Hydrobiologia **415:** 207–211, 1999.
J. M. Caffrey, P. R. F. Barrett, M. T. Ferreira, I.S. Moreira, K. J. Murphy & P. M. Wade (eds),
Biology, Ecology and Management of Aquatic Plants.

Loss of native aquatic plant species in a community dominated by Eurasian watermilfoil

Charles W. Boylen[1,*], Lawrence W. Eichler[1] & John D. Madsen[2]
[1]*Darrin Fresh Water Institute, Rensselaer Polytechnic Institute, Troy, NY 12181, U.S.A.*
[2]*U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180, U.S.A.*

Key words: milfoil, *Myriophyllum spicatum*, aquatic plant communities, exotic species, invasive species, submersed aquatic macrophytes

Abstract

Ecological evaluation of the impact of an exotic species upon native plant species is frequently a combination of historical data prior to introduction and after full establishment with little observation in between. The introduction of *Myriophyllum spicatum* L. (Eurasian watermilfoil) into Lake George, New York, U.S.A. was first noted in 1985. In 1987, a few newly established plants were allowed to grow unimpeded by human management to document the rate of colonization of this species into a new habitat with its ultimate dominance over, and systematic elimination of, native species. This changing community has been closely monitored over the past decade. Initially a 6 m^2 grid system composed of 144 0.5 m^2 plots with four radiating transect lines was laid out with the isolated *M. spicatum* plants as the center. The site was revisited between 1987 and 1997 to mark the extent of the developing *M. spicatum* bed and its effect on the composition of the native plant community. Since 1987, the area of dense growth has expanded in all directions, impeded only where some physical barrier, such as upper or lower water depth limits or sediment type curtailed its growth. Concurrently, with this expansion, a decline in species richness and abundance of native species was observed.

Introduction

Myriophyllum spicatum L. (Eurasian watermilfoil), an alien species to North America, was first noticed in nuisance proportions in the Chesapeake Bay in the United States in the 1940s (Couch & Nelson, 1985). In the last five decades, its spread throughout much of North America has created nuisance level growth while drastically altering native plant communities (Smith, et al., 1966; Coffey & McNabb, 1974; Newroth, 1985). At the present time, it is found from Florida to Quebec in the east, and California to British Columbia in the west (Smith & Barko, 1990).

The proliferation of this species has serious impacts on aquatic ecosystems. From a human perspective, dense growth interferes with water-based recreation, disrupts use of waterways for waterflow, irrigation and drinking purposes, as well as contributing to flooding (Newroth, 1985). Dense canopies shade out native vegetation, alter the community composition of aquatic macroinvertebrates and may impair the ability of some fish species to spawn in the littoral zone (Aiken et al., 1979; Newroth, 1985). The high rates of plant sloughing and leaf turnover, as well as the decomposition of high biomass at the end of the growing season, can significantly increase the internal loading of phosphorus and nitrogen to the water column (Nichols & Shaw, 1986).

Domination of littoral zone vegetation by *M. spicatum*, and suppression of native plants has been noted in the literature, but generally not studied while plant community changes were actually occurring. For instance, Coffey & McNabb (1974) noted that *Vallisneria americana* appeared to survive under a canopy of *M. spicatum*, but other native species were already absent from dense stands of the exotic. Studies in British Columbia noted that 2–3 years were required for *M. spicatum* to dominate a given area of littoral zone (Aiken et al., 1979; Newroth, 1985). The present

* Author for correspondence

study is a continuation of observations made during 1987–1989 (Madsen et al., 1991a).

Description of study site

Lake George is a large (114 km^2) and deep (18 m average depth, 58 m maximum) lake located in northeastern New York State, U.S.A. *M. spicatum* was first observed in the lake in 1985 when three sites were discovered. Lakewide surveys have found approximately 10–15 new sites yearly. By 1997, *M. spicatum* was established at 123 different sites in the lake. Currently most of these sites are managed in some way. In 1986, 10 isolated plants were found at the Northwest Bay site. In 1987, a small bed had formed. Because of the small size of the population and physical characteristics of the site (e.g. no shoreline development, depth range, silty sediments and diverse native plant community), the site was selected for long-term study.

Materials and methods

In 1987, a permanently-fixed grid (6 m $\times$ 6 m) was centered over the newly established bed in Northwest Bay. The grid was subdivided every 0.5 m, creating a grid-work of 144 contiguous quadrats, each with an area of 0.25 m^2. Four radiating transects were set up from the central grid system, deployed along the four cardinal axes of the compass. The transects were 25 m long with a marker every meter.

The sediment type of the observation area was sandy silt. The bed covered a depth range from 2–4 m. Percent cover was estimated using the Daubenmire scale (Daubenmire, 1968). Within the grid, percent cover was estimated for each species within each quadrat of 0.25 m^2. For each transect, a portable 0. 1 m^2 quadrat was used to estimate percent cover. Daubenmire values were converted to the centroid of each cover range for calculations of (a) average percent cover of species (where total cover could exceed 100%), (b) percent of community – percent cover relative to total coverage of all plants (relative cover of all species adds up to 100% for each quadrat), and (c) percent frequency (percent of quadrats containing a given species). The expanding bed was mapped by divers using compass bearings and measuring marked intervals along the bed perimeter.

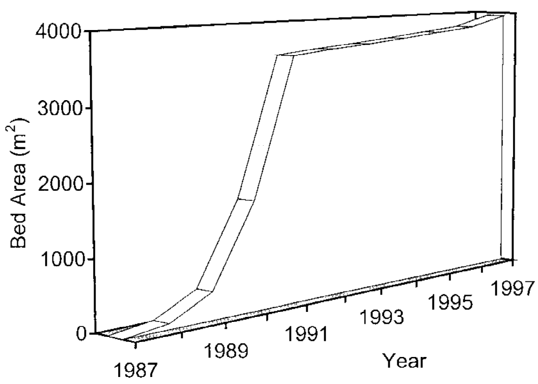

Figure 1. Areal expansion of the bed of *Myriophyllum spicatum* in Northwest Bay, Lake George, New York.

Results and discussion

The areal extent of the bed expanded rapidly between 1987 and 1991, but has leveled off in recent years (Figure 1). In 1997, the maximum area attained was approximately 4000 m^2, representing an expansion consistent within allowable environmental constraints (upper or lower depth limits and discontinuity in sediment type). In Lake George, the increase in bed density and area has been primarily through the growth of root crowns and stolons.

Within the quadrats of the central grid and along the four radiating transects (N, S, E and W), *M. spicatum* showed consistent increases in both abundance and presence (as measured by frequency and percent cover). The initial bed, where percent cover was greater than 50%, began in the grid center and spread outward. In 1987, almost all quadrats in the grid had some *M. spicatum*, with percent cover less than 30%. In 1988, percent cover in the grid was almost 80% and approached 100% by 1989. Since 1989, dense growth of *M. spicatum* has completely filled the grid and has spread outward along the four radiating transects. The east and south transects contained *M. spicatum* in only 10% of the quadrats in 1987 but over 80% had *M. spicatum* in 1989. The spread along the north and west transects has been due in part to the physical bathymetry of the site. Percent cover (Figure 2) increased from almost zero in 1987, to 30–40% in the east, north and west transects, and over 60% in the south transect.

Concomitantly, the percent frequency of *M. spicatum* found in the quadrats has increased (Figure 3). *M. spicatum* represented only 15% of the community within the grid in 1987 (Figure 3) to be-

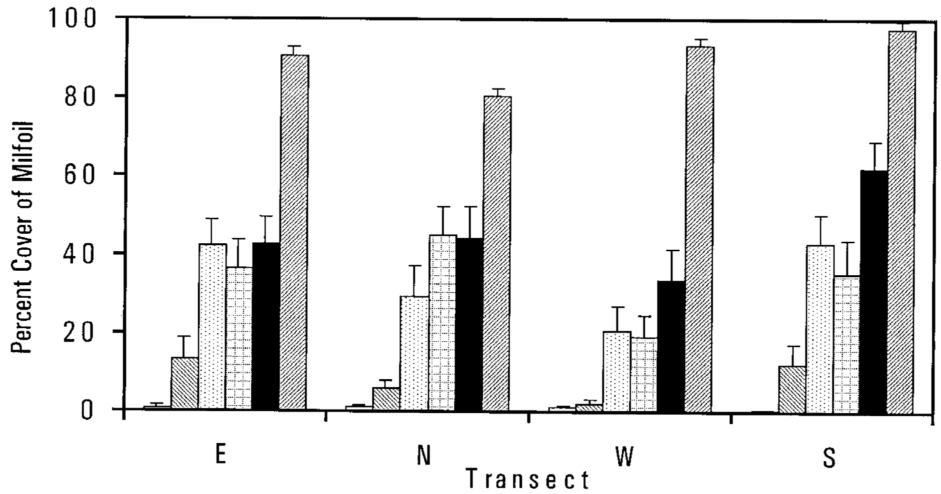

Figure 2. The percent cover of milfoil (*Myriophyllum spicatum)* in each of the transects radiating from the central grid. Bars for each transect represent data from years 1987, 1988, 1989, 1990, 1991 and 1997. Error bars equal the standard error of the mean, *n*=25.

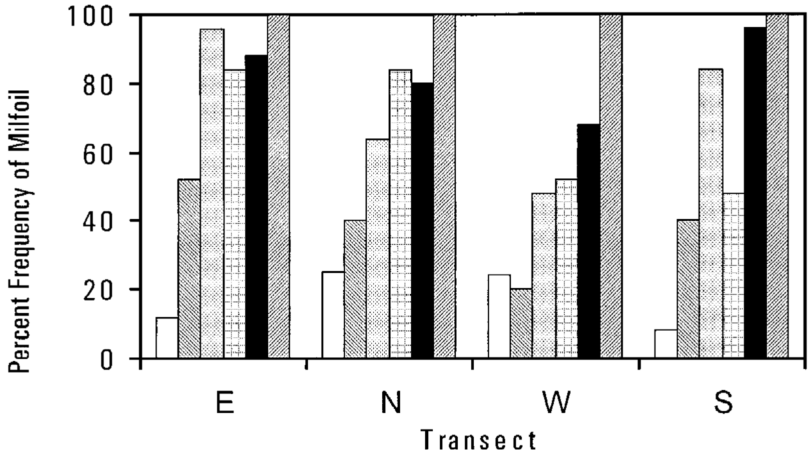

Figure 3. The percent frequency of milfoil (*Myriophyllum spicatum)* in each of the transects radiating from the central grid. Bars for each transect represent data from years 1987, 1988, 1989, 1990, 1991 and 1997.

come the overwhelming dominant species in 1989 in excess of 95%. Within three years (1989), the formerly native communities were reduced to only a few stems of native plants under a dense canopy of *M. spicatum*. Species richness declined from an average of 5.5 species per quadrat in 1987 to slightly over two in 1989 (of which one species was always *M. spicatum*). During 1990–1997, *M. spicatum* continued to suppress the native vegetation in this locality with species richness less than two species /quadrat for all years. The total number of species found in the grid (36 m^2) has also decreased linearly over time, from 20 in 1987 to 14 in 1988 and to nine in 1989. Since 1990, the number of species in the grid has leveled out at seven.

Not only did *M. spicatum* dominate along the radiating transects beyond the central grid work, the number of species per 0.1 m^2 quadrat measured at 1 m intervals along each transect also decreased (Figure 4). In 1997 the north transect had an average of three species per 0.1 m^2 quadrat, whereas the east, west and south transects had an average of 1.5 species per quadrat. Along the transects, the presence of native species which were abundant before *M. spicatum* became established has diminished considerably. Affected species include *Bidens beckii* Torr., an *Eleocharis* sp.,

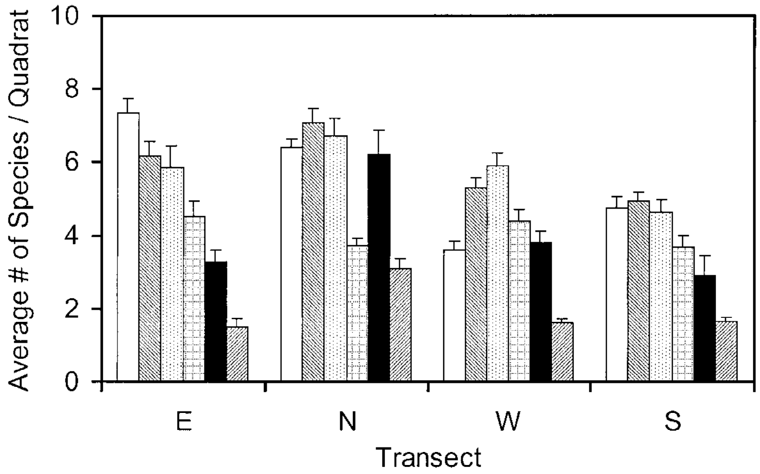

Figure 4. The average number of species found in each of the transects radiating from the central grid. Bars for each transect represent data from years 1987, 1988, 1989, 1990, 1991 and 1997. Error bars equal the standard error of the mean, *n*=25.

Elodea canadensis (Michx) Planchon., *Heteranthera dubia* (Jacq.) MacM., *Juncus pelocarpus* Meyer, *Myriophyllum tenellum* Bigel., *Najas flexilis* (Willd) Rostk. & Schmidt., *Nuphar lutea* (Durand) Beal, *Potamogeton amplifolius* Tuckerm., *P. gramineus* L., *P. praelongus* Wulfen, *P. robbinsii* Oakes, *P. spirillus* Tuckerm., *P. zosteriformis* Fern., *Sagittaria graminea* Michx., a *Sparganium* sp., *Utricularia vulgaris* L. and *Vallisneria americana* Michx. Species which were infrequent within the native plant community in 1987 (*Myriophyllum alterniflorum* DC, *Najas guadalupensis* (Spreng.) Morong., *Potamogeton perfoliatus* L., *P. pusillus* L., *P. vaseyi* Robbins, *Ranunculus longirostris* Godr. and *Utricularia resupinata* B.D.Greene.) had disappeared altogether by 1997.

The mechanism by which *M. spicatum* dominates other species has been the topic of some discussion. The allocation patterns of plant biomass and growth form allow *M. spicatum* to create a dense upper canopy that contributes substantially to reduced light intensity available to plants under the canopy (Madsen et al., 1991b). Two Lake George species, *V. americana* and *P. robbinsii*, have continued to survive at reduced abundance under the dense *M. spicatum* canopy. Similar tolerance of low light levels under a *M. spicatum* canopy has been reported for these two species in other lakes (Coffey & McNabb, 1974). In addition, the dense root mass formed by *M. spicatum* may competitively exclude some species. Prolific formation of stem fragments and an ability to exploit disturbed habitats also may be key elements to its success.

Conclusions

Invasion and subsequent explosive growth of *Myriophyllum spicatum* severely impacts the density and diversity of native aquatic plant communities. Over an 11-year period, 13 of 20 native plant species were eliminated and the abundance of the remaining species was substantially reduced under a dense canopy of *M. spicatum*. Species richness declined from an average of 5.5 species per quadrat (0.25 m^2) in 1986 to two species per quadrat in 1997, one of which was always *M. spicatum*. Loss of species richness and habitat complexity as a result of plant community dominance by *M. spicatum* may be extended to other components of the food web.

Acknowledgments

The authors greatly acknowledge the support of the FUND for Lake George, New York Department of Environmental Conservation and the Endowment of the Darrin Fresh Water Institute. Numerous DFWI student interns and technicians provided assistance.

References

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

Coffey, B. T. & C. D. McNabb, 1974. Eurasian watermilfoil in Michigan. Mich. Bot. 13: 159–165. Couch, R. & E. Nelson,

1985. *Myriophyllum spicatum* in North America. In Proc. First Int. Symp. on watermilfoil (*Myriophyllum spicatum*) and related Haloragaceae species. Vancouver, BC, Canada. Aquat. Plant Mgmt Soc. 8–18.

Daubenmire, R., 1968. Plant Communities: A Textbook of Synecology. Harper & Row, NY: 300 pp.

Madsen, J. D., C. F. Hartleb & C. W. Boylen, 1991a. Photosynthetic characteristics of *Myriophyllum spicatum* and six submersed aquatic macrophyte species native to Lake George, New York. Freshwat. Biol. 26: 233–240.

Madsen, J. D., J. W. Sutherland, J. A. Bloomfield, L. W. Eichler & C. W. Boylen, 1991b. The decline of native vegetation under dense Eurasian watermilfoil canopies. J. Aquat. Plant Mgmt 29: 94–99.

Newroth, P. R., 1985. A review of Eurasian Watermilfoil impacts and management in British Columbia. In Proc. First Int. Symp. on watermilfoil (*Myriophyllum spicatum*) and related Haloragaceae species, Vancouver, BC, Canada. Aquat. Plant Mgmt Soc. 139–153.

Nichols, S. A. & B. H. Shaw, 1986. Ecological life histories of the three aquatic nuisance plants, *Myriophyllum spicatum, Potamogeton crispus,* and *Elodea canadensis.* Hydrobiologia 131: 3–21.

Smith, C. S. & J. W. Barko, 1990. Ecology of Eurasian watermilfoil. J. Aquat. Plant Mgmt 28: 55–64.

Smith, G. E., T. F. Hall & R. A. Stanley, 1966. Eurasian watermilfoil in the Tennessee Valley. Weed: 15: 95–98.