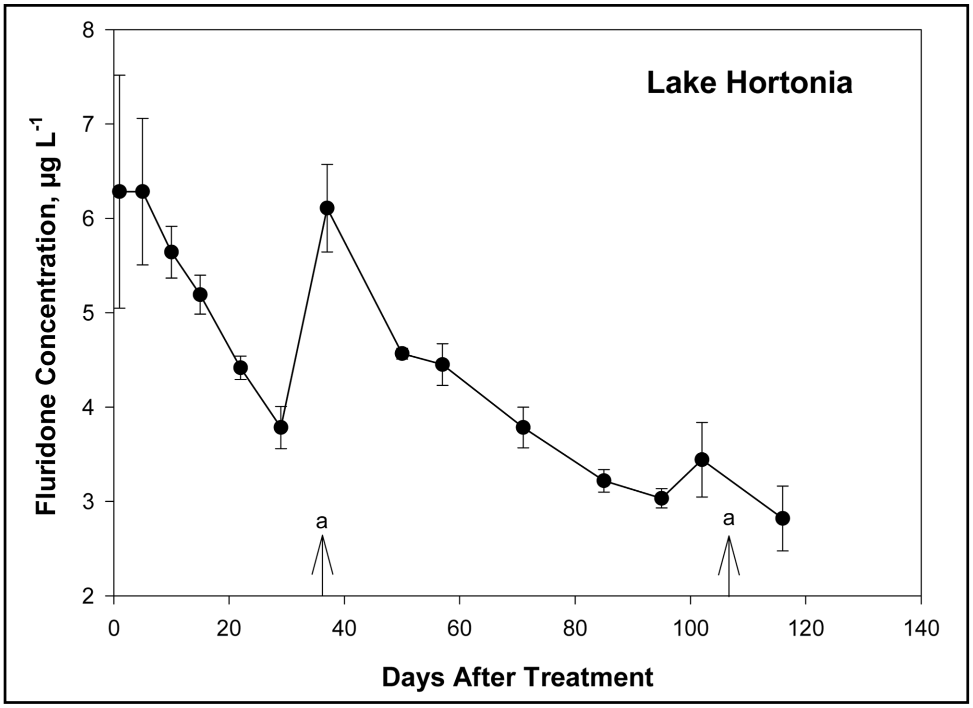

Figure 8. Mean (±SE) fluridone residues in Lake Hortonia for 5 June through 28 September 2000. Booster applications occurred on 9 July and 19 September 2000, as indicated by arrows (a)

within expected accuracy for precision-type operational treatments targeting 6 µg L^{-1}. This suggests that lake volume estimates from Appendix A were accurate for Lake Hortonia. This is further confirmed by the close agreement of the water depths reported in historical records (LHPOA/BPA 1999) and those measured in the plant assessment portion of this study (Table 3). Moreover, since a smaller proportion of Lake Hortonia contained shallow water with underlying "soft" sediment, the fathometer-generated depth readings were less likely to be inaccurate. Thus, calculated lake volumes (from Appendix A) were not overestimated (as apparently happened in Burr Pond).

In addition, pretreatment water temperature profiles were obtained for the lake, and they were used in a fashion to improve the accuracy of calculated water volumes in the various lake basins. This combination of accurate bathymetry and real-time thermal records resulted in a successful precision-type fluridone application, with respect to achieving initial whole-lake fluridone concentrations (where predicted water residues matched measured water residues).

Aqueous residues remained at 6.3 µg L^{-1} through 5 DAT, but had declined to a level of 3.8 µg L^{-1} by 30 DAT (3 July). Whole-lake residues had increased to 6.1 µg L^{-1} fluridone 2 days after the whole-lake booster application of 9 July, which showed that a reestablishment of the prescription target dose of 6 µg L^{-1} was essentially achieved. Fluridone residues slowly declined to a level of 3.4 µg L^{-1} by 15 September, 108 days after the initial herbicide application or 68 days after the booster application.

On 20 September, an aqueous fluridone level of 8.2 $\mu g\ L^{-1}$ was measured at Station 7 in Basin 3A. This sample was collected 1 day after a booster dose of fluridone was applied to that portion of the lake to improve the control of *M. spicatum*.

On 28 September (116 days after the initial treatment), whole-lake fluridone levels had reached a low of 2.8 $\mu g\ L^{-1}$. As noted for Burr Pond, above, the fluridone CET relationship maintained in Lake Hortonia was expected to provide acceptable control of *M. spicatum*, while minimizing injury to nontarget vegetation. Fluridone residues measured at Station 10, on the outlet stream approximately 1.6 km (1 mile) from the dam, ranged from 0 $\mu g\ L^{-1}$ fluridone on 5 June (1 DAT) to 2.2 $\mu g\ L^{-1}$ fluridone on 28 August (85 DAT).

3 Aquatic Plant Assessments

Background and Objectives

Burr Pond and Lake Hortonia were both scheduled for a June 2000 whole-lake treatment with the systemic aquatic herbicide, fluridone, at a target concentration of 6 µg L^{-1}. The goal of these herbicide applications was to reduce the distribution of *M. spicatum* in these lakes, while minimizing impacts to the native aquatic plant communities. The overall aquatic plant assessment study plan was designed to allow quantitative comparisons of the 1999 pretreatment (PRE) aquatic plant communities with the 2000 year-of-treatment (YOT) and 2001 year-one-posttreatment (YOP) aquatic plant communities. Further, for each of the three sampling years, surveys were conducted during June and August to allow evaluations of impacts to both early and late growing season aquatic plant communities. Main quantitative methods included on each of the six sampling dates were:

a. Point-intercept surveys to determine frequency of occurrence of individual plant species and species richness estimates at individual sampling points.

b. Plant biomass samples to document relative abundance of each species.

Because the herbicide treatments were whole-lake applications, the sampling plans for the aquatic plant communities were also designed to provide whole-lake assessments. Based on these whole-lake efforts, a comprehensive plant species list was compiled for each lake, and a herbarium collection based on voucher specimens was established. In addition, and separate from these whole-lake studies, line-intercept transects were sampled within adjacent wetland areas at both treated lakes during August sampling trips in each year, 1999 through 2001.

Methods

Study site characteristics

Burr Pond. Burr Pond is located in Rutland County, Vermont, near the town of Sudbury (Figure 1). Burr Pond has a surface area of approximately 34.5 ha. The average water depth reported from historical records is approximately 2.7 m; the maximum water depth is approximately 5.5 m; and the average Secchi disk measurement for a 4-year reporting period prior to this study is 4.1 m

(LHPOA/BPA 1999). Burr Pond supports a diverse native plant community. In August 1998, VTDEC biologists reported nineteen native submersed species, two native rooted, floating-leafed species, and one native emergent species (LHPOA/ BPA 1999). First confirmed in Burr Pond in 1991, *M. spicatum* was widespread and problematic at the time of the 1998 VTDEC survey.

Lake Hortonia. Lake Hortonia is located in Rutland County, Vermont, between the towns of Sudbury and Hubbardton (Figure 1). Lake Hortonia has a surface area of approximately 194.3 ha. Based on historical records, average water depth and maximum water depth are approximately 5.5 m and 18.3 m, respectively, and the average Secchi disk measurement for an 18-year reporting period prior to this study is 5.4 m (LHPOA/BPA 1999). Lake Hortonia supports a diverse native plant community. In September 1998, VTDEC biologists reported twenty-two native submersed species, two native rooted, floating-leaved species, and four native emergent species (LHPOA/BPA 1999). First confirmed in Lake Hortonia in 1984, *M. spicatum* was widespread and problematic at the time of the 1998 VTDEC survey.

Open-lake studies

Point-intercept survey. Species frequency of occurrence data were obtained by rake tosses at 191 points for Burr Pond (Figure 9) and 299 points for Lake Hortonia (Figure 10). Locations of these points were determined using MapInfo Software (MapInfo Corp., Troy, NY) by overlaying a grid onto each lake and determining coordinates for the intersecting points of the grid lines. For Burr Pond, a grid size of 40 m × 40 m was used; for Lake Hortonia, the grid size was 80 m × 80 m. In the field, an NT-200D differential GPS (DGPS) unit manufactured by Trimble Navigation Limited (Sunnyvale, CA) was used to navigate to each sampling point. At each point, plant species recovered by a rake toss were determined and recorded, and water depth was measured and recorded on a data sheet as per methods described in Madsen (1999). At points <2 m deep, a small-diameter polyvinyl chloride (PVC) pole (calibrated in 0.1-m increments) was used to measure water depth. At points >2 m deep, a Fish-Ray self-contained, handheld depth sounder (0.5- to 30-m range, 0.15-m accuracy) was used to measure water depth. To ensure accurate measurements, the depth sounder was positioned at the surface to prevent vegetation from interfering with the acoustical signal.

Biomass samples. Biomass samples were collected at 30 random points for each lake on each of the six sampling trips (June and August of 1999, 2000, and 2001). These points were selected randomly from the point-intercept survey points, with the exception that, for Lake Hortonia, points located at water depths >6 m were not considered for biomass sampling. This 6-m rule was used because the occurrence of vegetation other than *Chara* sp. or *M. spicatum* at greater depths was determined to be rare by initial point-intercept sampling at Lake Hortonia in June 1999. At each selected biomass sampling point, all plant tissue originating from within a 0.1-m^2 quadrat placed over the lake bottom was collected by a SCUBA diver and placed into a labeled mesh bag, as per methods described in Madsen (1993). After surfacing and transfer of collected plant

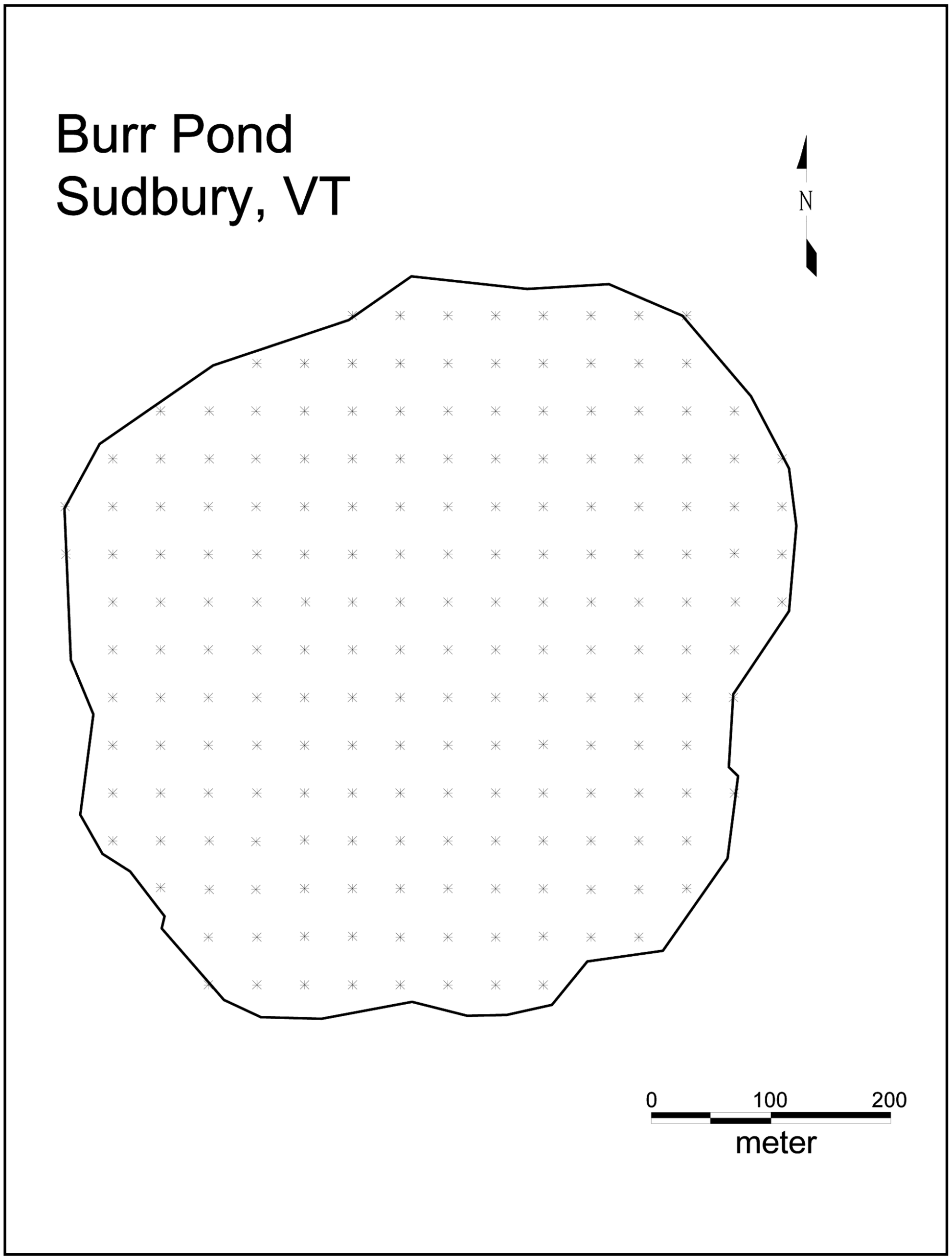

Figure 9. Map of Burr Pond showing the 191 point-intercept sampling locations

material to a labeled plastic bag, the individual samples were collectively shipped overnight to the ERDC Lewisville Aquatic Ecosystem Research Facility (LAERF), Lewisville, TX. At the LAERF, samples were sorted to species and dried in a Blue-M oven (General Signal, Atlanta, GA) to constant weight at 55 °C. Dry weight values were extrapolated to a square meter basis for analyses and reporting.

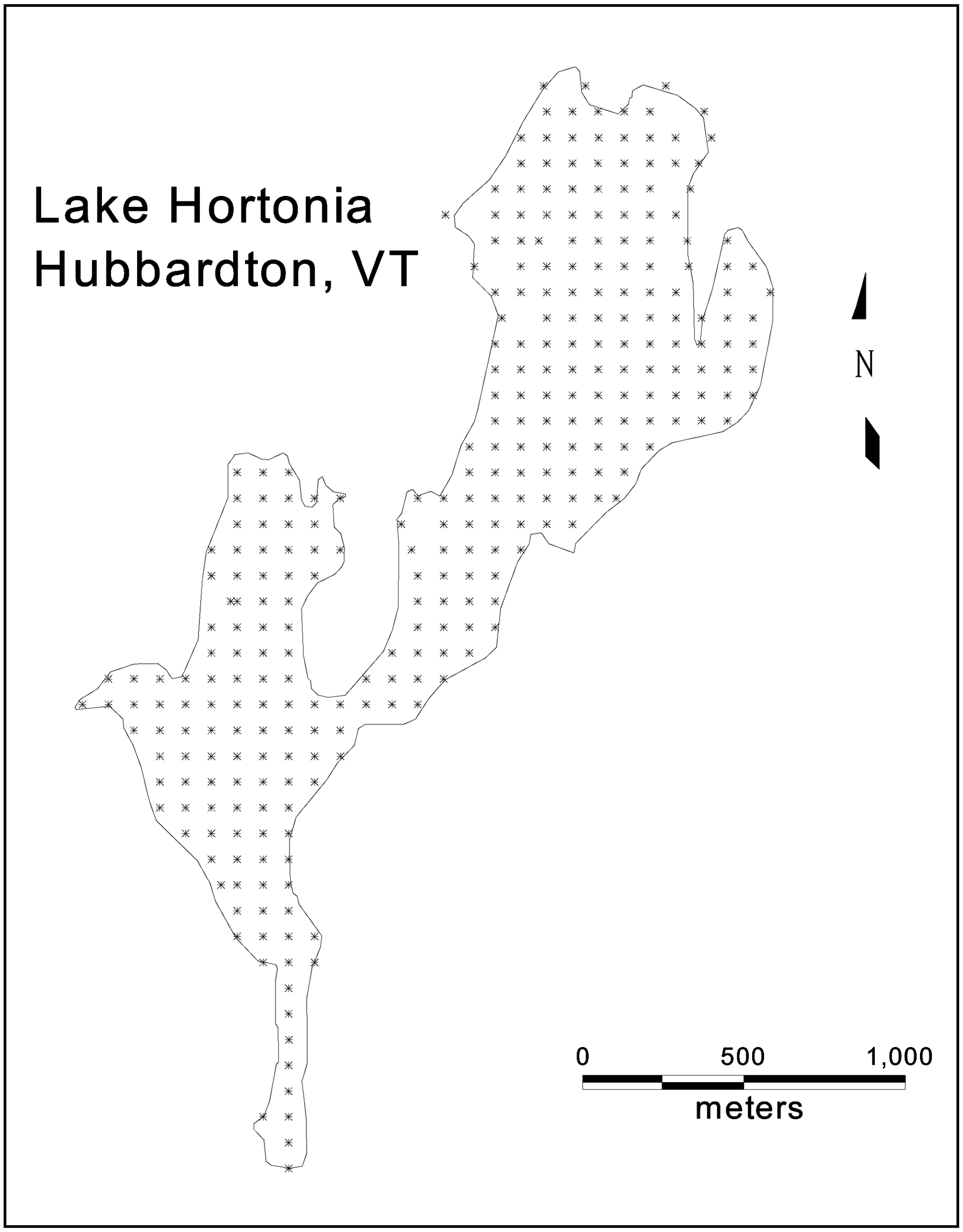

Figure 10. Map of Lake Hortonia showing the 299 point-intercept sampling locations

Wetland transects

Both Lake Hortonia and Burr Pond have adjacent wetlands of special interest to the VTDEC. To evaluate off-target herbicide impacts to the plant communities in these adjacent wetlands, line-intercept transects were sampled during the three August sampling trips. This consisted of recording plant species occurrences for each 1-m interval along a set transect length. Sampling was aided by the use of a transect sampling line marked with flagging at 1-m intervals. For Burr Pond, plant occurrences were determined for 80 transect intervals (i.e., overall transect length = 80 m). For Lake Hortonia, plant occurrences were determined for 205 transect intervals. Aquatic plant species were noted for each point, and voucher specimens were collected for addition to the herbarium collections.

Species lists and herbarium collections

Separate comprehensive species lists for all sampling periods were compiled for Burr Pond and Lake Hortonia, and for transects in the wetland areas adjacent to each lake. All plant species observed while conducting the surveys were recorded, even those not collected in samples. Representative herbarium specimens of all observed species were collected and shipped to the LAERF, where they were pressed, dried, and mounted (Hellquist 1993). All species identifications were per Crow and Hellquist (2000).

Secchi disk readings and maximum depth of colonization estimates

On each sampling trip during which sky conditions permitted, Secchi disk readings were recorded to allow detection of any significant changes in the underwater light climate of the two lakes during the 3-year study period. On each trip, triplicate Secchi disk readings were made from the sunny side of the boat. Secchi disk readings were used to calculate estimates for maximum depth of colonization (Z_C) (= maximum depth of colonization (MDOC) values in later sections of this report) by submersed macrophytes within the two lakes. These estimates were based on relationships reported in the literature and are referred to here as Canfield's estimate (Canfield et al. 1985) and Chambers' estimate (Chambers and Kalff 1985). Equations used to calculate these two estimates are as follows.

$$\text{Canfield's estimate:} \quad \log (Z_C) = 0.61[\log (Z_{SD})] + 0.26 \tag{1}$$

where

Z_C = estimated maximum depth of colonization, m

Z_{SD} = Secchi disk reading, m

$$\text{Chambers' estimate:} \quad Z_C = [1.33 * \log (Z_{SD}) + 1.40]^2 \tag{2}$$

Data analysis - open-lake studies

Frequency of occurrence. Frequency of occurrence data sets compiled from the six point-intercept sampling trips at each lake were analyzed using procedures for Chi-square analyses on 2 × 2 tables of frequencies included in the Statistix software package (Analytical Software 1996). Analyses were performed to compare frequency of occurrence values for June 1999 (PRE) with values for June 2000 (YOT) and June 2001 (YOP), and to compare frequency of occurrence values for August 1999 (PRE) with values for August 2000 (YOT) and August 2001 (YOP). Analyses were first conducted using frequencies of occurrence for individual plant species for sampling points from the whole lake. Additional analyses were later performed using frequencies of occurrence of three plant groupings at sampling points falling within three water depth classes. The three plant groupings considered were: points with at least one native plant species present, points with *M. spicatum* present, and points with at least one plant species present. The three water depth classes for which occurrences of the above three plant groupings were determined were: points at all depths (= whole lake), points at only water depths <4 m, and points at only water depths <2 m. Rationale for selecting these water depth classes was provided earlier.

Species richness. Species richness values were calculated for two plant groupings and three water depth classes for each sampling trip. Plant groupings were native plant species and total plant species. Water depth groupings were all water depths (= whole lake), only depths <4 m, and only water depths <2 m. Species richness data were analyzed using Analysis of Variance (ANOVA) techniques based on rankings of species richness values, followed by mean ranks comparison tests based on Kruskal-Wallis procedures included in the Statistix software package (Analytical Software 1996). Unlike for frequency of occurrence data sets, species richness analyses compared all three June data sets with each other, and all three August data sets with each other.

Plant biomass. Summary statistics including mean plant biomass and standard error values were calculated for individual species for each sampling trip. Subsequent analyses were performed on the three plant biomass categories: biomass from native plant species, biomass from *M. spicatum*, and biomass from all plant species. These analyses provided comparisons for each of the biomass groupings among June 1999 (PRE), June 2000 (YOT), and June 2001 (YOP) data sets, and August 1999 (PRE), August 2000 (YOT), and August 2001 (YOP) data sets and were performed using ANOVA techniques based on rankings of plant biomass values, followed by mean ranks comparison tests based on Kruskal-Wallis procedures included in the Statistix software package.

Data analysis - wetland transects

Frequency of occurrence. Frequency of occurrence data sets compiled for the three August sampling trips in each wetland area were analyzed using procedures for Chi-square analyses on 2×2 tables of frequencies included in the Statistix software package. Analyses were performed to compare frequency of occurrence values for August 1999 (PRE) with values for August 2000 (YOT) and August 2001 (YOP). Analyses were conducted using frequencies of occurrence for individual plant species determined for the 1-m intervals along the transect lines. For the Burr Pond wetland area, the total number of sampling intervals was 80; for the Lake Hortonia wetland, the total number was 205. Additional analyses based on plant groupings or water depth classes were not performed on wetland data sets.

Species richness. Species richness values were calculated for native plant species, exotic plant species, and total plant species groupings for each 1-m sampling interval along wetland transects for each sampling trip. Species richness values were analyzed using ANOVA techniques based on rankings of mean values, followed by mean ranks comparison tests based on Kruskal-Wallis procedures included in the Statistix software package.

Burr Pond Open-Lake Study Findings

Cumulative species list

The cumulative species list for Burr Pond is provided in Table 8. The list includes twenty-two submersed species, three floating-leaved species, and four emergent species. *Myriophyllum spicatum* was the only exotic species observed during surveys on Burr Pond.

Maximum depth of colonization and water depth profiles

Comparison of Secchi disk readings made at Burr Pond during this study with historical readings reported by the Vermont Lay Monitoring Program shows that underwater light penetration in Burr Pond was reduced during the study (Table 9). This was apparent in comparing annual average Secchi disk readings for 2000 and 2001 with annual average readings for pretreatment conditions in 1999, and also in comparison with the annual average reading for the 5-year time period 1983-1987. The MDOC estimates as calculated by Canfield's and Chambers' equations from these measured Secchi disk values were 4.3 m for both 2000 and 2001. In comparison, the MDOC based on the 1999 average annual Secchi disk reading was 5 m, while a similar estimate based on the 5-year period 1983-1987 was 4.8 m.

Based on the above noted changes in calculated MDOC values, it was determined that, in addition to analyses conducted on a whole-lake basis, data analyses should also include certain evaluations based on only those points that are within the MDOC. Further, since MDOC estimates based on the data changed for each year, it was decided that a suitable manner in which to proceed was to base additional analyses of the frequency data sets on three water depth classes. Depth class 1 included all points within the lake (= whole lake); depth class 2 included only points with depths <4 m; and depth class 3 included only points with depths <2 m.

The percent of points in 1-m depth classes from the Burr Pond August 1999 survey data are presented in Figure 11. These data confirm that the maximum depth of Burr Pond was ~6.0 m. The data further show that in 1999, approximately 90 percent of sampling points occurred at depths less than the 5-m MDOC estimate calculated using the 1999 average annual Secchi disk reading (Table 9). In comparison, only 50 to 60 percent of points were at depths less than the calculated MDOC estimate of 4.3 m based on 2000 and 2001 Secchi disk readings.

Table 8
Species Observed in Burr Pond

Scientific Name and Authority	Common Name	Growth Form	Native or Exotic
Ceratophyllum demersum L.	Coontail	Submersed	Native
Chara spp.	Muskgrass	Submersed	Native
Drepanocladus spp.	Liverwort	Submersed	Native
Elodea canadensis Michx.	American elodea	Submersed	Native
Equisetum spp.	Horsetail	Emergent	Native
Lythrum salicaria L.	Purple loosestrife	Emergent	Exotic
Megalodonta beckii (Torr. ex Spreng.) Greene	Water-marigold	Submersed/emergent	Native
Myriophyllum sibiricum Komarov	Northern milfoil	Submersed	Native
M. spicatum L.	Eurasian watermilfoil	Submersed	Exotic
Najas flexilis (Willd.) Rostkov and Schmidt	Bushy pondweed	Submersed	Native
Nuphar variegata Engelm.ex Durand	Bullhead lily, spatterdock	Floating-leaved	Native
Nymphaea odorata Aiton	White water lily	Floating-leaved	Native
Potamogeton amplifolius Tuckerman	Large-leaf pondweed	Submersed	Native
P. friesii Rupr.	Fries pondweed	Submersed	Native
P. gramineus L.	Variable pondweed	Submersed	Native
P. illinoensis Morong	Illinois pondweed	Submersed	Native
P. natans L.	Floating pondweed	Submersed	Native
P. nodosus Poiret	American pondweed	Submersed	Native
P. oakesianus Robbins	Oakes pondweed	Submersed	Native
P. pusillus L.	Slender pondweed	Submersed	Native
P. robbinsii Oakes	Fern pondweed	Submersed	Native
P. zosteriformis Fern	Fatstem pondweed	Submersed	Native
Ranunculus spp.	White water crowfoot	Submersed	Native
Scirpus validus Vahl	Softstem bulrush	Emergent	Native
Scirpus spp.	Bulrush	Emergent	Native
Stukenia pectinata (L.) Borner	Sago pondweed	Submersed	Native
Utricularia gibba L.	Creeping bladderwort	Submersed	Native
U. vulgaris L.	Common bladderwort	Submersed	Native
Vallisernia americana L.	Water celery	Submersed	Native
Zosterella dubia (Jacq.) MacM.	Water stargrass	Submersed	Native

Table 9
Burr Pond Water Depth Characteristics, Secchi Disk Readings, and Calculated Estimates for Maximum Depth of Colonization by Aquatic Plants

Time Period	Secchi Disk Reading, m	Canfield's Estimate (Eq 1), m	Chambers' Estimate (Eq 2), m	Average Estimate m
5-year June averages[1] (1983-1987)	4.5	4.6	5.2	4.9
5-year August averages (1983-1987)	4.3	4.5	5.1	4.8
5-year annual averages (1983-1987)	4.4	4.5	5.1	4.8
June 1999	5.0	4.9	5.4	5.2
August 1999	4.5	4.6	5.1	4.9
1999 annual average	4.8	4.7	5.3	5.0
June 2000 *(Not measured. Used June historical average)*	4.5	4.6	5.2	4.9
August 2000	2.9	3.5	4.1	3.8
2000 annual average	3.7	4.0	4.6	4.3
June 2001	4.9	4.8	5.4	5.1
August 2001	2.5	3.2	3.7	3.5
2001 annual average	3.7	4.0	4.6	4.3
Average depth 2.74 m				
Maximum depth 5.49 m				

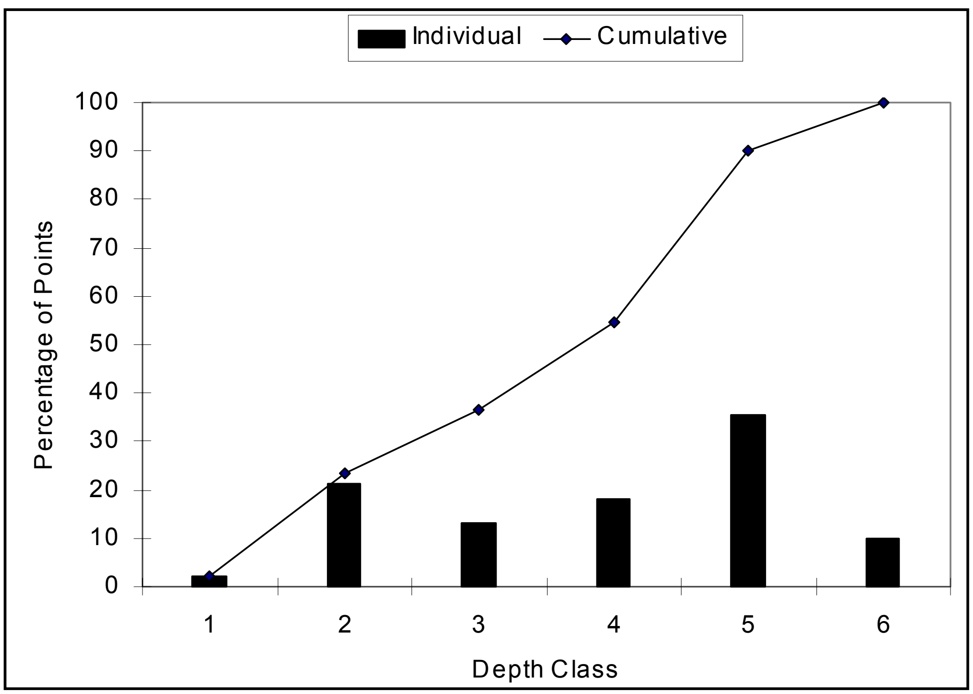

Figure 11. Percent occurrence of Burr Pond sampling points in 1-m depth classes

Frequency of occurrence survey results

June surveys. Burr Pond maps illustrating locations of occurrence during June sampling trips of commonly occurring plant species, or groups of species (i.e., broad-leaved pondweeds), are included in Appendix B, Figures B1–B13. Frequency of occurrence data for the June 1999, 2000, and 2001 surveys are given in Table 10. A total of 20 submersed or floating-leaved species and 3 emergent species were collected during the spring pretreatment point-intercept sampling survey conducted in June 1999. The most frequently collected species was *M. spicatum* (129), followed in decreasing order of occurrence by *Chara* spp. (74), *Elodea canadensis* (32), *Potamogeton amplifolius* (21), *P. gramineus* (16), *Vallisneria americana* (16), *Nymphaea odorata* (15), and *P. zosteriformis* (11). Frequency of occurrence data gathered during the June 2000 YOT spring survey (Table 10) indicated that *M. spicatum* was again the most commonly collected submersed species, being collected at 110 sampling points. Other common species in June 2000 in decreasing order were *Chara* spp., *P. amplifolius*, *E. canadensis*, *N. odorata*, *P. zosteriformis*, and *V. americana*. Species showing significant declines in occurrence between June 1999 and June 2000, as determined by Chi^2 analysis, were *P. gramineus*, *Najas flexilis*, *V. americana*, *M. spicatum*, and *Chara* spp. However, it should be noted that these declines cannot be attributed to impacts from the fluridone application since the initial herbicide application in Burr Pond was not made until June 4, 2000.

Table 10
Burr Pond Frequency of Occurrence Data and Chi^2 Summary Statistics for June Surveys. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

Plant Species	Frequency Values			June 1999 vs June 2000		June 1999 vs June 2001	
	June 1999	June 2000	June 2001	Chi^2 Value	Prob > Chi^2	Chi^2 Value	Prob > Chi^2
Submersed and Floating-Leaved Species							
Ceratophyllum demersum	3	6	5	1.02	0.312	0.51	0.475
Chara sp.	74	56	70	3.78	0.052 ▼	0.18	0.673
Drepanocladus sp.	0	1	0	1.00	0.317	0.00	1.000
Elodea canadensis	32	23	0	1.72	0.190	43.93	0.000 ▼
Megalodonta beckii	0	0	0	0.00	1.000	0.00	1.000
Myriophyllum sibiricum	6	2	0	2.04	0.153	6.10	0.014 ▼
Myriophyllum spicatum	129	110	10	4.03	0.045 ▼	160.15	0.000 ▼
Najas flexilis	9	0	3	9.22	0.002 ▼	3.10	0.078
Nuphar variegata	4	9	10	1.99	0.158	2.67	0.102
Nymphaea odorata	15	19	18	0.52	0.472	0.30	0.585
Potamogeton amplifolius	21	27	4	0.86	0.354	12.37	0.000 ▼
Potamogeton gramineus	16	0	1	16.70	0.000 ▼	13.85	0.000 ▼
Potamogeton illinoensis	2	7	0	2.84	0.092	2.01	0.156

(Continued)

Table 10 (Concluded)							
	Frequency Values			**June 1999 vs June 2000**		**June 1999 vs June 2001**	
Plant Species	**June 1999**	**June 2000**	**June 2001**	**Chi^2 Value**	**Prob > Chi^2**	**Chi^2 Value**	**Prob > Chi^2**
Potamogeton natans	3	2	2	0.20	0.653	0.20	0.653
Potamogeton nodosus	1	0	0	1.00	0.317	1.00	0.317
Potamogeton praelongus	0	0	0	0.00	1.000	0.00	1.000
Potamogeton robbinsii	2	4	8	0.68	0.411	3.70	0.055 ▲
Potamogeton zosteriformis	11	19	6	2.32	0.128	1.54	0.215
Ranunculus longirostris	1	2	4	0.34	0.562	1.82	0.177
Stukenia pectinata	1	1	0	0.00	1.000	1.00	0.317
Utricularia gibba	4	3	1	0.15	0.703	1.82	0.177
Utricularia vulgaris	0	0	0	0.00	1.000	0.00	1.000
Vallisneria americana	16	5	3	6.10	0.014 ▼	9.36	0.002 ▼
Zosterella dubia	1	1	3	0.00	1.000	1.01	0.315
Any submersed native species	101	89	89	1.51	0.219	1.51	0.219
Any submersed species	167	143	95	4.61	0.032 ▼	49.84	0.000 ▼
Emergent Species							
Equisetum sp.	1	0	0	1.00	0.317	1.00	0.317
Scirpus validus	2	0	0	2.01	0.156	2.01	0.156
Sparganium americanum	4	1	3	1.82	0.177	0.15	0.703

Discussion of possible causes of these differences is provided in "Differences in June 1999 and June 2000 data sets." In June 2001, the frequency of occurrence of *M. spicatum* was significantly lower than in June 1999, and this species was no longer the most frequently occurring submersed plant species (Table 10). Instead, the most frequently occurring species was *Chara* spp., followed in decreasing order by *N. odorata*, *Nuphar variegata* and *M. spicatum*, *P. robbinsii*, *P. zosteriformis*, and *Ceratophyllum demersum*. Six submersed species, including *M. spicatum*, experienced significant reductions in occurrence in June 2001 in comparison to occurrences in June 1999. Following *M. spicatum*, species exhibiting the next most significant reductions in comparison to June 1999 occurrences were *E. canadensis*, *P. gramineus*, *P. amplifolius*, *V. americana*, and *Myriophyllum sibiricum*.

Occurrence data summaries for the three plant groupings within the three water depth classes for June surveys are given in Table 11. These same data are illustrated separately for each depth class in Figures 12-14. In June 1999, 54 percent of the whole-lake sampling points were vegetated by at least one native plant species (Figure 12). At that time, at least one native species was found at 71 percent of sampling points with water depths <4 m (Figure 13), and at 98 percent of points with water depths <2 m (Figure 14). Occurrences of points with at least one native species within these depth classes were again near these levels during June 2000 and June 2001 surveys, other than the gradual

Table 11
Burr Pond Percent Occurrence of Any Native Plant Species, *Myriophyllum spicatum*, and Any Plant Species by Depth Class and Year for June Sampling Trips, and Chi^2 Summary Statistics for Comparing June 1999 Values with June 2000 and June 2001 Values. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

Plant Grouping	Percent Occurrence Values			June 1999 vs June 2000		June 1999 vs June 2001	
	June 1999	June 2000	June 2001	Chi^2 Value	Prob >p	Chi^2 Value	Prob >p
Any Native Plant Species							
Whole lake	52.9	46.6	46.6	1.51	0.219	1.51	0.219
<4 m	71.4	82.3	83.7	3.04	0.081	4.21	0.040 ▲
<2 m	97.7	90.3	95.8	1.98	0.156	0.26	0.609
Myriophyllum spicatum							
Whole lake	67.5	57.6	5.2	4.03	0.045 ▼	160.2	0.000 ▼
<4 m	75.6	74.7	8.1	0.02	0.879	91.22	0.000 ▼
<2 m	79.5	74.2	8.3	0.30	0.586	47.67	0.000 ▼
Any Plant Species							
Whole lake	83.8	74.9	49.7	4.61	0.032 ▼	49.84	0.000 ▼
<4 m	96.6	94.9	87.2	0.35	0.552	6.55	0.011 ▼
<2 m	97.7	93.5	97.9	0.83	0.363	0.00	0.950

increase in occurrences in the intermediate depth class. During the same time period, occurrences of points vegetated by the target plant species, *M. spicatum,* showed significant declines. In June 1999, occurrences of *M. spicatum* points across the three depth classes ranged from 68 percent (whole lake) to 80 percent (<2 m). By June 2001, *M. spicatum* occurred in less than 10 percent of points in each depth class. Even though significant declines in *M. spicatum* occurrences resulted in similar reductions in "vegetated point" occurrences (i.e., vegetated by any plant species), in the two deeper water depth classes, persistence of native plants maintained "vegetated" occurrences in June 2001 at near 50 percent on the whole-lake basis, and at near 100 percent in the <2-m depth class.

August surveys. Burr Pond maps illustrating locations of occurrence of common plant species during August sampling trips are provided in Appendix B, Figures B1–B13. Frequency of occurrence data for the August 1999, 2000, and 2001 point-intercept surveys are given in Table 12. Nineteen submersed and floating-leaved species were collected during the August 1999 late summer pre-treatment survey. The most frequently occurring species was *M. spicatum*. Other common species, in decreasing order of occurrence, were *Chara* spp., *Potamogeton illinoensis*, *V. americana*, *P. gramineus*, *N. flexilis*, *E. canadensis*, and *N. odorata*. No emergent species were collected. August 2000 survey data indicated that although *M. spicatum* had experienced a significant reduction in occurrence, it was still the most frequently collected submersed species.

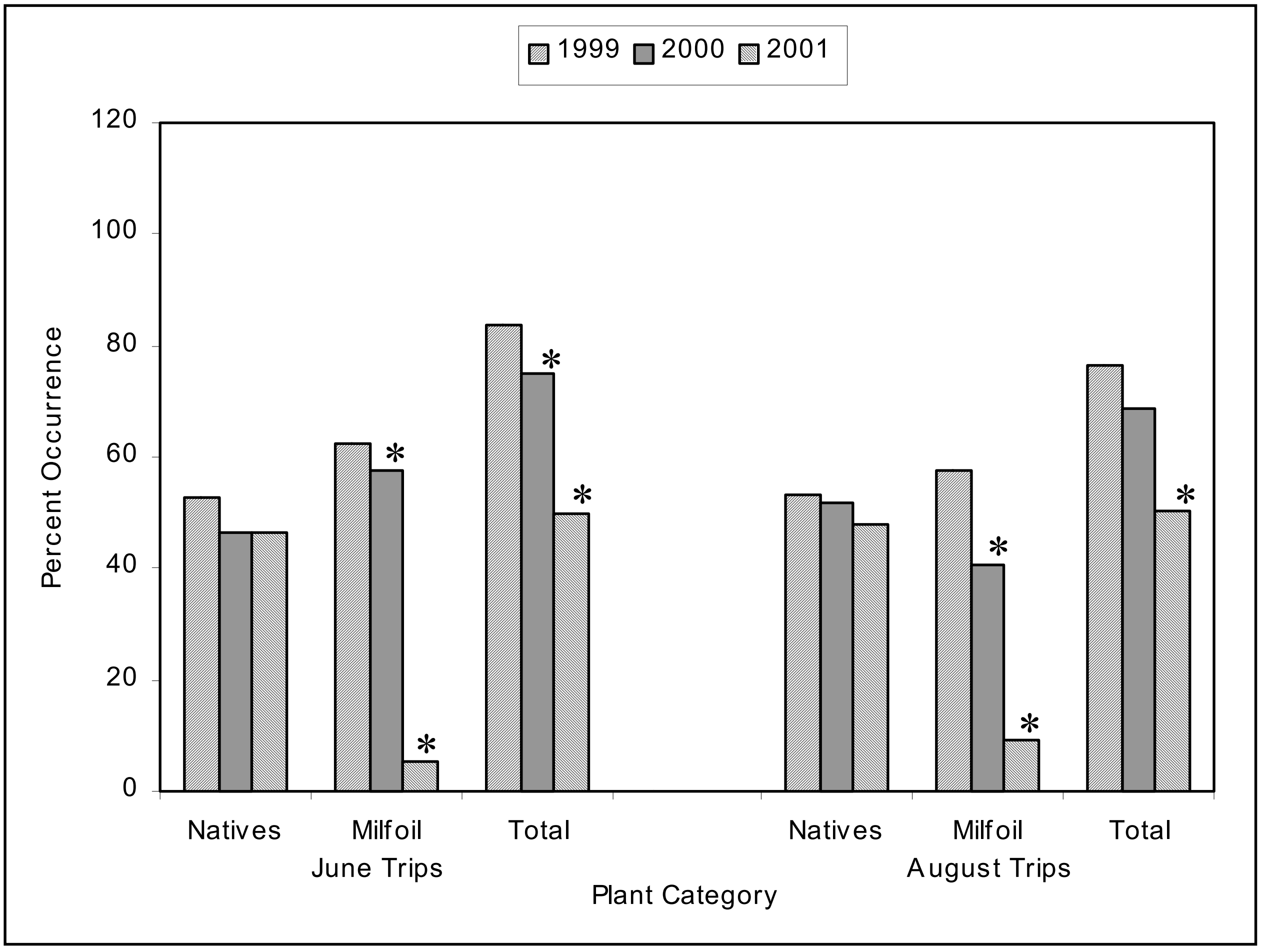

Figure 12. Burr Pond frequency of occurrence summaries for sampling points at all water depths. Frequency data are grouped into three plant types (native plant species, *Myriophyllum spicatum* only, and total plant species) and six sampling trips (June or August in 1999, 2000, or 2001). An asterisk above a 2000 or 2001 bar indicates a significant difference in comparison to the 1999 frequency value for that particular grouping of plant type and sampling month

Other frequently occurring submersed or floating-leaved species in August 2000 were *Chara* spp., *V. americana*, *N. odorata*, *E. canadensis*, *Zosterella dubia*, *P. robbinsii*, and *P. gramineus*. In addition to *M. spicatum*, four submersed species showed significant declines in occurrence in comparing August 2000 to August 1999 data sets. In contrast, *Z. dubia* and *P. robbinsii* actually experienced significant increases in occurrence during August 2000. In August 2001, *M. spicatum* occurrences were further reduced to only 18 sampling points, and this species was no longer the most frequently occurring plant species in point-intercept collections. In addition to *M. spicatum*, six other submersed or floating-leaved species were found less frequently in August 2001 than in August 1999 (Table 12). These species were *C. demersum*, *E. canadensis*, *M. sibiricum*, *P. graminues*, *P. illinoensis*, and *V. americana*. Most commonly found species in August 2001 were *Chara* spp., *N. flexilis*, *M. spicatum*, *V. americana*, *P. robbinsii*, and *N. variegata*. *Potamogeton robbinsii* was the only species observed significantly more frequently in August 2001 than in August 1999.

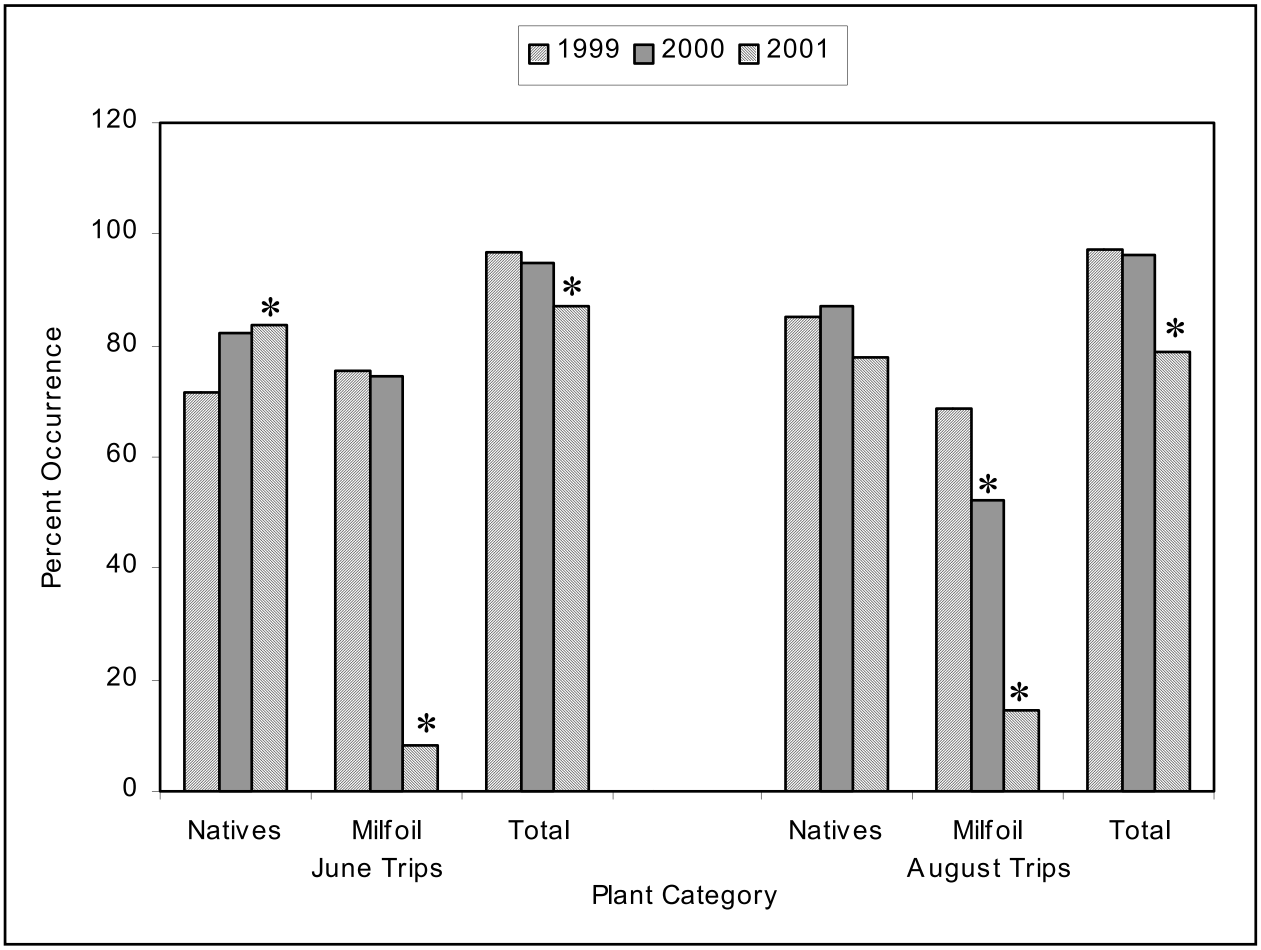

Figure 13. Burr Pond frequency of occurrence summaries for sampling points at water depths <4.0 m. Frequency data are grouped into three plant types (native plant species, *Myriophyllum spicatum* only, and total plant species) and six sampling trips (June or August in 1999, 2000, or 2001). An asterisk above a 2000 or 2001 bar indicates a significant difference in comparison to the 1999 frequency value for that particular grouping of plant type and sampling month

Occurrence data summaries for the three plant groupings within the three water depth classes for August surveys are given in Table 13, and these summaries are illustrated by water depth class in Figures 12-14. In August 1999, 53 percent of the whole-lake sampling points were vegetated by at least one native plant species (Figure 12). Also during August 1999, 85 percent of sampling points with water depths <4 m (Figure 13), and 98 percent of points with water depths <2 m (Figure 14), were vegetated by at least one native species. As with June sampling dates at Burr Pond, the percent occurrence of points vegetated by at least one native species, while decreasing slightly, did not change significantly during August 2000 or August 2001 in any of the three water depth classes. During the same time period, occurrences of points vegetated by the target plant species, *M. spicatum,* showed consistent and significant declines across all three depth classes. In August 1999, occurrence of *M. spicatum* points across the three depth classes ranged from 57 percent (whole lake) to 69 percent (<4 m). By August 2001, *M. spicatum* occurred in less than 10 percent of points on a whole-lake basis. However, occurrences of *M. spicatum* remained at near

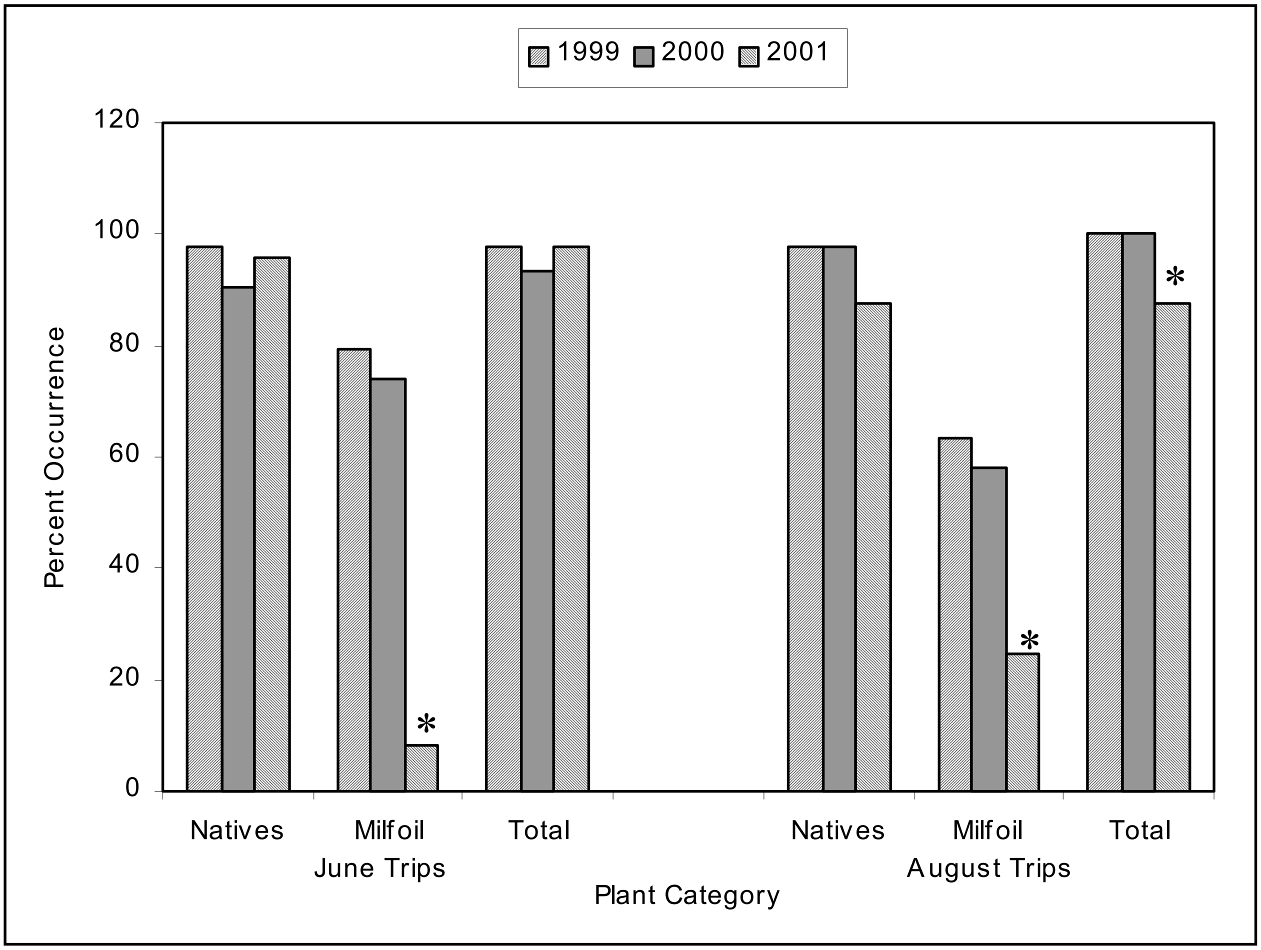

Figure 14. Burr Pond frequency of occurrence summaries for sampling points at water depths <2.0 m. Frequency data are grouped into three plant types (native plant species, *Myriophyllum spicatum* only, and total plant species) and six sampling trips (June or August in 1999, 2000, or 2001). An asterisk above a 2000 or 2001 bar indicates a significant difference in comparison to the 1999 frequency value for that particular grouping of plant type and sampling month

25 percent of points in the shallowest depth class in August 2001. The percent of whole-lake points "vegetated" by any plant species during August surveys declined significantly from 76 percent in 1999 to 51 percent in 2001. Percent occurrences for "vegetated" points were higher in shallower depth classes in all 3 years. In the <2-m depth class, even though statistically significant declines occurred between 1999 and 2001, percent occurrence of vegetated points was near 90 percent during each August survey.

Species richness data

Burr Pond species richness data for each sampling trip are summarized in Table 14 for two plant groupings (native plants and all plants) and three water depth classes (whole lake, points <4 m, and points <2 m). In June 1999, species richness of native plants based on all points was 1.23, while values for native plants in the <4-m and <2-m depth classes were 1.82 and 3.77, respectively.

Table 12
Burr Pond Frequency of Occurrence Data and Chi^2 Summary Statistics for August Surveys. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

Plant Species	Frequency Values			August 1999 vs August 2000		August 1999 vs August 2001	
	August 1999	August 2000	August 2001	Chi^2 Value	Prob > Chi^2	Chi^2 Value	Prob > Chi^2
Submersed and Floating-Leaved Species							
Ceratophyllum demersum	6	5	1	0.09	0.760	3.64	0.057 ▼
Chara sp.	56	69	69	2.01	0.156	2.01	0.156
Drepanocladus sp.	0	0	0	0.00	1.000	0.00	1.000
Elodea canadensis	19	18	1	0.03	0.863	17.10	0.000 ▼
Megalodonta beckii	1	0	0	1.00	0.317	1.00	0.317
Myriophyllum sibiricum	8	0	0	8.17	0.004 ▼	8.17	0.004 ▼
Myriophyllum spicatum	109	78	18	4.03	0.045 ▼	160.15	0.000 ▼
Najas flexilis	20	0	25	21.10	0.000 ▼	0.63	0.423
Nuphar variegata	9	9	12	0.00	1.000	0.45	0.501
Nymphaea odorata	17	20	8	0.27	0.604	3.47	0.063
Potamogeton amplifolius	2	5	3	1.31	0.252	0.20	0.653
Potamogeton gramineus	31	10	9	12.05	0.001 ▼	13.52	0.000 ▼
Potamogeton illinoensis	38	0	9	42.20	0.000	20.40	0.000 ▼
Potamogeton natans	1	1	1	0.00	1.000	0.00	1.000
Potamogeton nodosus	0	0	1	0.00	1.000	1.00	0.317
Potamogeton praelongus	0	0	0	0.00	1.000	0.00	1.000
Potamogeton robbinsii	4	12	15	4.17	0.041 ▲	6.70	0.010 ▲
Potamogeton zosteriformis	13	8	9	1.26	0.262	0.77	0.380
Ranunculus longirostris	1	1	0	0.00	1.00	1.00	0.317
Stukenia pectinata	2	0	1	2.01	0.156	0.34	0.562
Utricularia gibba	6	10	7	1.04	0.307	0.08	0.778
Utricularia vulgaris	2	0	1	2.01	0.156	0.34	0.562
Vallisneria americana	34	20	16	4.23	0.039 ▼	7.46	0.006 ▼
Zosterella dubia	2	12	7	7.41	0.007 ▲	2.84	0.092
Any submersed native species	102	99	91	0.09	0.759	1.27	0.260
Any submersed species	146	131	96	2.96	0.086	28.19	0.000 ▼
Emergent Species							
Equisetum sp.	0	1	0	1.00	0.317	0.00	1.000
Scirpus validus	0	0	0	0.00	1.000	0.00	1.000
Sparganium americanum	0	2	1	2.01	0.156	1.00	0.317

Table 13
Burr Pond Percent Occurrence of Any Native Plant Species, *Myriophyllum spicatum*, and Any Plant Species by Depth Class and Year for August Sampling Trips, and Chi^2 Summary Statistics for Comparing August 1999 Values with August 2000 and August 2001 Values. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

Plant Grouping	Percent Occurrence Values			August 1999 vs August 2000		August 1999 vs August 2001	
	August 1999	August 2000	August 2001	Chi^2 Value	Prob > Chi^2	Chi^2 Value	Prob > Chi^2
Any Native Plant Species							
Whole lake	53.4	51.8	47.9	0.09	0.759	1.27	0.260
<4 m	85.4	86.9	77.9	0.08	0.773	1.89	0.169
<2 m	97.7	97.9	87.8	0.00	0.950	3.31	0.069
Myriophyllum spicatum							
Whole lake	57.1	40.8	9.4	4.03	0.045 ▼	160.2	0.000 ▼
<4 m	68.9	52.4	14.7	5.35	0.021 ▼	59.24	0.000 ▼
<2 m	63.6	58.3	24.5	0.27	0.603	14.49	0.000 ▼
Any Plant Species							
Whole lake	76.4	68.6	50.5	2.96	0.086	28.19	0.000 ▼
<4 m	97.1	96.4	78.9	0.06	0.799	15.84	0.000 ▼
<2 m	100.0	100.0	87.8	0.00	1.000	5.76	0.016 ▼

Table 14
Burr Pond Species Richness Summary Statistics (Mean, N, Standard Error) Calculated for Two Plant Groupings and Three Water Depth Classes for June and August Survey Trips

Plant Grouping	Water Depth Class	Summary Statistic	June Surveys			August Surveys		
			1999	2000	2001	1999	2000	2001
Native plant species	Whole lake (all depths)	Mean	1.21	0.98	0.74	1.43	1.05	1.02
		N	191	191	191	191	191	191
		Std. Err.	0.14	0.11	0.07	0.14	0.11	0.11
	Points with depths <4.0 m	Mean	1.82	2.01	1.43	2.51	2.04	1.83
		N	119	79	86	103	84	95
		Std. Err.	0.20	0.19	0.12	0.20	0.21	0.17
	Points with depths <2.0 m	Mean	3.77	3.39	1.94	3.84	2.69	2.61
		N	44	31	48	44	48	49
		Std. Err.	0.38	0.33	0.16	0.30	0.29	0.27
All plant species	Whole lake (all depths)	Mean	1.89	1.55	0.79	2.01	1.46	1.11
		N	191	191	191	191	191	191
		Std. Err.	0.15	0.12	0.08	0.15	0.13	0.12
	Points with depths <4.0 m	Mean	2.57	2.76	1.51	3.20	2.56	1.98
		N	119	79	86	103	84	95
		Std. Err.	0.21	0.21	0.12	0.21	0.23	0.19
	Points with depths <2.0 m	Mean	4.57	4.13	2.02	4.48	3.27	2.86
		N	44	31	48	44	48	49
		Std. Err.	0.41	0.36	0.16	0.30	0.32	0.30

This relationship of higher species richness values in shallower water depth classes was consistent on each trip and for both plant groupings (native plants and all plants).

Comparisons of native species richness values for specified combinations of sampling month (June or August) and water depth class through time show a general trend toward slight, nonsignificant reductions in this parameter following the fluridone application (Figure 15). For example, the only comparable consecutive year pairing that actually showed an increase in the mean native species richness value was the pairing between June 1999 and June 2000 points in the <4-m depth class. Though slight reductions were calculated for all other consecutive year comparisons, the only water depth class that demonstrated statistically significant reductions in native plant species richness values was the <2-m depth class. It is noted that for June trip comparisons, the mean species richness value in this depth class did not significantly decline until 2001. In comparison, mean species richness value comparisons within this depth class for August trips show significant declines in both 2000 and 2001. This is consistent with potential impacts from the herbicide application since the June 2000 fluridone application date could not have caused an impact to the plant community prior to the June 2000 sampling trip, but could have effected an impact prior to the August 2000 survey.

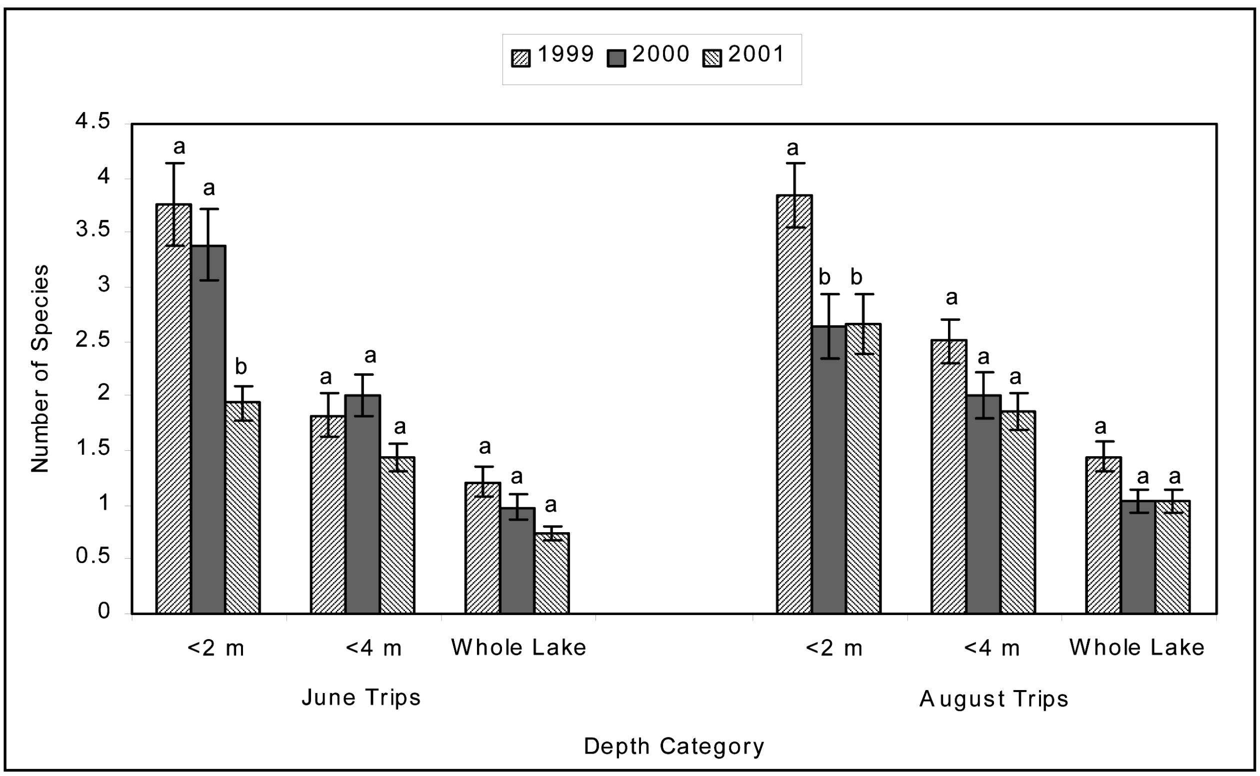

Figure 15. Species richness values for Burr Pond native species. Data are grouped into six categories by month of sampling (June and August) and water depth class (<2.0 m, <4.0 m, and whole lake) to allow comparisons within these six groupings between years (1999 vs 2000 vs 2001). Within a grouping, letters above bars indicate results of Kruskal-Wallis means separation tests at $p < 0.05$

Notwithstanding the above noted reduction in the shallowest depth class following the herbicide application, native species richness values remained high throughout the study in all three depth classes. In August 2001, mean values for the three water depth classes were 1.02 for the whole lake, 1.83 for points <4 m, and 2.61 for points <2 m (Figure 15).

Plant biomass samples

Burr Pond plant biomass data for individual plant species are summarized by sampling trip in Table 15. As noted in the "Methods" chapter, the biomass sampling scheme was designed to allow determination of whether a significant decline occurred in average biomass of *M. spicatum* following the fluridone application. It was considered in designing the sampling scheme that *M. spicatum* was widely distributed in the lake, and this was taken into account in determining the sample size (n = 30) of the biomass sampling effort. In designing the sample plan, researchers selected the minimum sample size that was felt would allow detection of significant changes within the *M. spicatum* population. By doing so, it was recognized that neither the sample size nor the process for selecting point locations was adequate for detecting significant changes in biomass levels of individual native species, which as a general rule were less common and more clumped in distribution pattern. Therefore, though data were collected on individual species and have been summarized and included in Table 15, less emphasis should be placed on individual native species as is placed on data for *M. spicatum.* For native species, the more appropriate data to consider are the cumulative totals for all native species (total natives in Table 15 and Figure 16).

Significant reductions were detected in biomass levels of *M. spicatum* during sampling trips following the fluridone application in June 2000 (Table 15; Figure 16). For June trip comparisons, the detection of significant changes did not occur until 2001. For August trip comparisons, significant reductions from 1999 levels were detected for both 2000 and 2001. Significant changes in biomass levels were not detected for the cumulative grouping of "total natives" in either June or August surveys (Table 15; Figure 16). Observed changes in biomass levels for the cumulative grouping of "total plants" were attributed to changes in *M. spicatum* biomass levels.

Discussion - Burr Pond open-lake studies

Pretreatment conditions. Pretreatment vegetation surveys conducted in June and August 1999 as part of this study confirmed reports that Burr Pond had a widespread and diverse aquatic plant community prior to the June 2000 fluridone application. Twenty-two submersed or floating-leaved species were reported in 1999 (Tables 10 and 12). Native species richness estimates calculated on a whole-lake basis ranged from 1.21 species per sampling point in June to 1.43 in August (Table 14, Figure 15), and the presence of at least one native species was found at approximately 53 percent of sampling points in both months. However, the target species, *M. spicatum*, was even more common,

Table 15
Burr Pond Plant Biomass (g dwt m^{-2}) Summary Statistics (Mean, SE) for 30 Samples Collected on Each Trip in June and August During 1999, 2000, and 2001. A "T" Denotes a Trace Level of Biomass (<0.05 g dwt m^{-2}) for Indicated Species

	June Survey Trips			August Survey Trips		
Plant Species	**1999 Mean (SE)**	**2000 Mean (SE)**	**2001 Mean (SE)**	**1999 Mean (SE)**	**2000 Mean (SE)**	**2001 Mean (SE)**
Ceratophyllum demersum	5.9 (5.9)	7.8 (7.8)	0.0 -	0.0 -	0.1 (0.1)	0.0 -
Ceratophyllum echinatum	0.2 (0.2)	0.0 -	0.0 -	0.0 -	0.0 -	0.0 -
Chara sp.	54.4 (27.7)	30.6 (14.7)	14.2 (6.0)	24.4 (11.1)	26.3 (12.4)	17.8 (7.1)
Elodea canadensis	1.3 (1.2)	3.4 (1.8)	0.1 (0.1)	2.6 (2.5)	0.1 (0.1)	0.0 -
Myriophyllum spicatum	142.5 (67.9)	39.2 (12.6)	0.1 (0.1)	49.3 (27.4)	3.1 (0.8)	0.3 (0.3)
Najas flexilis	0.1 (0.1)	0.0 -	0.0 -	2.0 (1.9)	0.0 -	4.1 (4.0)
Nuphar variegata	0.0 -	0.0 -	0.0 -	2.4 (2.4)	2.9 (2.2)	0.0 -
Nymphaea odorata	0.0 -	0.0 -	0.1 (0.1)	0.0 -	0.0 -	5.6 (4.5)
Potamogeton amplifolius	1.2 (1.2)	2.1 (0.8)	0.0 -	0.0 -	0.0 -	0.0 -
Potamogeton gramineus	0.0 -	0.0 -	T -	8.6 (3.1)	0.4 (0.2)	4.4 (4.2)
Potamogeton illinoensis	1.0 (0.5)	0.0 -	0.5 (0.5)	0.0 -	0.4 (0.4)	5.0 (2.4)
Potamogeton robbinsii	0.4 (0.4)	0.0 -	1.7 (1.1)	0.4 (0.4)	0.9 (0.6)	1.0 (0.5)
Potamogeton zosteriformis	0.6 (0.3)	2.6 (2.0)	0.4 (0.4)	T -	0.3 (0.3)	0.5 (0.3)
Ranunculus sp.	1.0 (1.0)	0.1 (0.1)	T -	0.0 -	0.0 -	0.0 -
Utricularia sp.	0.0 -	0.0 -	0.0 -	0.0 -	0.0 -	T -
Vallisneria americana	0.2 (0.2)	0.0 -	0.5 (0.3)	2.4 (1.5)	2.4 (2.3)	0.6 (0.4)
Zosterella dubia	0.0 -	0.0 -	0.0 -	0.0 -	0.0 -	T -
Total natives	65.9 (28.2)	46.4 (16.3)	22.3 (7.4)	45.3 (17.7)	34.0 (12.9)	39.1 (11.8)
Total all species	208.8 (70.5)	85.6 (18.2)	22.3 (7.4)	94.5 (32.5)	37.1 (12.8)	39.4 (11.8)

occurring in 67 percent of the points in June 1999 and in 57 percent of the points in August 1999 (Tables 11 and 13). This species was also the dominant species collected in pretreatment plant biomass samples at Burr Pond, accounting for 68 and 52 percent of total biomass estimates for June 1999 and August 1999 samples, respectively.

As expected, frequency of occurrence values and species richness values calculated on the basis of points with depths <4 m and points with depths <2 m were higher than values calculated on a whole-lake basis. Percent frequency of occurrence values for *M. spicatum* and native species as a group increased when calculations were based on only points with depths <4 m and points with

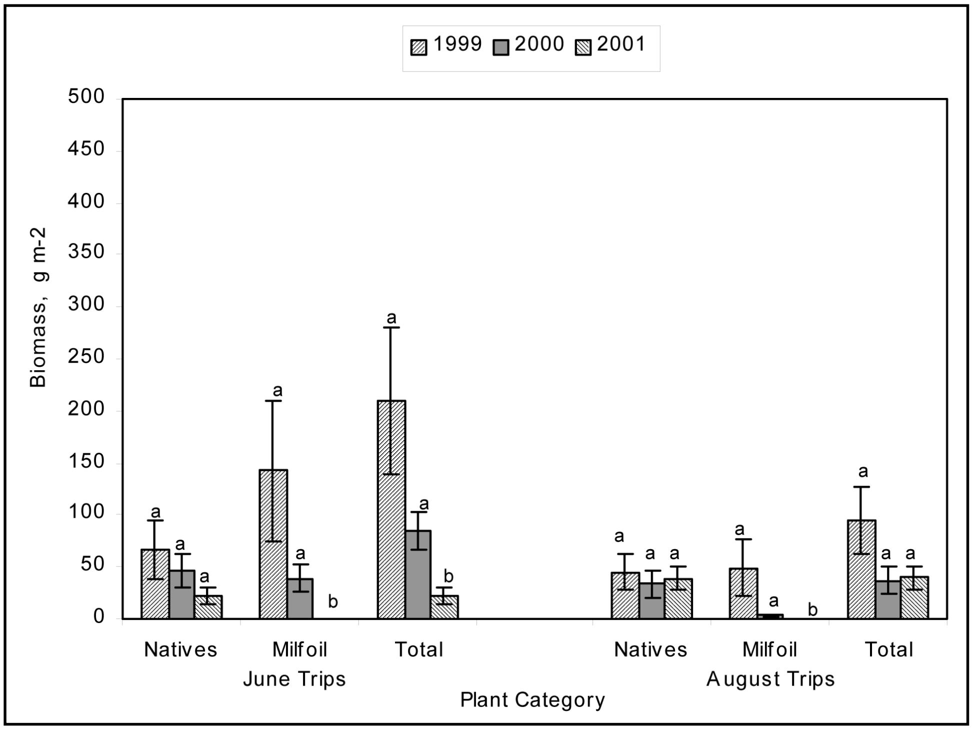

Figure 16. Plant biomass values for Burr Pond surveys. Data are grouped into six categories by month of sampling (June and August) and plant type (native plants, *Myriophyllum spicatum*, and total plants) to allow comparisons within these six groupings between years (1999 vs 2000 vs 2001). Within a grouping, letters above bars indicate results of Kruskal-Wallis means separation tests at $p < 0.05$

depths <2 m. At Burr Pond, *M. spicatum* occurred in 80 percent of points <2 m in June 1999 (Table 11), and in 64 percent of these shallow water points in August 1999 (Table 13). As a general rule, the percentages of points with at least one native species were also higher on both pretreatment sampling dates when just shallow water depth points were considered. Further, native species richness estimates were more than twofold higher if calculated for only sampling points with water depths <2 m.

Differences in June 1999 and June 2000 data sets. Analysis of Burr Pond data sets indicates that five submersed plant species were found at significantly fewer sampling points in June 2000 than in June 1999 (Table 10). Species exhibiting significant reductions were the target species, *M. spicatum*, and *Chara* spp., *P. gramineus*, *N. flexilis*, and *V. americana*. Because samples comprising the June 2000 data set were collected too early to have been impacted by the June 4, 2000, fluridone treatment, factors other than the fluridone treatment must have accounted for these significant differences. One likely possibility is that spring regrowth of plants at Burr Pond in June 2000 was delayed relative to regrowth at the time of sampling in June 1999. For *M. spicatum*, a delay in regrowth in June 2000 would also help explain why there was such a noticeable reduction in plant biomass in June 2000 relative to biomass levels reported for June 1999 (Figure 16). Further, the possibility of a delay in spring regrowth at Burr Pond in June 2000 relative to June 1999 is supported by reported differences in spring weather patterns between 1999 and 2000. In general, cooler than normal spring temperatures occurred in 2000 than in 1999 (Figure 17) (National Oceanic and Atmospheric Administration (NOAA) 1999). Thus, plant regrowth in spring 2000 was likely delayed by the combination of lower water temperatures resulting from these lower air temperatures and reduced underwater light levels reported in this study. However, regardless of cause, the fact that significant differences did occur between these two pretreatment data sets indicates that findings based on June data set comparisons should be used cautiously for evaluating impacts from the fluridone treatment. Further, because it seems likely that observed differences between the June 1999 and June 2000 data sets were caused by a delay in the onset of favorable growth conditions, it is assumed that had Burr Pond not been treated with fluridone, plants would have attained growth levels in August 2000 similar to August 1999 levels. For these reasons, except where noted, the following discussion of findings is based on August data set comparisons only.

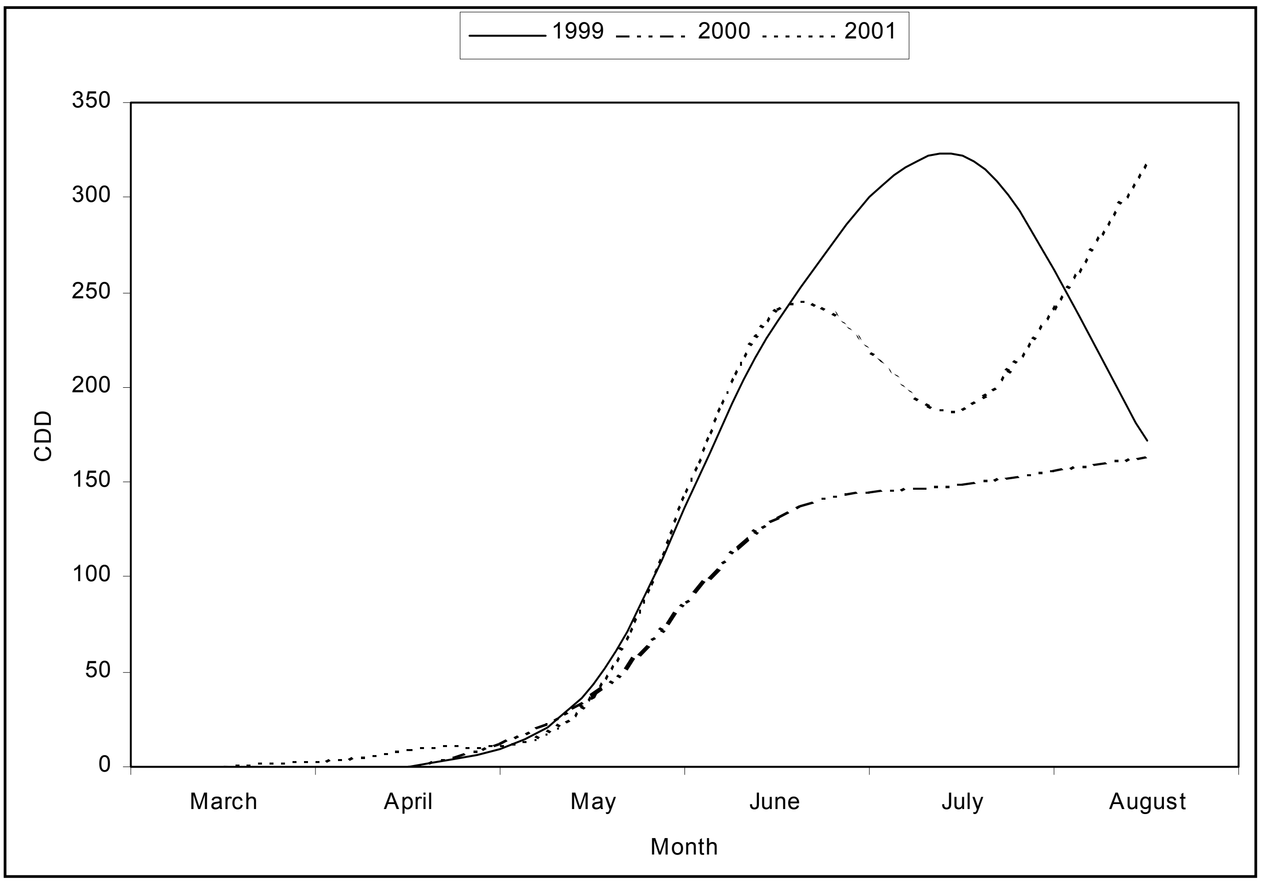

Figure 17. Monthly “cooling degree days” (CDD) for spring and summer months for Whitehall, New York, for the 3-year period, 1999, 2000, and 2001. Monthly “CDD’s” are calculated by summing the difference between the daily average air temperature and 65 ^{o}F, for only those days with average air temperatures greater than 65 ^{o}F. Therefore, as illustrated here, lower monthly CDD’s during June 2000 indicate much cooler spring weather during 2000 than during 1999 or 2001

Control of *M. spicatum* (August 1999 versus 2000 and 2001). *M. spicatum* infestations began showing widespread symptoms of fluridone injury in Burr Pond during the year of treatment. By August 2000, *M. spicatum* had experienced statistically significant reductions on whole-lake basis, even though it still occurred at approximately 40 percent of whole-lake sampling points (Table 13, Figure 12). Further, occurrences of *M. spicatum* were not significantly reduced below pretreatment levels in August 2000 at sampling points with depths <2 m. In 2001, *M. spicatum* occurrences were reduced to levels significantly below pretreatment levels in both June and August surveys for all three depth categories (i.e., whole lake, points <4 m, and points <2 m). In August 2001, whole-lake occurrences were at 9.4 percent, representing an approximate 83-percent reduction from August 1999 pretreatment occurrence levels.

Although whole-lake occurrences of *M. spicatum* had been reduced to less than 10 percent of points in August 2001, the plant remained established in approximately 25 percent of points in the shallowest water depth class, with the majority of those occurrences along the western shoreline (Figure B1). These data, therefore, indicate that the fluridone treatment may have been less effective in shallow water areas of Burr Pond. Possible reasons for such a differential response in effectiveness include:

a. Lowered target plant mortality in shallow water areas due to nearshore dilution of the fluridone by surface water runoff or groundwater upwelling.

b. Higher effectiveness in deeper water areas because of associated factors in these areas (e.g., reduced light levels).

c. Greater target plant recovery in shallow water areas following effects of the treatment.

The June 2000 fluridone application caused a 94-percent reduction in *M. spicatum* biomass levels prior to collection of the August 2000 samples. Therefore, even though the plant still occurred at approximately 40 percent of the whole-lake points, these data indicate that the vigor of the plant had been severely reduced. Further, phenological studies (Madsen 1997) indicate that significant late season biomass reductions to *M. spicatum* can disrupt its normal carbohydrate cycling strategy and significantly reduce its regrowth the following year. Throughout 2001, mean biomass values for *M. spicatum* remained at significantly reduced levels. Mean values in August 2001 were <1 percent of the August 1999 pretreatment value (Table 15). The combination of low frequency of occurrence (18) and low biomass (0.3 g m^{-2}) in August 2001 suggests that *M. spicatum* should not recover to nuisance levels in 2002.

Treatment impacts - Native species impacts. Though several individual species experienced significant reductions in occurrence following the fluridone treatment, over 47 percent of Burr Pond sampling points remained vegetated by native plants at the end of the study (Table 13). At water depths less than 4 m, native plant cover was approximately 78 percent, a level that exceeds the 20- to 40-percent littoral zone level deemed optimal for healthy sport fisheries in northern tier lakes (Savino and Stein 1982; Wiley et al. 1984).

As summarized in Table 16, statistically significant reductions in August frequency of occurrence values during either 2000 or 2001 were reported for seven native species at Burr Pond following the fluridone application. For the most part, species that were negatively impacted at both lakes were species previously reported by others (Smith and Pullman 1997; Kenaga 1993; Welling, Crowell, and Perleberg 1997) to be variably sensitive to fluridone. These included *C. demersum*, *E. canadensis, M. sibiricum, N. flexilis, P. gramineus,* and *P. illinoensis*. *Ceratophyllum demersum* and *E. canadensis*, reported to be very susceptible to fluridone, were each collected at only one sample point in August 2001, and *M. sibiricum* was not found at any sampling locations following the fluridone treatment. In comparison, *N. flexilis* rebounded to pretreatment levels during August 2001 after not being found during August 2000 (Figure B6). The broad-leaved pondweeds including *P. gramineus* and *P. illinoensis* also remained widely distributed in both lakes in August 2001 (Figure B9), although at significantly reduced levels. In addition to reductions to these relatively sensitive species, significant reductions in August 2000 and 2001 occurrences were also reported for *V. americana*, a relatively fluridone-tolerant species (Table 16).

Table 16
Summary of Changes ("-" = decrease; "+" = increase) in June and August Frequency of Occurrence Values for Aquatic Plant Species in Burr Pond During the 3-Year Period 1999 - 2001

Plant Species	Reported Fluridone Sensitivity[1,2]	June 1999 vs June 2000	August 1999 vs August 2000	June 1999 vs June 2001	August 1999 vs August 2001
Ceratophyllum demersum	S				-
Chara sp.	T	-			
Elodea canadensis	S			-	-
Myriophyllum sibiricum	S		-	-	-
Myriophyllum spicatum	S	-	-	-	-
Najas flexilis	S	-	-		
Potamogeton amplifolius	S			-	
Potamogeton gramineus	S	-	-	-	-
Potamogeton illinoensis	I,S		-		-
Potamogeton robbinsii	I,S		+	+	+
Vallisneria americana	I,T	-	-	-	-
Zosterella dubia	T		+		

[1] S = Susceptible, I = Intermediate, T = Tolerant.
[2] Sensitivity to fluridone as reported in Smith and Pullman (1997) and by SePRO Corporation, Carmel, IN.

Because the mechanism of fluridone action leads to a reduction of chlorophyll content in plant tissues, it is possible that plants of a given species growing in deep water might suffer greater mortality than plants of the same species growing in shallower water. Therefore, it is not surprising that reductions in the

MDOC were noted for several species, including *E. canadensis*, *N. variegata*, *N. odorata*, *P. zosteriformis*, and the grouped broad-leaved pondweeds *P. amplifolius, P. illinoensis*, and *P. gramineus* (Figure 18). In fact, effectiveness of the fluridone treatment might well have been increased by reductions in under-water light levels occurring in Burr Pond during the study and reported herein. This possible coupling of effects might also explain why *V. americana*, a species reported to be relatively tolerant of fluridone (Table 16), experienced reductions in its frequency of occurrence and maximum depth of occurrence. As illustrated in Figure 19, *V. americana* remained near pretreatment levels at depths <1.5 m, but was greatly reduced or eliminated at greater depths. Further, the MDOC for *V. americana* was reduced from over 4.5 m in 1999 to <2.5 m in 2001 (Figure 18). Though *V. americana* occurrences were significantly below pretreatment levels in 2001, the species remained widely distributed within all regions of the lake (Figure B12).

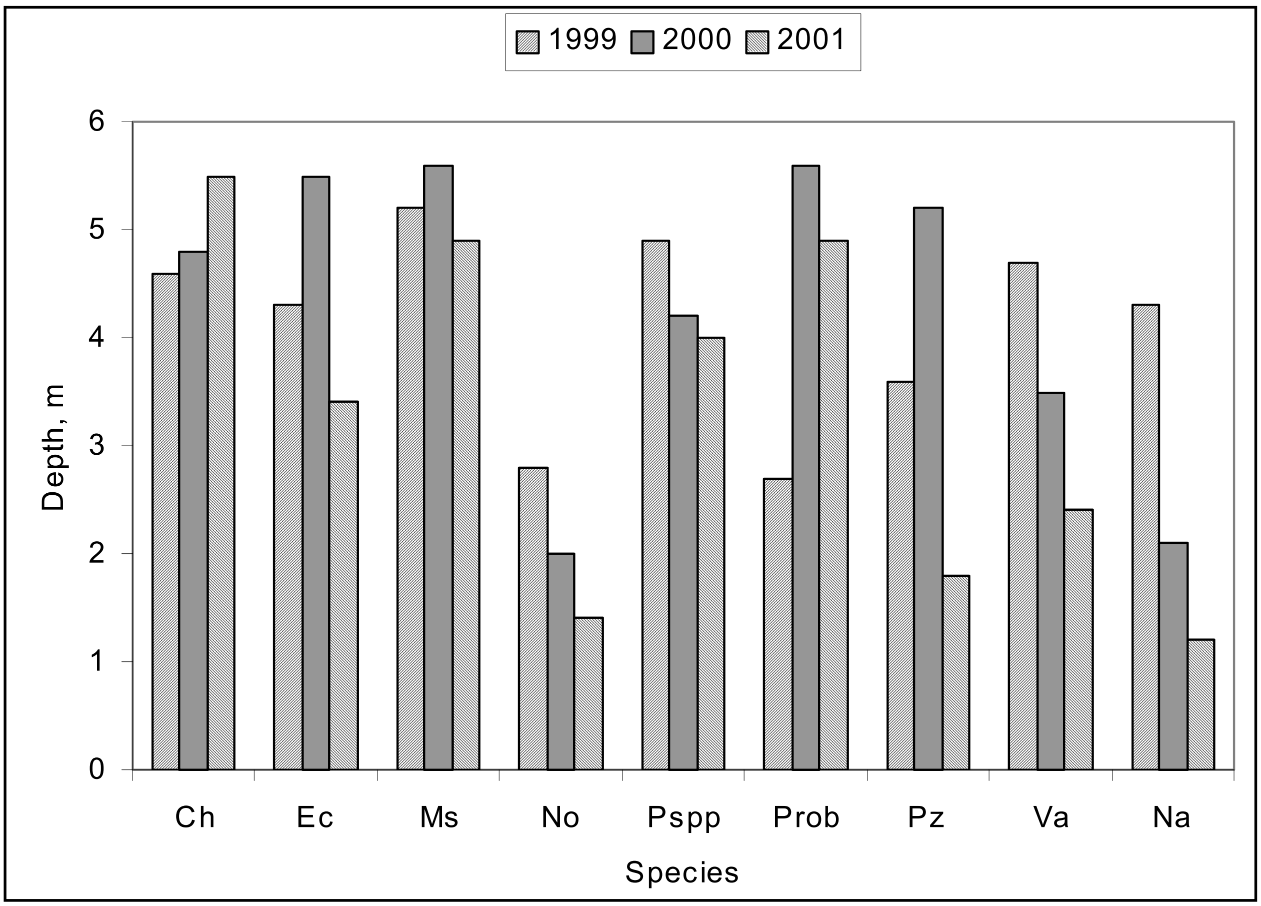

Figure 18. Maximum depth of occurrence for selected plant species in Burr Pond during August 1999, 2000, and 2001. Species codes are: Ch = *Chara* sp., Ec = *Elodea canadensis*, Ms = *Myriophyllum spicatum*, No = *Nymphaea odorata*, Pspp = broad-leaved pondweeds (*Potamogeton amplifolius, P, illinoensis*, and *P. gramineus*), Prob = *P. robbinsii*, Pz = *P. zosteriformis*, Va = *Vallisneria americana*, and Na = *Nuphar variegata*

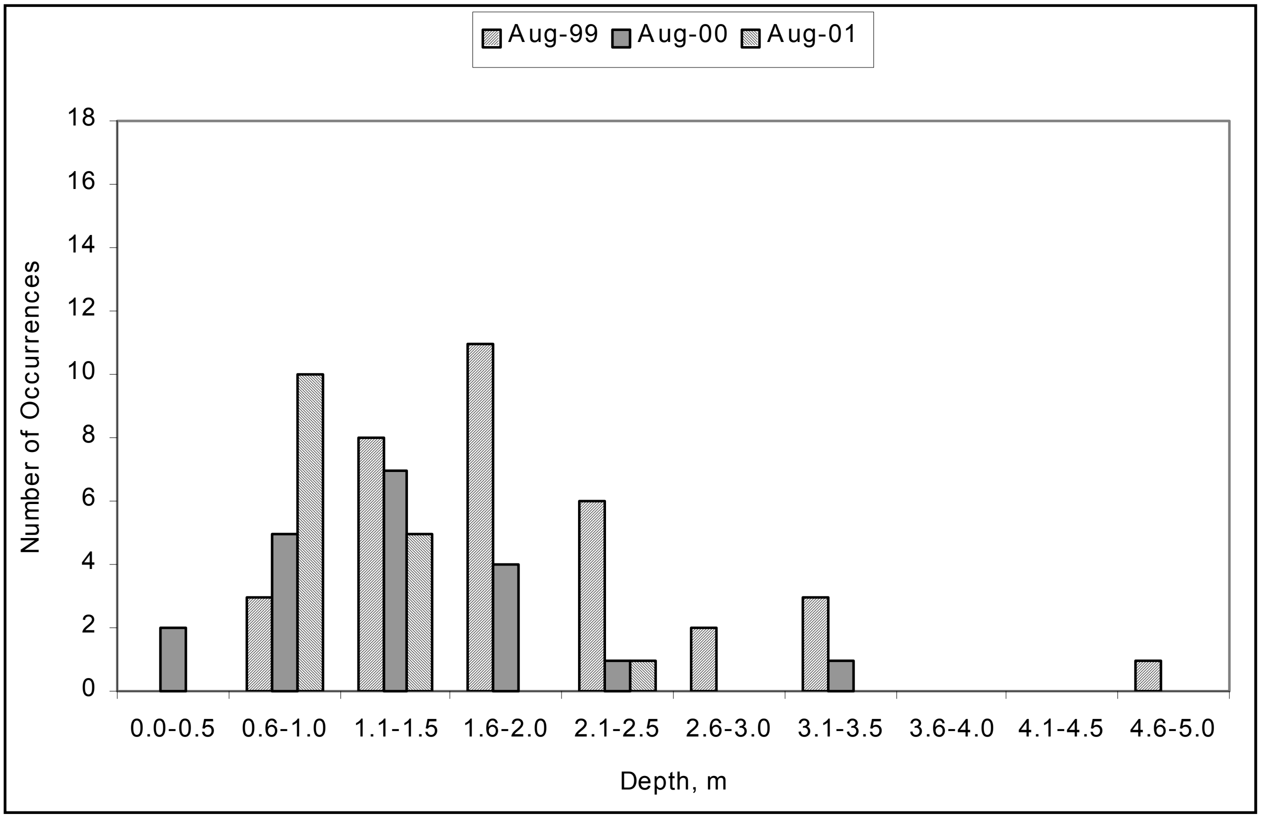

Figure 19. Frequency of occurrence of *V. americana* at different water depths in Burr Pond during August 1999, 2000, and 2001

Eighteen of the twenty native species collected in August 1999 pretreatment samples were again collected in August 2001 samples. The two species not reoccurring in August 2001 were *M. sibiricum* and *Megalodonta beckii,* both of which were infrequent species in August 1999 (Table 12). Though several native species were individually shown to experience significant reductions in frequency of occurrence, native species richness values on a whole-lake basis did not exhibit significant impacts from the fluridone application (Table 14; Figure 15). Although a statistically significant reduction in native species richness was noted in sampling points with depths <2 m (Figure 15), between two and three native species occurred on average at shallow-water locations in Burr Pond during August 2001. This level of native species richness has been reported for reference lakes and for lakes treated by "successful" fluridone applications in Michigan (Getsinger et al. 2001).

Although biomass levels for individual native plant species varied from year to year (Table 15), the summed total biomass of all native species on a per sample basis was not significantly reduced at Burr Pond following the fluridone treatment (Figure 16). Therefore, these data indicate that the fluridone treatment did not have a major impact on the overall abundance of native aquatic plants in Burr Pond.

Overall treatment effectiveness. At Burr Pond, frequency of occurrence of *M. spicatum* in August 2000 was reduced by approximately 28 percent below

August 1999 levels. While this is a lower YOT reduction in *M. spicatum* frequency than reported in other studies (Getsinger et al. 2001), the fact that *M. spicatum* biomass levels were reduced by 90 percent during the same time period indicates that the treatment was extremely effective in impacting severe damage to the target plant during the YOT. Further, phenological studies (Madsen 1997) aimed at determining improved control strategies for *M. spicatum* indicate that late season reductions in plant biomass can prevent the plant from storing energy reserves needed for effective regrowth the following spring. Therefore, even though *M. spicatum* remained widely distributed in Burr Pond during August 2000, it appeared that damage caused by the fluridone treatment was progressively lowering the plant's ability to attain problematic growth levels in 2001. This was confirmed by reductions of ~85 percent in occurrence and over 96 percent in biomass of *M. spicatum* in August 2001. The combination of low frequency of occurrence and low biomass in August 2001 suggests that *M. spicatum* should not recover to nuisance levels in 2002.

The level of *M. spicatum* control in Burr Pond is similar to control levels reported for whole-lake fluridone treatments in other northern tier states (Getsinger et al. 2001), and to control levels reported herein for Lake Hortonia. This level of control occurred even though fluridone residues during the 5-day posttreatment period were up to 50 percent higher in Burr Pond than levels measured during similar periods in these other lakes. Perhaps greater control of *M. spicatum* under the higher initial levels of fluridone did not occur because of reduced growth activity at Burr Pond compared to Lake Hortonia at time of treatment (as indicated by *M. spicatum* biomass values in Figures 16 and 26, respectively).

While effective control of *M. spicatum* was achieved, the widely distributed and diverse native plant community that remained at Burr Pond was sufficient to support a healthy sports fishery (Savino and Stein 1982; Wiley et al. 1984). Overall native plant cover at Burr Pond remained at near 50 percent at the end of the study. Further, species richness values on a whole-lake basis remained unchanged, as did native plant biomass levels. Individual species that experienced reductions following the fluridone treatment will likely expand within Burr Pond during the 2002 growing season.

Results: Burr Pond Wetland Transects

Cumulative species list

The cumulative species list for the Burr Pond wetland is at Table 17. The list includes 17 submersed species, 2 rooted, floating-leaved species, 1 floating species, and 1 emergent species. *Myriophyllum spicatum* was the only exotic species observed in the Burr Pond wetland.

Table 17
Species Observed in Wetland Adjacent to Burr Pond

Scientific Name	Common Name	Growth Form	Native or Exotic
Ceratophyllum demersum L.	Coontail	Submersed	Native
C. echinatum A. Gray	Spiny hornwort	Submersed	Native
Elodea canadensis Michx.	American elodea	Submersed	Native
Myriophyllum spicatum L.	Eurasian watermilfoil	Submersed	Exotic
Najas flexilis (Willd.) Rostkov and Schmidt	Bushy pondweed	Submersed	Native
Nuphar variegata Engelm.ex Durand	Bullhead lilly, spatterdock	Floating-leaved	Native
Nymphaea odorata Aiton	White water lily	Floating-leaved	Native
Polygonum amphibium L.	Smartweed	Emergent	Native
Potamogeton diversifolius Raf.	Variable-leaf pondweed	Submersed	Native
P. epihydrus Raf.	Ribbon-leaf pondweed	Submersed	Native
P. foliosus Raf.	Leafy pondweed	Submersed	Native
P. illinoensis Morong.	Illinois pondweed	Submersed	Native
P. nodosus Poir.	Long-leaf pondweed	Submersed	Native
P. spirillus Tuckerm.	Spiral-fruited pondweed	Submersed	Native
Spirodela polyrhiza Schleiden	Giant duckweed	Floating	Native
Utricularia geminiscapa Benj.	Mixed bladderwort	Submersed	Native
U. gibba L.	Creeping bladderwort	Submersed	Native
U. intermedia Hayne	Flat-leaf bladderwort	Submersed	Native
U. minor L.	Small bladderwort	Submersed	Native
U. vulgaris L.	Common bladderwort	Submersed	Native
Zosterella dubia (Jacq.) MacM.	Water stargrass	Submersed	Native

Frequency of occurrence of individual species

The most frequently occurring species along the Burr Pond wetland transect during August 1999 were the submersed species, *C. demersum*, the two rooted, floating-leaved species, *N. variegata* and *N. odorata*, and the floating species, *Spirodela polyrhiza* (Table 18). *Myriophyllum spicatum* occurred in only seven intervals in August 1999 and was the only exotic species observed. The species of special concern, *Ceratophyllum echinatum*, occurred in only two intervals. *Ceratophyllum echinatum* is of concern because it is ranked as “very rare” in Vermont (H. Crosson, VTDEC, Waterbury, VT). Analyses indicated that significant increases occurred in several of the less frequently collected species (i.e. less frequent in 1999) during 2000 and/or 2001. These included *E. canadensis*, several of the bladderwort species, and unfortunately the target species, *M. spicatum*, during August 2000 (Table 18). *Spirodela polyrhiza* was the only species for which a significant decline in occurrences was detected during the

Table 18
Burr Pond Wetland Transect Frequency of Occurrence Values and Chi^2 Summary Statistics for Comparisons Between August 1999 and 2000 and August 1999 and 2001. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

Plant Species	Frequency Values			1999 versus 2000		1999 versus 2001	
	August 1999	August 2000	August 2001	Chi^2 Value	Prob > Chi^2	Chi^2 Value	Prob > Chi^2
Submersed Species							
Ceratophyllum demersum	58	57	56	0.03	0.860	0.12	0.727
Ceratophyllum echinatum	2	0	0	2.03	0.155	2.03	0.155
Elodea Canadensis	3	10	8	4.10	0.040 ▲	2.44	0.118
Myriophyllum spicatum	7	27	4	14.94	0.000 ▲	0.88	0.349
Najas flexilis	0	1	0	1.01	0.316	0.00	1.000
Potamogeton diversifolius	0	3	0	3.06	0.080	0.00	1.000
Potamogeton epihydrus	2	0	0	2.03	0.155	2.03	0.155
Potamogeton foliosus	0	0	1	0.00	1.000	1.01	0.316
Potamogeton illinoensis	0	2	0	2.03	0.155	0.00	1.000
Potamogeton nodosus	0	0	1	0.00	1.000	1.01	0.316
Potamogeton spirillus	0	0	7	0.00	1.000	7.32	0.007
Utricularia geminascapa	0	0	6	0.00	1.000	6.23	0.013 ▲
Utricularia gibba	0	2	8	2.03	0.155	8.42	0.004 ▲
Utricularia intermedia	0	6	0	6.23	0.013 ▲	0.00	1.000
Utricularia minor	1	9	6	6.83	0.009 ▲	3.73	0.053 ▲
Utricularia vulgaris	1	9	18	6.83	0.009 ▲	17.26	0.000 ▲
Zosterella dubia	0	0	3	0.00	1.000	3.06	0.080
Floating and Floating-Leaved Species							
Nuphar variegata	58	59	56	0.03	0.859	0.12	0.727
Nymphaea odorata	27	23	41	0.47	0.500	5.01	0.025 ▲
Spirodela polyrhiza	13	40	0	20.57	0.000 ▲	14.15	0.000 ▼
Emergent Species							
Polygonum amphibium	0	0	0	0.00	1.000	0.00	1.000

study. However, it should be noted that since *S. polyrhiza* is a floating species, natural events occurring within the wetland area not associated with the fluridone application (e.g., water flow due to runoff, wind-induced movement) could have easily attributed to the lack of occurrence of this species along the transect during the August 2001 sampling event. Also, the fact that occurrences of *C. demersum*, a species relatively sensitive to fluridone, did not change during the study, suggests that the fluridone treatment did not significantly impact the wetland plant community.

Species richness data

Mean numbers of exotic, native, and total plant species occurring within 1-m intervals along the Burr Pond wetland transect for the August 1999, August 2000, and August 2001 surveys are illustrated in Figure 20. Native species outnumbered exotic species within the sampling intervals along the transect on all three sampling dates. Mean native species richness numbers ranged from 2.2 in August 1999 to 2.95 in August 2000. Native species richness values were significantly higher in both August 2000 and August 2001 than in August 1999. Because species occurrences along the transects were dominated by native species, total species richness values plotted in Figure 20 followed similar levels and trends as native species richness values.

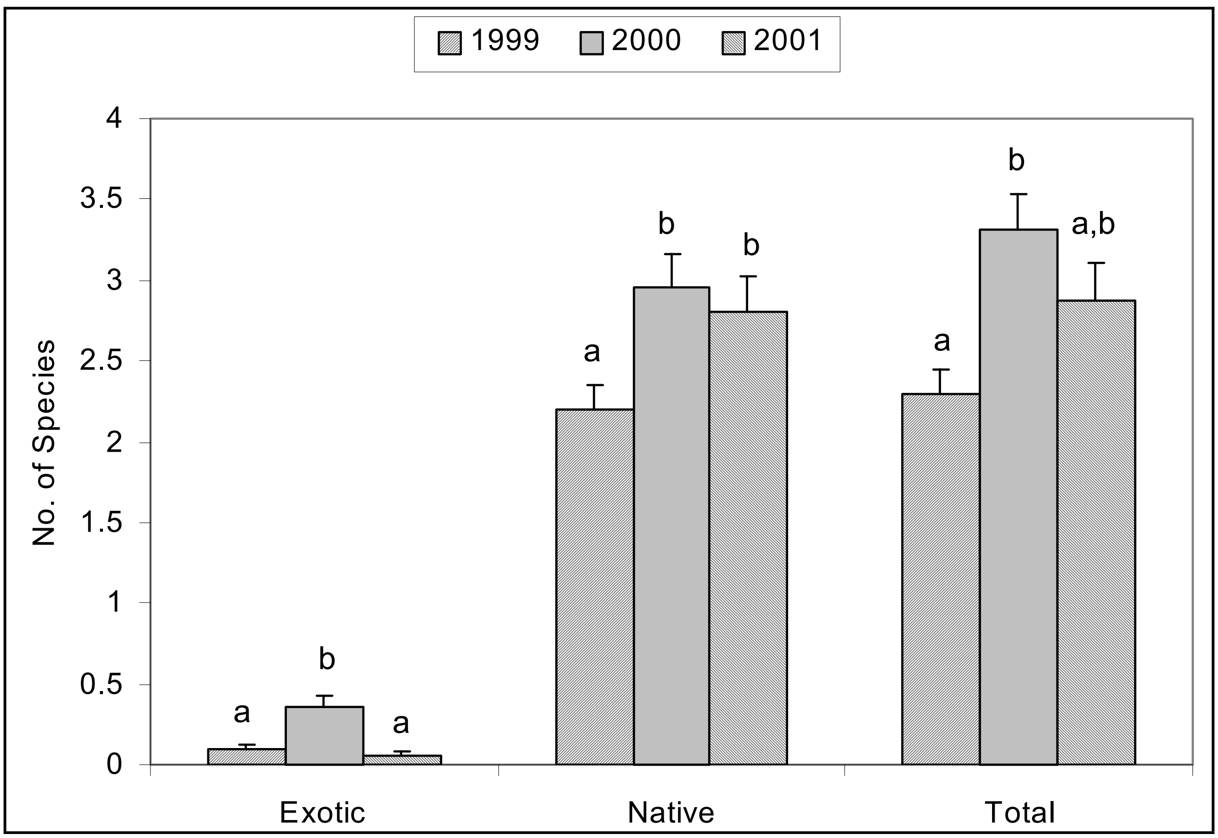

Figure 20. Mean numbers of exotic, native, and total plant species within 1-m sampling intervals along the Burr Pond wetland transect during August 1999, 2000, and 2001

Discussion and summary - Burr Pond wetland transect studies

The open-lake fluridone application in Burr Pond did not cause significant impacts to the aquatic plant community in the adjacent wetland area. Several species occurring in the wetland area have reported sensitivity to fluridone and may have been impacted if fluridone treatments had been made in this area. However, several species occurring in the wetland area are relatively tolerant of fluridone, and these species would probably withstand higher fluridone exposure if future *M. spicatum* control plans include direct application of fluridone into the wetland areas.

Lake Hortonia Open-Lake Study Findings

Cumulative species list

The cumulative species list for Lake Hortonia is at Table 19. The list includes 24 submersed species, 2 rooted, floating-leaved species, 1 floating species, and 2 emergent species. *Myriophyllum spicatum* and *P. crispus* were the only two exotic submersed species observed in Lake Hortonia during the study.

Maximum depth of colonization estimates and water depth profiles

Summaries of Secchi disk readings taken during this study and of historical readings taken by the Vermont Lay Monitoring Program are provided in Table 20. As for Burr Pond, consistent declines in annual average Secchi disk readings occurred from 1999 (5.6 m), to 2000 (4.9 m), and to 2001 (4.3 m). Of these 3 years, the 1999 annual average is closest to the annual average (5.6 m) reported for the 5-year period immediately preceding this study. Maximum depth of plant colonization estimates included in Table 20 indicate that changes in the underwater light climate at Lake Hortonia could have impacted plant growth during this study, similar to reports for Burr Pond. The MDOC based on the 1999 average annual Secchi disk reading was 5.9 m, while a similar MDOC estimate of 5.8 m was calculated for the 5-year period preceding this study. In comparison, the calculated MDOC estimates for 2000 and 2001 were 5.2 and 4.6 m, respectively.

Based on the above noted changes in calculated values for MDOC, it was determined that analyses of Lake Hortonia data sets would consider the same three depth classes established for Burr Pond. Depth class 1 included all points within the lake (= whole lake); depth class 2 included only points < 4 m in depth; and depth class 3 included only points < 2 m in depth.

The percent of points in 1-m depth classes from the Lake Hortonia August 1999 survey data are presented in Figure 21. These data confirm that the maximum depth of Lake Hortonia was approximately 18 m. Figure 21 also illustrates that between 65 and 70 percent of the sampling points occurred at depths less than the 5.9-m MDOC estimate calculated from the 1999 annual average Secchi disk reading and the 5.8-m MDOC estimate calculated from

Table 19
Species Observed in Lake Hortonia

Scientific Name and Authority	Common Name	Growth Form	Native or Exotic
Ceratophyllum demersum L.	Coontail	Submersed	Native
Chara spp.	Muskgrass	Submersed	Native
Drepanocladus spp.	Aquatic moss	Submersed	Native
Elodea canadensis Michx.	American elodea	Submersed	Native
Lemna minor L.	Small duckweed	Floating	Native
Lythrum salicaria L.	Purple loosestrife	Emergent	Exotic
Megalodonta beckii (Torr. ex Spreng.) Greene	Water-marigold	Submersed/emergent	Native
Myriophyllum sibiricum Komarov	Northern milfoil	Submersed	Native
M. spicatum L.	Eurasian watermilfoil	Submersed	Exotic
Najas flexilis (Willd.) Rostkov and Schmidt	Bushy pondweed	Submersed	Native
Nuphar variegata Engelm. ex Durand	Bullhead lilly, spatterdock	Floating-leaved	Native
Nymphaea odorata Aiton	White water lily	Floating-leaved	Native
Polygonum amphibium L.	Smartweed	Emergent	Native
Pontederia cordata L.	Pickerelweed	Emergent	Native
Potamogeton amplifolius Tuckerman	Large-leaf pondweed	Submersed	Native
P. crispus L.	Curly-leaf pondweed	Submersed	Exotic
P. gramineus L.	Variable pondweed	Submersed	Native
P. illinoensis Morong	Illinois pondweed	Submersed	Native
P. natans L.	Floating pondweed	Submersed	Native
P. oakesianus Robbins	Oakes pondweed	Submersed	Native
P. praelongus Wulfen	White-stem pondweed	Submersed	Native
P. pusillus L.	Slender pondweed	Submersed	Native
P. robbinsii Oakes	Fern pondweed	Submersed	Native
P. zosteriformis Fern	Flatstem pondweed	Submersed	Native
Ranunculus spp.	White water crowfoot	Submersed	Native
Stukenia pectinata (L.) Borner	Sago pondweed	Submersed	Native
Utricularia gibba L.	Creeping bladderwort	Submersed	Native
U. vulgaris L.	Common bladderwort	Submersed	Native
Vallisernia americana L.	Water celery	Submersed	Native
Zosterella dubia (Jacq.) MacM.	Water stargrass	Submersed	Native

historical Lake Hortonia Secchi disk readings. Further, Figure 21 illustrates that approximately 60 percent of Lake Hortonia sampling points were at depths not exceeding calculated MDOC estimates for 2000 (5.2 m) and 2001 (4.6 m) (Table 20). Therefore, the percent of points not exceeding calculated MDOC estimates did not change as much between years at Lake Hortonia as they did at Burr Pond.

Table 20
Lake Hortonia Water Depth Characteristics, Secchi Disk Readings, and Calculated Estimates for Maximum Depth of Colonization by Aquatic Plants

Time Period	Secchi Disk Reading, m	Canfield's Estimate (Eq. 1), m	Chambers' Estimate (Eq. 2), m	Average Estimate m
5-year June averages[1] (1994-1998)	6.2	5.5	6.0	5.8
5-year August averages (1994-1998)	6.3	5.6	6.1	5.9
5-year annual averages (1994-1998)	6.2	5.5	6.0	5.8
June 1999	6.7	5.8	6.2	6.0
August 1999	6.1	5.5	6.0	5.8
1999 annual average	6.4	5.6	6.1	5.9
June 2000 *(Not measured. Used June historical average)*	6.2	5.5	6.0	5.8
August 2000	3.8	4.1	4.7	4.4
2000 annual average	5.0	4.9	5.4	5.2
June 2001	4.1	4.3	4.9	4.6
August 2001	4.1	4.3	4.9	4.6
2001 annual average	4.1	4.3	4.9	4.6
Average depth 5.48 m				
Maximum depth 18.29 m				

[1] Based on data reported by Vermont Lay Monitoring Program.

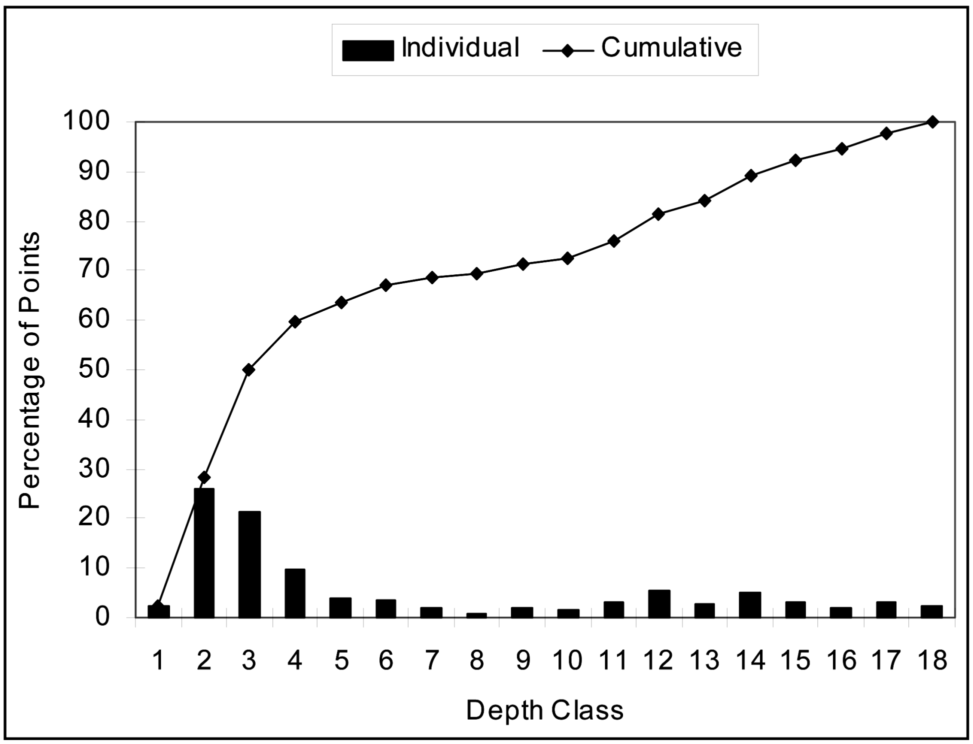

Figure 21. Percent occurrence of Lake Hortonia sampling points in 1-m depth classes

Frequency of occurrence survey results

June surveys. Maps of Lake Hortonia illustrating locations of occurrence of common plant species, or groups of plant species (i.e., broad-leaved pondweeds), for June sampling trips are included in Appendix C, Figures C1–C17. Frequency of occurrence data for individual species for the June 1999, 2000, and 2001 trips are given in Table 21. A total of 20 submersed or floating-leaved species and 2 emergent species were collected during the June 1999 survey. The eight most commonly occurring species in decreasing order of occurrence were *M. spicatum* (174), *P. amplifolius* (67), *Chara* spp. (63), *N. odorata* (46), *E. canadensis* (44), *P. robbinsii* (44), *V. americana* (30), and *P. zosteriformis* (2). In June 2000, *M. spicatum* occurred at 168 points and was again the most frequently occurring species. The list of the next seven most commonly occurring species in June 2000 is identical to the June 1999 list, with the exception that *Potamogeton praelongus* replaced *V. americana* as the seventh most common species. Significant reductions in June occurrences between 1999 and 2000 were detected for four submersed species, while significant increases in June occurrences were detected for two species. As at Burr Pond, these changes in occurrence could not have been effected by the fluridone application since the herbicide application was not made until June 4, 2000. More likely, these differences were caused by delayed regrowth in June 2000 compared to June 1999 (see pages 42 and 66). In June 2001, in apparent response to the fluridone treatment, the *M. spicatum* occurrences were significantly reduced to one tenth their June occurrence levels in 1999 and 2000 (Table 21). No longer was this target species the most common plant. In June 2001, the eight most commonly occurring species were *Chara* spp., *P. robbinsii*, *N. odorata, P. amplifolius*, *P. zosteriformis*, the exotic *M. spicatum*, the exotic *P. crispus*, and *Utricularia vulgaris* (Table 21). Occurrences of 11 submersed or floating-leaved species were significantly lower in June 2001 than in June 1999 (Table 21). Significant increases in occurrence were detected for three submersed species between June 1999 and June 2001, including *S. pectinata, Chara* spp., and *P. crispus*.

Occurrence data summaries for the three plant groupings within the three water depth classes for June surveys are provided in Table 22. These data are illustrated by depth class in Figures 22-24. In June 1999, 53 percent of the whole-lake sampling points was vegetated by at least one native plant species (Figure 22). At that time, at least one native species was also found at 79 percent of sampling points with water depths <4 m (Figure 23), and at 97 percent of points with water depths <2 m (Figure 24). Occurrences of points with at least one native species within these depth classes were at similar levels during June 2000 and June 2001 surveys, other than the decrease in occurrences in the <2-m depth class in June 2001. During the June 1999 and June 2000 surveys, occurrences of points vegetated by the target plant species, *M. spicatum,* also remained fairly consistent within each depth class. In June 2001, this species showed significant declines in all depth classes. In June 1999, occurrences of *M. spicatum* across the three depth classes ranged from 58 percent (whole lake) to 96 percent (<2 m) of sampled points. By June 2001, *M. spicatum* occurred in less than 10 percent of points in the whole lake and <4-m depth classes, and in

Table 21
Lake Hortonia Frequency of Occurrence Data and Chi^2 Summary Statistics for June Surveys. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

Plant Species	Frequency Values			June 1999 vs June 2000		June 1999 vs June 2001	
	June 1999	June 2000	June 2001	Chi^2 Value	Prob > Chi^2	Chi^2 Value	Prob > Chi^2
Submersed Species							
Ceratophyllum demersum	7	5	0	0.34	0.560	7.08	0.008 ▼
Chara sp.	63	60	100	0.09	0.762	11.55	0.001 ▲
Drepanocladus sp.	0	1	1	1.00	0.317	1.00	0.317
Elodea canadensis	44	37	3	0.70	0.403	38.82	0.000 ▼
Megalodonta beckii	0	0	0	0.00	1.000	0.00	1.000
Myriophyllum sibiricum	10	5	3	1.71	0.191	3.85	0.049 ▼
Myriophyllum spicatum	174	168	18	0.25	0.620	186.69	0.000 ▼
Najas flexilis	0	0	0	0.00	1.000	0.00	1.000
Nuphar variegata	10	17	7	1.90	0.168	0.54	0.460
Nymphaea odorata	46	38	29	0.89	0.364	4.41	0.036 ▼
Potamogeton amplifolius	67	76	21	0.74	0.388	28.19	0.000 ▼
Potamogeton crispus	0	17	16	17.50	0.000 ▲	16.44	0.000 ▲
Potamogeton gramineus	8	7	5	0.07	0.794	0.71	0.400
Potamogeton illinoensis	36	1	0	35.29	0.000 ▼	38.31	0.000 ▼
Potamogeton natans	13	3	0	6.42	0.011 ▼	13.29	0.000 ▼
Potamogeton nodosus	0	0	1	0.00	1.000	1.00	0.317
Potamogeton praelongus	16	28	0	3.53	0.060	16.44	0.000 ▼
Potamogeton robbinsii	44	29	46	3.51	0.061	0.05	0.819
Potamogeton zosteriformis	20	19	18	0.03	0.869	0.11	0.737
Ranunculus longirostris	2	4	3	0.67	0.412	0.20	0.653
Stukenia pectinata	1	8	7	5.53	0.019 ▲	4.56	0.033 ▲
Utricularia gibba	9	1	2	6.51	0.011 ▼	4.54	0.033 ▼
Utricularia vulgaris	8	11	15	0.49	0.484	2.22	0.137
Vallisneria americana	30	13	7	7.24	0.007 ▼	15.24	0.000 ▼
Zosterella dubia	2	2	1	0.00	1.000	0.34	0.563
Any submersed native species	157	143	143	1.31	0.252	1.31	0.252
Any submersed species	197	193	149	0.12	0.731	15.80	0.000 ▼
Emergent Species							
Polygonum amphibium	2	0	0	2.01	0.157	2.01	0.157
Pontederia cordata	1	1	1	0.00	1.000	0.00	1.000
Sparganium americanum	0	0	0	0.00	1.000	0.00	1.000

Table 22
Lake Hortonia Percent Occurrence of Native Plants, Milfoil, and Total Plants by Depth Class and Year for June Sampling Trips, and Chi² Summary Statistics for Comparing June 1999 Values With June 2000 and June 2001 Values. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

Plant Grouping	Percent Occurrence Values			June 1999 vs June 2000		June 1999 vs June 2001	
	June 1999	June 2000	June 2001	Chi^2 Value	Prob > Chi^2	Chi^2 Value	Prob > Chi^2
Any Native Plant Species							
Whole lake	52.5	47.8	47.8	1.31	0.252	1.31	0.252
<4 m	78.9	74.9	78.2	0.85	0.356	0.03	0.855
<2 m	96.9	93.3	86.5	1.14	0.285	6.59	0.010 ▼
Myriophyllum spicatum							
Whole lake	58.2	56.2	6.0	0.25	0.620	176.7	0.000 ▼
<4 m	91.6	88.3	9.8	1.08	0.299	243.7	0.000 ▼
<2 m	95.9	96.7	17.6	0.06	0.811	110.1	0.000 ▼
Any Plant Species							
Whole lake	65.9	64.5	49.8	0.12	0.731	15.80	0.000 ▼
<4 m	98.4	98.8	80.5	0.11	0.739	32.09	0.000 ▼
<2 m	100.0	100.0	89.2	0.00	1.000	11.11	0.001 ▼

18 percent of points in the <2-m depth class. Chiefly because of the *M. spicatum* reductions, occurrences of points vegetated by at least one plant species were reduced significantly in June 2001 at each of the depth classes. However, the observed persistence of points vegetated by at least one native species in June 2001 maintained the occurrences of points with at least one plant species in June 2001 at near 50 percent on the whole-lake basis, and near 80 and 90 percent in the <4- and <2-m depth classes, respectively.

August surveys. Lake Hortonia maps illustrating locations of occurrence of commonly occurring plants species or groups of plant species (i.e., broad-leaved pondweeds) during August point-intercept surveys are included in Appendix C, Figures C1–C17. Frequency of occurrence data for individual species from these surveys are provided in Table 23. During the August 1999 pretreatment survey, a total of 21 submersed or floating-leaved species were collected at sampling points. *Myriophyllum spicatum* was the most common species, occurring at 162 of the sample points. Other common species, in decreasing order of occurrence, were *Potamogeton illinoensis*, *V. americana*, *Chara* spp., *E. canadensis*, *P. robbinsii*, *U. gibba*, and *P. gramineus*. Because the sampling design was aimed at open-water locations, only two emergent species were collected in August 1999. *Polygonum amphibium* was collected at two points, and *Pontederia cordata* was collected at a single point. In comparison to the August 1999 pretreatment survey data, results of the August 2000 YOT survey showed statistically significant declines in occurrence for 10 native submersed or

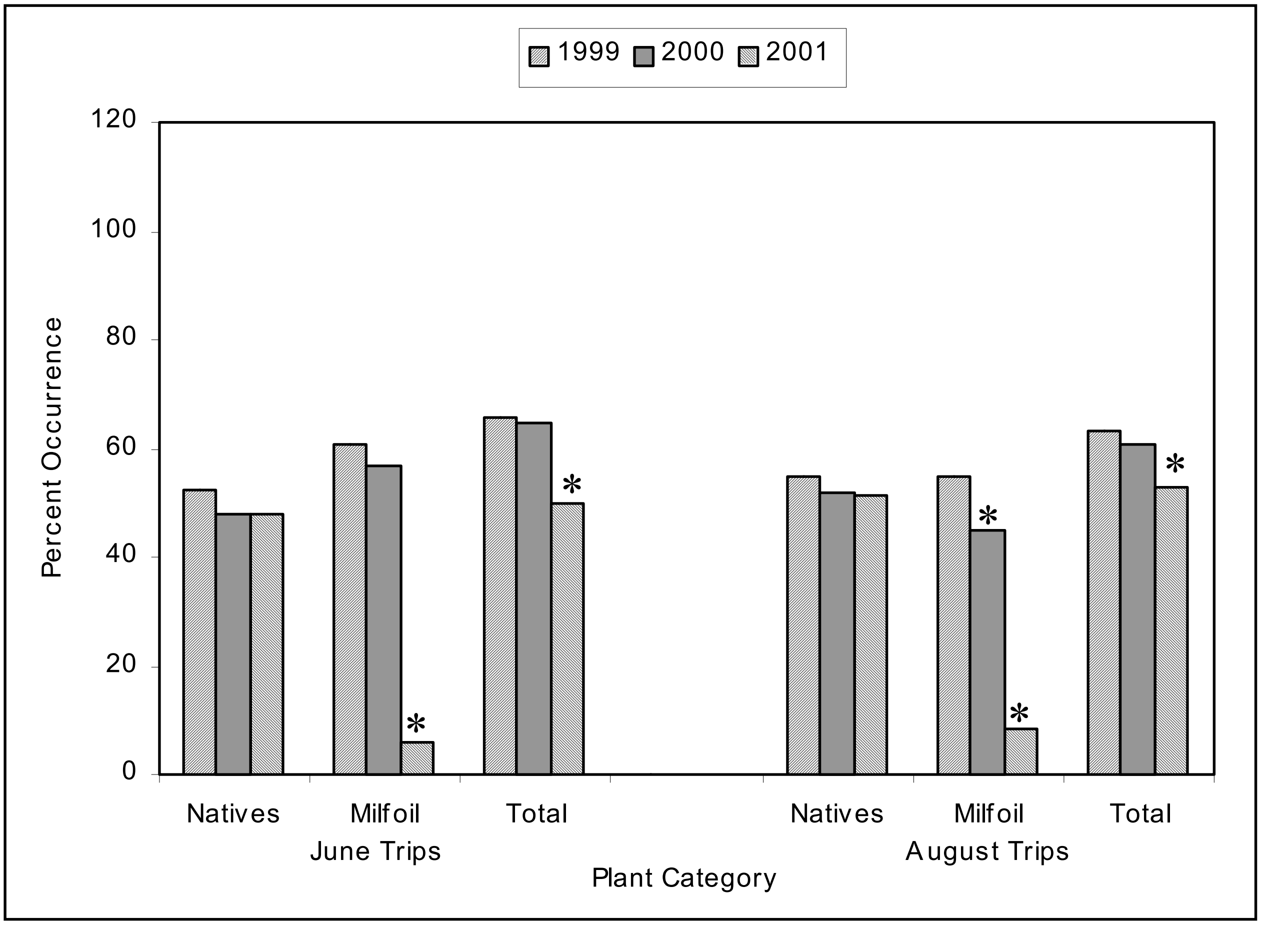

Figure 22. Lake Hortonia frequency of occurrence summaries for sampling points at all water depths. Frequency data are grouped into three plant types (native plant species, *Myriophyllum spicatum* only, and total plant species) and six sampling trips (June or August in 1999, 2000, or 2001). An asterisk above a 2000 or 2001 bar indicates a significant difference in comparison to the 1999 frequency value for that particular grouping of plant type and sampling month

floating-leaved species (Table 23). Species showing the most significant declines were *P. illinoenis*, *E. canadensis*, *V. americana*, and *S. pectinata*. Though *M. spicatum* occurrences were also significantly lower in August 2000 than in August 1999, this species was still present at 134 points and remained the most frequently occurring species. The second most common species in August 2000 was *Chara* spp., which actually showed a significant increase in occurrence over August 1999 occurrences. The other common species in decreasing order were *P. illinoensis*, *U. gibba*, *P. robbinsii*, *V. americana*, *N. odorata*, and *P. gramineus*. In the August 2001 data set, *M. spicatum* occurrences were reduced to only 25 locations, a reduction greater in comparison to its August 1999 occurrence level than for any other species (Table 23). Nine native submersed or floating-leaved species also occurred at significantly fewer points in August 2001 than in August 1999. Interestingly, two species (*N. flexilis* and *S. pectinata*) that had experienced significant reductions in occurrence in August 2000 had returned to levels similar to pretreatment levels (August 1999) during August

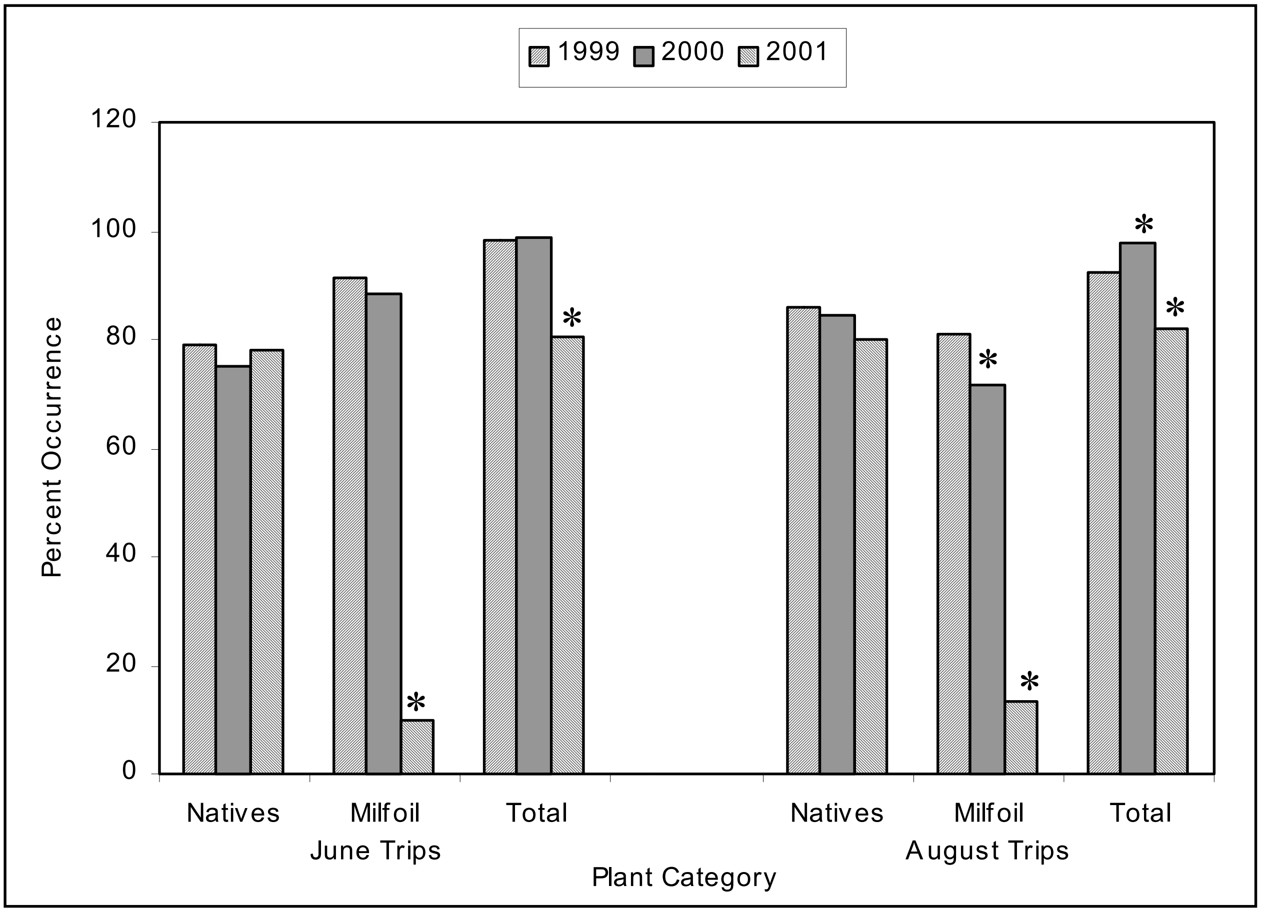

Figure 23. Lake Hortonia frequency of occurrence summaries for sampling points at water depths <4.0 m. Frequency data are grouped into three plant types (native plant species, *Myriophyllum spicatum* only, and total plant species) and six sampling trips (June or August in 1999, 2000, or 2001). An asterisk above a 2000 or 2001 bar indicates a significant difference in comparison to the 1999 frequency value for that particular grouping of plant type and sampling month

2001. Three species, *Chara* spp., the exotic *P. crispus,* and *P. zosteriformis*, were more frequent in August 2001 than in August 1999. The eight most frequently occurring species in August 2001 were *Chara* spp., *N. odorata*, *P. illinoensis*, *P. robbinsii*, *V. americana*, *H. dubia*, *M. spicatum*, and *S. pectinata*.

Occurrence data summaries for the three plant groupings within the three water depth classes for August surveys are given in Table 24, and these summaries are illustrated by water depth class in Figures 22-24. In August 1999, at least one native plant species occurred in 55 percent of the whole-lake sampling points (Figure 22), in 86 percent of points <4 m (Figure 23), and in 86 percent of points <2 m (Figure 24). As with June sampling dates at Lake Hortonia, the percent occurrence of points vegetated by at least one native species did not change significantly during August 2000 or August 2001 in any of the three water depth classes, with the exception that there was an increase in occurrence of points vegetated by native plants in the <2-m depth class in August 2000. During the same time period, occurrences of points vegetated by

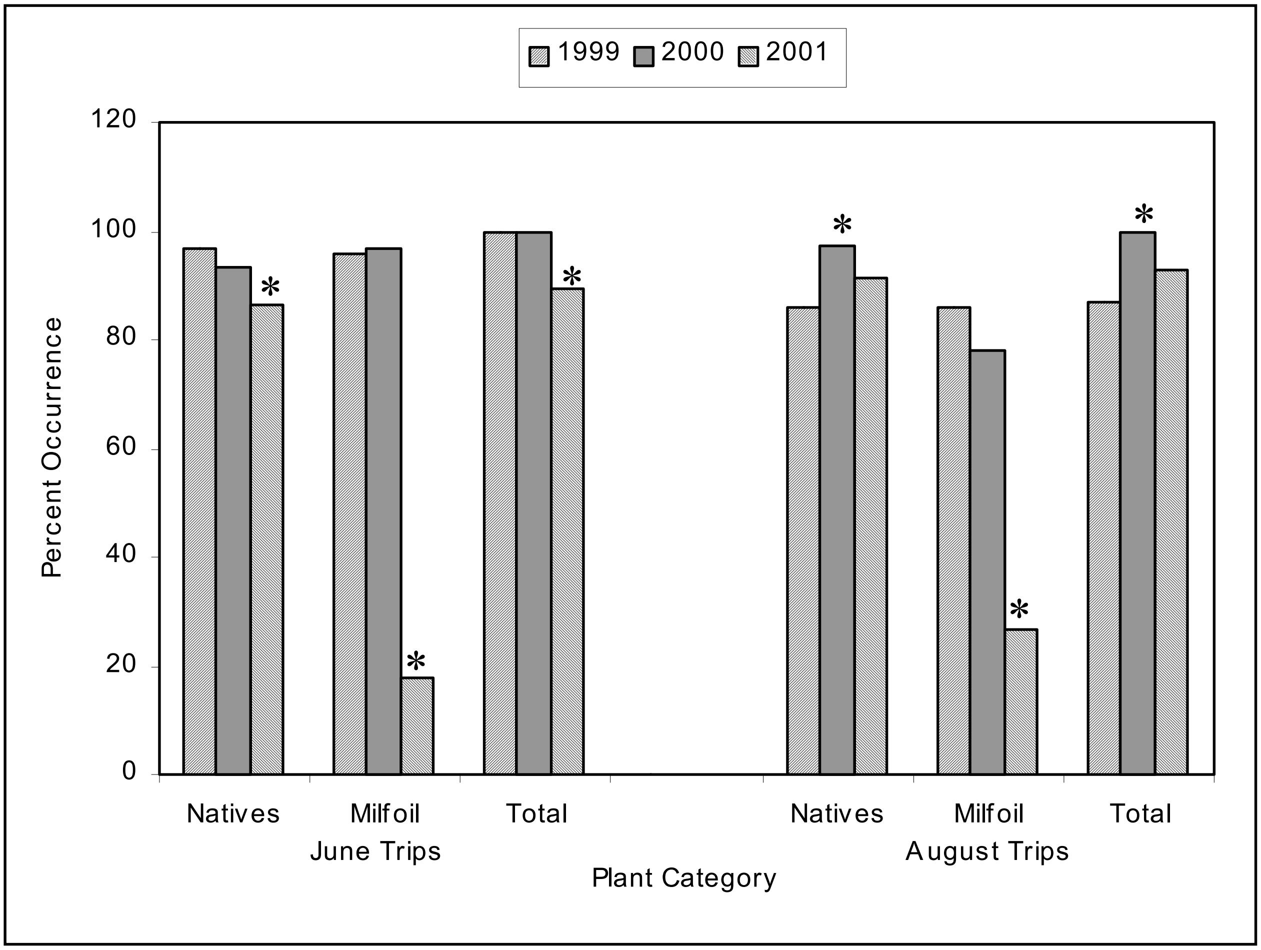

Figure 24. Lake Hortonia frequency of occurrence summaries for sampling points at water depths <2.0 m. Frequency data are grouped into three plant types (native plant species, *Myriophyllum spicatum* only, and total plant species) and six sampling trips (June or August in 1999, 2000, or 2001). An asterisk above a 2000 or 2001 bar indicates a significant difference in comparison to the 1999 frequency value for that particular grouping of plant type and sampling month

M. spicatum showed consistent and significant declines across all depth classes. In August 1999, occurrences of *M. spicatum* points across the three depth classes ranged from 54 percent (whole lake) to 86 percent (<2 m). By August 2001, *M. spicatum* occurrences were near 5 percent of whole-lake points, near 13 percent of points <4 m, and near 25 percent of points <2 m. The percent of whole-lake points "vegetated" by at least one plant species during August surveys declined significantly to 53 percent in 2001. However, this was primarily due to the decrease in *M. spicatum*, and not reduction of native species. Percent occurrences for vegetated points were higher in shallower depth classes in all 3 years. In August 2001, percent occurrence of vegetated points was 82 percent in the <4-m depth class (Table 24; Figure 23) and 93 percent in the <2-m depth class (Table 24; Figure 24).

Table 23
Lake Hortonia Frequency of Occurrence Data and Chi^2 Summary Statistics for August Surveys. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

Plant Species	Frequency Values			August 1999 vs August 2000		August 1999 vs August 2001	
	August 1999	August 2000	August 2001	Chi^2 Value	Prob > Chi^2	Chi^2 Value	Prob > Chi^2
Submersed Species							
Ceratophyllum demersum	26	10	1	7.57	0.006 ▼	24.24	0.000 ▼
Chara sp.	52	77	102	6.18	0.013 ▲	21.86	0.000 ▲
Drepanocladus sp.	0	0	0	0.00	1.000	0.00	1.000
Elodea canadensis	44	3	5	38.82	0.000 ▼	33.81	0.000 ▼
Megalodonta beckii	2	0	1	2.01	0.157	0.34	0.563
Myriophyllum sibiricum	9	0	2	9.14	0.003 ▼	4.54	0.033 ▼
M. spicatum	162	134	25	5.24	0.022 ▼	146.04	0.000 ▼
Najas flexilis	7	0	14	7.08	0.008 ▼	2.42	0.120
Nuphar variegata	6	4	8	0.41	0.524	0.29	0.589
Nymphaea odorata	28	31	39	0.17	0.681	2.03	0.154
Potamogeton amplifolius	5	9	3	1.17	0.279	0.51	0.477
Potamogeton crispus	0	1	13	1.00	0.317	13.29	0.000 ▲
Potamogeton gramineus	33	15	3	7.34	0.007 ▼	26.60	0.000 ▼
Potamogeton illinoensis	116	45	37	42.85	0.000 ▼	54.82	0.000 ▼
Potamogeton natans	6	1	0	3.61	0.057	6.06	0.014 ▼
Potamogeton nodosus	0	0	0	0.00	1.000	0.00	1.000
Potamogeton praelongus	11	1	1	8.50	0.004 ▼	8.50	0.004 ▼
Potamogeton robbinsii	35	33	34	0.07	0.797	0.02	0.898
Potamogeton zosteriformis	9	7	21	0.26	0.612	5.05	0.025 ▲
Ranunculus longirostris	0	0	3	0.00	1.000	3.02	0.083
Stukenia pectinata	17	2	20	12.23	0.001 ▼	0.26	0.611
Utricularia gibba	34	38	13	0.25	0.615	10.18	0.001 ▼
Utricularia vulgaris	7	10	14	0.54	0.460	2.42	0.120
Vallisneria americana	71	31	34	18.91	0.000 ▼	15.81	0.000 ▼
Zosterella dubia	19	12	28	1.67	0.197	1.87	0.171
Any submersed native species	164	155	154	.054	0.460	0.67	0.413
Any submersed species	189	182	158	0.35	0.555	6.06	0.010 ▼
Emergent Species							
Polygonum amphibium	2	2	0	0.00	1.000	2.01	0.157
Pontederia cordata	1	0	1	1.00	0.317	0.00	1.000
Sparganium americanum	0	0	1	0.00	1.000	1.00	0.317

Table 24
Lake Hortonia Percent Occurrence of Native Plants, Milfoil, and Total Plants by Depth Class and Year for August Sampling Trips, and Chi^2 Summary Statistics for Comparing August 1999 Values with August 2000 and August 2001 Values. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

Plant Grouping	Percent Occurrence Values			August 1999 vs August 2000		August 1999 vs August 2001	
	August 1999	August 2000	August 2001	Chi^2 Value	Prob > Chi^2	Chi^2 Value	Prob > Chi^2
Any Native Plant Species							
Whole lake	54.8	51.8	51.5	0.54	0.460	0.67	0.413
<4 m	85.7	84.6	80.0	0.08	0.772	2.13	0.144
<2 m	86.0	97.3	91.5	6.28	0.012 ▲	1.40	0.236
Myriophyllum spicatum							
Whole lake	54.2	44.8	8.4	5.24	0.022 ▼	146.0	0.000 ▼
<4 m	80.8	71.6	13.1	4.08	0.043 ▼	170.9	0.000 ▼
<2 m	86.0	78.1	26.6	1.79	0.181	67.05	0.000 ▼
Any Plant Species							
Whole lake	63.2	60.9	52.8	0.35	0.555	6.60	0.010 ▼
<4 m	92.3	97.6	82.1	5.11	0.024 ▲	8.61	0.003 ▼
<2 m	87.1	100.0	92.6	10.15	0.001 ▲	1.52	0.217

Species richness data

Lake Hortonia species richness data for each sampling trip are summarized in Table 25 for two plant groupings (native plants and all plants) and three water depth classes (whole lake, points <4 m, and points <2 m). In June 1999, species richness of native plants based on all points was 1.57, while values for native plants in the <4- and <2-m depth classes were 2.37 and 3.77, respectively. This relationship of higher species richness values in shallower water depth classes was consistent on each trip and for both plant groupings.

Comparisons of native species richness values for specified combinations of sampling month (June or August) and water depth class through time show a consistent trend toward reductions in this parameter following the fluridone application (Table 25; Figure 25). For June comparisons, significant reductions were not detected until June 2001 in any of the depth classes (Figure 25). For August comparisons, a significant reduction in native species richness was only detected in the <4-m depth class; however, significant reductions were detected in this intermediate depth class in both 2000 and 2001. As at Burr Pond, the timing of these impacts is consistent with potential impacts from the herbicide application since the June 2000 fluridone application date could not have caused an impact to the plant community prior to the June 2000 sampling trip, but could have effected an impact prior to the August 2000 survey.

Table 25
Lake Hortonia Species Richness Summary Statistics (Mean, N, Standard Error) Calculated for Two Plant Groupings and Three Water Depth Classes for June and August Survey Trips

Plant Grouping	Water Depth Class	Summary Statistic	June Surveys			August Surveys		
			1999	2000	2001	1999	2000	2001
Native plant species	Whole lake (all depths)	Mean	1.57	1.26	0.91	1.83	1.12	1.28
		N	299	299	299	299	299	299
		Std. Err.	0.13	0.10	0.08	0.13	1.01	0.10
	Points with depths <4.0 m	Mean	2.37	2.09	1.51	2.95	2.03	2.01
		N	1.90	171	174	182	169	190
		Std. Err.	0.17	0.15	0.11	0.17	0.14	0.13
	Points with depths <2.0 m	Mean	3.77	3.75	2.36	3.82	3.19	3.05
		N	98	60	74	93	73	94
		Std. Err.	0.25	0.25	0.19	0.86	0.24	0.21
All plant species	Whole lake (all depths)	Mean	2.17	1.88	1.02	2.38	1.67	1.41
		N	299	299	299	299	299	299
		Std. Err.	0.14	0.12	0.08	0.15	0.11	0.11
	Points with depths <4.0 m	Mean	3.32	3.06	1.70	3.76	2.75	2.21
		N	190	171	174	182	169	190
		Std. Err.	0.17	0.16	0.12	0.18	0.15	0.15
	Points with depths <2.0 m	Mean	4.72	4.93	2.70	4.68	3.99	3.41
		N	98	60	74	93	73	94
		Std. Err.	0.25	0.26	0.22	0.28	0.24	0.22

As was noted for Burr Pond, although the above noted reductions in native species richness following the herbicide application occurred, native species richness values remained high throughout the study in all three depth classes. In August 2001, mean values for the three water depth classes were 1.28 for the whole lake, 2.01 for points <4 m, and 3.05 for points <2 m.

Plant biomass samples

Lake Hortonia plant biomass data for individual plant species are summarized by sampling trip in Table 26. As noted in the "Methods" chapter, the primary objective of the biomass sampling effort was to allow determination of whether a significant decline occurred in average biomass of *M. spicatum* following the fluridone application. Therefore, though data were collected on individual species and have been summarized and are included in Table 26, less emphasis should be placed on individual native species as is placed on data for *M. spicatum.* For native species, the best data to consider is the cumulative total for all native species (total natives in Table 26 and Figure 26).

Significant reductions were detected in biomass of *M. spicatum* during sampling trips following the fluridone application in June 2000 (Figure 26). For June trip comparisons, the detection of significant changes did not occur until 2001. For August trip comparisons, significant reductions from 1999 levels were detected for both 2000 and 2001. A significant change in biomass levels was not detected for the cumulative grouping of "total natives" in June surveys.

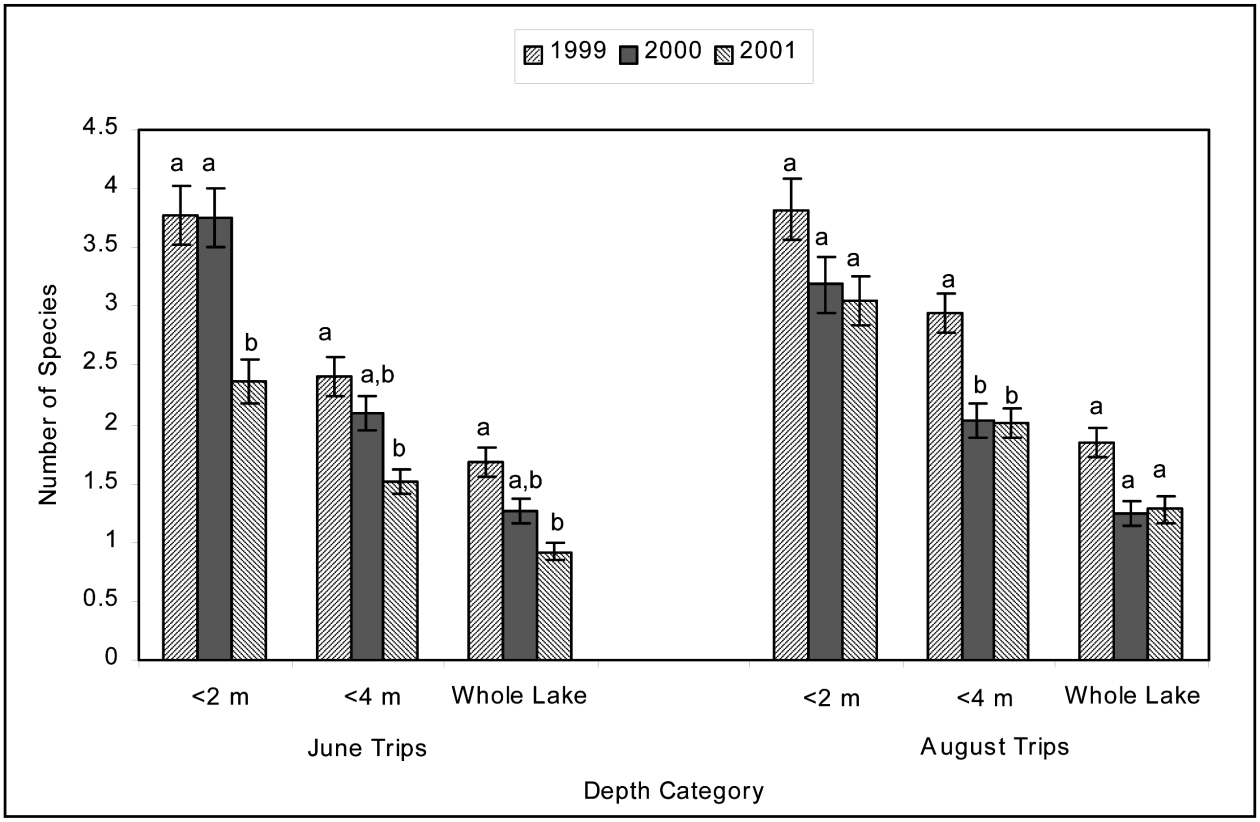

Figure 25. Species richness values for Lake Hortonia native species. Data are grouped into six categories by month of sampling (June and August) and water depth class (<2.0 m, <4.0 m, and whole lake) to allow comparisons within these six groupings between sampling years (1999 vs 2000 vs 2001). Within a grouping, letters above bars indicate results of Kruskal-Wallis means separation tests at $p < 0.05$

However, comparison of August values for native species biomass indicates that a significant increase in abundance of native plants occurred in August 2001 samples (Figure 26). Inspection of biomass values for individual species in Table 26 indicates that this increase was due chiefly to an increase in the abundance of *Chara* spp., although less dramatic increases in biomass levels were also observed for *P. robbinsii*, *P. illinoensis,* and *V. americana* during August 2001. Also in August 2001, the exotic species *P. crispus* was found at detectable levels in biomass samples. As for Burr Pond, observed reductions in biomass levels for the cumulative grouping of "total plants" were attributed to reductions in biomass levels of *M. spicatum*.

Discussion - Lake Hortonia open-lake studies

Pretreatment conditions. Pretreatment vegetation surveys conducted in June and August 1999 confirmed that a healthy aquatic plant community existed in Lake Hortonia prior to the June 2000 whole-lake fluridone application. As shown in Tables 21 and 23, 22 submersed or floating-leaved species were

Table 26
Lake Hortonia Aquatic Plant Biomass (g dwt m^{-2}) Summary Statistics (Mean, SE) for 30 Samples Collected During June and August Survey Trips in 1999, 2000, and 2001. A "T" Denotes a Trace Level of Biomass (<0.05 g dwt m^{-2}) for Indicated Species

	June Survey Trips			August Survey Trips		
Plant Species	**1999 Mean (SE)**	**2000 Mean (SE)**	**2001 Mean (SE)**	**1999 Mean (SE)**	**2000 Mean (SE)**	**2001 Mean (SE)**
Ceratophyllum demersum	1.3 (1.3)	0.3 (0.2)	0.0 -	0.0 -	0.5 (0.5)	0.0 -
Chara sp.	42.6 (23.6)	18.7 (10.5)	9.3 (9.3)	32.2 (27.6)	5.4 (2.4)	97.9 (59.8)
Elodea canadensis	6.8 (4.7)	1.7 (1.0)	T -	0.2 (0.2)	0.4 (0.4)	0.1 (0.1)
Myriophyllum spicatum	254.3 (53.3)	171.5 (33.9)	T -	284.9 (75.7)	33.8 (9.3)	7.4 (5.9)
Najas flexilis	0.0 -	0.0 -	0.0 -	0.0 -	0.0 -	0.3 (0.3)
Nymphaea odorata	0.6 (0.6)	0.8 (0.8)	0.5 (0.5)	2.5 (2.5)	3.6 (2.7)	2.3 (1.7)
Potamogeton amplifolius	0.7 (0.7)	8.9 (2.9)	0.0 -	0.0 -	0.0 -	0.0 -
Potamogeton crispus	0.0 -	1.3 (1.3)	0.0 -	0.0 -	0.0 -	3.9 (2.4)
Potamogeton gramineus	0.0 -	0.0 -	0.0 -	10.7 (5.3)	0.5 (0.2)	0.0 -
Potamogeton illinoensis	12.8 (4.2)	0.0 -	0.2 (0.1)	26.3 (12.5)	1.4 (0.6)	7.1 (4.5)
Potamogeton robbinsii	16.7 (16.5)	0.9 (0.7)	20.0 (11.0)	4.0 (2.2)	1.6 (1.1)	16.6 (6.8)
Potamogeton zosteriformis	0.4 (0.4)	0.6 (0.5)	0.3 (0.2)	0.0 -	0.0 -	0.6 (0.6)
Ranunculus sp.	0.0 -	0.2 (0.2)	0.6 (0.6)	0.0 -	0.0 -	T -
Stukenia pectinata	0.0 -	0.0 -	0.0 -	0.0 -	0.0 -	0.3 (0.3)
Utricularia sp.	0.2 (0.2)	0.0 -	0.1 (0.1)	0.3 (0.3)	0.0 -	1.1 (0.6)
Vallisneria Americana	0.0 -	1.2 (0.6)	0.1 (0.1)	1.5 (1.4)	3.1 (2.0)	13.0 (8.5)
Zosterella dubia	0.2 (0.1)	0.0 -	0.0 -	0.0 -	0.5 (0.5)	6.5 (5.0)
Total natives	82.3 (27.5)	34.6 (10.7)	40.5 (13.6)	77.8 (29.3)	16.9 (6.6)	149.6 (63.9)
Total all species	336.6 (50.2)	206.1 (31.6)	40.5 (13.6)	362.6 (78.2)	50.8 (9.9)	157.0 (64.3)

reported in 1999, and native species richness estimates calculated on a whole-lake basis ranged from 1.57 to 1.83 (Table 25, Figure 25). The percent of whole-lake points at Lake Hortonia that contained at least one native species were 52 and 55 percent in June and August 1999, respectively. Pretreatment surveys at Lake Hortonia also documented that *M. spicatum* occurred in 58 percent of points in the June 1999 survey (Table 22) and in 54 percent of the points in the August 1999 survey (Table 24). *Myriophyllum spicatum* also dominated pre-treatment plant biomass in Lake Hortonia, accounting for 76 and 79 percent of total biomass collections in June 1999 and August 1999, respectively (Table 26).

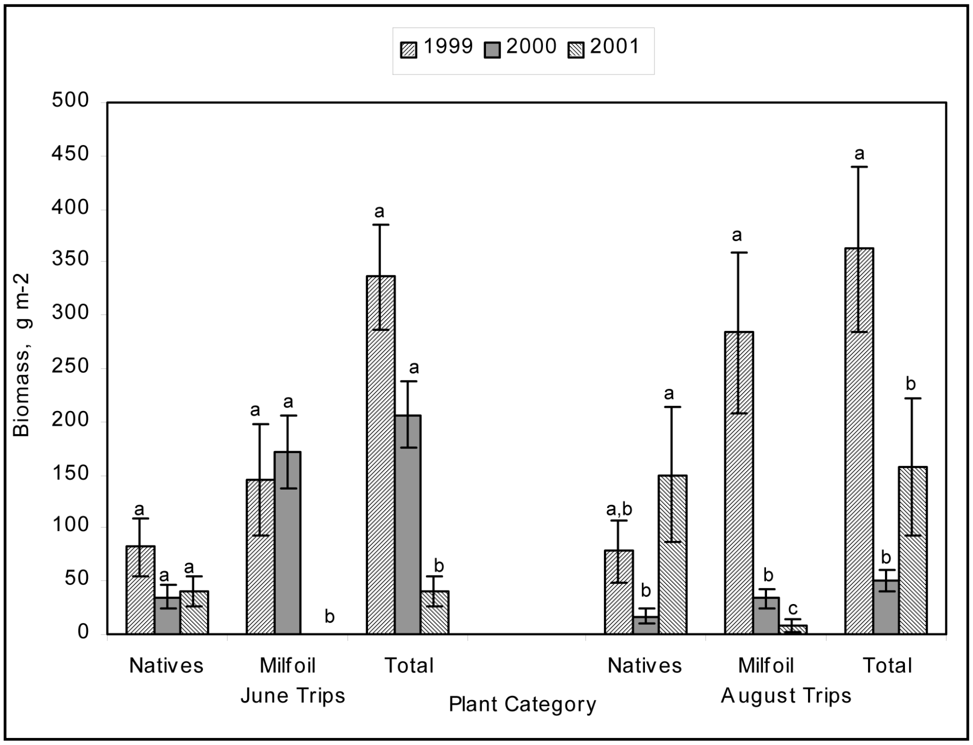

Figure 26. Plant biomass values for Lake Hortonia surveys. Data are grouped into six categories by month of sampling (June and August) and plant type (native plants, *Myriophyllum spicatum*, and total plants) to allow comparisons within these six groupings between years (1999 vs 2000 vs 2001). Within a grouping, letters above bars indicate results of Kruskal-Wallis means separation tests at $p < 0.05$

As for Burr Pond, frequency of occurrence values and species richness values calculated on the basis of points with depths <4 m and points with depths <2 m were higher than values calculated on a whole-lake basis. At Lake Hortonia, *M. spicatum* occurrences totaled 96 and 86 percent, respectively, of the points with depths <2 m in June and August 1999. As a general rule, the percentages of points with at least one native species and native species richness estimates were also higher when just shallow water depth points were considered.

Differences in June 1999 and June 2000 data sets. Analysis of Lake Hortonia data sets indicates that four submersed plant species were found at significantly fewer sampling points in June 2000 than in June 1999 (Table 21). Species exhibiting significant reductions were *P. illinoensis*, *P. natans*, *U. gibba*, and *V. americana*. Because samples comprising the June 2000 data set were collected too early to have been impacted by the June 4, 2000, fluridone treatment, factors other than herbicide impacts must have accounted for these significant differences. As at Burr Pond, it is likely that differences resulted from differences in spring temperatures that caused a delay in the onset of spring regrowth (see page 42). Regardless, because significant differences were again detected in these two June pretreatment data sets, the following discussion of findings, except where noted, is based on August data set comparisons.

Treatment impacts – *M. spicatum* control. By August 2000, *M. spicatum* had experienced significant reductions at Lake Hortonia, although it still occurred at approximately 45 percent of whole-lake sampling points (Table 24). In both June and August 2001 surveys, *M. spicatum* occurrence was reduced to levels significantly below pretreatment levels in all three depth categories (i.e., whole lake, points <4 m, and points <2 m). By August 2001, *M. spicatum* occurrences had been reduced to 8.4 percent of whole-lake sampling points, representing an approximate 85-percent reduction in pretreatment whole-lake occurrences (Table 24). This level of reduction in *M. spicatum* occurrence is similar to reduction levels reported for similar whole-lake fluridone treatments reported for Michigan lakes (Getsinger et al. 2001).

At Lake Hortonia, *M. spicatum* remained established in approximately 27 percent of points in the shallowest water depth class. Areas in Lake Hortonia with most numerous *M. spicatum* occurrences in August 2001 were areas immediately adjacent to the two untreated wetland areas, areas within the wetland area located in the extreme southern end of the lake, and areas within the outflow cove (Figure B1). Locations of these occurrences suggest that establishment of the fluridone treatment "buffer zones" around wetland areas (see page 10) may have had the unintended consequence of maintaining uncontrolled pockets of *M. spicatum* in Lake Hortonia. While these widespread pockets of *M. spicatum* may serve as propagules for the reestablishment of the plant throughout the lake in future years, a rapid increase of *M. spicatum* frequency or biomass did not occur in 2001.

The June 2000 fluridone application was effective in reducing *M. spicatum* biomass levels prior to collection of the August 2000 samples. Mean biomass values for *M. spicatum* remained at significantly reduced levels throughout the 2001 growing season. Levels in August 2001 were approximately 1 percent of August 1999 pretreatment levels (Table 26). As noted for Burr Pond, the combination of low frequency of occurrence and low biomass in August 2001 suggests that *M. spicatum* should not recover to nuisance levels in 2002.

Reduction levels at Lake Hortonia were also similar to levels reported herein for Burr Pond, even though the Burr Pond application unintentionally resulted in significantly higher initial fluridone concentrations of 10 ppb (Figure 5 and Table 4). Reasons for achieving similar *M. spicatum* control levels at the Lake Hortonia and Burr Pond are discussed on page 47.

Treatment impacts - Native species impacts. At Lake Hortonia, over 51 percent of whole-lake sampling points remained "vegetated" by native plants at the end of the study (Table 24). At water depths <4 m, native plant cover was 80 percent in August 2001. Therefore, on both levels, native vegetated occurrences exceeded the 20- to 40-percent littoral zone level deemed optimal for healthy sport fisheries in northern tier lakes (Savino and Stein 1982; Wiley et al. 1984).

As summarized in Table 27, statistically significant reductions in August frequency of occurrence values were reported for 11 native species at Lake Hortonia following the fluridone applications. Most species that were negatively impacted were species previously reported by others (Smith and Pullman 1997;

Table 27
Summary of Changes ("-" = decrease; "+" = increase) in June and August Frequency of Occurrence Values for Aquatic Plant Species in Lake Hortonia During the 3-Year Period 1999-2001

Plant Species	Reported Fluridone Sensitivity[1,2]	June 1999 vs June 2000	August 1999 vs August 2000	June 1999 vs June 2001	August 1999 vs August 2001
Ceratophyllum demersum	S		-	-	-
Chara sp.	T		+	+	+
Elodea canadensis	S		-	-	-
Myriophyllum sibiricum	S		-	-	-
Myriophyllum spicatum	S		-	-	-
Najas flexilis	S		-		
Nymphaea odorata	I,S			-	
Potamogeton amplifolius	S			-	
Potamogeton crispus	S	+		+	+
Potamogeton gramineus	S		-		-
Potamogeton illinoensis	I,S	-	-	-	-
Potamogeton natans	S	-	-	-	-
Potamogeton praelongus	I,S		-	-	-
Potamogeton zosteriformis	I,S				-
Stukenia pectinata	S	+	-	+	
Utricularia gibba	S	-		-	-
Vallisneria Americana	I,T	-	-	-	-

[1] S = Susceptible, I = Intermediate, T = Tolerant.
[2] Sensitivity to fluridone as reported in Smith and Pullman (1997) and by SePRO Corporation, Carmel, IN.

Kenaga 1993; Welling, Crowell, and Perleberg 1997) to be sensitive to fluridone. These included *C. demersum*, *E. canadensis, M. sibiricum, N. flexilis, P. gramineus, P. illinoensis, P. natans, P. praelongus, P. zosteriformis, S. pectinata*, and *U. gibba*. Widespread and frequent pretreatment occurrences of *C. demersum* (Table 23 and Figure C2), a species reported to be very susceptible to fluridone, were reduced to a single occurrence in August 2001. Similarly, widespread pretreatment occurrences of the highly sensitive *E. canadensis* were reduced to only five points in August 2001 (Table 23 and Figure C4). The less common *M. sibiricum* was found at only two locations in August 2001, while it had occurred at nine locations in August 1999 (Figure C5). Other less common species, including *P. natans* (Figure C11), *P. praelongus* (Figure C12), *S. pectinata* (Figure C15), and *U. gibba* (Figure C17), all occurred at levels significantly below pretreatment levels during August 2001 (Table 23).

The only two species that exhibited significant increases during the study were the relatively resistant species, *Chara* spp. (Figure C3), and the exotic species *P. crispus* (Figure C10). The increase in *P. crispus* has been observed in other whole-lake fluridone treatments, and as such has been presented as a weakness in this type of *M. spicatum* control technique. However, in this case, while *P. crispus* did increase, it did not grow to nuisance levels. *Najas flexilis*, which was reduced to no occurrences during the August 2000 survey, once again occurred at pretreatment levels in August 2001 (Table 23, Figure C6). The broad-leaved pondweeds, including *P. amplifolius*, *P. illinoensis*, and *P. gramineus*, also remained widely distributed in both lakes in August 2001 (Figure C9), although at significantly reduced levels (Table 23).

As at Burr Pond, it is possible that impacts from the fluridone treatment may have been increased by observed reductions in underwater light levels (Table 20). For example, reductions in the MDOC are illustrated for several native species in Figure 27, including *Chara* spp., *E. canadensis*, *P. zosteriformis*, *V. americana*, *N. variegata*, and the broad-leaved pondweeds as a group. As for Burr Pond, this coupling of effects would help explain why *V. americana*, a species reported to be relatively tolerant of fluridone (Table 27), experienced reductions in its frequency of occurrence and MDOC. As illustrated in Figure 28, *V. americana* remained near pretreatment levels at depths less than 1.5 m, but was greatly reduced or eliminated at greater depths. Further, the maximum depth of occurrence for *V. americana* was reduced from slightly less than 6 m in 1999 to approximately 2.5 m in 2001 (Figure 27). Though *V. americana* occurrence was significantly below pretreatment levels in 2001, the species remained widely distributed within all regions of the lake (Figure C16).

Though several native species were individually shown to experience significant reductions in frequency of occurrence, native species richness values on a whole-lake basis did not exhibit significant impacts from the fluridone applications. The high species richness values reported herein for all water depth classes demonstrate that a diverse native plant community remained in existence at Lake Hortonia following the whole-lake fluridone application.

Native plant biomass levels actually increased above pretreatment levels at Lake Hortonia in August 2001 (Table 26). Though the majority of the biomass increase was contributed by *Chara* spp., summed biomass values of other native species were similar to their pretreatment levels.

Overall treatment effectiveness. At Lake Hortonia, frequency of occurrence of *M. spicatum* in August 2000 was reduced by approximately 17 percent below August 1999 levels. While this is a lower YOT reduction in *M. spicatum* frequency than reported in other studies (Getsinger et al. 2001), the fact that *M. spicatum* biomass levels were reduced by ~90 percent during the same time period indicates that the treatment was extremely effective in impacting severe damage to the target plant during the year of treatment. Further, phenological studies (Madsen 1997) aimed at determining improved control strategies for *M. spicatum* indicate that eliminating plant biomass during the latter portions of the growing season prevents the plant from storing necessary energy reserves needed for effective regrowth the following spring. Therefore, even though *M. spicatum* remained widely distributed in Lake Hortonia during August 2000,

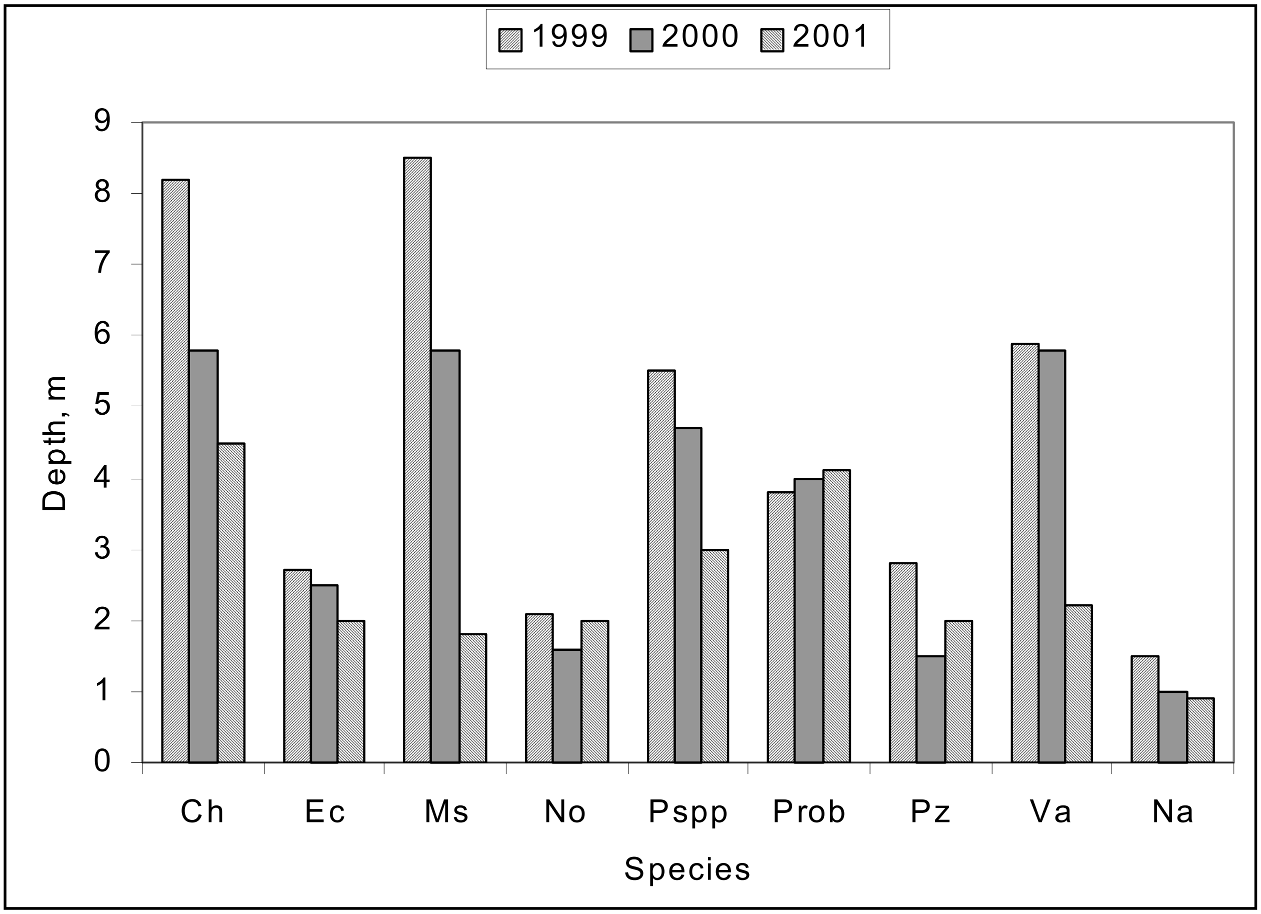

Figure 27. Maximum depth of occurrence of selected species in Lake Hortonia during August 1999, 2000, and 2001. Species codes are: Ch = *Chara* sp., Ec = *Elodea canadensis*, Ms = *Myriophyllum spicatum*, No = *Nymphaea odorata*, Pspp = broad-leaved pondweeds (*Potamogeton amplifolius, P, illinoensis*, and *P. gramineus*), Prob = *P. robbinsii*, Pz = *P. zosteriformis*, Va = *Vallisneria americana*, and Na = *Nuphar variegata*

it appeared that damage caused by the fluridone treatment was progressively lowering the plant's ability to attain problematic growth levels in 2001. This was confirmed by reductions of ~85 percent in occurrences and over 99 percent in biomass of *M. spicatum* in August 2001.

While effective control of *M. spicatum* was achieved, the widely distributed and diverse native plant community that remained at Lake Hortonia was sufficient to support a healthy sports fishery (Savino and Stein 1982; Wiley et al. 1984). Overall native plant cover at Lake Hortonia remained at ~52 percent at the end of the study. Further, species richness values on a whole-lake basis remained unchanged, as did native plant biomass levels. Individual species that experienced reductions following the fluridone treatment will likely expand within Lake Hortonia during the 2002 growing season.

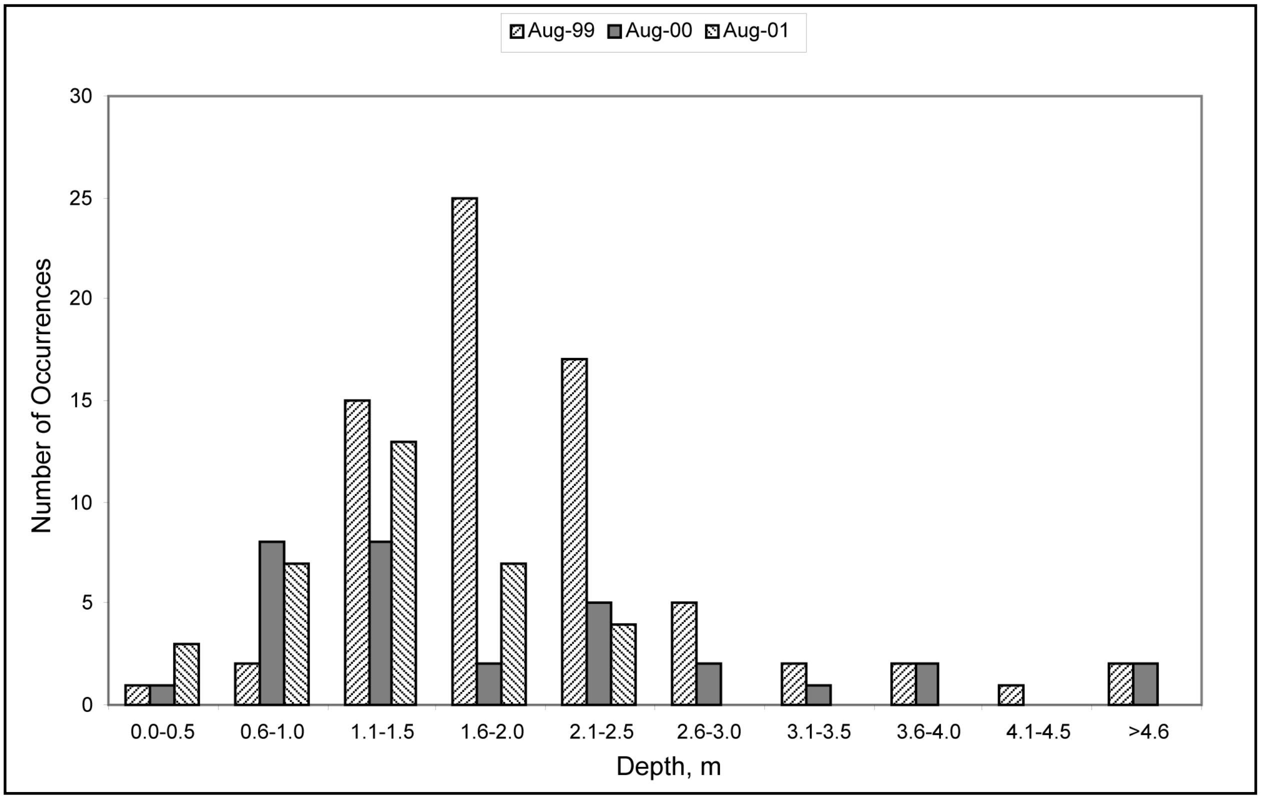

Figure 28. Frequency of occurrence of *V. americana* at different water depths in Lake Hortonia during August 1999, 2000, and 2001

Results: Lake Hortonia Wetland Transects

Cumulative species list

The cumulative species list for the Lake Hortonia wetland is at Table 28. The list includes 11 submersed species, 2 rooted and floating-leaved species, 2 floating species, and 9 emergent species. *Myriophyllum spicatum* and the emergent *Lythrum salicaria* were the only exotic species observed in the Lake Hortonia wetland.

Frequency of occurrence of individual species

The three most frequently occurring species along the Lake Hortonia wetland transect during August 1999 were the rooted, floating-leaved species, *N. odorata,* and the two submersed species, *Utricularia minor* and *U. vulgaris* (Table 29). *Myriophyllum spicatum* did not occur in any transect intervals in August 1999. The only exotic species observed in August 1999 was *L. salicaria*. Statistical analyses indicated that a significant increase in occurrence from August 1999 levels occurred during 2000 and 2001 for *N. variegata*. In fact, *N. variegata* was the second most frequent species in August 2001 transect intervals. Less significant increases also occurred in several of the less frequently collected species (i.e., less frequent in 1999) during 2000 and/or 2001. These included

Table 28
Species Observed in Wetland Adjacent to Lake Hortonia

Scientific Name	Common Name	Growth Form	Native or Exotic
Bidens cernua L.	Bur-marigold	Emergent	Native
Carex spp.	Sedge	Emergent	Native
Ceratophyllum demersum L.	Coontail	Submersed	Native
Chara spp.	Muskgrass	Submersed	Native
Cyperus spp.	Nutgrass	Emergent	Native
Eleocharis spp.	Spikerush	Emergent	Native
Epilobium glandulosum Lehm.		Emergent	Native
Hypericum spp.		Emergent	Native
Juncus pelocarpus E. Meyer	Brown-fruited rush	Submersed	Native
Lemna minor L.	Small duckweed	Floating	Native
Ludwigia palustris (L.) Elliot.	Creeping primrose	Emergent	Native
Lythrum salicaria L.	Purple loosestrife	Emergent	Exotic
Myriophyllum sibiricum Komarov	Northern milfoil	Submersed	Native
M. spicatum L.	Eurasian watermilfoil	Submersed	Exotic
Nymphaea odorata Aiton	White water lily	Floating-leaved	Native
Nuphar variegata Engelm. ex Durand	Bullhead lilly, spatterdock	Floating-leaved	Native
Potamogeton gramineus L.	Variable pondweed	Submersed	Native
P. robbinsii Oakes	Fern pondweed	Submersed	Native
Sphagnum spp.		Emergent	Native
Spirodela polyrhiza Schleiden	Giant duckweed	Floating	Native
Utricularia gibba L.	Creeping bladderwort	Submersed	Native
U. intermedia Hayne	Flat-leaf bladderwort	Submersed	Native
U. minor L.	Small bladderwort	Submersed	Native
U. vulgaris L.	Common bladderwort	Submersed	Native

M. sibiricum, *U. gibba*, *U. intermedia*, and *U. vulgaris*. While these latter three bladderwort species demonstrated increases in occurrence, *U. minor* was reported to experience significant reductions in occurrence. Other species showing less significant reductions were the floating species, *S. polyrhiza*, and the two emergents, *Bidens cernua* and an unidentified *Eleocharis* species. The fact that fluridone-sensitive species (e.g., *M. sibiricum* and *U. gibba*) showed significant increases in abundance in posttreatment surveys suggests that observed changes were not the result of direct herbicide injury.

Species richness data

Mean numbers of exotic, native, and total plant species occurring within 1-m intervals along the wetland transect sampled in Lake Hortonia for the August

Table 29
Lake Hortonia Wetland Transect Frequency of Occurrence Values and Chi² Summary Statistics for Comparisons Between 1999 and 2000 and 1999 and 2001. A "▼" Denotes a Significant Decrease; A "▲" Denotes a Significant Increase

	Frequency Values			1999 versus 2000		1999 versus 2001	
Plant Species	August 1999	August 2000	August 2001	Chi^2 Value	Prob > Chi^2	Chi^2 Value	Prob > Chi^2
Submersed Species							
Ceratophyllum demersum	2	0	0	2.01	0.156	2.01	0.156
Chara spp.	1	0	1	1.00	0.317	0.00	1.000
Juncas pelocarpus	0	5	0	5.06	0.025 ▲	0.00	1.000
Myriophyllum sibiricum	0	3	14	3.02	0.082	14.49	0.000 ▲
Myriophyllum spicatum	0	1	1	1.00	0.317	1.00	0.317
Potamogeton gramineus	2	0	0	2.01	0.156	2.01	0.156
Potamogeton robbinsii	1	0	6	1.00	0.317	3.63	0.057
Utricularia gibba	22	74	102	36.78	0.000 ▲	73.99	0.000 ▲
Utricularia intermedia	0	27	0	28.9	0.000 ▲	0.00	1.000
Utricularia minor	101	55	3	21.89	0.000 ▼	123.73	0.000 ▼
Utricularia vulgaris	56	136	83	62.69	0.000 ▼	7.93	0.005 ▲
Floating and Floating-Leaved Species							
Lemna minor	3	0	0	3.02	0.082	3.02	0.082
Nymphaea odorata	190	198	196	3.07	0.079	1.59	0.207
Nuphar variegata	15	98	107	84.16	0.000 ▲	98.77	0.000 ▲
Spirodela polyrhiza	4	0	0	4.04	0.044 ▼	4.04	0.044 ▼
Emergent Species							
Bidens cernua	4	0	0	4.04	0.044 ▼	4.04	0.044 ▼
Carex spp.	0	2	0	2.01	0.156	0.00	1.000
Cyperus spp.	1	0	0	1.0	0.317	1.0	0.317
Eleocharis spp.	14	0	0	14.49	0.000 ▼	14.49	0.000 ▼
Epilobium glandulosum	2	0	0	2.01	0.156	2.01	0.156
Hypercium spp.	2	0	0	2.01	0.156	2.01	0.156
Ludwigia palustrus	2	0	0	2.01	0.156	2.01	0.156
Lythrum salicaria	3	3	0	0.00	1.000	3.02	0.082
Sphagnum spp.	2	0	0	2.01	0.156	2.01	0.156

1999, August 2000, and August 2001 surveys are illustrated in Figure 29. Native species outnumbered exotic species within the transect sampling intervals on all three sampling dates. Mean native species richness numbers showed a significant increase from 2.12 in August 1999 to 2.99 in August 2000. In August 2001, native species richness values had declined and were again at a level similar to the August 1999 pretreatment levels. Because of the rare occurrence of exotic

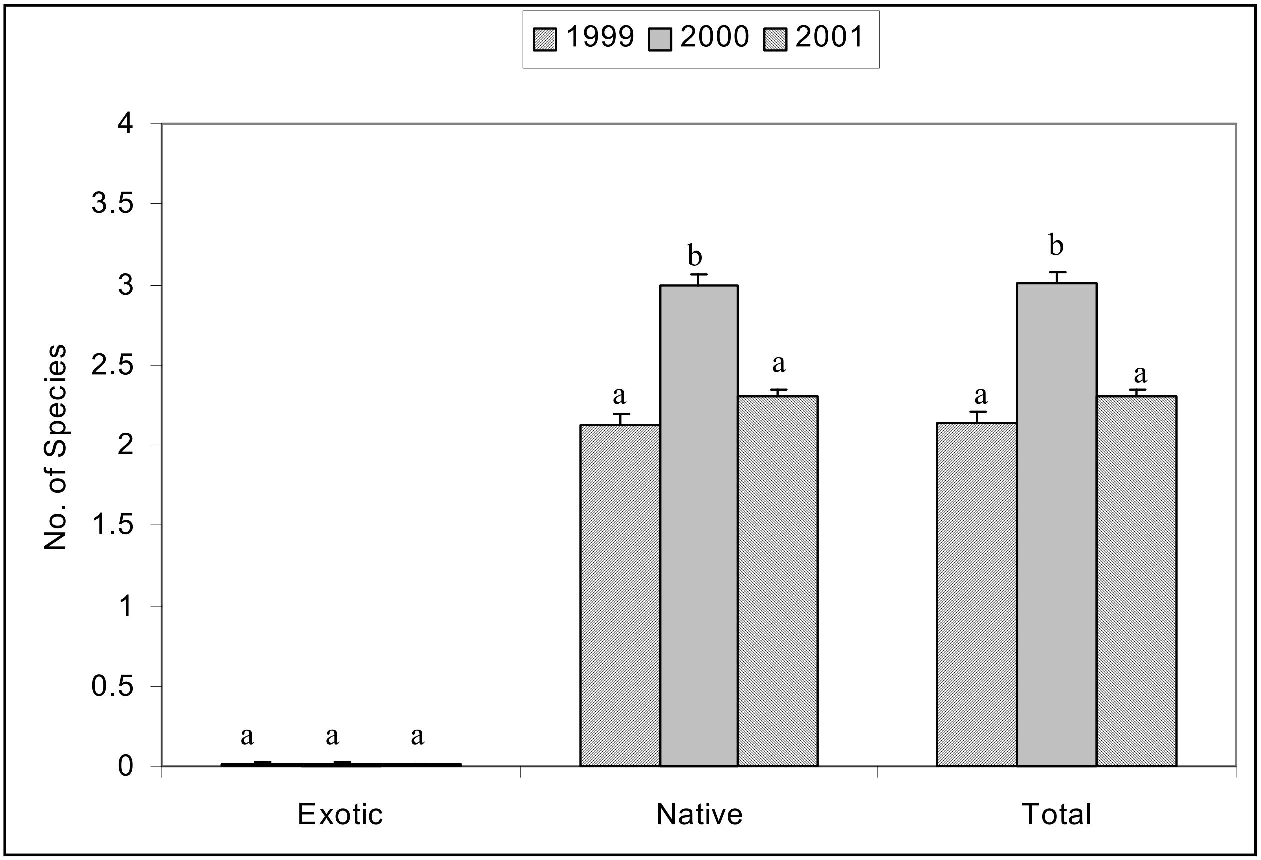

Figure 29. Mean numbers of exotic, native, and total plant species within 1-m sampling intervals along the Lake Hortonia wetland transect during August 1999, 2000, and 2001

species within the transect intervals (Figure 29), total species richness values were almost identical to native species richness values.

Discussion - Lake Hortonia wetland transect studies

The open-lake fluridone application in Lake Hortonia did not cause significant impacts to the aquatic plant community in the adjacent wetland area. As in the Burr Pond wetland area, several species occurring in the Lake Hortonia wetland area are reported to be sensitive to fluridone and may have been impacted if the herbicide applications had been made directly into this area. However, several species occurring in the wetland area are relatively tolerant of fluridone, and these species would probably withstand higher levels of exposure if future *M. spicatum* control plans include direct application of fluridone into the wetland areas. This may especially be a consideration at Lake Hortonia because *M. spicatum* was sampled within the wetland area. Also, by restricting application of fluridone in areas immediately to the south of the wetland area, several areas infested with *M. spicatum* were left with minimal exposure to fluridone. Our findings indicate that *M. spicatum* is quickly rebounding in this and similarly treated wetland areas (see page 66 and Figure C1).

4 Conclusions and Recommendations

Conclusions

Based on the results of this investigation, the following conclusions can be drawn when using prescription, low-dose, whole-lake fluridone application techniques:

a. Acceptable control of *M. spicatum* (20- to 30-percent reduction in frequency, but ~90-percent reduction of biomass) can be achieved in the year-of-treatment, while good control (~85-percent reduction in frequency; >96-percent reduction of biomass) can be achieved by 1-year posttreatment. Moreover, recovery of *M. spicatum* to pretreatment nuisance levels by 2 years posttreatment seems unlikely.

b. Overall cover, species richness, and biomass of native plants can be maintained at levels supportive of good fish and wildlife habitat (i.e., 20- to 40-percent littoral zone vegetative cover).

c. Establishment of treatment buffer zones will prevent fluridone-induced injury to plant communities in adjacent wetlands. However, *M. spicatum* infestations are likely to remain in both the untreated wetlands and the buffer zones, serving as sites for potential reinfestation of treated areas in future years.

d. Documentation of water temperature profiles immediately prior to treatment is a necessary part of a reliable precision fluridone application technique. If these profiles are not considered, initial target fluridone concentrations may not be achieved. In addition, this temperature information may also be used to better correlate the growth activity of *M. spicatum* with its susceptibility to fluridone and timing of application. Likewise, inaccurate lake bathymetry may result in erroneous water volume calculations, critical to achieving initial target fluridone concentrations.

Recommendations

Based on the results of this investigation, the following recommendations are provided:

a. Since thermoclines affect the accuracy of water volume calculations used for precision fluridone application techniques, profiles of water temperature should be measured in the lake within 48 hr of such treatments.

b. Since bathymetric measurements affect the accuracy of water volume calculations used for precision fluridone application techniques, depth measurement devices, such as fathometers, should be properly calibrated to allow accurate detection of the bottom.

c. To prevent the potential reinfestation of *M. spicatum* following a low-dose fluridone whole-lake application, waters adjacent to wetland areas should be included in the treatment process.

d. To better understand the extended effects of whole-lake fluridone treatments, assessment of plant communities should be conducted for at least 2 years posttreatment.

e. To select the most efficacious herbicide rates for precision whole-lake applications, dose/response effects of fluridone should be correlated to pretreatment *M. spicatum* growth activity.

f. Evaluations are needed to allow correlation of fluridone dose/response effects with plant growth activity and associated factors, such as temperature and light. Linking these relationships to timing of whole-lake treatments will maximize control of *M. spicatum* while minimizing injury to nontarget vegetation.

g. In order to provide consistent, precise, and selective control of *M. spicatum* using low doses of fluridone on a whole-lake basis, factors such as accurate lake bathymetry, pretreatment thermocline information, rapid posttreatment water residue analysis, bioassays that monitor plant injury, and fluridone dose/response relationships must be used in concert and in a knowledgeable fashion, with maximum site-specific flexibility.

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Appendix A
Bathymetric Assessment of Lake Hortonia and Burr Pond, Vermont[1]

[1] This appendix was prepared by ReMetrix for the U.S. Army Corps of Engineers.

Bathymetric Assessment Of Lake Hortonia and Burr Pond, Vermont

Report prepared for the
United States Army Corps of Engineers

June 30, 2000

Bathymetric Assessment of Lake Hortonia and Burr Pond, Vermont

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Tables

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Introduction

Water volume information on large lake systems is often incomplete or dated. Much of the government work to develop accurate bathymetry in lake systems around the US was performed in the 1970's or earlier. Lakes are dynamic systems and can change dramatically over time. Since the lake is the lowest point on the watershed, eroded soils are transported and deposited in lakes over time. Excessive amounts of aquatic vegetation can also contribute to the buildup of organic sediments on the lake bottom over time. Treatment assumptions made using outdated water volume information can significantly affect the results obtained.

In 2000, the resource agencies tasked with managing Lake Hortonia and Burr Pond identified a need to update the water volume information for these two water bodies. In an effort to better understand the bathymetry and water volumes of these lakes, the US Army Corps of Engineers retained ReMetrix to develop a current understanding of the water volumes present in the system. This information is vital for developing treatment recommendations for managing Eurasian water milfoil (*Myriophyllum spicatum*) in these lakes.

Methods

Project activities included two components: data acquisition and data assembly/ interpretation. Bathymetry data were collected on the water using the technologies described below. Aerial imagery was acquired to cover the project area. Image processing and data analyses were performed in ReMetrix's Carmel, IN facility.

Field Work in Rutland County

On receipt of permission to commence work on this project, ReMetrix staff made arrangements to acquire the necessary survey boats for the mission.

The primary data collection tool used for this mission was a Trimble Pathfinder PRO submeter Global Position System (GPS) receiver. The GPS system includes a constellation of 24 US Department of Defense Satellites that transmit signals that can be used by a GPS receiver to determine its exact position, altitude, heading and velocity. The primary mission of the Global Positioning System is to provide this type of information in real time to our military for defense purposes. The Global Positioning System was licensed for civilian use in the early 1990's.

Though full GPS signal accuracy was available during the field work for this project, ReMetrix also employed a methodology called Differential GPS that allows high-end systems to more accurately fix a location to within approximately one foot. Differential GPS relies on the use of two receivers working at the same time. The first receiver is a base station. The base station is set up at a known point. It is programmed with its exact location. As it collects GPS signals during the day, it compares the results with the known location of the station and builds a correction file. The field unit is called the Rover. This GPS system is used at the project location to store the locations of features that the team is mapping. At the end of each day, the Rover data files and the base station data files are downloaded and computer software routines are used to combine the two files and correct the field data to a high degree of accuracy. For this project, ReMetrix accessed a community base station in central Vermont recognized by the National Geodetic Survey.

The rover unit has an attribute data logger that is used to attach information for the project to the location where the information is collected. For this project, a data dictionary was created for water-depth attributes. An attribute was created for each one-foot contour level the crew found in the water bodies.

Field maps were created for each of the lakes. These maps were developed to show the location of each of the transects that the vessel would follow to collect the depth information that would be used to develop bathymetric coverages. The crew mobilized to the field each day and implemented the protocol for data collection.

Each day the field crew established the boat along each transect, and traveled slowly down the transect recording the depths under the vessel. The operator selected the starting depth attribute on the GPS data logger and marked that contour. The vessel then traveled along the transect until the next one-foot drop in the bottom occurred, and the GPS data logger recorded that location with the depth attribute attached.

A Garmin GPS unit was used to maintain a heading on the longer transects where the boat operation would otherwise be subject to drift off line without navigational assistance. The Garmin unit was also used to move to the next transect line when one line was completed, so that transect lines were properly spaced.

At the end of each day, the GPS data logger was downloaded into a PC laptop computer. The base station correction files were also downloaded. The two files were used to perform differential correction and the data could then be displayed as an overlay on the project maps maintained in our Carmel, IN lab. All of the data was backed up and transmitted via e-mail to the Carmel lab for processing.

When all of the transects for each lake were completed, the point overlays were reviewed and it was determined whether additional transects would improve the coverage of the lake. By displaying the collected points over a map of each lake, areas could be identified where additional data points could improve accuracy. This work was also part of the quality-assurance methodology for this project.

Data and Imagery Processing

Once all of the field data were assembled, work began in the Carmel lab to develop the end product for this mission. In order to accurately display this information and analyze key features like shorelines, remotely sensed imagery was acquired. The objective was to utilize aerial photography to supplement ground mapping efforts and provide additional relevant information about the lake system and conditions. The imagery also serves as the background for the figures in this report. The imagery was acquired from existing archives at the United States Geological Survey and dates from 1993 and 1994.

The next step in this process involved merging the GPS data and interpreting the information for the final report.

All of the GPS points were brought into the image processing and mapping software, given a common projection and then displayed as a layer over the top of each lake's image. As each GPS point had an attached depth attribute, the image processing group would select three-foot depth intervals one at a time and create a contour line connecting those points. This step was performed for each depth attribute until the bathymetry for each lake was completed.

The results of the bathymetric analyses were used to create a table of the water volume in each system. These calculations were made by measuring the surface area of the upper and lower polygons for each contour level in each lake and averaging them. This provided an accurate number of acre-feet of water in each contour "slice" of the lake. A table was created for each lake showing the volume of water in each contour and a cumulative water volume (included in the next section of the report).

All of the maps included in this report can be found in the Appendix.

Results and Discussion

The primary objective of this project was to develop accurate bathymetry and water volume information for Lake Hortonia and Burr Pond. This information is necessary to support the application of aquatic herbicides.

As the volume statistics for the contour intervals were calculated, it became apparent that the basin morphology of Lake Hortonia creates a unique situation for predicting concentrations of aquatic herbicide treatments. Over 90% of the water volume of Lake Hortonia is in the northeastern basin. Upon further investigation, it was determined that, from a treatment standpoint, there are six distinct basins within the lake (Figure 2, Appendix).

In order to better plan the treatments so that they achieve the desired target concentrations, rounded volume calculations were performed for each of the six basins. From this information, application rates can be fine-tuned to an unprecedented level of accuracy. A summary of the calculations for this approach is shown in the table below.

The volume for each basin in Lake Hortonia is presented on the following pages. Because of its simpler morphology, Burr Pond is calculated as one basin. The first table for each basin contains the water volume at three-foot contour intervals and the cumulative volume of each incremental depth.

Thermoclines can become established at various depths throughout Lake Hortonia, and the exact depth of the thermocline can vary seasonally and from year to year in many lakes. Thus, the second table for each basin provides data for future determination of water volume above potential thermocline depths, not just the thermocline depth at the time of this study.

The third table for each basin shows average and median depths for each division of the lake.

Summary of Water Volumes for Individual Basins in Lake Hortonia

Description	Volume (acre-feet)
Entire Lake Hortonia	**9,673**
Basin 1	7,224
Basin 1A	161
Basin 2	702
Basin 3	1,061
Basin 3A	382
Basin 3B	107

*(*Individual basin calculations were rounded and do not exactly total 9,673 acre-feet.)*

Lake Hortonia (Entire Lake)
Water Volume Tables

Contour	Volume of Contour (acre-feet)	Cumulative Volume (acre-feet)
Surface to 3 Foot	1475.5	1475.5
3 Foot to 6 Foot	1281.0	2756.5
6 Foot to 9 Foot	1015.9	3772.4
9 Foot to 12 Foot	811.5	4584.0
12 Foot to 15 Foot	655.0	5238.9
15 Foot to 18 Foot	532.2	5771.1
18 Foot to 21 Foot	463.8	6234.9
21 Foot to 24 Foot	438.2	6673.2
24 Foot to 27 Foot	417.2	7090.4
27 Foot to 30 Foot	402.0	7492.4
30 Foot to 33 Foot	382.0	7874.4
33 Foot to 36 Foot	358.1	8232.6
36 Foot to 39 Foot	337.7	8570.3
39 Foot to 42 Foot	295.9	8866.1
42 Foot to 45 Foot	241.9	9108.1
45 Foot to 48 Foot	189.2	9297.3
48 Foot to 51 Foot	144.0	9441.3
51 Foot to 54 Foot	107.6	9549.0
54 Foot to 57 Foot	74.4	9623.3
57 Foot to 60 Foot	49.9	9673.2

Thermocline Calculations	Volume (acre-feet)
Total Volume above 3-feet	1,476
Total Volume above 6-feet	2,757
Total Volume above 9-feet	3,772
Total Volume above 12-feet	4,584
Total Volume above 15-feet	5,239
Total Volume above 18-feet	5,771
Total Volume above 21-feet	6,235

Entire Lake	
Average Depth	19.0 feet
Median Depth	9.4 feet

Lake Hortonia, Basin 1
Water Volume Tables

Contour	Volume of Contour (acre-feet)	Cumulative Volume (acre-feet)
Surface to 3 Foot	699.1	699.1
3 Foot to 6 Foot	626.5	1325.6
6 Foot to 9 Foot	574.2	1899.8
9 Foot to 12 Foot	532.2	2431.9
12 Foot to 15 Foot	480.5	2912.4
15 Foot to 18 Foot	449.4	3361.9
18 Foot to 21 Foot	436.7	3798.6
21 Foot to 24 Foot	427.6	4226.2
24 Foot to 27 Foot	414.5	4640.7
27 Foot to 30 Foot	402.0	5042.7
30 Foot to 33 Foot	382.0	5424.7
33 Foot to 36 Foot	358.1	5782.9
36 Foot to 39 Foot	337.7	6120.6
39 Foot to 42 Foot	295.9	6416.5
42 Foot to 45 Foot	241.9	6658.4
45 Foot to 48 Foot	189.2	6847.6
48 Foot to 51 Foot	144.0	6991.7
51 Foot to 54 Foot	107.6	7099.3
54 Foot to 57 Foot	74.4	7173.7
57 Foot to 60 Foot	49.9	7223.5

Thermocline Calculations	Volume (acre-feet)
Total Volume above 3-feet	699
Total Volume above 6-feet	1326
Total Volume above 9-feet	1900
Total Volume above 12-feet	2432
Total Volume above 15-feet	2912
Total Volume above 18-feet	3362
Total Volume above 21-feet	3799
Total Volume above 24-feet	4226

Basin 1	
Average Depth	29.6 feet
Median Depth	17.6 feet

Lake Hortonia, Basin 1A
Water Volume Tables

Contour	Volume of Contour (acre-feet)	Cumulative Volume (acre-feet)
Surface to 3 Foot	74.8	74.8
3 Foot to 6 Foot	54.1	128.9
6 Foot to 9 Foot	22.1	151.0
9 Foot to 12 Foot	5.6	156.6
12 Foot to 15 Foot	2.3	158.9
15 Foot to 18 Foot	1.2	160.1
18 Foot to 21 Foot	0.5	160.6
21 Foot	0.2	160.8

Thermocline Calculations	Volume (acre-feet)
Total Volume above 3-feet	75
Total Volume above 6-feet	129
Total Volume above 9-feet	151
Total Volume above 12-feet	157
Total Volume above 15-feet	159
Total Volume above 18-feet	160
Total Volume above 21-feet	161

Basin 1A	
Average Depth	6.3 feet
Median Depth	3.3 feet

Lake Hortonia, Basin 2
Water Volume Tables

Contour	Volume of Contour (acre-feet)	Cumulative Volume (acre-feet)
Surface to 3 Foot	159.8	159.8
3 Foot to 6 Foot	153.4	313.3
6 Foot to 9 Foot	136.2	449.5
9 Foot to 12 Foot	100.6	550.1
12 Foot to 15 Foot	68.4	618.5
15 Foot to 18 Foot	46.3	664.8
18 Foot to 21 Foot	26.6	691.4
21 Foot to 24 Foot	10.5	701.9

Thermocline Calculations	Volume (acre-feet)
Total Volume above 3-feet	160
Total Volume above 6-feet	313
Total Volume above 9-feet	450
Total Volume above 12-feet	550
Total Volume above 15-feet	619
Total Volume above 18-feet	665
Total Volume above 21-feet	691

Basin 2	
Average Depth	12.7 feet
Median Depth	4.5 feet

Lake Hortonia, Basin 3
Water Volume Tables

Contour	Volume of Contour (acre-feet)	Cumulative Volume (acre-feet)
Surface to 3 Foot	277.7	277.7
3 Foot to 6 Foot	274.4	552.0
6 Foot to 9 Foot	235.6	787.6
9 Foot to 12 Foot	169.2	956.9
12 Foot to 15 Foot	103.7	1060.6

Thermocline Calculations	Volume (acre-feet)
Total Volume above 3-feet	278
Total Volume above 6-feet	552
Total Volume above 9-feet	788
Total Volume above 12-feet	957
Total Volume above 15-feet	1061

Basin 3	
Average Depth	11.5 feet
Median Depth	5.8 feet

Lake Hortonia, Basin 3A
Water Volume Tables

Contour	Volume of Contour (acre-feet)	Cumulative Volume (acre-feet)
Surface to 3 Foot	214.8	214.8
3 Foot to 6 Foot	131.9	346.7
6 Foot to 9 Foot	31.0	377.7
9 Foot to 12 Foot	3.9	381.7

Thermocline Calculations	Volume (acre-feet)
Total Volume above 3-feet	215
Total Volume above 6-feet	347
Total Volume above 9-feet	378
Total Volume above 12-feet	382

Basin 3A	
Average Depth	5.2 feet
Median Depth	2.3 feet

Lake Hortonia, Basin 3B
Water Volume Tables

Contour	Volume of Contour (acre-feet)	Cumulative Volume (acre-feet)
Surface to 3 Foot	49.3	49.3
3 Foot to 6 Foot	40.8	90.1
6 Foot to 9 Foot	16.8	106.8

Thermocline Calculations	Volume (acre-feet)
Total Volume above 3-feet	49
Total Volume above 6-feet	90
Total Volume above 9-feet	107

Basin 3B	
Average Depth	6.3 feet
Median Depth	3.1 feet

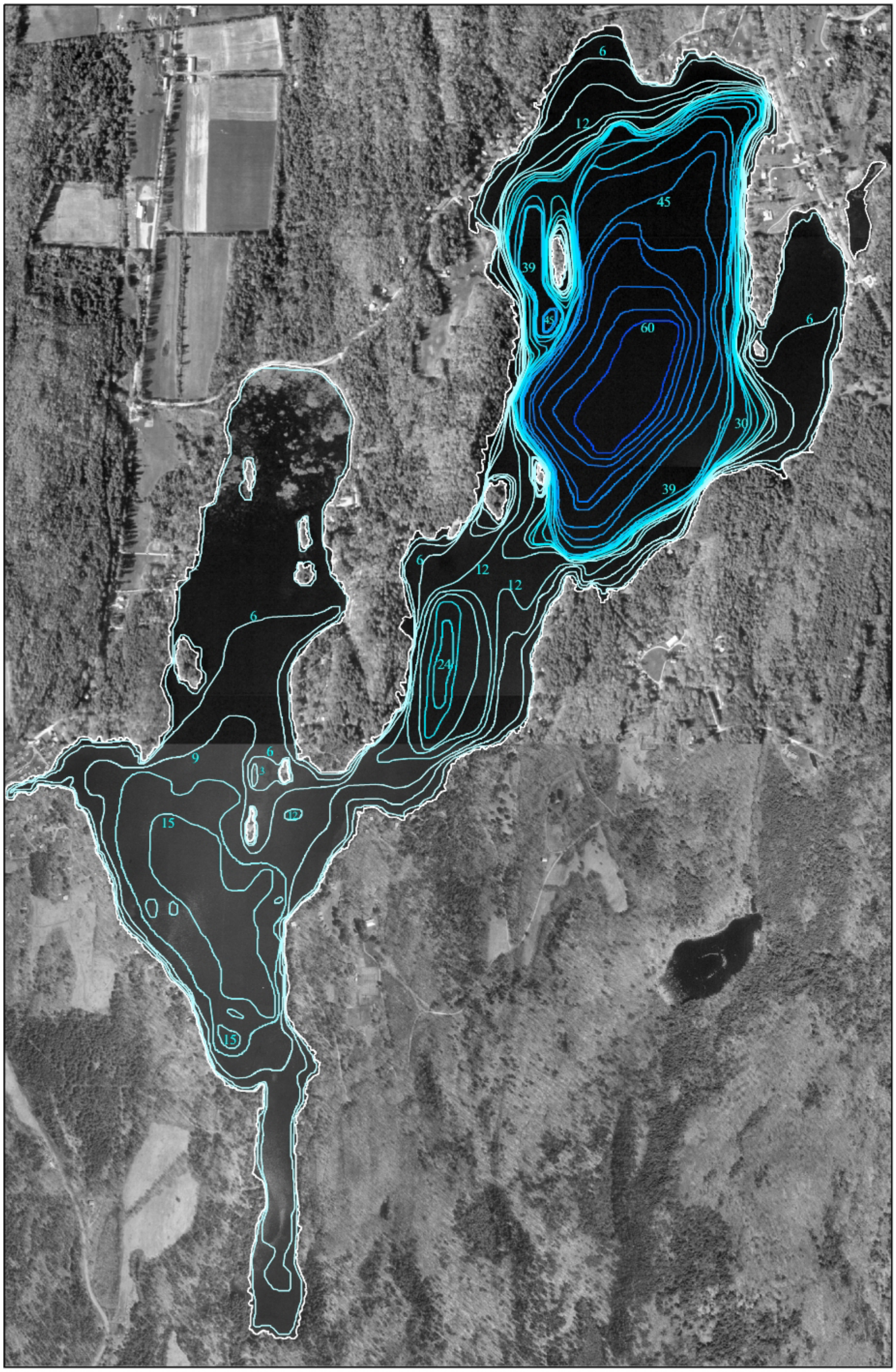
Burr Pond
Water Volume Tables

Contour	Volume of Contour (acre-feet)	Cumulative Volume (acre-feet)
Surface to 3 Foot	249.5	249.5
3 Foot to 6 Foot	230.4	479.9
6 Foot to 9 Foot	193.8	673.7
9 Foot to 12 Foot	162.1	835.8
12 Foot to 15 Foot	142.5	978.3
15 Foot to 18 Foot	115.8	1094.1
18 Foot to 21 Foot	76.8	1170.9
21 Foot to 24 Foot	35.9	1206.8
24 Foot to 27 Foot	9.5	1216.3
27 Foot to 30 Foot	0.2	1216.5

Thermocline Calculations	Volume (acre-feet)
Total Volume above 3-feet	249
Total Volume above 6-feet	480
Total Volume above 9-feet	674
Total Volume above 12-feet	836
Total Volume above 15-feet	978
Total Volume above 18-feet	1,094
Total Volume above 21-feet	1,171

Burr Pond	
Average Depth	14.4 feet
Median Depth	5.0 feet

Appendix



Legend: 3-foot contour intervals

shoreline	30' - 39' depth
1' - 9' depth	40' - 49' depth
10' - 19' depth	50' - 59' depth
20' - 29' depth	60' depth

Scale 1:10,000

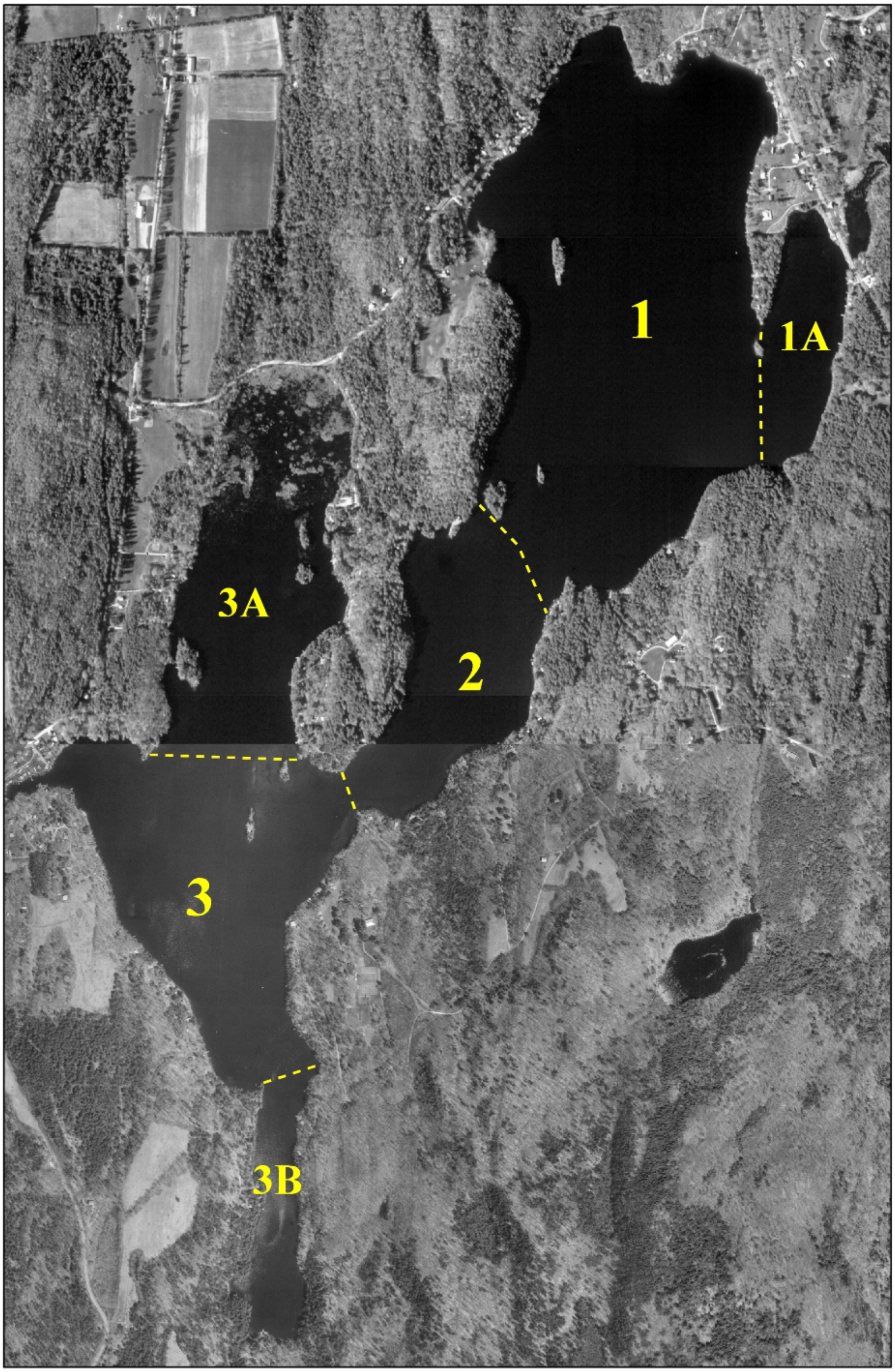
N W E S

0 1000 2000
Feet

Base Image (Top): USGS Digital Ortho Quad (May 8, 1993)
Base Image (Bottom): USGS Digital Ortho Quad (May 3, 1994)

Lake Hortonia Bathymetry

Project 1102	Date: 5/2000	Figure 1



Legend:

1A - basin identification number, corresponding to the individual basin calculations in the report

Scale 1:10,000

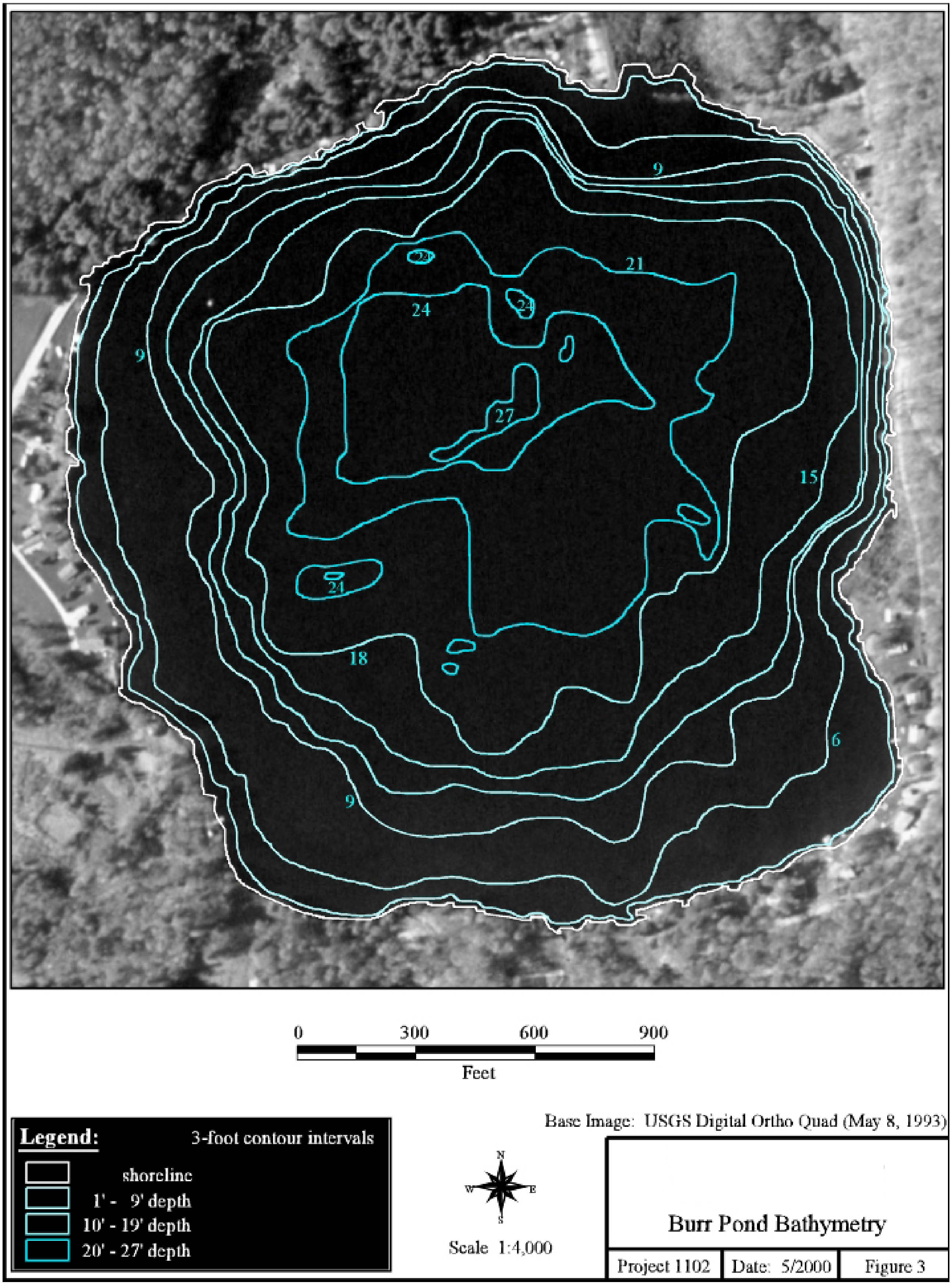
0 1000 2000

Feet

Base Image (Top): USGS Digital Ortho Quad (May 8, 1993)
Base Image (Bottom): USGS Digital Ortho Quad (May 3, 1994)

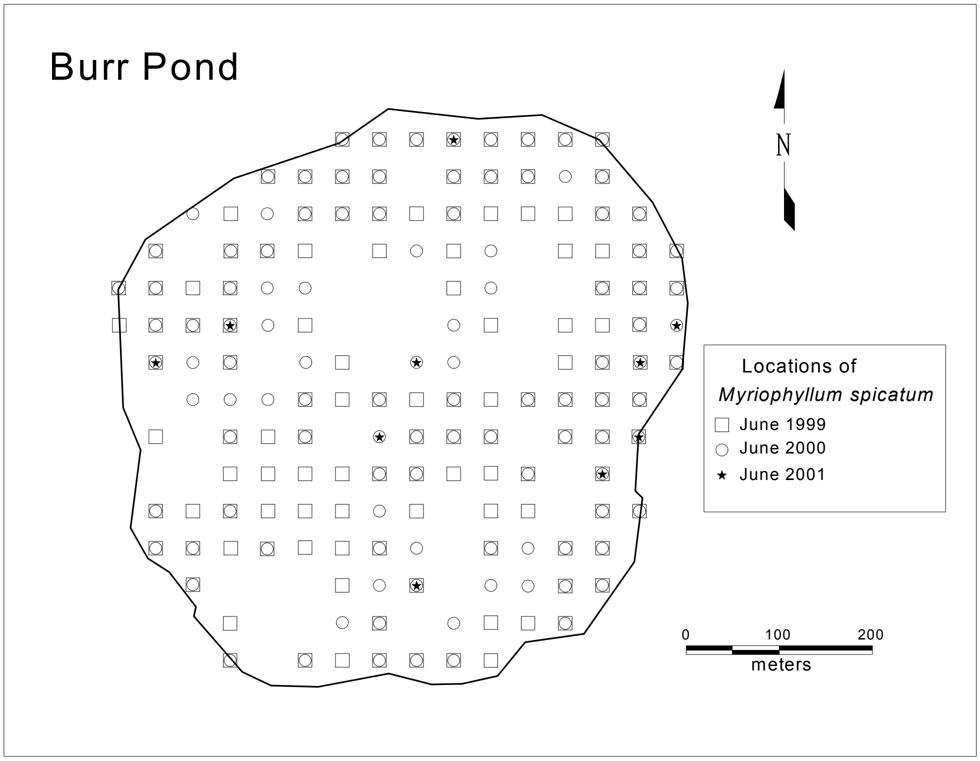
Lake Hortonia Basin Map

Project 1102	Date: 5/2000	Figure 2

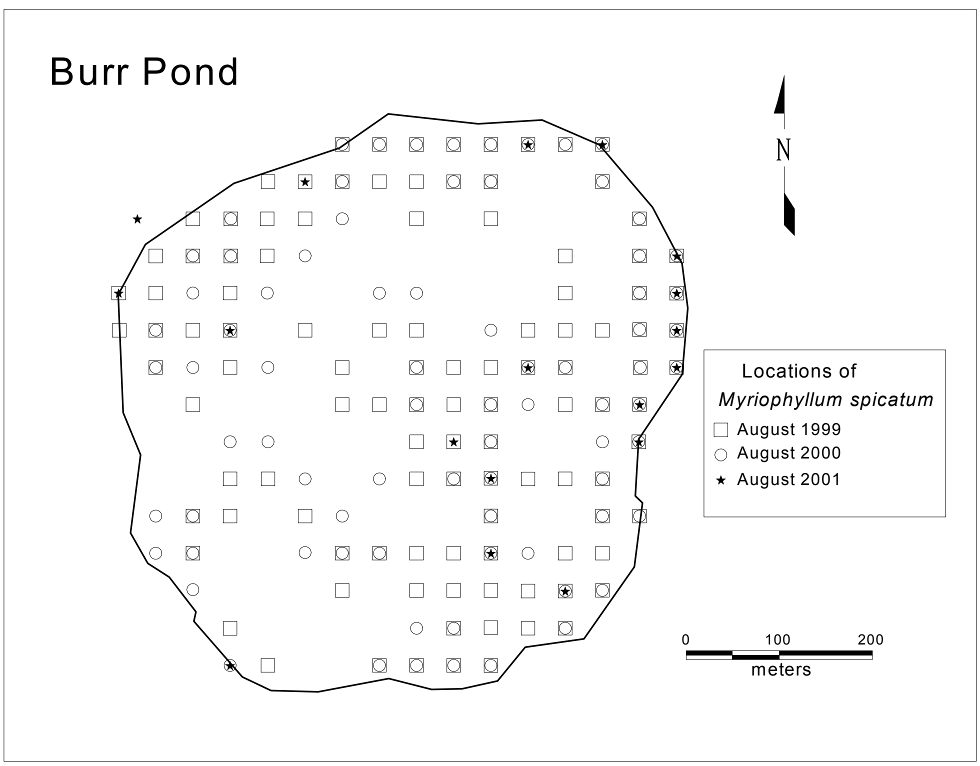


9
21
24
24
24
27
15
9
24
18
6
9
0
300
600
900
Feet
Base Image: USGS Digital Ortho Quad (May 8, 1993)
Legend:
3-foot contour intervals
shoreline
1' - 9' depth
10' - 19' depth
20' - 27' depth
N
W
E
S
Scale 1:4,000
Burr Pond Bathymetry
Project 1102
Date: 5/2000
Figure 3

Appendix B
Burr Pond Plant Distribution Maps

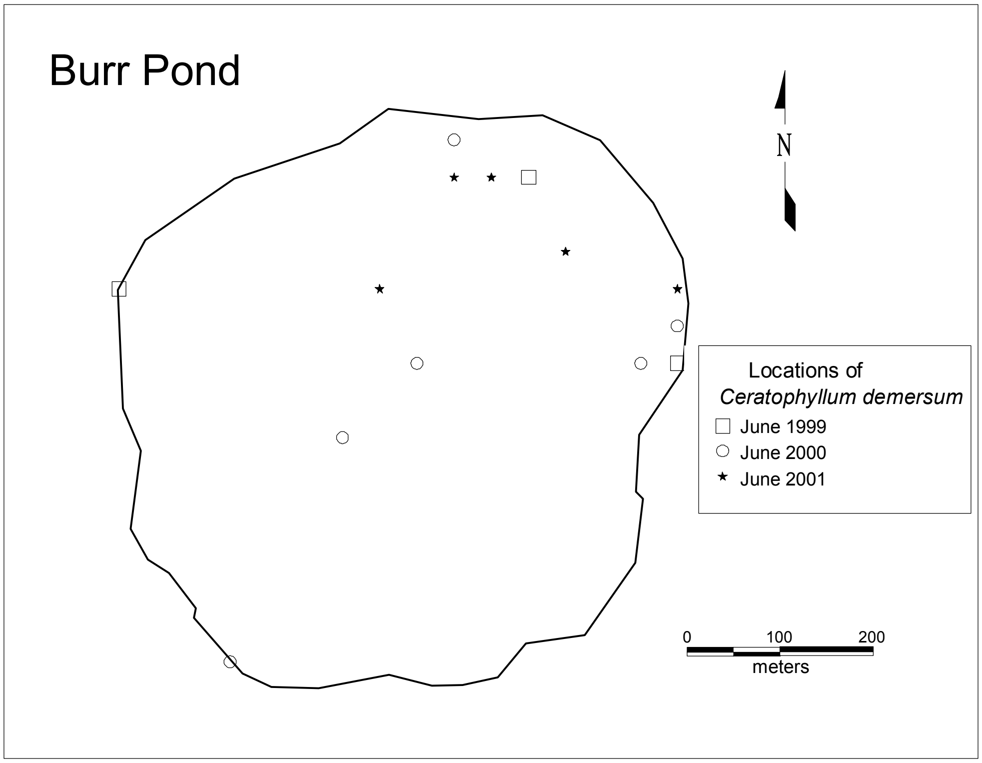


a) June Surveys

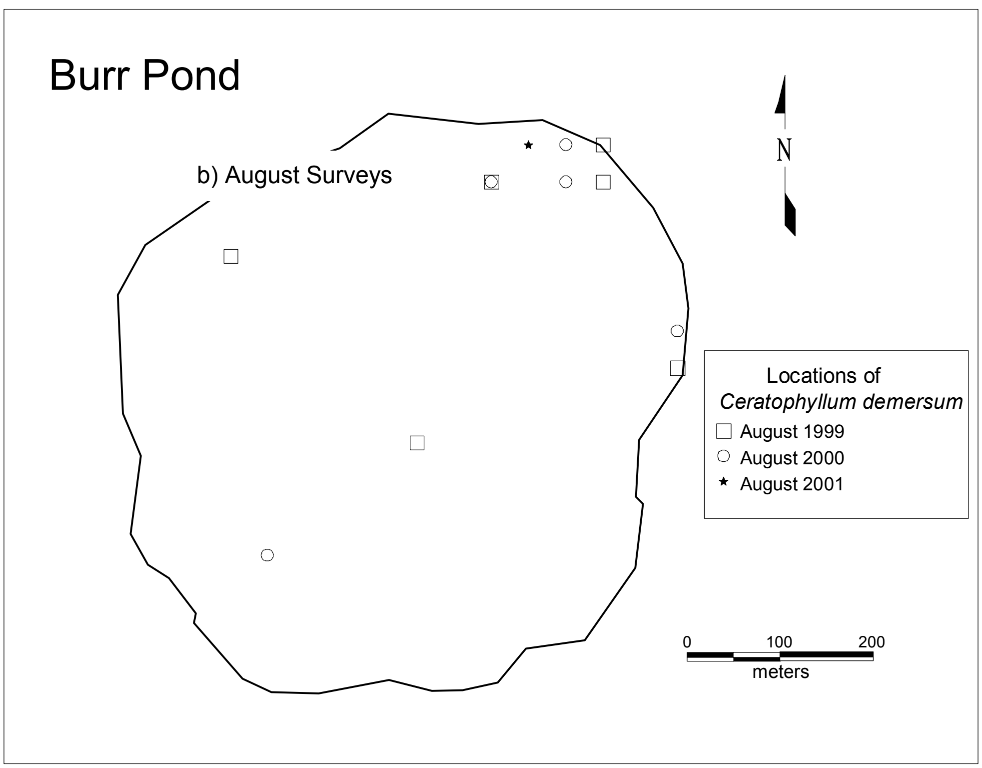


b) August Surveys

Figure B1. Map illustrating Burr Pond locations where *Myriophyllum spicatum* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001

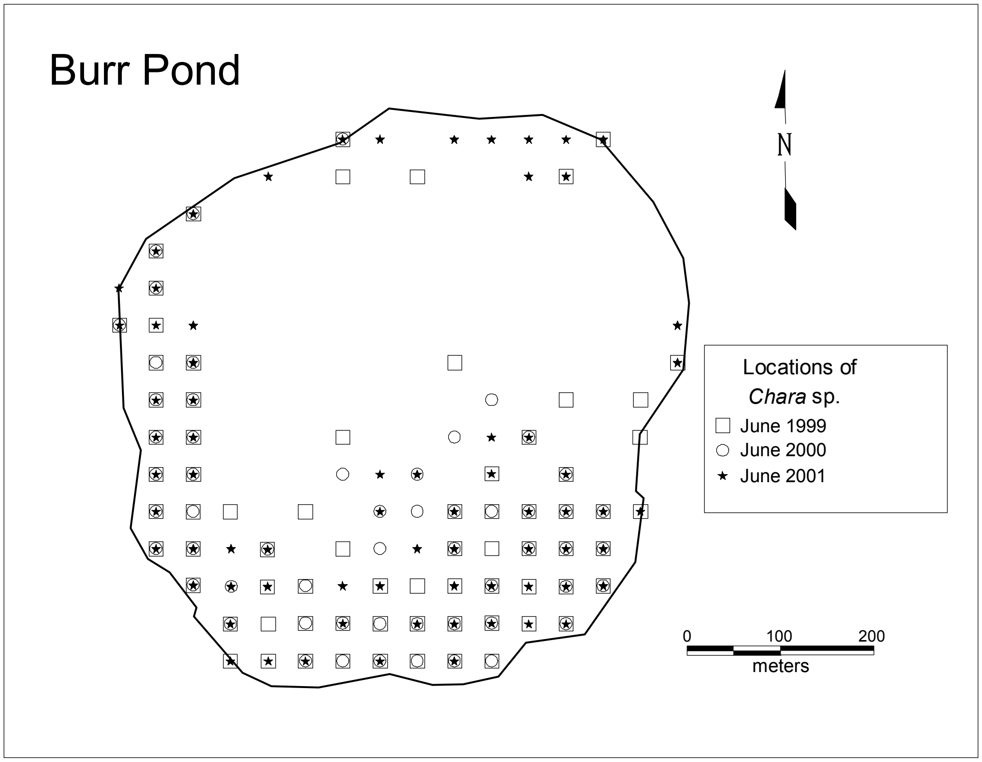


a) June Surveys



b) August Surveys

Figure B2. Map illustrating Burr Pond locations where *Ceratophyllum spicatum* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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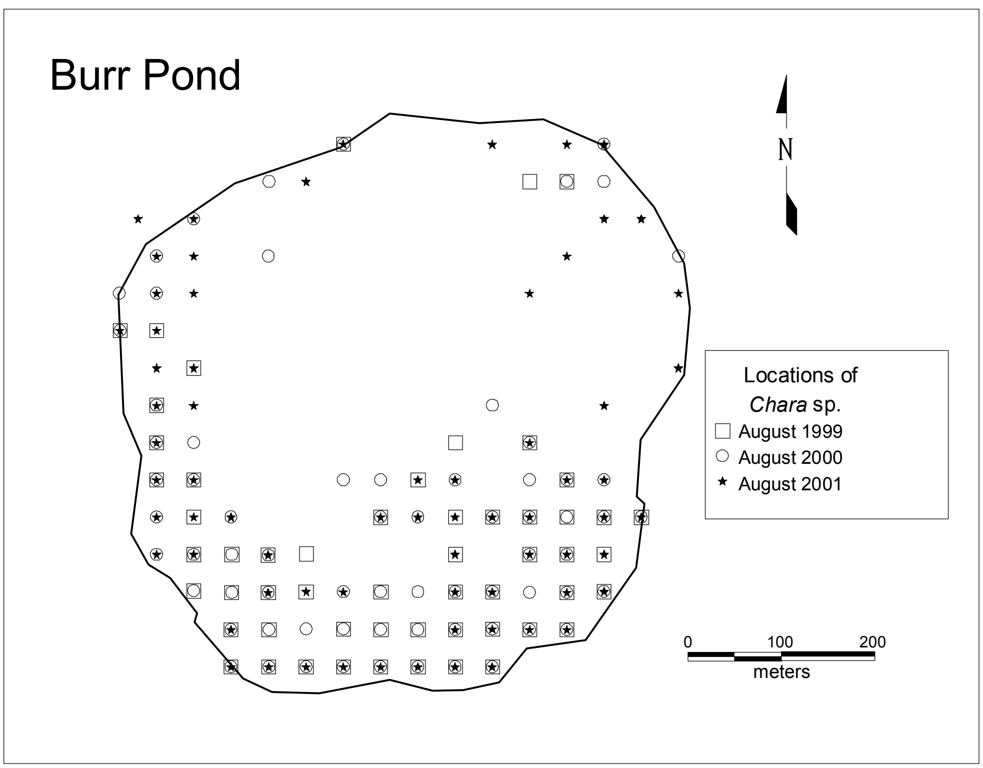
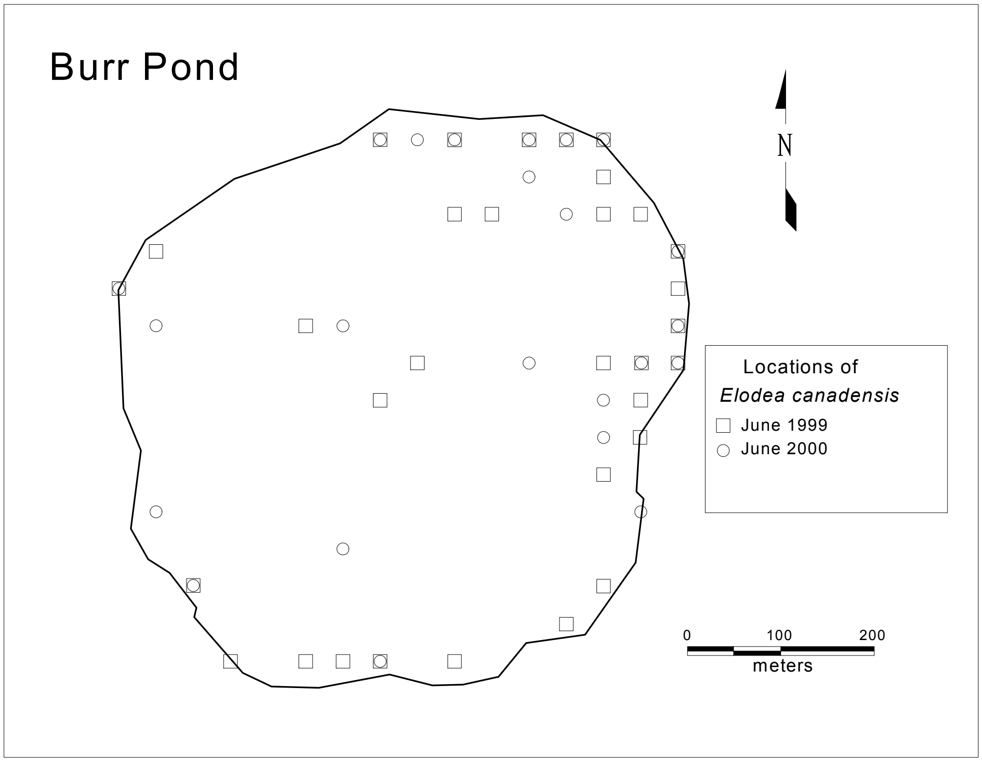
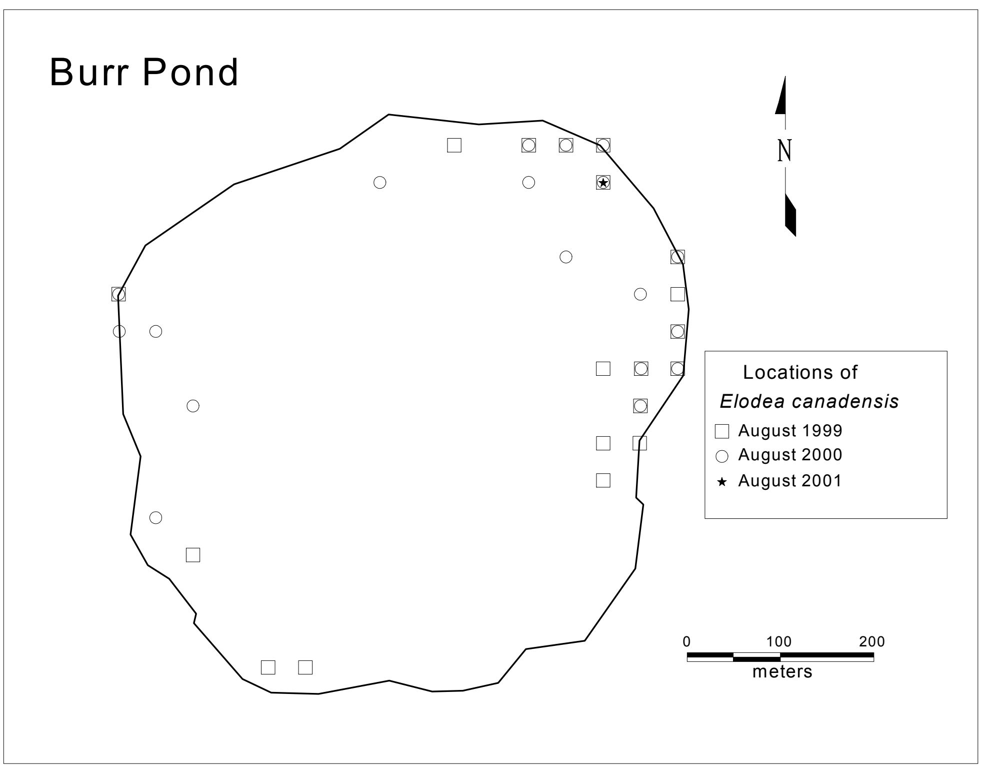


b) August Surveys

Figure B3. Map illustrating Burr Pond locations where *Chara* sp. was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001

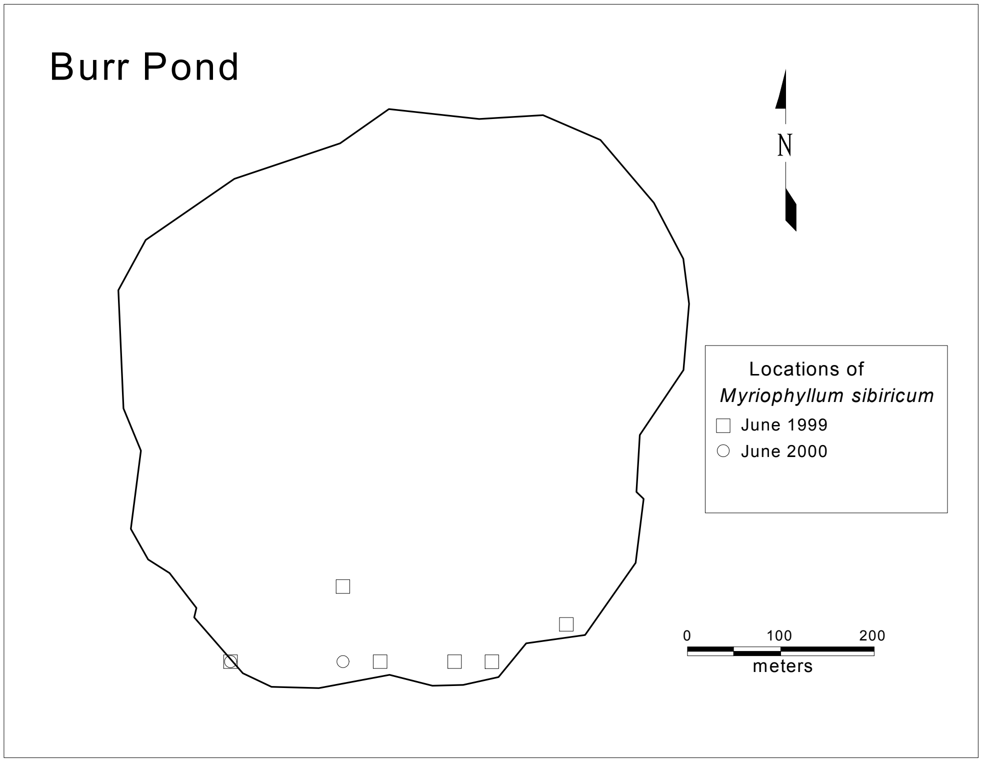


a) June Surveys



b) August Surveys

Figure B4. Map illustrating Burr Pond locations where *Elodea canadensis* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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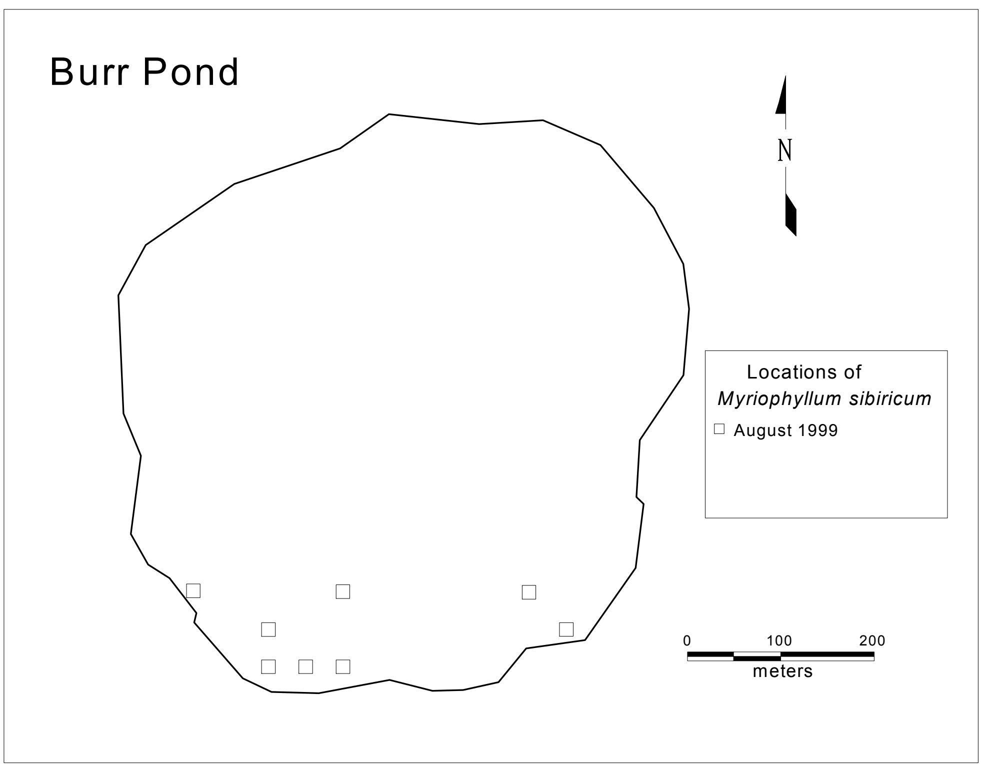
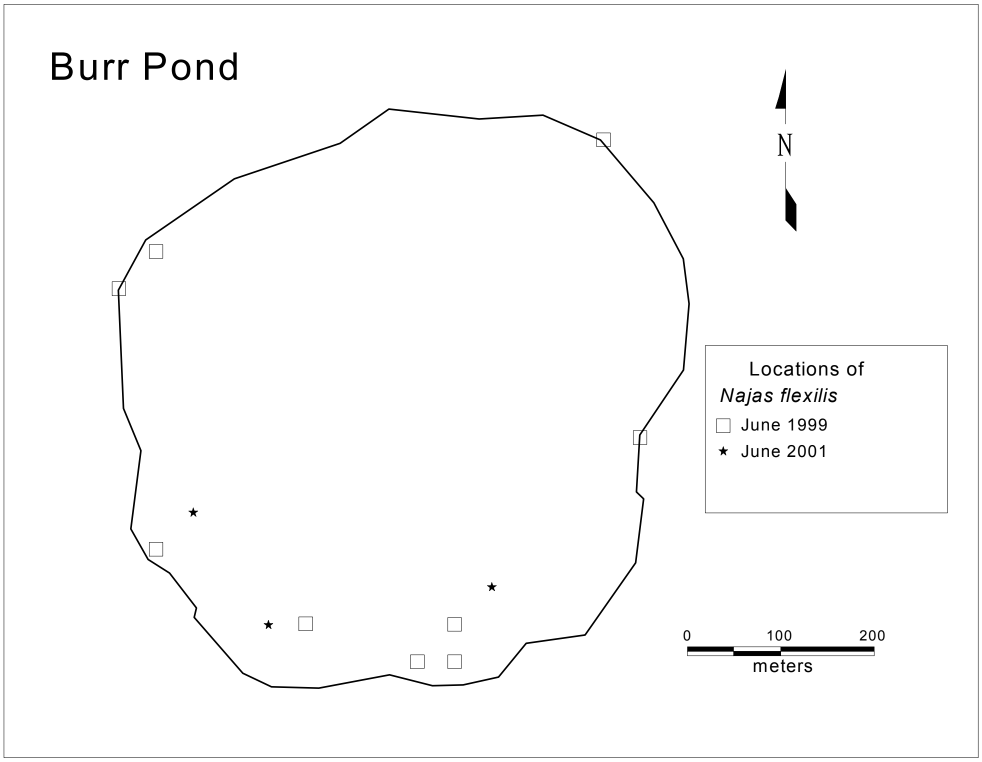


b) August Surveys

Figure B5. Map illustrating Burr Pond locations where *Myriophyllum sibiricum* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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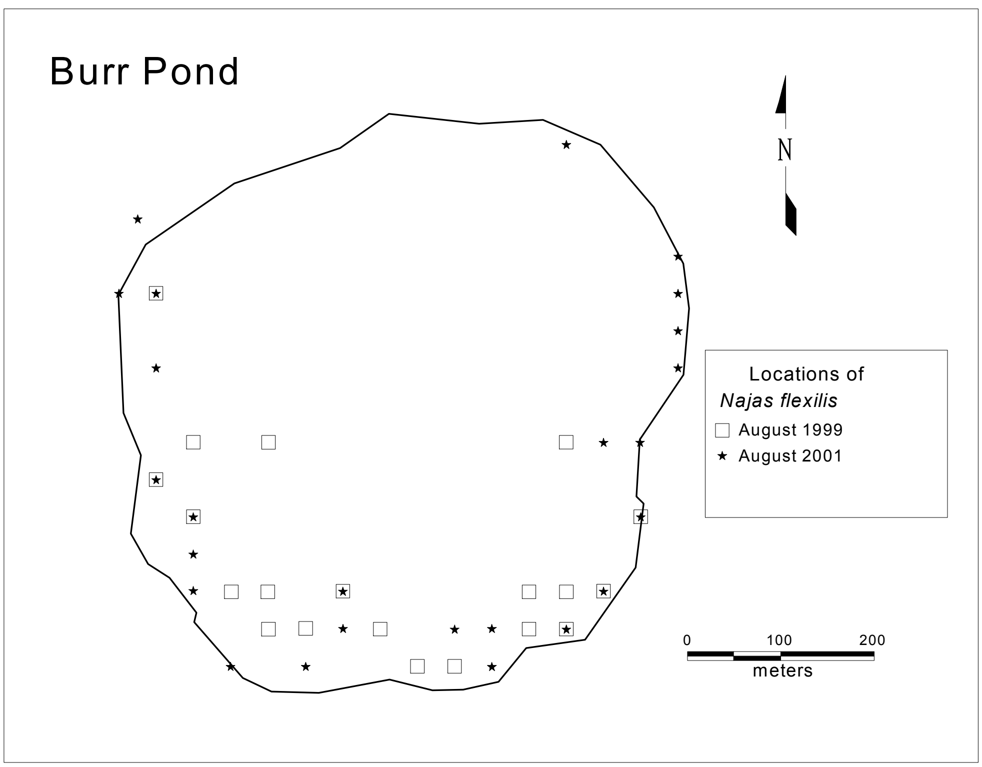

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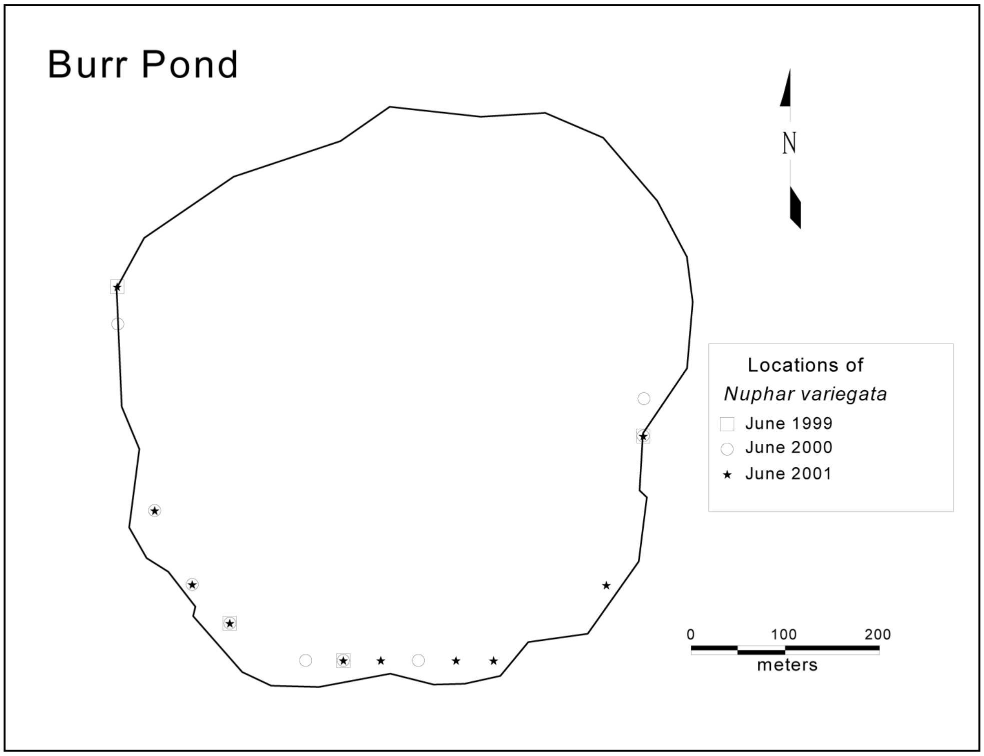
Figure B6. Map illustrating Burr Pond locations where *Najas flexilis* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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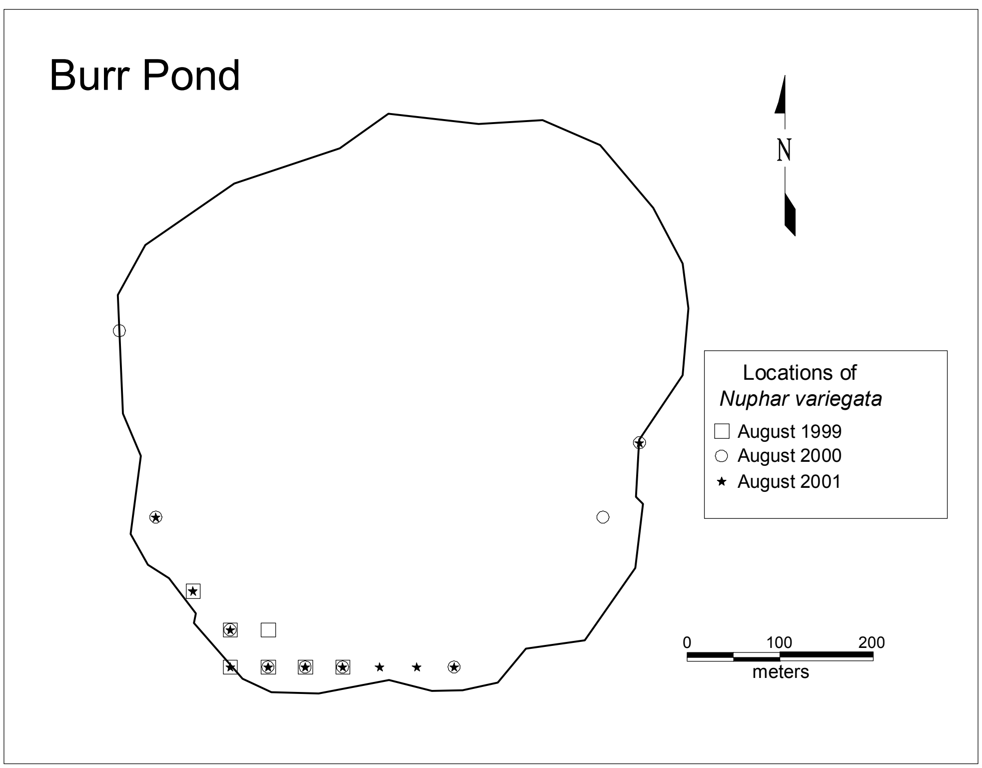

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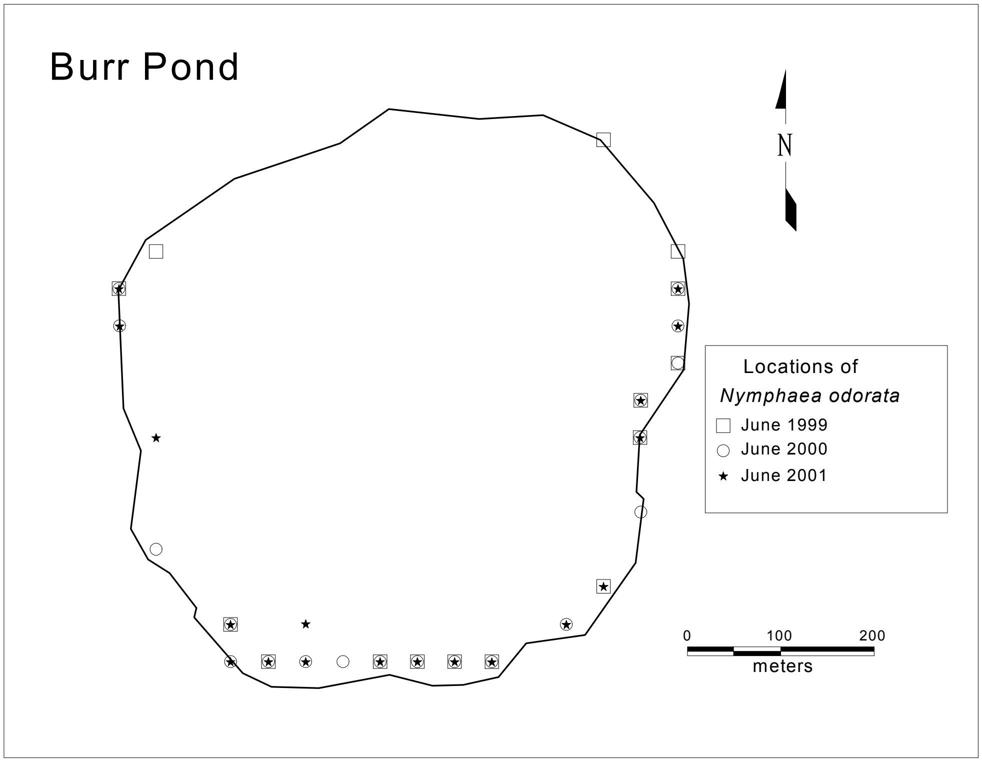
Figure B7. Map illustrating Burr Pond locations where *Nuphar variegata* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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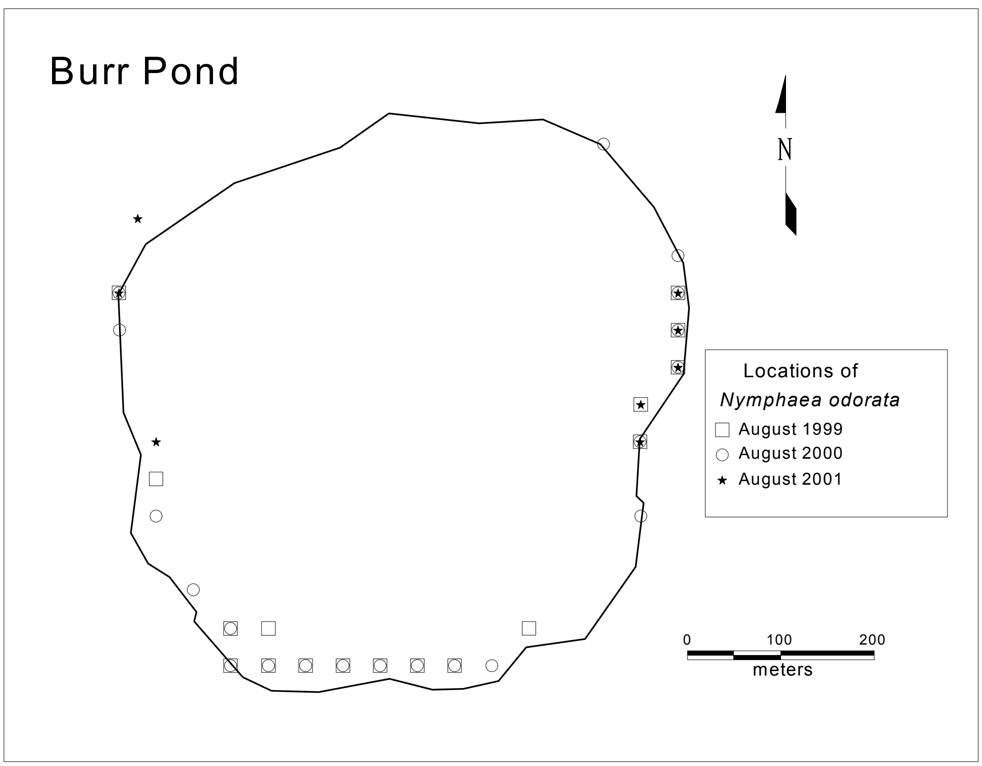
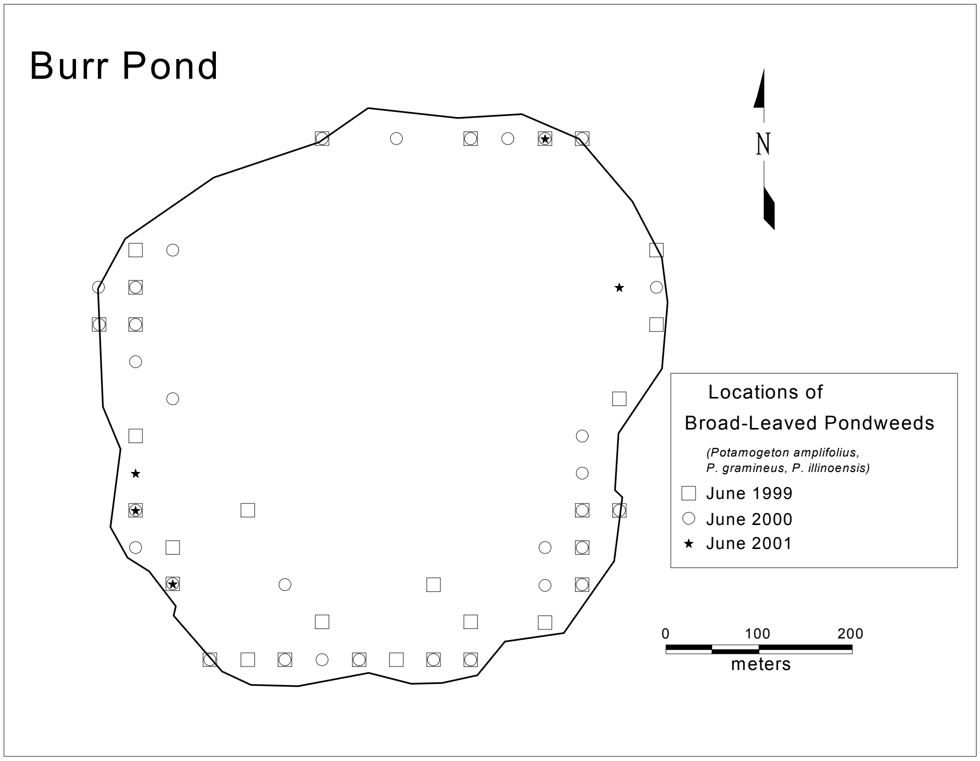


b) August Surveys

Figure B8. Map illustrating Burr Pond locations where *Nymphaea odorata* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001.



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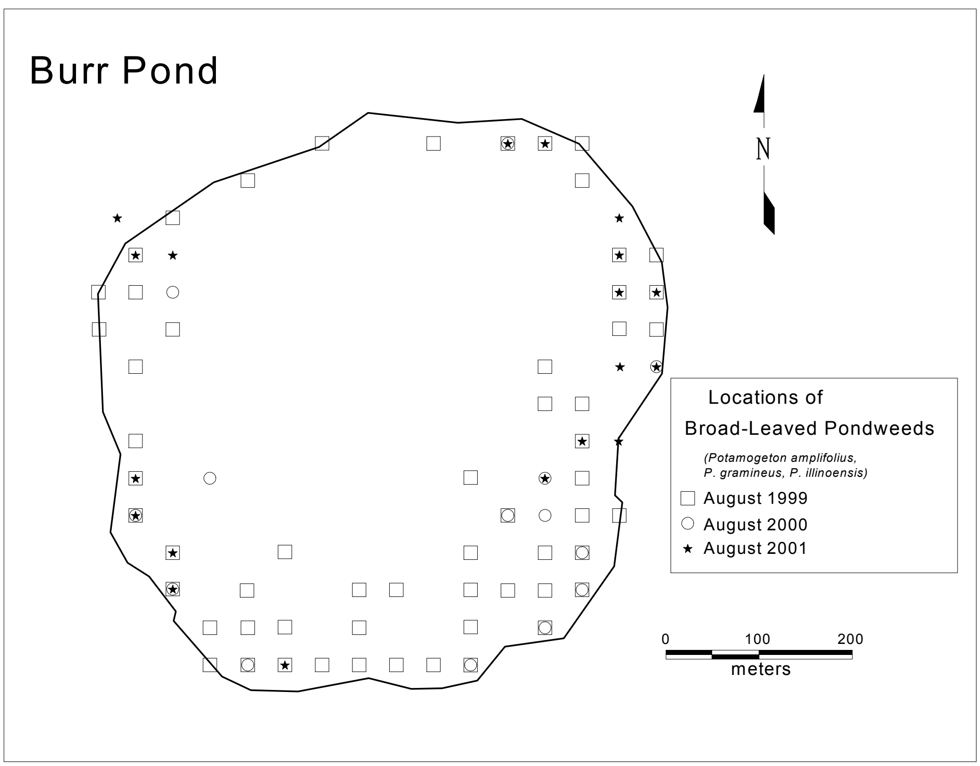
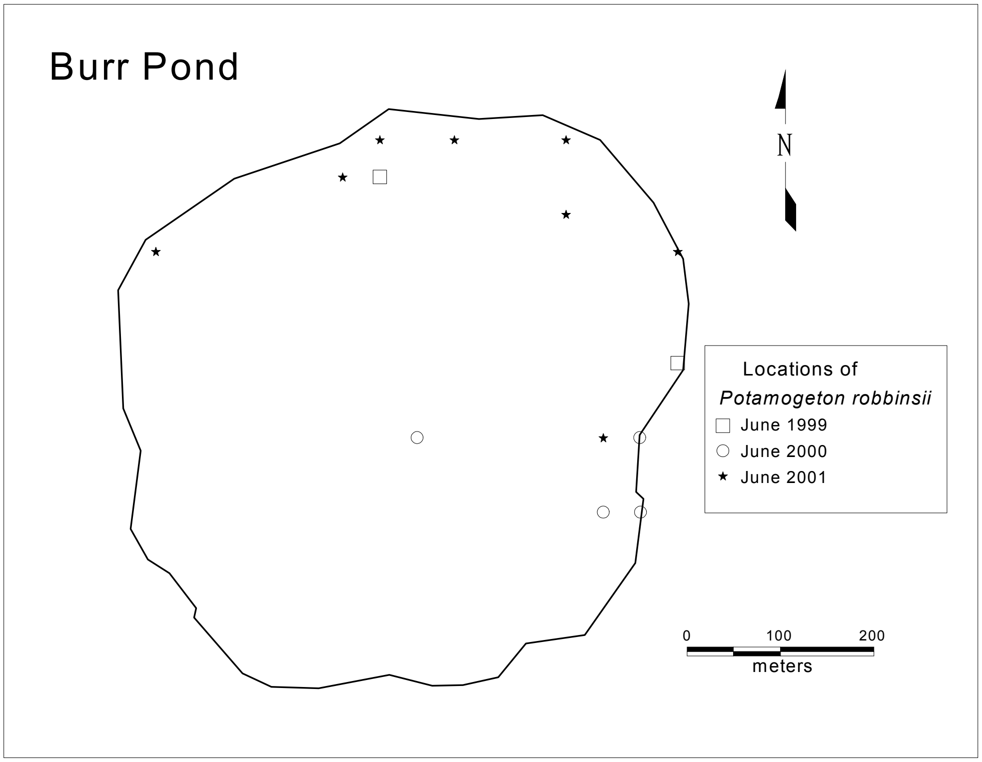


b) August Surveys

Figure B9. Map illustrating Burr Pond locations where broad-leaved pondweeds (i.e., *Potamogeton amplifolius*, *P. illinoensis*, or *P. gramineus*) were collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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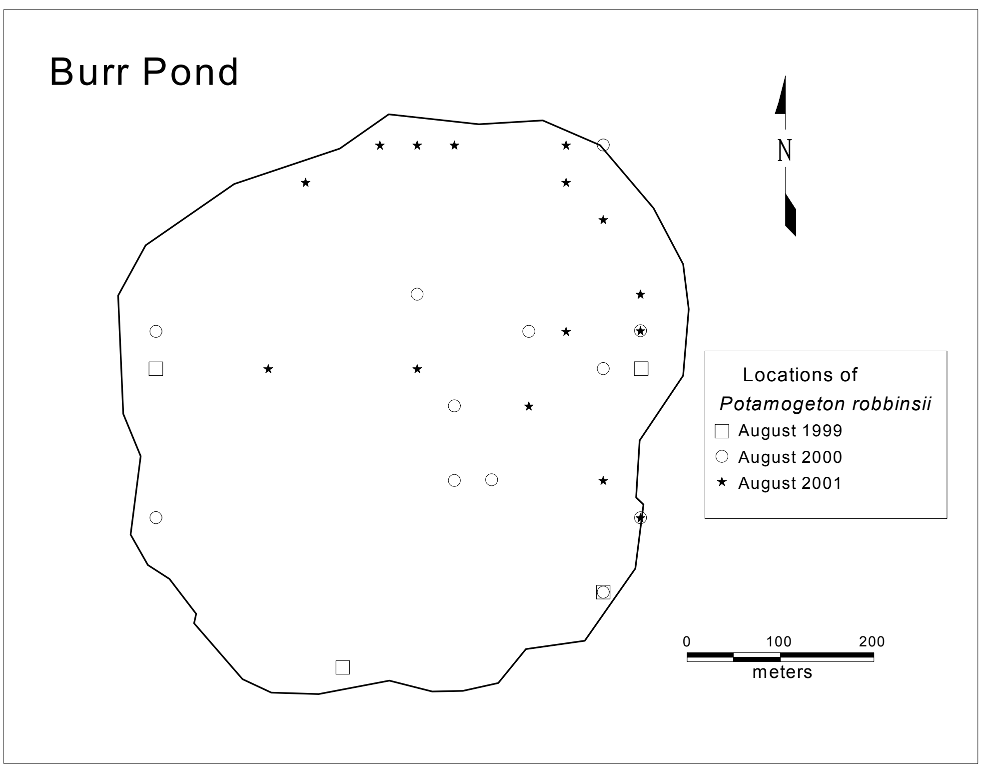

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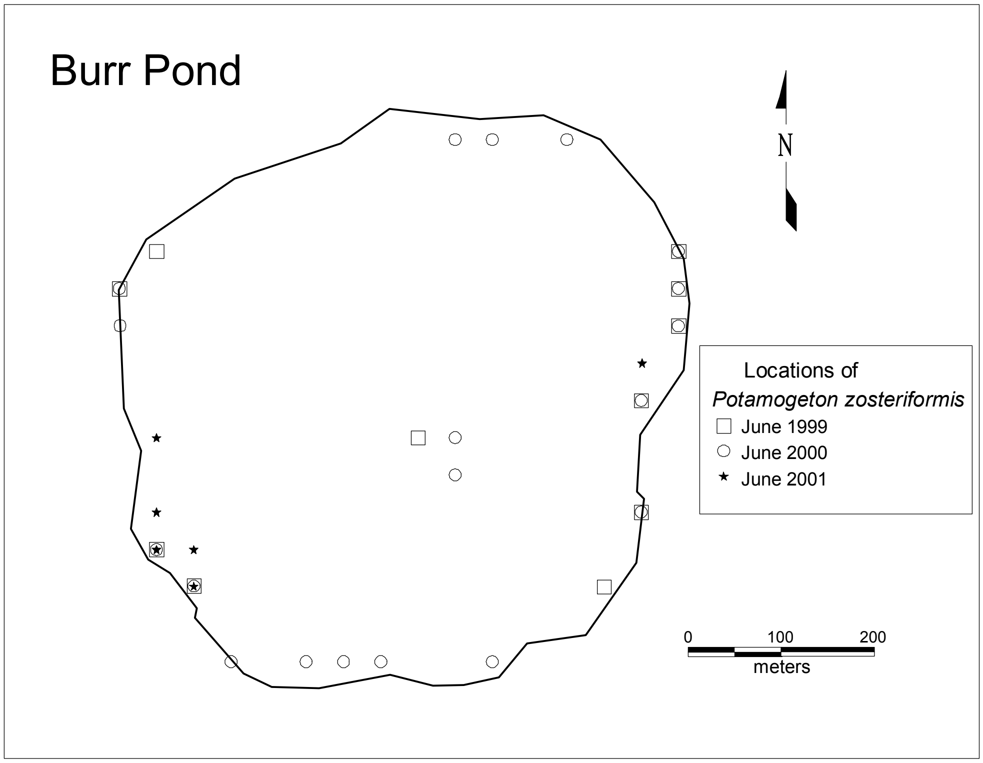
Figure B10. Map illustrating Burr Pond locations where *Potamogeton robbinsii* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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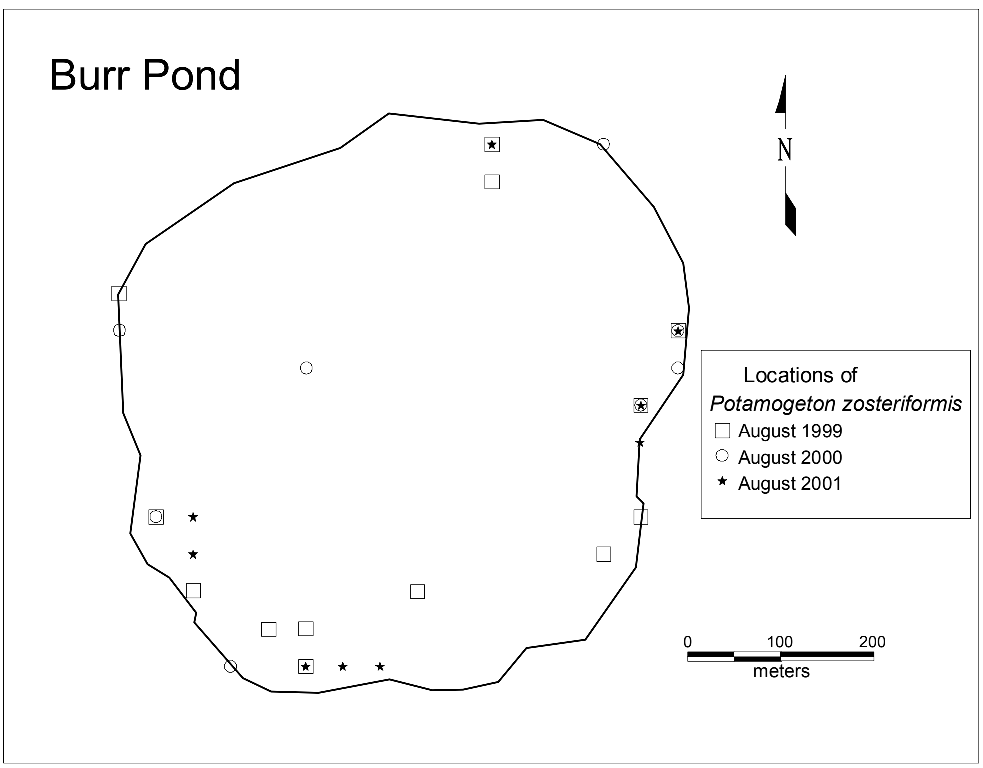

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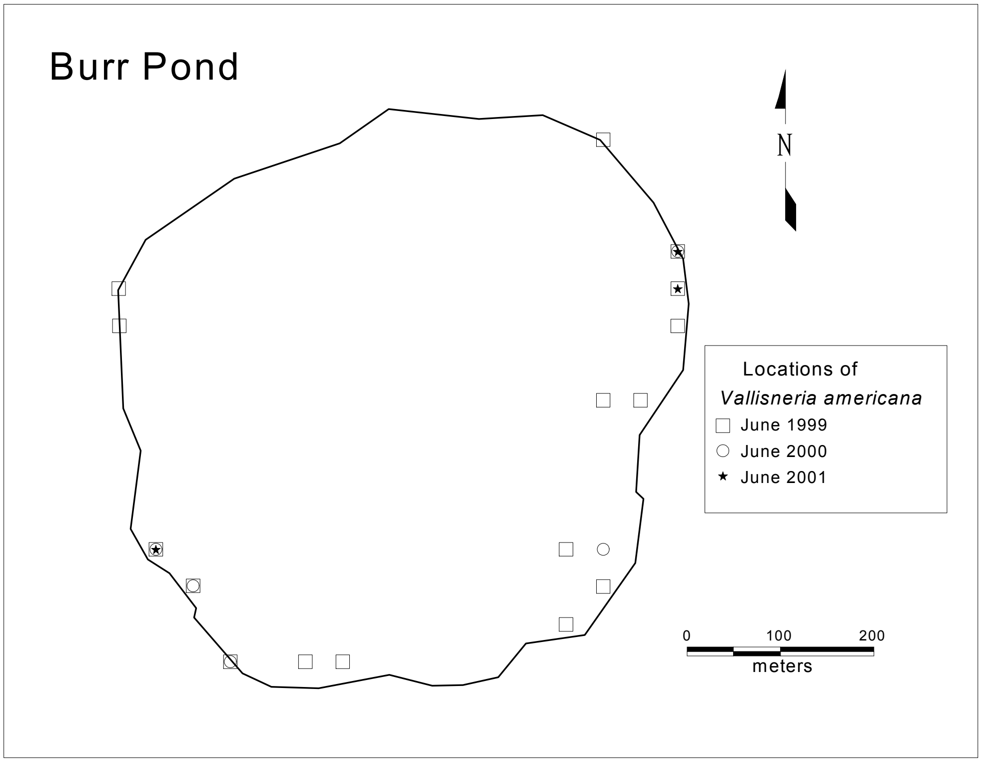
Figure B11. Map illustrating Burr Pond locations where *Potamogeton zosteriformis* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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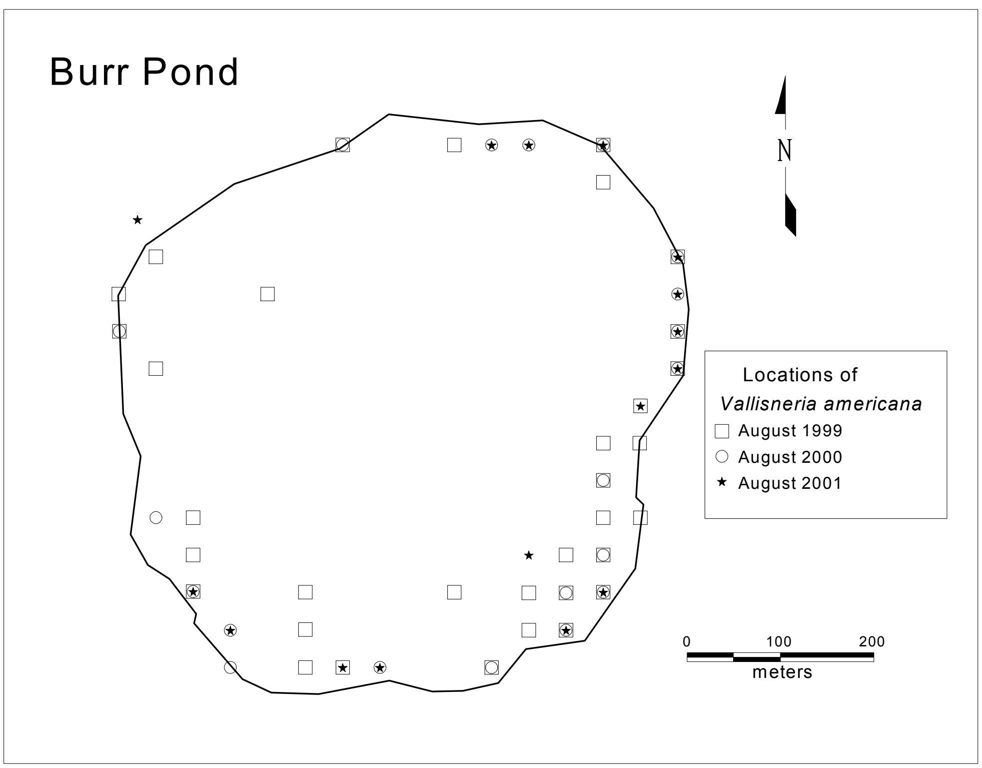

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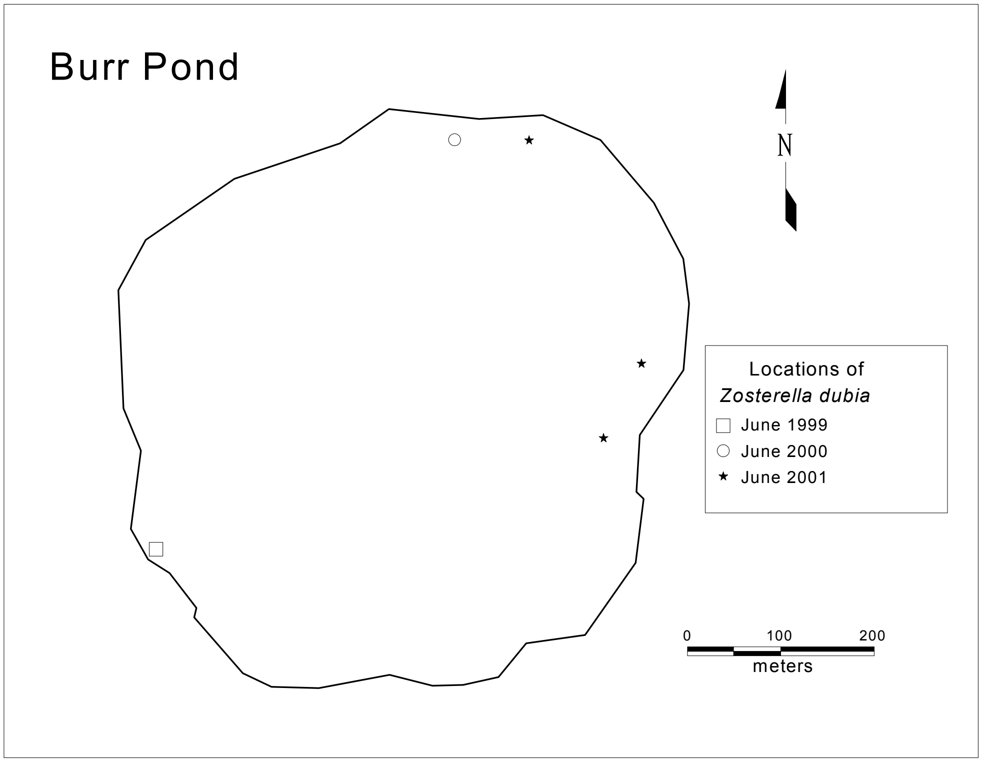
Figure B12. Map illustrating Burr Pond locations where *Vallisneria americana* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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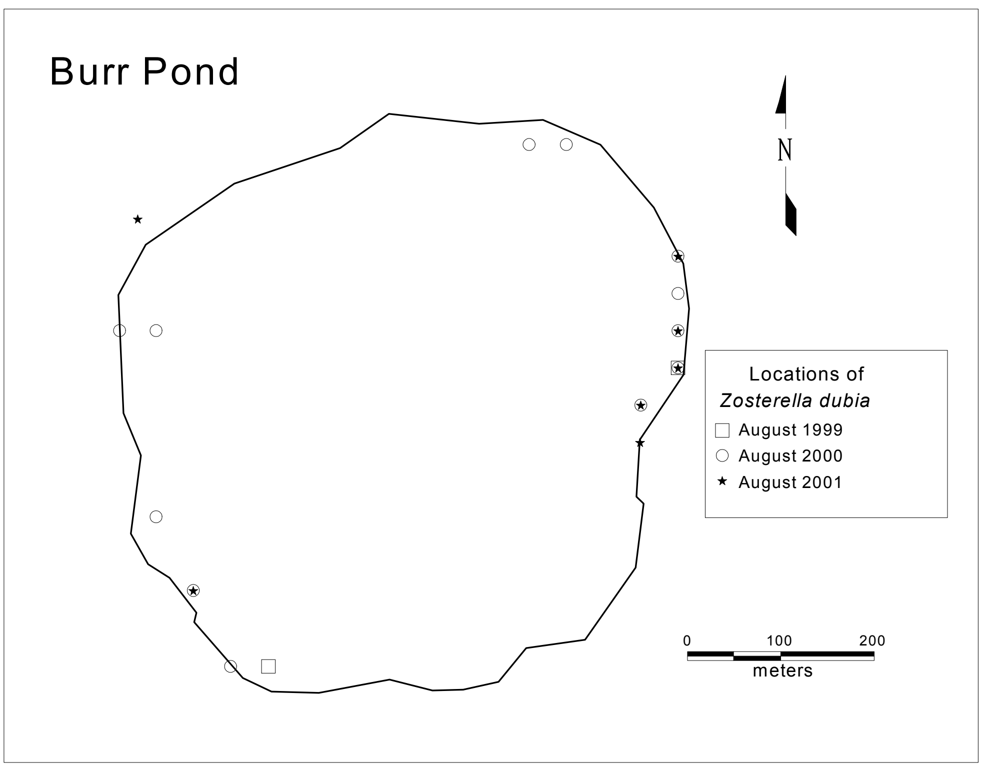
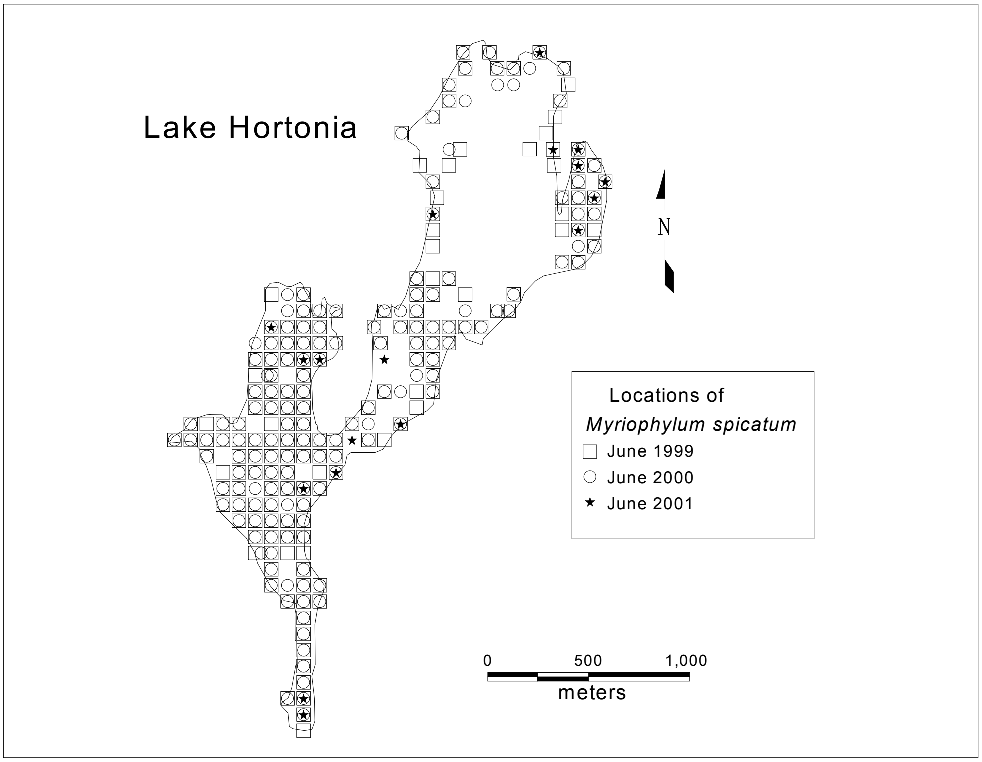


b) August Surveys

Figure B13. Map illustrating Burr Pond locations where *Zosterella dubia* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001

Appendix C
Lake Hortonia Plant Distribution Maps



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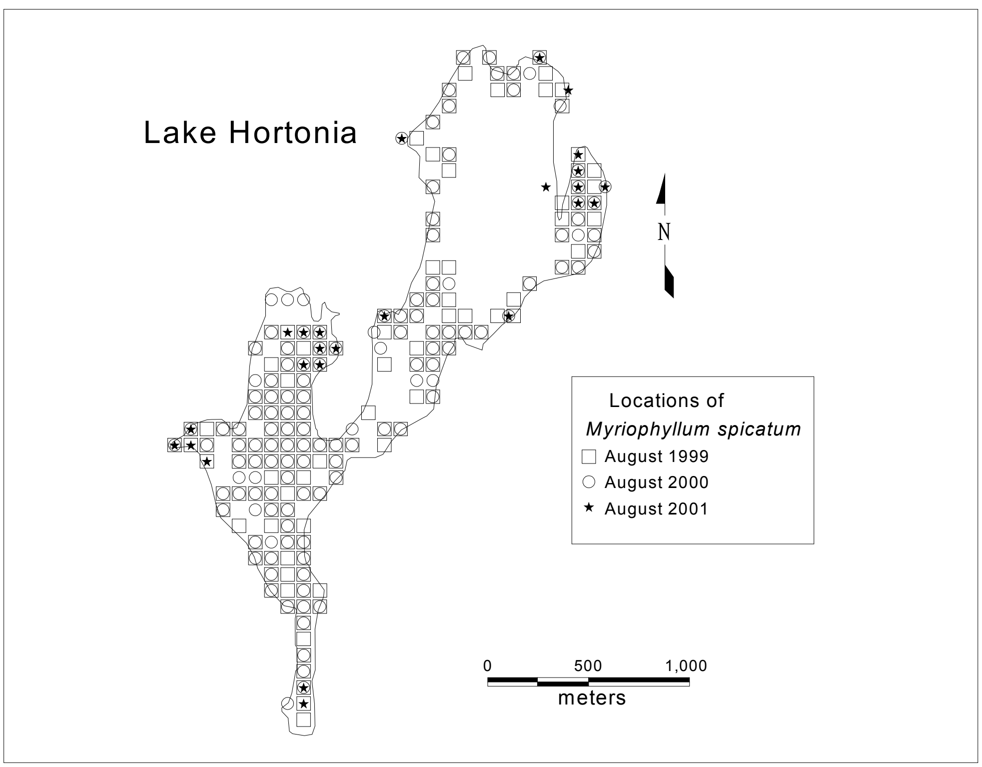
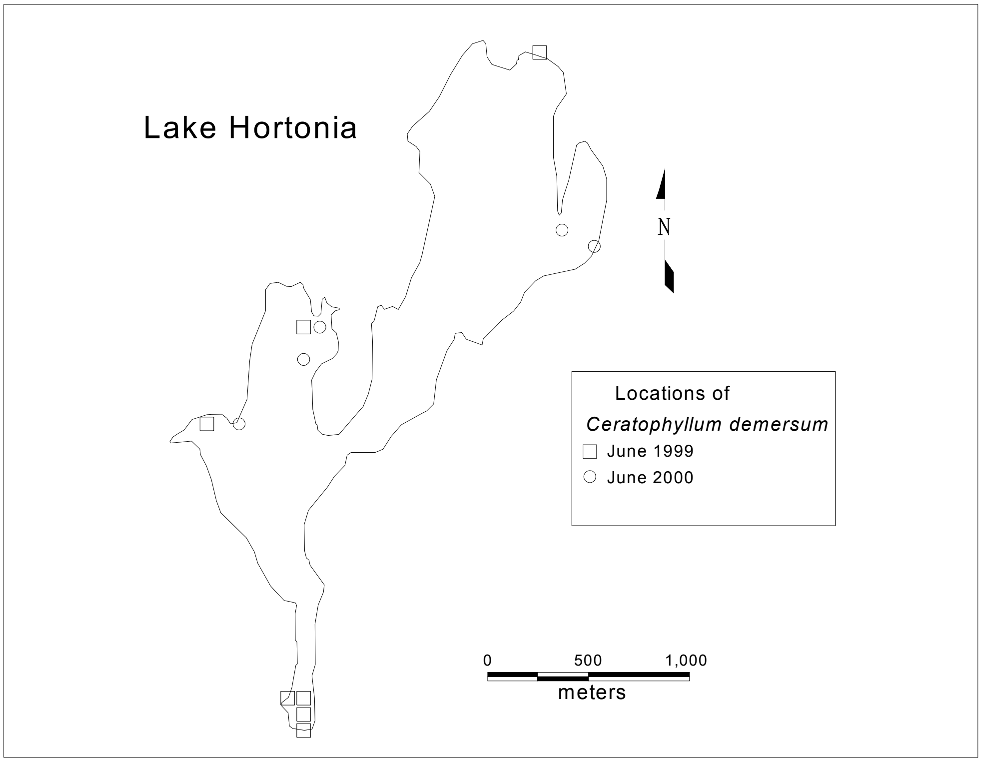


b) August Surveys

Figure C1. Map illustrating Lake Hortonia locations where *Myriophyllum spicatum* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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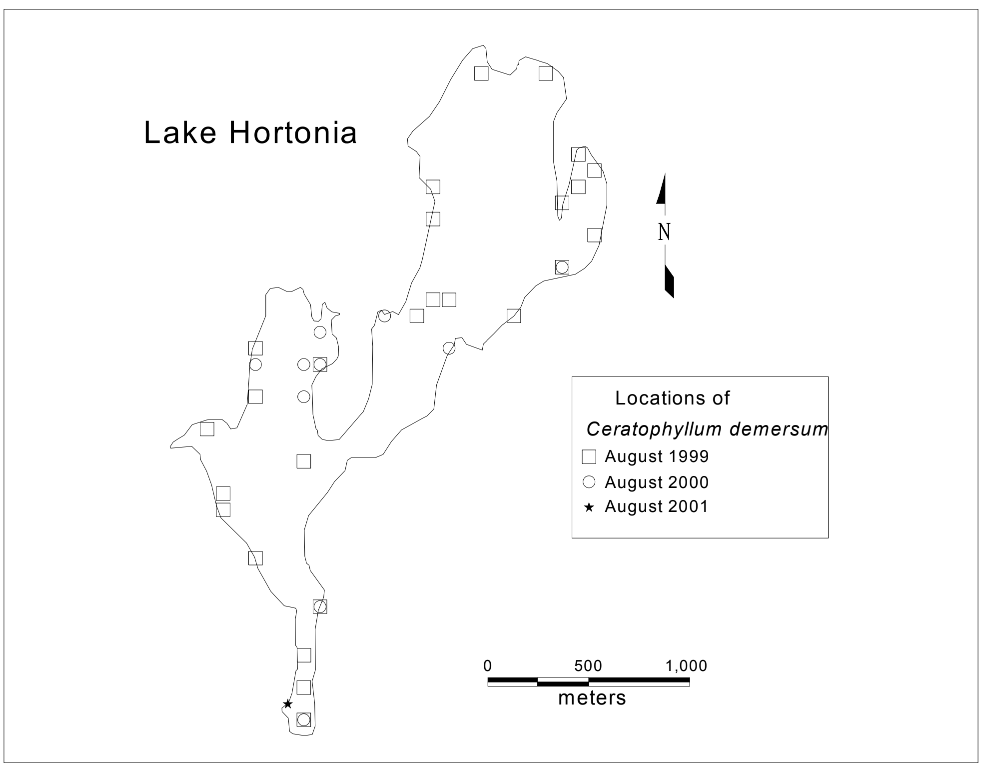
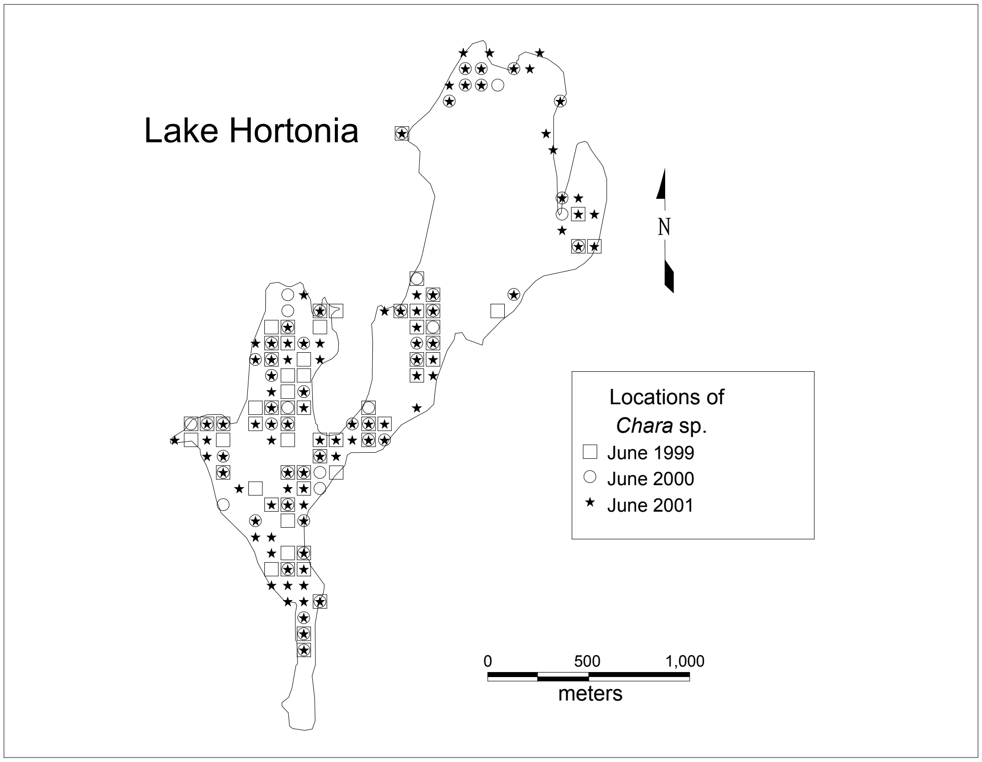


b) August Surveys

Figure C2. Map illustrating Lake Hortonia locations where *Ceratophyllum demersum* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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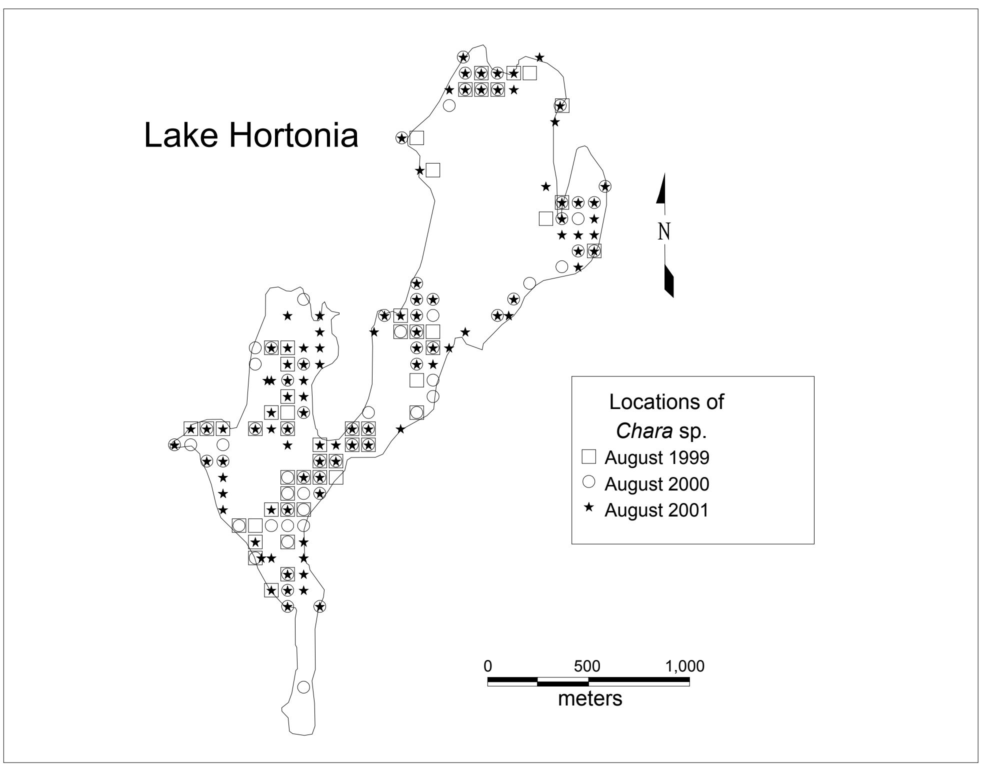
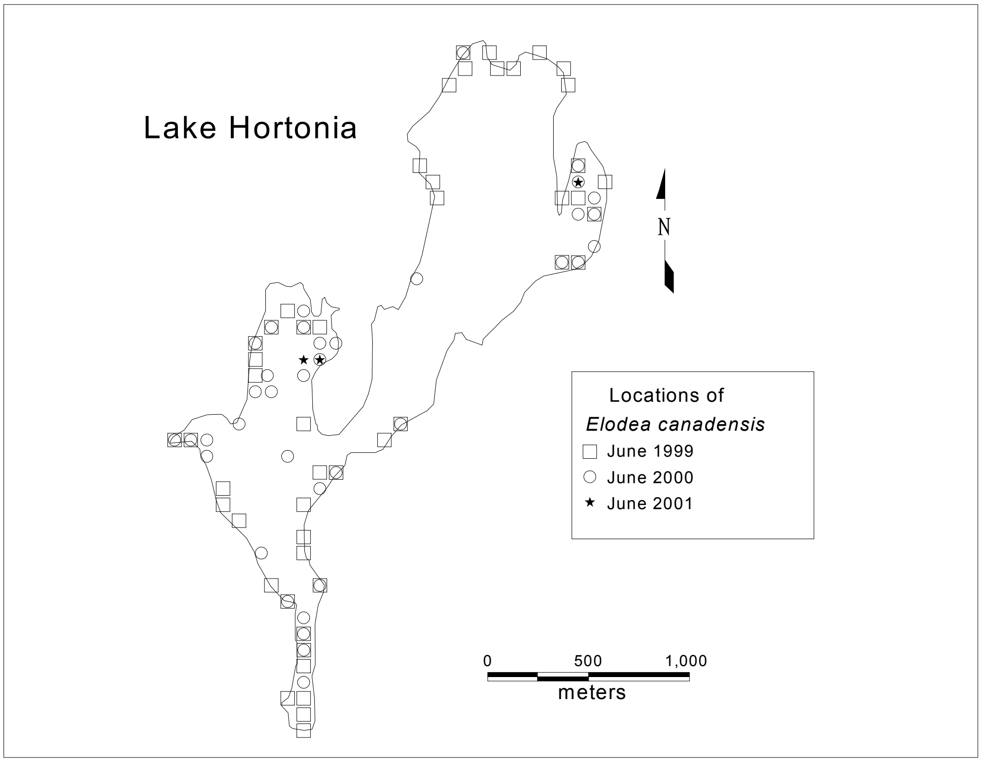


b) August Surveys

Figure C3. Map illustrating Lake Hortonia locations where *Chara* sp. was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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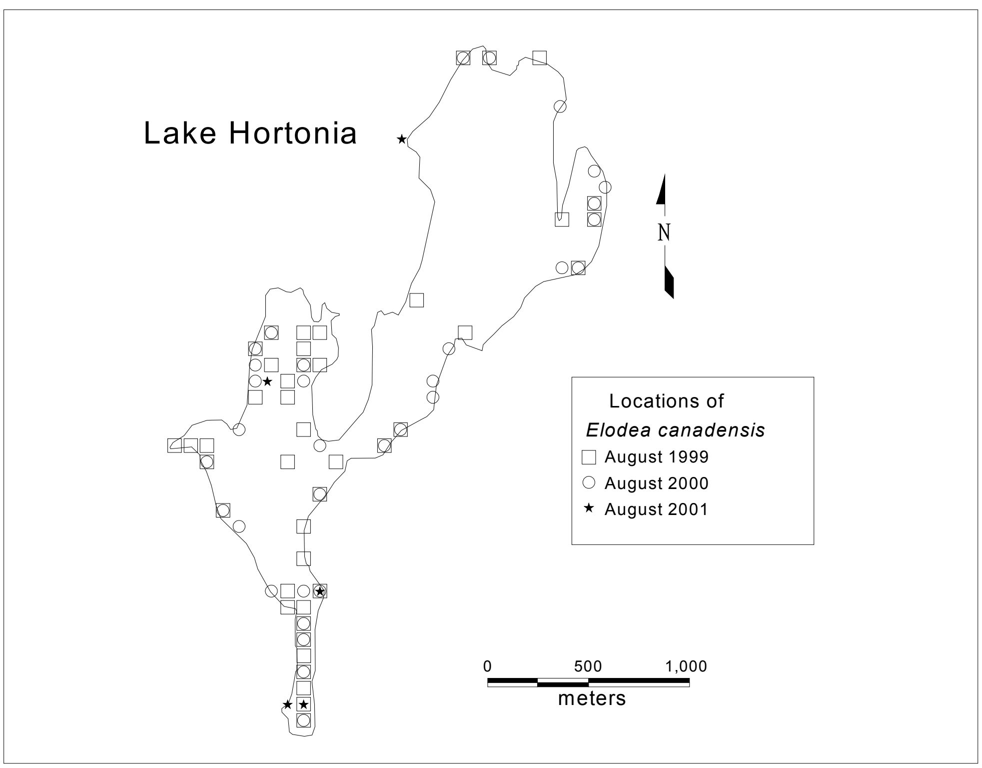

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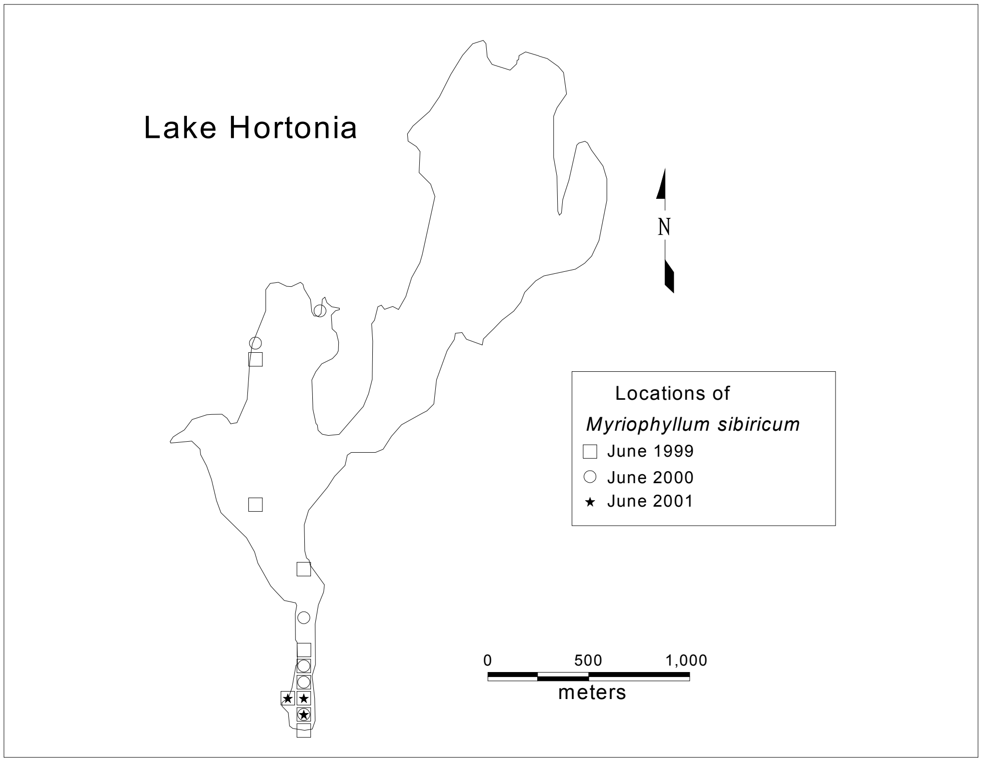
Figure C4. Map illustrating Lake Hortonia locations where *Elodea canadensis* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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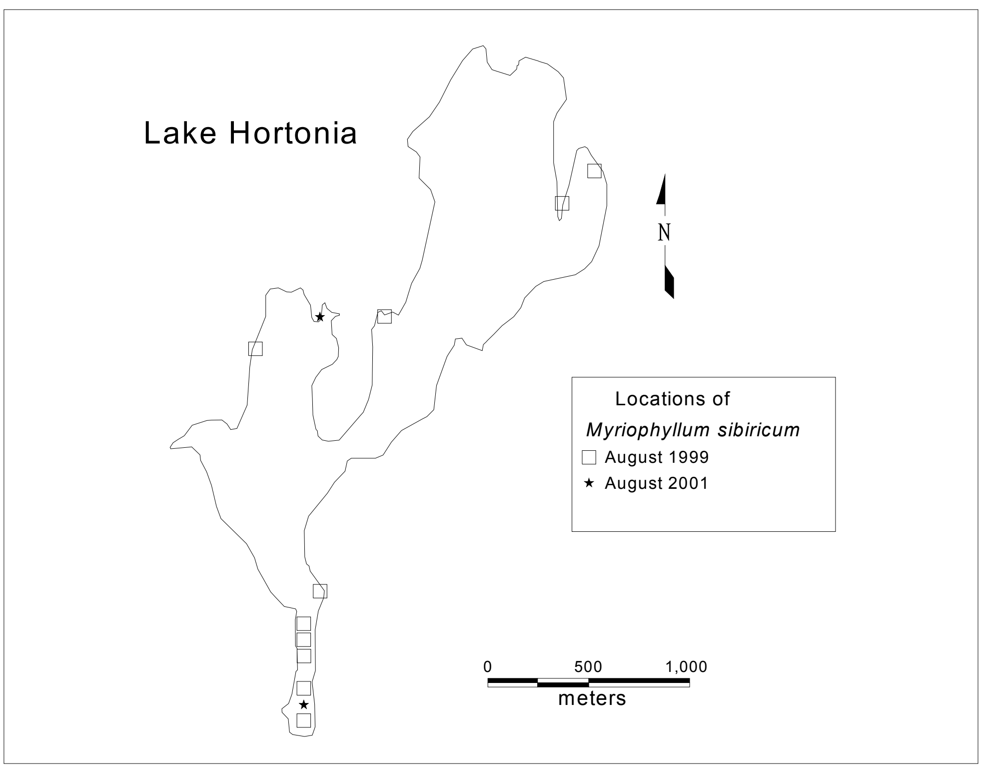
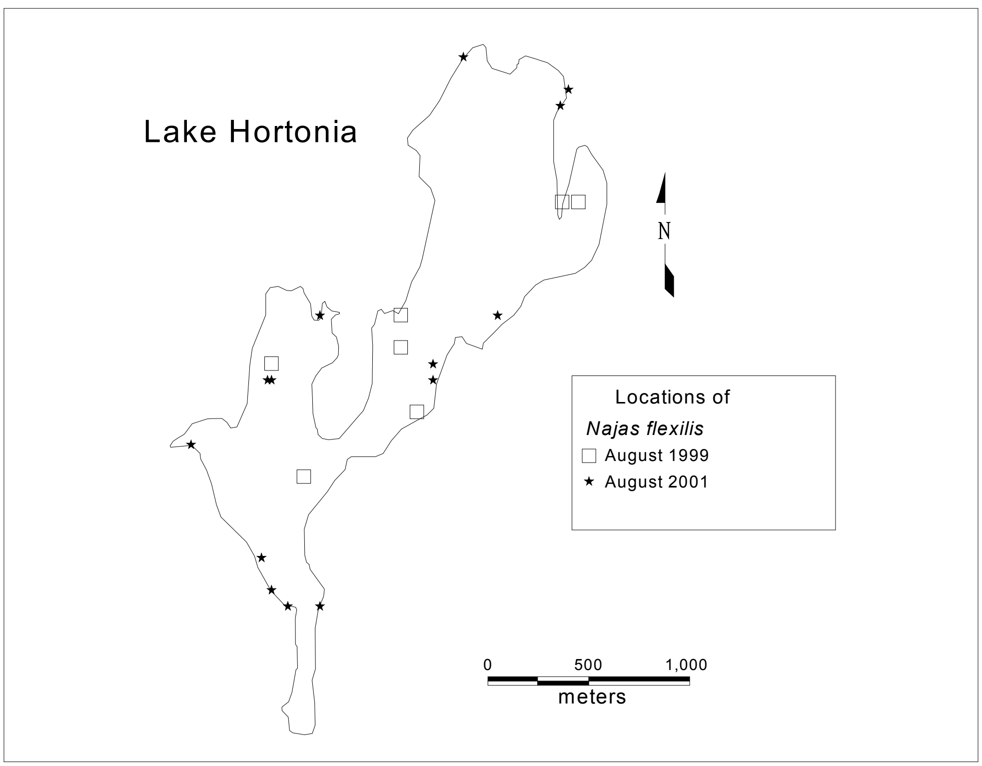


b) August Surveys

Figure C5. Map illustrating Lake Hortonia locations where *Myriophyllum sibiricum* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001

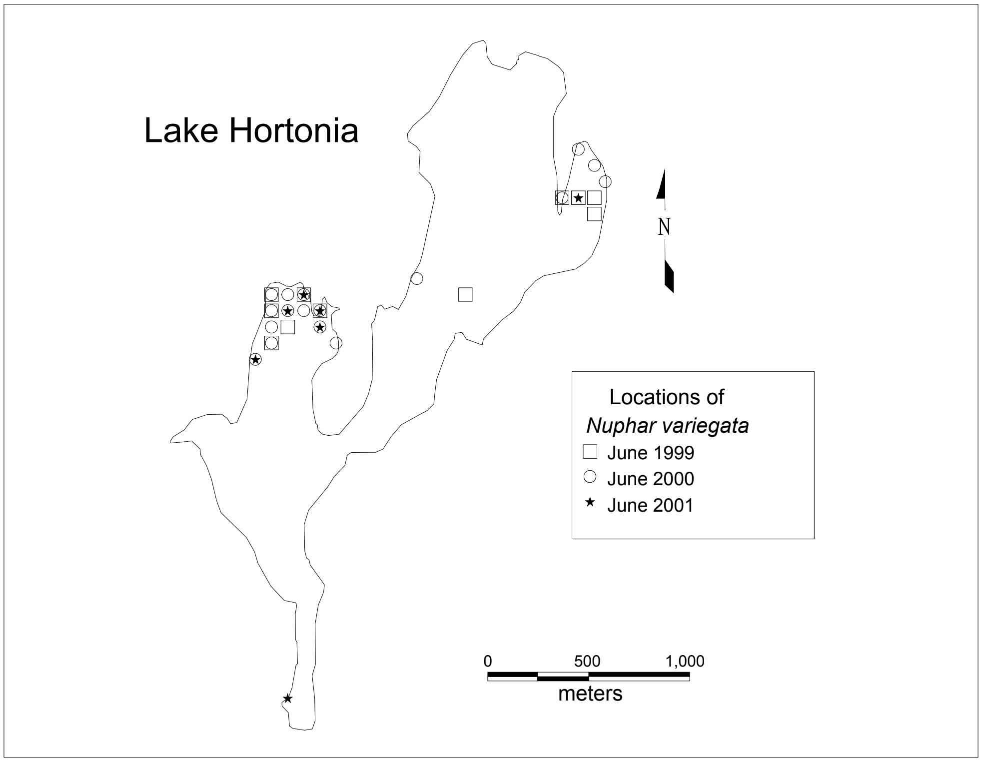
a) June Surveys

No occurrences of *Najas flexilis* in June surveys



b) August Surveys

Figure C6. Map illustrating Lake Hortonia locations where *Najas flexilis* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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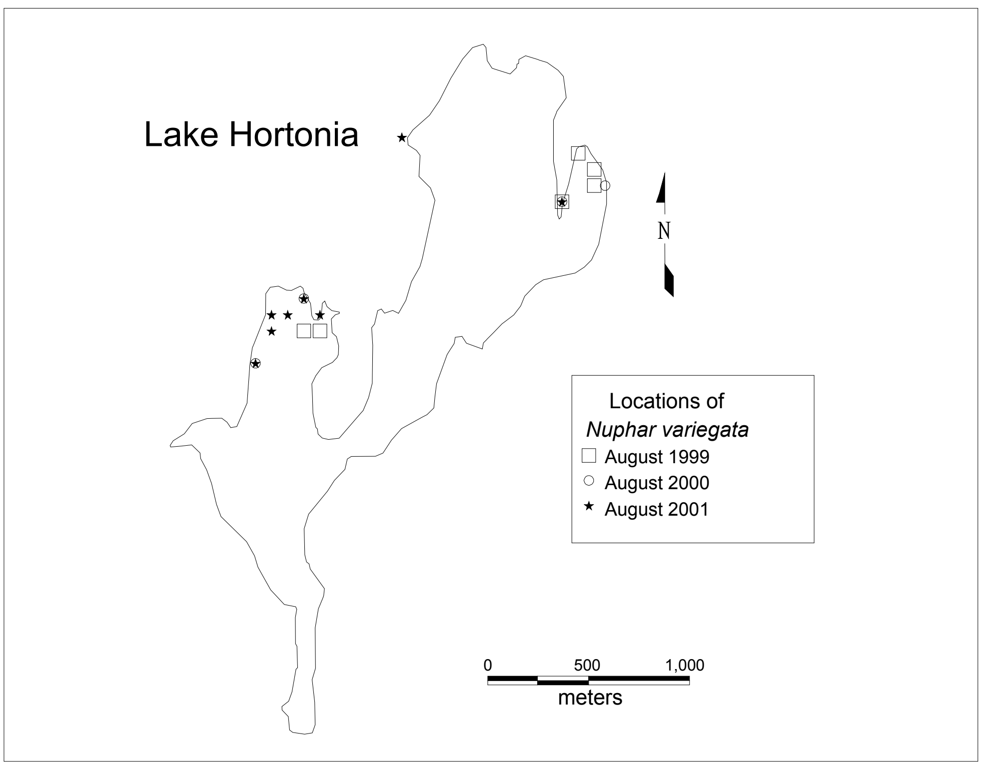
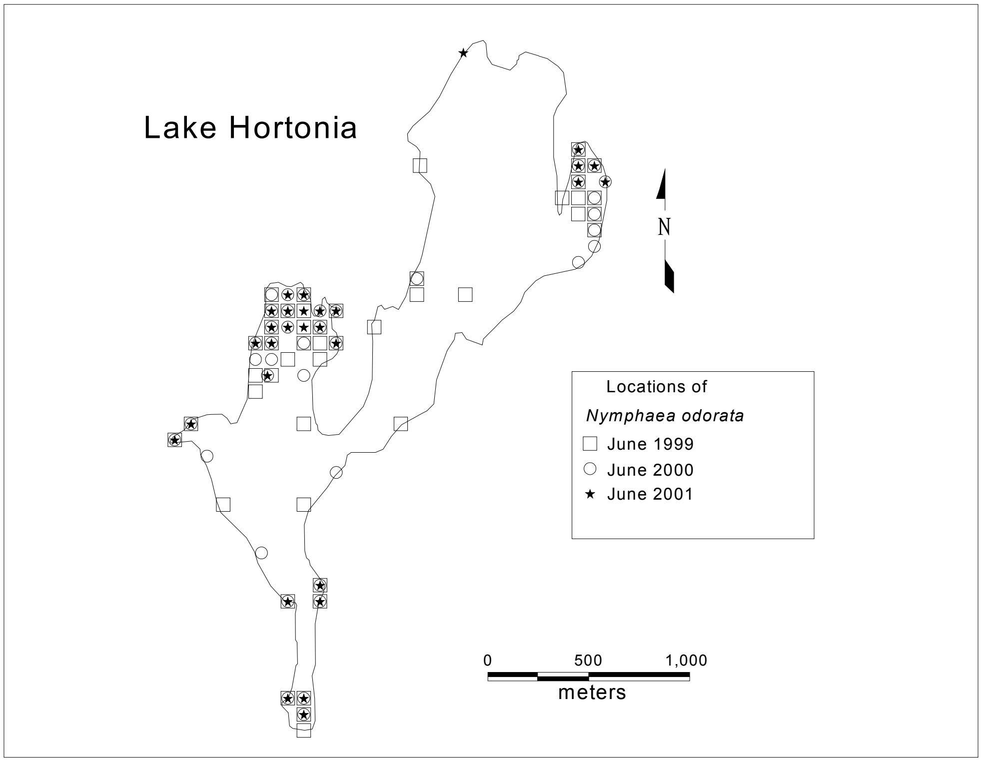


b) August Surveys

Figure C7. Map illustrating Lake Hortonia locations where *Nuphar variegata* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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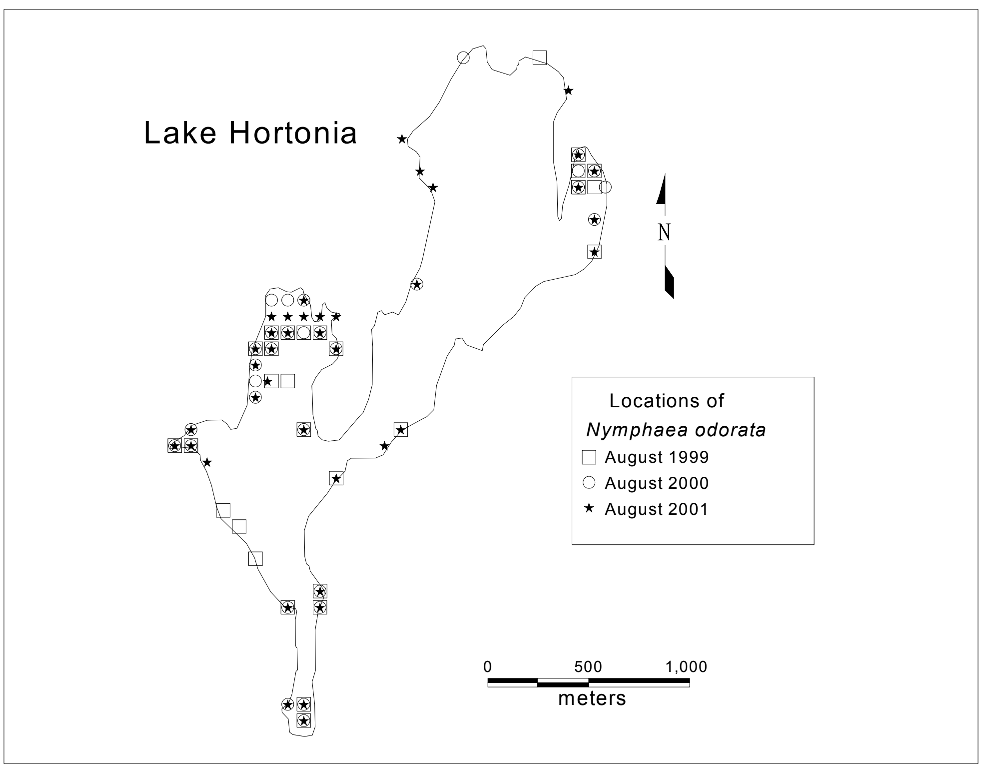

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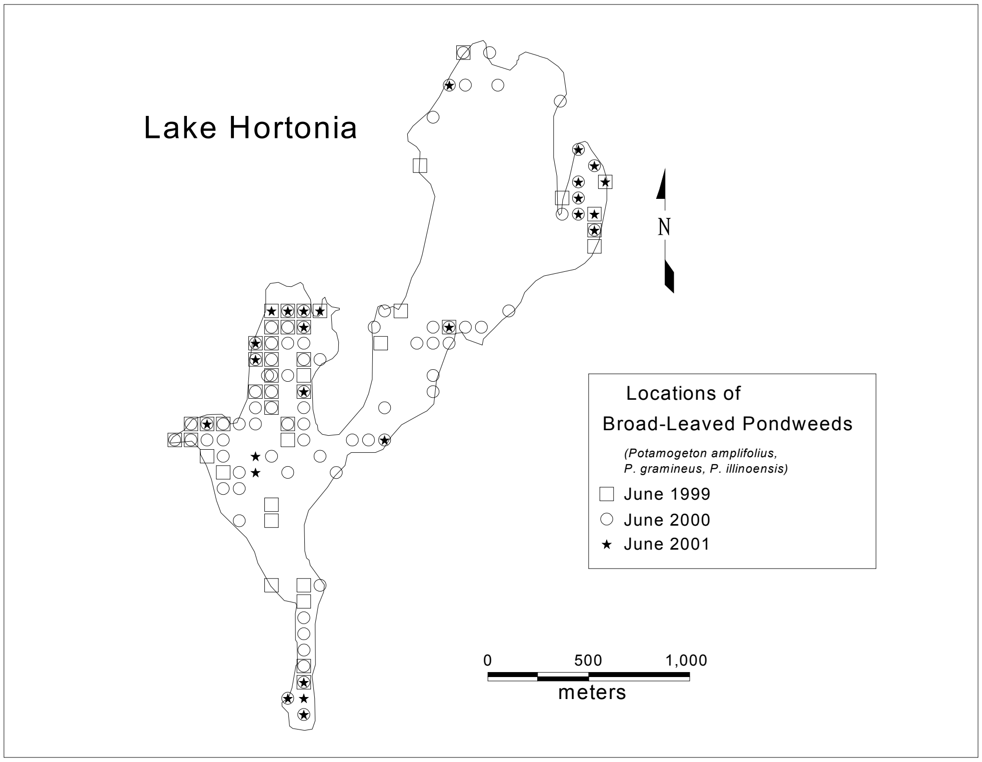
Figure C8. Map illustrating Lake Hortonia locations where *Nymphaea odorata* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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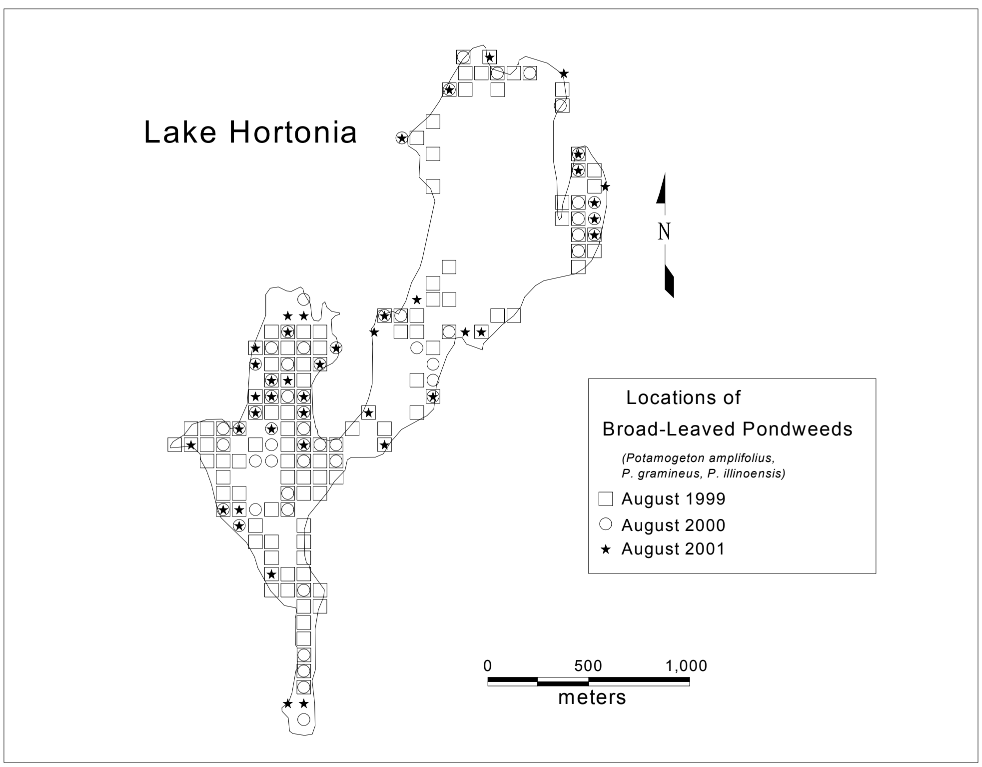
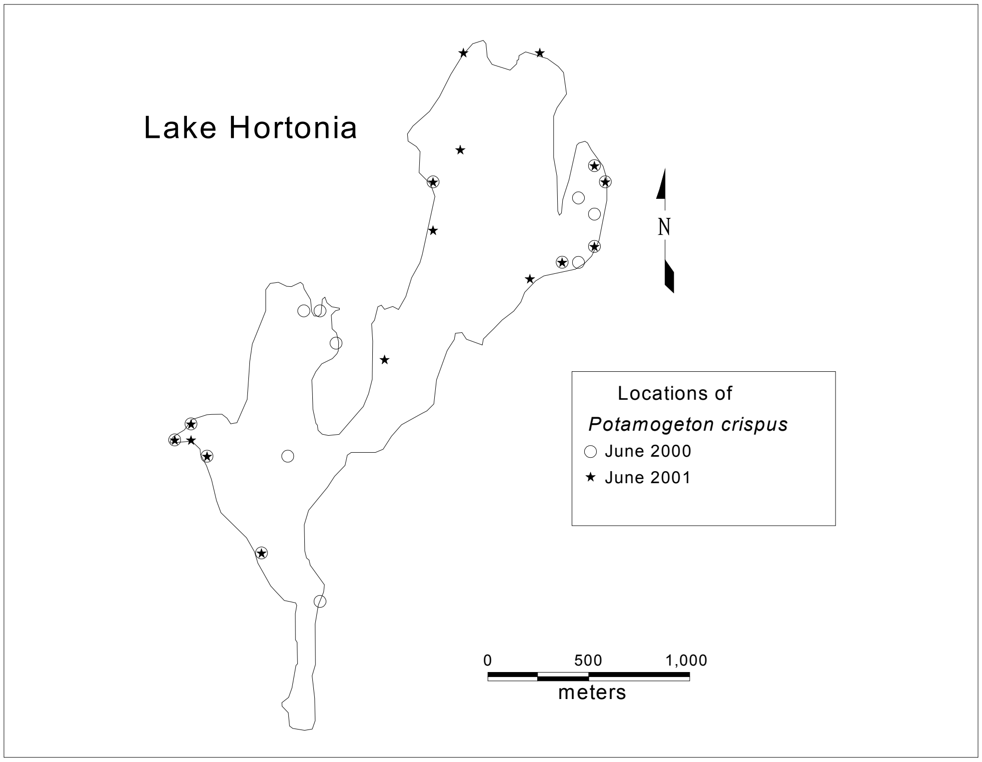


b) August Surveys

Figure C9. Map illustrating Lake Hortonia locations where broad-leaved pondweeds (i.e., *Potamogeton amplifolius*, *P. illinoensis*, or *P. gramineus*) were collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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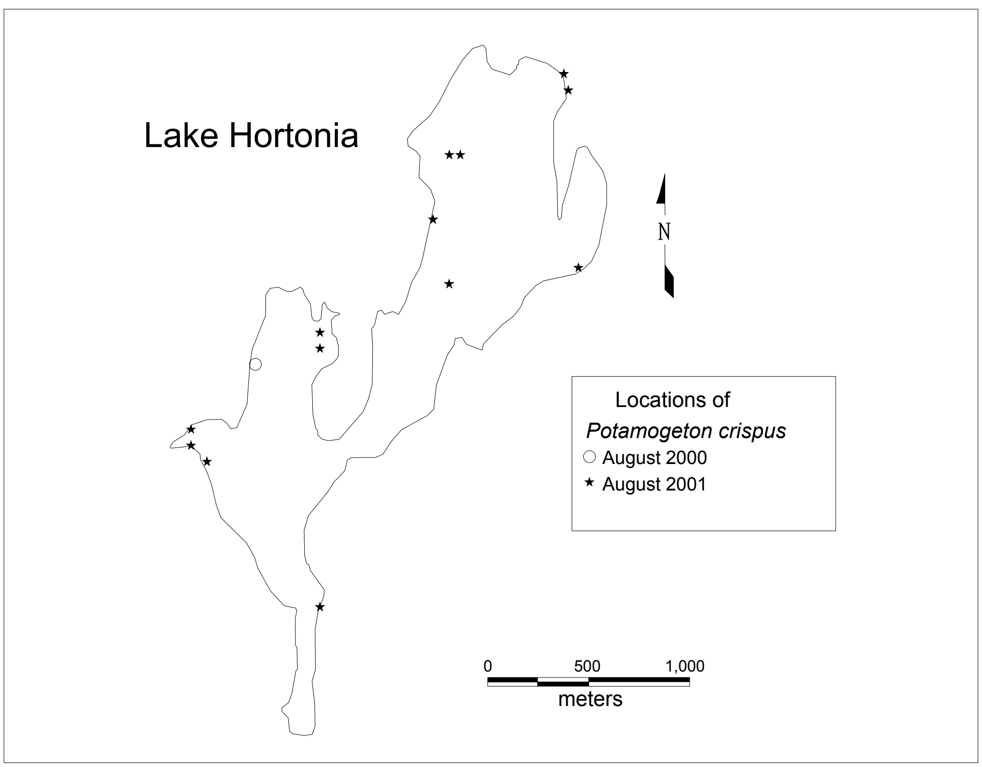
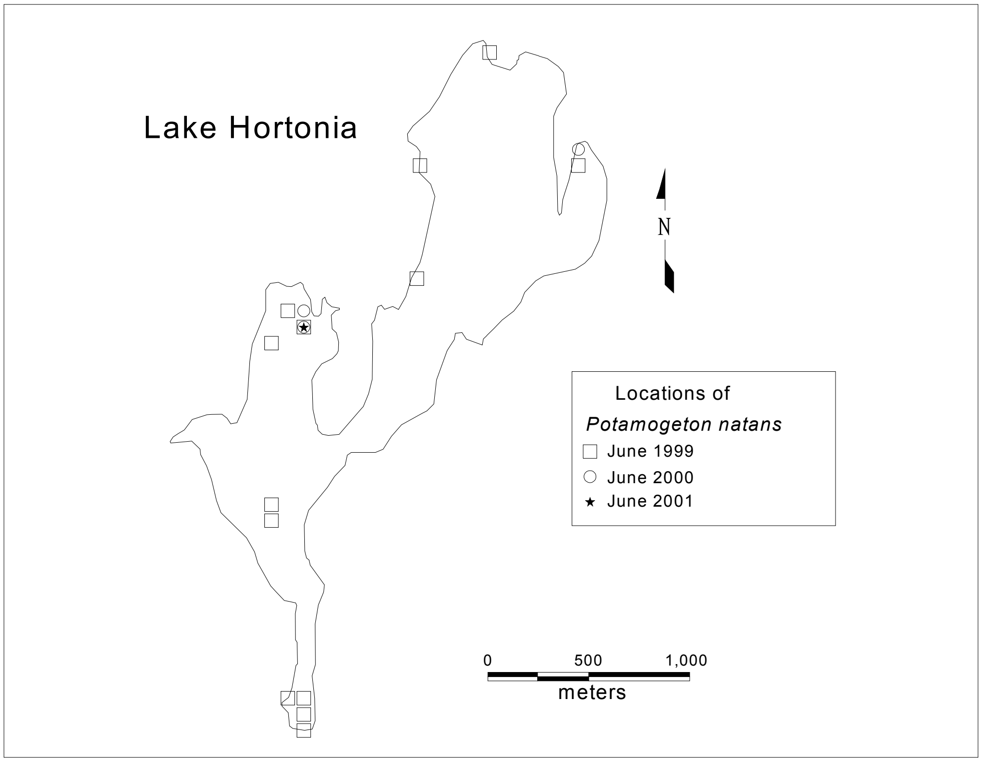


b) August Surveys

Figure C10. Map illustrating Lake Hortonia locations where *Potamogeton crispus* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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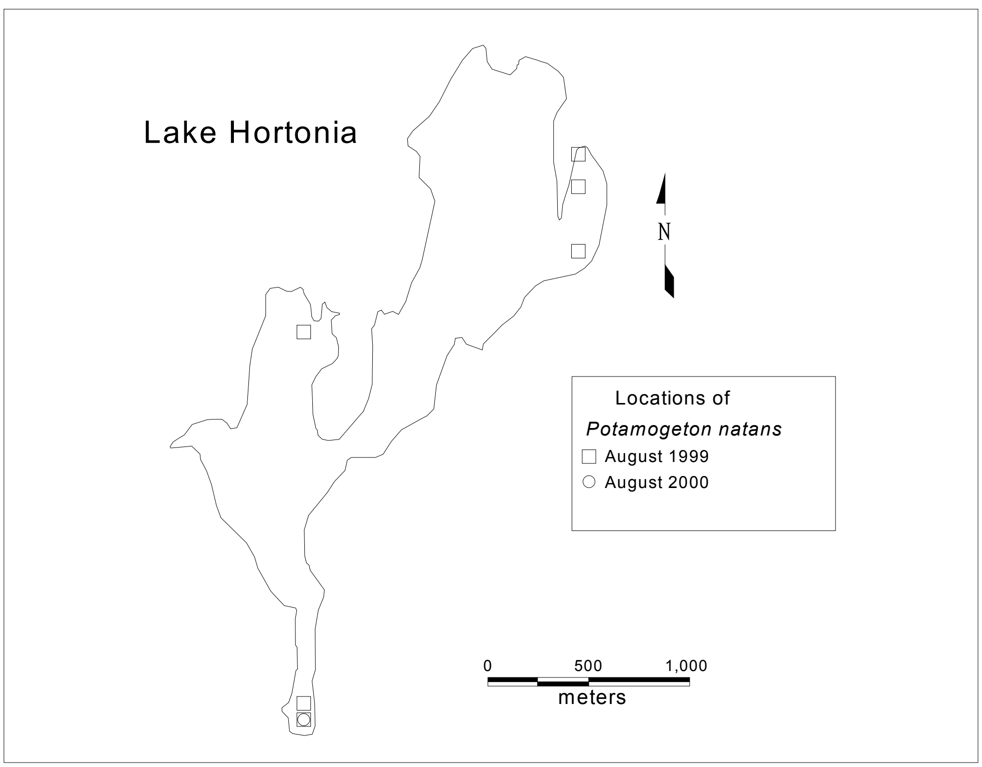
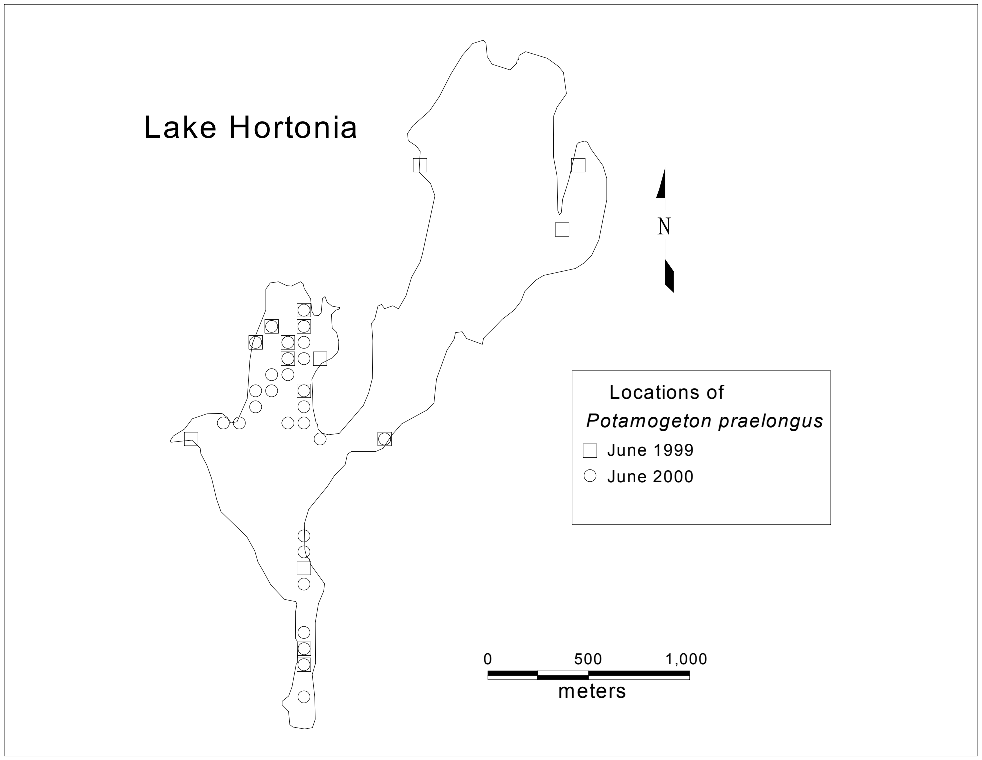


b) August Surveys

Figure C11. Map illustrating Lake Hortonia locations where *Potamogeton natans* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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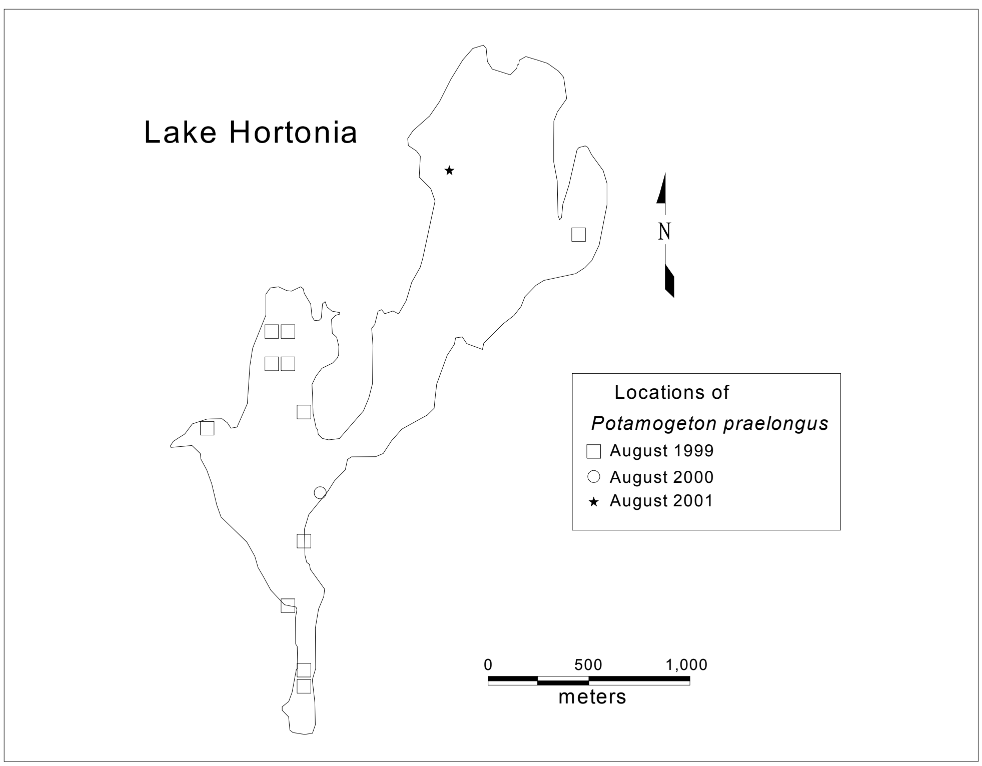

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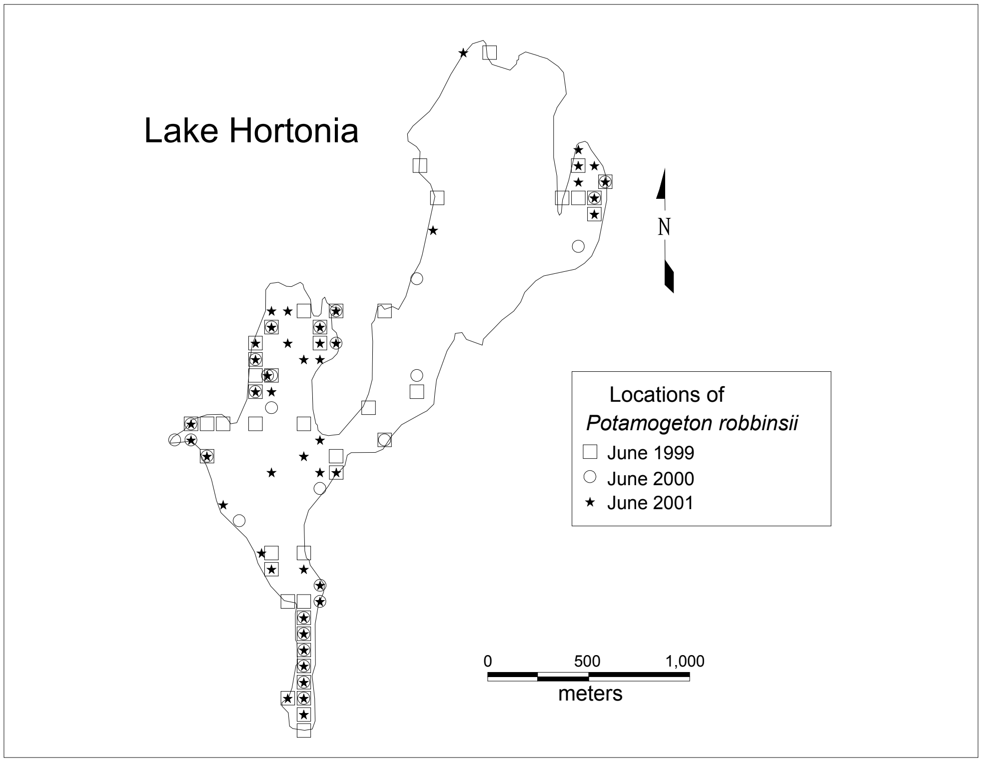
Figure C12. Map illustrating Lake Hortonia locations where *Potamogeton praelongus* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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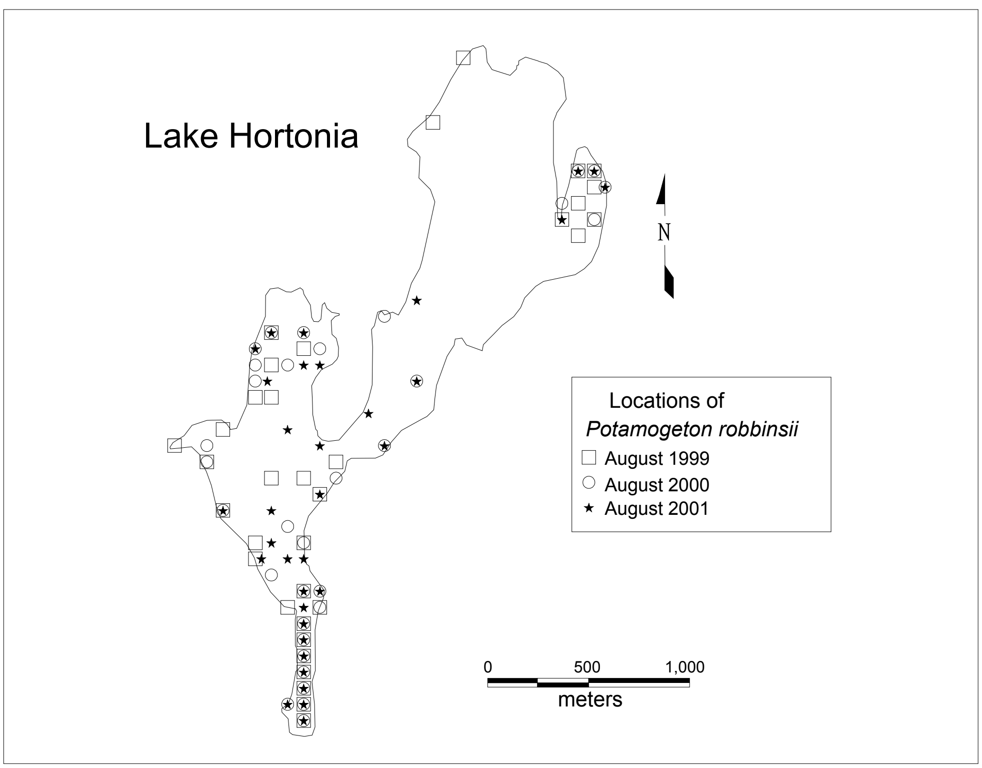

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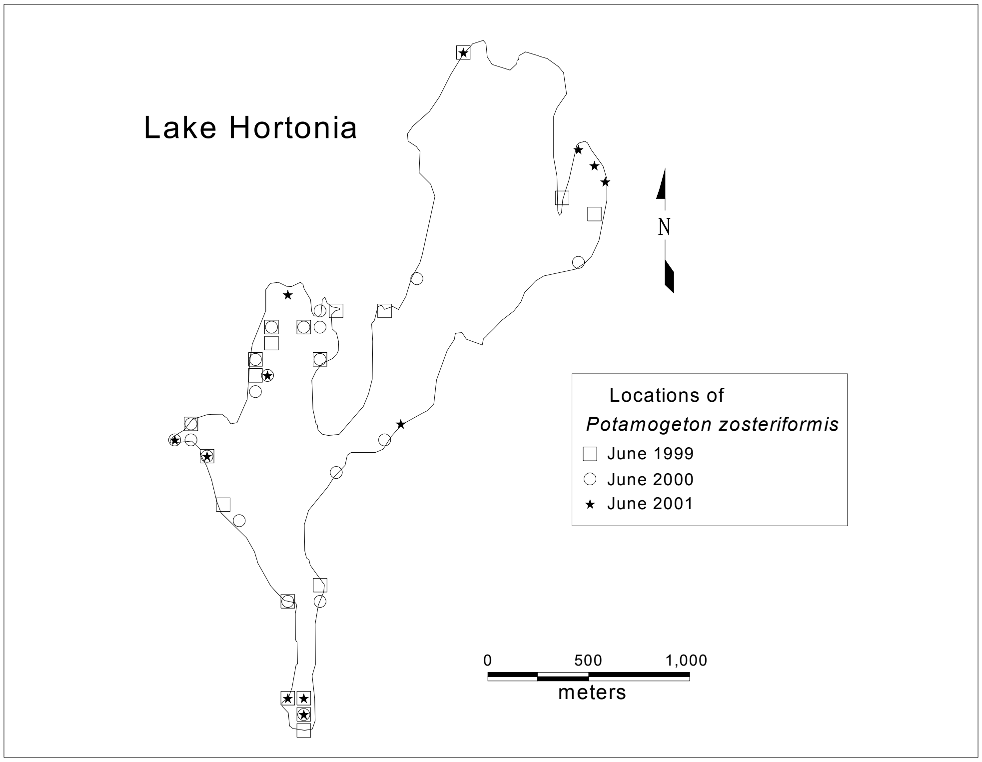
Figure C13. Map illustrating Lake Hortonia locations where *Potamogeton robbinsii* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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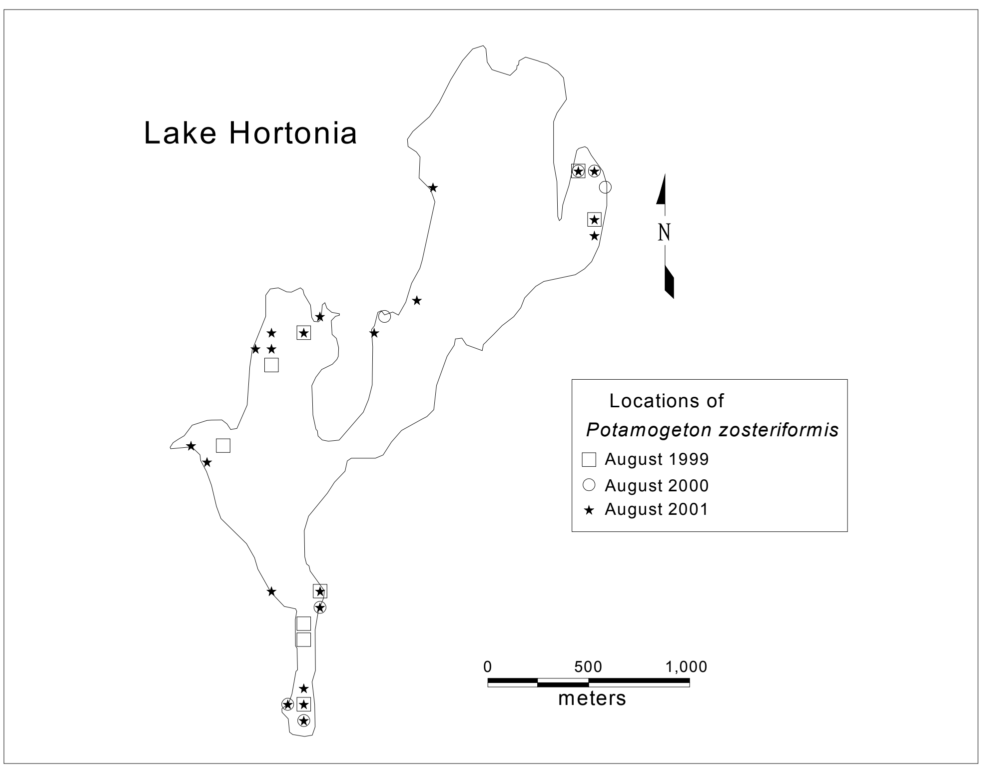

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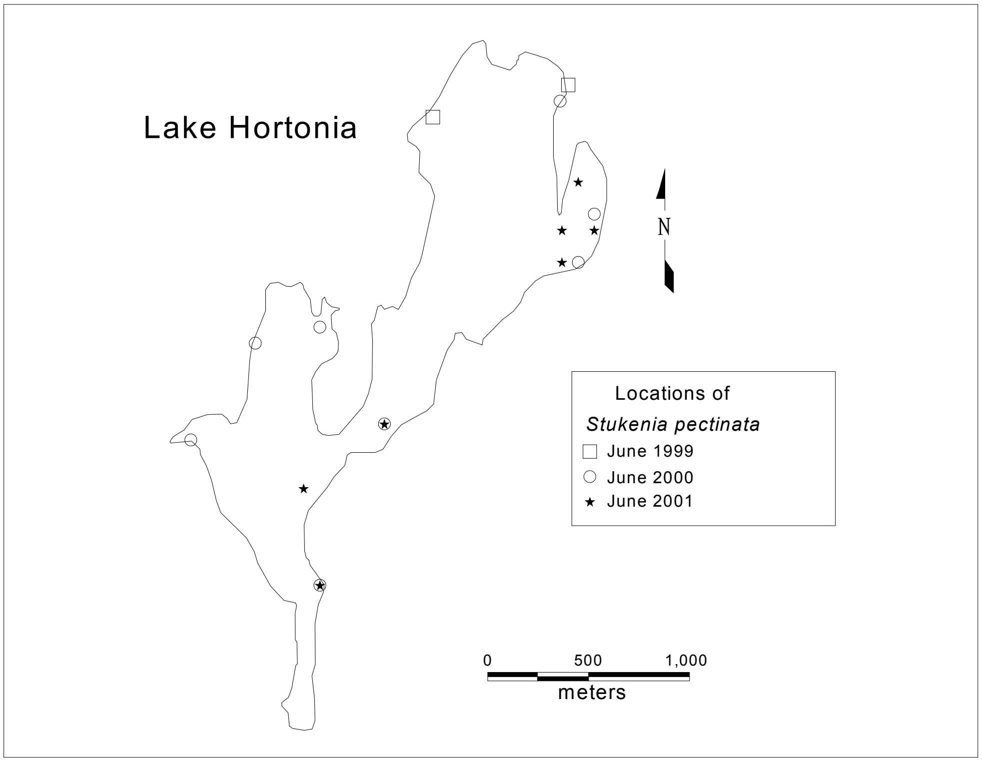
Figure C14. Map illustrating Lake Hortonia locations where *Potamogeton zosteriformis* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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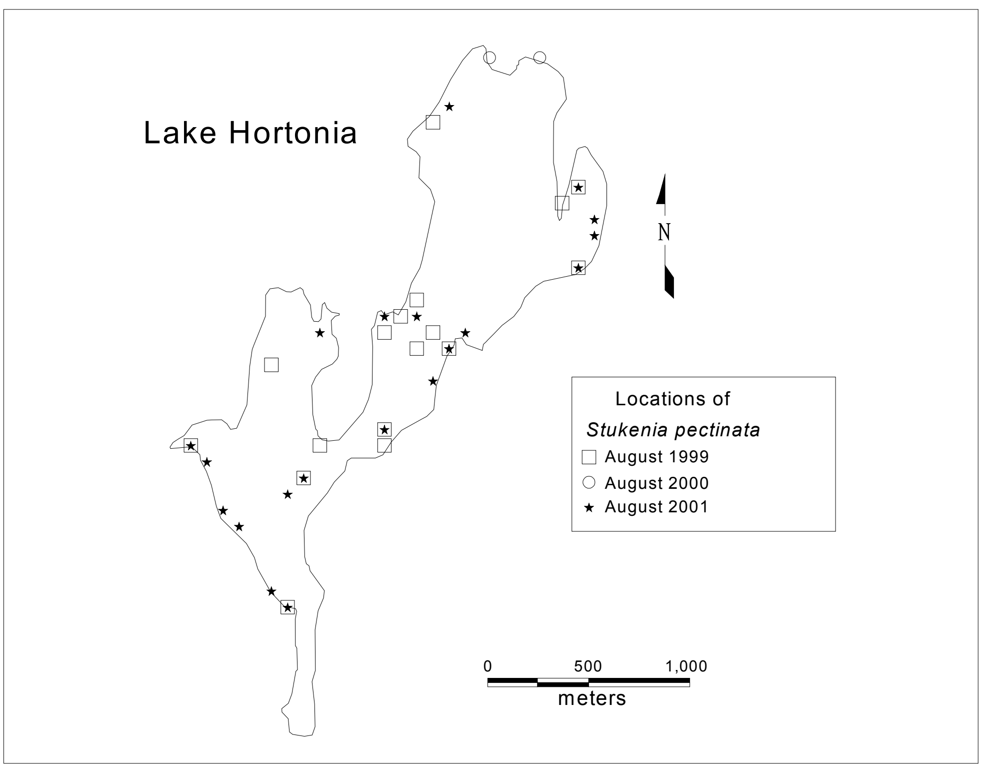

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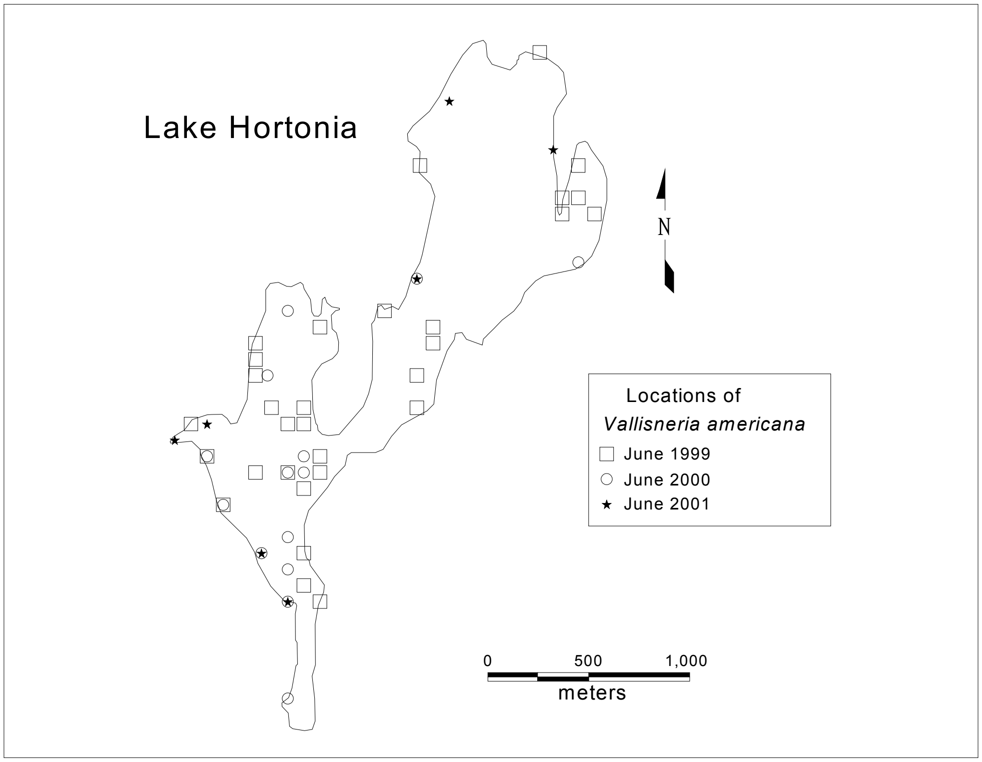
Figure C15. Map illustrating Lake Hortonia locations where *Stukenia pectinata* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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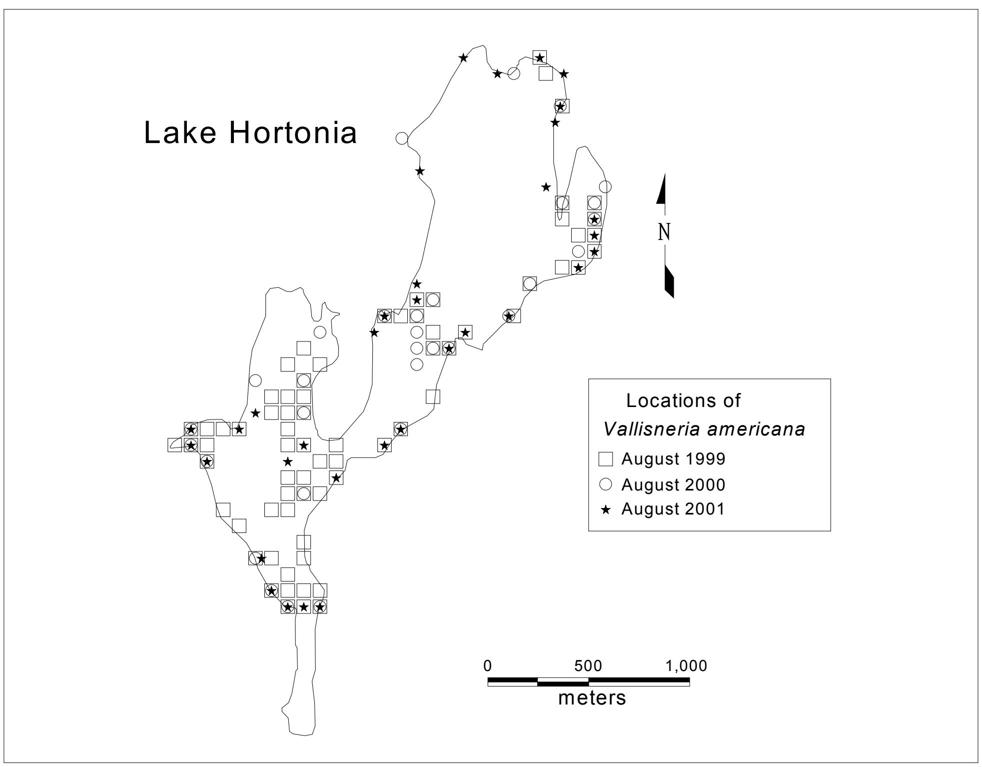

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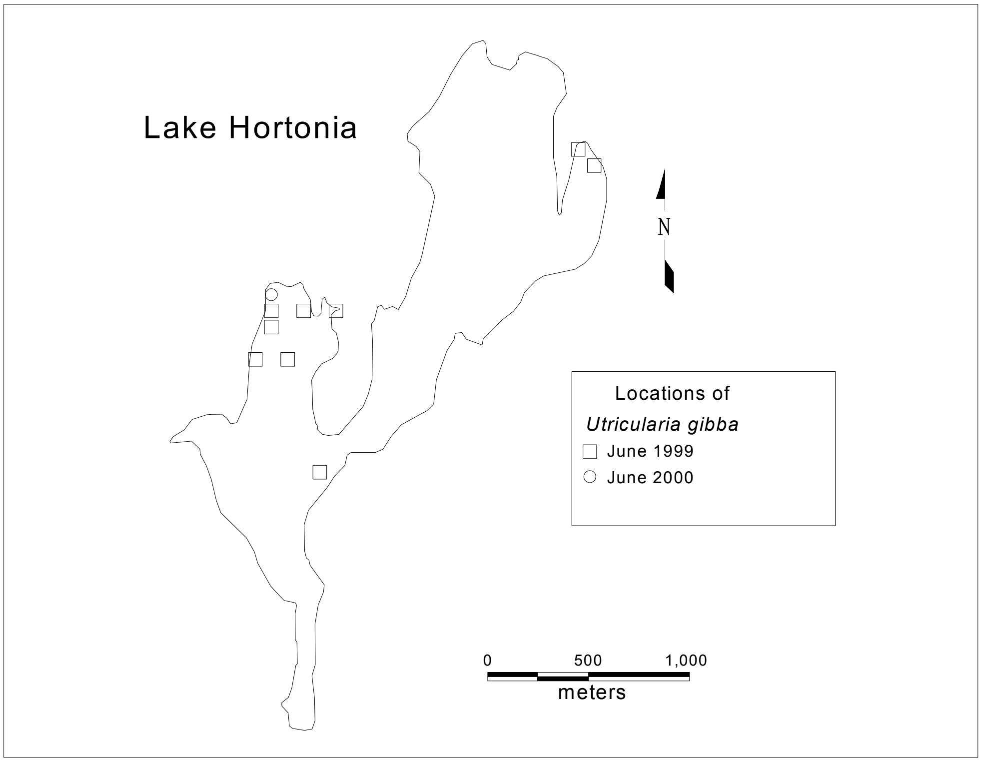
Figure C16. Map illustrating Lake Hortonia locations where *Vallisneria americana* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001



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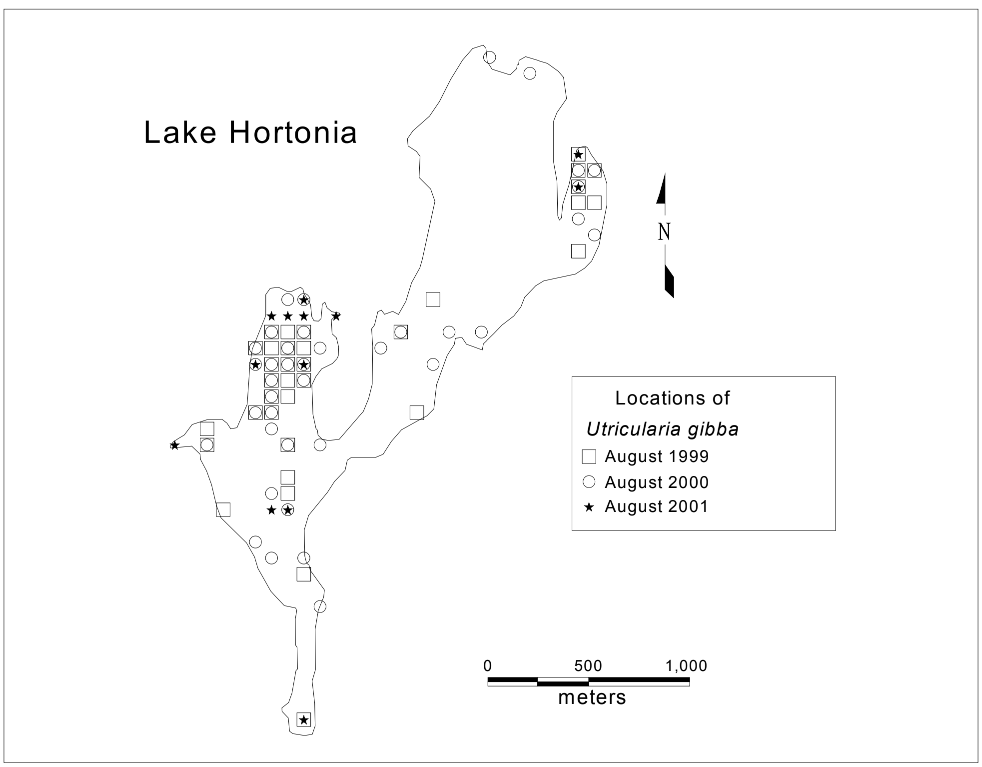

b) August Surveys

Figure C17. Map illustrating Lake Hortonia locations where *Utricularia gibba* was collected during June and August point-intercept sampling efforts in 1999, 2000, and 2001

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14. ABSTRACT

One method of selectively managing the invasive submersed plant *Myriophyllum spicatum* L. (Eurasian watermilfoil) in northern lakes is to treat the entire water body with low doses (6 to 8 $\mu g\ L^{-1}$) of the herbicide fluridone (1-methyl-3-phenyl-5-(3-(trifluromethyl)-phenyl)-4(1H)-pyridinone). A 3-year study (1999-2001) was conducted at Burr Pond and Lake Hortonia, Vermont, to determine whether submersed plant diversity and frequency of occurrence were impacted by whole-lake, low-dose fluridone applications in the year of treatment, and beyond, when targeting for control of *M. spicatum*.

Bathymetric maps of both lakes were developed using fathometers and global positioning system techniques in May 2000, which was matched with thermocline data (29 May 2000 – Lake Hortonia only) to determine the amount of herbicide required to achieve the target concentration (6 $\mu g\ L^{-1}$ of fluridone) in each lake. On 4 June 2000, Burr Pond (34.5 ha; average depth, 4.4 m) and Lake Hortonia (195 ha; average depth, 5.8 m) were treated to achieve a nominal rate of 6 $\mu g\ L^{-1}$ of fluridone using the aqueous suspension (AS) formulation Sonar® AS. Both lakes were subsequently treated with a booster application of Sonar AS on 9 July 2000, 35 days after the initial treatment to re-set the whole-lake concentration to 6 $\mu g\ L^{-1}$ of fluridone. Water samples were collected at various locations on both lakes from immediately prior to application through 116 days after treatment (DAT), and were analyzed for fluridone using immunoassay.

(Continued)

15. SUBJECT TERMS

Aquatic herbicide	Invasive species	*Myriophyllum spicatum*
Aquatic plant control	Low-dose herbicide	Sonar

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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SePRO Corporation, Carmel, IN 46032-4565

14. (Concluded

Plant species frequency of occurrence data were collected using a whole-lake grid system on both lakes, and a differential global positioning system unit was used to locate each intercept point on the grid in the field. Plant samples were collected at 30 random intercept points on each lake using 0.1-m^2 quadrats and SCUBA divers and analyzed for dry weight biomass. Species frequency of occurrence and biomass data were collected twice per season (June and August) from 1999 through 2001. Plant species occurrences were also determined for 1-m increments along transect lines through adjacent wetlands at both lakes during each August survey.

In Burr Pond, water residues at 1 DAT indicated that the whole-lake aqueous concentration was 9.9 $\mu g\ L^{-1}$ fluridone, which had exceeded the nominal treatment rate of 6 $\mu g\ L^{-1}$. This level declined to 6.3 $\mu g\ L^{-1}$ by 10 DAT, and to 4 $\mu g\ L^{-1}$ by 29 DAT. Following the booster application, whole-lake aqueous residues recovered to 5.6 $\mu g\ L^{-1}$, and slowly declined to a level of 2.5 $\mu g\ L^{-1}$ by 103 DAT. In Lake Hortonia, water residues at 1 DAT indicated that the whole-lake aqueous concentration was 6.3 $\mu g\ L^{-1}$ fluridone, very near the nominal treatment rate. This level declined to 3.8 $\mu g\ L^{-1}$ by 29 DAT. Following the booster application, whole-lake aqueous residues recovered to 6.1 $\mu g\ L^{-1}$, and slowly declined to a level of 2.8 $\mu g\ L^{-1}$ by 116 DAT.

In Burr Pond, pretreatment surveys showed a widespread and diverse plant community, with 22 species recorded in the open-lake zone, and native species richness ranged from 1.21 (June 1999) to 1.43 (August 1999) species per sampling point. *Myriophyllum spicatum* was the most common plant, occurring >55 percent of the points sampled and was the only exotic species observed. Predominant native species included *Chara* spp., *Elodea canadensis*, *Potamogeton amplifolius*, and *Vallisneria americana*. By 2 months posttreatment (August 2000), *M. spicatum* was found at significantly lower levels (~40 percent), while by 14 months posttreatment (August 2001) its occurrence had been reduced >85 percent of pretreatment levels. Biomass of *M. spicatum* was reduced by 92 percent within 2 months posttreatment and remained extremely low (-99 percent) by 14 months posttreatment (August 2001). Of 20 native species collected at pretreatment (August 1999), 18 were present at 14 months posttreatment (August 2001). While several native species experienced significant reductions in occurrence following the herbicide treatment (such as *Ceretophyllum demersum*, *E. canadensis*, *M. sibiricum*, *Najas flexilis*, *P. gramineus*, *P. illinoensis*, and *V. americana*), >47 percent of the sampling points remained vegetated by natives. The treatment did not have a major impact on overall abundance of natives, as total biomass of all native species was not significantly reduced following treatment. The treatment did not cause significant impacts to the aquatic plant community in the adjacent wetland areas.

In Lake Hortonia, pretreatment surveys showed a widespread and diverse plant community, with 22 species recorded in the open-lake zone. *Myriophyllum spicatum* and *P. crispus* comprised the exotic species. Native species richness ranged from 1.57 (June 1999) to 1.83 (August 1999) species per sampling point. *Myriophyllum spicatum* was the most common species occurring in >54 percent of the points sampled and dominated pretreatment biomass accounting for >76 percent of the total plant mass. Predominant native species included *Chara* spp., *E. canadensis*, *P. amplifolius*, *P. robinsii*, and *V. americana*. By 2 months posttreatment (August 2000), *M. spicatum* was found at significantly lower levels (~45 percent), while by 14 months posttreatment (August 2001), the plant had been reduced >85 percent of pretreatment levels. Biomass of *M. spicatum* was reduced by 80 percent within 2 months posttreatment and remained extremely low (-96 percent) by 14 months posttreatment (August 2001). While some native species experienced significant reductions in occurrence following the herbicide treatment (such as *C. demersum*, *E. canadensis*, *M. sibiricum*, *N. flexilis*, *P. gramineus*, *P. illinoensis*, and *V. americana*), >51 percent of the sampling points remained vegetated by natives. The treatment did not have a long-standing impact on overall abundance of native species, as total biomass of all natives returned to pretreatment levels by 14 months post-treatment. Although an increase in the exotic species *P. crispus* was measured, it had not attained widespread nuisance levels by August 1999. The treatment did not cause significant impacts to the aquatic plant community in the adjacent wetland areas.

When using low-dose whole-lake fluridone applications, acceptable control of *M. spicatum* (~55-percent reduction in frequency, ~90-percent reduction in biomass) can be achieved in the year-of-treatment, while good control (~85-percent reduction in frequency, ~95-percent reduction in biomass) can be achieved by 1 year post-treatment. Overall cover, species richness, and biomass of native plants can be maintained at levels supportive of good fish and wildlife habitat (20- to 40-percent littoral zone vegetative cover). In order to provide consistent, precise, and selective control of *M. spicatum* using low doses of fluridone on a whole-lake basis, it is recommended that factors such as accurate lake bathymetry, pretreatment thermocline information, rapid water residue analysis, and plant injury assessments be coupled with established fluridone concentration and exposure time relationships.