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NOTES

Effects of Repeated Fluridone Treatments Over Nine Years to Control Eurasian Watermilfoil in a Mesotrophic Lake

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INTRODUCTION

Eurasian watermilfoil (*Myriophyllum spicatum* L.), hereafter called milfoil, is a non-native, invasive submersed aquatic plant that was first found in Minnesota in 1987. Milfoil can limit recreational activities on water bodies and alter aquatic ecosystems by displacing native plants (Madsen et al. 1991).

In 1988 milfoil was discovered in Lac Lavon (44°43'11"N, 93°14'43"W), a 22 ha (55 acre) former gravel pit just south of the Twin Cities metropolitan area in Minnesota. Lac Lavon is considered mesotrophic by the Minnesota Pollution Control Agency (2005) based on water clarity (4.1 m), chlorophyll-a (4 ppb), and total phosphorus (14 ppb). By 1996 milfoil had become the dominant plant in the lake, which created problems for users of Lac Lavon. In 1996, the cities of Apple Valley and Burnsville, in cooperation with the Lac Lavon Association, contracted to have the lake treated with Sonar A.S.™ herbicide, in which the active ingredient is fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1*H*)-pyridinone). The Minnesota Department of Natural Resources (DNR) evaluated the effects of this treatment by monitoring the plant community one to two times per year over a period of nine years, during which the lake was subjected to three whole-lake treatments with fluridone.

MATERIALS AND METHODS

Surveys of the aquatic plants in Lac Lavon were conducted during August or September of each year, and during May or June of some years. For this note, only data from the August or September surveys will be presented except for the three years of treatment.

Twelve transects were evenly spaced around the lakeshore perpendicular to shore with sample locations located along each transect approximately every five feet of change in water depth. A total of 24 sample locations were surveyed on each sample date. At each sampling location, a plant grapple was thrown four times and visual observations were made to determine plant species presence. Each grapple throw was in a different direction, two from the bow, and two from the stern of the boat. In some cases, plants could be identified to the level of genus, but not species. Consequently, they are reported as taxa, which includes both plants identified to genus and those identified to species. Nomenclature follows Crow and Hellquist (2000a, b). Frequency of occurrence of individual aquatic plant taxa, the average number of native taxa per sample location, and total number of taxa were determined to evaluate the effects of fluridone.

In this note, we describe apparent trends and differences in the observations we report. Since there was only one lake that was treated, and no observations from an un-treated reference lake, we did not perform statistical tests.

Observations of Secchi disk transparencies were made on most sampling dates. In addition, Secchi disk transparencies for 1996 through 2004 were obtained from the Minnesota Pollution Control Agency, which maintains a database of Secchi depths for Minnesota lakes (Minnesota Pollution Control Agency 2006). Secchi disk transparencies for 2005 were obtained from the Metropolitan Council Citizen-Assisted Monitoring Program (unpublished data).

Fluridone Treatments

Lac Lavon was treated with fluridone during May or June in 1996, 1998, and 2002. All treatments had an initial treatment followed by a second treatment 15-30 days later. Concentrations of fluridone were measured either with an enzyme-linked immunosorbent assay developed by SePRO Corporation (FastTEST™) or with a gas chromatograph (Netherland et al. 2002). FastTEST™ assays were performed by SePRO Corporation and gas chromatograph tests were performed by the laboratory of the Minnesota Department of Agriculture.

Both the initial concentration of fluridone and the duration of exposure to the herbicide affect the results of treatment with fluridone. Treatments done in Lac Lavon represent relatively low-dose treatments (Netherland et al. 1997). In 1996, the initial fluridone concentration one day after treatment (DAT) was 9.4 ppb. The second treatment maintained the concentration of fluridone above 3.0 ppb for 60 DAT. In 1998, the initial fluridone concentration three DAT was 6.9 ppb. The second treatment maintained the con-

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centration of fluridone above 3.0 ppb for 90 DAT. In 2002, the initial fluridone concentration three DAT was 7.1 ppb. The second treatment maintained the concentration of fluridone above 2.9 ppb for 80 DAT.

RESULTS AND DISCUSSION

Direct Effects of Fluridone on Milfoil and other Plants

The first treatment of Lac Lavon with fluridone in 1996 reduced the frequency of milfoil from 88% to 13% during the following year (Table 1). The second treatment in 1998 reduced the frequency of milfoil to 0% during the year of treatment. By August of 2000, milfoil increased to 25% frequency and in September of 2001 milfoil was again the dominant plant in the lake. The third treatment in 2002 reduced milfoil to 4% in 2002 and 2003. Milfoil increased in 2004 and by August 2005, milfoil was again the dominant plant in the lake.

Fluridone treatments also reduced the distribution of some native taxa in Lac Lavon (Table 1). The frequency of *Myriophyllum sibiricum* Komarov was reduced from 17% to zero following the 1996 treatment and has not been found in Lac Lavon since that time. The frequency of *Ceratophyllum demersum* L. decreased following treatment in 1998, but not in 1996 or 2002. *Ranunculus* L. sp. declined after each treatment and did not return to its original frequency of 46%. *Elodea canadensis* Michx. declined from a frequency of 38% at the time of the treatment in 1996 and has not been found above 4% since then. A group of native species including *Stuckenia pectinata* (L.) Borner, *Potamogeton illinoensis* Morong, and *P.* cf. *foliosus* Raf. tended to decline in the year of treatment, and then increase for one or two years following treatment.

The failure of *M. sibiricum* and *E. canadensis* to re-establish in Lac Lavon following elimination by fluridone may be related to the lack of summer-dormant propagules in lake sediments that would enable them to re-establish following elimination of growing plants. Turions or over-wintering buds are produced primarily in fall by *M. sibiricum* (Aiken and Walz 1979) and E. *canadensis* (Spicer and Catling 1988). Reproduction by seeds appears to be relatively unimportant in *E. canadensis* (Spicer and Catling 1988) and *M. sibiricum.* Haag (1983) reported that these two species were common in the vegetation of a lake in Alberta, but did not emerge from samples of sediment collected from the lake.

Indirect Effects of Fluridone on Plant Taxa other than Milfoil

The frequency of two native plant taxa increased during the year of treatment two times out of three. *Ceratophyllum demersum* L. and *Zosterella dubia* (Jacq.) Small increased following the 1996 and 2002 treatments. *Chara* sp. increased following each treatment (Table 1). The frequency of *P. crispus* L. increased during May 1998, following the first treatment. Since the focus of this study was on vegetation during August or September, limited information on this non-native species exists, which usually occurs at low frequency at this time of year (Catling and Dobson 1985).

A second group of native species tended to decline in the year of treatment, and then increased for one or two years following treatment. This group includes *S. pectinata*, *P. illinoensis*, and *P.* cf. *foliosus*. Lastly, *Najas flexilis* (Willdl.) Rostk. & Schmidt was not detected during the years of treatment, but was present at frequencies from 8 to 63% during years after treatment.

Increases in the frequencies of certain plants in Lac Lavon following application of fluridone may be due to decreases in the abundance of milfoil during the years of treatment and the first two years after treatment. This in turn may have created an environment that allowed either growth of plants that survived exposure to herbicide or recruitment from populations of summer-dormant propagules or both. Summer-dormant propagules, either seeds or vegetative structures, are present in *S. pectinata* (Kantrud 1990), *P. crispus* L. (Catling and Dobson 1985), *Najas flexilis* (Willdl.) Rostk. & Schmidt (Sheldon 1986), *Z. dubia* (McFarland and Rogers 1998), and others. *Chara* sp. has spores (Hutchinson 1975) and is known to increase following control of submersed plants (Pieterse and Murphy 1990).

Increases in milfoil to frequencies of 79% or 92% in the third year after treatment was associated with declines in several native plants, including *S. pectinata*, *P.* cf. *foliosus, N. flexilis*, *Z. dubia*, and *Chara* sp. (Table 1). In contrast to this pattern, the frequencies of *C. demersum* increased as the frequency of milfoil increased in the second and third years after the second treatment of Lac Lavon.

Overall, fluridone treatments in Lac Lavon were associated with a decline in the average number of native taxa per sampling location during the year of treatment (Table 1). During the first and second years after treatment, there was an increase in the average number of native taxa per sampling location and the frequency of milfoil. During the third year after treatment, the frequency of milfoil reached a level of 79% or higher and the average number of native taxa per site declined.

Following treatments of Lac Lavon with fluridone, Secchi disk transparencies remained roughly constant for the first and second years after treatment (Table 1). During the third year after the third treatment, Secchi disk transparencies appeared to increase. This pattern is different from that observed in a eutrophic Minnesota lake, where Secchi disk transparencies decreased following treatment with fluridone (Valley et al. 2006).

Results of this study showed that application of fluridone can reduce the frequency of milfoil without reducing the distribution of submersed vegetation in a lake (percent vegetated sampling locations—Table 1). This result is different from that observed following treatment with fluridone of a eutrophic lake in Minnesota, which decreased the distribution of submersed vegetation (Valley et al. 2006). The eutrophic lake had an average of 5.6 submersed species, a number that was lower than the average of 10 submersed taxa observed in Lac Lavon (Table 1). While the distribution of submersed vegetation in Lac Lavon was not substantially reduced by treatment with fluridone, there were shifts in species composition of the plant community.

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TABLE 1. PERCENT FREQUENCY OF OCCURRENCE (N = 24) OF SUBMERSED MACROPHYTES DURING AUGUST OR SEPTEMBER IN LAC LAVON, MINNESOTA. FLURIDONE HERBICIDE WAS APPLIED TO LAC LAVON ON 23 MAY 1996, 5 MAY 1998, AND 5 JUNE 2002. NON-NATIVE TAXA IN LAC LAVON ARE *MYRIOPHYLLUM SPICATUM, POTAMOGETON CRISPUS* L., AND *NAJAS MINOR* ALL. TAXA THAT OCCURRED AT LESS THAN 25% FREQUENCY AND NOT INCLUDED IN THE TABLE WERE: *MYRIOPHYLLUM SIBIRICUM* KOMAROV, WHICH OCCURRED AT 17% IN MAY, 1996 AND WAS NOT OBSERVED THEREAFTER; *P. NODOSUS* POIR.; *P. NATANS* L.; *N. MINOR*; AND *NITELLA* SPP.

		Vascular plants															
		Dicots			Monocots							Macro-alga					
Year	Year post-treatment	*Ceratophyllum demersum* L.	*Ranunculus* L. sp.	*Myriophyllum spicatum* L.	*Elodea canadensis* Michx.	*Stuckenia pectinata* (L.) Borner	*Potamogeton crispus* L.	*P. illinoensis* Morong	*P.* cf. *foliosus* Raf.	*Najas flexilis* (Willdl.) Rostk. & Schmidt	*Zosterella dubia* (Jacq.) Smal	*Chara* sp.	Avg. number of native taxa per sampling location	Total number of taxa	Percent vegetated sampling stations	Average Secchi disk transparency (m)	Number of observations of Secchi disk transparency
1996a	0	46	46	88	38	0	38	13	21	0	13	33	2.3	10	100	—	—
1996	0	67	0	21	0	13	0	0	0	0	54	42	1.8	6	92	2.6	5
1997	1	33	0	13	0	83	50	38	54	63	83	75	4.4	10	100	3.8	12
1998b	0	29	17	8	4	29	79	17	8	0	83	79	2.7	10	100	—	—
1998	0	4	0	0	0	8	0	4	0	0	79	96	2.0	6	100	3.5	14
1999	1	8	0	4	0	54	0	46	21	17	71	100	3.4	11	100	3.3	10
2000	2	29	4	25	0	75	4	46	21	46	54	100	3.8	11	100	4.0	7
2001	3	54	8	79	4	46	0	46	4	25	33	75	3.2	12	100	5.3	2
2002c	0	38	25	92	4	42	13	46	33	0	13	75	2.8	10	100	—	—
2002	0	42	8	4	0	8	0	29	4	0	46	79	2.3	10	96	3.4	6
2003	1	17	4	4	0	79	8	38	38	17	29	92	3.3	12	100	3.7	10
2004	2	33	25	58	0	79	17	75	33	42	42	63	3.9	11	100	3.4	10
2005	3	38	0	92	4	38	0	50	4	8	29	58	2.3	11	100	4.4	10

[a]Observations made on 28 May, five days after application of fluridone to the lake.
[b]Observations made on 22 May, 17 days after application of fluridone to the lake.
[c]Observations made on 28 June, 23 days after application of fluridone to the lake.

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