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Vegetative Spread of Eurasian Watermilfoil in Lake George, New York

J. D. MADSEN[1], L. W. EICHLER[2], AND C. W. BOYLEN[3]

ABSTRACT

Vegetative spread of Eurasian watermilfoil (*Myriophyllum spicatum* L.) was studied in two field experiments and one laboratory experiment on populations from Lake George, New York. Local spread by stolons exhibited a strong seasonal component related to growth, with an increase in colonization in mid-summer followed by a decline late in the season, correlated to plant mortality. Plant colonies are therefore dynamic seasonally, not merely colonies that increase linearly. Fragment deposition on littoral substrates showed a strong seasonal trend, with highest fragmentation in late September. Laboratory experiments in which Eurasian watermilfoil fragments were grown in lake water indicated that fragments not only survived, but increased in length and biomass while suspended in the water column for long periods of time. Two effective means of vegetative spread were studied for Eurasian watermilfoil in Lake George: local spread by stolons and medium to long distance spread by fragmentation.

Key words: fragments, stolons, rhizomes, reproduction, propagation, milfoil.

INTRODUCTION

Vegetative propagules are generally accepted as the most important mechanism for propagation and dispersal of many submersed aquatic macrophytes (Sculthorpe, 1967; Weber, 1972; Rogers and Breen, 1980). Eurasian watermilfoil propagules (stolons and fragments) are the most significant mechanism for intra- and interlake dispersal (Aiken *et al.*, 1979; Kimbel, 1982; Johnstone *et al.*, 1985). However, the importance of different dispersal mechanisms relative to distance from established populations (short range versus long range), and seasonality of dispersal have not been previously reported. Investigation of these two aspects of vegetative spread of Eurasian watermilfoil in Lake George, New York were the goals of our initial studies.

Although Eurasian watermilfoil has been found in regional lakes for at least two decades, it was first observed in Lake George in 1985 (Rensselaer Fresh Water Institute, 1986). An extensive survey of the lake in 1974 (Ogden *et al.*, 1976) did not report Eurasian watermilfoil. Surveys currently report that Eurasian watermilfoil has a distribution throughout the lake basin, with dense monotypic stands totalling over 5000 m² (Rensselaer Fresh Water Institute *et al.*, 1988).

METHODS

Lake George is a large (51 km long by 2.3 km wide, 58 m maximum depth), oligotrophic lake situated on the southeastern edge of the Adirondack Mountains of New York State. Waters of the lake are characteristically low in nutrients and alkalinity; however, recent evidence of progressive eutrophication in the south basin has been reported (Rensselaer Fresh Water Institute, 1988).

All field experiments were conducted in Huddle Bay (Figure 1), which has the largest stands of Eurasian watermilfoil found in Lake George (Rensselaer Fresh Water Institute *et al.*, 1988). The first field experiment examined local spread of Eurasian watermilfoil. Four grids of contiguous 1 m² quadrats were set up as four arms radiating from the center of a large, shallow (1.5 m depth average) population, each arm being 3 m by 18 m (Figure 1). The presence or absence of Eurasian watermilfoil in this grid system was recorded by divers on a monthly basis from June through early November of 1987. The presence or absence of Eurasian watermilfoil was mapped, and both the percentage of occupied grids, as well as the transition of occupancy in each quadrat recorded and transition frequencies tabulated.

The second field experiment examined medium-distance dispersal of Eurasian watermilfoil by fragments. Three 100 m² quadrats (approximately 33 m by 3 m) were placed beyond the fringe of the scattered plant zone and 30 to 50 m away from a dense Eurasian watermilfoil bed, thus only fragments that moved some distance were collected. Quadrats were placed at 1 m, 3 m and 5 m depths (Figure 1). Divers collected all fragments found within these quadrats at monthly intervals from June through November 1987. The fragments from each quadrat were counted, dried at 70 C to constant weight (generally 48 hours), and weighed. Since fragments were collected in June to clear the area, results are reported beginning in July. Results are also incomplete for August, due to human disturbance of the quadrats.

The laboratory experiment evaluated the ability of fragments to survive long-term dispersal by suspension in the water column. Healthy fragments were brought into the laboratory and cut to 20 cm length. A subset of 20 fragments were weighed wet, dried at 70 C to constant weight, and weighed for an average at the initial point in time. Ten one-liter cylinders were placed in a temperature-controlled water bath maintained at 20 C. Filtered lake

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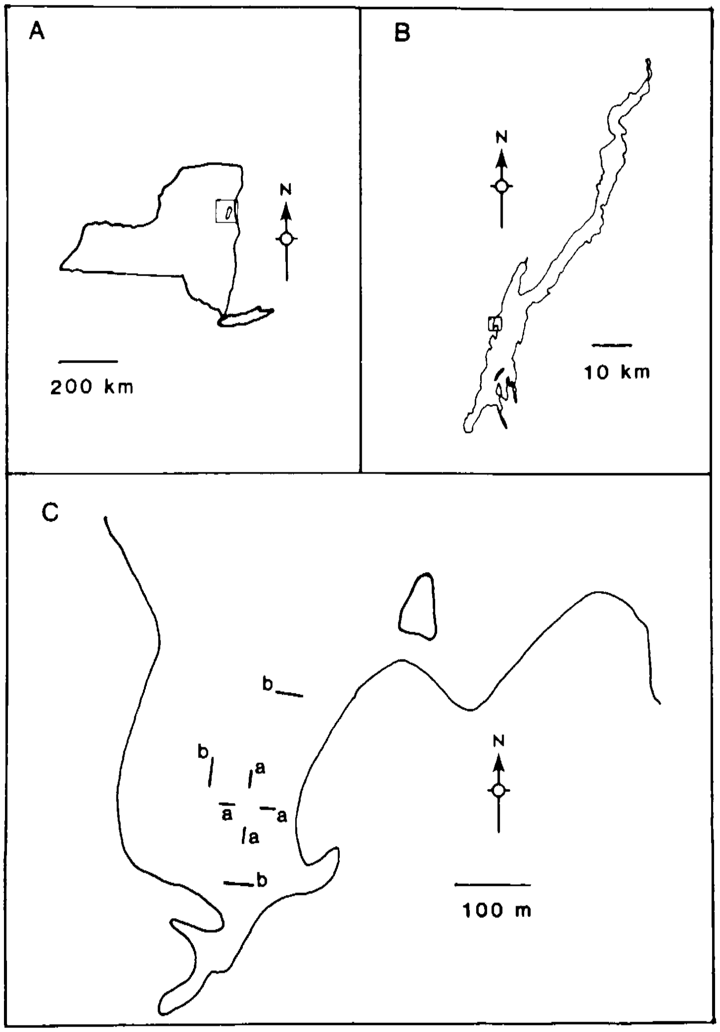

Figure 1. Map showing location of Lake George, New York (A), the location of Huddle Bay within Lake George (B), and the arrangement of the grid system and fragment collection quadrats in Huddle Bay (C). The experimental structures indicated are the grid system (a) and fragment collection quadrats (b).

water was used in each cylinder, and replaced weekly during the duration of the experiment. Five fragments were placed in each cylinder. Light intensity incident on the experimental cylinders was 400 uE m^{-2} s^{-1} on a 14 h light:10 h dark daylength cycle. After 36 days, all fragments were removed and length and dry weight measured.

RESULTS AND DISCUSSION

The spread of Eurasian watermilfoil as measured in the grid system (field experiment 1) displayed a pronounced seasonal influence. In June, only 44% of the quadrats contained Eurasian watermilfoil. By July, this percentage had increased to 54% and peaked in August at 71%. Percent occupancy decreased to 64% in September, and 69% in October.

Transition frequencies provide a much more detailed picture of local plant dynamics. For a given quadrat within the grid, Eurasian watermilfoil was recorded as either absent (–) or present (+). The transition from one sampling period to the next was then interpretted as: survival (+/+), uncolonized (–/–), colonization (–/+), or mortality (+/–). Survival of individuals in plots from one sampling to the next (+/+) increased slowly over the entire sampling period, finally reaching 62% during September and October (Figure 2). Maintenance of uncolonized space within the grid system (–/–) dropped rapidly from 45% in July to 28% in August, and then maintained that level. Rapid colonization (–/+) occurred in July (10%) and August (19%), but decreased for the last two months (3% and 7%, respectively). Finally, mortality of Eurasian watermilfoil in an individual quadrat of the grid system (+/–) was low (<1%) in July and August, peaked in September at 10% and later in October declined to 2%. It appears that margins of beds are dynamic, with territory being invaded and then lost.

An inspection of individual arms of the grid system revealed that some areas were overtaken with Eurasian watermilfoil, and remained at or near total occupancy throughout the sampling period. Other arms, possibly of less suitable depth or substrate, were more dynamic. The east arm contained 63% occupancy in June and approached 94% occupancy the next month, maintaining near total occupancy for the remainder of the sampling period. The south and west arms were 30% occupied in June, increased to 61% and 52%, respectively, in August, and both then receded to 46% in October. The pattern for the remaining arm (north) was intermediate to that observed for the other three.

Fragment counts in the grid system indicate that local spread of Eurasian watermilfoil appeared to occur largely by stolons or rhizomes, and not by fragments. Only 6.5% of the quadrats were colonized by fragments over the entire study period, comprising 26.4% of colonization. However, 50% of quadrats newly colonized by fragments earlier in the season did not have Eurasian watermilfoil present at the last date of observation. Local spread was quite vigorous in mid-summer (July and August), and ceased in early Autumn. This may well be tied to the overall productivity of the plant. The impact of interannual growth on expansion remains to be determined.

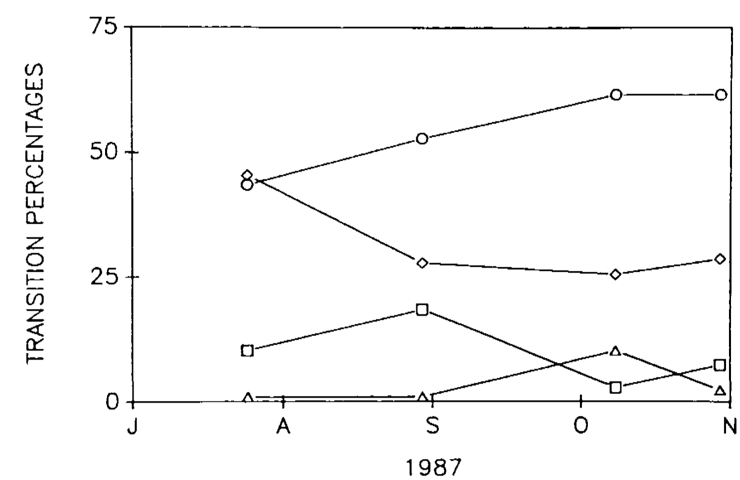

Figure 2. Transition frequencies of Eurasian watermilfoil in grids, over time in months of 1987. ○, Survival (+/+); □, Colonization (–/+); Δ, Mortality (+/–); ◇, Uncolonized (–/–).

Fragment deposition on hydrosoils can provide longer distance dispersal than growth by stolons. Fragment deposition on hydrosoils was almost nonexistent in June and July when plants were actively elongating (Figure 3). However, after the period of peak biomass in August (Rensselaer Fresh Water Institute *et al.*, 1988; Madsen and Boylen, 1988; Rensselaer Fresh Water Institute, 1986), fragmentation increased dramatically. Within each depth of measurement, the pattern for all three quadrats was similar. Fragmentation peaked in September as plants began to senesce (Rensselaer Fresh Water Institute *et al.*, 1988; Madsen and Boylen, 1988) and then dropped as sharply as it rose, with almost no fragments found in October, although plant biomass remained high.

The number of fragments found in the quadrats correlated with the favorability of depths for Eurasian watermilfoil in Lake George (Rensselaer Fresh Water Institute *et al.*, 1988). The greatest number of fragments were always found in the 3 m quadrat, the optimal depth for Eurasian watermilfoil in Lake George. The 1 m depth interval was intermediate, with fragments occasionally present, however this depth is generally shallower than major Eurasian watermilfoil occurrences to date. The 5 m depth had the fewest fragments. At 5 m, only occasional scattered plants were found in the lakewide survey. Most fragments observed in this field experiment were believed to have come from nearby beds in Huddle Bay, and traveled a distance of 30 to 50 m.

The strong seasonality in fragment rain suggests that the occurrence of fragments is related to the phenology of the plant. An alternative explanation is that human activity may cause increased fragmentation (allofragments). However, the experimental plots within Huddle Bay were marked to minimize boat traffic. Thus, self-generated fragments (autofragmentation) are more likely. Local spread of Eurasian watermilfoil begins in early summer, accompanying increases in shoot length and biomass. Vegetative spread mechanisms are tightly coupled to the phenology of the plant.

In view of the large numbers of fragments observed, the ability of fragments to survive with only lake water as

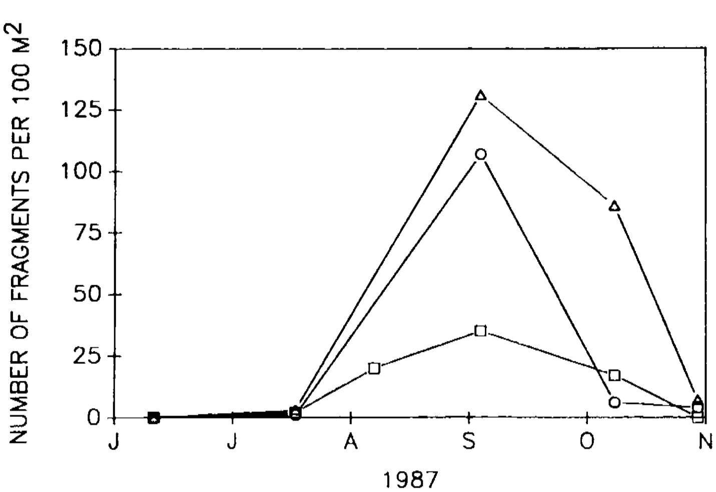

Figure 3. Number of fragments per 100 m^2 quadrat at each of three depths for months in 1987; ○, 1 m; ◇, 3 m; □, 5 m.

TABLE 1. INCREASE IN FRAGMENT LENGTH AND DRY WEIGHT AFTER INCUBATION FOR 36 DAYS UNDER LABORATORY CONTROLLED CONDITIONS. DATA PRESENTED AS AN AVERAGE, WITH STANDARD ERROR IN PARENTHESES.

Parameter	Initial	After 36 days
Length (cm)[a]	20 (0)	37.3 (0.61)
Dry Weight (g)[b]	0.172 (0.0089)	0.241 (0.0089)
Sample Size	20	50

[a]Rank-sum p-value<0.001
[b]T-test p-value<0.001; Rank-sum p-value<0.001

a substrate is of major importance. In eutrophic lakes, adequate soluble nutrients (N and P) are generally available to sustain growth within the water column. In oligotrophic lakes, such as Lake George, ambient concentrations of essential nutrients are exceedingly low in midsummer (Rensselaer Fresh Water Institute, 1988). In order to assess the ability of fragments to survive under oligotrophic conditions, a laboratory growth experiment was conducted. After 36 days of incubation, the experimental fragments increased from an initial length of 20 cm to an average of 37 cm (85%; Rank-sum $p<0.001$; Table 1). Average dry weight increased from 0.172 g to 0.241 g (40%; T-test $p<0.001$). Fragments were not only capable of survival in lake water, but increased in both length and weight. While free-floating, neither nutrient availability nor light intensity appeared limiting in the time frame of this experiment.

In this study we have addressed the seasonal patterns of vegetative propagation by Eurasian watermilfoil, as well as testing a methodology to estimate spread by its two most important mechanisms: colony expansion by lateral stems, and dispersal by fragments. We have also shown that fragments can survive well on the nutrient content of oligotrophic lake water. Several other factors are important to fragment survival; e.g., adequate light intensities must be received to maintain a daily positive carbon balance. In addition, fragment settling rates, light compensation points, and reserve stored carbon pools (Kimbel, 1982) are important factors for fragment survival and establishment in littoral environments. These factors are important considerations for future studies of vegetative propagation.

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Allelopathy In Threesquare Burreed (*Sparganium americanum*) and American Eelgrass (*Vallisneria americana*)

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ABSTRACT

Water extracts of dried threesquare burreed (*Sparganium americanum* Nutt.) shoots, threesquare burreed roots, and American eelgrass (*Vallisneria americana* Michx.) plants were shown to have allelopathic properties when tested by a bioassay technique using lettuce (*Lactuca sativa* L. var. "Buttercrunch") as the test organism. Allelopathy was manifested as a reduction in germination percentage and in radicle growth and it showed a concentration response. Osmotic potentials of less than 70 milliosmols per kilogram (mOs/kg) did not affect lettuce germination or gowth. The pH of the plant extracts was shown to have no effect on germination or growth. Extract of burreed roots caused the lettuce hypocotyls to be short and bulbous but the same phenomenon was not observed with extract of burreed shoots

Key words: allelopathy, aquatic plants, burreed, eelgrass, leachates, *Sparganium, Vallisneria.*

INTRODUCTION

The existence of allelopathy has been well documented over the past few decades. A myriad of weed species have been reported to have allelopathic properties (Putnam, 1985; Rice, 1984). Most of these reports pertain to terrestrial weeds but a few workers did report on allelopathy in aquatic species (Ashton, *et al.*, 1985; Szczepanski, 1977). Documenting the extent of allelopathy in aquatic weeds and isolating and identifying the allelochemicals which occur in them is an important undertaking. It could lead to the use of these compounds in the control of terrestrial or aquatic weeds. It could also lead to the eventual commercial extraction of these compounds from mechanically harvested aquatic weeds which would provide a market for the harvested biomass, thereby reducing the disposal problem and the cost of harvesting to the consumer. The commercial use of natural products is not without precedent. At least 17 natural products have already been developed for commercial use as pesticides or plant growth regulators (Rice, 1983; Misato, 1982).

To prove the existence of allelopathy, several procedures must be undertaken. Among the most important of these are bioassays. Although no standardized and universally accepted bioassays have been developed, they are still useful and necessary tools in the study of allelopathy (Leather and Einhellig, 1986). However, many non-allelopathic factors can affect seed germinanation when conducting bioassays to study allelopathy. Among these are the osmotic potential, ionic strength, and pH of the plant extracts being studied (Duke *et al.*, 1983; Chou and Young, 1974; Anderson and Loucks, 1966; Bell, 1974; Leather, 1983a, b; Leather and Einhellig, 1985; Chou and Chung, 1974; El-Ghazal and Riemer, 1986 Reynolds, 1975). The studies reported on herein were conducted to determine if crude water extracts of aquatic angiosperms had the ability to inhibit or delay seed germination in terrestrial plants or to affect radicle growth after germination. The effects of osmotic potential and pH of the water extracts were also considered.

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