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Recolonization of the Littoral Zone by Macrophytes following the Removal of Benthic Barrier Material

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ABSTRACT

Removal of benthic barriers one to two years following installation allowed a systematic study of macrophyte recolonization. Within grids installed in the barren zone, species presence and relative abundance were recorded at 30-day intervals through two growing seasons. At each site, colonization of the 18 m^2 grid systems was observed, with typically 9 to 12 species found 30 days post benthic barrier removal. Sixty days post barrier removal (August), both the number of species (averaging 4.7 m^{-2}) and plant cover peaked (49% cover). A decline in species number and average percent cover observed after 120 days (October) was related to seasonal patterns of growth and die back of annual species. In the second growing season, the number of species stabilized while overall average percent cover (areal coverage) continued to increase. Eurasian watermilfoil colonized all sites, with 71% of all grid squares containing milfoil by the end of the second growing season, representing an average percent cover of 13.6% while total community percent cover averaged 74%. Removal of benthic barrier allowed for the rapid recolonization of both native species and Eurasian watermilfoil.

Key words: Milfoil, *Myriophyllum spicatum,* Palco, Aquascreen.

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INTRODUCTION

Eurasian watermilfoil has progressively infested lakes and ponds across temperate zones of North America over the last 50 years (Reed 1977). The presence of Eurasian watermilfoil in Lake George was first reported in 1985, denoting the start of a potential aquatic weed problem. Today over 110 discrete locations in the lake are known to harbor milfoil (Eichler et al. 1994). Lake George serves as a primary drinking water supply causing public concern over herbicide control of milfoil, and mechanical cutting would only exacerbate its spread to new areas in the lake. Consequently, a management strategy utilizing physical control techniques which included hand harvesting, benthic barrier installation, and suction harvesting was initiated in 1989.

In ecologically sensitive habitats where the control of excessive aquatic vegetation by either herbicides or mechanical harvesting is unacceptable, the installation of benthic barrier material to control macrophyte growth is commonly used (Cooke et al. 1993, Engel 1984). For the most part, it has been shown to be an effective means of controlling Eurasian watermilfoil (Perkins et al. 1980). Although benthic barriers often require maintenance on a yearly basis in areas of high siltation rate, effectiveness may range from 2 to 10 years (WSDOE 1992). By providing immediate control throughout the water column, benthic barriers adversely impact fish spawning (NYSDEC 1990, WSDOE 1992) and benthic invertebrate populations (Bartodziej 1992). Little documentation exists evaluating the longterm impact on macrophyte communities and hence other components of the aquatic food chain once the matting is removed.

The objectives of the present study were to 1) determine the effectiveness of controlling Eurasian watermilfoil in Lake George with benthic barriers, and 2) determine how these benthic barriers may affect native aquatic macrophytes.

MATERIALS AND METHODS

As part of the US EPA Clean Lakes Phase II program of nuisance aquatic plant control targeted at Eurasian watermilfoil in Lake George, sites managed with benthic barriers were limited to areas where Eurasian watermilfoil dominated the aquatic plant community (greater than 50% of total cover) and formed dense beds. This limitation was based on pronounced environmental impacts to the native plant community and cost considerations relative to this particular management technique.

Nine sites were selected for benthic barrier in 1990 and 1991. Prior to mat installation, each site was surveyed for species and their relative abundance. Two types of benthic barrier material were utilized: Palco™[3], a solid polyvinyl chloride (PVC) sheet 20 mil thick, and Aquascreen™[4], an open mesh screen material. Each was shipped as a 7 ft wide roll. For boat transport to a site, 100 ft sections were cut, accordion-folded in 2 ft sections, and laid across the bow. Divers working in pairs pulled the material into the water over the plants. Rebar stakes were used to secure the material to the lake bottom and to adjacent strips.

Of the nine sites covered, four were selected for benthic barrier removal to assess both recolonization rates for native species as well as for Eurasian watermilfoil. Each site had a slope of 5-10%, silty sediment, and similar nutrient loadings. Immediately following benthic barrier removal, a PVC grid system of contiguous 1 m^2 quadrats was established in each of the four study areas. Two grids were installed side-by-side at sites with sufficient area devoid of plants, while smaller sites received a single grid (3 m by 6 m). The species present in each grid and their relative abundance were recorded at the time of grid installation and at 30-day intervals following installation through early October. Species and percent cover were recorded one year post installation. A modified Daubenmire scale (1968) was used with abundance classes denoted as: abundant (greater than 50% cover), common (25 to 50%), present (15 to 25%), occasional (5 to 15%), and rare (less than 5%).

Recolonization of littoral zone areas following the removal of benthic barrier material was evaluated in two ways: 1) frequency, or the number of species recolonizing the grid areas, and 2) relative percent cover of each species within the developing plant population. Percent cover is the areal extent of lake bottom covered by each species of plant. Frequency provides information on the diversity of the aquatic plant community while percent cover indicates the dominance of species within the community.

RESULTS AND DISCUSSION

The four study sites and areal coverage of benthic barrier material installed at each site are listed in Table 1. Also included is the amount of each type of barrier material installed at each site. No plants were present in the grids immediately following benthic barrier removal when Palco Pond Liner served as the benthic barrier material. At sites where Aquascreen benthic barrier was used, certain species were able to survive beneath the barrier, root through the barrier or send shoots up through the mesh openings of the barrier. At Cannon Point, *Heteranthera dubia*, *Elodea canadensis*, and *Myriophyllum spicatum* were found growing through the Aquascreen. These species were removed as the benthic barrier material was removed. At Harris Bay, *Potamogeton robbinsii* and *Sagittaria graminea* were found growing under the Aquascreen bottom barrier and remained following removal of the barrier material. Percent cover and distribution of plants immediately following Aquascreen removal, however, was extremely limited; less than one plant per grid square (1.0 m^2). Visual inspection of the rooting zone in the sedi-

TABLE 1. RECOLONIZATION STUDY SITES IN LAKE GEORGE, N.Y. WITH THE AREA COVERED (M^2) AND TYPE OF BENTHIC BARRIER INSTALLED.

Site	Total barrier area	Palco	Aquascreen
Congers Point	334.7	40.5	294.2
Harris Bay	124.7	—	124.7
Shadow Bay	435.6	435.6	—
Cannon Point	460.3	416.3	44.0

[3]Palco is a registered trademark of Palco Linings, South Plainfield, NJ.

[4]Aquascreen is a registered trademark of Menardi-Southern Corp., Augusta, GA.

ments where Palco Pond Liner was used indicated that all root masses had decomposed within 60 days of original barrier installation. Thus, plants present within the treatment area after barrier removal were not growing from root stocks present prior to barrier installation.

Data from the initial survey of the treated areas indicated primary recolonization by a large number of native species. Six of the seven grid areas had ten or more species established at the time of the first survey; the seventh site had nine species. The number of species within the grids reached a maximum within 30 days after barrier removal and remained constant until autumn senescence. This suggests rapid initial colonization by a diverse assemblage of species. The most common species present, occurring in at least 6 of the 7 grids were: *Najas flexilis, H. dubia, P. robbinsii, E. canadensis,* and *M. spicatum.* These species are common members of the littoral plant community and occur in areas surrounding the treatment zones (Madsen et al. 1989).

Of these, *Najas flexilis* is propagated primarily by seeds. Since seeds of many macrophyte species can survive for many years in unfrozen sediment prior to germination (Sculthorpe 1967), we assume a bank of seeds is present in these sediments in which *Najas* originally occurred. This seed bank would account for the rapid return of *N. flexilis* following barrier removal. The other four species disperse primarily through fragmentation and/or turion formation. In Lake George Eurasian watermilfoil spreads primarily by fragmentation (Madsen et al. 1988).

The average number of species per m^2, representative of plant community diversity, ranged from 3.3 to 5.8 within the first 90 days following benthic barrier removal. The average number of species per m^2 increased rapidly in the first 30 days then stabilized with a peak of 4.7 ± 1.6 at 60 days post barrier removal (Figure 1). The sampling times 90 and 120 days post barrier removal were generally in September and October when autumn senescence of annual species was occurring. Harris Bay, which was managed with Aquascreen, had the highest average number of species per m^2 (5.8 ± 1.1)

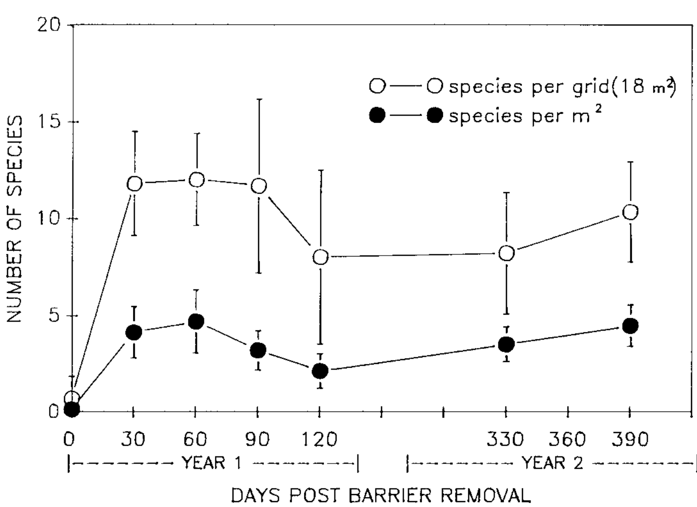

Figure 1. Average numbers of species per grid (n = 7)and per m^2 (n = 126) for all the benthic barrier recolonization sites in Lake George, N.Y. Error bars are 1 standard deviation of the mean.

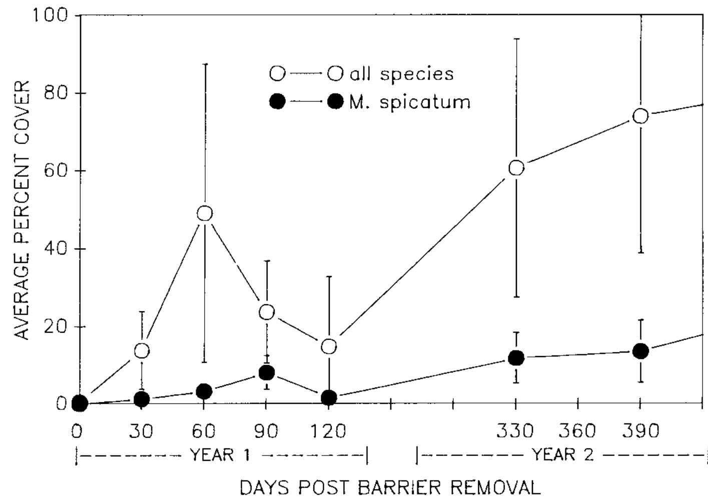

Figure 2. Average percent cover for all species and for Eurasian watermilfoil at the benthic barrier recolonization sites in Lake George, N.Y. Error bars are 1 standard deviation of the mean (n = 126).

within 90 days following benthic barrier removal. This site also had the largest average number of species per m^2 (0.9 ± 0.7) growing beneath the barrier at the time of removal and typically had a more diverse assemblage of native aquatic plants surrounding the original barrier site (Madsen et al. 1989). At other sites, the average number of species per m^2 increased to between 3 and 4 at 60 days post barrier removal, and then declined during the autumn sampling (Figure 1). In the second year (1992), the average number of species per m^2 (4.5 ± 1.1) reached its maximum in the August sampling (day 390).

Percent cover increased rapidly during the first 60 days following barrier removal in 1991 (Figure 2). Average percent cover was nearly zero for all sites immediately following benthic barrier removal. Within 30 days, average percent cover had increased to approximately 10% at all sites (mean 13.8%) except Harris Bay. At Harris Bay, average percent cover had risen to approximately 30% after the first month, coinciding with the largest increase in the number of species present per m^2.

By the October sampling (day 120) in 1991, average percent cover was declining from the maximum (49% ± 38.3) observed in August (day 60), coinciding with the time for autumn senescence of annual species. At sites where the average percent cover was still low (less than 20%) in August, continued increases in percent cover were observed into the October sampling. By the first sampling date in 1992 (day 330, June), average percent cover (60.7% ± 33.3) exceeded the August maximum (49%) observed in 1991. A portion of this increase, however, may be due to extensive growth of curly-leaf pondweed, *Potamogeton crispus,* within one of the grids at Cannon Point. Average percent cover per m^2 at this site exceeded 110% for the June, 1992 sampling. Curly-leaf pondweed grows rapidly in water less than 20 C and generally reaches peak biomass in June. Declining rapidly thereafter, it becomes only a small component of the aquatic plant population by August. Curly-leaf pondweed reaches nuisance proportions in a number of regional lakes, and has been the subject of plant management activities in New York state

(Tobiessen et al. 1992). Percent cover by all species continued to increase to an average of 74% ± 36.3 for all grids through the second sampling in August 1992 (day 390) indicating continuing growth and colonization at the Cannon Point site.

Eurasian watermilfoil. Eurasian watermilfoil rapidly recolonized all areas treated with benthic barrier. Immediately after barrier removal, Eurasian watermilfoil was not present in any of the grids; however, within 30 days, milfoil was found in 44% of grid squares. The maximum number of grid squares containing milfoil (74%) was observed 90 days after benthic barrier removal. This coincided with the month of September, a time of maximum fragmentation of watermilfoil in Lake George (Madsen et al. 1988). Many of the grid squares may have contained fragments of milfoil which did not survive because by 120 days after barrier removal, the number of grid squares containing milfoil had declined to 56%. At the conclusion of data collection in August of 1992, 71% of all grid squares contained Eurasian watermilfoil. Proximity to milfoil infested areas had a major effect on the rate of colonization of areas treated with benthic barrier.

Average percent cover for milfoil increased throughout the term of the present study (Figure 2). By 60 days following benthic barrier removal, average percent cover for milfoil was 3.3%. Between 60 and 90 days following barrier removal, average percent cover for Eurasian watermilfoil increased to 8.1%, while average percent cover for all species declined from 49% to 23.6%. Eurasian watermilfoil, a perennial, contributes a greater portion of the overall percent cover in the fall of the year since it does not die back to the extent that annual species do. In Lake George, peak milfoil biomass is reported to occur in October (Madsen et al. 1989). For year 2 (1992), average percent cover of milfoil continued to increase reaching a maximum of 13.6% in August of 1992. At this time, average percent cover for all species was 74%. The slope of average percent cover is much greater for the total community than for Eurasian watermilfoil, suggesting that growth and colonization by all species, taken as a group, is not impeded by milfoil at the density present at this time. At high density levels, however, milfoil has been shown to cause a decline in native vegetation (Madsen et al. 1991).

The Cannon Point site showed the most rapid colonization and growth of Eurasian watermilfoil with average percent cover approaching 50% in grid 2 and milfoil present in all grid squares one year following barrier removal. Large areas of low and moderate density growth of Eurasian watermilfoil surround this site, acting as a continuing source for fragments. In areas more remote from large populations of Eurasian watermilfoil such as Shadow Bay, recolonization was much less rapid. After two growing seasons following benthic barrier removal at Shadow Bay, only 20% of grid squares contained milfoil with an average percent cover of 1%.

Benthic barrier, as a management tool for Eurasian watermilfoil, needs to be incorporated with other control techniques. In order to maximize the effectiveness of benthic barrier, it should either be used in areas remote from other populations of milfoil, or perhaps more appropriately, peripheral areas containing milfoil should be managed and maintained prior to and following benthic barrier removal. Without continued maintenance, sites managed with benthic barrier developed extensive milfoil populations within two growing seasons following the removal of benthic barrier.

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LITERATURE CITED

Bartodziej, W. 1992. Effects of weed barrier on benthic macroinvertebrates. Aquatics 14: 14-18.

Cooke, G. D., E. B. Welch, S. A. Peterson and P. R. Newroth. 1993. Restoration and Management of Lakes and Reservoirs. 2nd Ed. CRC Press, Inc. Boca Raton, Florida. 548 pp.

Daubenmire, R. 1968. Plant Communities: A Textbook of Synecology. Harper and Row, New York. 300 pp.

Eichler, L. W., R. T. Bombard and C. W. Boylen. 1994. Final report on the Lake George tributary survey. Fresh Water Institute Technical report 94-1, Troy, New York. 17 pp.

Engel, S. 1984. Evaluating stationary blankets and removable screens for macrophyte control in lakes. J. Aquat. Plant Manage. 22: 43-48.

Madsen, J. D., L. W. Eichler and C. W. Boylen. 1988. Vegetative spread of Eurasian watermilfoil in Lake George, New York. J. Aquat. Plant Manage. 26: 47-50.

Madsen, J. D., J. W. Sutherland, J. A. Bloomfield, K. M. Roy, L. W. Eichler and C. W. Boylen. 1989. Lake George Aquatic Plant Survey: Final Report. New York State Department of Environmental Conservation, Albany, New York. May 1989.

Madsen, J. D., J. W. Sutherland, J. A. Bloomfield, L. W. Eicher and C. W. Boylen. 1991. The decline of native vegetation under dense Eurasian watermilfoil canopies. J. Aquat. Plant Manage. 29: 94-99.

New York State Department of Environmental Conservation (NYSDEC). 1990. Diet for a Small Lake. New York State Department of Environmental Conservation and the Federation of Lake Associations, Inc. Albany and Rochester, New York.

Perkins, M. A., H. L. Boston and E. F. Curren. 1980. The use of fiberglass screens for control of Eurasian watermilfoil. J. Aquat. Plant Manage. 18: 13-19.

Reed, C. F. 1977. History and distribution of Eurasian watermilfoil in the United States and Canada. Phytologia 36:417-436.

Sculthorpe, C. D. 1967. The Biology of Aquatic Vascular Plants. Edward Arnold Publishers, London. 610 pp.

Tobiessen, P., J. Stewart and S. Benjamin. 1992. Dredging to control curly-leaved pondweed: A decade later. J. Aquat. Plant Manage. 30: 71-72.

Washington State Department of Ecology (WSDOE). 1992. Final Supplemental Environmental Impact Statement and Responsiveness Summary Volume 1. Aquatic Plant Management Program for Washington State. Washington State Department of Ecology, Olympia, Washington.