Nontarget Aquatic Plant Species Responses from 2007 Spot Treatments of Triclopyr in Lakes Morey and St. Catherine, Vermont

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Introduction

A few Agency of Natural Resources (Agency) biologists have recently voiced concerns over the effects of Vermont lake herbicide treatments on nontarget aquatic plants. The target plant species of these treatments is the invasive exotic Eurasian watermilfoil (*Myriophyllum spicatum* L.). The primary concern is that a loss or reduction of nontarget, and sometimes target, plant species poses a potential impact on habitat quality for those fish species reliant on aquatic vegetation for various life history stages. Concern has also been expressed over the possible elimination of certain nontarget plant species sensitive to herbicide treatments. In addition, the potential for low dissolved oxygen levels within treated areas that may result from decomposition of large amounts of plant material following herbicide treatments and potential impact on fish has also been identified as a concern.

The control of Eurasian watermilfoil populations in Vermont waterbodies has included hand pulling, benthic barriers, stocking of the Eurasian watermilfoil weevil, mechanical controls (e.g. harvesting, suction harvesting) lake level drawdowns, and lake-wide and spot treatments using aquatic herbicides. Currently, the only two aquatic herbicides requested for use and subsequently permitted by the Agency to date are formulations of fluridone and triclopyr, both systemics. Triclopyr is applied to only a portion of a lake, referred to as spot treatment, while fluridone is applied over the entire waterbody above the thermocline and is referred to as whole-lake treatment.

A few Agency biologists speculated that even short-term losses of nontarget plants during the year of treatment may impact fish predator-prey relationships by removing vegetative protection for prey fish species and exposing them to increased predation. The temporary reduction of plant density experienced during the same year of treatment may not be fully documented by a plant survey conducted the following year. Past Aquatic Nuisance Control permits issued for aquatic herbicide use have required follow-up plant surveys the year of treatment and only one year following. Since 2006, an additional follow-up plant survey two years following treatment has also been required as a permit condition.

The goal of this study is to qualitatively assess nontarget plant impacts from 2007 treatments of triclopyr in two Vermont lakes. Treatment effects are evaluated in terms of nontarget plant species richness and the relative amount of plant density. The current study is limited to a report and discussion of data collected from the two 2007 treated lakes. No attempt was made to present a literature review on nontarget impacts of triclopyr treatments.

Methods

Lake Morey in Fairlee, Vermont is a 547-acre waterbody with a maximum depth of 43 feet and an average depth of approximately 24 feet. Eurasian watermilfoil was first confirmed in the lake in 1991 and has been the target of on-going management in an effort to control and prevent lakewide spread. Lake St. Catherine in the towns of Poultney and Wells, Vermont is a 904-acre waterbody with an average depth of 37 feet. Eurasian watermilfoil was first confirmed in the lake in 1983. The triclopyr spot treatments in Lake Morey occurred on June 24, 2007. Two formulations of triclopyr were used:

Renovate OTF, a flake formulation, applied at a concentration of 1.85 ppm (in the bottom four feet of water) in three areas, totaling 15 acres along north, east and west shores, and Renovate 3, a liquid, applied at 1.5 ppm in one area in the north end, 30 acres in size (see Appendix 1). Lake St. Catherine was treated on July 17, 2007 with Renovate OTF at 1.75 ppm (in the bottom four feet of water) in two areas, totaling 15 acres on the east and west shores (see Appendix 2).

The study design compared plant composition, pre- and post-treatment, at both treated and untreated sites (plots). Two control plots (untreated) and four plots within treated areas (treatment plots) were included for Lake Morey, and two control and two treated plots were established for Lake St. Catherine. Study plots were a subset of point intercept sampling points established by Aquatic Control Technology, Inc. (ACT), the contractor who conducted the aquatic vegetation surveys on both lakes (Aquatic Control Technology, Inc., 2007a, b). ACT generated a total of 166 data points based on an 80-m grid throughout the littoral zone for Lake Morey. A total of 218 data points were established for Lake St. Catherine (includes points in Lily Pond and Little Lake). In general, study plots were selected from a central point at each of treated and untreated sites. For untreated plots, a point was selected that contained a mix of plant species. Sample plot depths of 1.0 to 2.0 m were selected to facilitate snorkeler observations and photography. Each plot was identified with a J-shaped section of rebar (pin) that was driven into the substrate and marked by plastic flagging, a small plastic jug or both. During some sampling events, the pin could not be located and sampling occurred at the latitude/longitude location for that plot. Point intercept sampling points and study plots are shown in Appendix 1 for Lake Morey and Appendix 2 for Lake St. Catherine.

Plots in each lake were sampled once prior to treatment and at approximately one-month intervals following treatment for three months in Lake Morey and two months in Lake St. Catherine. Snorkeler observations of aquatic plant species occurrence (presence/absence) at each site were recorded during each sampling event. Photographs were taken at each plot to visually assess plant structure and physical presence during the course of the summer months. The snorkeler, deployed directly over the plot pin, took photos at approximately 0.5 m below the surface. A photo was taken of the pin on the lake bottom and a photo parallel to the lake bottom outward from the pin at each of the four primary compass directions (north, east, south and west) for a total of five frames per plot.

Directional photos were analyzed by assigning a numerical value to the coverage of plant density (target and nontarget) included in the photo as follows: heavy - 3, moderate - 2, light – 1 and no vegetation - 0. Values were independently assigned by two biologists. The two observers agreed 75% of the time for Lake Morey and 69% on Lake St. Catherine. Disagreements were expressed as an average of the two estimates. Numeric plant density estimates from the four directional photos taken at each plot were averaged to represent the density for each plot per visit.

Dissolved oxygen was measured during one sampling visit to Lake Morey using a Hydrolab water quality sonde. Measurements were taken at the surface, and at 0.5, 1.0 and 1.5 m depths. The 1.5 m depth generally corresponded with the bottom at each plot.

RESULTS

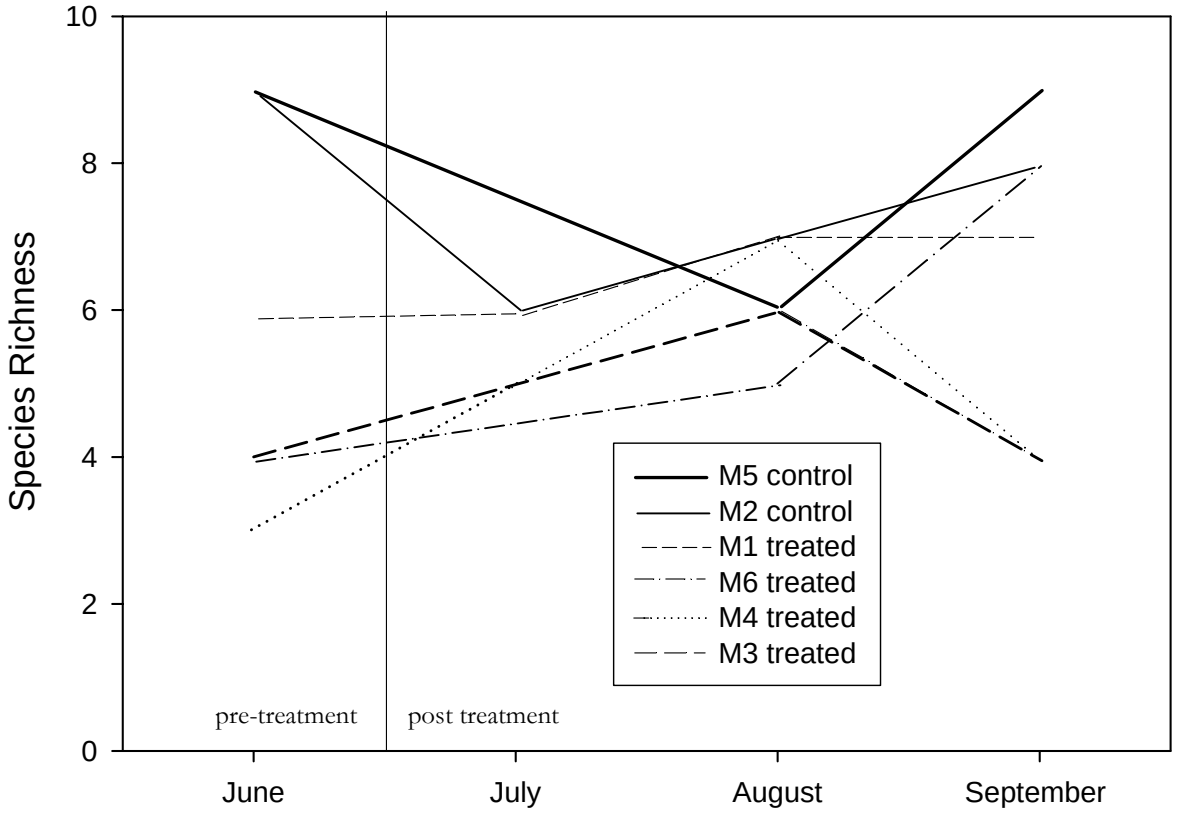
Lake Morey

Nontarget Plant Species Occurrence

Untreated plots. Nontarget aquatic plant species occurrence data for the untreated plots were collected to provide a picture of temporal variation unrelated to the triclopyr treatment. Untreated Plot M5 showed fairly consistent species occurrence between the June, August and September visits (Appendix

3). No observations were made for the July date due to inability to locate the pin at that plot. Seven out of a total of ten species at this plot were recorded on all three sampling dates. Species richness per visit was 9 pre-treatment, and 6 and 9 post-treatment (Figure 1). The other untreated plot (M2) had a more dynamic species assemblage with only 4 of 12 species being recorded during all four dates. Species richness by date was 9 pre-treatment, and 6, 7 and 8 post-treatment (Figure 1).

Figure 1. Total nontarget aquatic plant species richness for two untreated and four treated plots from Lake Morey, Vermont 2007.



Untreated Plots M5 and M2 supported a combined 13 species pre-treatment and 11 species post treatment. Table 1 shows how these 15 species recorded from the untreated plots changed between monthly visits with respect to the June pre-treatment occurrence. Four of the fifteen species (27%) (indicated in Table 1 as ' - ') were found before treatment but not post-treatment. Two species (13%) were found only post-treatment and were depicted by a '+' in Table 1. All occurrence data indicate that species richness by date declined slightly at the two untreated plots over the course of the summer.

Table 1. Trends of occurrence for each nontarget aquatic plant species in relation to the pre-treatment observation date and the two to three post-treatment observation dates at untreated and triclopyr-treated plots in Lake Morey, Vermont 2007. Symbols in columns indicate species presence before and after treatment (=), before but not after treatment (-) or only after treatment (+). Number of symbols corresponds with number of plots where each species was found. "Absent" means that species was not found.

Species	**Untreated Plots (n=2)[1]**	**Treated Plots (n= 4)[1]**
Ceratophyllum demersum	-	+ = =
Chara sp.	-	absent
Eleocharis acicularis	-	absent
Elodea canadensis	=	absent
Megalodonta beckii	= =	+ = =
Najas flexilis	=	+ + + +
Nitella sp.	absent	+
Nymphaea sp.	absent	+
Potamogeton amplifolius	= =	= =
P. gramineus	= =	- +
P. illinoensis	=	+ +
P. obtusifolius	absent	+
P. pusillus spp. *pusillus*	= +	=
P. robbinsii	+	+ = = =
P. zosteriformis	-	+ =
Sagittaria sp.	+ +	absent
Valisinaria americana	= =	+ =
Zosterella dubia	= +	+ = = =

[1] Status in relation to June pre-treatment species occurrence

Treated plots. Plots M1, M4 and M6 were located within Renovate OTF-treated areas, and Plot M3 was within the Renovate 3-treated area. Species occurrence at the four treated plots generally varied between visits. No observations were made during the July visit for Plots M3 and M6 due to inability to locate the pin at those sites. In contrast with the two untreated plots, richness appeared to *increase* or remain about the same at these sites from June to September (Figure 1). The four treated plots supported a combined 9 plant species pre-treatment and 14 plant species post-treatment. Appendix 1 illustrates that no species was consistently lost following treatment at all four plots. Two species (*Potamogeton gramineus*, *Ceratophyllum demersum*) were not found after the treatment at two of the treated plots, but were found *only after* treatment at the other two treated plots. Five of the fourteen species (36%) were identified in plots only after treatment.

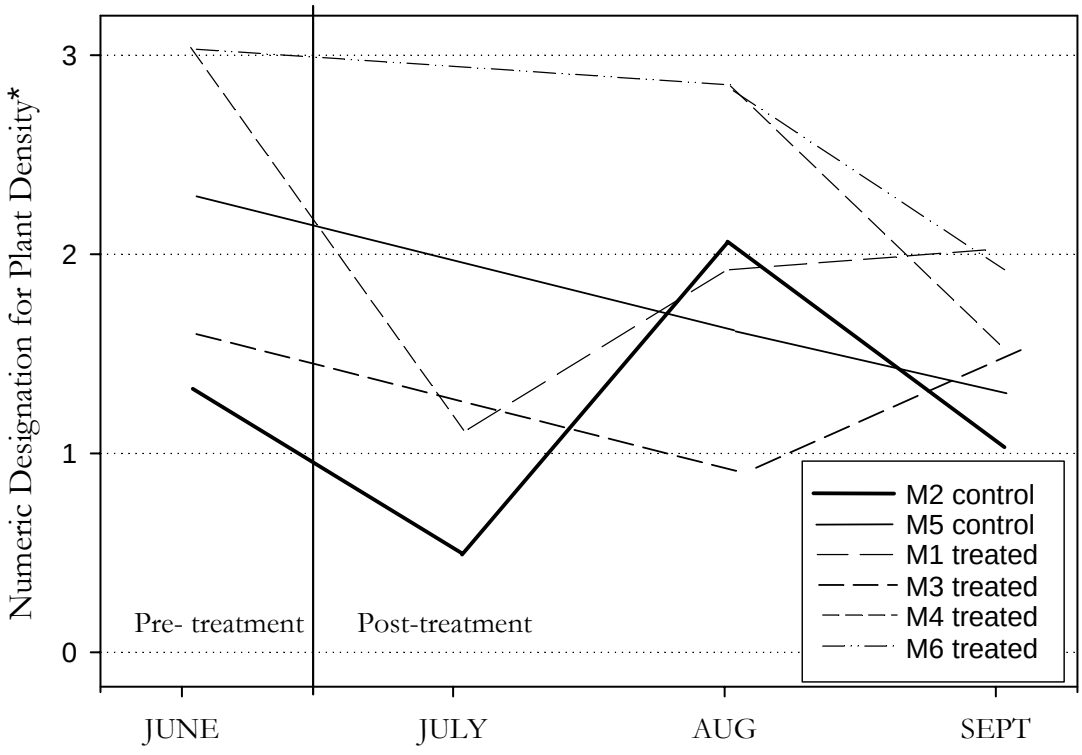
Photographic Assessments of Plant Density

Untreated Plots. Photographs taken from 0.5 m below the surface towards the pins on the lake bottom showed consistently dense total plant cover throughout the summer at the two untreated plots (Appendix 4). Directional photos taken at Plot M2 showed no apparent trend in growth with plant density dropping from *light*-to-*moderate* in June to *very light* in July followed by *moderate* in August and finally decreasing to *light* in September (Appendix 4, Table 2). Photos taken from Plot M5 showed more consistency with *moderate* growth in June, and *light*-to-*moderate* growth in August and September (Appendix 4, Table 2). No July assessment was made for Plot M5.

Table 2. Numeric scores for categorical aquatic plant density estimates from one photograph taken at each of the four compass points from two untreated and four triclopyr-treated plots in Lake Morey, Vermont 2007. Values correspond with subjective assessments in a photographic frame as 3-heavy, 2-moderate, 1-light, 0-none visible and "na"– not assessed.

Plot Number	Date Sampled	Compass Direction of Photo				
		North	East	South	West	Mean
Untreated Plots						
M2	20-Jun-07	2.0	1.0	1.0	1.0	**1.3**
	24-Jul-07	1.0	1.0	0.0	0.0	**0.5**
	22-Aug-07	2.0	2.0	2.0	2.0	**2.0**
	18-Sep-07	1.0	1.0	1.0	1.0	**1.0**
M5	20-Jun-07	2.0	3.0	2.0	2.0	**2.3**
	24-Jul-07	na	na	na	na	**-**
	22-Aug-07	2.0	1.5	2.0	1.0	**1.6**
	18-Sep-07	2.0	1.0	1.0	1.0	**1.3**
Treated Plots						
M1	20-Jun-07	na	na	na	na	**-**
	24-Jul-07	1.0	2.5	0.0	1.0	**1.1**
	22-Aug-07	1.5	3.0	1.0	2.0	**1.9**
	18-Sep-07	3.0	2.5	1.0	1.5	**2.0**
M3	20-Jun-07	3.0	1.5	1.0	1.0	**1.6**
	24-Jul-07	na	na	na	na	**-**
	22-Aug-07	0.0	0.0	1.5	2.0	**0.9**
	18-Sep-07	2.0	1.0	1.0	2.0	**1.5**
M4	20-Jun-07	3.0	3.0	3.0	3.0	**3.0**
	24-Jul-07	1.0	1.5	1.0	1.0	**1.1**
	22-Aug-07	3.0	2.0	3.0	3.0	**2.8**
	18-Sep-07	1.5	1.5	1.0	1.0	**1.3**
M6	20-Jun-07	3.0	3.0	3.0	3.0	**3.0**
	24-Jul-07	na	na	na	na	**-**
	22-Aug-07	3.0	3.0	3.0	2.0	**2.8**
	18-Sep-07	1.5	2.0	2.0	2.0	**1.9**

Figure 2. Relative aquatic plant density as assessed by directional photographs at two untreated and four triclopyr-treated plots in Lake Morey, Vermont 2007.



* 3= Heavy, 2=Moderate, 1=Light, 0-None

Treated Plots. Photographs taken from approximately 0.5 m below the surface towards the pins on the lake bottom showed, as with the untreated plots, consistently dense total plant cover throughout the pre-and post-treatment visits. No directional photos were taken at treated Plots M1 in June, and M3 and M6 in July due to failure to find pins or loss of photos. The lack of directional photos from June (M1) and July (M3, M6) made it difficult to clearly determine consistent trends in the four treated plots. Despite this, available data show no evidence of an extended trend of decreasing plant density in the four treated plots. At Plot M1, the three post-treatment assessments were *light, moderate* and *moderate* respectively, showing an increase in density with time (Figure 2). Plot M3 had a pre-treatment density of *light*-to-*moderate,* followed by a *light* in August and a *light*-to-*moderate* during September. Plot M4 began the study with *heavy* growth, falling to *light* the following month, increasing to *heavy*- to-*moderate* in August and finally dropping to *light*-to-*moderate* in September. As in Plot M4, the three rounds of photographs from Plot M6 showed *heavy* growth during pre-treatment, dropping slightly to *heavy*-to-*moderate,* then to *moderate* in September. The two available July observations from treated Plots M1 and M4 showed *light* densities (average value 1.1). No pretreatment directional photos were available for Plot M1, but directional photos for Plot M4 clearly indicated lower density in July than in June, possibly showing the effects of the triclopyr on the target species, Eurasian watermilfoil. It can be noted that post-treatment densities at all four treated plots supported between *light* and *moderate* densities of plants of varying height throughout the three post-treatment site visits, indicating that habitat structure was present for fish.

Dissolved Oxygen. Measurements were taken during the August sampling event at both treated and untreated plots. Dissolved oxygen levels for all plots were consistently between 6.2 and 6.7 ppm ranging from 95-102% saturation (Appendix 5).

Lake St. Catherine

Nontarget Plant Species Occurrence

Untreated Plots. Nontarget plant species occurrence at both untreated plots varied between the three visits of July, August and September. At untreated Plot SC1, a total of 6 species were noted during the summer. Of the 6, only 1 was consistently present during all three visits. Species richness by sample date for Plot SC1 was 5, 3 and 2 (Appendix 6, Figure 3). At untreated Plot SC3, only 3 of the total 10 species were observed during all three visits. Species richness increased from 6 in July to 7 during both August and September. The combined richness from untreated Plots SC1 and SC3 was 8 species before the treatment (July) and 9 species post-treatment (August and September). Table 3 shows how the combined 10 total species recorded from these plots changed between the monthly visits with respect to the July pre-treatment occurrence. Three species were present before the treatment date but not observed after that and four species (44%) were found only *after* the treatment, in August and September (Appendix 6).

Figure 3. Total nontarget aquatic plant species richness for two untreated and two treated plots from Lake St. Catherine, Vermont 2007.

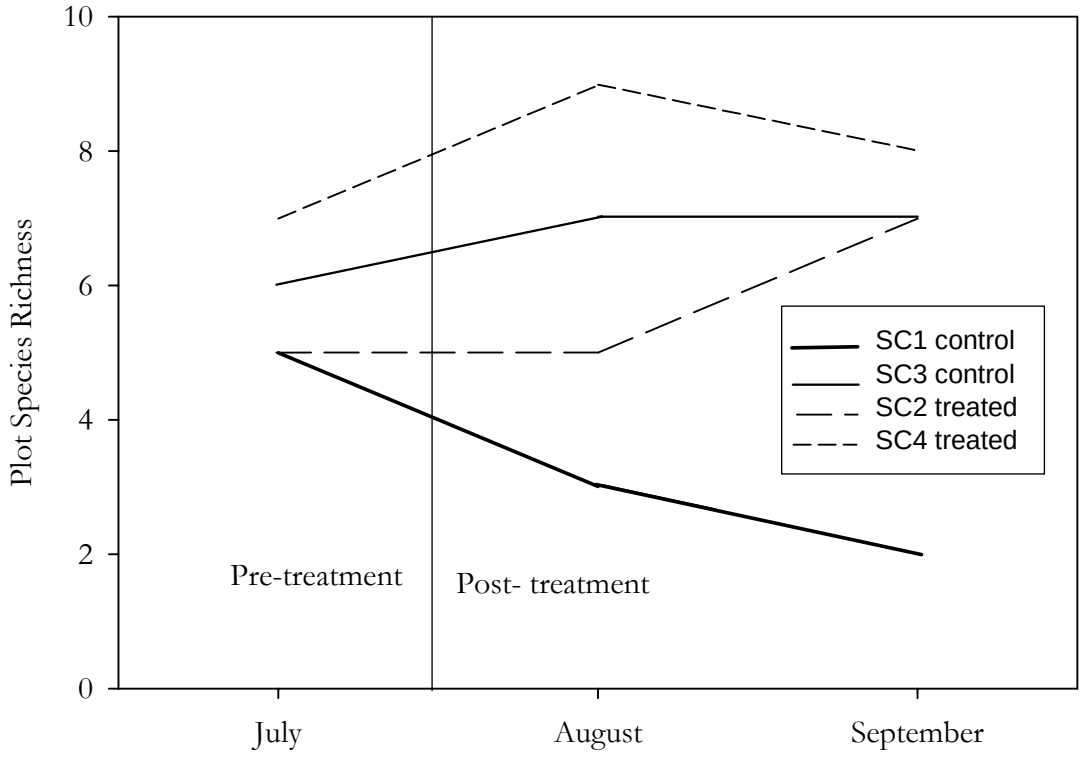


Table 3. Trends of occurrence for each non-target aquatic plant species in relation to the pre-treatment observation date at untreated and triclopyr-treated plots in Lake St. Catherine, 2007. Symbols in columns indicate species presence before and after treatment (=), before but not after treatment (-) or only after treatment (+). Number of symbols corresponds with number of plots where each species was found. "Absent" means that species was not found.

Species	**Untreated Plots (n=2)** [1]	**Treated Plots (n=2)** [1]
Ceratophyllum demersum	absent	+
Chara sp.	absent	+
Elodea canadensis	absent	= +
Isoetes sp.	+	absent
Megalodonta beckii	absent	- (1 plant)
Najas sp.	-	absent
N. flexillis	- =	= =
Nitella sp.	absent	=
P. amplifolius	absent	= =
P. crispus	- -	=
P. gramineus	+	absent
P. illinoensis	+	+
P. pusillus ssp. *pusillius*	+	absent
P. spirillus	-	absent
P. robbinsii	= =	= =
P. zosteriformis	=	+
Sagittaria sp.	=	-
Valisneria americana	absent	+
Zosterella dubia	= +	= +

[1] Status in relation to July pre-treatment species occurrence

Treated Plots The two treated plots (SC2 and SC4) showed generally the same inconsistency between the three sample dates as did the untreated plots. Only 4 of 7 species were recorded during all three dates at Plot SC2, while 3 of 12 were consistently recorded at Plot SC4 (Appendix 6, Figure 3). Species richness per sampling date was 5, 5 and 7 at Plot SC2, and 7, 9 and 8 at Plot SC4. For both treated plots combined, 8 species were identified before treatment and 12 after treatment. Two species (14%), *Megalodonta beckii* and *Sagittaria* sp., were found only *before* the treatment, while 5 species (36%) were found only *after* the treatment (Appendix 6).

Photographic Assessments of Plant Density

Untreated Plots Photographs taken from approximately 0.5 m below the surface towards the pins on the lake bottom showed consistently heavy vegetative growth and cover during all three sampling months in both untreated plots, SC1 and SC3 (Appendix 7). The directional photographs taken at the untreated PlotSC1 showed that total aquatic plant density, expressed by the average of the four numeric values, increased consistently from July to September from *light*-to-*moderate* to *moderate* and *heavy* (Appendix 7, Table 4). Untreated Plot SC3, began at *light*-to-*moderate* shifted to *moderate*-to-*heavy* and then decreased to *moderate*-to-*light* (Table 4, Figure 4).

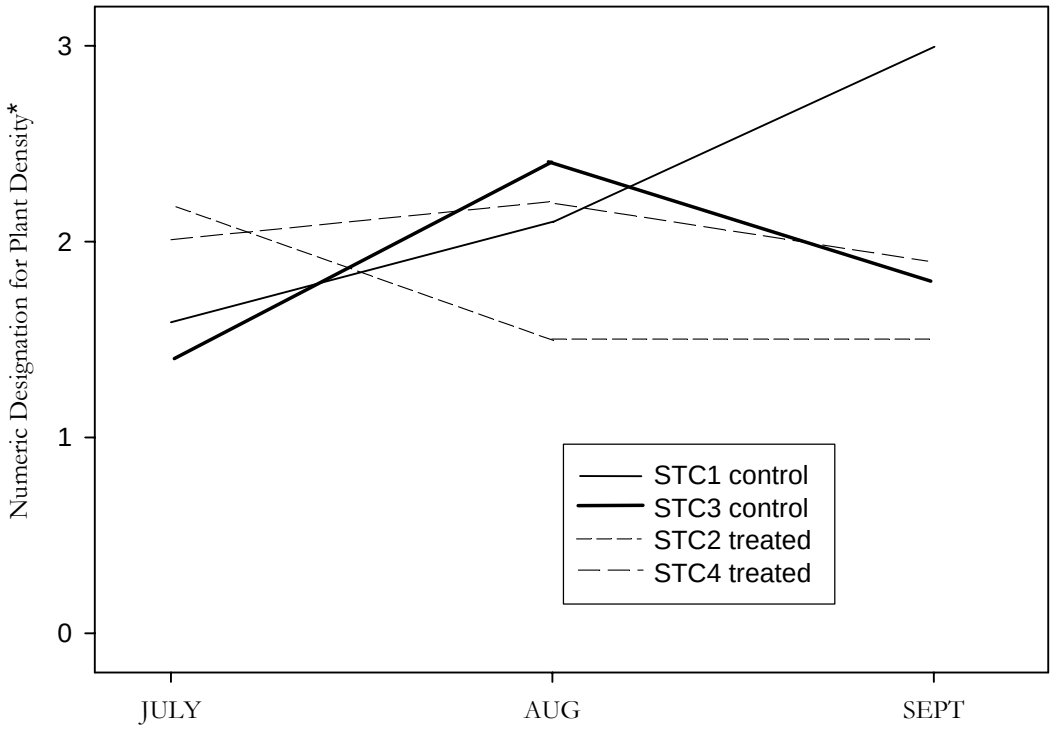
Treated Plots Photographs taken from approximately 0.5 m below the surface towards the pins on the lake bottom showed consistently heavy vegetative growth and cover during all three months. Vegetation at both two treated plots (SC2, SC4) in July was *moderate*. August levels dropped at Plot SC2

from *moderate* to *light*-to-*moderate*. At Plot SC4, plant density remained approximately the same (*moderate)* throughout the observational period (Table 4, Figure 4).

Table 4. Numeric scores for categorical aquatic plant density estimates from one photograph taken at each of the four compass points from two untreated and two triclopyr-treated plots in Lake St. Catherine, 2007. Values correspond with subjective assessments in a photographic frame as 3-heavy, 2-moderate, 1-light and 0-none visible.

Plot Number	Date Sampled	Compass Direction of Photo				
		North	East	South	West	**Mean**
Untreated plots						
STC 1	11 Jul	1.0	1.5	2.0	2.0	**1.6**
	13 Aug	1.0	1.5	3.0	3.0	**2.1**
	13 Sep	3.0	3.0	3.0	3.0	**3.0**
STC 3	11 Jul	1.5	1.5	1.5	1.0	**1.4**
	13 Aug	2.0	3.0	2.5	2.0	**2.4**
	13 Sep	2.5	1.5	2.0	1.0	**1.8**
Treated Plots						
STC 2	11 Jul	3.0	3.0	2.0	1.0	**2.2**
	13 Aug	1.0	1.0	2.0	2.0	**1.5**
	13 Sep	1.0	1.0	2.0	2.0	**1.5**
STC 4	11 Jul	2.0	2.0	2.0	2.0	**2.0**
	13 Aug	2.0	3.0	2.0	2.0	**2.2**
	13 Sep	0	2.5	2.5	2.5	**1.9**

Figure 4. Relative aquatic plant density as assessed by photographs at two untreated and two triclopyr-treated plots in Lake St. Catherine, Vermont 2007.



* 3= Heavy, 2=Moderate, 1=Light, 0-None

Discussion

Lake Morey

Plant species richness in the two untreated plots remained the same or dropped during the three post-treatment visits from the June high of 9 species each, to the September richness of 9 and 8 respectively. Plant species richness at one untreated plot was more consistent over time than the other. Species richness over the summer between treated plots was also inconsistent, with some plots showing 50% or more of the species present during all visits, while other plots experienced far fewer reoccurring species. No consistent trend was observed in species richness over time nor was there any clear loss of species noted after treatment. In fact, more species were identified during each visit *after* treatment than before treatment at three of the four treated plots. The fourth plot (M3) showed two less species during July followed by a drop to pre-treatment levels in September.

Photographic assessments of relative plant density at the two untreated plots failed to show any consistent seasonal trend in plant density. As a result, no expectations for trend can be established for the treated sites. Comparison may be made however, of post-treatment densities between treated and untreated plots. The mean August-September density value for the untreated plots was 1.5 (range 1.0-2.0). The mean August-September value for the four treated plots was 1.9 (range 0.9-2.8).

Photographic assessments of Plot M4 and perhaps M3 showed possible effects of triclopyr on the target Eurasian watermilfoil. Mean density scores were much lower in July at Plot M4 and moderately lower in August at Plot M3. At treated plots, the target species dominated pre-treatment photo frames and was absent or dramatically reduced during later visits.

There was no significant loss of native species richness or relative density at any of the treated sites following treatment. Bottom cover as assessed by the top-down photo showed luxurious, dense and often diverse growth during all assessment periods. The appearance of higher-growing plants varied after treatment but was always judged from *light* to *heavy*-to-*moderate* in the treated plots. Even when observed growth was *light* within the photo frame, lower growing plants still thickly covered the bottom, out of view of the directional photographs but documented in the top-down photos.

Lake St. Catherine

Species richness from snorkeler observations at the untreated plots (SC1, SC4) between July and September varied between the two plots, one increased slightly and the other clearly decreased. Species richness at the two treated plots (SC2, SC4) increased. Of a total of 13 species identified at the treated plots, only two, *Megalodonta beckii* and *Sagittaria* sp. were found before treatment and not after treatment (Plot SC4). The pre-treatment record (July) for *M. beckii* however, was represented by only a single plant. *M. beckii* may have been present in subsequent visits (August and September) but gone unnoticed. Alternately, 36% were identified only *after* the treatment, boosting the total treated plot richness during the August and September visits. Richness generally *increased* after the treatment for both treated and one untreated plot. The 2007 triclopyr treatment appeared to have no negative impact on species occurrence or richness.

Photographic evaluations at both treated and untreated plots consistently showed substantial plant growth during all site visits. Top-down photographs showed complete cover in both treated and untreated plots throughout all site visits. Treatment Plot SC2 showed a decline from *moderate* to

light-to-*moderate* plant density following the treatment, reflecting the reduction in Eurasian watermilfoil from the effects of triclopyr. The relative plant density at treatment Plot SC4 remained *moderate* throughout the summer. Treatment Plots SC2 and SC4, and control Plot SC3 supported at least a *moderate*-to-*light* plant density during the two post-treatment visits.

The only observable reduction in plant density following treatment was at treatment Plot SC2 where Eurasian watermilfoil was nearly eliminated by the treatment. Total plant density following the treatment was judged to be less, but it was comprised almost entirely by native species, many of which grew tall enough to be visible in photographs contributing to the *moderate* growth observed in half of the frames. Overall, there was no observable reduction in native aquatic plant species growth post-treatment at either of the two triclopyr-treated plots.

In directional photographic frames, most visible plants were ones that grew over a foot from the bottom. Plant growth less than about a foot from the bottom was generally not visible. As stated earlier, all plots (treated and untreated) had near 100% bottom cover of at least low growing species or younger stages of intermediate and higher growing species.

Summary

We observed the seasonal dynamic nature of aquatic plant occurrence and species richness at fixed locations in both Lakes Morey and St. Catherine. Many aquatic plant species would be identified one month and not the next at both untreated and treated plots. This changing species assemblage during the growing season could confound before- and -after treatment species richness counts. The dynamic nature of these plant communities must be taken into account when evaluating lake herbicide treatments, not only within a single growing season but on an annual scale as well. Additional test plots would have lent more confidence to our observations, especially in Lake St. Catherine. However, our in-the-water impressions of the plots and the surrounding areas after both lakes' triclopyr treatments were an appearance of healthy, normal aquatic plant growth with no indications of any reduction in native plant structure. We observed effective control of Eurasian watermilfoil at treated sites in both lakes with the exception of one Renovate OTF site in Lake Morey (west shore) where watermilfoil was poorly controlled by the treatment.

End of season aquatic plant survey reports for both lakes submitted by ACT indicated that Eurasian watermilfoil responded favorably to the treatment in most areas with significant reductions of watermilfoil density and distribution observed. Control was poor however at one Renovate OTF-treated site in Lake Morey (west shore). Reasons for the lack of control could include dilution, topped out watermilfoil or both. No obvious impacts to non-target species were noted in the ACT reports (Aquatic Control Technology, Inc., 2007 a, b).

We recommend that in future studies of this nature, directional photographs be taken at two depths instead of one in order to capture the shorter growing species within the photo frame and provide a more complete portrayal of aquatic plant architecture at studied plots.

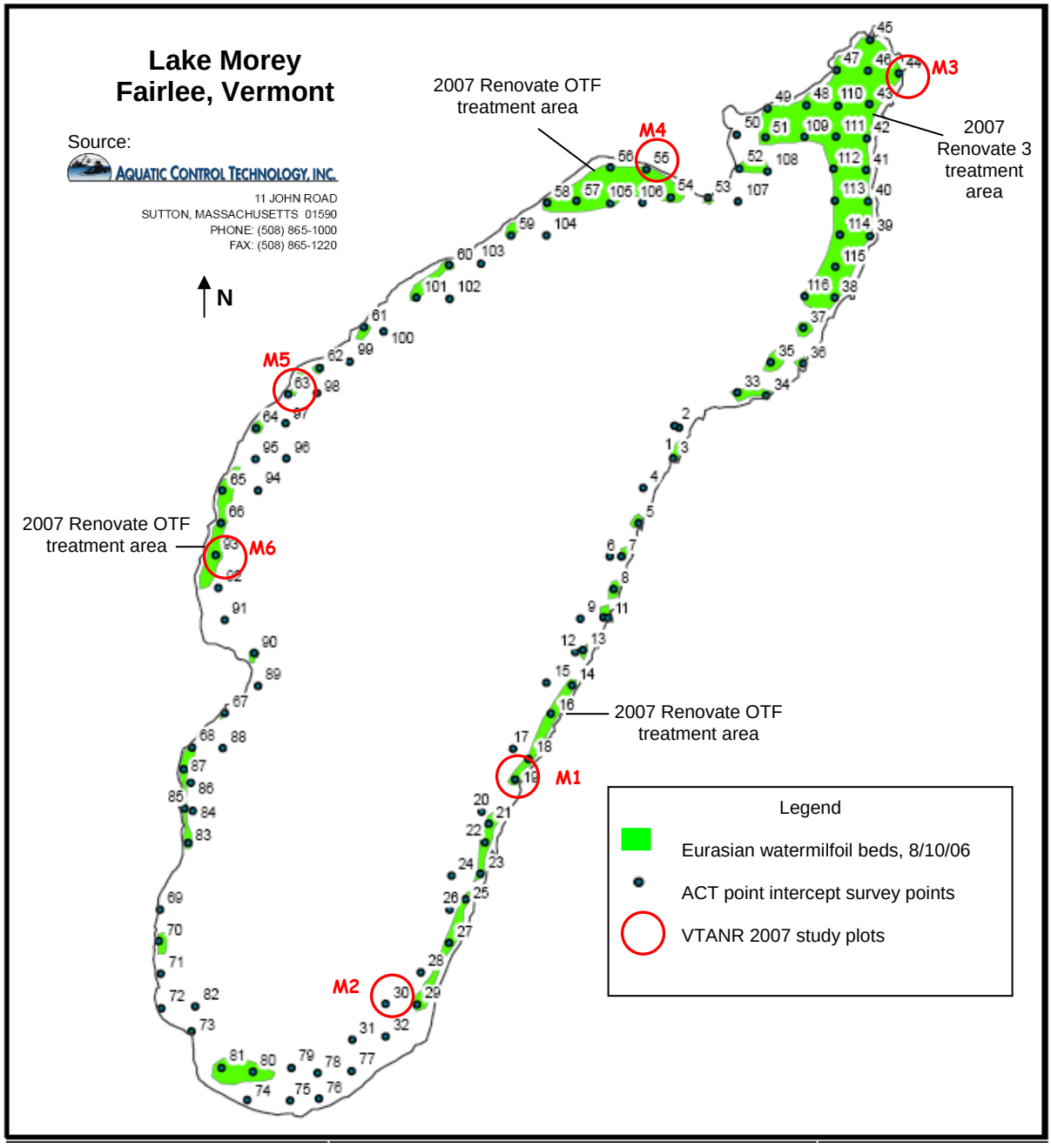
References

Aquatic Control Technology, Inc. 2007a. Lake Morey Aquatic Vegetation Management Program 2007 – Year One Report.

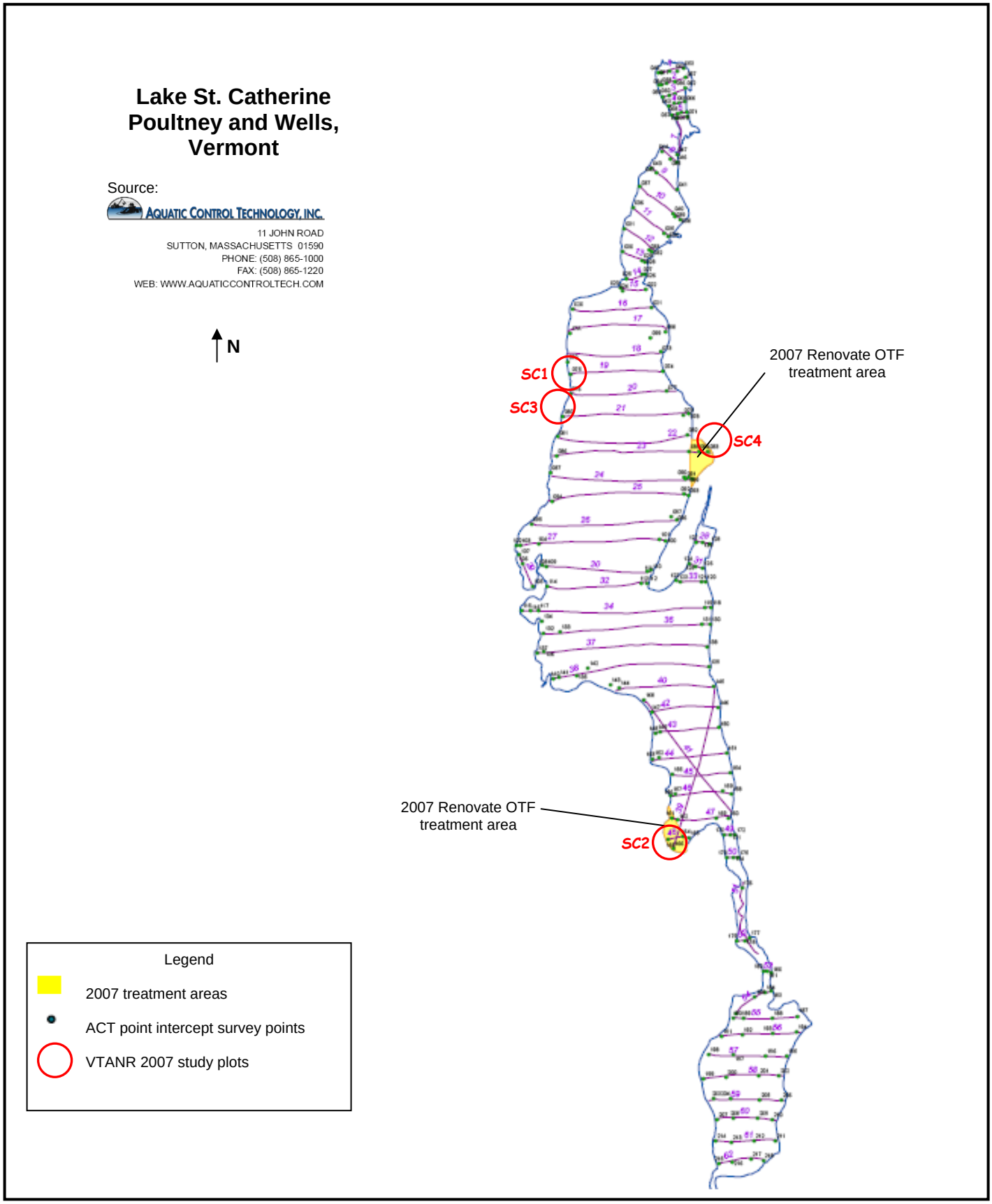
Aquatic Control Technology, Inc. 2007b. Lake St. Catherine Aquatic Vegetation Management Program 2007 – Year Four Report.

Appendices

Appendix 1. Map of Lake Morey, Vermont with established aquatic plant survey point intercept sampling points, and 2007 treatment areas and study plots.



Appendix 2. Map of Lake St. Catherine, Vermont with established aquatic plant survey point intercept sampling points, and 2007 treatment areas and study plots.



Appendix 3. Nontarget plant occurrence at four triclopyr-treated and two untreated plots in Lake Morey, Vermont 2007. 1= present, 0 = absent and na = not assessed

Plot M5 - Untreated				
	June 20	July 24	August 22	September 18
Ceratophyllum demersum	1	na	1	1
Megalodonta beckii	1	na	1	1
Najas flexilis	1	na	1	1
Potamogeton amplifolius	1	na	1	1
P. gramineus	1	na	0	1
P. pusillus ssp. *pusillus*	1	na	1	1
P. robbinsii	0	na	1	1
Sagitaria sp.	0	na	0	1
Valisneria americana	1	na	1	1
Zosterella dubia	1	na	1	1
Total Richness by Date	**9**		**6**	**9**

Plot M2 - Untreated				
	June 20	July 24	August 22	September 18
Chara sp.	1	0	0	0
Eleocharis acicularis	1	0	0	0
Elodea canadensis	1	1	1	1
Megalodonta beckii	1	1	1	1
Potamogeton amplifolius	1	1	1	1
P. gramineus	1	0	0	1
P. illinoensis	1	1	1	1
P. pusillus ssp. *pusillus*	0	0	1	0
P. zosteriformis	1	0	0	0
Sagitaria sp.	0	0	1	1
Valisneria americana	1	1	0	1
Zosterella dubia	0	1	1	1
Total Richness by Date	**9**	**6**	**7**	**8**

Appendix 3, continued

Plot M1 - Renovate OTF				
	June 20	July 24	August 22	September 18
Ceratophyllum demersum	1	0	1	1
Najas flexilis	0	0	0	1
Nitella sp.	0	0	1	0
Potamogeton amplifolius	1	1	1	1
P. gramineus	1	0	0	0
P. illinoensis	0	1	1	1
P. pusillus ssp. *pusillus*	1	1	1	0
P. robbinsii	0	1	0	1
Valisneria americana	1	1	1	1
Zosterella dubia	1	1	1	1
Total Richness by Date	**6**	**6**	**7**	**7**

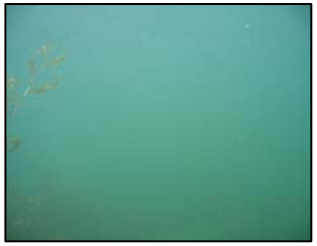
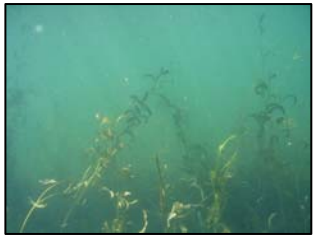
Plot M6 - Renovate OTF				
	June 20	July 24	August 22	September 18
Ceratophyllum demersum	1	na	1	1
Megalodonta beckii	0	na	0	1
Najas flexilis	0	na	0	1
Potamogeton amplifolius	1	na	1	1
P. illinoensis	0	na	1	1
P. robbinsii	1	na	1	1
P. zosteriformis	0	na	0	1
Zosterella dubia	1	na	1	1
Total Richness by Date	**4**		**5**	**8**

Plot M4 - Renovate OTF				
	June 20	July 24	August 22	September 18
Ceratophyllum demersum	0	1	1	0
Megalodonta beckii	1	1	1	1
Najas flexilis	0	0	1	0
P. gramineus	0	0	1	0
Potamogeton robbinsii	1	1	1	1
Valisneria americana	0	1	1	1
Zosterella dubia	1	1	1	1
Total Richness by Date	**3**	**5**	**7**	**4**

Plot M3 - Renovate 3				
	June 20	July 24	August 22	September 18
Ceratophyllum demersum	1	na	0	0
Megalodonta beckii	1	na	1	1
Najas flexilis	0	na	1	1
Nymphaea sp.	0	na	1	0
Potamogeton obtusifolius	0	na	0	1
P. robbinsii	1	na	1	0
P. zosteriformis	1	na	1	0
Zosterella dubia	0	na	1	1
Total Richness by Date	**4**		**6**	**4**

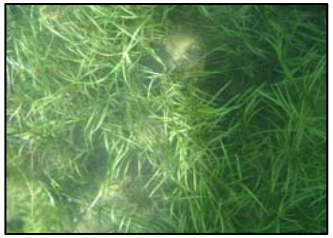
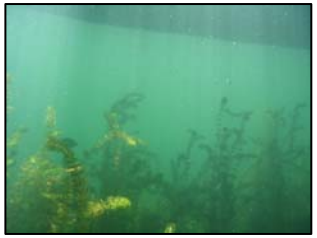
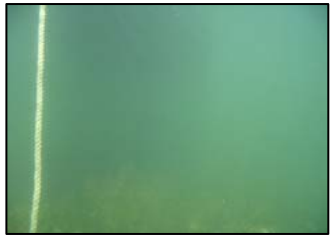
Appendix 4. Photographs at two untreated and four triclopyr-treated plots in Lake Morey, Vermont taken during four visits, June - September 2007.

Plot M2 - untreated

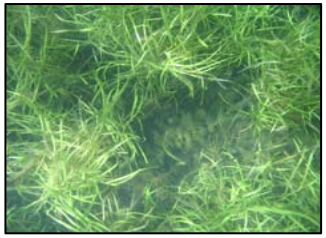
Date	Surface	N	E	S	W
20 Jun 2007 2m					
24 Jul 2007 1.7m *at gps pt; no pin located					
22 Aug 2007 1.7m *at gps pt; no pin located					
18 Sep 2007 1.7m *at gps pt; no pin located					

Appendix 4 continued

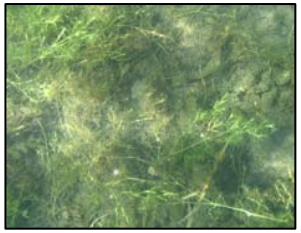
Plot M5 - untreated

Date	Surface	N	E	S	W
20 Jun 2007 1.7m					
24 Jul 2007	na	na	na	na	na
22 Aug 2007 1.7m *at gps pt; no pin located					
18 Sep 2007 1.7m *at gps pt; no pin located					

Plot M1 – Renovate OTF-treated

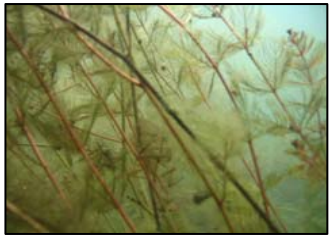
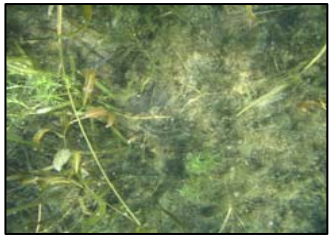
Date	Surface	N	E	S	W
20 Jun 2007 2m		na	na	na	na
24 Jul 2007 1.7m *at gps pt; no pin located					
22 Aug 2007 1.7m *at gps pt; no pin located					
18 Sep 2007 1.7m *at gps pt; no pin located					

Plot M3 – Renovate 3-treated

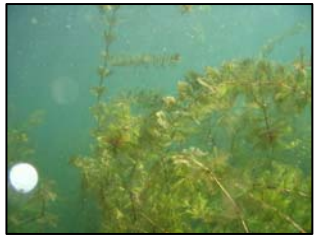
Date	Surface	N	E	S	W
20 Jun 2007 2m					
24 Jul 2007 1.7m *at gps pt; no pin located	na	na	na	na	na
22 Aug 2007 1.7m *at gps pt; no pin located					
18 Sep 2007 1.7m *at gps pt; no pin located					

Appendix 4 continued

Plot M4 – Renovate OTF-treated

Date	Surface	N	E	S	W
20 Jun 2007 1.3m					
24 Jul 2007 1.3m					
22 Aug 2007 1.3m *at gps pt; no pin located					
18 Sep 2007 1.3m					

Plot M6 – Renovate OTF-treated

Date	Surface	N	E	S	W
20 Jun 2007 1.75m					
24 Jul 2007	na	na	na	na	na
22 Aug 2007 1.7m *at gps pt; no pin located	na				
18 Sep 2007 1.7m *at gps pt; no pin located					

Appendix 5. Dissolved oxygen concentrations and (% saturation) in Lake Morey from all six study plots, August 22, 2007.

Depth	Untreated Plots		Triclopyr-treated Plots			
	M2	M5	M1	M3	M4	M6
Surface	6.4 (98)	6.2 (95)	6.2 (95)	6.2 (95)	6.3 (97)	6.6 (102)
0.5 m	6.4 (99)	6.2 (95)	6.2 (96)	6.2 (95)	6.3 (97)	6.6 (102)
1.0 m	6.4 (99)	6.3 (97)	6.2 (96)	6.6 (102)	6.4 (98)	6.6 (102)
1.5 m	6.4 (100)	6.4 (98)	6.2 (96)	6.7 (101)	6.4 (99)	6.7 (102)

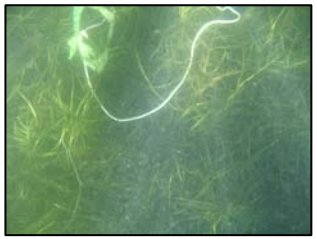
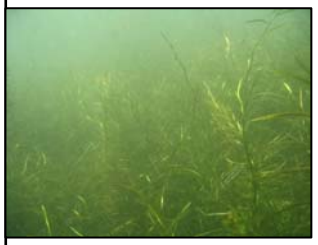
Appendix 6. Nontarget aquatic plant occurrence at the two untreated and two triclopyr-treated plots in Lake St. Catherine, Vermont 2007. 1= present and 0 = absent.

Plot SC1 - untreated			
	July 16	August 13	September 13
Najas flexilis	1	0	0
Potamogeton crispus	1	0	0
P. gramineus	0	0	1
P. robbinsii	1	1	0
P. zosteriformis	1	1	0
Zosterella dubia	1	1	1
Total Richness by Date	**5**	**3**	**2**
Plot SC3 - untreated			
	July 11	August 13	September 13
Isoetes sp.	0	1	1
Najas flexilis	1	1	1
Najas sp.	1	0	0
Potomogeton crispus	1	0	0
P. illinoensis	0	1	1
P. pusillus ssp. *pusillus*	0	1	1
P. robbinsii	1	1	1
P. spirillus	1	0	0
Sagittaria sp.	1	1	1
Zosterella dubia	0	1	1
Total Richness by Date	**6**	**7**	**7**

Plot SC2 – Renovate OTF			
	July 16	August 13	September 13
Ceratophyllum demersum	0	0	1
Elodea canadensis	1	1	1
Najas flexilis	1	1	1
Potamogeton robbinsii	1	1	1
P. amplifolius	1	1	1
Valisneria americana	0	1	1
Zosterella dubia	1	0	1
Total Richness by Date	**5**	**5**	**7**
Plot SC4 – Renovate OTF			
	July 11	August 13	September 13
Chara sp.	0	1	1
Elodea canadensis	0	1	1
Megalodonta beckii	1*(one plant)*	0	0
Najas flexilis	1	1	1
Nitella sp.	1	1	1
Potamogeton amplifolius	1	0	1
Potamogeton crispus	1	1	0
P. illinoensis	0	1	1
P. robbinsii	1	1	1
P. zosteriformis	0	1	0
Sagittaria sp.	1	0	0
Zosterella dubia	0	1	1
Total Richness by Date	**7**	**9**	**8**

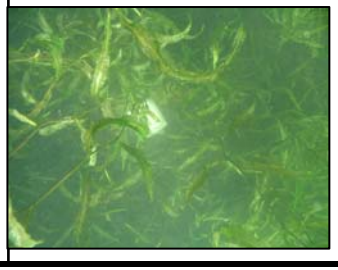
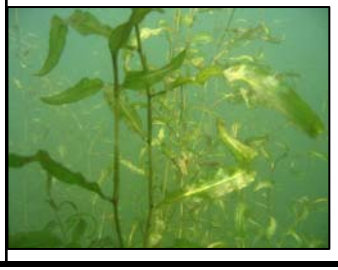
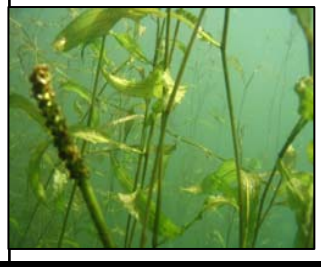
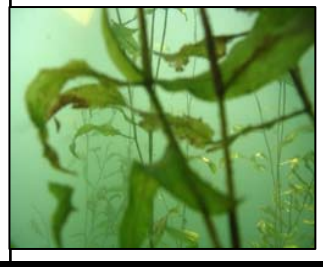
Appendix 7. Photographs at two untreated and two triclopyr-treated plots in Lake St Catherine, Vermont taken during three visits, July –September 2007.

Plot SC1 - untreated

Date	Surface	N	E	S	W
16 Jul 2007 1.5m					
13 Aug 2007 1.5m *no pin located; installed new					
13 Sep 2007 1.5m					

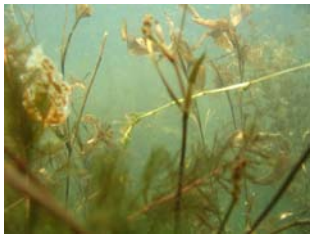
Appendix 7 continued

Plot SC3 - untreated

Date	Surface	N	E	S	W
11 Jul 2007 2m					
13 Aug 2007 2m (added buoy to pin)					
13 Sep 2007 2m					

Appendix 7 continued

Plot SC2 – Renovate OTF-treated

Date	Surface	N	E	S	W
16 Jul 2007 1.5m					
13 Aug 2007 1.5m					
13 Sep 2007 1.5m					

Appendix 7 continued

Plot SC4 – Renovate OTF-treated

Date	Surface	N	E	S	W
11 Jul 2007 1m					
13 Aug 2007 1m					
13 Sep 2007 1m