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Note

Efficacy of 2,4-D ester on variable-leaf milfoil control for partial lake treatments in New Hampshire waterbodies

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INTRODUCTION

Variable-leaf milfoil (*Myriophyllum heterophyllum* Michx) is one of the most widespread invasive aquatic plant known in freshwater lakes and ponds in New Hampshire (Smagula 2008). In 2008, variable-leaf milfoil was found in 59 of the then 67 New Hampshire waterbodies infested with exotic species (Smagula 2008). Invasive species such as variable-leaf milfoil can have detrimental impacts on water quality, result in the loss of native plant diversity, and impair recreational uses (U.S. Congress 1993, Wilcove et al. 1998, Halstead et al. 2003). Variable-leaf milfoil has also been estimated to reduce lake-front property values by as much as 20 to 40% (Halstead et al. 2003). As a result, considerable state, municipal and private funds are spent each year on herbicide treatment programs to control variable-leaf milfoil.

Evaluation of chemical control methods can yield benefits such as reduced herbicide use rates, increased environmental compatibility and reduced application costs (Getsinger et al. 1998). Recent herbicide studies completed by the U.S. Army Engineer Research Development Center determined that 2,4-D BEE (2,4-dichlorophenoxy butoxyethyl ester) (granular formulation) was the most effective herbicide studied for the control of New Hampshire strains of variable-leaf milfoil (Netherland and Glomski 2007). These findings have been anecdotally confirmed by the results of lake treatments performed in recent years, but limited comprehensive analysis of actual treatment sites have been performed. Results of field applications can vary from laboratory results because of dissipating herbicide concentrations caused by water exchange, diffusion, plant uptake, soil adsorption, herbicide breakdown and other factors (Green and Westerdahl 1990). Partial or shoreline variable-leaf milfoil infestations are typical of many New Hampshire waterbodies. When this is the case, generally only a partial lake treatment is required. Higher herbicide use rates are typically used to overcome the effects of dilution in partial lake treatment plots particularly where there is more water movement, a greater average water depth, or a larger perimeter to area ratio. (The perimeter of a treatment plot is compared to its area to help determine the possible effects of dilution. Treatment plots with larger perimeter to area ratios will typically experience greater dilution because a greater proportion of the treated area comes into direct contact with untreated water.) This ensures that sufficient herbicide-concentration–exposure-time (CET) is maintained to maximize plant control (Green and Westerdahl 1990, Netherland and Getsinger 1992). Variable-leaf milfoil growing in low alkalinity and low pH waters in New Hampshire is highly susceptible to 2,4-D BEE and appears to require a considerably shorter CET than 2,4-D amine and other auxin-mimic herbicides (Netherland and Glomski 2007). No field studies have been performed to determine if higher use rates of 2,4-D BEE granular would yield more complete variable-leaf milfoil control for partial lake treatment plots in the acidic waters of New Hampshire.

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MATERIALS AND METHODS

The product label of the Navigate® formulation of 2,4-D BEE granular[1] suggests that treatment rates between 112 kg of 2,4-D BEE granular per ha (hereafter abbreviated as 112 kg ha^{-1}) and 224 kilograms of 2,4-D BEE granular per hectare (hereafter abbreviated as 224 kg ha^{-1}) be used to control variable-leaf milfoil. The current study sought to identify variations in treatment efficacy and associated impacts to nontarget native plant species at multiple sites over the 2009 growing season in response to either the maximum label treatment rate (224 kg ha^{-1}) or a lower recommended treatment rate (112 kg ha^{-1}). Measures of treatment efficacy and nontarget impacts included comparisons of the frequency of occurrence of variable-leaf milfoil pre and post-treatment and changes in species richness.

Plot selection/description

Sites were selected in consultation with the New Hampshire Department of Environmental Services (New

Table 1. Study site, treatment rates, plot attributes and survey/treatment dates.

Study site	Lake area (ha)	Treatment plot attributes: Area (ha)	Average depth (m)	Treatment rate (kg ha^{-1}) [a.e. ppm][1]	Perimeter to area ratio (m m^{-2})	Number of data points	Plot type	Dates: Pretreatment survey	Treatment	Post-treatment survey
Massasecum—West	165	2.3	2.3	112 [0.93]	0.03	35	½ C. Ad.[2]	5/22/09	6/30/09	9/22/09
Massasecum—East	165	2.7	2.2	224 [1.94]	0.04	36	½ C. Ad.[2]	5/22/09	6/30/09	9/22/09
Long Pond—South	41	3.6	1.6	112 [1.34]	0.07	49	O.S.[3]	6/8/09	6/17/09	9/9/09
Long Pond—North	41	4.3	1.5	224 [2.85]	0.05	55	O.S.[3]	6/8/09	6/17/09	9/9/09
Winnipesaukee—Round Cove	18,044	2	2.8	112 [0.76]	0.03	30	< 1/2C[4]	6/5/09	6/9/09	9/1/09
Winnipesaukee—Fish Cove	18,044	5.7	1.7	224 [2.5]	0.03	84	< 1/2C[4]	5/29/09	6/9/09	9/1/09
Winnipesaukee—Meredith Bay	18,044	2.1	1.3	0 [0]	0.03	30	< 1/2C[4]	6/2/09	N/A	9/2/09
Gorham Pond	40	2	1.2	0 [0]	0.04	30	< 1/2C[4]	6/19/09	N/A	9/22/09

[1]a.e. ppm = acid equivalent concentration in parts per million.
[2]1/2C. Ad. = half of cove treated; adjacent to other treatment site. The two treatment sites (112 kg ha^{-1} and 224 kg ha^{-1}) in Lake Massasecum were adjacent to one another in a single cove.
[3]O.S. = treatment along open shoreline.
[4]< 1/2C = less than half of cove treated. Treatment area not adjacent to other in-lake treatment area.

Hampshire DES) and represented typical variable-leaf milfoil infestations found in New Hampshire waterbodies. Six treatment plots located in larger waterbodies were selected out of previously planned treatment programs. With the addition of two control plots, a total of eight plots on four different lakes were surveyed. The eight plots were comprised of three plots in the 112 kg ha^{-1} treatment group, three plots in the 224 kg ha^{-1} treatment group and two plots in the untreated control group (Table 1).

Lake Winnipesaukee was determined to be large enough that a no-treatment (control) plot could be selected that would not be influenced by the two treatments occurring elsewhere in the lake. This was not the case for either Long Pond or Lake Massasecum. As a result, a second representative control plot was sampled in Gorham Pond.

Treatment methods

Each lake was treated in June with the Navigate® formulation of 2,4-D BEE granular. The 112 kg ha^{-1} and 224 kg ha^{-1} treatments were performed on the same day in each waterbody. Treatments were performed from an airboat utilizing two different commonly used herbicide application techniques. For the Lake Winnipesaukee and Lake Massasecum treatments, the airboat was outfitted with a granular eductor spray system that fed the granular herbicide into a stream of water using a calibrated venturi-type eductor. The mixture was then sprayed off the stern of each boat using fan-pattern nozzles, thereby reducing off-target drift of dust from the granules. For the Long Pond treatment a calibrated, 12-volt Herd cyclone spreader was mounted on the bow of the airboat that delivered the 2,4-D BEE in a fan-shaped pattern. Both techniques allowed the granular herbicide to be evenly distributed over the surface at the correct doses. The different application methods were utilized out of necessity due to access availability at the lakes. The authors do not expect that the difference in application method influenced the results to any discernable degree. For all treatments, the airboat was equipped with a GPS navigation system loaded with polygons of the treatment plots. For each treatment, a track of the treatment passes was recorded in real time to ensure even treatment within designated treatment areas.

Survey methods

Aquatic plant surveys were conducted to determine the presence or absence of variable-leaf milfoil and all other aquatic plant species within each study site. Surveys were performed pretreatment and approximately 12 wk post-treatment (Table 1).

The study utilized a point-intercept survey (Madsen 1999) to facilitate the collection of a large data set in a relatively short timeframe. Randomly generated data points were created for each survey site using ArcView 9.2 software. The data point locations were created based on the intersection

Table 2. Effects of 112 kg ha^{-1} and 224 kg ha^{-1} of 2,4-D BEE on percent change in variable-leaf milfoil frequency of occurrence and on native species richness.

Study site	VLM[1] frequency of occurrence: Pretreatment	Post-treatment	Percent change	Native species richness: Pretreatment (x ± se)	Post-treatment (x ± se)
Massasecum—West	40.0%	0.0%	−100.0%	2.1 ± 0.2	2.5 ± 0.4
Massasecum—East	30.6%	0.0%	−100.0%	2 ± 0.2	2.2 ± 0.3
Long Pond—South	69.4%	6.1%	−91.2%	3.5 ± 0.3	2.1 ± .3
Long Pond—North	87.3%	14.5%	−83.3%	3.4 ± 0.2	2.9 ± 0.3
Winnipesaukee—Round Cove	33.3%	3.3%	−90.0%	1.4 ± 0.2	2.4 ± 0.2
Winnipesaukee—Fish Cove	85.7%	15.5%	−88.4%	1.5 ± 0.11	3.3 ± 0.1
Winnipesaukee—Meredith Bay	86.7%	86.7%	0.0%	1.3 ± 0.2	2.7 ± 1.5
Gorham Pond	90.0%	93.3%	+3.7%	2.1 ± 0.2	2.7 ± 0.3

[1]VLM = Variable-leaf milfoil.

points of a standardized grid with each cell measuring approximately 26 m by 26 m. This grid size resulted in 30 to 84 data points per study site (Table 1). The grid size was maintained between sites to preserve a consistent sampling per unit area.

Data points were located in the field using a Trimble Pro XRS Differential GPS unit. The presence of all aquatic plant species at each pre-established data point was assessed from two rake tosses, observations from the surface and observations directly below the boat using an underwater camera system. Points that were inaccessible in the field due to geographical features, such as floating islands, rocks or land, that were not discernable in orthophotographs, were omitted from the study.

Statistical comparison

Chi-square analysis was used to compare the pooled variable-leaf milfoil presence/absence data for each treatment group individually pretreatment to post-treatment. Chi Square analysis followed by the Marascuilo Procedure was utilized to compare the pooled variable-leaf milfoil presence/absence data of the three groups (control group, 112 kg ha^{-1} and 224 kg ha^{-1}) pretreatment and the same analysis was utilized to compare this data post-treatment.

In terms of species richness (the average number of species per data point), the 112 kg ha^{-1}, 224 kg ha^{-1} and control groups were not statistically compared to one another, because of differences in species composition in the different groups; pretreatment to post-treatment statistical comparisons were only conducted within treatment groups. The mean rank native species richness per data point within each group pretreatment was compared to post-treatment within the same group utilizing Mann-Whitney nonparametric hypothesis tests. Comparing each group to the same group post-treatment, avoided the bias caused by differences in species composition. All statistical comparisons used an alpha value of 0.01 to determine significance.

RESULTS AND DISCUSSION

As expected, no significant difference was observed in the frequency of occurrence of variable-leaf milfoil pretreatment to post-treatment for the control group ($P = 0.77$) and a significant decrease in the frequency of occurrence of variable-leaf milfoil was observed in both the 112 kg ha^{-1} group ($P = 9.18$ E-16) and the 224 kg ha^{-1} group ($P = 1.86$ E-32) pretreatment to post-treatment. When the variable-leaf milfoil pretreatment frequency of occurrence values for all three groups were compared, the 112 kg ha^{-1} group was significantly different from both the control group and the 224 kg ha^{-1} group; however, no significant difference was observed between the control group and the 224 kg ha^{-1} group. When the post-treatment variable-leaf milfoil frequency of occurrence values for all three groups were compared, the variable-leaf milfoil frequency of occurrence for control group was significantly higher than both the 112 kg ha^{-1} group and the 224 kg ha^{-1} group as expected. A significant and surprising observation was that the variable-leaf milfoil frequency of occurrence post-treatment in 112 kg ha^{-1} group was not significantly different from that of the 224 kg ha^{-1} group.

Netherland and Glomski (2007) observed enhanced efficacy of the 2,4-D BEE on variable-leaf milfoil in low alkaline waters. It is probable that this enhanced effect would also increase the impact on susceptible native plant species in the low alkaline waters of New Hampshire. Because of differences in species composition, the two treatment groups and the control group were not statistically compared to one another in terms of native species richness; however, interesting patterns were observed when pretreatment and post-treatment conditions within each group were examined. A significant increase in mean native species richness rank from pretreatment to post-treatment conditions was observed in both the 224 kg ha^{-1} treatment group ($P = 4.11$ E-6) and the control group ($P = 0.0002$) but not in the 112 kg ha^{-1} treatment group ($P = 0.553$). Aside from seasonal growth patterns, it is possible that prior to treatment the growth of native species in all plots was slowed or prohibited by the early emergence of variable-leaf milfoil plants and the subsequent shading by variable-leaf milfoil plants, which were 1 to 2 m tall during the early season pretreatment surveys. The study plots for both the control group and the 224 kg ha^{-1} treatment group had higher average frequency of occurrence values for variable-leaf milfoil pretreatment than the 112 kg ha^{-1} treatment group. As such, it is hypothesized by the authors that if variable-leaf milfoil shading were the cause of the slow growth of native species this effect would have been more pronounced in these two groups.

This study focused on comparisons of use rates rather than on CET. The authors hypothesized that differences in control achieved by different application rates are more likely to be adopted into the everyday practices of applicators as opposed to the calculations of theoretical CET in each given scenario. Some of the observed differences in the frequency of occurrence of variable-leaf milfoil and native species richness were likely attributable in part to the varied plot conditions and resulting differences in CET. A variety of environmental conditions, which are generally thought to warrant higher use rates in partial lake treatment plots, such as high water exchange, greater average water depths and large perimeter to area ratios were present for both treatment groups. Both treatment rates were effective at controlling variable-leaf milfoil in the partial lake treatment plots under these conditions.

These results provide some support for the use of 112 kg ha^{-1} of 2,4-D BEE over the use of 224 kg ha^{-1} of 2,4-D BEE for control of variable-leaf milfoil in partial lake treatment plots in New Hampshire. These results are consistent with the laboratory findings that in the low alkaline waters of New Hampshire, 2,4-D BEE is highly effective on variable-leaf milfoil (Netherland and Glomski 2007), thereby providing good efficacy at low use rates (Glomski and Netherland 2008).

SOURCES OF MATERIALS

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