J. Aquat. Plant Manage. 27: 119-121

NOTES

Eurasian Watermilfoil Seed Ecology from an Oligotrophic and Eutrophic Lake

J. D. MADSEN[1] AND C. W. BOYLEN[2]

INTRODUCTION

In all research efforts to date, investigators have indicated that seeds of *Myriophyllum spicatum* are not important to their propagation (Aiken *et al.* 1979). However, numerous seeds are produced by Eurasian watermilfoil, and a significant portion are able to germinate in laboratory studies (Coble and Vance 1987; Patten 1955). The potential importance of propagation by seeds lies in the formation of a genetically diverse population, with an enhanced ability to adapt to various environmental conditions. Therefore, a need exists for a broader examination of the seed ecology of Eurasian watermilfoil including comparisons of seed set and germination between populations.

Our study examined Eurasian watermilfoil (*Myriophyllum spicatum* L.) populations in eutrophic Cossayuna Lake and oligotrophic Lake George comparing, respectively, the seed ecology of an older, more established community in a nutrient-enriched, eutrophic environment to that of a younger population in a relatively nutrient-poor, oligotrophic environment. The purpose of this study was to assess the potential contribution seed production had on the propagation of the Eurasian watermilfoil populations in these diverse lake ecosystems. The results of the first year of this study are reported here.

STUDY SITES

Lake George is a large (114 km^2, 58 m maximum depth), oligotrophic lake on the southeastern edge of the Adirondack Mountains of New York State. The Eurasian watermilfoil population in Lake George is fairly young, with significant populations first observed in 1985 (Rensselaer Fresh Water Institute 1986). The study site was a small, sheltered bay in the northwestern portion of Lake George's south basin that contained a dense 164 m^2 Eurasian watermilfoil bed in 1 to 3 m water depth. Flowering in this bed was scattered and occurred over a seven-week period, mid-August through early October in 1987 (Rensselaer Fresh Water Institute *et al.* 1988).

Cossayuna Lake, a small (2.7 km^2), shallow (7.6 m maximum depth) eutrophic lake, is located 35 km southeast of Lake George. The Cossayuna Lake Eurasian watermilfoil population is older and more homogeneous than the Lake George population, dating from about 1976 (David Smith, pers. comm.). Eurasian watermilfoil in this lake has been observed to flower throughout much of the population, but the flowering period is generally very short (ca. two weeks). Plants used in this study were in 1 to 2 m of water depth at the southern end of the lake near the outlet.

METHODS

Flowering stalks (inflorescence) were collected from the two lakes along with approximately 20 cm of vegetative stem material. Upon return to the laboratory, they were incubated in aquaria with Lake George water under controlled light (400 uE m^{-2} s^{-1}, 14 h light : 10 h dark) and temperature (18-22 C). Flowering stalks were maintained until seed set and maturity were achieved, a period of approximately four weeks. This procedure was used in order to quantitatively collect all seeds, avoiding losses that may occur by premature abscission of seeds if the seeds were allowed to fully mature *in situ*. We assumed that pollination had occurred prior to collection. Stems from Cossayuna Lake were collected at two times in the mid-summer of 1987 (20 and 27 July). The collection time was limited by the short flowering period in Cossayuna Lake, but a total of 50 stalks were collected and analyzed. Twenty flower stalks were collected from Lake George at weekly intervals throughout the seven-week flowering period.

Flower stalks were enumerated for female flowers, fruit maturity, and number of seeds set. Seeds were counted and used for further tests only if they were firm and resistant to crushing by forceps. Seed set was calculated as a percentage of the total number of seeds formed per inflorescence versus the potential number of seeds for that inflorescence (the potential number of seeds being equivalent to the number of ovules per inflorescence). A subsample of seeds from each population was dried at 50 C, and weighed in groups of 5 seeds on an analytical balance.

Seed germination was tested using 100 mature seeds from each population. Twenty seeds, which were exposed to 4 C for 8 weeks, were surface sterilized for 30 minutes in 5.25% sodium hypochlorite, rinsed with sterilized distilled water, and were placed into each of five sterile 250 ml

[1]Research Scientist, Rensselaer Fresh Water Institute, MRC 238, Rensselaer Polytechnic Institute, Troy, New York 12180-3590.
[2]Director, Rensselaer Fresh Water Institute, and Associate Professor of Biology; Rensselaer Fresh Water Institute, MRC 203, Rensselaer Polytechnic Institute, Troy, New York 12180-3590. Received for publication February 3, 1989 and in revised form April 24, 1989.

flasks with 200 ml of filter-sterilized Lake George water. Filtered air was bubbled into the flasks to prevent anoxia. Flasks were placed under 14 h light : 10 h dark daylength conditions, with a light intensity of 400 uE m^{-2} s^{-1}. Temperature was maintained at 25 C in a water bath using a constant temperature circulator. The number of germinating seeds in each flask was counted weekly for a period of one month. Seed germination was selected to test seed viability, only after extensive efforts to develop a tetrazolium testing procedure failed (Madsen and Boylen 1988).

Statistical tests were applied following Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

The Cossayuna Lake population had significantly more female flowers per stalk (median = 32) than did the Lake George population (median = 28; rank sum p = 0.028; Figure 1A). The greater number of female flowers could have been due to the trophic status of Cossayuna Lake.

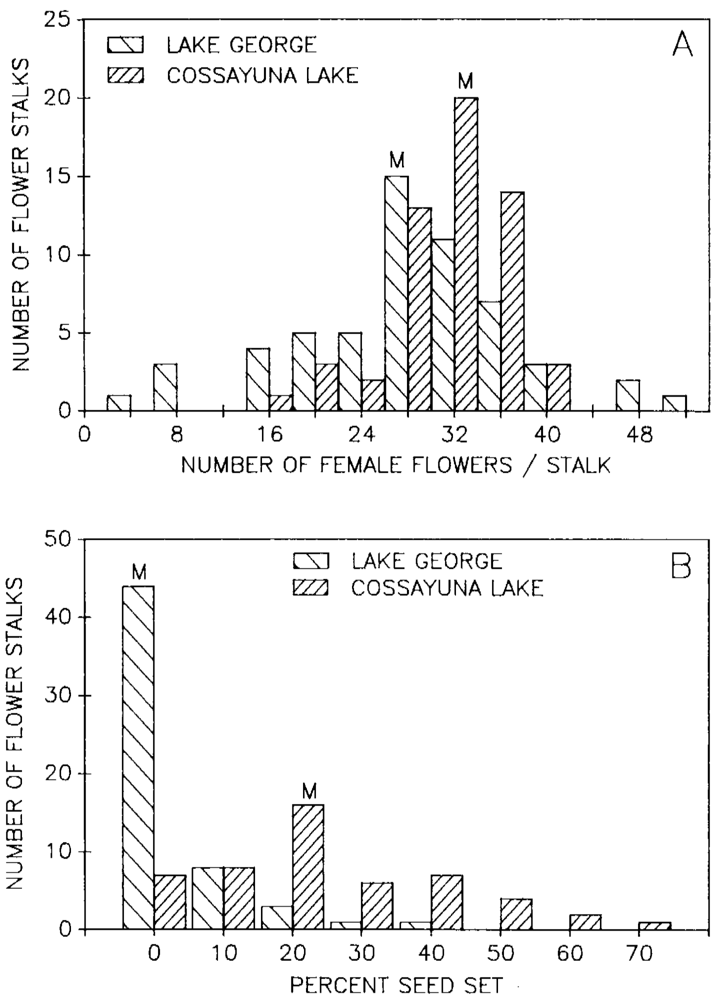

Figure 1A (above). Histogram of the number of female flowers per stalk for the populations in Lake George and Cossayuna Lake. "M" = median for population and Figure 1B (lower). Histogram of percent seed set for flowers from populations at Lake George and Cossayuna Lake. "M" = median for population.

The more productive, eutrophic environment may allow for greater allocation of resources to flower production. However, other significant factors could be water temperature and sediment nutrition.

Percent seed set in Cossayuna Lake (median = 18%, mean = 24%) was significantly higher than Lake George (median = 0.0%, mean = 1.6%; rank sum $p < 0.0001$; Figure 1B), indicating that a larger number of seeds may be produced *in situ* in Cossayuna Lake than in Lake George. The difference in the percentage of seed set may have resulted from the relative difference in the density of flowers in the two populations, but no data have yet been collected on flower spike density in relation to seed set. Eurasian watermilfoil, being wind pollinated and having flower stalks close to the water's surface, should be very sensitive to the density of flowers. Therefore, percent seed set may be related to flower stalk density, stamen production, and pollen/ovule ratios.

Statistically, no significant difference was found (rank sum p = 0.86) between the Cossayuna Lake population seed dry weight (mean = 0.60 mg, n = 50) and the Lake George population seed dry weight (mean = 0.62 mg, n = 45). However, weighing seeds in batches of five each may have diminished the variability, thus affecting the sensitivity of statistical tests.

Cossayuna Lake seeds had a significantly greater rate of germination under light conditions than Lake George seeds (Chi-square p = 0.0004). Germination of Cossayuna Lake seeds incubated in the light (mean = 69%) is comparable to other published reports (77.8% to 97.2%, Coble and Vance 1987; 85%, Patten 1955), while Lake George seed germination rates were substantially lower (mean = 41%).

Seed production has an undetermined importance to the propagation of Eurasian watermilfoil under natural conditions. In some populations, such as Lake George, seed production does not appear sufficient to contribute to the spread of the population due to the low numbers of seeds set and lower rate of germination. In others, such as Cossayuna Lake, there is potential for seeds to contribute to annual propagation and expansion of the population due to relatively high seed set percentages and germination rates, adding to its genetic diversity. One important factor in determining the relative contribution of seeds to plant propagation might be site fertility, both in terms of the nutrient status of the sediments, and the alkalinity (dissolved inorganic carbon content) of the water which control overall productivity of the plants (Smart and Barko 1986). Other factors may well be important to seed set, such as flower stalk density and male flower density. In addition, total allocation to flowers may also be affected by water depth, plant biomass and productivity, available sediment nutrients, disturbance and herbivory (Barko *et al.* 1986).

Although studies to date suggest a low rate of germination *in situ*, laboratory studies show that Eurasian watermilfoil seeds are quite capable of germination. Further studies of seed germination are needed to demonstrate the actual ability of seeds to germinate *in situ*, and seedlings survive (e.g., McDougall 1983). In general, seeds are not considered to be important to the annual propagation of Eurasian watermilfoil, but may provide both genetic diversity and a long-term reservoir for the species in a given location. Further studies are ongoing to assess flower density and factors controlling seed germination and seedling survival.

ACKNOWLEDGMENTS

This manuscript was initially prepared as part of Rensselaer Fresh Water Institute Report #88-7. Partial support of this project was provided by grants from the United Parcel Service and the Lake George Association Fund. The authors would like to thank David Smith for collecting plants from Cossayuna Lake, and Lawrence Eichler, Elizabeth Lawrence, David Smith, Reginald Soracco, and Leslie Taggett for comments on the manuscript.

LITERATURE CITED

Aiken, S. G., P. R. Newroth, and I. Wile. 1979. The biology of Canadian weeds 34. *Myriophyllum spicatum* L. Can. J. Plant Sci. 59:201-215.

Barko, J. W., M. S. Adams, and N. L. Clesceri. 1986. Environmental factors and their consideration in the management of submersed aquatic vegetation: A review. J. Aquat. Plant Manage. 24:1-10.

Coble, T. A. and B. D. Vance. 1987. Seed germination in *Myriophyllum spicatum* L. J. Aquat. Plant Manage. 25:8-10.

Madsen, J. D. and C. W. Boylen. 1988. Seed ecology of Eurasian Watermilfoil (*Myriophyllum spicatum* L.). Rensselaer Fresh Water Institute Report 88-7, Rensselaer Polytechnic Institute, Troy, New York. November 1988. 25 pp.

McDougall, I. A. 1983. A study of germination potential in *Myriophyllum spicatum* L. seeds. Studies of Aquatic Macrophytes Part XXIV. British Columbia Ministry of Environment, Water Management Branch. October, 1983. 31 pp.

Patten, B. C., Jr. 1955. Germination of the seed of *Myriophyllum spicatum* L. Bull. Torrey Bot. Club 82:50-56.

Rensselaer Fresh Water Institute. 1986. A Survey of Eurasian Watermilfoil in Lake George. Fresh Water Institute Report 86-3, Rensselaer Polytechnic Institute, Troy, New York. August, 1986. 8 pp.

Rensselaer Fresh Water Institute, New York State Department of Environmental Conservation, and Adirondack Park Agency. 1988. The Lake George Aquatic Plant Survey 1987 Interim Report. New York State Department of Environmental Conservation, Albany, New York. March 1988.

Smart. R. M. and J. W. Barko. 1986. Effects of water chemistry on aquatic plants: Growth and photosynthesis of *Myriophyllum spicatum* L. Tech. Rep. A-86-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS. 34 pp.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical Methods, 7th Edition. Iowa State University Press, Ames. 507 pp.