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Landscape Structure and Spread of the Exotic Shrub
Lonicera maackii (Amur honeysuckle) in
Southwestern Ohio Forests

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ABSTRACT.—The Asian shrub Lonicera maackii (Rupr.) Herder has been widely used as an
ornamental in the eastern United States. First planted in Oxford, Ohio, around 1960, it has
since spread into forest patches in the surrounding agricultural landscape. Despite its
abundance, and its bird-dispersed fruits, the spread of Lonicera maackii has been unequal in
different directions, with local distribution limits much farther N than W of Oxford. Our
objective was to determine whether the distribution limits of L. maackii in these two
directions were correlated with differences in landscape structure: percentage of forest land and
degree of forest connectivity. Aerial surveys were used to determine the current distribution
of L. maackii in forest patches in a belt transecting N and W from Oxford. The N transect,
which had more extensive spread of L. maackii, had greater forest cover and connectivity.
In both transects, L. maackii reached its distribution limit when forest cover dropped to
<5% and forest connectivity was 0%. Large expanses of agricultural land apparently act as
a barrier to the dispersal of this naturalized shrub.

INTRODUCTION

An important objective of landscape ecology is to determine the influences of landscape
structure on ecological processes, including the movement of organisms (cf. Risser et al.,
1984; Forman and Godron, 1986; Turner, 1989). Of special interest is the spread of invading
exotic species that often have a negative impact on native plant and animal communities.
Historical records, such as herbarium collections (Mack, 1981, 1985), long-term floristic
and faunal surveys (Hengeveld, 1988; Lubina and Levin, 1988; Andow et al., 1990; Pysek
and Prach, 1993), and aerial photos (Lonsdale, 1993) have been used to examine the spread
of invading plants and animals across large geographic areas. Such studies often have cited
the amount and spatial distribution of suitable habitat (i.e., landscape structure) as impor-
tant factors affecting the rate of spread of invading organisms. Also, corridors of suitable
habitat can facilitate the movement of exotic plants (Thebaud and Debusche, 1991; Pysek
and Prach, 1993). Information on the relationship between landscape structure (i.e., the
quantity and connectivity of suitable habitat) and the spread of exotic species could be
important in predicting and controlling the invasion process, but rarely has this relationship
been quantified.

We studied the spread of an invading exotic species at the landscape-scale, not with
historical records, but by examining the pattern of spread as shown by variability in the
species’ current distribution. Our study species was Lonicera maackii (Rupr.) Herder (Amur
honeysuckle), an Asian shrub that was introduced to North America in 1897 (Luken and
Thieret, 1996) and has escaped from cultivation in at least 24 states E of the Mississippi
River (Trisel, 1997). Lonicera maackii was first planted in the Oxford, Ohio, area by mem-

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bers of a local garden club about 1960 (T. J. Cobbe, pers. comm.). It was first collected for the Miami University herbarium from the Oxford area in 1962 and counts of annual rings from *Lonicera maackii* stems in 85 stands near Oxford lend support to this date of introduction (see Hutchinson and Vankat, 1997).

*Lonicera maackii* produces numerous red berries that ripen in the autumn and are bird-dispersed (Ingold and Craycraft, 1983). *Lonicera maackii* fruits are low quality (lipid-poor) and may be dispersed primarily in late autumn and winter, after higher quality fruit stocks have been depleted (White and Stiles, 1992). Since its introduction in the Oxford area, *L. maackii* has spread throughout Oxford and into forest patches in the surrounding agricultural landscape. *Lonicera maackii* establishes in most forest habitats and often becomes abundant along forest edges, where seedling establishment is greater (Luken and Goessling, 1995) and in forests with some canopy disturbance (Hutchinson and Vankat, 1997). It is absent in cultivated fields and rarely occurs in permanent pastures. Where *L. maackii* becomes established in the understory of forests, it has a negative impact on tree seedlings and herbs (Gould, 1996; Collier, 1997; Hutchinson and Vankat, 1997; Trisel, 1997).

The spread of *Lonicera maackii* from Oxford has been unequal in different directions, with the local distribution limits of the species being much farther N than to the W (pers. observ.). The objective of this study was to determine whether the distribution limits of *L. maackii* in these two directions were correlated with differences in landscape structure (i.e., forest cover and connectivity).

**Methods**

**Study areas.**—The study areas were belt transects two township sections wide (two sections = 2 miles = 3.22 km), one N and one W from Oxford. Each transect began with the first section pair lacking suburban housing and continued until *L. maackii* was determined to be absent or rare in all forest patches for at least three consecutive section pairs. The north transect began with sections 14 and 15 in Oxford Township and ended with sections 14 and 15 in Dixon Twp. (length = 13 miles = 20.9 km). The W transect began with sections 20 and 29 in Oxford Twp. and ended with sections 19 and 30 in Bath Twp. (length = 8 miles = 12.9 km). We report results in miles, the basic unit of the township grid system.

**Landscape structure.**—U.S. Geological Survey (U.S.G.S.) topographic maps (photo revised 1980–1988) were used to classify landscape elements into two broad categories: forest and nonforest. Forests were shown on the maps; nonforest included croplands, permanent pastures, old fields, lakes, etc.

We conducted low-elevation aerial surveys in 1993 and 1994 to update the U.S.G.S. maps. Corrections were made for areas recently converted from forest to nonforest. Also, we noted open woodlands (<75% estimated tree canopy cover) and heavily grazed forests and treated these as nonforest in analysis; such areas were uncommon.

Percentage forest cover for each section pair was determined by digitizing the forest cover from our updated U.S.G.S. maps. For each section pair, we calculated the percentage of forest area continuously connected to Oxford and to forests in the adjacent section pair nearer to Oxford. Forests were treated as one contiguous patch unless separated by >75 m.

*Lonicera maackii* distribution.—Aerial surveys were conducted in November 1993 and April 1994 (altitude 150–250 m) to determine the distribution of *L. maackii* in forest patches in the transects. *Lonicera* is highly visible during these months, because it is the only common woody plant in leaf (Trisel, 1997). Of three methods attempted, photography, videography and recording directly on topographic maps, the last was most efficient. *Lonicera* abundance was estimated using three broad categories: high (>25% cover), medium (25–1% cover), and rare/absent (maximum of several widely scattered shrubs).
The number of spatially separated observations per forest patch varied with patch size and number of flight paths over the patch. For example, a large patch may have been divided into several sections, and each section assigned a cover estimate. In patches with such multiple observations of *L. maackii* abundance, high cover was assigned to the entire patch when one-third or more of the observations indicated high *L. maackii* cover; medium cover was assigned if less than one-third of the observations indicated high *L. maackii* cover, and for any combination of medium and absent/rare observations; and absent/rare cover was assigned only when all observations indicated rare/absent cover.

We did not ground check every patch, because aerial estimates were similar to *Lonicer maackii* cover data obtained from line transects in 13 stands in the N transect (cf. Hutchinson and Vankat, 1997). Instead, we focused on ground checking stands at and beyond the limits of *L. maackii* distribution where cover estimates were most critical. Here we found that aerial cover estimates were accurate. A few forest patches were unresolved, because *L. maackii* abundance was not determined from the air and the privately owned patches were not accessible for ground observations. However, these unresolved patches represented only a small percentage of all forest area (0–12% per section pair).

**RESULTS**

*Landscape structure.*—The two transects had different landscape structure, as the N transect was characterized by more forested land with higher connectivity (Fig. 1a–c). In the N transect, the percentage of forested land in miles 1–5 (i.e., section pairs 1–5) ranged from 29–58% (Fig. 1a). Hueston Woods State Park, which occupies much of miles 3 and 4 and a portion of mile 5, contributed to the relatively high forest cover in these section pairs. Forested land decreased and was <20% per section pair in miles 6–13, reflecting more extensive agricultural land and forest fragmentation. The W transect had more agricultural land, with forest cover <25% in all section pairs and <3% in five of the eight section pairs (Fig. 1a).

In the N transect the percentage of forested land that was connected to forests in Oxford was 88–99% in miles 1–5, but with greater forest fragmentation this percentage decreased to zero by mile 7 (Fig. 1b). In miles 1–3, forest corridors were continuous along Four Mile Creek and the slopes above its floodplain (Fig. 2). In the W transect, all forested land was unconnected to forests in Oxford.

In the N transect, the connectivity of forested land to forests in the previous section pair was 91–100% in miles 1–5, 20–55% in miles 6 and 7, zero in miles 8–12 and 25% in mile 13 (Fig. 1c). In the W, connectivity to forests of the previous section pair was 0% in mile 1, 88 and 62% in miles 2 and 3, where the Indian Creek riparian corridor crossed the belt transect, and zero in all other section pairs.

*Lonicer maackii* distribution limits.—The local distribution limits of *Lonicer maackii* were much more distant N of Oxford than to the west. In both transects, *L. maackii* cover was high in most forested land in miles 1 and 2 and then decreased from mile 3 outward (Fig. 1d–f). In the N, *Lonicer maackii* cover became rare/absent in all observed forest patches beginning in mile 11; however, in the W this distribution limit was reached at mile 4 (Fig. 1f). With the Oxford area as the initial site of introduction about 34 yr earlier, these distances give an approximate rate of spread of 0.1 km/yr to the W and 0.5 km/yr to the N.

The general pattern in both directions suggests an advancing wave from high cover nearest Oxford, to medium cover, and then rare/absent cover with increasing distance from Oxford. However, there were some deviations from this pattern. For example, in miles 3–5 to the N, *Lonicer maackii* cover was medium in most forested land but absent/rare in one large patch in mile 4 and high in one patch in both miles 5 and 6 (Fig. 2).
FIG. 1. a–c.—Attributes of landscape structure per section pair N and W of Oxford. d–f: Estimated Lonicera maackii cover per section pair in forested land N and W of Oxford; the sum of cover values is <100% in section pairs where L. maackii cover was unresolved in one or more forest patches

DISCUSSION

Our results suggest that greater forest cover and connectivity of forests in the N transect facilitated the spread of Lonicera maackii, whereas the abundance of agricultural land to the W acted as a barrier. In both transects, L. maackii became rare/absent in all patches at the first section pair where forest cover dropped to <5% and connectivity to forests in Oxford and the previous section pair was zero. The higher forest cover in the N transect
Fig. 2.—The N belt transect showing estimated *Lonicera maackii* cover in forests. Mile 1 represents the first section-pair north of Oxford. Shaded regions are forested and white regions are nonforest.

Fig. 3.—The W belt transect showing estimated *Lonicera maackii* cover in forests. Mile 1 represents the first section-pair W of Oxford. Shaded regions are forested and white regions are nonforest.
(particularly in miles 1–5) may have provided habitat for larger population bases of *Lonicera*. Greater fruit density has been shown to increase removal rate by attracting flocks of frugivorous birds (Sargent, 1990). Although Luken (1988) reported that the productivity of *L. maackii* was higher in nonforest areas (roadside) than in forests, most of the non-forested land in the Oxford region is agricultural (cropland and pasture) and not conducive to *L. maackii* establishment (only limited land recorded as nonforest, e.g., roadsides, small ravines, and open woodlands are suitable habitat for *L. maackii*).

Another factor in the unequal distribution of *Lonicera maackii* in this landscape was forest connectivity. The barrier to spread of *L. maackii* appears to be that birds are less likely to disperse seeds across large areas of agricultural land, especially when woody vegetation that serves as recruitment foci for bird-dispersed plants (McDonnell and Stiles, 1983) is lacking. For example, in a similar agricultural landscape, Haas (1995) showed that the movement of several bird species among forested patches was rare, but was facilitated by connecting wooded corridors.

Although birds often defecate seeds distant from the parent plant, seed deposition decreases steadily with distance from the seed source (Holthuijzen and Sharik, 1985a, b; Hoppes, 1988; Masaki et al., 1994). Moreover, the population size of birds capable of dispersing *Lonicera maackii* seeds may be reduced in landscapes that exhibit high levels of forest fragmentation (van Dorp and Opdam, 1987). Robinson et al. (1995) showed decreased nesting success of neotropical migratory birds in fragmented landscapes because of increased rates of nest parasitism and predation. Therefore, bird-dispersed plants may migrate into isolated forests very slowly (Matlack, 1994), reducing the probability of occurrence (van Ruremonde and Kalkhoven, 1991).

Although the results indicate that forest cover and connectivity affect the spread of *Lonicera*, several additional factors may be significant. For example, the vegetation structure of individual forest patches is important. Disturbed and/or young secondary forests with less tree canopy cover have proven more invisible than less disturbed forests (Hutchinson and Vankat, 1997). Indeed, *L. maackii* is absent/rare in the old-growth forest stand W of Acton Lake in Hueston Woods State Park (Fig. 2, mile 4), despite being adjacent to secondary forests with medium *Lonicera* cover. Future studies that link frequency of dispersal, probability of seed germination and establishment, and community invisibility with patterns of spread are needed to understand more clearly the invasion process. Also, some non-forested areas such as roadsides and fence lines not mowed or otherwise kept clear of shrubs provide habitat for *L. maackii* (Luken, 1988). We did not distinguish these landscape elements (not abundant in our study area), from other nonforested areas; however, these areas may still be important to *L. maackii* dispersal by providing connectivity. Third, the size and configuration of unconnected forest patches likely affects the rate of *L. maackii* spread as it has been documented that larger, evenly dispersed patches of suitable habitat increased the rate of exotic plant spread within a community, even when total patch area was held constant (Bergelson et al., 1993).

The results presented here also have implications for managing forest patches in human-dominated landscapes. For both tropical and temperate old-growth forest patches, it has been suggested that adjacent croplands and pastures act as barriers preventing secondary vegetation from developing adjacent to forests and acting as a staging areas for exotic plants to invade sites of natural disturbance (e.g., treefall gaps) within the forests (Janzen, 1983; Brothers and Spingarn, 1992). Although we are unable to determine whether the cover or the connectivity of forests is more important in limiting the spread of *Lonicera maackii* in our study area, a broad zone of unsuitable habitat (e.g., cropland) surrounding a forest patch may serve to inhibit *Lonicera* invasion and prove an effective management strategy.
If, however, land managers want to maintain a zone of secondary vegetation to reduce edge effects between the cropland and the forest preserve, that zone would need to be kept free of *L. maackii*.

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LITERATURE CITED


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