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DISTURBANCE AS A FACTOR IN THE DISTRIBUTION OF SUGAR MAPLE AND THE INVASION OF NORWAY MAPLE INTO A MODIFIED WOODLAND

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ABSTRACT. Disturbances have the potential to increase the success of biological invasions. Norway maple (*Acer platanoides*), a common street tree native to Europe, is a foreign invasive with greater tolerance and more efficient resource utilization than the native sugar maple (*Acer saccharum*). This study examined the role disturbances from a road and path played in the invasion of Norway maple and in the distribution of sugar maple. Disturbed areas on the path and nearby undisturbed areas were surveyed for both species along transects running perpendicular to a road. Norway maples were present in greater number closer to the road and on the path, while the number of sugar maples was not significantly associated with either the road or the path. These results suggest that human-caused disturbances have a role in facilitating the establishment of an invasive species.

Key Words: invasive plants, Norway maple, *Acer platanoides*, sugar maple, *Acer saccharum*, disturbance

Biological invasions happen when non-native species are introduced into new environments (Drake 1988). Although many of these species are absorbed into the community without influencing it very much (Begon et al. 1996), the detrimental effects of some invasives have been recognized as one of the major threats to biological diversity (Soule and Kohm 1989). These species may alter population dynamics, community structure (Elton 1958; Mooney and Drake 1986), and ecosystem structure and diversity (Vitousek 1990).

While natural disturbances often increase species richness and diversity (Hobbs and Hunneke 1992), they can also increase the likelihood of invasion. The potential for invasion is enhanced when a combination of disturbances is present (Hobbs 1991). For this study, disturbance refers to events that stress the community and influence resource availability and mortality rates. Examples include soil exposure, edge effects, nutrient addition (Hobbs 1991), and any event that removes plants, leaving a space open for colonization (Begon et al. 1996).

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One common type of disturbance occurs when an edge of a community faces a more open area, such as a field, path, road, or body of water. An "edge effect" occurs because the edges of a forest have a different microclimate than the forest interior. This results in a different plant species composition, including a higher number of exotics, and different community structure. In North Carolina, Fraver (1994) measured the percent cover of individual species and the relative cover of exotic species, and found edge effects extended 20–60 m into the interior of the forest. In addition, exotics were found mainly on the edges and did not make up a significant portion of the forest interior. In Pennsylvania and Delaware, the edge effect significantly influenced light, temperature, litter moisture, humidity, and shrub cover up to 50 m from the edge (Matlack 1993).

A primary reason for the spread and establishment of invasive species is their introduction by humans as crops, ornamentals, or for forestry (Elton 1958). Norway maple (*Acer platanoides* L.) is an ornamental that has been described as an invasive exotic in urban forests in New Jersey (Webb and Kaunzinger 1993), Pennsylvania (Kloeppel and Abrams 1995), and Great Britain (Nowak and Rowntree 1990). Norway maple is the widest ranging maple in its native European habitat. Introduced into the United States in 1756 by John Bartram of Philadelphia, its optimal range in the United States includes coastal northern New England, southern New England, and the Midwest (Nowak and Rowntree 1990). It may be able to transform the native woodland by outcompeting sugar maple (*Acer saccharum* Marshall; Webb and Kaunzinger 1993), which is native to the United States.

Norway maple and sugar maple grow side by side as street trees and in urban forests and share many life-history characteristics. Both species produce seeds in the fall that require 2–3 months of stratification before spring germination (Hartmann et al. 1990) and both have been described as shade tolerant in their native ranges (Diekmann 1996; Sipe and Bazzaz 1995). Sugar maple grows best in small gaps (Runkle 1984). Although it grows faster in a gap than in the closed canopy (Canham 1988), sugar maple has a strong negative correlation with large gaps of 400m^2 (Runkle 1984).

Norway maple has certain advantages that allow it to outcompete sugar maple and influence species composition when it invades urban woodlands. Since its introduction, Norway maple has become one of the most widely planted street trees due to its longevity, disease resistance, and ability to withstand poor soils and pollution. In urban areas, its wide tolerances and abundant seeds allow it to colonize woodlots and urban forests (Spongberg 1990). Norway maple also has a physiological advantage over sugar maple due to its higher rate of photosynthesis, longer retention of leaves in the fall, and faster sapling growth (Kloeppel and Abrams 1995). In addition, Norway maple can influence community structure. In a New Jersey sugar maple/beech/oak forest that had been invaded by Norway maple, the understory species richness for each of the canopy trees was compared. Norway maple had a significantly lower species richness in its understory than the other tree species (Wyckoff and Webb 1996).

The purpose of this study was to determine if there is a correlation between disturbance and the establishment of Norway maple.

STUDY SITE

The Middlesex Fells Reservation in eastern Massachusetts was created in 1894. European colonists, arriving in the area in the 1600s, used the land primarily for farming but also for mills, firewood, cattle grazing, and mining (Levin and Mahlstedt 1990). Today the Fells is a mostly wooded, popular urban retreat. Only 10 km north of Boston, it is located in the towns of Winchester, Stoneham, Melrose, Malden, and Medford. Routes 23 and 93 run through the middle of the Reservation and divide it into eastern and western halves. Two-lane paved roads run along the perimeter, with Norway maples planted as street trees in some areas. The trees range from 10–40 cm in diameter. No record could be found of exactly when they were planted, but all are large enough to produce seeds.

The western side of the Fells, where this study was done, covers about 400 ha. The landscape changes greatly over short distances, due to high ridges with exposed ledges that run north to south with slopes running down to streams, ponds, and large man-made reservoirs (Drayton and Primack 1996). Foot, animal, and mountain bike traffic can be heavy on the extensive 3–5 m wide carriage roads and the smaller footpaths. The first major carriage paths were likely due to the creation of the reservoirs from 1870–1901. Later, in the 1930s, the Civilian Conservation Corps and the Works Progress Administration also built many roads and paths (Levin and Mahlstedt 1990).

MATERIALS AND METHODS

Twenty-four transects were established perpendicular to the paved roads along the western side of the Middlesex Fells Reservation. At each of twelve sites two parallel transects were set up, one with a path as the transect line (disturbed), and another 20 m away in an area with no path (undisturbed). Along each transect, 10×10 m plots were established with the first plot at the road. On the transect that ran along the path, half of each plot was placed on either side of the path. The next two plots leading away from the road (numbers 2 and 3) had 50 m between them, with 100 m between remaining plots (Figure 1). Sampling was discontinued when the plots had no Norway maples, and a visual inspection showed no more further on. In each plot, the number of Norway and sugar maples above 50 cm in height was counted.

To determine the influence of the path, a Mann-Whitney test was performed on the number of Norway maples and sugar maples on and off of the path. To determine the influence of the road, a Mann-Whitney test was performed comparing the number of Norway maples and sugar maples in plots 1 and 2. Plots 2 and 3 were also compared. Only the first three plots at each site, both on and off the path, were used in the analysis due to the lack of replication for plots 4–6. All statistical analysis was done on SPSS (SPSS, Version 6.1, Chicago, Illinois).

RESULTS

The path and distance from the road (using plot as a proxy for distance) correlated with the presence of Norway maples but not the presence of sugar maples. Results of the Mann-Whitney tests indicated there were significantly more Norway maples closer to the road and on the path (Figure 2; path: $df=65$, $Z=-2.538$, $P=0.011$; plot 1–plot 2: $df=49$, $Z=-3.628$, $P<0.001$; plot 2–plot 3: $df=41$, $Z=-1.345$, $P=0.179$). Results of the Mann-Whitney tests indicated that the number of sugar maples was not affected by the road or path (Figure 3; path: $df=65$, $Z=-0.367$, $P=0.713$; plot 1–plot 2: $df=49$, $Z=-0.504$, $P=0.614$; plot 2–plot 3: $df=41$, $Z=-0.699$, $P=0.484$).

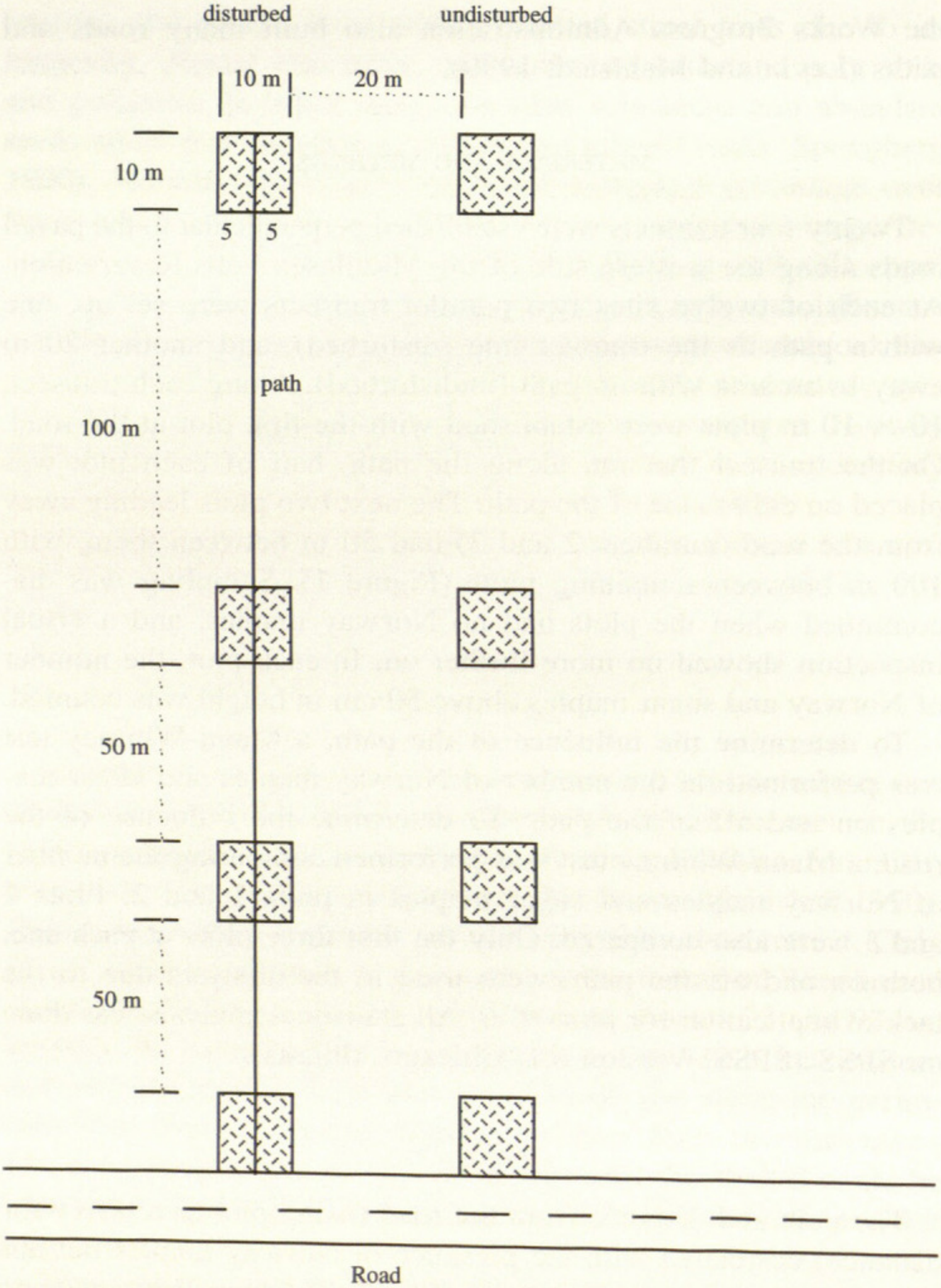

Figure 1. Representation of placement of transects and plots at the Middlesex Fells Reservation.

DISCUSSION

Two specific factors were hypothesized to aid Norway maple's invasion. First, that the road, planted with Norway maples as street trees, created an edge effect and acted as a seed source.

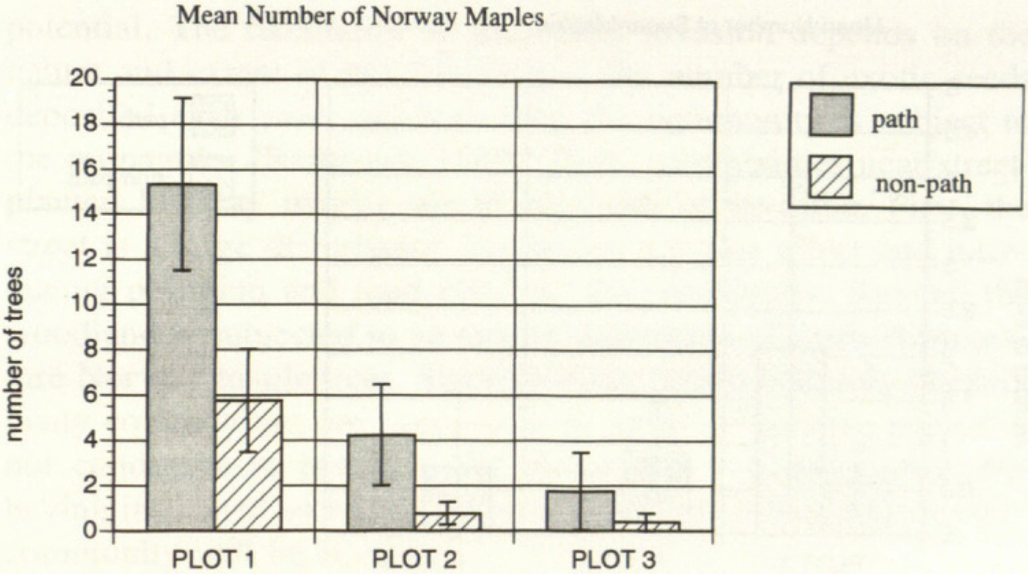

Figure 2. Mean number of Norway maples in plots 1–3 at the Middlesex Fells Reservation. Error bars indicate ±1 SE.

Second, that the paths running perpendicular to the road allowed Norway maple to penetrate greater distances along the path than in nearby nondisturbed areas with no paths.

As hypothesized, there were significantly more Norway maples by the road and on the path (Figure 2). The effect of the road seems not to have exceeded 50 m, as there was no significant difference in the number of Norway maple trees in plots 2 and 3. It is possible that there were more Norway maples closer to the road because there were abundant seeds from the nearby street trees, and not due to Norway maple's tolerance for salt or other edge effects. Even if edge effects were not a significant factor, the path seems to have acted as a place for Norway maple to become established.

Since sugar maple abundance has been shown to have a significant negative correlation with large gaps (Runkle 1984), its abundance was expected to increase with distance from the road. Contrary to expectations, the presence of sugar maples was not significantly affected by the road or the path (Figure 3). The edge effects may not have been strong enough to influence the sugar maple.

These results suggest that Norway maple relies more on disturbed habitats for establishment than sugar maple does. Invasive plants can follow one of two patterns, either advancing in a front or as scattered small populations (Baker 1986). Species that de-

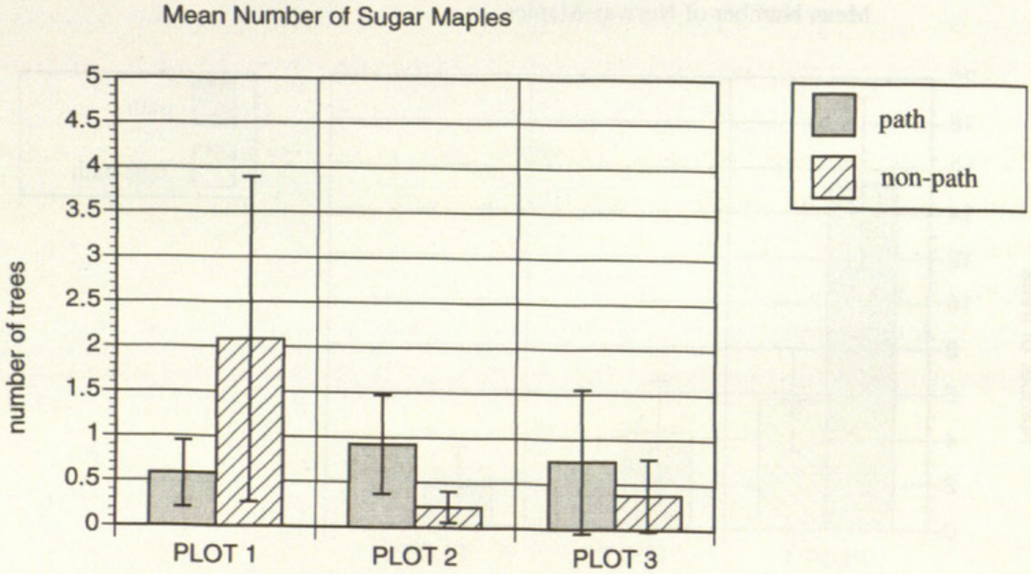

Figure 3. Mean number of sugar maples in plots 1–3 at the Middlesex Fells Reservation. Error bars indicate ±1 SE.

pend on disturbance for successful invasion favor the second pattern. These species also share many characteristics of early-successional plants, such as high rates of population growth, photosynthesis, respiration, transpiration, and growth (Bazzaz 1986). In this study, there were often large numbers of Norway maples near the road, but they penetrated further into the forest with large spaces in-between, not in a solid front. In comparison to sugar maple (Kloeppel and Abrams 1995), Norway maple has many of the characteristics listed by Bazzaz that would make it better adapted than sugar maple to exploit disturbance.

Norway maple may be contributing to a proposed trend of invasion by exotics and loss of native species in the Middlesex Fells. A survey of species lost over one hundred years found three trends: the number of native species declined, the number of exotics increased in proportion to the total flora, and species were most affected in moist habitats (Drayton and Primack 1996). This suggests several effects Norway maple could have in the Fells. For example, in this study, I observed that Norway maple invaded furthest in low, moist areas, which may lead to its contributing to any loss of native species in the moist areas. As Norway maple also has a lower species diversity under its canopy than sugar maple (Wyckoff and Webb 1996), this may also influence the Middlesex Fells' herbaceous layer in the moister areas.

As a common street tree, Norway maple has great invasive potential. The likelihood of successful invasion depends on the nature and extent of the disturbance, the number of exotic seeds deposited each year, and how long the community is subject to the propagules (Rejmanek 1989). Thus, communities near street-planted Norway maples are at high risk of invasion. First, the street is a large disturbance, producing an edge effect and introducing pollution and road salt into the community. Second, the woodland is subjected to an annual deposition of seeds from mature Norway maple trees. Since Norway maple is widely planted, many communities are exposed to its seeds. Where the habitat is not conducive to invasion, the threat may not materialize, but having it planted so widely increases the chance that a vulnerable community will be nearby.

Since Norway maple is becoming established in the Fells, and becoming the dominant tree near the road at many sites, it would be worthwhile to investigate other species in the Fells that might be influenced by Norway maples' dense stands. It may be reasonable to cut down the roadside trees that are the seed source, replacing them with a native tree such as sugar maple. It is especially important to remove those trees in the Fells that are in sensitive areas. These results also support restrictions on further path construction for recreational purposes.

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