EFFECT OF HABITAT VARIATION ON RATE AND SUCCESS OF
COLONIZATION OF TWO INVASIVE SHRUBS, LONICERA MAACKII AND
LIGUSTRUM VULGARE, IN A FORESTED GLEN

A Thesis

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By

Ann Gayek, B.S.

The Ohio State University
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Master’s Examination Committee:

Martin Quigley, Ph.D., Advisor
Peter Curtis, Ph.D.
Pablo Jourdan, Ph.D.

Approved by

Advisor
Department of Horticulture and Crop Science
ABSTRACT

*Lonicera maackii* (Amur honeysuckle) and *Ligustrum vulgare* (Common privet) are two exotic shrubs widely naturalized in the eastern and midwestern United States. This study examines whether habitat affects the rate (numbers of small, medium, large) and success (absolute numbers of plants) of colonization of *Lonicera maackii* and *Ligustrum vulgare* in a second-growth forested glen in southwestern Ohio (Glen Helen, Yellow Springs, Ohio). The habitats compared were east-facing slope, bottomland, and west-facing slope. Methods: twelve 100 meter transects were run through each of the three habitats for a total of 36 transects. *L. maackii* and *L. vulgare* plants were counted in ten 3 x 3 m quadrats along each transect for a total of 120 quadrats per habitat. Transects sampled about 14 ha of the North Glen.

Two-way analysis of variance was used to compare interaction between habitat and numbers of plants in the three size classes. Total density of *L. maackii* for all size classes was 3406 plants/ha. East-facing slopes were most heavily invaded with 1490 plants/ha; there were 713/ha in the bottomland; 1203 on the west-facing slopes. East-facing slopes are closest to town, the original source of seed. West-facing slopes have significantly fewer large plants than east-facing slopes but it may only be a matter of time until they are as heavily colonized as the east-facing. For now, the native species of the
bottomland are able to compete successfully against the *L. maackii* and the *L. vulgare*.

Without management, however, colonization of the bottomland may progress. *L. vulgare* overall, is not as invasive in this woodland setting as *L. maackii*. Except for the moist seeps, it remains stunted.
Dedicated to my father

Henry Gayek
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VITA

May 7, 1953 .................................. Born – Schenectady, New York

1975........................................... B.S. Fine Arts/Elementary Education
                       Utah State University

1976-1994................................. Teacher,
                       Various school districts in Utah and Ohio

1995-1997................................. Gardener
                       Cox Arboretum
                       Five Rivers Metroparks
                       Dayton, Ohio

1987-present............................. Horticulturist
                       Perennial Design
                       Yellow Springs, Ohio

FIELDS OF STUDY

Major Field: Horticulture and Crop Science

Minor Field: Landscape Architecture
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CHAPTER 1

AMUR HONEYSUCKLE (LONICERA MAACKII): HERE TO STAY IN MIDWESTERN FORESTS

INTRODUCTION

One of the main threats to biodiversity in the world is the human-caused disturbance and destruction of natural habitats. This alteration of ecosystems opens plant communities to invasion by exotic, non-native species (Baker, 1986; Crawley, 1986; Hobbs, 1989; Hobbs and Huenneke, 1992). Invasion is a natural biological process that has occurred throughout evolutionary time; recent human population growth however, has accelerated this process (Mooney and Drake, 1989; Huenneke, 1997; Woods, 1997; Becher, 1998).

Invasive plants produce significant changes in the structure, composition, and functioning of the ecosystems they invade (Bazzaz, 1986; Vitousek, 1986, 1990; Cronk and Fuller, 1995; Woods, 1997). Human introduction of plants has been going on for hundreds of years and continues to accelerate. While many of these species are not invasive, and some, in fact, are quite desirable from a horticultural viewpoint, a number of introduced plants have become naturalized and are replacing native plant species in forested ecosystems (Mack, 1985; Woods, 1993; Hutchinson and Vankat, 1997, 1998).
Invasive plants are characterized by preadaptation to varied habitats, phenotypic plasticity, a generalized pollination system, high net seed production, small seed size, efficient dispersal, short juvenile period, and rapid growth rates (Baker, 1986; Bazzaz, 1986).

In the Midwestern United States, the Ohio Department of Natural Resources (ODNR) lists 100 of the approximately 700 non-native species of plants in Ohio as invasive in natural areas. The most common invasive shrubs are listed as the bush honeysuckles, Lonicera maackii (Amur honeysuckle), L. morrowii (Morrow honeysuckle), L. tatarica (Tatarian honeysuckle), the buckthorns, Rhamnus frangula (Glossy buckthorn) and R. cathartica (European buckthorn), Elaeagnus umbellata (Autumn Olive), and Rosa multiflora (Multiflora Rose) (Ohio Department of Natural Resources, 1999). Of these, Lonicera maackii has become the dominant shrub in many forests and open areas in Ohio and adjacent states (Luken, 1988; Luken and Goessling, 1995; Luken and Thieret, 1996; Hutchinson and Vankat, 1997). The story of Lonicera maackii is similar to that of the other Eurasian deciduous shrubs; all the bush honeysuckles, the buckthorns, autumn olive, and multiflora rose were originally introduced for their floral, fruit, and foliage displays and subsequently became invasive problems (Luken and Thieret, 1996).

SPECIES DESCRIPTION

Amur honeysuckle: an attractive weed

Lonicera maackii (Rupr.) Herder (Caprifoliaceae), commonly known as Amur honeysuckle, is an upright spreading deciduous shrub that was once perceived as a
beautiful and desirable plant for the garden (Dirr, 1998). Its native range is central and northeastern China, the Amur River and Ussuri River valleys, Korea, and isolated parts of Japan. As an ornamental shrub, Amur honeysuckle was widely planted throughout eastern North America and has now naturalized in at least 24 states and adjacent Canada (Hutchinson and Vankat, 1998). Most land managers now regard Amur honeysuckle as a highly undesirable, noxious weed (Luken and Thieret, 1996).

**History of the introduction of Amur honeysuckle**

The earliest specimens were collected near the Amur River in China in 1855 by the Russian plant explorer Richard Maack. Over the next 28 years, the species was collected by many European and U.S. plant hunters. The first successful flowering of the plant in cultivation was recorded in Russia at the St. Petersburg Botanical Garden in 1883. Within 10 years it was being cultivated in Germany and at Kew Royal Botanic Gardens. The archives of the New York Botanical Garden hold the first United States record of Amur honeysuckle; seeds were received there in 1898 (Luken and Thieret, 1996).

The agricultural explorer Niels E. Hansen was originally sent to Russia in 1897 by the USDA to search for cold resistant alfalfa varieties. He expanded his assignment however, and Amur honeysuckle seeds were among the first seeds he shipped to the newly created Section of Foreign Seed and Plant Introduction (SPI). SPI records of foreign country imports indicate that Amur honeysuckle seeds were introduced at least seven times between 1898 and 1927. It is not clear exactly where these seeds originated, and the Amur honeysuckles now naturalized in the United States represent a variety of genotypes (Luken and Thieret, 1996).
By 1931, at least eight commercial nurseries in the United States offered Amur honeysuckle and some newly developed cultivars for sale. The species and its cultivars were widely promoted by the USDA Soil Conservation Service (now known as the Natural Resource Conservation Service). The goals of this promotion were to encourage the use of Amur honeysuckle to improve habitat for wildlife and to serve as ornamental landscape plants. Amur honeysuckle was also used in large reclamation projects, for example, over strip-mined areas in southeastern Ohio (Luken and Thieret, 1996).

**First warnings**

The invasive nature of Amur honeysuckle was first mentioned by the Morton Arboretum in the mid-1920s. In the late 1950s, evidence of naturalized populations began to be reported. Lucy Braun (1961) wrote that Amur honeysuckle was “reported only from Hamilton County [Ohio], where it is becoming abundant in pastures and woodlands.”

**Size, reproduction, and light level requirements**

*Lonicera maackii* (Amur honeysuckle) can achieve heights greater than 6 m, crown widths greater than 9 m, and stem diameters larger than 15 cm. Its average height in northern Kentucky in open habitats is 2-3 m with equal width. Average height in forested habitats of the region is 4-5 m. Shrubs in forested habitats tend to branch less and have longer vertical branches than those in open habitats (Tholemeier and Luken, 1996).

Individual plants of Amur honeysuckle take 3-8 years to become reproductive, with 5.7% reproductive at age 3, but over 50% reproductive at age 5. Shrubs less than a meter tall are not reproductive, but all shrubs greater than or equal to 2.5 m are generally reproductive. Reproduction therefore is not simply a consequence of age: height and
basal area are more important factors. After shrubs become reproductive at age 5-8, height growth continues but basal stem recruitment is reduced and the basal area of all stems combined increases exponentially (Deering & Vankat, 1999).

Biomass allocation of the Amur honeysuckle is remarkable (Luken, 1988). Net primary production (total biomass of stems, branches, leaves, fruits, flowers, and fruits) of open-grown thickets of Amur honeysuckle was measured to have a maximum production of 1350 g/m²/yr. This approaches the total net productivity of an entire woodland community (Luken and Thieret, 1996).

The fact that *Lonicera maackii* is best suited to relatively open environments is supported by Luken’s observation of this species in its native habitat of open woodlands and periodically disturbed floodplains. The forest communities in North America where *L. maackii* typically does best are disturbed forest patches with large amounts of edge and canopy gaps (Luken et al., 1995 a; Hutchinson and Vankat, 1997). When light levels are above 25% of full sun, *L. maackii* seed germination and seedling establishment are most successful. Below this light level seedling growth is significantly reduced. The habitat of the second-growth forests of eastern North America that *Lonicera maackii* now occupies is very similar to the early successional environments of Eastern Asia where it evolved (Luken et al., 1995 a).

*How good is the fruit for the birds?*

Individual shrubs of *Lonicera maackii* produce copious amounts of seeds; the red fruits are ingested by birds and occasionally by small mammals (Deering and Vankat, 1999). The low number of species and individual birds that Ingold and Craycraft (1983) found feeding on *Lonicera* berries led them to question the quality of honeysuckle berries as an
energy source. They analyzed the berries for two measures of fruit quality: carbon:nitrogen ratios to measure for proteins, and percent total lipid (fat content). They concluded that the *Lonicera maackii* berries are low in both protein and fats and are therefore a poor energy source.

White and Stiles (1992) found that bird feeding on the fruit of non-native shrubs was predominantly after peak bird migration. This suggests that migrating birds and those that stay in the area year-round prefer the fruit of native shrubs and use such non-natives as *Lonicera maackii* only when other food supplies are exhausted.

**COLONIZATION**

*Disturbance and invasion*

Disturbance plays an integral role in the structure of plant communities. Canopy gaps created, for example, by hurricane, fire, or treefall are an important component in the regeneration of natural systems (Hobbs and Huenneke, 1992). Logging, grazing, and building within forests are all examples of anthropogenic disturbance that cause habitat destruction and fluctuations of botanical diversity, opening plant communities to invasion. In light-limited systems such as the eastern North American second-growth forests of today, a treefall will often result in an increase in the frequency and density of the well established invasive plant *Lonicera maackii*.

*Rate of spread from town to forest*

Deering and Vankat (1999) characterized the colonization of a second-growth forest woodlot and subsequent growth and development of *L. maackii*. They sampled an isolated woodlot near Oxford in southwestern Ohio. Colonization occurred by bird
dispersed seed (Ingold and Craycraft, 1983), slowly bringing the shrub population closer to the studied woodlot over a period of years. The timing of colonization hinged on when seeds became available rather than by a sudden disturbance in the forest structure. The oldest shrub, aged 17 years, indicates that the invasion may have occurred in 1979, about 19 years after *L. maackii* was introduced in the Oxford region 9 km away (Deering and Vankat, 1999). *Lonicera maackii* was first planted in the Oxford, Ohio area by members of a local garden club about 1960 (Hutchinson and Vankat, 1998). Assuming migration from Oxford, the average rate of migration was 0.5 km/yr. (Deering and Vankat, 1999).

In contrast, Brothers and Spingarn (1992) assessed plant invasion of old-growth forest islands in rural central Indiana. They found the fragments resistant to invasion; the forest interiors were relatively free of non-natives. The historically low level of disturbance, the size of the forest fragments (greater than 3.8 ha) and the fact that the forests were surrounded by acres of cropland are all likely key factors in the resistance of these forests to invasion.

*Spreading forest to forest*

Hutchinson and Vankat (1998) looked at the distribution of *Lonicera maackii* relative to forest land and degree of forest connectivity. *L. maackii* reached its distribution limit when forest cover dropped to less than 5% and forest connectivity was 0%, i.e. when there was no forest connectivity. Large expanses of agricultural land act as a barrier to the dispersal of this naturalized shrub, though non-forested fence rows provide enough connectivity for it to spread from one forest patch to another. These bird-dispersed plants migrate into isolated forests very slowly.
Available light affects proportion of Lonicera maackii cover

The light regime at the time of initial invasion appears to be a key factor correlated with Lonicera cover. In a study near Oxford, Ohio, Hutchinson and Vankat (1997) found that L. maackii cover was greater than 50% when tree canopy cover was less than 85%, but highly variable when canopy cover was greater. Most tree saplings are tolerant of a shade index greater than 400, the light level at which Lonicera maackii cover drops below 50%.

EFFECTS ON NATIVE SHRUBS, TREES, AND HERBACEOUS PLANTS

Lonicera maackii and Lindera benzoin (Spicebush)

Forest grown Lonicera maackii and the common native forest shrub Lindera benzoin were compared for responses to conditions of increased light. L. maackii had maximum stem growth at 100% PPFD (photosynthetic photon flux density) while maximum stem growth of Lindera benzoin occurred at 25% PPFD. The inability of Lindera to use light above 25% PPFD was probably the result of biochemical limitation to carbon capture. In competition with Lonicera maackii, things don’t look good for Lindera benzoin. If canopy thinning and fragmentation increase light availability in disturbed forests, high resource invasive species such as Lonicera maackii will definitely have the advantage over the deep-shade adapted Lindera benzoin (Luken et al., 1997).

Effects on tree regeneration and herbaceous plants

Research shows that when Lonicera maackii becomes abundant, tree seedlings and herbs are negatively affected (Collier 1996). Fraxinus americana (White ash) germination and Acer saccharum (Sugar maple) seedling growth are inhibited by
*Lonicera maackii* (Hutchinson and Vankat 1997). *Impatiens pallida* (Jewelweed) and *Pimea pumila* (Clearweed), two native annuals, declined in survival and fecundity in disturbed habitats with high densities of *Lonicera maackii*. *Galium aparine* (Cleavers) declined in fecundity only. Survival was not affected, probably because it germinated before *Lonicera maackii* leafed out in the spring (Gould and Gorchov, 1999, in press). Possible causes of these negative effects on tree seedlings and herbs include reduced light under *L. maackii* canopies, reduced nutrients and moisture due to *L. maackii*’s extensive shallow root system, and allelopathy (Hutchison and Vankat, 1997).

This parallels similar findings for *Lonicera tatarica* in Vermont and Massachusetts. Woods (1993) found that once *L. tatarica* reached 30% cover, diversity of herbaceous plants and woody seedlings was reduced.

*Lonicera maackii* is photosynthetically active over a longer period than most native woody deciduous species. In 1992, in Oxford Ohio, *L. maackii* leaf expansion began in early March and green photosynthetically active leaves were retained through mid November, resulting in a photosynthetic period of 254 days. The photosynthetic periods of *Acer saccharum* and *Lindera benzoin* were 190 and 180 days, respectively. End of season leaf damage was lower for *L. maackii* than for native woody species. Leaf phenology and the relative lack of pathogens and herbivores contributes to the success of this invasive shrub (Trisel and Gorchov, 1994).

Doersam and Gorchov (1998) examined the effects early leaf expansion of *Lonicera maackii* had on *Allium tricoccum* Aiton. (Liliaceae), wild leek, a spring ephemeral herb. In the study area where *Lonicera maackii* was removed, *A. tricoccum* had more leaves, greater leaf area, and fruit and seed production were higher than in the
area where *L. maackii* was present. They suggest that high densities of *L. maackii* negatively affect spring ephemerals in disturbed deciduous forests.

This reduction in tree regeneration and tree, shrub, and herbaceous seedling abundance and richness has the potential to alter the future structure and composition of forests. If the regeneration of late-successional species is inhibited, early to mid-successional tree species may persist with eventual loss of a tree canopy. Thus, continued dominance by early-successional tree species and reduced diversity in native shrubs and herbs would have enormous ecological and economic impacts on southwestern Ohio forests (Hutchinson and Vankat, 1997).
CHAPTER 2

DOES HABITAT VARIATION AFFECT THE RATE AND SUCCESS OF COLONIZATION OF _LONICERA MAACKII_ AND _LIGUSTRUM VULGARE_ IN A FORESTED GLEN IN SOUTHWESTERN OHIO?

INTRODUCTION

Patterns of invasion and colonization have generally been examined at broad regional scales (Baker, 1986; Luken and Thieret, 1996; Nuzzo, 1993). Two studies have examined patterns of invasion and colonization in individual stands (Deering and Vankat, 1999; Brothers and Spingarn, 1992). The primary objective of my research is to test the hypothesis that density of the invasive shrubs _Lonicera maackii_ (Amur honeysuckle) and _Ligustrum vulgare_ (Common privet) is habitat dependent. I hypothesized that colonization would be more successful on the east-facing slopes compared to the relatively drier west-facing slopes in a well-defined ravine with good forest cover. I also wanted to test whether the Amur honeysuckle and the privet would have lower density in the bottomland, presumably due to competition from a well-established native plant community. I wanted to compare the overall density of the two species with each other. Finally, I wanted to test my observation that the direction of colonization in the study area is from the town into the nature preserve (west to east).
METHODS

Site description

The research was conducted in Glen Helen, a 400 ha (1000 acre) nature preserve located in Miami Township in the north central part of Greene County, Ohio, adjacent to the town of Yellow Springs. The study area is in the North Glen, an area of mixed mesophytic forest (Anliot, 1973). Elevations in the uplands above the study area are 290 meters (950 feet) above msl. Bottomland or valley floor elevations are 273 meters (900 feet) (Anliot, 1973).

The valleys of Glen Helen are enclosed by limestone cliffs and talus slopes. These are the result of the Wisconsin ice sheet, which advanced and retreated a number of times over southwestern Ohio, the last glacier having left this area about 16,000 years ago (Anliot, 1973). The gorges of the Little Miami River, the Yellow Springs Creek, and the Birch Creek follow these carved valleys, cutting their channels into the glacial deposits (Anliot, 1973).

The orientation of the Glen is 20° west of north. The Yellow Springs Creek runs south, making the valley slopes either east- or west-facing. The Birch Creek, a tributary of Yellow Springs Creek, runs southwest into the Yellow Springs Creek approximately 100 meters southeast of Trailside Museum. The bottomland or valley floor is 75 to 100 m (about 500 feet) wide in the study area. Principal soils have developed under 2 forest vegetation and are well-drained loam over calcareous till. The talus slopes are mostly lithosols (Anliot, 1973).
Vegetation

In the Glen, the vegetation of the forested uplands is primarily oak-sugar maple. The Glen has been cited (Anliot, 1973) as containing one of the best remaining examples of the oak-sugar maple forest in Ohio. The chinquapin oak (*Quercus muhlenbergii*) is the major canopy dominant. Though senescent, some of the largest of these trees still stand at 250 years old. The chinquapin oak is typically found on calcareous soils and appears to reach its maximum development on limestone outcrops. The red oaks are next in importance. Other canopy trees include hickories (*Carya* spp.), sugar maple (*Acer saccharum*), honey locust (*Gleditsia triacanthos*), and occasionally black oak (*Quercus velutina*). Prior to the 1900s, grazing and some selective logging took place in some of the upland areas (Anliot, 1973).

On the east- and west-facing talus slopes, typical trees are basswood (*Tilia americana*), sugar maple, slippery elm (*Ulmus rubra*), chinquapin oak, red oak, honey locust, hornbeam (*Carpinus caroliniana*), white ash (*Fraxinus americana*), green ash (*Fraxinus pennsylvanica*), black walnut (*Juglans nigra*), and tulip poplar (*Liriodendron tulipifera*). Sugar maple is predominant. Also found are redbud (*Cercis canadensis*), hackberry (*Celtis occidentalis*), and black cherry (*Prunus serotina*). Blackhaw viburnum (*Viburnum prunifolium*), wild hydrangea (*Hydrangea arborescens*), and spicebush (*Lindera benzoin*) are common shrubs.

On the floodplains, the willow (*Salix* spp.)-cottonwood (*Populus deltoides*)-sycamore (*Platanus occidentalis*) community is dominant along the larger waterways. Bur oak (*Quercus macrocarpa*), silver maple (*Acer saccharinum*), black walnut, Ohio buckeye (*Aesculus glabra*), and black maple (*Acer saccharum* subsp. *nigrum*) also occur.
in the bottomlands. Common shrubs or small trees are box-elder (*Acer negundo*),
spicebush, prickly-ash (*Xanthoxylum americanum*), bladdernut (*Staphylea trifolia*),
wafer-ash (*Ptelea trifoliata*), and pawpaws (*Asimina triloba*) (Anliot, 1973; Case et al.,
1999).

In Glen Helen, the steepness of the talus slopes prevented them from being
cultivated or easily timbered. More important for the preservation of the glen however,
are its scenic features including the cascades and the many springs, the most famous
being the Yellow Spring, so called for its high iron content which stains the limestone
around the spring a deep yellow-orange (Anliot, 1973; pers. obs.).

*Brief history of Glen Helen*

When white man explored this area in the 1700s, one of the main Shawnee
villages was located a few miles south of the yellow spring at what is now Oldtown on
Rte 68. The local natives considered the spring water as health-giving and many of their
trails passed by it.

The Glen lay in the first tract to be purchased in southwest Ohio; it was the
famous Symmes Purchase, one million acres extending northward from Cincinnati
between the Little and Great Miami Rivers. Judge Symmes bought this tract from the
U.S. government about 1786. He sold the area around the yellow spring to Lewis Davis
in 1803, who built a log cabin there for himself and his family. In the same year, a stage
coach road was authorized northward from Cincinnati. It was considered excellent time if
a coach and four left Cincinnati at dawn and reached the yellow spring by dusk (Lueba,
1973).
Over time, as the cabin changed hands, numerous additions were made to the original building which came to serve as a tavern and an inn. In 1868, a large hotel with 250 guest rooms was built next to the original cabin. Unfortunately for the hotel owners, tourism in Yellow Springs continued to decline from its peak in the 1840s and 50s, and the hotel was torn down by the turn of the century (Sanders, pers. com.). Despite the creation of a lake in a hollow close to the spring, and the construction of a dance pavilion, the Glen never recaptured its popularity as a vacation and health resort. The dam failed and the lake disappeared entirely by the 1950s. The unused dance pavilion was taken down in the 1950s by Antioch students who used some of the timber for constructing buildings of the new Outdoor Education Center on the far eastern side of Glen Helen (Leuba, 1972).

In the 1920s, Arthur Morgan, the president of Antioch College, acquired a small portion of the present Glen for the college. Beginning in 1929, Hugh Taylor Birch, a nature loving Antioch alumnus, wealthy Chicago attorney, and friend of Arthur Morgan, set out to buy the many parcels, some of them parts of farms, which now make up the present Glen. He donated this land to Antioch College in memory of his daughter Helen (Leuba, 1972). Though owned as a nature preserve by Antioch College since the 1930s, the Glen Helen Association was not founded until the late 1950s when the Glen was threatened by a proposed highway. In 1996, the Glen Helen Ecology Institute was created to manage Glen Helen Nature Preserve, directing education and environmentally conscious activities.

Given more than two centuries of human impact in the Glen, it is not surprising that Anliot (1973) found a significant number of herbaceous and woody exotics
naturalized or adventive in the Glen and adjacent John Bryan State Park. 188 species out of the 872 listed (22%) for the entire 770 hectares (1900 acres) were not native to Ohio. Interestingly, *Lonicera maackii* was not listed in Anliot’s 1960-62 survey as present in the Glen at all. He noted it only as “rare in the fields in John Bryan State Park”. He lists *Ligustrum vulgare* as “frequent in moist disturbed woods” (Anliot, 1973).

**Field work**

During the summer of 1999, I ran twelve 100 meter transects through each of the three habitats: east-facing slopes, bottomland, and west-facing slopes for a total of 36 transects. I counted all *Lonicera maackii* and *Ligustrum vulgare* plants in ten 3 x 3 m quadrats equally spaced along each transect. This made a total of 120 quadrats per habitat. Within each quadrat, I counted the two species in three size classes: small (less than 1 m tall, age 1-2 years), medium (1-3 m tall, age 3-5 years), and large (over 3 m tall, age 6-30 years). Age was determined by clipping stems and roots and counting rings (Deering and Vankat, 1999).

Transects on the east-facing slopes were parallel to each other and to the cliff walls. The easternmost transect was at the base of the east-facing limestone wall. Parallel transects were then run across the slopes, across the bottomlands, and across the west-facing slopes to the base of the west-facing limestone walls. The northern end of the first transect (it was on an east-facing slope) began approximately 75 m south of the old dam and the southernmost transect ended about 500 meters south of the Trailside Museum. All slope transects were on the talus slopes below the east- and west-facing vertical cliffs and overhangs. Bottomland transects were run through the floodplains of the Yellow Springs Creek and the Birch Creek. Transects on the west-facing slopes ran either parallel to the

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Birch Creek or parallel to the Yellow Springs Creek. The transects sample about 14 ha of the North Glen. The combined area of the sample plots was 3240 m$^2$ or .32 ha (Fig. 1).

RESULTS

Statistical analysis was by two-way analysis of variance (ANOVA) with the sources of variation being (a) habitat (east-facing slopes, bottomland, and west-facing slopes) and (b) size class (small, medium, large). Transect means were used in these analyses. Density values were converted from # plants/area sampled (90 m$^2$ for each transect) to # plants/ha. Results are presented in tabular (Table 1, 2) and graphical (Fig. 2, 3) form. For comparison among means for *Lonicera maackii*, LSD$_{0.05}$ = 0.036, MSR$_{0.05}$ = 0.058, and P = .05. For comparison among means for *Ligustrum vulgare*, LSD$_{0.05}$ = 0.063, MSR$_{0.05}$ = 0.100, and P < .01. ANOVA tables are presented as Table 3 and 4.

*Density of Lonicera maackii*

Total density of *L. maackii* on the east-facing slopes was 1490 plants/ha, 713/ha in the bottomland transects, and 1203/ha on the west-facing slopes. The total density of *L. maackii* for all size classes was 3406 plants/ha. In a 1.2 ha woodlot near Oxford, Ohio, Deering and Vankat (1999) found *L. maackii* at 2586 plants/ha. Their oldest shrubs were 17 years. 89.2% of their shrubs were 1-5 years old, 9.3% were 6-10 year old shrubs, and older shrubs were only 1.5%. In Glen Helen, small individuals (1-2 years old) made up 46% of the census, medium sized individuals (aged 3-5 years) were 30%, and large individuals (over 6 years old) were 24%. Grouping the 6-10 year and older shrubs
together Deering and Vankat (1999) got 10.8%. This compares to 24% large sized (6-35 year old) shrubs in Glen Helen.

Colonization of *L. maackii* in Glen Helen probably began in the mid 1960s. Though the Glen Helen colony is about twice the age of the *L. maackii* colony in the Oxford woodlot (35 years:17 years), there are only about 50% more *L. maackii* plants in Glen Helen. It may be inferred that because the Glen Helen colony consists of more medium and large *L. maackii* than the Oxford woodlot, the rate of increase in the Glen Helen population has slowed.

*Habitat comparisons of density of Lonicera maackii*

The numbers of *L. maackii* on the west-facing slopes show a normal trend, a reverse J-curve, for a colonizing species: high numbers of small plants aged 1-2 years (694/ha), half as many medium 3-5 years old (314/ha), and much fewer large 6-35 years old (194/ha) (Fig. 2).

The east-facing slope also follows the trend for a colonizing species, with 620/ha small shrubs and 407/ha medium sized shrubs. However, there are more large shrubs than expected (463/ha). This could be a reflection of relative age, as *L. maackii* came from town (from the west) down into these east-facing slopes. The only significant difference in overall density of *L. maackii* between the east- and west-facing slopes is in the large size class. The east-facing slope has 463 large shrubs/ha while the west-facing slope has only 194/ha (Fig. 2).

For both small and large size classes, two-way ANOVA showed significant differences in the density of *L. maackii* between the bottomland and the slopes. There are fewer *L. maackii* in both small and large size classes in the bottomland (250 small/ha and
148 large/ha) than on both the east-facing slopes (620 small plants/ha and 463 large plants/ha) and west-facing slopes (694 small/ha and 194 large/ha) (Fig. 2).

For medium sized plants, 1-3 m tall, aged 3-5 years, there are no significant differences, among any of the three habitats.

*Habitat comparisons: density of Ligustrum vulgare*

The colonization of *Ligustrum vulgare* in the Glen also reflects the trend of an establishing species. In all three habitats small plants are numerous. There are fewer medium, and very few large shrubs (Fig. 3). There are far fewer small (1-2 yrs. old) privet on the east-facing slope (259/ha) than on the west-facing slope (1269/ha) or in the bottomland (1037/ha). This may be due to the extreme rockiness of the east-facing slope. Even though the west-facing slope is characterized as a talus slope, in fact it is less rocky than the east-facing slope, and less steep overall, with a slightly deeper soil profile. Another factor in the lower numbers of small privet on the east-facing slope may be competition from the dense shade of the large *L. maackii*.

West-facing slopes and bottomland have about half as many medium sized privet plants as small privet plants. East-facing slopes have approximately one-third as many medium sized plants as small plants (Fig. 3). There are also significant differences in the medium size class between the west-facing slopes and bottomland and the east-facing slopes. There are only 83 medium-sized *L. vulgare*/ha on the east-facing slopes compared to 602/ha on the west-facing slopes and 713/ha in the bottomland (Fig. 3).

Over all three habitats, the number of large plants of privet is very small, especially compared to the vast numbers of small plants (ramets and genets). There were only 28 large plants/ha on the east-facing slopes, 148/ha in the bottomland, and 19/ha on
the west-facing slopes (Fig. 3). *Ligustrum vulgare* definitely prefers a moist environment, but the deep shade of the forest may prevent privet from reaching the height and width of an open sunny environment. The west-facing slopes appear to be too dry for *L. vulgare* to thrive.

**DISCUSSION**

*Colonization of east-facing slopes compared to west-facing slopes*

The east-facing slopes are heavily invaded by *L. maackii*. The density of large size *L. maackii* on the east-facing slopes far exceeds that of the west-facing slopes (463/ha compared to 194/ha on the west-facing slopes). This is largely because of the proximity of the east-facing slopes to the town of Yellow Springs, the original source of the seed.

My hypothesis that the difference in success of colonization (density) is due to habitat alone is debatable. Though the west-facing slopes are drier, the only current measure of lack of colonization success on them is the lower numbers of older plants of both species. It could be argued that it is only a matter of time (assuming lack of management) before the west-facing slopes are as heavily colonized as those facing east. The high numbers of juvenile *L. maackii* on the west-facing slopes may become the future high numbers of large *L. maackii*.

*Lonicera maackii in the bottomland*

There are fewer *L. maackii* in the bottomland than either slope for two reasons. The first is that the native plant understory there is relatively dense. There are large
stands of pawpaws, and many other native shrubs. “Wet habitats do not provide open space for invaders because of fast growth and high competitiveness of resident species” (Rejmanek, 1989). I believe, however, that without management, the honeysuckle will, over time, become more predominant in the bottomland. There are thousands of seedlings along the banks of the Yellow Springs Creek. The narrower, far shadier Birch Creek has none. However, if a significant treefall were to occur in the bottomland area near Birch Creek, the conditions would be favorable for more honeysuckle to become established and for the honeysuckle that is already there to spread and grow more quickly. But for the time being, due to the deep shade and existing plant community, L. maackii is suppressed in the bottomlands.

In the watershed of the Yellow Springs Creek, the honeysuckle is generally spreading from west to east. As treefalls occur, new invasions are establishing over a patchy area through the bottomlands and up the west-facing slopes. There are areas in the Glen, in the bottomlands, on the west-facing slopes, and in the uplands, that are far enough away from the town to the west and the fence rows of the farm fields to the east to be still relatively free of Lonicera maackii. I encourage active management of small new invasions in these areas.

Habitat differences: Ligustrum vulgare

There are significantly fewer privet in all sizes classes on the east-facing slopes compared to the bottomland or west-facing slopes. This could be due to the rockier conditions of the east-facing slopes. It is also partially because of the competition from the high density of the large L. maackii on the east-facing slopes.
In the case of *Ligustrum vulgare*, my hypothesis that colonization would be more successful on the east-facing slopes than on the west-facing is not supported. Colonization was actually more successful on the west-facing than on the east-facing slopes, except for the large size class, which is so small on both slopes as to be negligible.

My observations and counts do not reflect Haragan’s (Randall and Marinelli, 1996) description of privet as “extremely aggressive”, forming “dense, impenetrable thickets that crowd out more desirable plants.” In Glen Helen, I observed many native spring wildflowers and summer perennials growing among stands of privet, especially in the moist seeps which privet apparently prefers.

It is interesting to note that the *L. vulgare* has been in the woods longer than *L. maackii*. Anliot lists it in his 1960-62 survey as “frequent in moist disturbed woods” (Anliot, 1973). The 1960 Encyclopedia of Gardening describes *Ligustrum vulgare* as a “native of the Mediterranean region that has become naturalized in the Eastern United States” (Everett, 1960). Though naturalized, *L. vulgare* in the woods of Glen Helen is a far smaller plant than *L. maackii*. A 2.5 m (8 ft) tall *L. vulgare* for example is only about 1 m (3 ft) wide. The 30 cm (1 ft) *L. vulgare* juveniles have no branching at all. A *L. maackii* shrub at 8 ft tall is at least 8 ft wide even in the shade. A 1 ft *L. maackii* plant is also about 1 ft across. Overall, I believe that the deep shade of the forested environment keeps the privet from attaining much size. Also due to the shade, even in seeps where it is tall, *L. vulgare* is still not broad.

From the lack of vigor of all privet I observed on the west-facing slopes, I believe dryness and deep shade are the controlling factors inhibiting the colonization of privet. The very few privet on the west-facing slopes that grow above 1½ m (5 ft) are scrawny.
and struggling. Those on the east-facing slopes generally stay $1\frac{1}{2}$ m (4 ft) or less, due to competition from *L. maackii* or from native shrubs. Though privet will continue to colonize, I believe it will be found primarily in moist areas and never become the problem *Lonicera maackii* is.
CHAPTER 3

MANAGEMENT OF THE INVASIVE PLANT *Lonicera maackii* (AMUR HONEYSUCKLE)

INTRODUCTION

Ecologists today recognize that ecological systems are in a constant state of flux. Both internal and external biotic pressures are always operating. The idea of closed and self-regulating plant communities is no longer an adequate foundation for land management strategies (Pickett et al., 1992).

Management efforts aimed at controlling plant invasions are more effective when the focus is on the whole ecosystem rather than on the individual invading species. Management of non-indigenous invasive plants in natural areas is an expensive undertaking. A program that includes detection and early control in the context of dynamic, changing ecosystems is called for. It is often necessary to prioritize the relative values of different areas of a large park or preserve. A manager must decide where to focus his conservation efforts. Invasion problems are too extensive and pervasive to allow the dissipation of resources through haphazard decisions (Hobbs and Humphries, 1995).
MANAGEMENT

Removal: greater costs than benefits

There are situations where control or exclusion tactics have greater costs than benefits (Huenneke, 1997). When the natural system has been so radically changed by disturbance, chronic anthropic effects, or long term occupation by invasive non-indigenous species, the reestablishment of the native ecosystem may not be possible. In ecosystems where non-indigenous plants are now well established, land managers should assess whether these plants are serving valuable ecological functions (e.g. nutrient retention, carbon storage, animal habitat) before resorting to wholesale removal (Luken and Thieret, 1996). Whelan and Dilger (1992) found that a number of species of birds nested in the exotic shrubs of Euonymus spp., Lonicera maackii, L. tatarica, and Rhamnus cathartica. Sudden and total removal without previous replanting of native shrubs would result in loss of nesting habitat.

Another example of weighing the costs of control tactics is in the case of the Tamarix ramosissima (tamarisk, salt cedar) in the Southwest. This species is native to southeastern Europe and central Asia where it is found in saline soils. Tamarisk was introduced in the early 1800s (Anderson, 1998), and has become an extremely invasive plant in the riparian habitats of the West.

Anderson, a practicing ecologist in the Southwest, has come to believe that there are many situations where removal of salt cedar is misguided. He argues that salt cedar has value as a habitat for a number of native birds, rodents, and insects; it is difficult to remove, and quickly reinvades without prompt revegetation of a cleared area. Anderson
points out that due to the damming of all major Southwestern rivers, the riparian habitat is often no longer suitable for native cottonwoods and willows, and most revegetation projects fail. “Conditions have changed in such a way that in the absence of enormous and perpetual subsidies, restoration is actually impossible” (Anderson, 1998).

Though Barrows (1998) would argue with Anderson and cite such success stories as the Coachella Valley Preserve near Palm Springs, California and the Ahakhav site on the Colorado River Indian Reservation near Parker, Arizona, it may be useful to look at some of their points in light of *Lonicera maackii*. In the Midwest, the cause of system change and subsequent problems with invasive species is due mainly to the fragmentation of forests by clearing for agriculture and the disturbance caused by logging, grazing, and building within the remaining forests.

In some Midwestern forests, the distribution and richness of the native species has declined to such a point that what remains is an understory monoculture of *Lonicera maackii*. In cases such as this, the manager must make decisions about the feasibility of replanting with natives, also asking whether the elimination of the invasive species will be a step toward ecosystem health or whether it will result in a more severely degraded community. He must also consider the extent of the resources he has available for future *Lonicera maackii* control.

*Better to go after large or small invasions first?*

It is often the practice to go after the largest, most conspicuous populations of invasive plants. The areas of the worst infestations are assigned the highest priority of control, while smaller, less infected areas are ignored. Schwartz and Randall (1995) believe that this strategy should be reversed. They believe that prevention of new
invasions and elimination of newly established populations should be given top priority. Control efforts are most effective and efficient at these early stages of invasions. Once a species is well established on a site, it is extremely difficult to control (Moody and Mack, 1988; Randall, 1993).

Cutting and hand pulling

Luken and Mattimiro (1991) studied the resilience of L. maackii during repeated clipping. They suggest that in a deeply shaded forest environment, repeated clipping will control adult plants of Lonicera maackii. Clipping Lonicera maackii in open areas, however, will develop populations that are more dense and productive than prior to clipping (Luken, 1996). Hand pulling of isolated shrubs less than three years old is not difficult. Honeysuckle seedlings reestablish themselves quickly once large shrubs are removed from forest areas. Though hand pulling is possible in moist soils, the quantity and spread of the invasion often makes this an unrealistic method of control (Geiger, pers. com.).

Glyphosate control of amur honeysuckle

Donald Geiger (Conover and Geiger, 1999) began a control program on the 40-hectare Mt. St. John/Bergamo Nature Preserve near Dayton, Ohio, in 1985. The woods there are second growth; the characteristic woodland community is oak-hickory-maple. The oaks are white, black, red, and shingle (Quercus alba, Q. velutina, Q. rubra, Q. imbricaria). Common hickories are shagbark (Carya ovata) and bitternut (Carya cordiformis). The sugar maple (Acer saccharum) is also fairly common. Characteristic small trees and shrubs are dogwood (Cornus florida), hackberry (Celtis occidentalis), black haw (Viburnum prunifolium), spicebush (Lindera benzoin), and some sassafras
(Sassafras albidum) (Geiger, pers. com., pers. obs.). The nature preserve also includes a wet meadow, two prairie areas, and an open field area. Geiger’s goal is to eventually replace the well established Lonicera maackii with native shrubs.

The management staff at Mt. St. John/Bergamo uses two methods of treatment for honeysuckle removal. The first is a cutting and stump treating method. Since it is highly selective, this can be done at any time of the year provided the temperature is above 55-60°F. They saw or lop the shrubs at or just above soil level and immediately apply a 20% Roundup (glyphosate) solution to the stumps. The Roundup solution is mixed in quart size spray bottles for the volunteers, or in 3 gallon backpack sprayers for staff use. The cut brush is generally left to decompose in place next to the stump. For the 2 years 1998 and 1999, an average of 15 gallons of 20% solution per year was used on approximately 6 acres each year. Since some of the same areas treated in 1998 were treated again in 1999, the total area treated was approximately 10 acres. The areas varied in the density of honeysuckle. The total hours (average of 40 volunteers plus 2 staff) spent doing the saw/lop and spray method of honeysuckle treatment came to an average of 264 hours per year (Guggenbiller, pers. com.). Geiger has found this method to be highly effective in killing most of the shrubs. Those that resprouted were cut and sprayed again the following fall (Conover and Geiger, 1999).

Following the removal of large shrubs, there is usually a flush of growth of small plants and newly germinated seedlings in the cleared area. To eradicate the seedlings and small shrubs, Geiger oversprays the young plants in the late fall with 1% glyphosate. Records over several years show that most of the young honeysuckle shrubs and seedlings are killed by this treatment (Conover and Geiger, 1999).
The 1% method of honeysuckle treatment is also used on large shrubs. This is done in late fall (in southwestern Ohio, from late October through mid November) before the honeysuckle is dormant but after the native plant leaves have senesced. The air temperature must be above 55° F to ensure photosynthetic action. Overspraying is especially applicable to monocultures of honeysuckle less than 10 ft tall. It is hard to get complete coverage of taller shrubs while spraying from the ground. The 1% Roundup solution is mixed in a 100 gallon tank or in a 3 gallon backpack. At Mt. St. John/Bergamo Nature Preserve in 1998, one staff member covered approximately 3 acres using 116 gallons of 1% solution in 8 hours (Guggenbiller, pers. com.).

When planning the management of large areas of significant invasions of *Lonicera maackii*, it is important to consider the level of remaining herbaceous perennials on the forest floor. In areas where a significant herbaceous layer is still intact, Geiger believes that it is important to avoid repeated walking over the same area. For this reason, the shrubs are not removed from the woods after overhead spraying; within a season only the woody skeleton remains standing and will eventually fall as decomposition of the shallow root system takes place (Geiger, pers. com., pers. obs.).

During 1996, 1997, and 1998, district-wide fall honeysuckle removal campaigns took place at Five Rivers Metroparks in Dayton, Ohio. Staff from many different parks worked together at one park for one or two days at a time. Five Rivers Metroparks also uses the 20% Roundup solution on cut stumps. With 2-3 staff cutting and spraying stumps and 20–30 staff pulling and chipping the cut shrubs, 2-5 acres could be cleared in two days. The acreage cleared varied with the steepness of the terrain and density of the *L. maackii* invasion. Piling the honeysuckle for burning or composting made such
phenomenal brush piles that chipping became the preferred method of dealing with the brush. The chipped brush was generally blown back into the woods. Treatment (overspraying with 1% Roundup) for subsequently emerging honeysuckle seedlings in the woods was done the following fall when native shrubs and herbaceous plants were dormant.

Costs of the rental of 4 chippers for 2 days was approximately $1200. Thirty employees earning an average of $12 an hour for 2 days comes is nearly $6000. During the first year the park district rented a Bobcat for 2 days on one of the sites for $450. The Brush Brute attachment was used to pull entire large shrubs out by their roots. This was not used in subsequent years as this method causes too much disturbance to the herbaceous plant layer. Other costs included lunch for the crew at the hosting park that was getting the benefit of everyone’s labor. $250 fed a crew of 30 for two make-your-own-sandwiches lunches. Costs related to chainsaws and loppers were absorbed into the general operating costs of the hosting park. Safety glasses, ear plugs, and marker dye for two days of spraying ran about $70. For 3-4 days work approximately three 2 ½ gallon containers of Roundup (diluted to a 20% solution) were used in treating stumps. At $60/gallon, approximately $450 worth of Roundup was used. Total equipment rental, labor, Roundup, and miscellaneous expenses for a two day honeysuckle removal project ran approximately $8200 for about 5 heavily invaded acres ($1640/acre) (Klunk, pers. com.). With volunteers and leaving brush in place, the staff at Mt. St. John/Bergamo was able to treat about 10 moderately invaded acres over a two year period for about $2000. Looking at costs of labor alone, the value of volunteers becomes immeasurable. Chipping
the brush as opposed to leaving it in the woods becomes a budget constraint as well as an ecological and aesthetic decision.

Taylorsville Metropark (one of the Five Rivers Metroparks) has an ongoing removal campaign. When staff can be spared from regular park maintenance duties, honeysuckle removal gets underway. With a full time staff of 4, 1 mile of trail (6 ft wide trail plus 12-15 ft on either side) was cleared of Lonicera maackii in 7 working days. The amount of Roundup used was three 2 1/2 gallon containers undiluted. Faced with an extremely well-established honeysuckle population, the choice of the park manager was to go after the edge plants, the highest seed producers, and pay less attention to the honeysuckle in the shadier woodlands (Davis, pers. com.). Removing honeysuckle from overgrown trails addresses the issue of safety as well as ecological restoration. Honeysuckle removal also has aesthetic advantages. In Five Rivers Metroparks, views are now opened to the Stillwater River from Wegerzyn Gardens, and a beautiful view of the Miami River can now be seen from the bikeway along Crain's Run.

In Glen Helen Nature Preserve in Yellow Springs, Ohio, a honeysuckle removal project was recently undertaken (Fall, 1999). Antioch College students and community volunteers pulled and dug 328 plants from eight 30 m x 30 m quadrats (.72 ha) along the western (town) edge of the Glen (Yellow Springs News, Dec. 9, 1999). For this project, the consensus was not to use herbicide. Though the effort of hand removal is commendable, I believe that the use of herbicide (cut and stump treatment with 20% glyphosate) would make it possible to treat shrubs that are too large to dig or pull out. Herbicide stump application would also solve the problem of the resprouting of roots that may be left behind in the hand removal of medium to large size shrubs. Another
consideration in hand removal is the potential disturbance to the existing herbaceous layer caused by pulling out medium to large shrubs and their root systems. Also, soil compaction occurs from continued walking over and standing in the same area while removing plants by hand pulling or by using a shovel or prying tool. In areas of less dense *Lonicera maackii* invasions, where small to medium size plants are scattered over a large area, hand pulling may be the best choice. In areas of high density of *L. maackii*, especially where very large shrubs are mixed with medium and small, herbicide treatment may be more effective than hand pulling.

**CONCLUSION**

Resource management policies reflect the different values that people hold regarding nature preservation (Luken and Thieret, 1996). For example, cultivars of Amur honeysuckle are still being distributed and planted while managers of parks and natural areas attempt to control and remove them. Efforts are being made to address these discrepancies, however. In 1983, the Illinois Department of Conservation committed to growing of only native species in their nurseries. The native trees and shrubs are used in developing wildlife habitat, reclamation projects, and community restoration (Harty, 1993). Similarly, Mt. St. John/Bergamo in Dayton, Ohio has a small native plant nursery as stock for replanting areas cleared of *Lonicera maackii*. Blanket policies for preserving indigenous species only must be approached with caution however. Fragmentation and human disturbance have changed our ecosystems significantly. Land managers must make decisions based on existing conditions, rather than on the idealized and
scientifically incorrect concept of a former time in which ecosystems were “balanced and stable”. The most successful management policies will include preservation goals developed in the context of an entire ecosystem, taking into account the ecological functions non-indigenous species may be playing, determining where removals should occur, and stipulating the availability of resources for follow-up management. Invasive plants such as *Lonicera maackii* do produce significant changes in the composition and functioning of the ecosystems they invade. For the health of our ecosystems we cannot afford to ignore these changes. Where *Lonicera maackii* and other invasive plants have already or are in the process of displacing native plants and altering their ecosystems, active management must take place.
APPENDIX A

Tables and Figures
<table>
<thead>
<tr>
<th>HABITAT</th>
<th>Small (1-2 yr)</th>
<th>Medium (3-5 yr)</th>
<th>Large (6-35 yr)</th>
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<tr>
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<td>620 (212)</td>
<td>407 (75)</td>
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<td>250 (90)</td>
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<td>West facing slope</td>
<td>694 (209)</td>
<td>315 (100)</td>
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Table 1. Mean density of *Lonicera maackii* (Amur honeysuckle) per hectare. Density was converted from # plants/area sampled (90m² per transect). Means are presented (± 1 SE). Small = < 1 m tall. Medium = 1-3 m tall. Large = > 3 m tall.
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<th>HABITAT</th>
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<th>Medium (4-6 yr)</th>
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Table 2. Mean density of *Ligustrum vulgare* (Common privet) per hectare. Density was converted from # plants/area sampled (90m² per transect). Means are presented (± 1 SE). Small = < 1 m tall. Medium = 1-3 m tall. Large = > 3 m tall.
### ANOVA

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Table 3. Two-way analysis of variance for *Lonicera maackii* (Amur honeysuckle) using transect density means.
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Table 4. Two-way analysis of variance for Ligustrum vulgare (Common privet) using transect density means.
Fig. 1. Map of study area in Glen Helen, Yellow Springs, Ohio. Topography section shows habitats.
Mean density of *Lonicera maackii*

![Bar chart showing mean density of *Lonicera maackii* across different habitats and distances.](chart.png)

**Habitat**
- East facing slope
- Bottomland
- West facing slope

**Density:** # plants/ha

![Density bars for different habitats and distances.](chart.png)

*Fig. 2.* Mean density (± 1 SE) of *Lonicera maackii* (Amur honeysuckle) per hectare. Density was converted from # plants/area sampled (90m² per transect).
Mean density of *Ligustrum vulgare*

![Graph showing mean density of Ligustrum vulgare across different habitats and height classes.](image)

**Habitat**

- East facing slope
- Bottomland
- West facing slope

**Density: # plants/ha**

- $<3$ m
- 3-6 m
- $>6$ m

Fig. 3. Mean density (± SE) of *Ligustrum vulgare* (Common privet) per hectare. Density was converted from # plants/area sampled (90m² per transect).
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