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A Microhabitat Assessment of Five Species of Invasive Plants in the Ozarks and Appalachians

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A Microhabitat Assessment of Five Species of Invasive Plants in the Ozarks and Appalachians

A Microhabitat Assessment of Five Species of Invasive Plants in the Ozarks and Appalachians

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Biology

by

Eric Richard Hearth
University of Arkansas
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Abstract

Invasive species present a threat to native communities and their introduction and expansion can alter community structure and dynamics. Multiple approaches can be employed for invasive species management including prevention and detection. In this study, microhabitat assessments were conducted on colonies of five species of invasive plants, *Alliaria petiolata* (M. Bieb.) Cavara & Grande, *Lespedeza cuneata* (Dum. Cours.) G. Don, *Lonicera japonica* Thunb., *Microstegium vimineum* (Trin.) A. Camus, and *Rosa multiflora* Thunb. in the Ozark Plateau and Appalachians. Elevation, soil moisture, soil pH, light ratio, slope, aspect, distance to disturbance, as well as soil nutrient levels were recorded for each colony. A series of multiple linear regression models and simple linear regressions to attempt to predict colony stem count as well as Daubenmire cover class comparisons for each species were conducted for the two ecoregions as well as together to assess each species. There were various amounts of success at determining which environmental and soil variables play a role in determining colony size for these species and some difference were detected across species for cover class comparisons.

Acknowledgments

This study could not have been completed without the continued and unyielding support from my family and friends; the cooperation from the supporting agencies and personnel I have met and worked with during the course of this thesis, including Canaan Valley Wildlife Refuge, The Monogahela National Forest, The Fernow Experimental Forest “Nursery Bottom”, the Claytor Nature Study Center, Blue Ridge Parkway, Mountain Lake Biological Station, Dr. Joan Gibson, Pea Ridge National Military Park, Devil’s Den State Park, Hobbs State Park, the city of Tulsa, and Joyce Haynes. Steven Ericksen, Kristen Becker, and Karen Willard whom assisted with field work; Jennifer Ogle at the University of Arkansas herbarium who helped with specimen identification; the Arkansas Native Plant Society and Mountain Lake Biological Station provided fiscal support; and members of my thesis committee Dr. Steve Stephenson, Dr. Johnnie Gentry, Dr. John Willson, and Dr. Jason Tullis who guided my efforts. Thank you all.

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Introduction

Non-native and invasive species are an established and challenging problem for ecologists because these invasive species pose a threat to native ecosystems. An invasive species can be defined as any species that is not native to the area in question and its occurrence can cause or is causing damage to the ecosystem, the economy, or human health (USDA, 2014). Economic damage caused by the introduction of invasive species is estimated to cost the United States $120 billion annually, and invasive species cause various agencies to allocate more funds to manage these species and/or to close recreational areas while control is in progress (Pimentel et al., 2005).

Numerous ecological impacts of invasive species are commonly reported throughout the literature. One notorious example is the elimination of the American chestnut (*Castenea dentata* [Marshall] Borkh.) as a dominant tree in the Southeastern United States by the chestnut blight. The chestnut blight was caused by an invasive fungal pathogen, *Cryphonectria parasitica* (Murrill) Barr., which was introduced from Asia about 1900 and decimated chestnuts trees, which drastically altered the composition of the southeastern forests (Burke, 2012). Other ecological impacts of invasive species are documented to alter ecosystem processes. Meiners (2007) assessed the apparent competition that two invasive shrubs, *Lonicera mackii* (Rupr.) Herder and *Rosa multiflora* Thunb., had on green ash, *Fraxinus pennsylvanica* Marshall, regeneration. The two invasive shrubs seemed to be providing a beneficial habitat for a mouse seed predator, protecting the mouse from predation and thus facilitating predation on the ash (Meiners, 2007). Other detrimental effects of invasive shrubs have been documented to occur on avian taxa. Borgman and Rodewald (2004) reported that invasive shrubs reduced nest success rates because they are less protected against mammalian predators, leading to increased mortality.

Species richness is also affected by invasive species. Declines in species richness that could be attributed to invasive plant infestations are well documented. Butler and Cogan (2004) documented a decline in species richness in North Dakota in association with infestations of leafy spurge (*Euphorbia esula* L.); however they conclude that the decline in richness observed is not caused by the infestation at the present. Arthropod diversity have been reported to be negatively affected by plant invasions as well. In a literature review conducted by Litt et al. (2014), the majority of studies indicated that herbivorous and predatory arthropod taxa decreased as a result to plant invasions, while detritivore taxa displayed an increase as a result. Similar results were reported for *Lespedeza cuneata* (Dum. Cours.) G. Don infestations in which the total number of insect species in invaded plots experienced a 63% decrease and the number of families recorded experienced a 53% decrease (Eddy and Moore, 1998). Fickenscher et al. (2014) reported comparable results to the introduction of invasive plants in which the introduction significantly changed the composition of the insect community.

Biological characteristics may be able to help define or predict what species are invasive (Rejmanek and Richardson, 1996; Rejmanek, 2000). The following characteristics are reviewed by Rejmanek (2000) in which he summarized biological traits of invasive species include (1) stable fitness in the environment, (2) small genomes, (3) reduced reproductive limitations, (4) vertebrate assisted dispersal, (5) size of native range facilitating stable fitness in a new ecosystem, (6) vegetative reproduction, (7) “exoticness” and no natural enemies/predators in the new environment (enemy release hypothesis), (8) mutualism with generalists, (9) varied growth habits, and (10) dispersal assisted by human activity (Rejmanek, 2000). Other characteristics that have been reported in the literature include tall growth habit and larger seed size when compared to native plants (Crawley et al., 1996). Crawley et al. (1996) also expanded on reproductive characteristics of potential invaders, by providing evidence that invasive species flower earlier or later than native species and that pollination of invasive species was more likely to occur through insect vectors. However, contradictory evidence is presented by Goodwin et al. (2001) in which stem height and flowering period were not good predictors of invasiveness, while geographic distribution was. Williamson and Fitter (1996) also provided evidence that invasive plants have large leaf area than native comparisons. However, these characteristics cannot be applied to every situation because of other factors limiting the biology of the specific plant (Rejmanek and Richardson, 1996) and there are doubts about the ability to predict the invasive nature of a species based on its biology (Mack et al., 2000).

Non-native species do not spontaneously enter a new ecosystem. Some mechanism of introduction must occur to extend the distribution of the species, whether the mechanism is natural or unnatural is a key defining characteristic in invasive species. A key distinction needs to be made, however, between what is meant by the introduction of a non-native species and the dispersal of a non-native species. For the purposes of this thesis, introduction can be defined as the mechanism in which a non-native species was eventually established into a new ecosystem (e.g. soil transportation), while dispersal can be defined as the mechanism of spread of propagules of a species within an ecosystem. Introductions of invasive species have been well recorded in the literature for some time (Foy et al., 1983; Baker, 1986). There is no doubt that many non-native species are introduced with the assistance of anthropogenic activity. Baker (1986) links the introduction of *Silene latifolia* Poir. ssp. *alba* (Mill.) Greuter & Burdet (bladder campion) and *Erechtites minimus* (Poir.) DC. (coastal burnweed) to past shipping activity (in these cases, the shipment of ballast) on the west and east coast of the United States, respectively. Foy et al. (1983) reviews many unintentional introductions of species, and they are all related to problems of contamination through the shipment of soils, seeds, or other biological/agriculture related materials.

Intentional introductions of non-native species are a different subject matter. These introductions differ from the previous introductions because these species introduced were introduced with the goal that they would serve in some ecological/biological/economical/social role (e.g. soil stabilization) and are either actively promoted or planted. Many examples of intentional introductions into North America include many species that were brought over from Europe by colonizers (Foy et al., 1983; Baker, 1986). Intentional introductions of plant species might be the cause for the majority of their subsequent plant invasions (Mack et al., 2000). *Peuraria montana* (Lour.) Merr. (Kudzu) is a well-known example of an invasive species that was intentionally introduced. Kudzu was introduced from Japan in the early 1900s and was planted for soil stabilization (Baker, 1986; Miller et al, 2010). Kudzu is a "quick growing… easily escaping, and rapidly spreading" (Reed, 1970) and is well known today to have overtaken other vegetation and established monodominant stands. According to Foy et al. (1983), ornamentation is the most common reason for introduction of non-native species (see table III in Foy et al., 1983). Nurseries are prime locations that assist the spread of invasive species and in a survey done by Burt et al. (2007) some nurseries do not fully accept responsibly for their role in the spread (through sales and planting) of invasive species, thus impacting management issues.

Study Species

Alliaria petiolata (M. Bieb.) Cavara & Grande (garlic mustard) is an invasive biennial herbaceous plant of the Brassicaceae (mustard family) (Nuzzo, 2000). Garlic mustard was introduced from Europe in 1868 on Long Island, New York, and the plant was originally cultivated as an herb for garden use (Nuzzo, 2000; Miller et al., 2010). Garlic mustard can also be used for erosion control as well (Cavers et al., 1979). Currently, garlic mustard is found throughout much of the United States (Fig. 1; Kartesz, 2014). Mature garlic mustard is identified by its deltate to cordate dark green alternate leaves with a crenate leaf margin and acuminate apex (Cavers et al., 1979; Miller et al., 2010). Flowers of the mature plants are distinctly white and resemble a cross, like other members of the Brassicaceae (Cavers et al., 1979; Miller et al., 2010). Flowering occurs in April to May but sometimes can occur as late as August through smaller inflorescences if the plant has been damaged (Cavers et al., 1979; Nuzzo, 2000; Miller et al., 2012). Fruit production occurs through May into September in the form of siliques (Cavers et al., 1979; Nuzzo, 2000; Miller et al., 2012). Seeds can be dispersed by water run offs or by disturbance activity (Caver et al., 1979; Nuzzo, 1999; Burls and McClaugherty, 2008). Garlic mustard typically occurs in moist, shaded, and disturbed areas (eg: roadsides, trails, and forest edges) (Cavers et al., 1979; Nuzzo, 2000; Welk et al., 2002; Miller et al., 2012).

Ecological impacts of an infestation of garlic mustard are varied. Like other invasive species, colonies of garlic mustard have the potential to change resource levels. Stinson et al. (2007) reported that medium and high densities of the plant can induce a shading effect and thus have negative consequences for establishment and regeneration of native species. Other reports of the effects of infestations of are briefly reviewed in Nuzzo (2000). However, there is some conflicting evidence as to the ecological effects of garlic mustard. In the same study, Stinson et al. (2007) reported that species diversity and species equitability were negatively related to infestations but overall species richness was not. In a separate study, positive associations

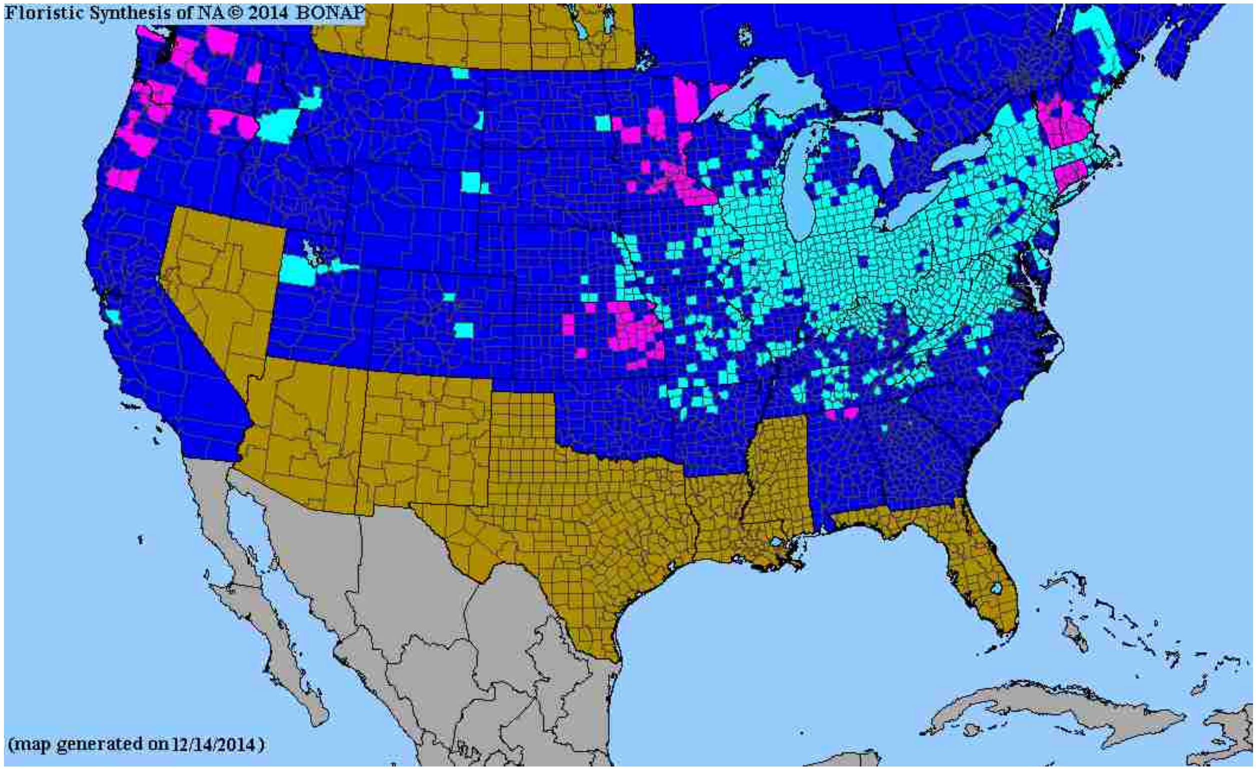


Figure 1: County level distribution map of *Alliaria petiolata*. Data may not be up to date in all cases. Dark blue, exotic and in state; light blue, exotic and species present; pink, noxious. Reproduced with permission. (Kartesz, 2014).

Figure 2: Stems of garlic mustard bearing multiple siliques. Image taken by Eric Hearth.

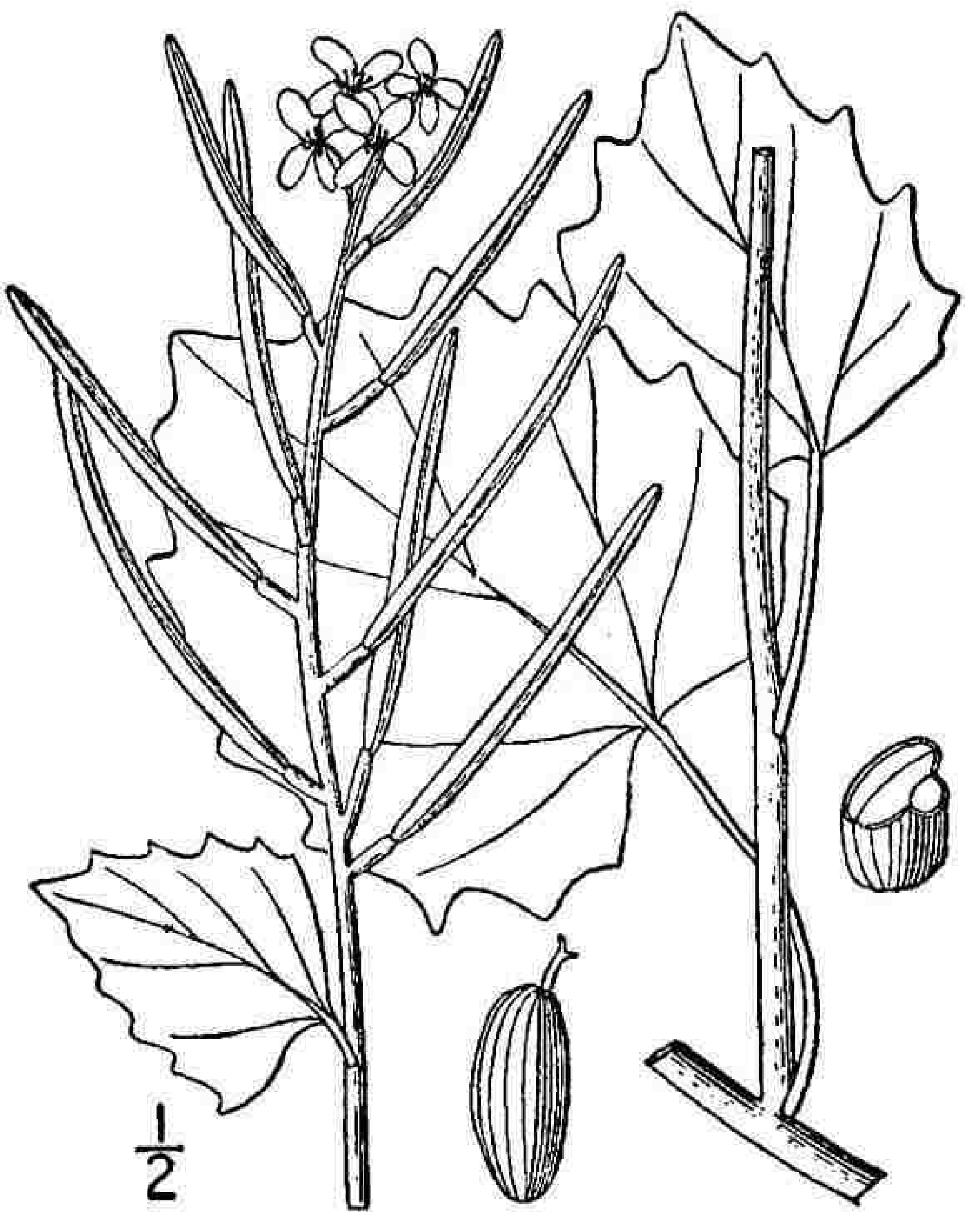


Figure 3: Line drawing of garlic mustard (Britton and Brown, 1913).

between garlic mustard abundances and abundances and richness of associated plants were positively related (Davis et al, 2012). A more serious ecological threat that garlic mustard poses is its ability to produce allelopathic chemicals. Chemicals like this are not novel among plants and are found among a variety of species, invasive and native (e.g., *Juglans nigra* L., black walnut, Comas and Eissenstat, 2009), but new instances of allelopathy in an ecosystem can act as a "novel weapons" by allowing invasive plants to exploit their new ecosystems (Callaway and Ridenour, 2004). There is an abundance of evidence supporting the impact of the alleopathic potential of garlic mustard disrupting associated endomychorrhizal and ectomycorrhizal fungi (eg: Roberts and Anderson, 2001; Prati and Bossdorf, 2004; Stinson et al., 2006; Callaway et al., 2008; Wolfe et al., 2008; Castellano and Gorchov, 2012). The ability to interfere with these associations might be the more significant impact of an infestation of garlic mustard. However, the strength of garlic mustard's allelopathy seems to diminish as populations "age" and become more genetically diverse, indicating that the allelopathy produced might have evolved to allow garlic mustard to establish itself in its new host community and then spread via other mechanism (e.g., shading native vegetation) (Lankau et al., 2009).

Lespedeza cuneata (Dum. Cours.) G. Don (sericia lespedeza; henceforth referred to as lespedeza) is an invasive perennial legume that belongs to the Fabaceae (bean family) (Stevens, 2002). Lespedeza was introduced from Japan in 1899 in Arlington, Virginia, then again in Tennessee (Miller et al, 2010). However, there are reports of it being first introduced much later in 1940 by Stevens (2002) when the "value" of the plant was discovered by agronomists. According to Miller et al. (2010) the plant is still planted for quail food, soil stabilization, and grazing, and there are breeding programs underway. Lespedeza is common throughout the Southeastern United States (Fig. 4; Kartesz, 2014). Lespedeza has alternate trifoliately compound leaves, with oblong to linear leaflets with a rounded apex and a cuneate tip (Stevens, 2002; Miller et al., 2010). A single plant can form multiple branches from the stem and the stem itself can grow to up to 2 meters in height (Stevens, 2002; Miller et al., 2010). It has been reported that stem density of lespedeza in an infested oak savannah in Kansas ranged from 141 to 466 plants/m^2 (Eddy and Moore, 1998). Chasmogamous flowers of lespedeza are axillary and are produced from July through October and are white with purple guides. The cleistogamous flowers that can be produced are not showy (Stevens, 2002; Miller et al., 2010). Single-seeded legumes are produced through October to March (Miller et al., 2010). Dispersal of lespedeza can be assisted by animal vectors (e.g., cotton rats) or by anthropogenic means (e.g., vehicle tires) or by planting a batch of seeds that contain seeds of lespedeza (Eddy et al., 2003; Silliman and Maccarone, 2005; Pitman, 2006). Silliman and Maccarone (2005) also hypothesize that dispersal of lespedeza may be linked to water runoff. Lespedeza is a shade intolerant, drought tolerant species that is common along disturbed areas (Eddy and Moore, 1998, Stevens, 2002).

Like other invasive species, lespedeza can form a canopy from colonies of plants and shade out native vegetation through expanded light interception for leaf area (Allred et al., 2010). Allred et al. (2010) reported that lespedeza has greatest monthly carbon gain, through photosynthesis, in June and July, while the contrasting native species in their study, *Ambrosia psilostachya* DC. (Cuman ragweed), had greatest carbon gain in August and September. They also report that total leaf area of lespedeza is significantly larger than two native competitors, *A. psilostachya* and *Andropogon gerardii* Vitman (big bluestem) (see Fig. 7 in Allred et al., 2010) and this larger leaf area is hypothesized by the authors to allow the plant to survive stressed conditions (Allred et al., 2010). Canopy cover changes between invaded and non-invaded plots

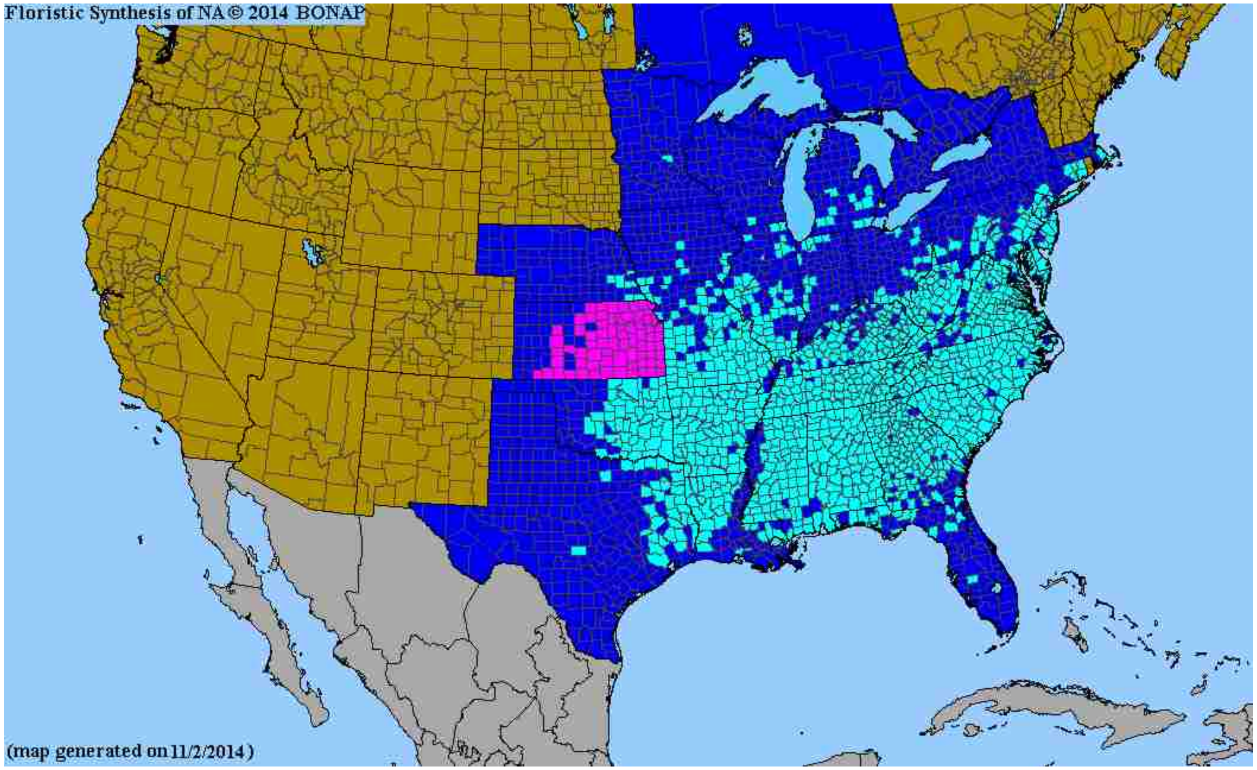


Figure 4: County level distribution map of *Lespedeza cuneata*. Data may not be up to date in all cases. Dark blue, exotic and in state; light blue, exotic and species present; pink, noxious. Reproduced with permission. (Kartesz, 2014).

Figure 5: A roadside infestation of lespedeza. Image taken by Eric Hearth.

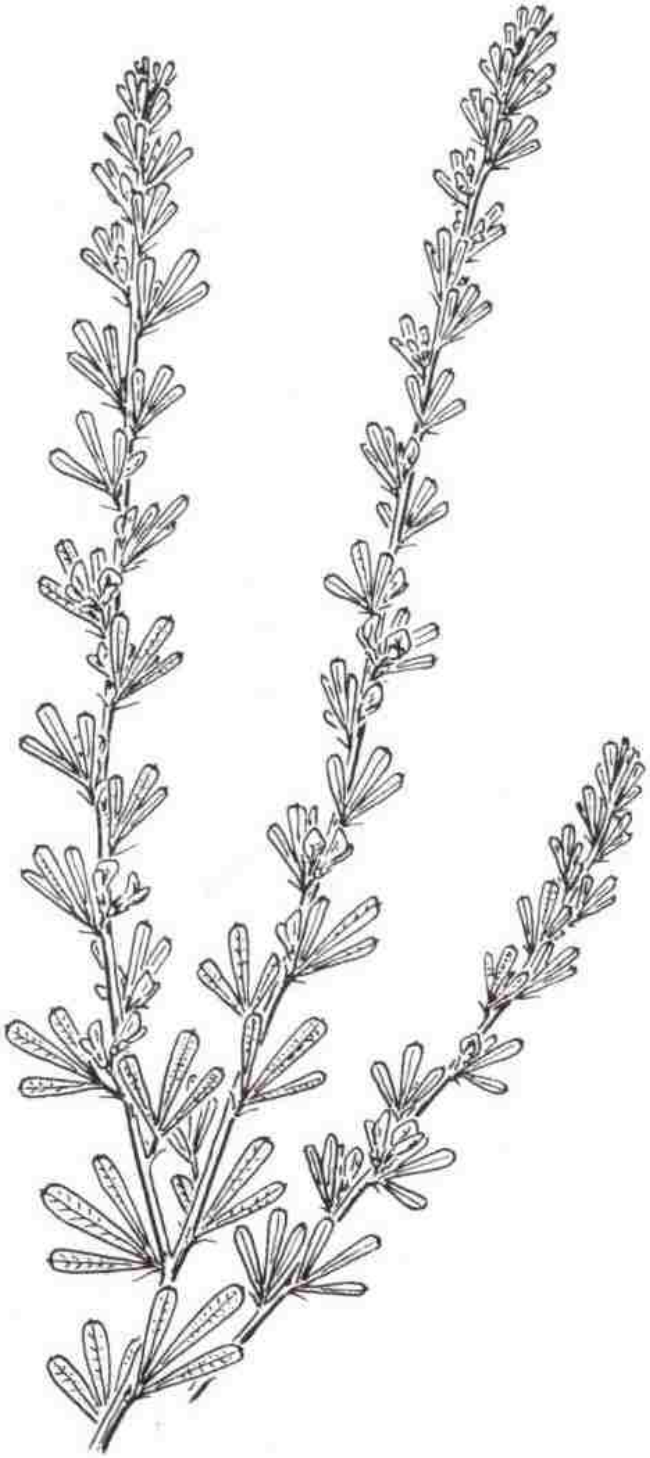


Figure 6: Line drawing of lespedeza (Strausbaugh and Core, 1965).

were documented by (Eddy and Moore, 1998) in their study in Kansas. Invaded plots had a lespedeza canopy cover of 84%, the remaining cover consisted of native grasses and forbs, while uninvaded plots had a native grass cover of 79% and a native forb cover of 28% (Eddy and Moore,1998). Lespedeza alters soil characteristics by increasing the nitrogen content available through nodulation (Coykendall and Houseman, 2014). Lespedeza provided a short term benefit to *Sorghastrum nutans* (L.) Nash (Indiangrass) when grown next to it in potted experiments, results that were contrast to *in situ* observations and a hypothetic long-term invasion by lespedeza (Coykendall and Houseman, 2014). Lespedeza also has been demonstrated to establish a potential positive feedback loop pertaining to future individual and therefore colony establishment and spread through higher amounts of root nodules produced in previously invaded soil, potentially resulting a greater lespedeza biomass (see Fig. 2 & 3. In Coykendall and Houseman, 2014). It is reported that lespedeza produces allelopathic chemicals (Kalburtji and Mosjidis, 1992 & 1993; Dudely and Fick, 2003).

Lonicera japonica Thunb. (Japanese honeysuckle; henceforth referred to as honeysuckle) is a perennial woody vine that is a member of the Caprifoliaceae (honeysuckle family) (Nuzzo, 1997). Honeysuckle is native to Japan, Korea, China, and Formosa and has since greatly expanded beyond its native range as a result of being introduced into many countries, including the United States in 1806 in Long Island, New York (Leatherman, 1955; Nuzzo, 1997; Miller et al. 2010). Applications of honeysuckle, and probable reasons for its introduction, include ornamentation, erosion control, and forage (particularly for deer), and promotion of wildlife programs and some of which are still favored (Leatherman, 1955, Nuzzo, 1997; Miller et al. 2010). Honeysuckle is abundant throughout the Southeastern United States (Fig. 7, Kartesz, 2014) and is so widespread that Miller et al. (2010) considerd it “the most commonly occurring

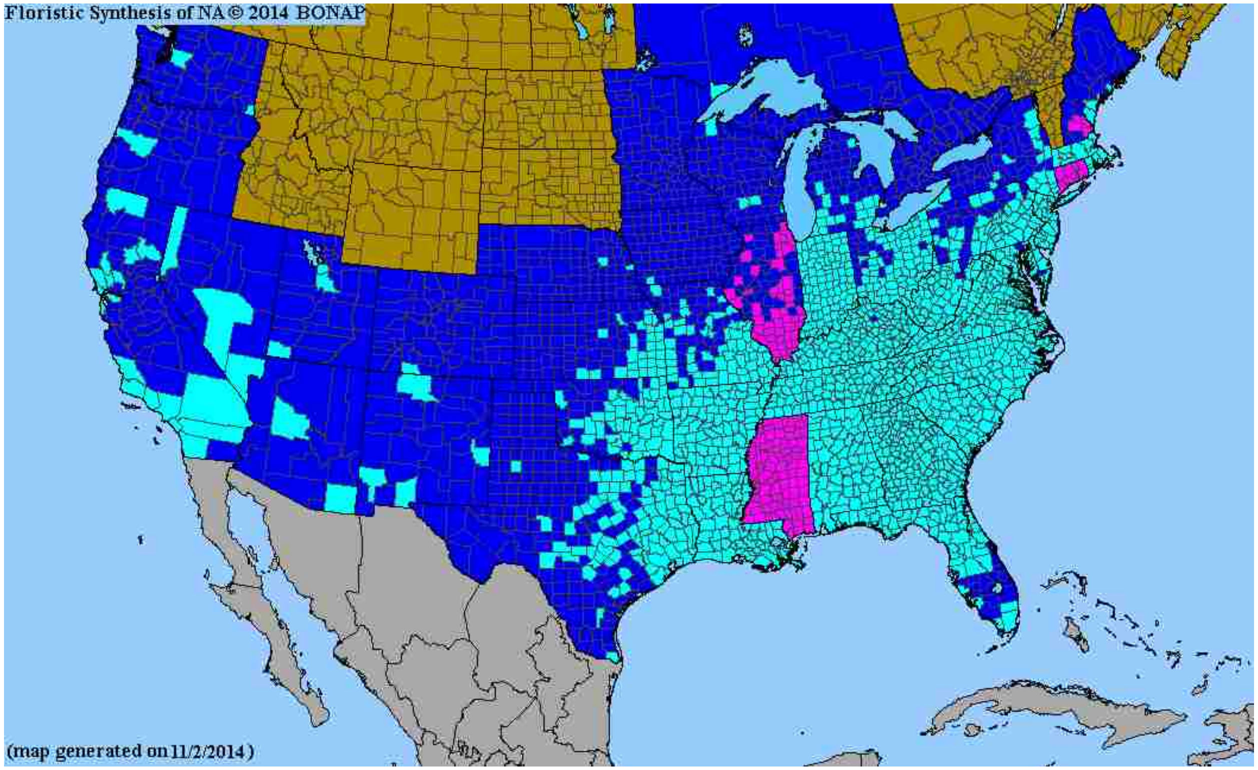


Figure 7: County level distribution map of *Lonicera japonica*. Data may not be up to date in all cases. Dark blue, exotic and in state; light blue, exotic and species present; pink, noxious. Reproduced with permission. (Kartesz, 2014).

Figure 8: A stem of honeysuckle appearing to girdle a native *Platanus occidentalis* L. (sycamore). Image taken by Eric Hearth.

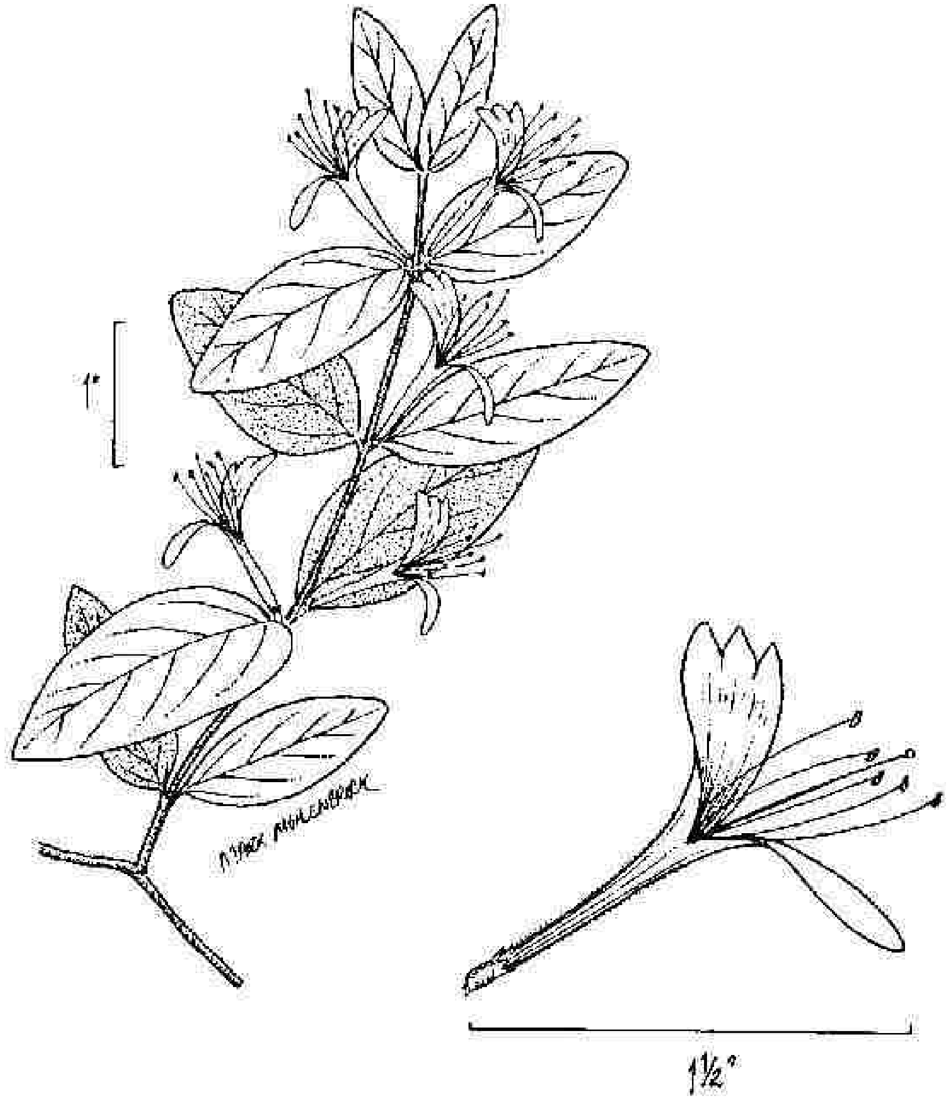


Figure 9: Line drawing of honeysuckle (Wetland Flora).

invasive plant in the South." The simple, oblong to ovate leaves of honeysuckle are oppositely arranged and typically unlobed. However, immature leaves may be pinnately lobed (Nuzzo, 1997; Miller et al. 2010). Leaves are either evergreen in the southern distribution or semi-evergreen in the northern distribution of the species, a characteristic that undoubtedly contributes to the success of the species in the south east (Nuzzo, 1997). The axillary tubular flowers of honeysuckle are distinctly yellow, white, or a mix of the two and are usually produced in April but can continue through October (Nuzzo, 1997; Miller et al. 2010). Stalked bluish-black berries are produced as early as June and as late as November, Miller et al. (2010) reported honeysuckle can be in fruit until the following March (Nuzzo, 1997; Miller et al. 2010). Honeysuckle is spread with the assistance of animal vectors, most commonly birds that eat the berries because of their high protein and fat content as well as the fact that they are available in harsh conditions (e.g., after ice storms) (Andrews, 1919; Handley, 1945; Leatherman, 1955, Nuzzo, 1997). Dispersal can also be vegetative (Leatherman, 1955; Schierenbeck, 2004). Honeysuckle invades disturbed areas and can "lie in wait" in a forest to exploit any disturbance that allows it to expand; the species is shade and drought tolerant and can invade a variety of habitats (Andrews, 1919; Nuzzo, 1997). An increase in the amount of sunlight increases the vigor of the plant (Thomas, 1980).

The most significant threat honeysuckle presents to native communities is brought about by its growth habit, which allows it to shade out native vegetation or girdle other individuals. Andrews (1919) reported that honeysuckle can utilize the structures that other climbing plants (e.g., *Parethenocissus quinquefolia* (L.) Planch., Virginia creeper) produce, exploiting them and also producing its own to ultimately kill whatever it is growing on. Andrews (1919) also reported how the terrestrial growth habit, which produces a network of interlacing stems, allows the plant to smother native vegetation. Oosting (1942) reported that honeysuckle outgrows saplings, using them as support, and causes the plant to die due to stress of the honeysuckle. This growth pattern creates a positive feedback loop for the plant, facilitating the spread of the colony and potentially allowing it to take over entire communities (Thomas, 1980; Larson et al., 2007). Similar reports of the prolific growth habit having a negative impact of native vegetation are found elsewhere in the literature (Handley, 1945; Leatherman, 1955; Dillenburg et al., 1993a & 1993b; Nuzzo, 1997).

Honeysuckle is also reported to compete with native vegetation through other mechanisms. Dillenburg et al. (1993a, 1993b) provided evidence of honeysuckle's capacity to compete for nutrient levels in the soil when growing in association with the native *Liquidambar styraciflua* L. (sweetgum), and Dillenburg et al. (1993b) concluded that belowground interaction might assist honeysuckle in the earlier stages of an infestation. There is also evidence that honeysuckle produces allelopathic chemicals. In a bioassay, Pisula and Meiners (2010) reported a weak allelopathic inhibition on *Raphanus sativus* L. (radish). Ladwig et al. (2012) presented evidence to suggest that the strength of honeysuckle's allelopathic potential is related to the amount of light received, becoming more allelopathic when growing in shade. Skulman et al. (2004) examined litter and root exudates on loblolly (*Pinus taeda* L.) and short leaf pine (*Pinus echinata* Mill.) and found evidence for allelopathy.

Microstegium vimineum (Trin.) A. Camus (Japanese stilt grass; henceforth referred to as microstegium) is an invasive annual C4 grass in the Poaceae (grass family) (Tu, 2000). The native range of microstegium is India, Nepal, China, and Japan and it was first identified in the United States outside of Knoxville, Tennessee, in 1919, thought to be introduced as packing material for shipping (Fairbrothers and Gray, 1972; Tu, 2000; Miller et al., 2010). There are no reports of microstegium's importation being applied for any ecological (e.g., soil stabilization) or economical (e.g., ornamentation) purposes (Tu, 2000). Microstegium is common throughout the eastern United States (Fig. 10, Kartesz, 2014). Microstegium has alternate, liner to lanceolate shaped leaves with a distinct silvery midvein that is somewhat off center (Tu, 2000). The flowers of microstegium are produced in terminal or axillary racemes and the plant flowers from July through October (Barden, 1987; Tu, 2000; Miller et al., 2010). Fruits are produced as a caryopsis and are produced as early as August and can continue through December (Miller et al., 2010), but a shorter fruiting period is reported by Tu (2000) and Barden (1987) as September through October. Microstegium seeds can be dispersed via water or by vectors, such as animals or vehicles (Barden, 1987; Tu, 2000; Mortensen et al., 2009; Turner, 2011). Reported natural dispersal does not exceed 3.7 m from the parental plant (Rauschert et al. 2010). In a separate study, dispersal in roadside environments was almost twice the distance as dispersal in non-roadside habitats, implying that another mechanism involved in these habitats (Mortensen et al., 2009). Non-natural dispersal factors might be the more important means of dispersal for the species. Corroborating reports of increased dispersal linked to disturbance were provided by Oswalt and Oswalt (2007); however, they also provide evidence that microstegium spread significantly, although spreading a much shorter distance (0.37 m compared to 2.2 m) even from undisturbed colonies, alluding to the idea that disturbance allows microstegium to spread more quickly. Christen and Matlack (2009), Mortensen et al., (2009), and Rauschert et al. (2010) provided evidence that roads and their upkeep provide facilitative habitats for the dispersal of microstegium. The abundance of microstegium along trail edges might indicate that human hiking activity represents an important dispersal factor for the species when seeds are captured between crevices in boots (personal observation). Microstegium grows in moist, shaded habitats typically associated with disturbance (see above; Tu, 2000; Gibson et al., 2002; Glasgow and Matlack; 2007; Warren et al., 2013). Increased light levels might be an important environmental variable for the plant as well (Horton and Neufeld, 1998; Cole and Weltzin, 2004; Flory, 2010). Microstegium readily invades habitats that have suppressed (e.g., deer browsing) or absent associated woody vegetation (Kuebbing et al., 2013). Kuebbing et al. (2013) reported that increased woody plant cover, richness, and overall plant diversity decrease microstegium abundance. Leaf litter can suppress the recruitment of microstegium and removal of leaf litter can facilitate invasions (Cole and Weltzin, 2004; Glasgow and Matlack, 2007; Oswalt and Oswalt, 2007; Warren et al., 2013).

Microstegium overwhelms native vegetation and produces monodominant stands following establishment (Oswalt et al., 2007). The formation of a “mat” of microstegium can potentially suppress regeneration of native vegetation through the formation of a canopy of microstegium, and can potentially facilitate further spread of the infestation (Oswalt et al., 2007; Kuebbing et al., 2013). A decrease in species richness has been reported later in the season, after stands of microstegium have matured, but no decrease in richness was documented earlier in the season (Adams, 2009). Lee at al. (2012) provided evidence that microstegium alters nitrogen in the soil and that the plant is more productive in nitrogen-rich environments. DeMeester and Richter (2010) also provide evidence that microstegium out competes native vegetation by sequestering nitrogen.

Reports of whether or not microstegium produces allelopathic chemicals are contradictory in the literature. Barden (1987) reported no mortality decrease of honeysuckle grown in soil that previously sustaining microstegium, however, this might indicate that exudates are no longer present or that honeysuckle is resistant to the allelopathic compound. Woods and

Ashbrun (1989) found no allelopathic properties either. However, more recent studies indicate the production of allelopathic compounds. Pisula and Meiners (2010) demonstrated the production of allelopathic chemicals and ranked the effect of mictrostegium's compounds as high as garlic mustard, a plant notorious for producing allelopathic chemicals (see above). Similarly, microstegium extracts had a negative effects on both lettuce and radish germination rates and the number of germinating seeds (Corbett and Morrison, 2012).

Rosa multiflora Thunb. (multiflora rose; henceforth referred to as multiflora) is shrub in the Rosaceae (rose family) (Eckardt, 1987). Multiflora is native to Japan, Korea, and China and was introduced to the east coast of the United States in 1886 for the use in ornamentation and as an application as a living fence (Steavenson, 1946; Eckardt, 1987). Steavenson (1946) championed multiflora as a prime candidate for use of a living fence and that its fruits (hips) as food sources for many animal taxa. Schery (1977) claimed that the drawbacks of multiflora are outweighed by the benefits and if "planted in an area with enough room". The spread of multiflora across the United States was undoubtedly assisted by claims that multiflora was a jack-of-all-trades plant for agriculture and land management purposes (Steavenson, 1946; Scott; 1965; Schery, 1977). Multiflora is common throughout the United States (Fig. 13, Kartesz, 2014). Multiflora is armed with prickles and has pinnately compound leaves, usually with 7-9 leaflets, but the plant can sometimes have 5 leaflets (Eckardt, 1987; Smith, 1994). Leaflet margins are serrated with an acute to slightly acuminate apex, with a leaflet shape that is elliptical (Miller et al, 2010). Multiflora can be easily distinguished by the presence of "fringed" stipules on the petiole. Flowers are white or sometimes pink and are produced in April and continue through June (Eckardt, 1987; Hunter, 1995; Miller et al. 2010). The red fruits are hips and are produced during September through October; these can overwinter on the plant

(Steavenson, 1946; Tucker, 1976; Eckhardt, 1987). Multiflora is most commonly spread with the assistance of birds, who eat the hips and provide the scarification required to germinate the seeds (Eckardt, 1987, Schery, 1977). Scott (1965) reviewed multiple accounts of the spread of multiflora caused by bird vectors and Schery (1977) provided evidence of birds sustaining themselves during winter by eating multiflora hips. The plant can also spread vegetatively (Christen and Matlack, 2009; Jesse et al., 2010; Miller at al., 2010). Jesse et al. (2010) hypothesized that the ability to reproduce both vegetatively and sexually (then be dispersed by animal vectors) compounds the management of the species. Multiflora grows readily in a wide range of open areas or canopy gaps receiving sun, typically following disturbances or deposition from birds along a perching location (e.g., fencerow) (Steavenson, 1946; Schery, 1977; Robertson et al., 1994; Glasgow and Matlack, 2007). Banasiak and Meiners (2009) reported that multiflora invades forest edges and does not readily move into the canopy because of the potential shading brought about by other species; however, it has been observed that multiflora can grow in shaded areas, but it does not take the same growth habit (e.g., reduced flowering) as it would if growing in full sun (personal observation). Schery (1977) and Huebner et al. (2014) also reported the shade tolerance of multiflora.

An infestation of multiflora has been shown to decrease plant species richness, colonization, and to increase extinction for certain species in abandoned agricultural land (Yurkonis et al., 2005). Similar reports of a decrease in species richness brought about by an increase of the abundance of multiflora are reported by Meiners et al. (2001) in which medium and high densities of the plant reduced species richness, while lower densities do not (Fig. 1 in Meiners et al., 2001). These reports of a decrease in species richness is in contrast to results reported by Banasiak and Meiners (2009) who reported an increase of species richness with an increase of multiflora cover, a phenomena which could be explained by a productive habitat for all taxa involved or perhaps that infestations of multiflora are relatively mild until a certain ecological threshold is reached. Meiners (2007) provided evidence of the effects that an invasion of multiflora had on native species through apparent competition brought about by animal taxa. An infestation of multiflora was shown to increase seed predation, through a favorable environment, potentially suppressing the regeneration of native plants. Munger (2002) reported that an invasion of multiflora inhibits the growth of native vegetation and blocks access to pastures and other recreational areas.

Other interactions multiflora has with non-plant taxa are not uncommon in the literature. Borgman et al. (2004) reported that bird nests in multiflora had an increase in mortality caused by predation because of the nest construction differences in multiflora as well as growth habit differences between multiflora and the native plant comparisons. Masse and Vulinec (2010) reported a decrease in bird richness at locations in which multiflora was the most abundant, citing the plant's ability to change habitat characteristics that the local bird community requires. Research into the interactions between multiflora invasion and insect communities is recent. Jesse et al. (2006) cataloged the different taxa visiting multiflora in Iowa and reported that the two most common pollinators are syrphid flies (Syrphidae) and *Apis mellifera*. Chung et al. (2014) hypothesized that multiflora is likely to have a significant impact on pollinator communities in the habitats in which it invades and provide some evidence that the presence of multiflora could increase the visitation to other plants by attracting generalist pollinators.

Study Objectives

Rejmanek (2000) and Radosevich (2007) outlined three basic management approaches when dealing with invasive species, prevention, detection, and control. Cost effective control for some invasive plants can be economically unsustainable because of the resource input required to combat the expansive nature of the species (e.g., honeysuckle) (Pimentel et al., 2005; Radosevich, 2007). Instead, focus should be turned to controlling invasions of plants before they become wide scale problems through prevention and detection. In order to do that, it is essential to understand the habitat in which the plants grow.

The purpose of this study was to assess the microhabitat of the above mentioned species with the objective of answering (1) what are the environmental variables that are important in determining the growth of these species in the Ozarks and Appalachians and do they differ between the two ecoregions and what are the environmental variables across both regions, (2) what soil characteristics are important in the growth of these species in the Ozarks and Appalachians, and (3) what are the associated species found in the invaded communities?

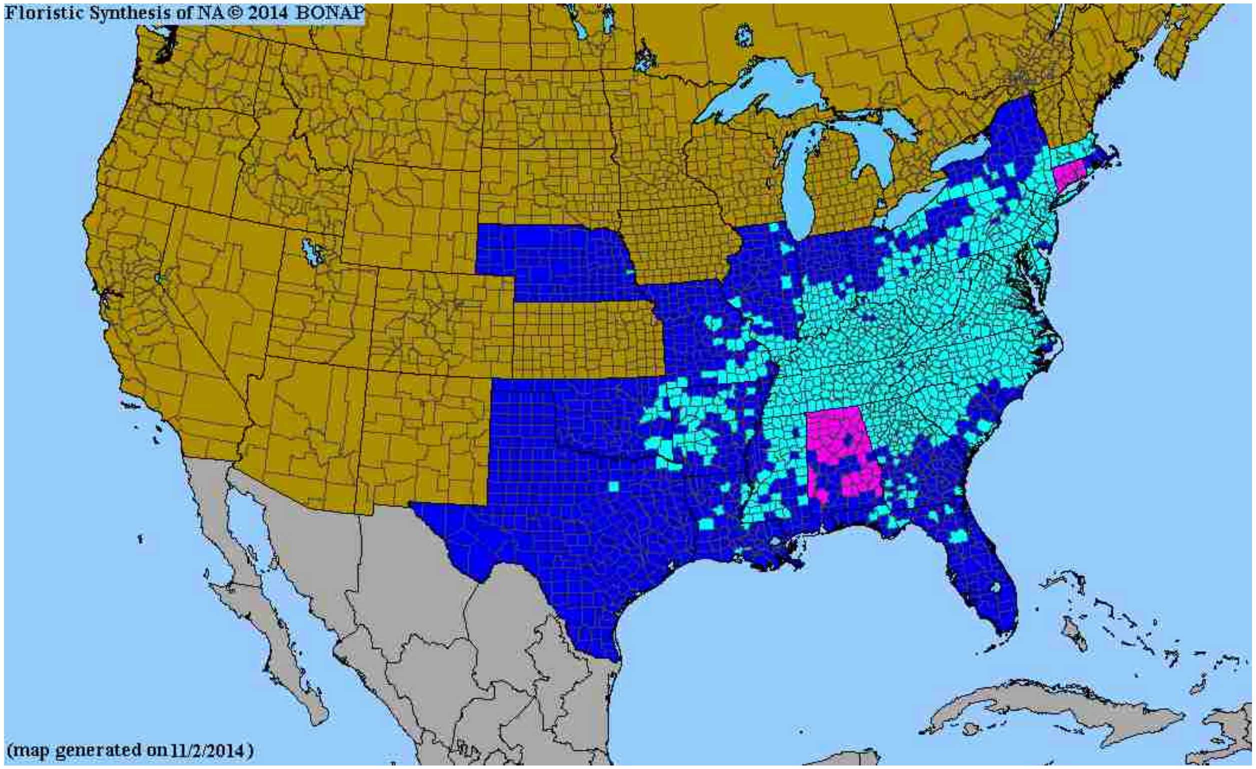
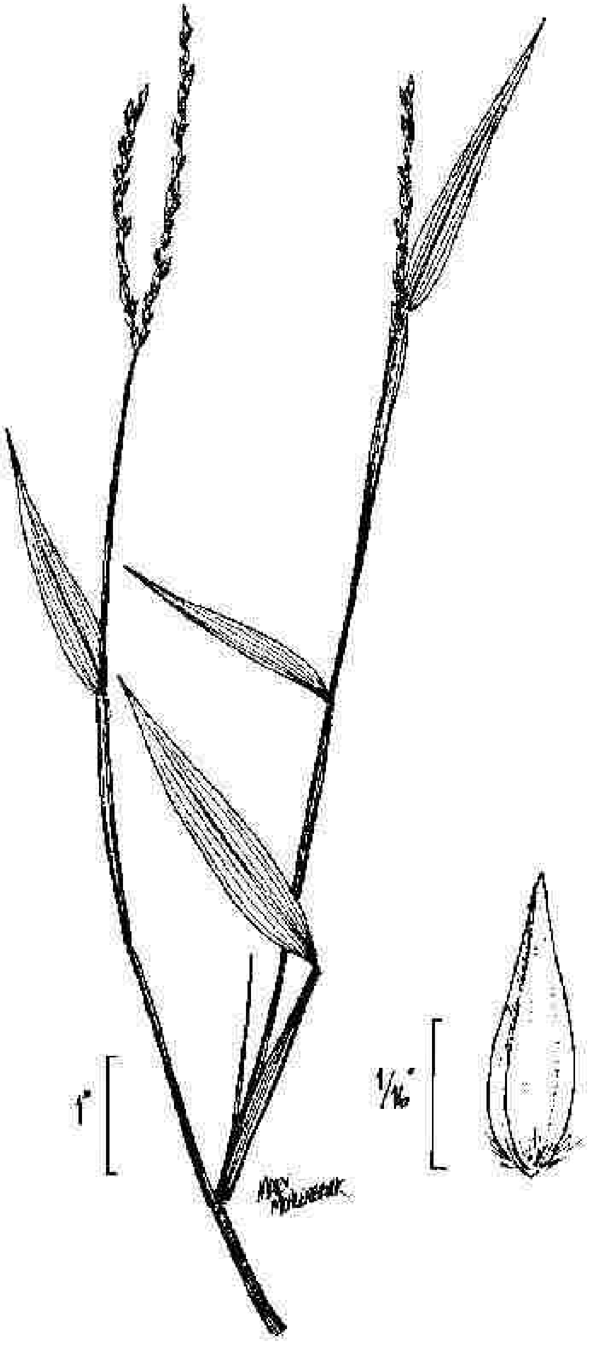


Figure 10: County level distribution map of *Microstegium vimineum*. Data may not be up to date in all cases. Dark blue, exotic and in state; light blue, exotic and species present; pink, noxious. Reproduced with permission. (Kartesz, 2014).

Figure 11: A “mat” infestation of microstegium. Image take by Eric Hearth.

Figure 12: Line drawing of microstegium (Wetland Flora, ND).



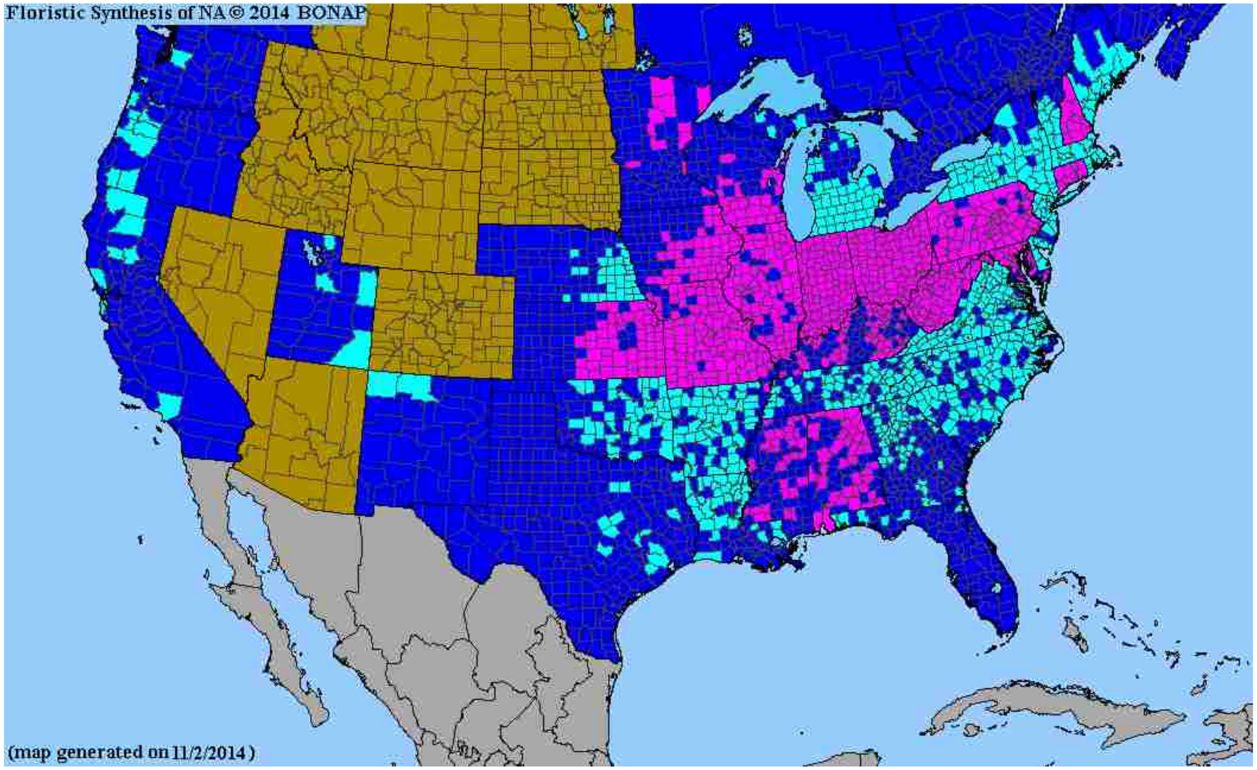


Figure 13: County level distribution map of *Rosa multiflora*. Data may not be up to date in all cases. Dark blue, exotic and in state; light blue, exotic and species present; pink, noxious. Reproduced with permission. (Kartesz, 2014).

Figure 14: Multiflora growing along an old home site road. Image taken by Eric Hearth.

Figure 15: Line drawing of multiflora (Strausbaugh and Core, 1965).

Methods

Major Vegetation Assemblages of Study Regions

The vegetation of the Ozark Plateau can be broadly classified into Oak-Hickory-Pine or Oak-Hickory assemblages (Braun, 1950; Bryant et al., 1993; Skeen et al., 1993). Oak-Pine forests are typically found on drier sites and consist of such dominants as *Quercus stellata* Wangenh. (post oak), *Q. marilandica* Münchh. (blackjack oak), *Carya texana* Buckley (black hickory), and *Pinus echinata* Mill. (shortleaf pine). Other common species present in these forests type include *Ulmus alata* Michx. (winged elm), *Carya* spp., *Diospyros virginiana* L. (persimmon), *Q. alba* L. (white oak), *Q. velutina* Lam. (black oak), and *Juniperus virginiana* L. (eastern red cedar). These forests are not too widespread throughout the Ozarks (see Fig. 1 in Skeen et al., 1993) and Braun (1950) suggested their ecological "replacement" by oak-hickory forests. The more common forest type of the Ozarks belong to the Oak-Hickory association. These forest types are composed mainly of *Q. alba, Q. rubra* L. (northern red oak), *Q. velutina*, and various species of *Carya* (e.g., *Carya cordiformis* (Wangenh.) K. Koch (bitternut hickory) and *Carya glabra* (Mill.) Sweet (pignut hickory)). It is not uncommon to see *J. nigra, Fraxinus americana* L. (white ash), and *F. pennsylvanica* Marshall (green ash) also occurring as canopy trees in these forest types. Other associated trees in these forests include *Cornus florida* L. (flowering dogwood), *Acer* spp. (maples), *Cercis canadensis* L. (redbud), *Amelanchier arborea* (Michx. f.) Fernald (service berry), *Ostrya virgiana* (Mill.) K. Koch (hophornbeam), *Carpinus caroliniana* Walter (American hornbeam), and the occasional patch of *Asimina triloba* (L.) Dunal (pawpaw). Under the appropriate environmental circumstances, *Acer saccahrum* Marshall (sugar maple) can become more dominant in the community, thus suggesting an Oak-Maple assemblage. The American chestnut was never recorded to have occurred in the Ozarks, but the

Ozark chinquapin, *Castanea ozarkensis* Ashe., does occur here, which Braun (1950) suggested is an indication of ancient linkage to the Appalachians. Currently, *J. virginiana* is a major “exploitative species” adopting the role of an invasive in the Ozarks because of systematic fire suppression (Braun, 1950; Bryant et al., 1993; Skeen et al., 1993; Ansley and Rasmussen, 2005; DeSantis et al., 2011).

Vegetation of the Appalachians is more divided because of the broad climate and geographic features of the region. According to Braun (1950) the areas sampled in the present study fall within what she designated as “Mixed Mesophytic Forests” for the areas sampled in West Virginia as well as what she referred to as “Oak-Chestnut Forests” for the areas sampled in Virginia. The mixed mesophytic forests as a whole have a high biodiversity and were considered by Braun (1950) to be the progenitor of the other forest assemblages seen today (Hinkle et al., 1993). The areas sampled in this study fall within the Allegheny Mountains subsection of the mixed mesophytic forest designated by Braun (1950). Forest composition in this section is dominated by various species of *Quercus*, mainly *Q. alba*, *Q. montana* Willd. (chestnut oak), *Q. rubra, Q. velutina,* and *Q. coccinea* Münchh. (scarlet oak). Other species present include *Liriodendron tulipifera* L. (tulip poplar), *Castanea dentata*, *Acer* spp., *Tilia americana* L. (basswood), *Betula lutea* Michx. f. (yellow birch), *B. lenta* L. (sweet birch), and *Fagus grandifolia* Ehrh. (American beech) (Braun, 1950; Hinkle et al., 1993).

The designation of Oak-Chestnut by Braun (1950) is an homage to the once dominant American chestnut before the blight; a more recent classification (Appalachian Oak Forests) given to the region following the treatment by Stephenson et al. (1993). The two subsections of the region sampled in the present study were from the Ridge and Valley section and the Blue Ridge geographic regions. Vegetation of the Blue Ridge consists primarily of oaks, such as *Q.*

alba, Q. rubra, Q. montana, and *Q. velutina*. Other notable species include *L. tulipifera, Carya* spp., *Betula lenta*, *Rhododendron* spp. (azaleas and rhododendrons), *Kalmia latifolia* L. (mountain laurel), and various *Vaccinium* spp. (blueberries). The vegetation of the Ridge and Valley section is similar to that of the Blue Ridge. A dominant assemblage of oaks is present, typically *Quercus alba, Q. rubra, Q. coccinea,* and *Q. montana*. Other important trees present include *Carya* spp., *L. tulipifera* and a variety of pines, including *Pinus virginiana* Mill. (Virginia pine), *P. rigida* Mill. (pitch pine), and *P. pungens* Lamb. (Table Mountain pine). Throughout the Appalachians as a whole, a developed shrub layer is common (e.g., *Rhododendron* spp.), which is notably missing in the Ozarks, although certain understory genera (e.g., *Vaccinium*) are shared between the two regions (Braun, 1950; Stephenson et al., 1993).

Geology and Soils

The areas in which sampling occurred in the Ozarks are located on the Springfield Plateau which is underlain with limestone (Foti and Bukenhofer, 1998). The Springfield Plateau covers areas of eastern Oklahoma, northwestern Arkansas, and small portions of southern Missouri (see Fig. 3 in Foti and Bukenhofer, 1998). The primary soil type in Benton County in Arkansas is the Clarksville, a gravelly silt loam that drains well. Washington County in Arkansas is primarily composed on an Enders-Leesburg soil complex, which consists of a well drained combination of gravelly, sandy, clay, and loamy soils that are underlain by sandstone or shale (limestone for Leesburgs soils). A Reuter-Goss-Jollymill complex is the primary soil type for McDonald County in Missouri, which is a deep well drained gravely silt loam formed from cherty limestone or dolomite in the case of Goss soils. Delaware County in Oklahoma has a primary soil type of the Clarksville (Soil Survey Staff a & b).

The areas sampled in the Appalachians are located in the Allegheny Mountains, Blue Ridge, and Ridge and Valley geographic provinces, which are underlain with sandstone (Hinkle et al., 1993; Stephenson et al. 1993). The primary soil type for Pendleton County in West Virginia consists of a Dekalb-Elliber-Blackthorn association, which is a well-drained, sandy, chirty, silty, loam formed from acidic sandstone or shale (or limestone in the case of Elliber and Blackthorn). Soils of Monogalia County in West Virginia are primarily members of the Cuelleoka-Westmoreland complex comprising of well drained, silt loams derived from limestone, sandstone, and shale. Soils of Randolph County in West Virginia are primarily Berks channery silt loam, which is well drained and formed from sedimentary rocks. Gilpin channery silt loam is the primary soil type for Tucker County in West Virginia. This soil type is well drained and is formed from sandstone and shale. Cecil fine sandy loam is the primary soil type for Bedford County in Virginia, the former is well drained and originates from granite and gneiss. A Berks-Weikert complex is the most common soil type for Botetourt County in Virginia, this is a well-drained silty loam formed from shale and siltstone. Nolichucky, the primary soil type of Giles County in Virginia, is well drained, stony, sandy, and originates from sandstone, shale, and some limestone. Montgomery County in Virginia, has a primary soil type complex of Berks and Weikert (Soil Survey Staff a & b).

Climate

The Ozarks have a moderate continental climate with mean winter temperatures about 3.4C and mean summer temperatures about 24.9C. However, it is not uncommon for local extremes to occur during the winter and summer seasons. The mean annual temperate is approximately 14.5C. Of the counties sampled in this study, Delaware County, Oklahoma, has the highest mean annual temperate recorded (15.7C). The warmest months are July and August, with a mean temperature of 26.7C and the coolest month is January with a mean temperature of 3.6C. Benton County, Arkansas, is the county with the lowest annual temperature of 13.8C, with the warmest month being July with a mean of 25.3C and the coolest month being January with a mean of 1.4C. Temperature data for the Ozark counties are summarized in Table 1 (NOAA NCDC).

The mean annual precipitation for the sampled area in the Ozarks is 116.8cm. The most common form of precipitation in the Ozarks is rain, but snow and the occasional ice storm are not uncommon during the winter. Spring is the wettest season, with a mean precipitation of 34.8cm, while the winter is the driest season with a mean precipitation of 20.6cm. Delaware County, Oklahoma, receives the most annual precipitation, with a mean precipitation of 121.1cm, with the wettest month being May with a mean precipitation of 13.4cm and the driest month being February, with a mean precipitation of 6.9cm. McDonald County, Missouri, is the driest county in the sampled area with a mean precipitation of 110.9cm. The wettest month is May, with a mean precipitation of 14.1cm, and the driest month is January with a mean precipitation of 5.2cm. Precipitation data for the Ozark counties are summarized in Table 2 (NOAA NCDC).

The mean annual temperature across the counties sampled in the Appalachians is 11.6C. The mean winter temperature is approximately 1.0C while the mean summer temperature is approximately 21.7C. Botetourt County, Virginia, has the highest mean annual temperature of the sampled Appalachian counties with a mean of approximately 13.9C. July is the warmest month, with a mean temperature of 25.2C, while the coolest month is January with an approximate mean temperature of 1.8C. The coolest county is Tucker, with an annual temperature of 10.0C. The warmest month is July, with a mean temperature of 21.5C and the

Table 1: Summary of mean temperature (C) across sampled counties in each region in the current study. Data are reproduced from 1981-2010 NCDC Station Normals (NCDC).

County	Ann.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Benton, Arkansas	13.77	1.38	3.72	8.33	13.5	18.27	22.72	25.33	25.16	20.55	14.44	8.38	2.61
Delaware, Oklahoma	15.66	3.61	6.16	10.94	15.7	19.83	24.05	26.72	26.72	22.22	16.27	10.27	4.55
McDonald, Missouri	13.83	1.61	4.05	8.94	14.05	18.27	22.5	25.11	24.83	20.22	14.33	8.61	2.61
Washington, Arkansas	14.55	2.38	4.66	9.16	14.33	18.77	23.38	26.11	25.83	21.22	14.94	9.22	3.66
Bedford, Virginia	13.38	2.05	3.44	7.88	13.27	17.55	22.22	24.33	23.38	19.5	13.83	8.77	3.66
Botetourt, Virginia	13.94	1.88	3.88	8.05	13.88	18.72	23.22	25.16	24.5	20.66	14.44	8.55	3.5
Giles, Virginia	11.2	-0.22	1.66	5.94	10.88	15.33	19.89	21.94	21.33	17.61	11.77	6.61	1.38
Monongalia, West Virginia	11.66	-0.38	1.22	5.61	11.5	16.16	20.77	22.88	22.22	18.44	12.33	7.16	1.55
Montgomery, Virginia	10.88	-0.27	1.22	5.33	10.38	15.16	19.83	21.78	21.11	17.27	11.27	6.27	1
Pendleton, West Virginia	11.33	-0.11	1.44	5.72	10.94	15.72	20.11	21.94	21.38	17.61	12.11	6.83	1.66
Randolph, West Virginia	10.16	-1.55	0.11	4.33	9.83	14.5	19.05	21.11	20.61	16.77	10.66	5.5	0.27
Tucker, West Virginia	10	-2.33	-0.66	3.61	9.83	14.77	19.27	21.55	20.94	17.05	10.72	5.22	-0.22

Table 2: Summary of mean precipitation (cm) across sampled counties in each region in the current study. Data are reproduced from 1981-2010 NCDC Station Normals (NCDC).

County	Ann.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Benton, Arkansas	119.6	6.62	6.73	10.92	10.84	14.52	12.16	8.45	8.5	11.96	9.11	11.07	8.66
Delaware, Oklahoma	121.08	6.55	6.88	10.69	11.17	13.38	12.11	8.02	9.32	12.47	11.2	10.51	8.73
McDonald, Missouri	110.92	5.18	5.48	8.73	10.49	14.07	12.21	8.45	8.05	11.63	9.11	10.18	7.28
Washington, Arkansas	115.64	6.47	6.07	10.21	10.92	13.2	12.11	8.17	7.74	11.58	10.41	10.99	7.72
Bedford, Virginia	114.5	8.61	7.46	8.78	9.85	10.66	11.12	11.25	9.98	10.18	9.16	8.38	9.09
Botetourt, Virginia	104.64	7.36	7.11	8.99	8.76	10.21	8.68	11.5	8.38	9.52	8.15	8.1	7.84
Giles, Virginia	99.33	7.36	6.93	8.71	8.5	10.76	9.42	10.38	8.22	7.84	6.73	7.21	7.21
Monongalia, West Virginia	106.24	7.13	6.6	9.27	8.94	11.7	10.43	11.73	9.01	8.15	7.06	8.78	7.39
Montgomery, Virginia	103.86	7.82	7.13	9.24	8.83	10.99	10.16	10.82	9.11	7.87	7.06	7.28	7.49
Pendleton, West Virginia	91.51	5.48	5.02	7.87	7.51	10.36	7.95	10.74	8.66	8.66	5.84	7.28	6.09
Randolph, West Virginia	116.66	8.2	7.87	10.05	9.65	13	11.17	13.61	9.75	9.22	7.23	8.58	8.28
Tucker, West Virginia	130.37	9.16	8.73	10.84	10.94	14.02	13.18	14.83	10.94	10.05	8.35	9.49	9.77

coolest month is January with a mean of -2.3C. Temperature data for the Appalachian counties are summarized in Table 1 (NOAA NCDC).

Mean annual precipitation for the counties sampled in the Appalachians is 108.4cm. Summer is the wettest season, with a mean precipitation of approximately 31.4cm. The driest season is winter with a mean precipitation of 22.6cm. Tucker County, West Virginia, receives the most annual precipitation, with a mean annual precipitation of 130.4cm. The wettest month is July, with a mean of 14.8cm, and the driest month is October with a mean of 8.4. The driest county sampled, was Pendleton County, West Virginia, with a mean of 91.5cm. The wettest month is July, with a mean of 10.7cm and the driest month is February with a mean of 5.0cm. Precipitation data for the Appalachians counties are summarized in Table 2 (NOAA NCDC).

Data Acquisition

Field data were collected during the late spring and early summer months (May, June, July, and August) of the 2013 and 2014 field seasons. Data collected in the Ozark Plateau during the 2013 field season were from Pea Ridge National Military Park (Benton County, Arkansas) and Devil’s Den State Park (Washington County, Arkansas) during the 2013 field season. Data were collected in Hobbs State Park (Benton County, Arkansas), on private property maintained by a master naturalist in Pineville, Missouri (McDonald, County; henceforth referred to as Pogue), and at Lake Eucha Park in Tulsa, Oklahoma (Delaware, County; henceforth referred to as Eucha). A total of 50 sites were sampled in the Ozark Plateau in 2013 (15 *Lespedeza cuneata*, 13 *Lonicera japonica*, 12 *Microstegium vimineum*, and 10 *Rosa multiflora*) and 53 in 2014 (13 *Alliaria petiolata*, 9 *Lespedeza cuneata*, 10 *Lonicera japonica*, 11 *Microstegium vimineum*, and 10 *Rosa multiflora*). *Alliaria petiolata* was not sampled in the Ozark Plateau in 2013.

Data collected in the Appalachians during the 2013 field season were collected from the Fernow Experimental Forest (Tucker County, West Virginia), Monongahela National Forest (Randolph County, West Virginia), private land in Morgantown, West Virginia (Monogalia, County), and roadsides located in Pendleton and Monogalia Counties, West Virginia. In 2014, data were collected at the Claytor Nature Center (Bedford Country, Virginia; henceforth referred to as Claytor), atop the Blue Ridge Parkway (Botetourt County, Virginia), at the Mountain Lake Biological Station (Giles County, Virginia; henceforth referred to as MLBS), and at Pandapas Pond (Montgomery County, Virginia). A total of 55 sites were sampled during the 2013 field season (20 *Alliaria petiolata*, 2 *Lespedeza cuneata*, 6 *Lonicera japonica*, 10 *Microstegium vimineum*, and 17 *Rosa multiflora*) and 63 sites during the 2014 field season (12 *Alliaria petiolata*, 8 *Lespedeza cuneata*, 13 *Lonicera japonica*, 19 *Microstegium vimineum*, and 11 *Rosa multiflora*).

Study sites were located by hiking along trails, forest edges, or driving roads and were selected on the basis of the target species being present and the immediate surrounding topography being relatively homogenous. Some sites contained multiple target species and these were sampled together. For the purposes of this study, each site was considered a separate colony and colonies that occurred more than 10 m apart and/or separated by a nature or anthropogenic barrier (e.g., stream or road) were considered separate from each other and sampled independently. For instances in which colonies were too expansive (e.g., microstegium forming "carpets" under the canopy), a sub-colony was selected for study based off uniform topography. No uniform area was used for determining sub-colonies.

Environmental Predictor Variables

For each colony, the approximate mid-point was located to serve as the midpoint for a 3 m radius circle for data collection. Collection points for obtaining data on the environmental variables were haphazardly chosen to the left, right, and near the midpoint of the 3 m radius circle. Associated species were identified from up to 5 m away of the midpoint. Species that were not identified in the field were collected, pressed, and identified at a later date. GPS coordinates were obtained for the colony's general location as well as the colony's boundaries using a Garmin etrex handheld unit. Elevation was obtained using the same device.

Stems were counted for each of the target species by determining the visible number of stems arising from the ground throughout the colony. For colonies in which stem count was too prolific, a standard area (e.g., a standard clipboard) was used to count the stems and later extrapolation of stem count for the colony was carried out for the area of the colony based off the colony's boundaries as determined using GIS software (ArcGIS, esri). In some instances, *in situ* extrapolation was conducted.

Distance to disturbance was measured from midpoint of the colony to the nearest disturbance (e.g., mowed edge of road). Certain sites had multiple disturbances and each was measured separately and then averaged together to obtain this measurement. The type of disturbance was also classified. Soil moisture and soil pH were measured with the use of a Kelway Soil Tester (Kelway Instruments Company). For many sites, soil moisture and pH measurements were unobtainable due to the soil being too dry and/or too rocky to safely operate the device. For certain sites, a supplemental pH soil sample was haphazardly taken from three locations within the 3 meter circle and pH measured in lab. These sample were processed in a 2mm sieve and then mixed with distilled water in a 50:50 soil water slurry before testing. Light intensity was measured with a digital lux meter (Dr. Meter). The three “inside” light intensity readings were averaged together. One additional light intensity reading was taken outside the colony from the nearest location with no canopy cover (100% light intensity to the ground). To generate a light intensity variable for the colony, the averaged light intensity reading was divided by the outside reading.

Slope was recorded facing the colony using a clinometer. Aspect was recorded facing the colony using a standard compass. Slope and aspect were taken using the midpoint of the colony as reference.

Bare soil (the presence of top soil without anything else), rock, woody debris, leaf litter, bryophytes, herbaceous plant cover, woody plant cover (regardless of growth habit), and notable disturbance were all estimated with the Daubenmire cover class ranking system (Daubenmire, 1959).

Soil samples were collected for certain sites by combining an aggregate of collected soil based of the same sampling method (left, right, and midpoint). Soil was air-dried on newspaper and processed through a 2mm sieve at a later date and sent to Brookside Laboratories (New Bremen, Ohio) for testing. Selection of sites chosen for soil sample collection was done haphazardly. No soils data was collected for garlic mustard in the Ozarks.

Data Analysis

For species that had larger sample sizes and more intact datasets ($n \geq 15$), a multiple regression model was constructed using the environmental variables sampled (elevation, distance to disturbance, soil moisture, soil pH, light ratio, slope, and aspect) using stem count as the response variable. For Ozark colonies of garlic mustard and lespedeza, a sample size cut off of $N = 13$ was used because of the condition of the dataset. Variables that had a high correlation with each other ($r \geq 0.70$, $r \leq - 0.70$) were not be used in the model because of the likelihood of the variable predicting similar phenomena.

Variables were removed from the global model based off the largest p value until the model was either significant or had three variables in the model. For species that had smaller sample sizes and less intact data (e.g., missing soil moisture) a series of simple linear regressions were conducted across the same response variables, using stem count as the predictor variable. Species data was also pooled together to generate a combined ecological dataset to analyze the microhabitat across both regions.

Daubenmire cover class results were converted to their respective cover percentage midpoints and results were analyzed with one-way ANOVA using species as treatments to check for significant differences among habitat characteristics. Tukey's HSD tests were run after each ANOVA to determine significant species groupings. Soil data was combined across the two ecoregions to generate sufficient sample sizes to construct multiple regression models ($N \geq 10$) using the following predictor variables, organic matter (OM), estimated N release (N/acre), S (ppm), P (mg/kg), Ca (mg/kg), Mg (mg/kg), K (mg/kg), and NA (mg/kg). These models were constructed the same way as the environmental models.

Test assumptions were checked graphically and data were transformed to better fit the normality assumption of the statistical tests (Tables 3 and 4). Data points were excluded from analysis if GIS extrapolation resulted in unreasonable sample areas or stem counts and/or missing data prevented inclusion in analysis. The data were analyzed in JMP Pro 11.2 (SAS Institute Inc.)

Results

Environmental Regression Models

Alliaria petiolata

For the Ozark colonies of garlic mustard, soil pH and slope were removed as predictors because of their colinearity with other variables (Table 5). The resulting model predicting garlic mustard colony stem count was not significant (R^2 = 0.109, F ratio = 0.370, p value = 0.776, AICc = 15.28, N = 13). The predictors included in this model were elevation (est. = -1.091, p value = 0.441), light ratio (est. = 0.299, p value = 0.579), and distance to disturbance (est. = 0.348, p value = 0.461).

No predictor variables were removed due to colinearity for the Appalachians colonies of garlic mustard (Table 6). The resulting model predicting colony stem count approached significance (R^2 = 0.228, F ratio = 2.757, p value = 0.061, AICc = 38.89, N = 32). The model included elevation (est. <-0.001, p value = 0.019), light ratio (est. = 0.053, p value = 0.784), and slope (est. -0.03, p value = 0.474).

No predictors were removed from the combined ecological model (Table 7). The ecological model was significant (R^2 = 0.286, F ratio = 2.65, p value = 0.04, AICc = 48.4, N = 39). Predictors included in this model were elevation (est. = -1.28, p value = 0.04), light ratio (est. = 0.09, p value = 0.66), aspect (est. <-0.01, p value = 0.63), pH (est. = 0.14, p value = 0.45), and distance to disturbance (est. = 0.07, p value = 0.73). All three models are summarized in Table 8.

Lespedeza cuneata

Soil moisture was removed as a predictor variable from use in the model (Table 9). The Ozark model was significant (R^2 = 0.78, F ratio = 5.24, p value = 0.02, AICc = 38.46, N = 13,

Table 3: Data transformations used for each predictor variable. Transformations were used to make the data better fit the normality assumption of the statistical tests. Daubenmire cover class data was not transformed.

Region	Predictor	Transformation Used
Ozarks	Elevation	Log 10
	Soil Moisture	Arc Sine
	Soil pH	Log 10
	Light Ratio	2nd Root of Arc Sine
	Slope	Log 10
	Aspect	None
	Distance to Disturbance	Log 10
Appalachians	Elevation	None
	Soil Moisture	None
	Soil pH	Log 10
	Light Ratio	Arc Sine
	Slope	2nd Root
	Aspect	None
	Distance to Disturbance	Log 10
Combined Ecological	Elevation	4th Root then 2nd Root
	Soil Moisture	None
	Soil pH	None
	Light Ratio	Arc Sine
	Slope	4th Root
	Aspect	2nd Root
	Distance to Disturbance	Log 10

Table 4: Data transformations used for each soil predictor variable. Transformations were used to make the data better fit the normality assumption of the statistical tests.

Predictor	Transformation Used
Organic Matter (OM)	2nd root
N	none
S	log 10
P	4th root
CA	2nd root
MG	log 10
K	log 10
NA	4th root

Table 5: Correlation matrix examining for colinearity among predictor variables for Ozark colonies of garlic mustard. Soil pH and Slope were removed from analysis because of colinearity.

	Elevation Log10	Soil Moisture ArcSine	Soil pH log10	Light Ratio 2nd root of Arcsine	Slope Log10	Aspect	Distance Log10
Elevation Log10	1.0000	0.2034	-0.1569	0.0060	0.2539	-0.2007	0.6600
Soil Moisture ArcSine	0.2034	1.0000	-0.8944	0.2783	0.7803	-0.2033	0.2492
Soil pH log10	-0.1569	-0.8944	1.0000	-0.2145	-0.8894	0.3895	-0.1115
Light Ratio 2nd root of Arcsine	0.0060	0.2783	-0.2145	1.0000	0.2588	-0.2740	0.0302
Slope Log10	0.2539	0.7803	-0.8894	0.2588	1.0000	-0.4774	0.4156
Aspect	-0.2007	-0.2033	0.3895	-0.2740	-0.4774	1.0000	0.0123
Distance Log10	0.6600	0.2492	-0.1115	0.0302	0.4156	0.0123	1.0000

Table 6: Correlation matrix examining for colinearity among predictor variables for Appalachian colonies of garlic mustard. No predictors were removed for analysis.

	Elevation	Soil Moisture	Soil pH log 10	Light Ratio ArcSine	Slope 2nd root	Aspect	Distance Log10
Elevation	1.0000	0.0658	-0.2206	0.0958	0.2739	0.1541	-0.3739
Soil Moisture	0.0658	1.0000	-0.5781	-0.3731	0.2802	0.0400	0.1742
Soil pH log 10	-0.2206	-0.5781	1.0000	0.1915	-0.2692	0.1573	-0.0889
Light Ratio ArcSine	0.0958	-0.3731	0.1915	1.0000	0.0006	-0.3390	0.0867
Slope 2nd root	0.2739	0.2802	-0.2692	0.0006	1.0000	-0.0369	-0.2635
Aspect	0.1541	0.0400	0.1573	-0.3390	-0.0369	1.0000	-0.0521
Distance Log10	-0.3739	0.1742	-0.0889	0.0867	-0.2635	-0.0521	1.0000

Table 7: Correlation matrix examining for colinearity among predictor variables for the combined ecological model for garlic mustard. No predictors were removed for analysis

	Elevation 4thRoot then 2ndRoot	Soil Moisture	pH	Light Ratio ArcSine	Slope 4th Root	Aspect 2nd Root	Distance Log10
Elevation 4thRoot then 2ndRoot	1.0000	0.1386	-0.3756	0.2592	0.1992	0.1030	-0.4145
Soil Moisture	0.1386	1.0000	-0.6215	-0.2280	0.3488	0.0471	0.0983
pH	-0.3756	-0.6215	1.0000	0.0404	-0.3736	0.1418	0.0424
Light Ratio ArcSine	0.2592	-0.2280	0.0404	1.0000	0.1064	-0.2570	-0.0337
Slope 4th Root	0.1992	0.3488	-0.3736	0.1064	1.0000	0.0075	-0.0862
Aspect 2nd Root	0.1030	0.0471	0.1418	-0.2570	0.0075	1.0000	0.0203
Distance Log10	-0.4145	0.0983	0.0424	-0.0337	-0.0862	0.0203	1.0000

Table 8: Multiple regression models for Ozark and Appalachian colonies of garlic mustard as well as the combined ecological model. A multiple regression model was constructed for the Ozark colonies with low sample size because data was only collected during one summer and the sample size was suitable for modelling.

Model	Predictors	R^2	F ratio	p value	AICc	N
Ozarks	elevation, light ratio, distance to disturbance	0.109	0.370	0.776	15.28	13
Appalachians	elevation, light ration, slope	0.228	2.757	0.061	38.89	32
Combined Ecological	elevation, light ratio, aspect, pH, distance to disturbance	0.286	2.65	0.04	48.4	39

Table 10) at predicting colony stem count. Predictor variables included were elevation (est. = 0.66, p value = 0.70), soil pH (est. = 15.95, p value = 0.05), light ratio (est. = 1.30, p value = 0.02), slope (est. = -0.39, p value = 0.25), distance to disturbance (est. = -0.24, p value = 0.07).

Simple linear regressions were run on the Appalachian colonies due to low sample size. No regression was significant (Table 11); however, light ratio, aspect, and distance to disturbance were approaching significance. Light ratio had a positive relationship with stem count (R^2 = 0.30, est. = 1.27, F ratio = 3.08, p value = 0.12, N = 9, Figure 16). Aspect had a positive relationship with colony stem count (R^2 = 0.35, est. < 0.01, F ratio = 3.81, p value = 0.09, N = 9, Figure 17). Distance to disturbance also had a positive relationship with colony stem count (R^2 = 0.43, est. = 0.93, F ratio = 3.82, p value = 0.10, N = 7, Figure 18).

Simple linear regressions were also run for the combined ecological model due to missing soil moisture and soil pH data, which removed a large portion of data points from the multiple regression model. None of the regressions were significant; however, slope, aspect, pH, and distance to disturbance approached significance (Table 12). Slope had a negative relationship with colony stem count (R^2 = 0.07, est. = -0.56, F ratio = 2.55, p value = 0.12, N = 33, Figure 19). Aspect had a positive relationship with colony stem count (R^2 = 0.07, est. = 0.05, F ratio = 2.38, p value = 0.13, N = 33, Figure 20). pH had a positive relationship with stem count (R^2 = 0.20, est. = 1.12, F ratio = 4.26, p value = 0.05, N = 19, Figure 21). Distance to disturbance also had a positive relationship with stem count (R^2 = 0.08, est. = 0.86, F ratio = 2.37, p value = 0.13, N = 28, Figure 22).

Lonicera japonica

Table 9: Correlation matrix examining for colinearity among predictor variables for Ozark colonies of lespedeza. Soil moisture was removed from analysis because of colinearity.

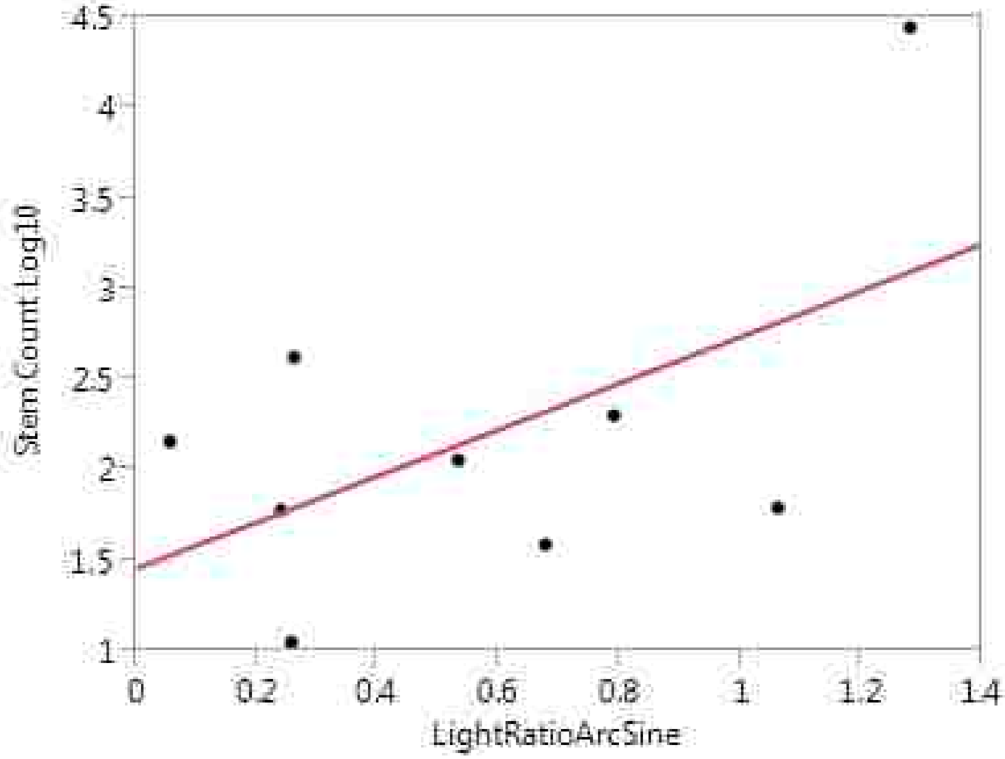
	Elevation Log10	Soil Moisture ArcSine	Soil pH log10	Light Ratio 2nd root of Arcsine	Slope Log10	Aspect	Distance Log10
Elevation Log10	1.0000	-0.7439	0.5648	0.1010	-0.1379	0.5503	-0.1384
Soil Moisture ArcSine	-0.7439	1.0000	-0.6117	0.0333	0.1133	0.0519	0.0340
Soil pH log10	0.5648	-0.6117	1.0000	-0.3205	-0.4066	-0.0798	-0.1107
Light Ratio 2nd root of Arcsine	0.1010	0.0333	-0.3205	1.0000	-0.1181	0.0426	0.0950
Slope Log10	-0.1379	0.1133	-0.4066	-0.1181	1.0000	0.1357	0.2536
Aspect	0.5503	0.0519	-0.0798	0.0426	0.1357	1.0000	-0.1529
Distance Log10	-0.1384	0.0340	-0.1107	0.0950	0.2536	-0.1529	1.0000

Table 10: The multiple regression model for Ozark colonies of lespedeza. A multiple regression model was constructed for the Ozark colonies with low sample size because of large amounts of missing data from the second field season and the remaining data was sufficient to construct a model.

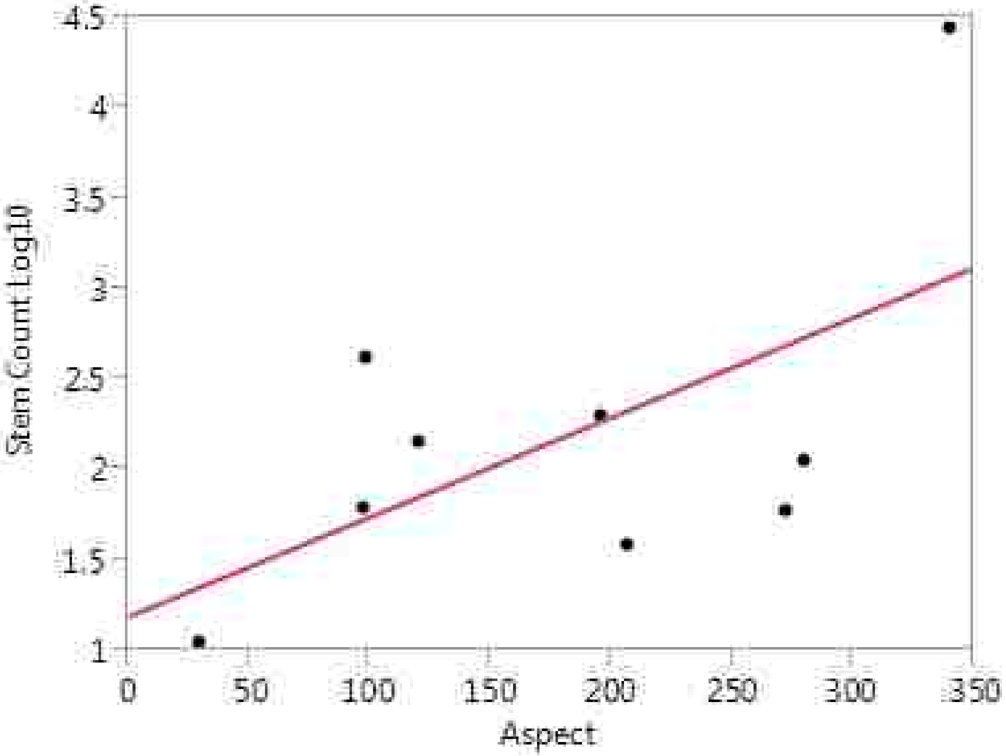
Model	Predictors	R^2	F ratio	p value	AICc	N
Ozarks	elevation, soil pH, light ratio, slope, distance to disturbance	0.78	5.24	0.02	38.46	13

Table 11: Results of multiple simple linear regressions of each predictor variable for the Appalachian lespedeza colonies.

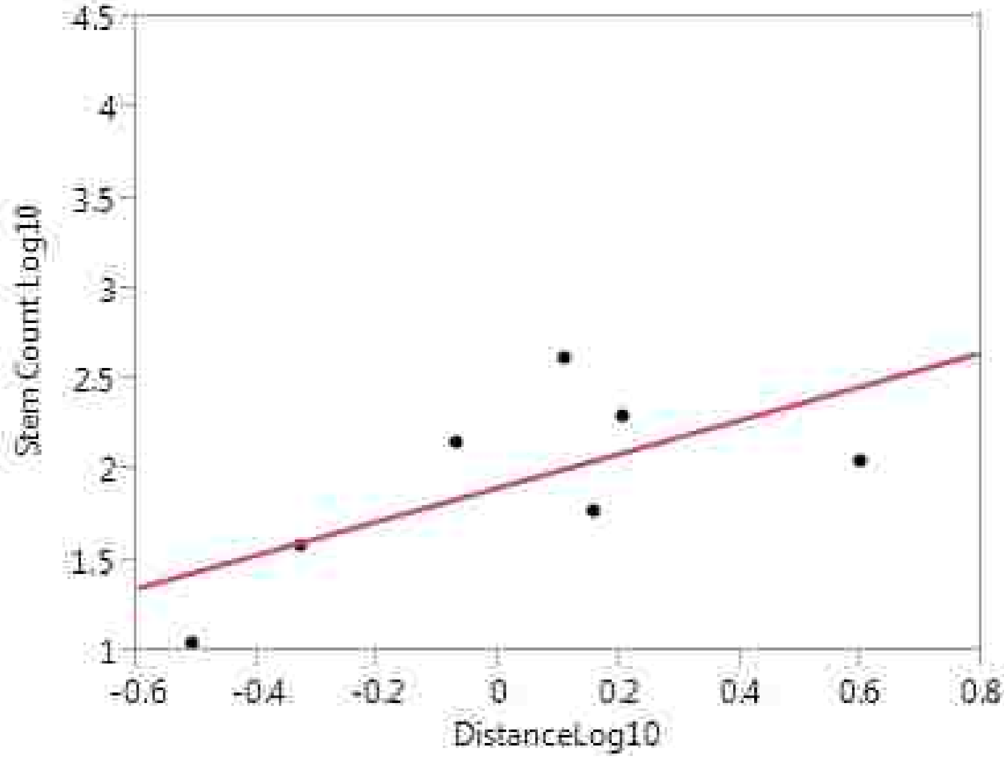
Region	Predictor	R^2	Estimate	F ratio	p value	N
Appalachian	elevation	< 0.01	< -0.01	< 0.01	0.93	8
Appalachian	light ratio	0.30	1.27	30.8	0.12	9
Appalachian	slope	0.02	-0.07	0.15	0.70	9
Appalachian	aspect	0.35	< 0.01	3.81	0.09	9
Appalachian	soil pH	0.01	1.89	0.05	0.82	5
Appalachian	soil moisture	0.16	0.02	0.58	0.50	5
Appalachian	distance to disturbance	0.43	0.93	3.82	0.10	7


4.5
4
3.5
3
2.5
2
1.5
1
Stem Count Log10
0
0.2
0.4
0.6
0.8
1
1.2
1.4
LightRatioArcSine

[redacted]


4.5
4
3.5
3
2.5
2
1.5
1
Stem Count Log10
0
50
100
150
200
250
300
350
Aspect

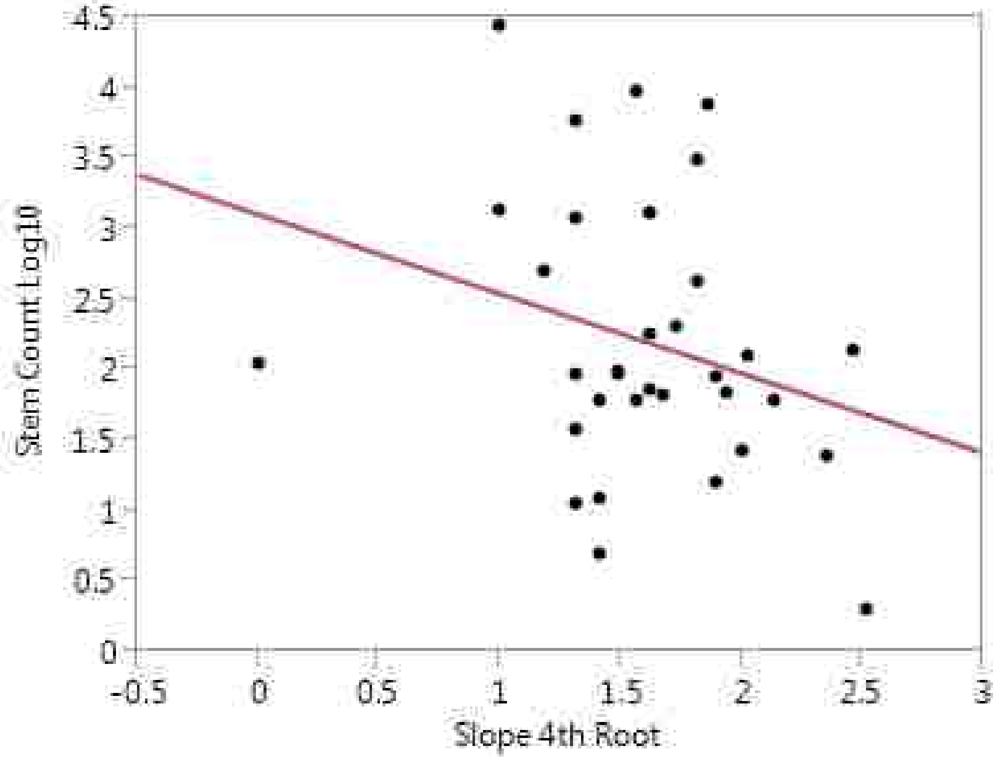
[redacted]


4.5
4
3.5
3
2.5
2
1.5
1
Stem Count Log10
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
DistanceLog10

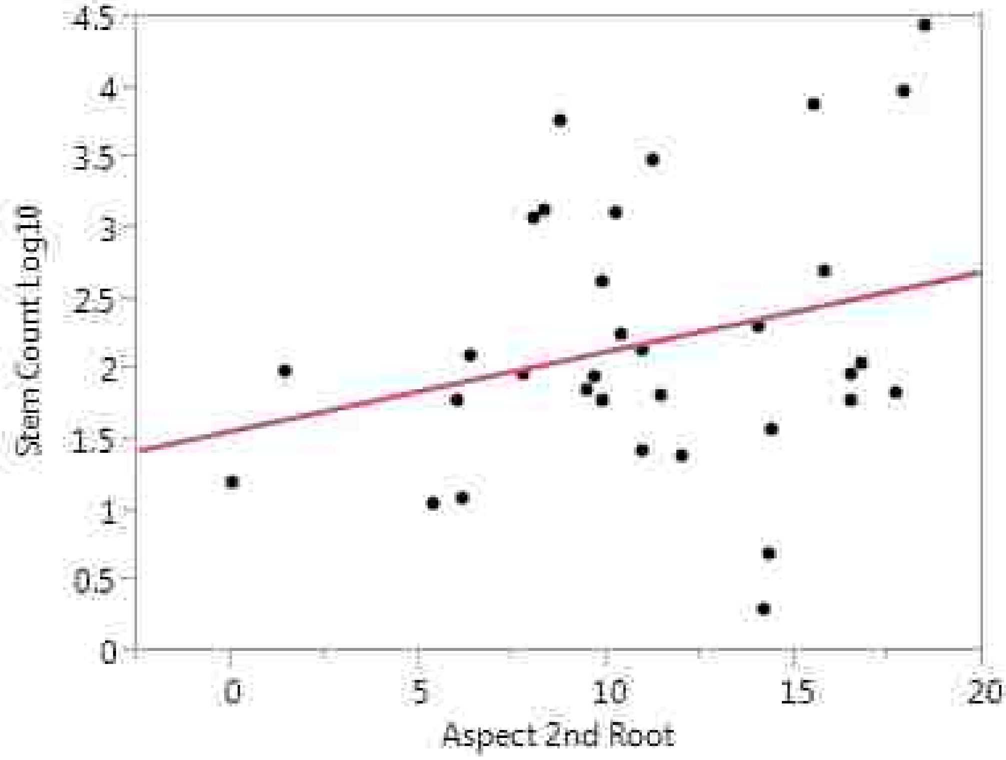
[redacted]

Table 12: Results of multiple simple linear regressions of each predictor variable for the combined ecological lespedeza colonies.

Region	Predictor	R^2	Estimate	F ratio	p value	N
Combined Ecological	elevation	0.01	1.39	0.41	0.52	31
Combined Ecological	light ratio	0.03	0.44	1.23	0.27	32
Combined Ecological	slope	0.07	-0.56	2.55	0.12	33
Combined Ecological	aspect	0.07	0.05	2.38	0.13	33
Combined Ecological	soil pH	0.20	1.12	4.26	0.054	19
Combined Ecological	soil moisture	0.01	< -0.01	0.22	0.64	14
Combined Ecological	distance to disturbance	0.08	0.86	2.37	0.13	28


Stem Count Log10
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
0
0.5
1
1.5
2
2.5
3
Slope 4th Root

[redacted]


Stem Count Log10
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
Aspect 2nd Root

[redacted]

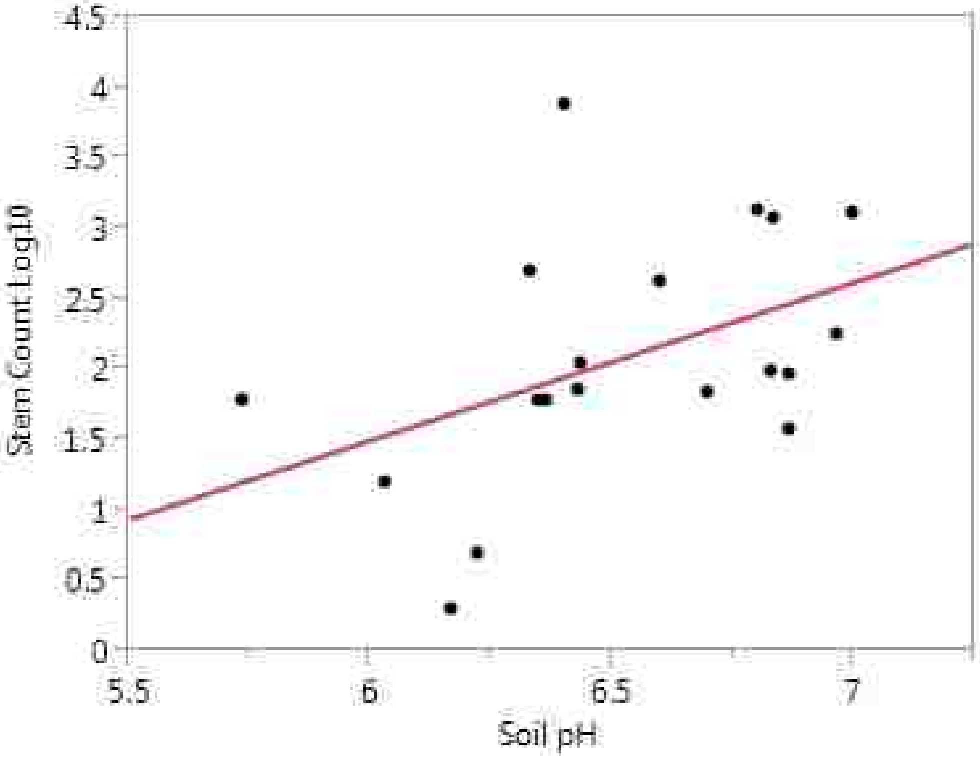
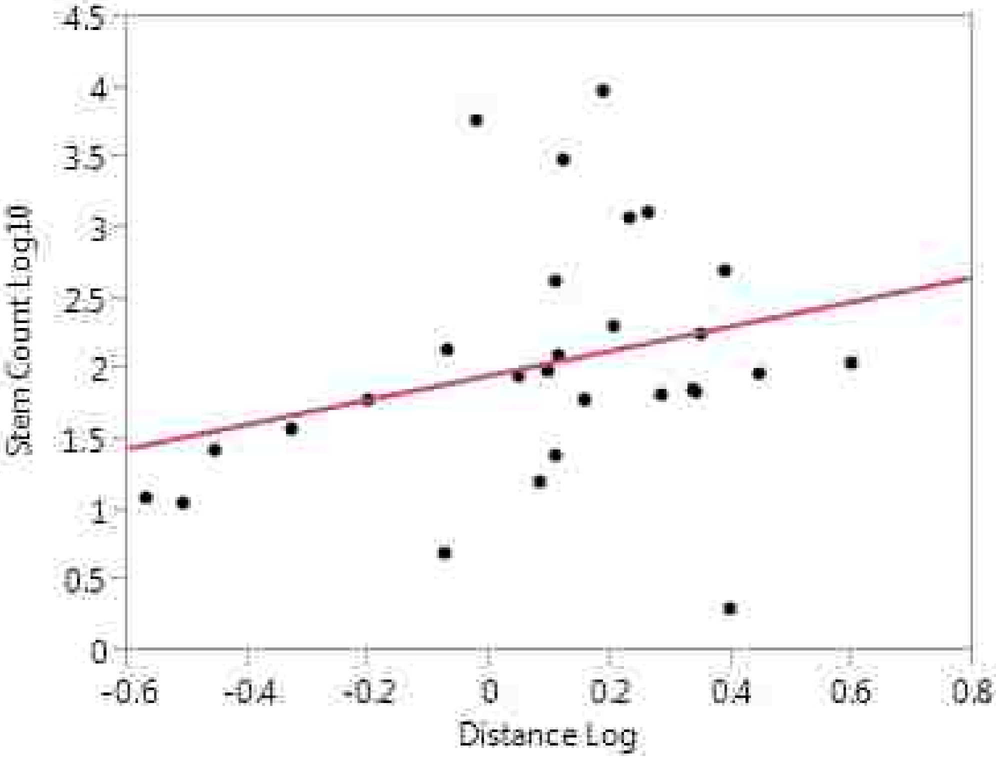


Figure 21: Simple linear regression of colony stem count predicted by soil pH for the combined ecological lespedeza colonies. The regression was approaching significance (R^2 = 0.20, est. = 1.12, F ratio = 4.26, p value = 0.054, N = 19***).***


Stem Count Log10
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Distance Log

[redacted]

Simple linear regressions were run for Ozark colonies of honeysuckle due to low sample size because the removal of sites with missing soil moisture and soil pH data. No regression was significant at predicting colony stem count (Table 13); however, soil moisture and distance to disturbance approached significance. Soil moisture had a positive relationship with stem count (R^2 = 0.26, est. = 2.81, F ratio = 3.99, p value = 0.07, N = 13, Figure 23). Distance to disturbance had a negative relationship with colony stem count (R^2 = 0.15, est. = -0.78, F ratio = 3.62, p value = 0.07, N = 22, Figure 24).

Appalachian honeysuckle sample size was sufficient to generate a regression model and pH was removed as a predictor variable because of colinearity (Table 14). The model was not significant (R^2 = 0.15, F ratio = 0.72, p value = 0.55, AICc = 61.9, N = 16) and included elevation (est. < 0.01, p value = 0.59), slope (est. = 0.17, p value = 0.44), and distance to disturbance (est. = 0.17, p value = 0.29) (Table 16).

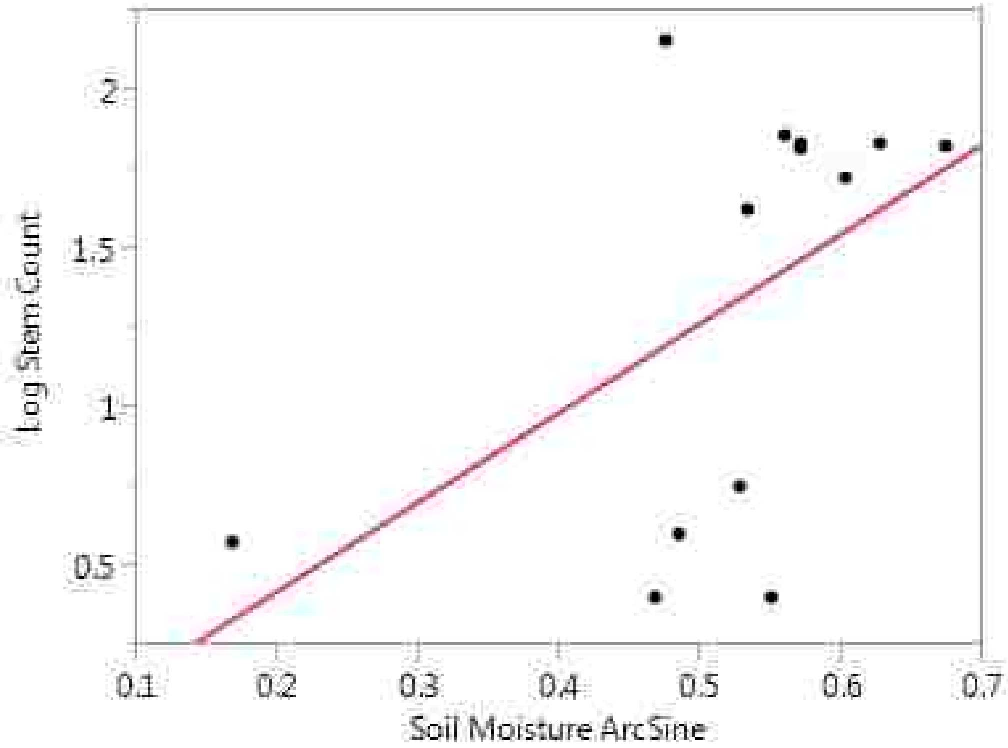
No predictor was removed because of colinearity in the combined ecological model (Table 15), and the model was significant (R^2 = 0.35, F ratio = 2.98, p value = 0.04, AICc = 89.2, N = 27, Table 16) and included elevation, light ratio, soil moisture, and soil pH as predictor variables. Light ratio was the only significant predictor included in the model (est. = 1.70, p value = 0.01), but elevation (est. = -6.30, p value = 0.06) and soil moisture (est. = 0.03, p value = 0.07) were approaching significance. The Appalachian and combined models are summarized in Table 16.

Microstegium vimineum

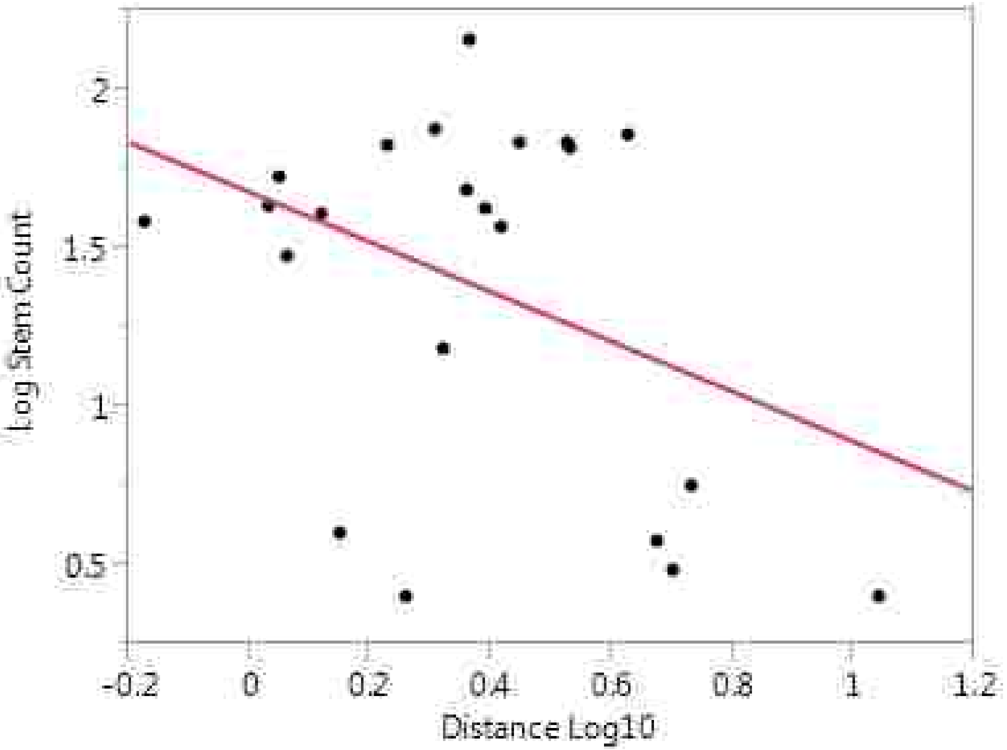
Simple linear regressions were run for Ozark colonies of microstegium because of missing soil moisture and soil pH data. Of the resulting regressions, none were significant (Table 17).

Table 13: Results of multiple simple linear regressions of each predictor variable for the Ozark honeysuckle colonies.

Region	Predictor	R^2	Estimate	F ratio	p value	N
Ozarks	elevation	0.016	-0.09	0.32	0.57	21
Ozarks	light ratio	0.07	0.51	1.51	0.23	22
Ozarks	slope	< 0.01	0.03	0.01	0.90	22
Ozarks	aspect	< 0.01	< -0.01	0.01	0.90	23
Ozarks	soil pH	0.01	-2.8	0.16	0.69	16
Ozarks	soil moisture	0.26	2.81	3.99	0.07	13
Ozarks	distance to disturbance	0.15	-0.78	3.62	0.07	22


Log Stem Count
2
1.5
1
0.5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Soil Moisture ArcSine

[redacted]



[redacted]

Table 14: Correlation matrix examining for colinearity among predictor variables for Appalachian colonies of honeysuckle. Soil pH was removed from analysis because of colinearity.

	Elevation	Soil Moisture	Soil pH log 10	Light Ratio ArcSine	Slope 2nd root	Aspect	Distance Log10
Elevation	1.0000	0.4331	-0.3047	0.2162	0.0550	0.1413	-0.1375
Soil Moisture	0.4331	1.0000	-0.7833	-0.4152	0.3431	-0.0780	0.3136
Soil pH log 10	-0.3047	-0.7833	1.0000	0.5184	-0.4208	0.1199	-0.1898
Light Ratio ArcSine	0.2162	-0.4152	0.5184	1.0000	-0.3841	-0.3518	-0.0239
Slope 2nd root	0.0550	0.3431	-0.4208	-0.3841	1.0000	0.0617	0.1504
Aspect	0.1413	-0.0780	0.1199	-0.3518	0.0617	1.0000	0.0034
Distance Log10	-0.1375	0.3136	-0.1898	-0.0239	0.1504	0.0034	1.0000

Table 15: Correlation matrix examining for colinearity among predictor variables for the combined ecological colonies of honeysuckle. No predictors were removed.

	Elevation 4thRoot then 2ndRoot	Soil Moisture	Soil pH	Light Ratio ArcSine	Slope 4th Root	Aspect 2nd Root	Distance Log
Elevation 4thRoot then 2ndRoot	1.0000	0.1318	-0.3883	0.2901	-0.0526	0.0525	0.0844
Soil Moisture	0.1318	1.0000	-0.5632	-0.0440	0.0820	-0.2402	-0.0199
pH	-0.3883	-0.5632	1.0000	-0.0293	-0.0962	0.2888	-0.0405
Light Ratio ArcSine	0.2901	-0.0440	-0.0293	1.0000	-0.1394	-0.1273	0.1133
Slope 4th Root	-0.0526	0.0820	-0.0962	-0.1394	1.0000	0.0919	-0.1636
Aspect 2nd Root	0.0525	-0.2402	0.2888	-0.1273	0.0919	1.0000	-0.0139
Distance Log	0.0844	-0.0199	-0.0405	0.1133	-0.1636	-0.0139	1.0000

Table 16: The multiple regression models for Appalachian and combined ecological colonies of honeysuckle.

Model	Predictors	R^2	F ratio	p value	AICc	N
Appalachian	elevation, slope, distance to disturbance	0.15	0.72	0.55	61.9	16
Combined Ecological	elevation, light ratio, soil moisture, soil pH	0.35	2.98	0.04	89.2	27

Soil moisture had a negative relationship with colony stem count and approached significance (R^2 = 0.21, est. = -1.70, F ratio = 2.71, p value = 0.13, N = 12, Figure 25).

No predictors needed to be removed from the Appalachians model due to colinearity (Table 18) and the model was significant (R^2 = 0.67, F ratio = 4.23, p value = 0.01, AICc = 50.9, N = 22). The resulting model was a global model and included all of the predictor variables, but only aspect (est. < 0.01, p value < 0.01) and distance to disturbance (est. = 0.97, p value = 0.01) were significant, although elevation (est. < 0.01, p value = 0.15) approached significance (Table 20).

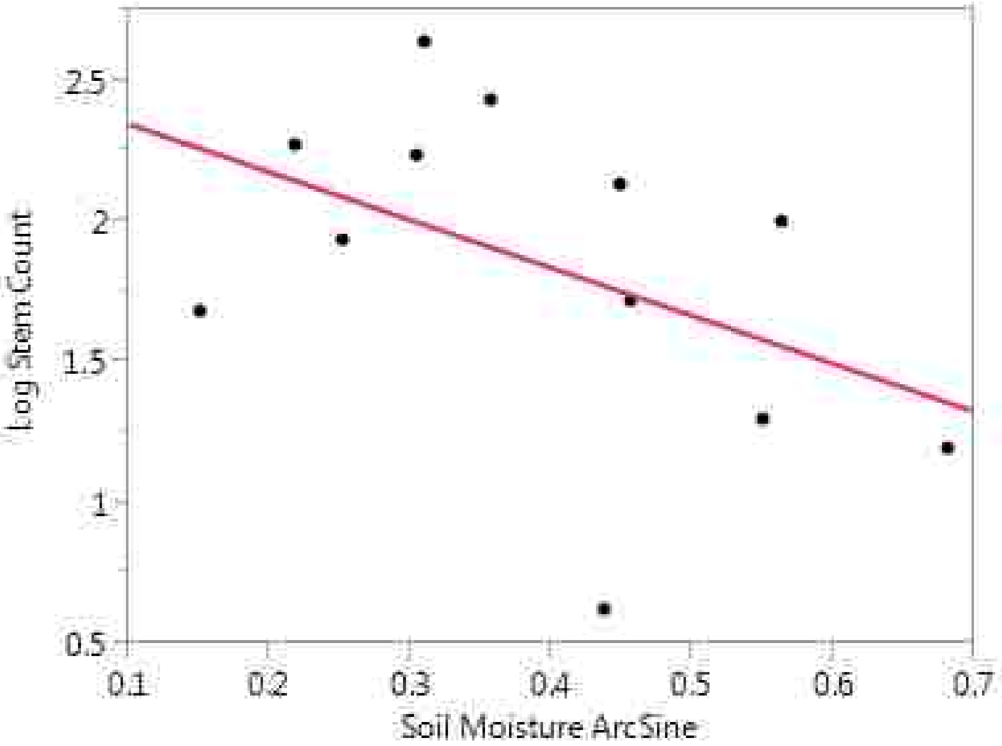
No predictors were removed from the combined ecological model (Table 19). The resulting model was borderline significant (R^2 = 0.18, F ratio = 2.85, p value = 0.05, AICc = 102.5, N = 41). Elevation (est. = 1.67, p value = 0.08), aspect (est. = 0.03, p value = 0.13), and distance to disturbance (est. = 0.43, p value = 0.15) were included in the model and approached significance. The Appalachian and combined models are summarized in Table 20.

Rosa multiflora

For the Ozark colonies, a series of simple linear regression were run because of missing soil moisture and soil pH data for many colonies. Two regressions were significant at predicting colony stem count, slope and distance to disturbance while elevation was approached significance (Table 21). Slope had a negative relationship with colony stem count (R^2 = 0.31, est. = -0.20, F ratio = 6.96, p value = 0.01, N = 17, Figure 26). Distance to disturbance (R^2 = 0.27, est. = 0.22, F ratio = 6.34, p value = 0.02, N = 19, Figure 27) and elevation (R^2 = 0.10, est. = 0.44, F ratio = 2.02, p value = 0.17, N = 20, Figure 28) both had positive relationships with colony stem count.

Table 17: Results of multiple simple linear regressions of each predictor variable for the Ozark microstegium colonies.

Region	Predictor	R^2	Estimate	F ratio	p value	N
Ozarks	elevation	0.03	-2.60	0.50	0.48	17
Ozarks	light ratio	0.05	0.40	0.96	0.34	19
Ozarks	slope	0.01	0.14	0.21	0.64	17
Ozarks	aspect	0.04	< -0.01	0.86	0.36	19
Ozarks	soil pH	0.10	7.32	1.53	0.23	15
Ozarks	soil moisture	0.21	-1.70	2.71	0.13	12
Ozarks	distance to disturbance	0.03	-0.14	0.66	0.42	19



log Stem Count
2.5
2
1.5
1
0.5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Soil Moisture ArcSine

[redacted]

Table 18: Correlation matrix examining for colinearity among predictor variables for Appalachian colonies of microstegium. No predictors were removed.

	Elevation	Soil Moisture	Soil pH log 10	Light Ratio ArcSine	Slope 2nd root	Aspect	Distance Log10
Elevation	1.0000	0.1249	-0.0886	0.4676	-0.4873	0.1793	-0.2703
Soil Moisture	0.1249	1.0000	-0.3882	-0.2297	-0.2789	-0.0583	0.2787
Soil pH log 10	-0.0886	-0.3882	1.0000	0.0743	-0.0358	-0.1667	-0.0742
Light Ratio ArcSine	0.4676	-0.2297	0.0743	1.0000	-0.3736	-0.0002	-0.1628
Slope 2nd root	-0.4873	-0.2789	-0.0358	-0.3736	1.0000	0.0089	-0.1580
Aspect	0.1793	-0.0583	-0.1667	-0.0002	0.0089	1.0000	-0.0063
Distance Log10	-0.2703	0.2787	-0.0742	-0.1628	-0.1580	-0.0063	1.0000

Table 19: Correlation matrix examining for colinearity among predictor variables for the combined ecological colonies of microstegium. No predictors were removed.

	Elevation 4thRoot then 2ndRoot	Soil Moisture	Soil pH	Light Ratio ArcSine	Slope 4th Root	Aspect 2nd Root	Distance Log10
Elevation 4thRoot then 2ndRoot	1.0000	0.2221	-0.1716	0.4738	-0.2168	0.1473	-0.1323
Soil Moisture	0.2221	1.0000	-0.6296	-0.0634	0.0213	-0.0955	0.3859
Soil pH	-0.1716	-0.6296	1.0000	-0.0513	-0.0637	-0.0470	-0.2668
Light Ratio ArcSine	0.4738	-0.0634	-0.0513	1.0000	-0.2079	-0.0076	-0.0342
Slope 4th Root	-0.2168	0.0213	-0.0637	-0.2079	1.0000	0.0525	0.1381
Aspect 2nd Root	0.1473	-0.0955	-0.0470	-0.0076	0.0525	1.0000	0.0609
Distance Log10	-0.1323	0.3859	-0.2668	-0.0342	0.1381	0.0609	1.0000

Table 20: The multiple regression models for Appalachian and combined ecological colonies of microstegium.

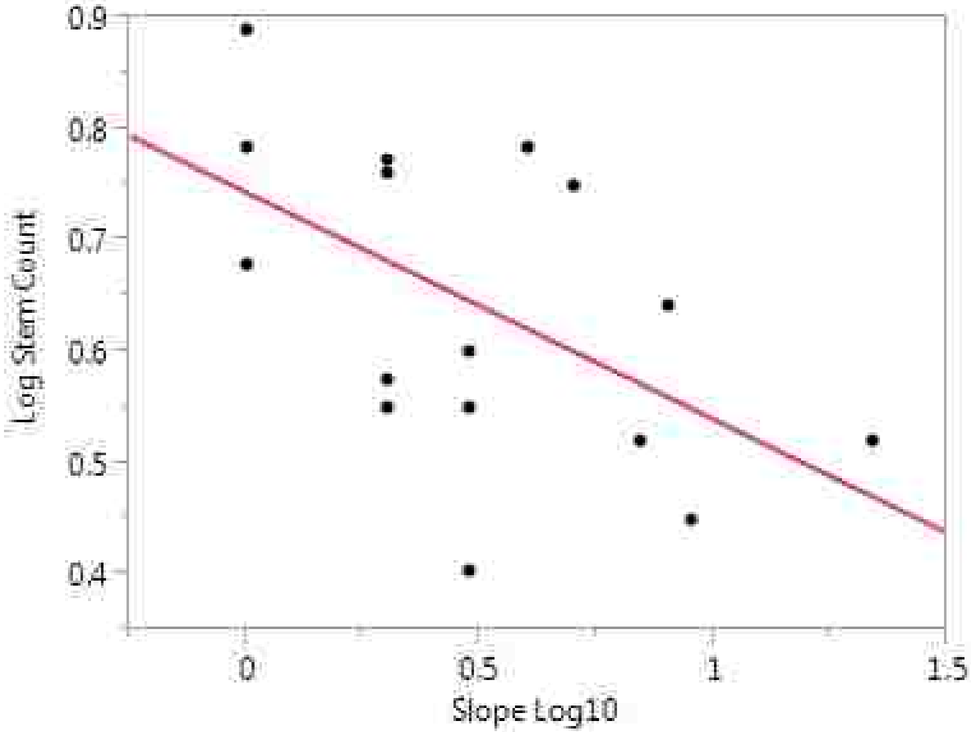
Model	Predictors	R^2	F ratio	p value	AICc	N
Appalachian	global	0.67	4.23	0.01	50.9	22
Combined Ecological	elevation, aspect, distance to disturbance	0.18	2.85	0.05	102.56	41

The Appalachian data set was more intact and allowed for a multiple regression model to be constructed and no predictors were removed because of colinearity (Table 22). The resulting model was not significant; however it approached significance (R^2 = 0.29, F ratio = 2.61, p value = 0.08, AICc = 17.02, N = 23) and included aspect, soil moisture, and distance to disturbance (Table 24). None of the predictors in the model were significant; however, aspect (est. < -0.01, p value = 0.11) and distance to disturbance (est. = 0.28, p value = 0.07) approached significance.

No predictors were removed from the combined model for colinearity and the resulting model was not significant, but approached significance (R^2 = 0.23, F ratio = 2.82, p value = 0.057, AICc = 14.7, N = 31) and included aspect, soil moisture, and distance to disturbance as predictor variables (Table 23). Distance to disturbance was significant in the model (est. = 0.26, p value = 0.04), while aspect and soil moisture were not significant. Both the Appalachian and combined multiple regression models are summarized in Table 24.

Table 21: Results of multiple simple linear regressions of each predictor variable for the Ozark multiflora colonies.

Region	Predictor	R^2	Estimate	F ratio	p value	N
Ozarks	elevation	0.10	0.44	2.02	0.17	20
Ozarks	light ratio	0.01	0.06	0.31	0.58	20
Ozarks	slope	0.31	-0.20	6.96	0.01	17
Ozarks	aspect	< 0.01	< 0.01	0.01	0.90	20
Ozarks	soil pH	0.07	-0.89	0.88	0.36	13
Ozarks	soil moisture	0.19	0.33	1.42	0.24	8
Ozarks	distance to disturbance	0.27	0.22	6.34	0.02	19



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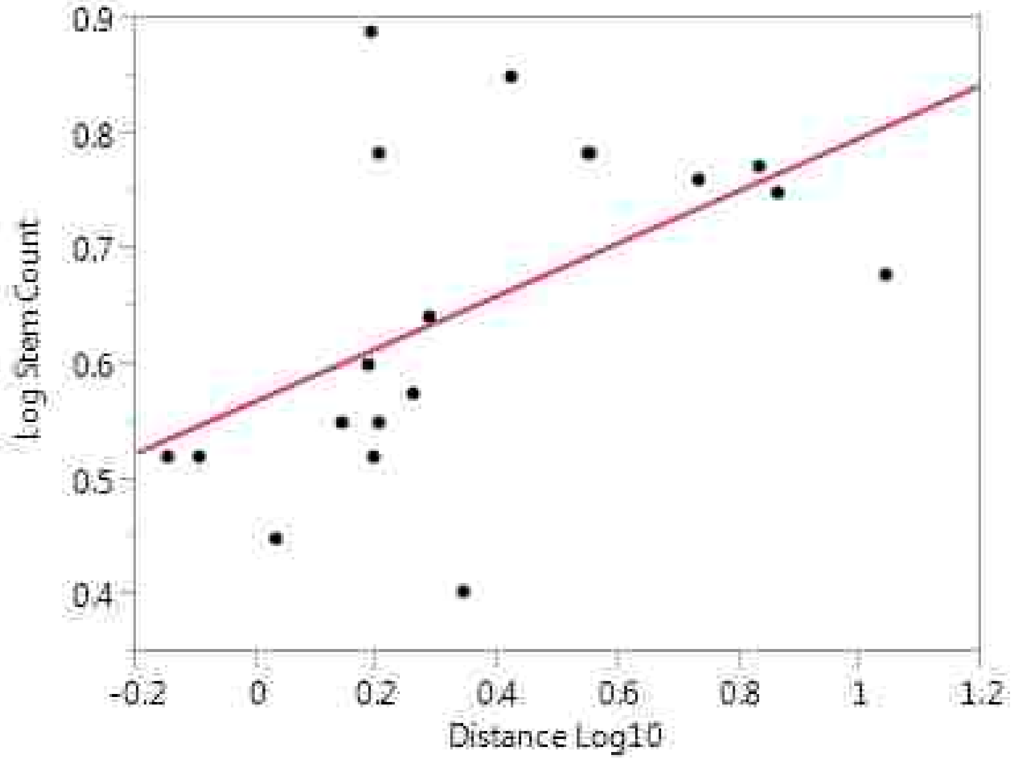
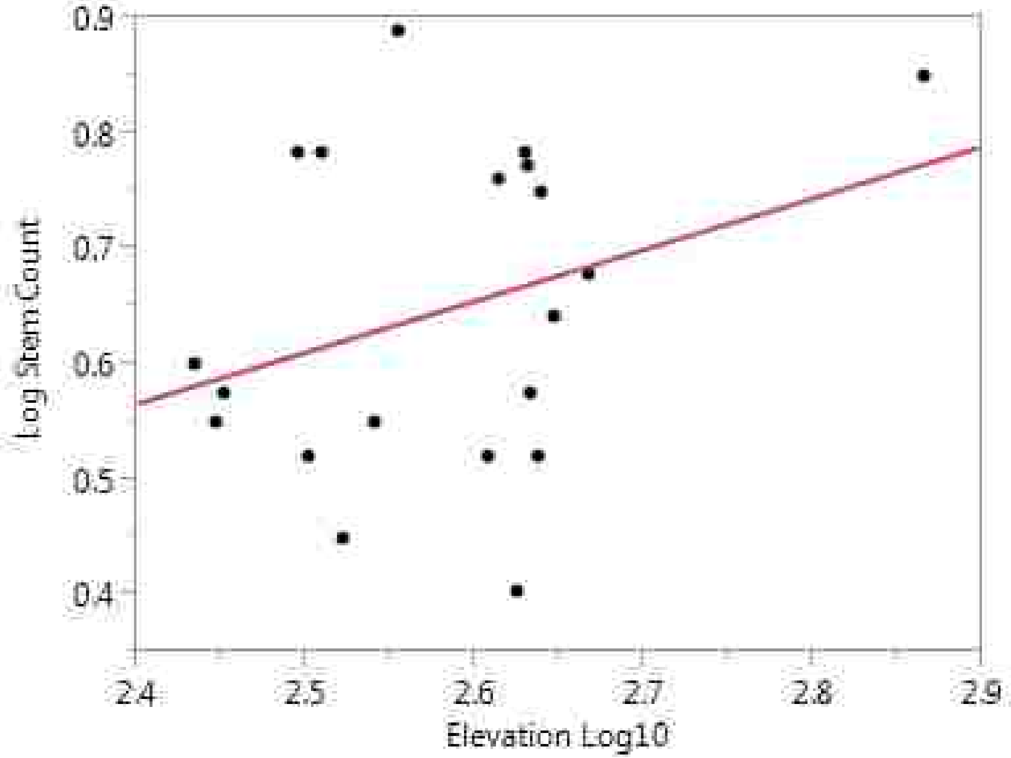

0.9
0.8
0.7
0.6
0.5
0.4
Log Stem Count
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
Distance Log10

[redacted]



0.9
0.8
0.7
0.6
0.5
0.4
Log Stem Count
2.4
2.5
2.6
2.7
2.8
2.9
Elevation Log10

[redacted]

Table 22: Correlation matrix examining for colinearity among predictor variables for the Appalachian colonies of multiflora. No predictors were removed.

	Elevation	Soil Moisture	Soil pH log 10	Light Ratio ArcSine	Slope 2nd root	Aspect	Distance Log10
Elevation	1.0000	-0.0948	0.2200	0.5461	0.1219	-0.1300	0.0971
Soil Moisture	-0.0948	1.0000	-0.5299	-0.1354	0.2676	0.0759	0.0900
Soil pH log 10	0.2200	-0.5299	1.0000	0.0095	-0.1305	-0.0740	-0.1195
Light Ratio ArcSine	0.5461	-0.1354	0.0095	1.0000	-0.2501	-0.2312	0.2411
Slope 2nd root	0.1219	0.2676	-0.1305	-0.2501	1.0000	0.1870	-0.0984
Aspect	-0.1300	0.0759	-0.0740	-0.2312	0.1870	1.0000	0.0325
Distance Log10	0.0971	0.0900	-0.1195	0.2411	-0.0984	0.0325	1.0000

Table 23: Correlation matrix examining for colinearity among predictor variables for the combined ecological colonies of multiflora. No predictors were removed.

	Elevation 4thRoot then 2ndRoot	Soil Moisture	Soil pH	Light Ratio ArcSine	Slope 4th Root	Aspect 2nd Root	Distance Log10
Elevation 4thRoot then 2ndRoot	1.0000	-0.0028	0.1695	0.6135	0.1792	-0.0156	0.2619
Soil Moisture	-0.0028	1.0000	-0.4800	0.0333	0.3659	0.0017	0.0712
Soil pH	0.1695	-0.4800	1.0000	-0.0963	-0.3288	0.0202	-0.1062
Light Ratio ArcSine	0.6135	0.0333	-0.0963	1.0000	0.0832	-0.1058	0.3201
Slope 4th Root	0.1792	0.3659	-0.3288	0.0832	1.0000	0.1108	-0.0740
Aspect 2nd Root	-0.0156	0.0017	0.0202	-0.1058	0.1108	1.0000	-0.0534
Distance Log10	0.2619	0.0712	-0.1062	0.3201	-0.0740	-0.0534	1.0000

Table 24: The multiple regression models for Appalachian and combined ecological colonies of multiflora.

Model	Predictors	R^2	F ratio	p value	AICc	N
Appalachian	aspect, soil moisture, distance to disturbance	0.29	2.61	0.08	17.02	23
Combined Ecological	aspect, soil moisture, distance to disturbance	0.23	2.8	0.057	14.7	31

Ozark Cover Class Comparisons

The only significant difference between the cover class values for the different species was found with the coverage of woody debris (F = 6.65, P value < 0.01, N = 102, Figure 29). Multiflora had the most cover of woody debris in the sites sampled with a mean coverage of 41.8%, and lespedeza had the lowest mean coverage of 8.5%. However, of the remaining cover classes, herbaceous cover, woody species cover, and notable disturbances approached significance and are notable. Herbaceous cover (F = 2.05, P value = 0.093, N = 103, Figure 30) indicated that multiflora had the lowest mean coverage of herbaceous plants of 58.9%, while garlic mustard had the greatest mean coverage of 86.3%. Woody species coverage (F = 2.22, P value = 0.071, N = 103, Figure 31) indicated that lespedeza colonies had lowest mean coverage of 44.6% and honeysuckle had the highest mean coverage of 68.6%. Values for notable disturbance (F = 2.39, P value = 0.055, N = 102, Figure 32) indicated that garlic mustard had the most disturbance is sites sampled, with a mean of 21.0%, and multiflora had the least disturbance with a mean of 6.1%. Results of each ANOVA are summarized in Table 25 and cover class means for each species are summarized in Table A3.

Appalachian Cover Class Comparisons

There was a significant difference between the coverage values recorded for woody debris, bryophytes, and woody species while rock cover approached significance. Woody debris values (F = 3.25, P value = 0.01, N = 116, Figure 33) indicated that garlic mustard had the highest amount of woody debris with a mean of 30.0% and lespedeza had the least coverage, with a mean of 5.7%. Multiflora had the highest amount of mean bryophyte coverage (9.8%), while lespedeza, honeysuckle, and microstegium all had the lowest mean coverage of 2.5% (F = 2.78, P value = 0.03, N = 118, Figure 34). Honeysuckle had the highest mean coverage of woody species, 49.3%, while microstegium had the lowest mean cover of 27.6% (F = 2.68, P value = 0.03, N = 118, Figure 35). Lespedeza had the greatest mean rock cover of 18% and honeysuckle had the lowest with 4.3% (F = 1.97, P value = 0.10, N = 118, Figure 36). Results of each ANOVA are summarizes in Table 25 and cover class means for each species are summarized in Table A3.

Combined Ecological Cover Class Comparisons

Woody debris (F = 5.67, P value < 0.01, N = 218, Figure 37) and woody species cover (F = 4.45, P value < 0.01, N = 221, Figure 38) were significant for the combined ecological comparisons, while herbaceous cover (F = 1.84, P value = 0.12, N = 221, Figure 39) and notable disturbance (F = 2.20, P value = 0.06, N = 220, Figure 40) approached significance. Multiflora had the greatest mean percent cover of woody debris of 29.1%, while lespedeza had the least mean cover with 7.8%. Honeysuckle has the greatest mean cover of woody species of 59.9%, and garlic mustard and the least mean percent of 36.2%. Garlic mustard had the greatest mean percent of herbaceous cover of 88.4% and multiflora had the lowest mean percent of 76.7%, although honeysuckle had a similar result of 76.7%. Garlic mustard had the greatest mean percent cover of notable disturbance of 17.6% and honeysuckle had the least mean percent cover of 7.6%; however, multiflora had a similar mean percent cover of 7.7%. Results of each ANOVA are summarizes in Table 25 and cover class means for each species are summarized in Table A3.

Table X: One way ANOVA results for each cover class for each region and combined model. Species were used as treatments.

Region	Cover Class	F	P	N
Ozarks	Bare Soil	0.08	0.98	103
Appalachians		1.78	0.13	118
Combined Ecological		1.02	0.39	221
Ozarks	Rock	0.08	0.98	103
Appalachians		1.97	0.10	118
Combined Ecological		0.87	0.48	221
Ozarks	Woody Debris	6.65	< 0.01	102
Appalachians		3.25	0.01	116
Combined Ecological		5.67	< 0.01	218
Ozarks	Leaf Liter	0.78	0.53	103
Appalachians		1.19	0.31	116
Combined Ecological		0.78	0.53	219
Ozarks	Bryophytes	0.61	0.65	103
Appalachians		2.78	0.03	118
Combined Ecological		1.47	0.21	221
Ozarks	Herbaceous	2.05	0.09	103
Appalachians		0.52	0.71	118
Combined Ecological		1.84	0.12	221
Ozarks	Woody	2.22	0.07	103
Appalachians		2.68	0.03	118
Combined Ecological		4.45	< 0.01	221
Ozarks	Notable Disturbance	2.39	0.05	102
Appalachians		1.33	0.26	118
Combined Ecological		2.20	0.06	220

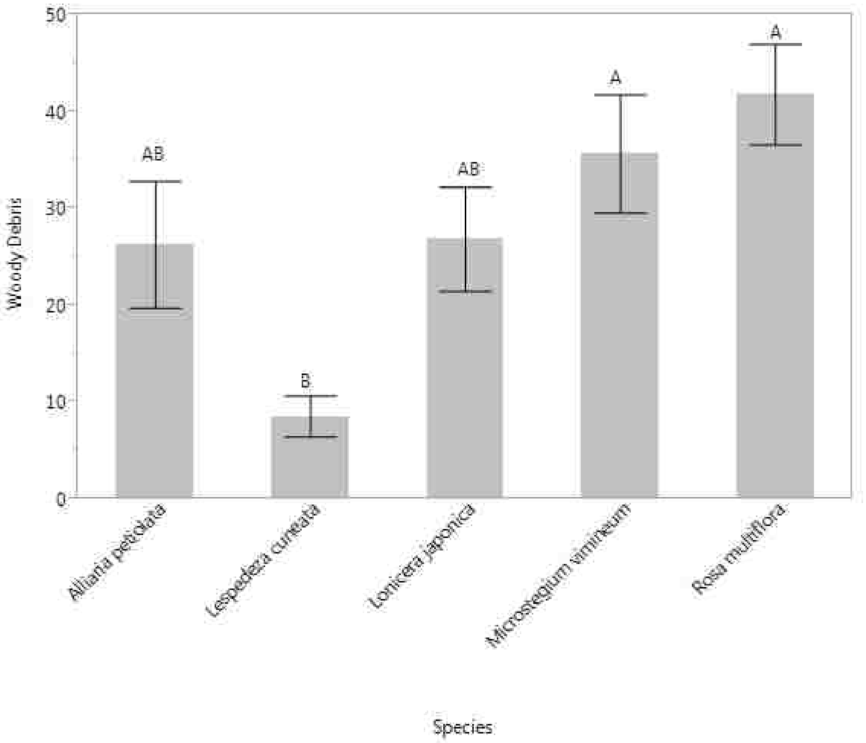


Figure 29: ANOVA results comparing woody debris across target species for Ozark colonies (F = 6.65, P value < 0.01, N = 102).

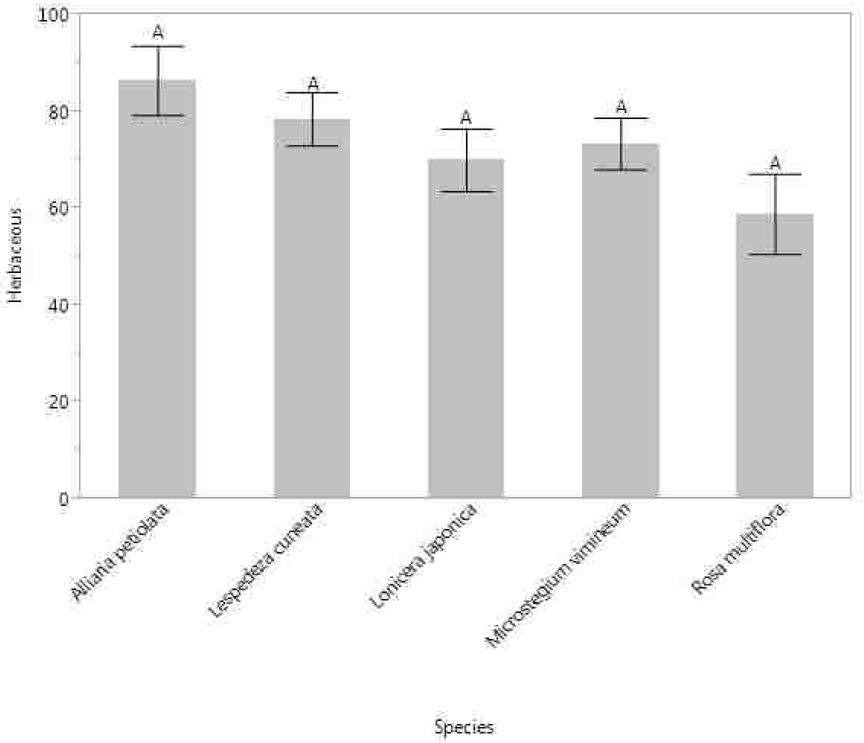


Figure 30: ANOVA results comparing herbaceous cover across target species for Ozark colonies (F = 2.05, P value = 0.093, N = 103).

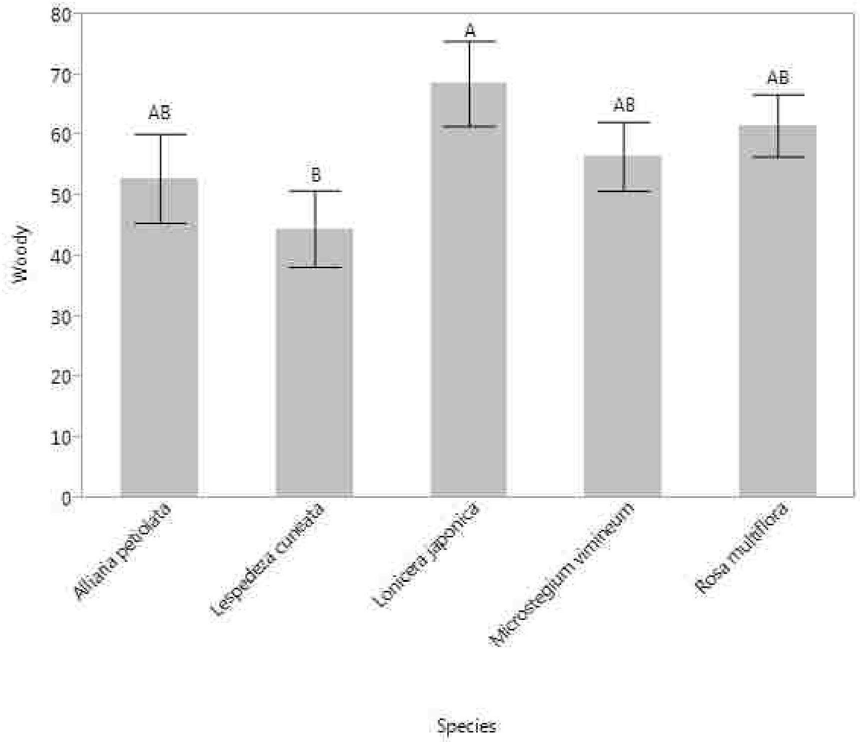


Figure 31: ANOVA results comparing woody species cover across target species for Ozark colonies (F = 2.22, P value = 0.071, N = 103).

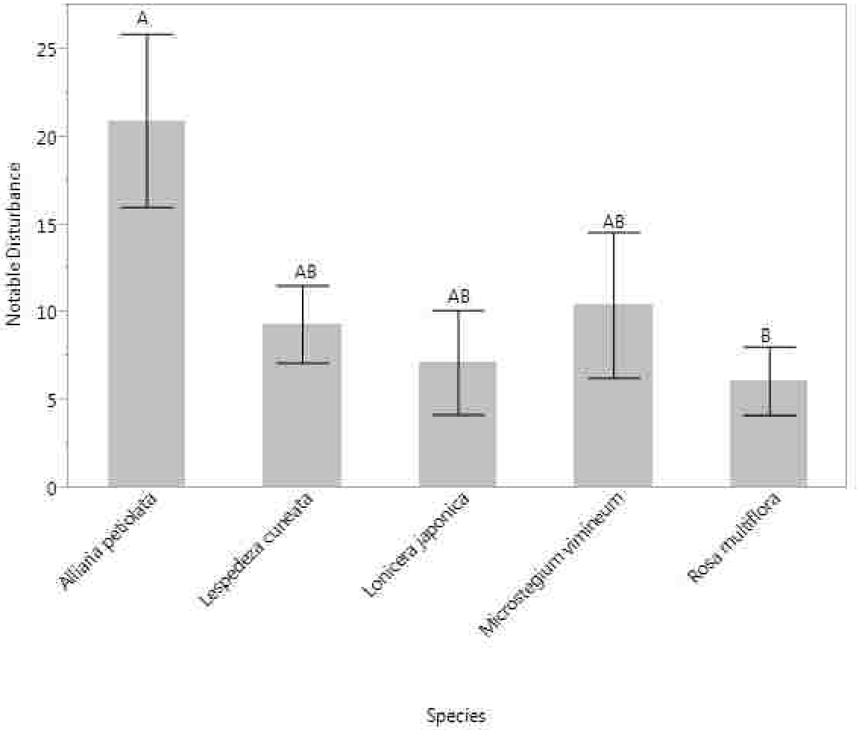


Figure 32: ANOVA results comparing notable disturbance cover across target species for Ozark colonies (F = 2.39, P value = 0.055, N = 102).

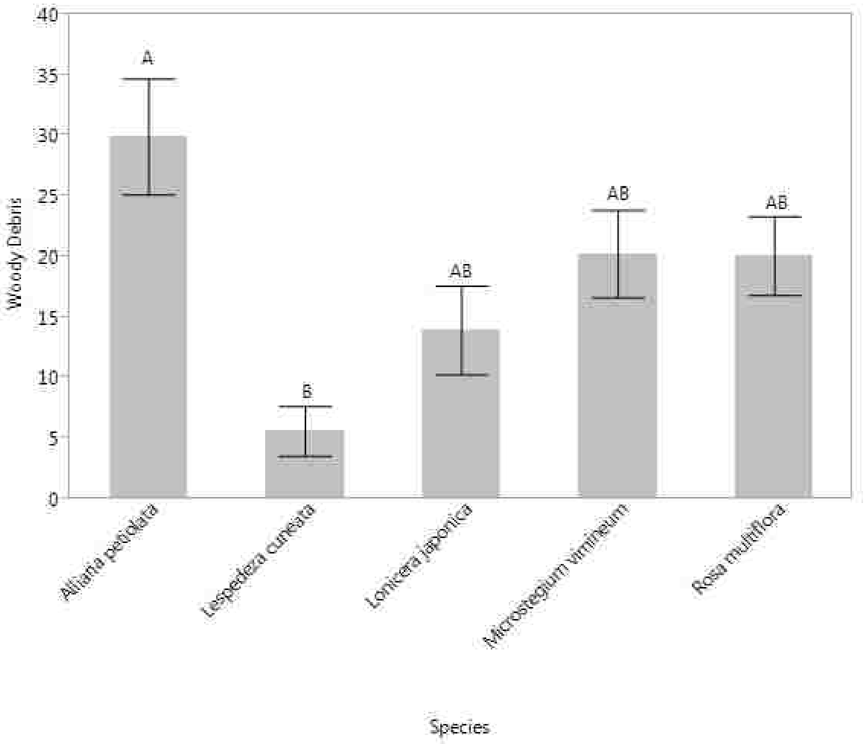


Figure 33: ANOVA results comparing woody debris cover across target species for Appalachian colonies (F = 3.25, P value = 0.01, N = 116).

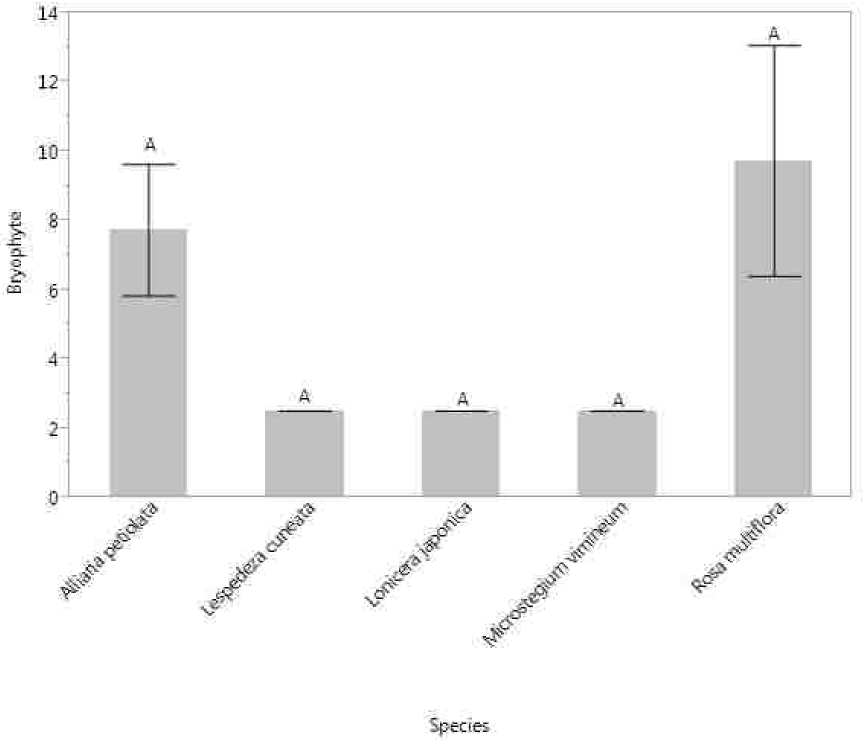


Figure 34: ANOVA results comparing bryophyte cover across target species for Appalachian colonies (F = 2.78, P value = 0.03, N = 118).

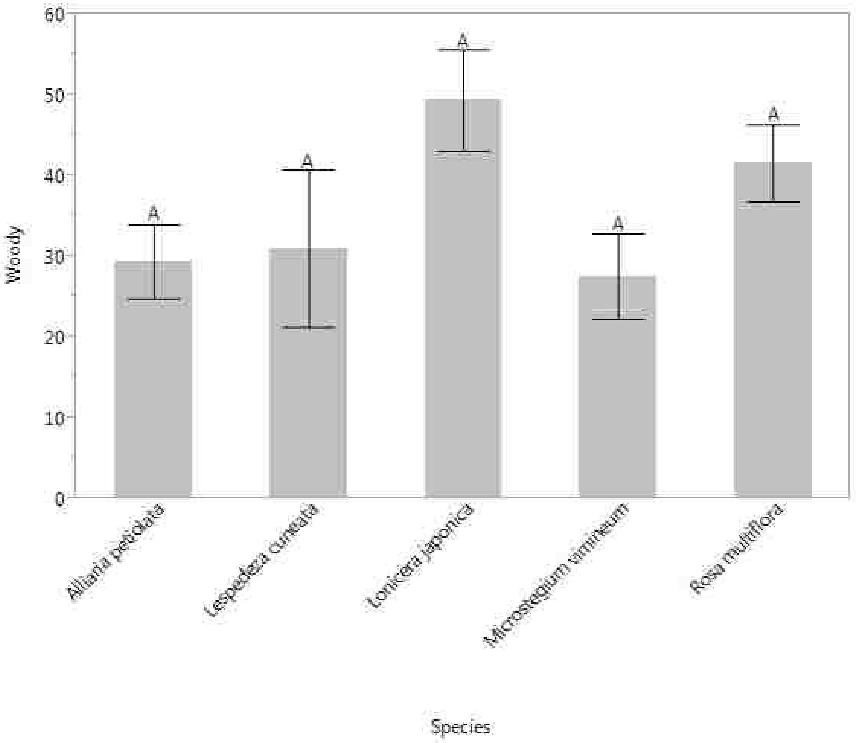


Figure 35: ANOVA results comparing woody species cover across target species for Appalachian colonies (F = 2.68, P value = 0.03, N = 118).

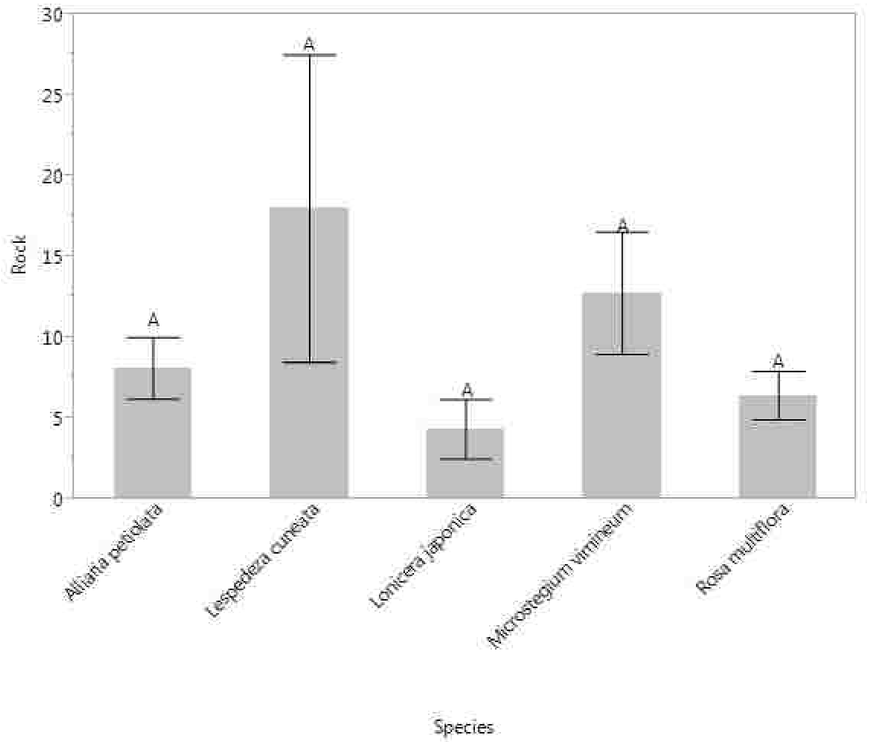


Figure 36: ANOVA results comparing rock cover across target species for the Appalachian colonies (F = 1.78, P value = 0.10, N = 118).

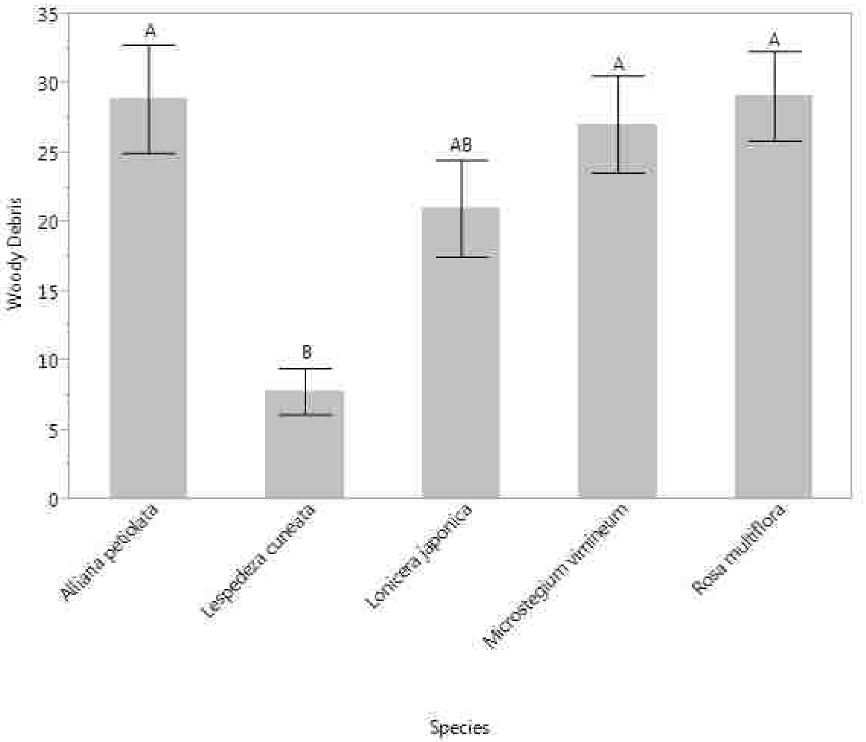


Figure 37: ANOVA results comparing woody debris cover across target species for the combined ecological colonies (F = 5.67, P value < 0.01, N = 218).

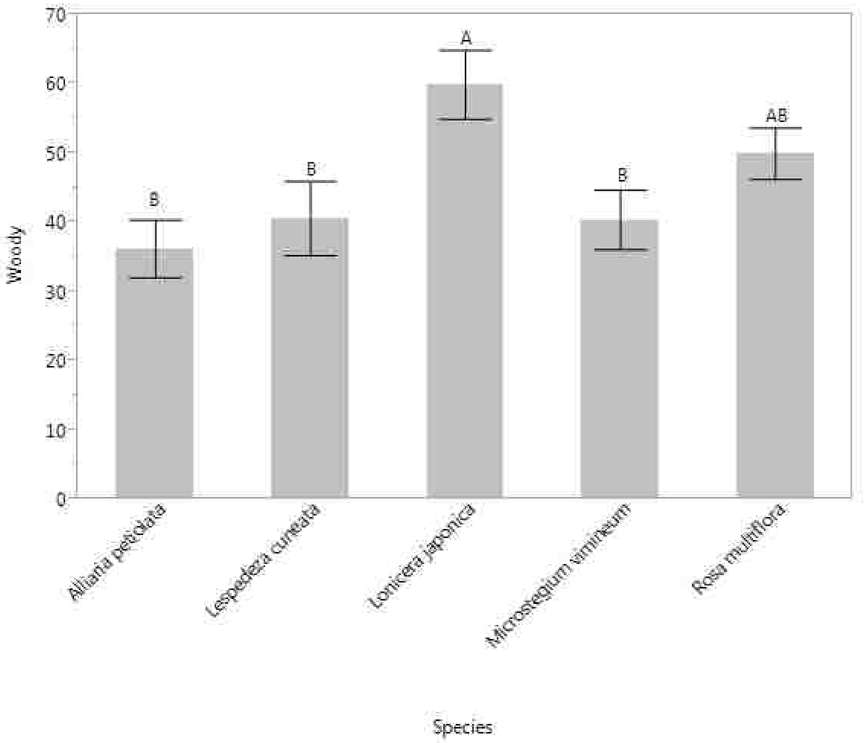


Figure 38: ANOVA results comparing woody species cover across target species for the combined ecological colonies (F = 4.45, P value < 0.01, N = 221).

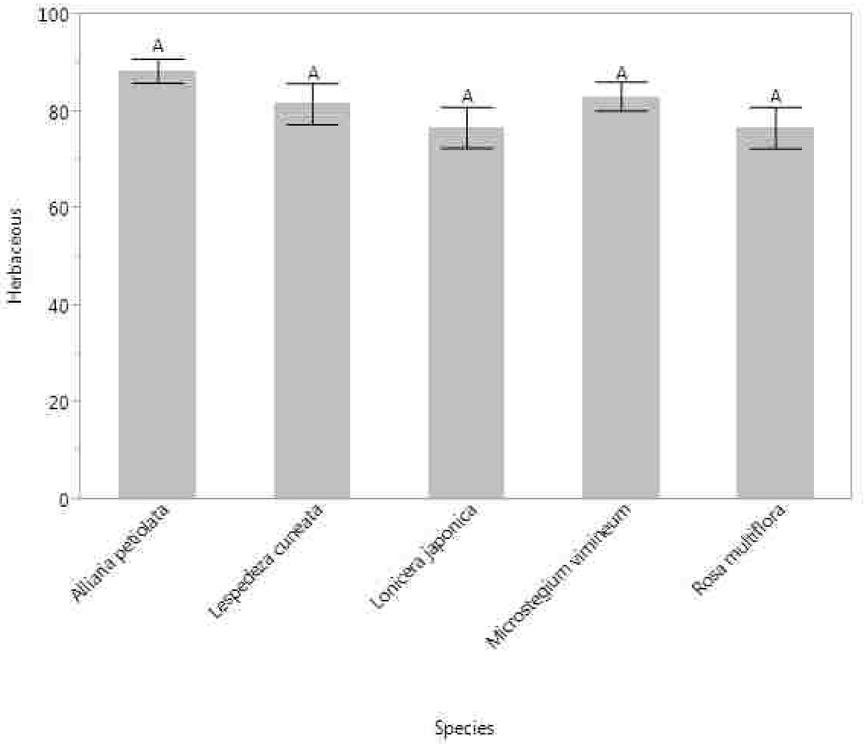


Figure 39: ANOVA results comparing herbaceous species cover across target species for the combined ecological colonies (F = 1.84, P value = 0.12, N = 221).

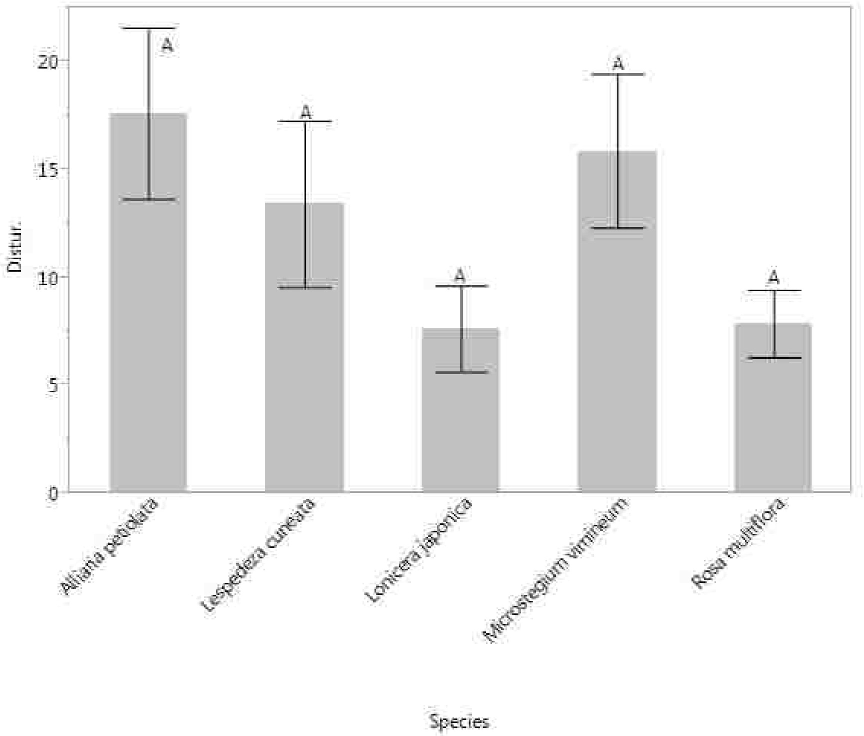


Figure 40: ANOVA results comparing notable disturbance species cover across target species for the combined ecological colonies (F = 2.20, P value = 0.06, N = 220).

Soil Regression Models

The only regression model that was significant was the multiflora regression model (R^2 = 0.54, F ratio = 3.57, p value = 0.038, AICc = 14.81, N = 17, Table 26). Predictors included in this model were N (est. < -0.01, p value = 0.36), S (est. = 1.56, p value = 0.03), CA (est. = -0.01, p value = 0.01), and NA (est. = -2.20, p value = 0.03). Organic matter and K were removed from use as predictor variables because of colinearity (Table 27). The other species' regression models are summarized in Table 26.

Associated Species

The list of associated species can be found in Table A1.

Table 26: Results of the soil multiple regression models. The only model that was significant was the model for multiflora.

Species	Predictors	R^2	F ratio	p value	AICc	N
Alliaria petilata	S, CA, MG	0.32	1.46	0.28	25.73	13
Lespedeza cuneata	CA, K, NA	0.28	0.80	0.53	42.11	10
Lonicera japonica	N, P, K	0.40	1.35	0.34	46.77	10
Microstegium vimineum	N, S, P	0.15	0.92	0.45	60.32	19
Rosa multiflora	N, S, CA, NA	0.54	3.57	0.038	14.81	17

Table 27: Correlation matrix examining for colinearity among soil predictor variables for multiflora. OM and K were removed from analysis because of colinearity.

	OM 2nd Root	N	S log 10	P 4th root	CA 2nd root	MG log 10	K log10	Na 4th root
OM 2nd Root	1.0000	0.9734	0.4269	0.1166	-0.2508	0.1526	0.3143	0.1829
N	0.9734	1.0000	0.3207	0.1933	-0.1875	0.2030	0.3984	0.0655
S log 10	0.4269	0.3207	1.0000	-0.0959	-0.1359	-0.2773	-0.0217	0.6023
P 4th root	0.1166	0.1933	-0.0959	1.0000	-0.0777	0.6017	0.8238	-0.4792
CA 2nd root	-0.2508	-0.1875	-0.1359	-0.0777	1.0000	0.4781	-0.1077	-0.1300
MG log 10	0.1526	0.2030	-0.2773	0.6017	0.4781	1.0000	0.4941	-0.4868
K log10	0.3143	0.3984	-0.0217	0.8238	-0.1077	0.4941	1.0000	-0.3364
Na 4th root	0.1829	0.0655	0.6023	-0.4792	-0.1300	-0.4868	-0.3364	1.0000

Discussion

Environmental Regression Models

Alliaria petiolata

Modeling for Ozark stem counts resulted in a non-significant regression model for garlic mustard colonies; however it might be worthwhile to examine shared predictor variables with the Appalachian and combined ecological models. Elevation and light ratio both were shared among all three models; however, elevation was the only predictor variable that was significant in the Appalachian model and combined model. It is important to note that the Appalachian model approached significance, and the combined ecological model was significant. In both models, elevation seems to be the predictor driving the models and raises questions on the contributions of the role of the other predictors. In all three models, elevation had a negative relationship with colony stem count; similar elevation results were reported by Burls and McClaugherty (2008). Burls and McClaugherty (2008) hypothesized that dispersal of garlic mustard seeds is linked to water runoff possibly following an elevation gradient, an explanation which could possibly account for the observed results in the present study. Meekins and McCarthy (2001) account for other ecological factors that could potentially be associated with an elevation gradient, not assessed in the present study (e.g., because differences between upland and lowland microhabitats) and how lowland environments can facilitate garlic mustard establishment and distribution. However, Kuhman et al. (2010) suggested that elevation might not play a significant role in distribution of garlic mustard.

Although not significant in any of the three models, light is known to play a role in the biology of garlic mustard and the plant is typically considered a shade adapted species (Cavers, 1979; Nuzzo, 2000; Meekins and McCarthy, 2000). The presence of light ratio in each model might be worth noting, but no conclusions can be drawn from this study because of the lack of significant evidence provided.

Lespedeza cuneata

The Ozark regression model constructed for lespedeza resulted in a significant model that included only one significant predictor variable, light ratio, but also included soil pH and distance to disturbance, which both approached significance. Other predictors in the model, elevation and slope, were not significant. Light ratio had a positive relationship within the model, which comes as no surprise because lespedeza is reported to be a shade intolerant species and readily invades open areas (Eddy and Moore, 1998). Distance to disturbance had a negative relationship as a predictor variable within the model. Although not significant, yet approached significance (p value = 0.07), this result could serve to reaffirm the notion that this species establishes itself along disturbed areas and the spread of colonies is linked to disturbances in some form or another, either through reduced competition or increased light availability. Disturbance-facilitated establishment was reported by Brandon et al. (2004), a study in which disturbance was linked to an increase in light exposure. Similar disturbance-linked results were also reported by Fei et al. (2009). Lespedeza was widely planted as a roadside species for soil stabilization and the present results might in part an artifact of that (Stevens, 2000, Miller et al., 2010). Nonetheless, it is possible that new colonies of lespedeza could still spread from a planted colony and management practices should take this into consideration. In both the Ozark model and the combined ecological simple linear regression, soil pH also had a positive relationship with colony stem count and was borderline significant (p value = 0.05 and 0.054, respectively). It has been reported that the variety “Serala” lespedeza performs better in more acidic soils so these results seem to be contradictory to other results found in the literature (Cline and Silvernail, 1997). However, Cline and Silvernail (1997) did suggest that nutrient levels in the soil might be interacting in a way that could inhibit growth of the plant. It is worthwhile to mention that the accuracy of the device used to test the soil pH in this study is questionable.

Regressions from the Appalachian and combined ecological colonies yielded somewhat similar results. From the Appalachian regressions, light ratio, aspect, and distance to disturbance approached significance. Concurring with the results in the Ozark model, light ratio had a positive relationship with colony stem count. However, distance to disturbance had a positive relationship with colony stem count, indicating that there are more stems per colony further from a disturbance. This might be explained by the fact that colonies sampled closer to the disturbance could have been recently established colonies and not of the same age as colonies further from the disturbance, thus having fewer stems as their older counterparts. It is unclear why these results occurred and they should be interpreted with caution. Aspect had a positive relationship with colony stem count and stem count increased as aspect approached North. It is also unclear whether this result occurred because of the biology of the plant or because of sampling, but it is reported that lespedeza can occur in moist environments (Stevens, 2000), a characteristics associated with more northern aspects. Distance to disturbance and aspect also had a positive relationships with stem count for the combined ecological data as well, although both approached significance. Slope approached significance for the combined ecological colonies and had a negative relationship with colony stem count. This result might be linked to seed dispersal of the species as Silliman and Maccarone (2005) hypothesized that water runoff might play a role in seed dispersal.

Lonicera japonica

The two regressions that approached significance at predicting Ozark colony stem count for honeysuckle were soil moisture (p value = 0.07) and distance to disturbance (p value = 0.07). Soil moisture had a positive relationship with colony stem count and distance to disturbance had a negative relationship. These two results are supported by other results reported in the literature about this species. Leatherman (1955) reported of the mesic nature of honeysuckle as an invasive species in North America, leading partially to a controlled distribution. Xeric conditions are an important factor for limiting the distribution for colony expansion, especially for seedling establishment (Fowler and Larson, 2004; Larson et al., 2006). This particular aspect of the biology of the plant is the reason it is sparse in the western United States and is limited to more mesic areas elsewhere (Larson et al., 2006). Targeted monitoring should be used in more mesic areas to watch for expansion of colonies or seedling growth.

The negative relationship with distance to disturbance serves to reinforce the notion that disturbances are associated with plant invasions. Wang et al. (2012) reported a similar finding of potential disturbance-assisted spread of honeysuckle, in which disturbed areas serve as corridors that allow seedlings to colonize new areas because of the exposure to light or lack of competition that is frequently associated with disturbances. Other reports in the literature provide more evidence for honeysuckle's associations with disturbance (e.g., Honu and Gibson, 2006). Management approaches should be focused on mitigating the impact disturbances have on the native communities.

The combined ecological regression model was significant and included elevation, light ratio, soil moisture, and soil pH as predictor variables, but the only predictor that was significant was light ratio (p value = 0.01), while elevation (p value = 0.06) and soil moisture (p value =

0.07) all approached significance. It is well known that honeysuckle is a shade tolerant species, but that it is more “robust” (e.g., flower production occurs) and grows more vigorously when it grows in full sunlight (Thomas, 1980; Larson et al., 2006; personal observation). According to Schierenbeck (2004), honeysuckle has a competitive advantage over native species in the ability to capture varying amounts of sunlight by increasing leaf area as well as growing more rapidly in high light environments. The positive relationship with light ratio seen in the present study seems to reinforce these reports. The negative relationship of stem count in this model associated with elevation in the present study is potentially explained by what might be honeysuckle’s aversion to higher elevations, although reports are varied (Leatherman, 1955). In the present study, the mean altitude for the combined ecological model was 395 m. Leatherman (1955) reported that honeysuckle is rare in the mountains of the Eastern United States but provides evidence that it does occur at elevations greater than 762m and at even higher elevations further west. Leatherman (1955) reported that the vine occurs at elevations of 853m in the Quachita Mountains in Arkansas (south of the Ozarks). It is unclear whether these reports are due to other microhabitat factors being suitable for honeysuckle’s establishment or whether the results in this study represent an anomaly. There is not sufficient evidence to draw conclusions from the Appalachian regression model.

Microstegium vimineum

The soil moisture regression for Ozark colonies of microstegium resulted in a non-significant regression that approached significance (p value = 0.13). There was a negative relationship between colony stem count and soil moisture for Ozark colonies of this plant. It is reported in the literature that microstegium is a shade tolerant invasive grass that invades moist forest understories, so these results seems contradictory to the biology of the plant (Barden, 1987; Tu, 2000; Gibson et al., 2002; Warren et al., 2013). A possible explanation for the result observed in this study is that locations with higher soil moistures could also have had other ecological factors associated with them that inhibited the growth of microstegium. Warren et al. (2013) provided evidence that leaf litter can act as an inhibitory agent in microstegium seed germination. Another possible explanation for this could be explained by biotic resistance. Barden (1987), Cole and Weltzin (2004), and Kuebbing et al. (2013) presented evidence that microstegium does not expand well into areas that are already occupied by other vegetation, native or non-native, and require a form of disturbance to facilitate its spread. These results could merely be a byproduct of the increased associated vegetation of sites with higher soil moisture that have not been disturbed.

The resulting Appalachian model and combined ecological model constructed in this study for microstegium are similar. Although the Appalachian model was a global model, the predictors (aspect, distance to disturbance, and elevation) that most likely drove the significance of the model were the same predictors that appeared in the combined ecological model, and most likely caused the borderline significant result in that model as well. Each predictor had a positive relationship within their respective models, although the strength of the relationship varied.

The significant global model constructed from the Appalachian data included aspect and distance as the only significant predictors in the model as well as elevation, which approached significance. The other predictors were included but were not significant nor approached significance. The weak positive relationship associated with aspect in the two models might indicate a preference of microstegium to invade more northern slopes due to the nature of northern slopes being more moist and shaded; however, this result should be interpreted with caution because there are many factors (e.g., disturbance) that play into the biology of this plant. There is some evidence that microstegium does prefer certain geographic aspects. Moretenson et al. (2009) reported that likelihood of occurrence of microstegium at disturbed and undisturbed sites is greater on the northeast and southeast aspects than northwest and southwest aspects; however, Kuhman et al. (2010) provided evidence that microstegium occurs more frequently on southwestern slopes.

Distance to disturbance showed a positive relationship with colony stem count within the model, which is contradictory to many other reports in the literature (Barden, 1987; Cole and Weltzin, 2004; Christen and Matlack, 2009; Moretneson et al., 2009). This result might be explained by a couple of reasons. First, as Christen and Matlack (2009) noted the invasion biology of microstegium seems to involve many factors and this observation could be a result of microstegium growing in more favorable conditions further away from disturbances. Another explanation could be that some sort of conduit allowed expansions of colonies to move further away from the initial disturbance. Water dispersal and small mammal dispersal can occur to spread the seeds of microstegium (Tu, 2000). It could be that seeds were dispersed to areas that were suitable for establishment and thus caused the current results; however, it is unclear what the ultimate explanation might be.

The inclusion of elevation in the Appalachian model (p value = 0.15) as well the borderline significant inclusion in the combined ecological model (p value = 0.08) seems to indicate that microstegium occurs more frequently at higher elevations. The mean elevations recorded were 646m and 550m, respectively. In Maryland, microstegium was reported to grow at a maximum 424m (Redman, 1995). Kuhman et al. (2010) reported a negative relationship with elevation and microstegium presence and indicated it was more likely to occur at lower elevations, results which are contrary to the results presented in the current study. Current results might indicate the spread of the species via vectors to higher elevations, although the cause of this result is unclear.

Rosa multiflora

For Ozark colonies of multiflora, slope had a significant negative relationship with colony stem count. The mean slope recorded for Ozark colonies was 3.8, which was lower than mean slopes reported for multiflora in other regions and states by Huebner et al. (2014). Huebner et al. (2014) compared *Kalmia latifolia* L. (mountain laurel) to multiflora in Ohio, Pennsylvania, and West Virginia and reported that a lower mean slope for multiflora in all three states compared to mountain laurel (27.8, 9.0, and 9.3 respectively). However, Fei et al. (2009) report that multiflora had a positive relationship with steeper slopes. The present result might be an indication of multiflora colonies preferring level slopes, or other environmental factors not assessed in the study could be more important and said factors occurred at on less steep slopes. Elevation, although not significant did approach significance, and also had a positive relationship with Ozark colony stem count. This result is also supported by reports by Fei et al. (2009). Mean elevation for Ozark colonies was 393m, which falls within recorded mean elevation range across three states recorded by Huebner et al. (2014) (253m-668m). More evidence is needed to draw accurate conclusions about the present results.

A weak negative relationship with aspect and colony stem count was included in the Appalachian model; although not significant, it approached significance. The mean aspect recorded for Appalachian colonies was 228 SW. Multiflora is known to be a species that can tolerate a wide range of environmental conditions (Steavenson, 1946; Schery, 1977; Eckardt, 1987), so it is unclear as to why this result approached significance. It could be the case that due to sampling, less stems were recorded with increasing aspect by chance or other microhabitat factors are playing a role at these aspects.

The positive distance to disturbance relationship with colony stem count seen in the Ozark regression and the regression models seems to be contrary to reports in the literature (e.g. McDonald et al., 2008; Christen and Matlack, 2009; Boyce, 2010). However, multiflora is noted to be a shade tolerant species that can survive beneath the canopy, but the reduction in growth association with shade does not support these results (Schery, 1977; Banasiak and Meiners, 2009). This result might be indicative of the presence of multiflora; however, this result could be the artifact of unintentional sampling of more stems further away from disturbances.

Cover Class Comparisons

All three cover class comparisons revealed that woody debris might be a good indicator of habitat differentiation for these species. Multiflora, although having the most woody debris coverage, did not have significantly more woody debris coverage when compared to garlic mustard, honeysuckle or microstegium in the Ozark comparison. In the Appalachian comparison, garlic mustard had the greatest mean cover of woody debris, although not different from honeysuckle, microstegium or multiflora. Multiflora had the greatest cover in the combined comparison, which was not different from any other species except lespedeza. Lespedeza did have significantly less woody debris in both regions and the combined ecological comparison, most likely because of its behavior of invading more open and less wooded areas (Tu, 2002). The coverage was not significantly different from garlic mustard or honeysuckle in the Ozarks; from honeysuckle, microstegium, or multiflora in the Appalachians; or from honeysuckle in the combined comparison. The increase in woody debris might be a sign of increased disturbance of the canopy, thus increasing light gaps, or disturbance of surrounding vegetation facilitating the spread of these species. The increase of woody debris could also just be an indicator that more forested areas were sampled and thus had more woody debris.

The Tukey's HSD revealed no difference among species for either Ozark herbaceous cover or the combined comparison (see text), so conclusions are uncertain. Garlic mustard had the greatest recorded herbaceous cover, while multiflora had the least in the Ozark comparison and combined comparison. The large cover in sites infested with garlic mustard could be attributed to the monodominant stands that were produced from these colonies as garlic mustard was counted among the cover. Similarly high cover results were seen with lespedeza and microstegium, in which these species can also quickly for monodominant stands shading out other species (Oswalt, et al., 2007; Allred et al., 2010).

The woody species cover comparison also could indicate the fundamental difference between lespedeza and the remaining species to a degree. Lespedeza was recorded as having the lowest coverage of woody species in the Ozark comparison, most likely attributed to the local environment; however, lespedeza was not different from garlic mustard, microstegium or multiflora, indicating that these species could potentially invade both open and wooded areas. In all three comparisons, the greatest percent coverage of woody species was recorded for honeysuckle; however, groupings in which honeysuckle is not different do occur (see text) most notable in the Appalachian comparison where Tukey's HSD indicated no differences. The large mean recorded for honeysuckle might be an artifact of itself being recorded as woody cover, because in many sites it was monodominant forming dense mats and high values were recorded.

Disturbance cover comparisons indicated that garlic mustard had the greatest mean disturbance in both the Ozark and combined comparisons; however, it was not different from lespedeza, honeysuckle or microstegium, but was different from multiflora in the Ozark comparison, and there was no difference among the species via Tukey's HSD in the combined comparison. This might indicate that garlic mustard colonies might be more dependent on disturbances to become established than the other species in the current study; however, all of these species, and invasive species in general, are associated with so level of disturbance.

The Appalachian ANOVA comparing bryophyte coverage was significant, but Tukey's HSD failed to resolve any differences between species. The greatest coverage was seen from multiflora colonies and lowest in lespedeza, honeysuckle and microstegium colonies. Caution should be used with interpretation of these results, but this could indicate that honeysuckles and microstegium colonies might also be negatively impacting the bryophyte taxa when the form their associated "mats". Results presented by Rubino et al. (2002) found no difference in in the coverage of bryophytes in "corridors", locations prime for establishment and spread of invasive plants, and forests. So an associated between infestations of these plants and bryophyte coverage needs more attention. The low cover of bryophytes recorded for lespedeza colonies might be more reflective of the general location, which is not typical for bryophytes. The cause high cover of bryophytes recorded for multiflora and garlic mustard are unclear, but it could be an artifact of the environment or other interactions might be taking place. Soudzilovskaia et al. (2011) provided evidence that bryophytes can play a role in forming community structure through suppressive mechanism; however, the authors did point out that bryophytes can act in a facilitating role as well. These results bring up some further questions, are there interactions between bryophytes and invasive species and if so, what are they? More information is needed to adequately asses the interaction between invasive species and bryophytes.

Soil Regression Models

In this study, the ability to predict colony stem count using soil nutrient levels was not achieved for four of the five species. The only species for which model construction was successful was multiflora rose. The resulting model included significant predictor relationships for sulfur, calcium, and sodium. The negative weak negative relationship observed with calcium is contrary to reported findings by Huebner et al. (2014), who reported that multiflora shows preferences to soils with higher levels of calcium. The increased calcium levels might indicate other ecological factors preventing multiflora. The negative relationship seen with sodium is supported in the literature (Lerner, 2006; Niu et al., 2008). Although both sources were from a horticultural perspective, both treated multiflora as a salt sensitive plant and that increased levels of salt can have damaging effects on plant growth. Levels of salt in the soil could lead to possible control factors for multiflora; however, non-target effects should be taken into consideration. The positive relationship observed with sulfur and stem count within the model is contradictory to the study presented by McDonald et al. (2008) in which they report an increase of sulfur results in a decreased chance of a site to contain multiflora.

Conclusions

The results of this study (1) provide a model of the microhabitats for *Alliaria petiolata* (M. Bieb.) Cavara & Grande, *Lespedeza cuneata* (Dum. Cours.) G. Don, *Lonicera japonica* Thunb., *Microstegium vimineum* (Trin.) A. Camus, and *Rosa multiflora* Thunb in the Ozarks and Appalachians and (2) determined what environmental factors might be related to colony size, which can be added to the body of knowledge on their habitat preferences. Although some of the results obtained seemed to be contradictory to well-established habitat preferences for these species; landscape heterogeneity, unforeseen ecological interactions, and/or sampling methods could have accounted for this. Caution should be used when viewing these species in an ecological or management perspective and realization of the broad niche that many invasive species can have is a necessity. More research should to be conducted to accurately assess the soil characteristics associated with these species.

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Appendix

Associated Species List

Table A1: List of associated species across all colony sites in the Ozarks (Oz.) and the Appalachians (App.). Genera included with "spp." indicate multiple taxa within that genus and not necessarily occurring at the same colony.

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Acalypha virginica L.							X			
Achillea millefolium L.			X	X	X	X		X		X
Acer negundo L.	X	X		X	X	X	X	X	X	X
Acer pensylvanicum L.		X						X		X
Acer rubrum L.		X		X	X	X	X	X		X
Acer saccharum Marshall	X	X								
Acer saccharinum L.	X	X	X			X	X	X		X
Actaea racemosa L.		X						X		X
Ageratina altissima (L.) R.M. King & H. Rob.		X		X					X	
Agrimonia gryposepala Wallr.								X		X
Agrimonia parviflora Aiton				X						

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Agrimonia pubescens Wallr.							X			X
Agrimonia rostellata Wallr.					X		X			
Agrimonia sp.								X		
Agrostis gigantea Roth									X	
Agrostis spp.		X		X				X		X
Ailanthus altissima (Mill.) Swingle					X					
Albizia julibrissin Durazz.			X	X		X		X		
Alliaria petiolata (M. Bieb.) Cavara & Grande	X	X		X	X	X	X	X	X	X
Allium spp.	X	X	X	X		X		X	X	X
Ambrosia artemisiifolia L.		X	X	X	X	X	X			
Amelanchier arborea (Michx. f.) Fernald				X						
Amelanchier sanguinea (Pursh) DC.								X		
Amelanchier sp.								X		
Ampelopsis cordata Michx.							X		X	
Amphicarpaea bracteata (L.) Fernald		X					X			

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Apios americana Medik.			X		X		X			
Apocynum cannabinum L.		X	X	X		X				X
Arabis sp.								X		
Arctium minus Bernh.		X				X		X		X
Arisaema triphyllum (L.) Schott		X						X		X
Aristida sp.			X							
Aristolochia macrophylla Lam.		X						X		
Arnoglossum reniforme (Hook.) H. Rob.									X	X
Asclepias sp.		X				X		X		X
Asimina triloba (L.) Dunal	X	X		X		X	X	X		X
Asplenium platyneuron (L.) Britton, Sterns & Poggenb.			X		X		X			
Aster sp.										X
Aster sp. cf *divaricatus*		X								
Barbarea vulgaris W.T. Aiton		X				X		X		X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Betula lenta L.		X				X				X
Betula sp.								X		X
Bidens aristosa (Michx.) Britton	X				X					
Bidens bipinnata L.						X				
Blephilia hirsuta (Pursh) Benth.		X								
Boehmeria cylindrica (L.) Sw.		X	X		X		X		X	X
Botrychium virginianum (L.) Sw.										X
Brachyelytrum erectum (Schreb. ex Spreng.) P. Beauv.							X			
Bromus arvensis L.			X							
Bromus kalmii A. Gray		X								
Bromus sp.		X								
Bromus sp. cf *catharticus*					X				X	
Bromus sterilis L.		X					X		X	
Bromus tectorum L.		X				X		X		

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Broussonetia papyrifera (L.) L'Hér. ex Vent.			X				X			
Campsis radicans (L.) Seem. ex Bureau	X			X						
Carduus nutans L.		X				X		X		
Carex blanda Dewey			X	X	X	X	X	X	X	
Carex davisii Schwein. & Torr.	X									
Carex frankii Kunth								X		
Carex gynandra Schwein.										X
Carex jamesii Schwein.							X			
Carex leptonervia (Fernald) Fernald		X								
Carex spp.						X		X	X	X
Carex vulpinoidea Michx.	X							X		X
Carpinus caroliniana Walter	X	X		X		X	X	X	X	X
Carya cordiformis (Wangenh.) K. Koch	X	X	X		X		X	X	X	X
Carya sp. cf *ovata*							X	X		
Carya sp. cf *tomentosa*						X		X		X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Carya spp.	X	X		X	X		X	X		X
Carya tomentosa (Lam.) Nutt.			X				X	X		
Carya ovata (Mill.) K. Koch		X					X	X		
Castanea dentata (Marshall) Borkh.										X
Celastrus orbiculatus Thunb.		X		X		X		X		X
Celtis occidentalis L.									X	
Celtis sp.	X									
Celtis laevigata Willd.					X		X		X	
Centaurea stoebe L.			X		X					
Cephalanthus occidentalis L.			X				X			
Cercis canadensis L.	X	X		X	X	X	X	X	X	X
Chasmanthium latifolium (Michx.) Yates		X	X		X		X		X	
Chelone glabra L.		X								
Chrysogonum virginianum L.				X						
Cinna arundinacea L.					X					

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Clematis sp.		X								X
Clitoria mariana L.			X			X	X			
Collinsonia canadensis L.		X								
Conyza canadensis (L.) Cronquist var. *canadensis*				X						
Cornus florida L.	X		X		X	X	X	X	X	X
Corydalis sp.										X
Crataegus spp.						X	X			X
Croton monanthogynus Michx.			X						X	
Croton sp.					X					
Cryptotaenia canadensis (L.) DC.		X		X		X		X		X
Cynanchum laeve (Michx.) Pers.						X		X		
Cystopteris bulbifera (L.) Bernh.										X
Dactylis glomerata L.	X	X	X	X	X	X	X	X		X
Danthonia compressa Austin								X		

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Daucus carota L.			X		X				X	
Delphinium sp.	X									
Desmodium glutinosum (Muhl. ex Willd.) Alph. Wood							X			
Desmodium nudiflorum (L.) DC.	X						X			
Desmodium pauciflorum (Nutt.) DC.					X					
Desmodium perplexum B.G. Schub.									X	
Desmodium spp.	X	X	X	X	X	X	X			
Dianthus armeria L.			X			X				
Dichanthelium acuminatum (Sw.) Gould & C.A. Clark						X				
Dichanthelium clandestinum (L.) Gould		X								
Dichanthelium dichotomum (L.) Gould var. *dichotomum*		X				X		X		
Dichanthelium malacophyllum (Nash) Gould			X							
Dichanthelium sp cf *clandestinum*					X				X	

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Dichanthelium spp.			X	X		X		X	X	X
Dichanthelium laxiflorum (Lam.) Gould								X		
Dichanthelium oligosanthes (Schult.) Gould var. *scribnerianum* (Nash) Gould			X		X					
Dioscorea oppositifolia L.		X						X		X
Dioscorea villosa L.		X					X			
Diospyros virginiana L.		X	X		X		X		X	
Dipsacus fullonum L.						X				
Dryopteris intermedia (Muhl. ex Willd.) A. Gray		X								X
Dryopteris marginalis (L.) A. Gray		X								X
Dryopteris sp.						X				X
Elaeagnus pungens Thunb.				X						
Elephantopus carolinianus Raeusch.			X		X		X			
Elymus hystrix L.					X		X			
Elymus sp. cf *virginicus*					X					

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Elymus spp.		X					X			
Elymus villosus Muhl. ex Willd.	X									
Elymus virginicus L.					X		X		X	
Equisetum arvense L.		X				X		X		X
Eragrostis sp.		X								
Erigeron annuus (L.) Pers.			X	X	X	X	X			X
Erigeron spp.						X	X			X
Erigeron strigosus Muhl. ex Willd.			X	X						
Euonymus atropurpureus Jacq.				X						X
Euonymus fortunei (Turcz.) Hand.-Maz.	X		X		X		X		X	
Euonymus sp.										X
Eupatorium serotinum Michx.					X				X	
Euphorbia sp.		X								
Fagus grandifolia Ehrh.		X				X				X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Fleischmannia incarnata (Walter) R.M. King & H. Rob.					X		X		X	
Fragaria vesca L.		X				X		X		
Fragaria virginiana Duchesne		X				X		X		X
Frangula caroliniana (Walter) A. Gray			X		X	X	X	X	X	
Fraxinus pennsylvanica Marshall	X	X				X	X		X	
Fraxinus spp.		X		X		X		X		
Fraxinus americana L.		X	X		X	X		X	X	X
Galium aparine L.	X	X						X		
Galium asprellum Michx.										X
Galium cf. *lanceolatum*										
Galium divaricatum Pourr. ex Lam.						X				
Galium latifolium Michx.										X
Galium spp.	X	X		X		X	X	X	X	X
Galium triflorum Michx.		X								

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Galium cf *asprellum*										X
Geranium maculatum L.		X		X		X		X		
Geranium sp.						X		X		
Geranium sp. cf *pusillum* cf *molle*			X							
Geum canadense Jacq.		X		X	X			X	X	X
Geum spp.	X				X		X			
Glechoma hederacea L.		X				X		X	X	X
Gleditsia triacanthos L.			X		X		X		X	
Glyceria striata (Lam.) Hitchc.		X						X		X
Hackelia virginiana (L.) I.M. Johnst.							X		X	
Hamamelis spp.	X	X					X	X		X
Hedera helix L.						X				X
Hemerocallis sp.		X								
Hieracium caespitosum Dumort.										X
Holcus lanatus L.		X								X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Houstonia longifolia Gaertn.								X		
Hydrangea arborescens L.		X								
Hydrophyllum canadense L.		X								
Hydrophyllum virginianum L.		X						X		
Hypericum drummondii (Grev. & Hook.) Torr. & A. Gray										X
Hypericum puntatum Lam.					X				X	
Hypericum sp.										X
Ilex opaca Aiton		X			X	X	X		X	
Ilex ambigua (Michx.) Torr.		X								
Impatiens capensis Meerb.		X				X		X		
Impatiens sp.	X	X	X	X	X	X	X	X		X
Ipomoea coccinea L.			X			X				
Ipomoea pandurata (L.) G. Mey.							X			
Ipomoea spp.		X		X						X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Iris virginica L.										X
Juglans nigra L.	X	X	X		X	X	X	X		X
Juncus tenuis Willd.				X						
Juniperus virginiana L.			X	X	X	X	X	X	X	X
Kalmia latifolia L.								X		
Krigia biflora (Walter) S.F. Blake	X									
Krigia virginica (L.) Willd.		X								
Lactuca floridana (L.) Gaertn.							X		X	
Lactuca serriola L.			X							
Lactuca sp.								X		
Lamium amplexicaule L.	X									
Lamium purpureum L.		X								
Laportea canadensis (L.) Weddell		X						X		
Lapsana communis L.								X		
Lespedeza cuneata (Dum. Cours.) G. Don		X	X	X	X	X	X		X	

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Lespedeza violacea (L.) Pers.			X							
Leucanthemum vulgare Lam.			X	X		X			X	X
Ligustrum vulgare L.		X								
Lindera benzoin (L.) Blume	X	X	X	X	X	X	X	X	X	X
Liquidambar styraciflua L.			X		X		X			
Liriodendron tulipifera L.		X		X		X		X		X
Lobelia inflata L.							X			
Lolium sp.					X				X	
Lonicera japonica Thunb.	X	X	X		X	X	X	X	X	X
Lonicera maackii (Rupr.) Herder	X	X								
Lotus corniculatus L.										X
Lysimachia quadrifolia L.						X				
Lysimachia sp.								X		
Magnolia acuminata (L.) L.		X								
Maianthemum racemosum (L.) Link				X						

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Malus angustifolia (Aiton) Michx.						X				
Malus sp. cf *pumila*										X
Medicago lupulina L.						X				
Melilotus officinalis (L.) Lam.				X						
Menispermum canadense L.	X	X								
Microstegium vimineum (Trin.) A. Camus		X	X	X	X	X	X	X	X	X
Mimosa quadrivalvis L.			X						X	
Monarda spp.		X				X		X		
Monarda bradburiana Beck					X					
Morus rubra L.			X					X		
Morus sp.							X			
Muhlenbergia schreberi J.F. Gmel.						X				
Myrrhis odorata (L.) Scop.								X		X
Onoclea sensibilis L.						X				
Orbexilum sp.			X							

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Origanum vulgare L.						X				
Orobanche uniflora L.										X
Osmorhiza claytonii (Michx.) C.B. Clarke		X				X		X		
Osmorhiza longistylis (Torr.) DC.		X								
Ostrya virginiana (Mill.) K. Koch					X				X	
Oxalis spp.	X	X	X			X	X	X	X	X
Oxalis stricta L.		X	X	X	X		X	X		
Oxydendrum arboreum (L.) DC.				X				X		X
Packera aurea (L.) Á. Löve & D. Löve										X
Packera obovata (Muhl. ex Willd.) W.A. Weber & Á. Löve		X								X
Panicum anceps Michx.					X				X	
Panicum dichotomiflorum Michx.		X				X		X		
Panicum sp.		X						X		X
Parthenocissus quinquefolia (L.) Planch.	X	X	X	X	X	X	X	X	X	X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Passiflora incarnata L.			X		X		X		X	
Penstemon digitalis Nutt. ex Sims					X			X		
Perilla frutescens (L.) Britton							X			
Perilla sp.		X				X		X		
Phleum pratense L.	X				X			X	X	
Phryma leptostachya L.					X		X			
Physalis heterophylla Nees					X		X			
Phytolacca americana L.		X				X		X		X
Picea sp.						X				
Picea rubens Sarg.		X				X				X
Pilea pumila (L.) A. Gray		X								
Pilea pumila (L.) A. Gray		X								
Pinus sp.						X				
Pinus strobus L.		X				X		X		
Pinus virginiana Mill.		X		X		X				X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Pinus taeda L.						X	X			
Plantago lanceolata L.										X
Plantago rugelii Decne.		X					X			X
Plantago sp.								X		
Platanus occidentalis L.	X		X	X	X			X	X	
Poa sylvestris A. Gray								X		
Poa autumnalis Muhl. ex Elliott						X				X
Poa chapmaniana Scribn.		X				X		X		X
Poa sp.		X		X				X		
Podophyllum peltatum L.	X							X	X	
Polemonium reptans L. var. *reptans*	X									
Polygonatum biflorum (Walter) Elliott		X				X		X		
Polygonum cespitosum Blume var. *longisetum* (Bruijn) A.N. Steward		X	X				X	X		
Polygonum cuspidatum Siebold & Zucc.		X					X	X		

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Polygonum virginianum L.	X	X				X	X	X	X	
Polystichum acrostichoides (Michx.) Schott	X	X	X	X	X	X	X	X	X	X
Potentilla simplex Michx.								X		X
Potentilla spp.				X				X		
Prenanthes alba L.										X
Prosartes lanuginosa (Michx.) D. Don		X								
Prunella vulgaris L.		X		X						
Prunus serotina Ehrh.	X	X	X		X	X	X		X	X
Prunus sp. cf *padus*										X
Prunus angustifolia Marshall		X								
Quercus alba L.	X	X		X	X	X	X	X	X	X
Quercus marilandica Munch.			X						X	
Quercus montana Willd.								X		X
Quercus muehlenbergii Engelm.	X		X		X				X	
Quercus nigra L.				X						

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Quercus phellos L.				X						
Quercus rubra L.		X	X	X	X	X	X	X	X	X
Quercus sp. cf texana				X		X		X		
Quercus spp.			X	X	X	X				
Quercus stellata Wangenh.			X		X		X		X	
Quercus texana Buckley									X	
Quercus velutina Lam.	X	X		X	X	X	X	X	X	X
Quercus falcata Michx.								X		X
Ranunculus abortivus L.		X				X		X		
Ranunculus acris L.		X						X		X
Ranunculus sp.		X								
Ranunculus pensylvanicus L. f.		X								
Ranunculus recurvatus Poir.		X								
Rhododendron spp.				X				X		X
Rhus copallinum L.			X		X				X	

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Rhus glabra L.							X			
Ribes missouriense Nutt.							X			
Ribes sp.							X		X	
Robinia pseudoacacia L.	X	X	X		X	X	X	X		
Rosa multiflora Thunb.	X	X	X	X	X	X	X	X	X	X
Rosa setigera Michx.					X					
Rubus canadensis L.										X
Rubus phoenicolasius Maxim.		X		X						
Rubus sp. A Arguti									X	
Rubus sp. B Arguti					X					
Rubus sp. C Arguti		X								
Rubus spp.	X		X	X	X	X	X	X	X	X
Rubus odoratus L.		X								
Rudbeckia hirta L.			X		X		X		X	
Rudbeckia laciniata L.	X	X								

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Rudbeckia sp.							X			
Rudbeckia triloba L.					X		X		X	
Ruellia caroliniensis (J.F. Gmel.) Steud.				X						
Ruellia humilis Nutt.			X							
Rumex crispus L.		X			X	X			X	
Salix nigra Marshall			X							
Sambucus nigra L. ssp. *canadensis* (L.) R. Bolli	X				X				X	X
Sanguinaria canadensis L.		X								
Sanicula canadensis L.		X	X				X		X	X
Sanicula canedensis L. var. *canadensis*	X									
Sassafras albidum Nutt.	X	X	X	X	X	X	X		X	X
Schedonorus arundinaceus (Schreb.) Dumort.	X	X	X		X	X		X	X	X
Scuterllaria sp.							X			
Securigera varia (L.) Lassen			X	X				X		X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Setaria pumila (Poir.) Roem. & Schult.			X							
Sherardia arvensis L.			X							
Sisyrinchium angustifolium Mill.								X		X
Smallanthus uvedalius (L.) Mack. ex Small							X		X	
Smilax bona-nox L.			X		X		X		X	
Smilax cf. *herbacea*									X	
Smilax glauca Walter	X				X					
Smilax herbacea L.		X								
Smilax spp.	X		X		X	X	X	X	X	X
Smilax tamnoides L.		X			X					X
Smilax rotundifolia L.		X			X		X			X
Solanum carolinense L.			X	X	X		X		X	
Solanum dulcamara L.		X								
Solanum spp.				X		X				
Solidago sp. cf *graminifolia*										X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Solidago spp.		X		X		X	X	X		X
Sorbus americana Marshall		X								
Sorghum halepense (L.) Pers.			X							
Spiraea sp. cf *tomentosa*										X
Stachys sp.		X						X		
Staphylea trifolia L.									X	
Stellaria media (L.) Vill.		X				X		X		
Stellaria longifolia Muhl. ex Willd.										X
Stellaria pubera Michx.								X		
Stylosanthes biflora (L.) Britton, Sterns & Poggenb.			X							
Symphoricarpos orbiculatus Moench		X	X	X	X	X	X	X	X	X
Symphyotrichum prenanthoides (Muhl. ex Willd.) G.L. Nesom								X		
Symphyotrichum spp.			X					X		
Symphyotrichum cordifolium (L.) G.L. Nesom		X		X						

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Taraxacum officinale F.H. Wigg.		X						X		X
Tephrosia virginiana (L.) Pers.			X							
Thelypteris noveboracensis (L.) Nieuwl.		X						X		X
Tilia americana L.	X	X	X		X		X	X	X	X
Toxicodendron radicans (L.) Kuntze	X	X	X	X	X	X	X	X	X	X
Tridens flavus (L.) Hitchc.			X		X					
Trifolium dubium Sibth.						X				
Trifolium pratense L.		X		X	X			X		X
Trifolium repens L.		X	X	X				X		
Trifolium spp.			X	X		X		X		
Trifolium campestre Schreb.			X							
Trillium sp.	X									
Triosteum perfoliatum L.		X								
Tsuga canadensis (L.) Carrière										X
Tussilago farfara L.		X				X		X		X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Typha sp.						X				
Ulmus alata Michx.			X		X		X			
Ulmus rubra Muhl.	X		X	X	X		X		X	
Ulmus sp. cf *rubra*	X		X							
Ulmus spp.	X				X	X				X
Uvularia grandiflora Sm.		X						X		
Vaccinium cf *pallidum*								X		
Vaccinium pallidum Aiton										X
Vaccinium spp.				X						X
Verbascum sp.					X				X	
Verbascum thapsus L.				X						
Verbena urticifolia L.			X	X				X		
Verbesina alternifolia (L.) Britton ex Kearney		X								X
Verbesina sp.		X		X		X		X		X
Verbesina virginica L.	X		X		X	X	X	X	X	X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Verlerianella sp.			X							
Vernonia sp.		X				X				
Veronica officinalis L.										X
Veronicastrum virginicum (L.) Farw.		X								
Viburnum prunifolium L.		X				X		X		
Viburnum recognitum Fernald										X
Viburnum sp.						X				
Vicia sativa L.			X						X	
Vicia spp.	X		X			X	X	X	X	X
Vinca minor L.		X				X				
Viola palmata L.								X		
Viola spp.	X	X	X	X	X	X	X	X	X	X
Viola striata Aiton		X								X
Viola sororia Willd.		X								
Vitis aestivalis Michx.							X			X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Vitis cinerea (Engelm.) Engelm. ex Millard		X	X							
Vitis spp.	X	X	X		X	X	X	X	X	X
Vitis vulpina L.					X		X		X	
Vulpia octoflora (Walter) Rydb.				X						
Yucca sp.			X							
Zizia aptera (A. Gray) Fernald										X
Unknown A						X				
Unknown Apiaceae A							X			
Unknown Asteraceae A									X	
Unknown Asteraceae B			X							
Unknown Asteraceae C									X	
Unknown Asteraceae D							X			
Unknown Asteraceae E								X		
Unknown Asteraceae F								X		
Unknown Asteraceae G							X			

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Unknown Asteraceae H							X			
Unknown Asteraceae I									X	
Unknown Asteraceae J			X							
Unknown Cyperaceae A	X									
Unknown Cyperaceae B				X						
Unknown Dicot A		X				X		X		
Unknown Dicot B								X		
Unknown Dicot C		X								X
Unknown Dicot D							X			
Unknown Dicot E							X			
Unknown Dicot F		X								
Unknown Dicot G								X		
Unknown Dicot H									X	
Unknown Dicot I									X	
Unknown Ericaceae A			X							

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Unknown Fern A					X					
Unknown Lamiaceae A		X								
Unknown Lamiaceae B							X			
Unknown Lamiaceae C			X							
Unknown Lamiaceae D					X					
Unknown Monocot A					X					
Unknown Monocot B					X					
Unknown Poaceae A			X						X	
Unknown Poaceae B			X							
Unknown Poaceae C										
Unknown Poaceae D			X		X				X	
Unknown Poaceae E			X							
Unknown Poaceae F					X				X	
Unknown Poaceae G						X				
Unknown Poaceae H										X

	Alliaria petiolata		*Lespedeza cuneata*		*Lonicera japonica*		*Microstegium vimineum*		*Rosa multiflora*	
Species	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.	Oz.	App.
Unknown Poaceae I						X				X
Unknown Poaceae J		X								
Unknown Poaceae J			X							
Unknown Poaceae K					X					
Unknown Poaceae L			X							
Unknown Poaceae O								X		
Unknown Poaceae P		X								
Unknown Poaceae Q		X								
Unknown Poaceae R						X				
Unknown Poaceae S						X				
Unknown Poaceae T						X				
Unknown Poaceae U				X						
Unknown Poaceae V		X								
Unknown Poaceae W								X		
Unknown Poaceae X		X								X

Basic Statistics per Species

Table A2-A4 provides basic statistics per species for Ozark, Appalachian, and combined ecological colonies as well as the soil means for each species.

Table A2: Means of each predictor variable for each species before data transformation. *The N reported is the maximum sample size for each species. Certain predictor variables had lower sample sizes due to missing or excluded data.

Region	Species	Elevation (m)	Soil Moisture (%)	Soil pH	Light Ratio (%)	Slope (%)	Aspect	Distance to disturbance (m)	N*
Ozarks	*A. petiolata*	311.84	45.46	6.77	14.42	8	162.23	3.72	13
Appalachians		638.59	55.13	6.37	30.83	8.93	170.93	2.36	32
Combined Ecological		544.2	52.72	6.47	26.09	8.66	168.42	2.76	45
Ozarks	*L. cuneata*	380.08	42.53	6.56	62.52	9.91	128.95	1.32	24
Appalachians		452.62	62.86	6.4	49.85	9.88	182.11	1.24	9
Combined Ecological		398.80	49.79	6.52	59.07	9.90	143.45	1.30	33
Ozarks	*L. japonica*	383.42	49.69	6.29	37.23	5.17	165.69	2.9	23
Appalachians		408.33	55.95	6.32	29.73	9.11	154.44	2.83	18
Combined Ecological		394.92	52.93	6.30	33.86	6.85	160.75	2.87	41
Ozarks	*M. vimineum*	405.22	38.29	6.71	27.74	4.75	186.35	3.01	20
Appalachians		646.07	53.86	6.39	34.45	7.17	209.33	1.88	27
Combined Ecological		549.73	48.39	6.52	31.68	6.14	199.55	2.37	47
Ozarks	*R. multiflora*	392.95	42.91	6.28	24.11	3.8	179.3	3.04	20
Appalachians		780.29	49.85	6.41	46.63	8.53	227.88	6.18	27
Combined Ecological		606.17	48.78	6.35	36.29	6.73	210.17	4.87	47

Table A3: Mean percent cover for each sampled variable calculated from the Daubenmire mid-point. *The N reported is the maximum sample size for each species. Certain cover classes had lower sample sizes due to misses data.

Region	Species	Bare Soil	Rock	Woody Debris	Leaf Litter	Bryophyte	Herbaceous	Woody	Notable Disturbance	N*
Ozarks	*A. petiolata*	5.19	8.84	26.25	68.26	6.15	86.34	52.88	20.96	13
Appalachians		5.85	8.12	29.92	66.95	7.73	89.21	29.37	16.25	32
Combined Ecological		5.66	8.33	28.92	67.33	7.27	88.38	36.16	17.61	45
Ozarks	*L. cuneata*	5.52	9.89	8.54	60.52	7.97	78.43	44.58	9.34	24
Appalachians		3.75	18	5.62	35.31	2.5	89.25	31	22.75	10
Combined Ecological		5.00	12.27	7.81	54.21	6.32	81.61	40.58	13.40	34
Ozarks	*L. japnonica*	4.56	7.71	26.84	77.28	5.65	70	68.58	7.17	23
Appalachians		2.5	4.34	13.94	56.05	2.5	84.86	49.34	8.15	19
Combined Ecological		3.63	6.19	21.01	67.67	4.22	76.72	59.88	7.61	42
Ozarks	*M. vimineum*	6.19	8.15	35.65	68.69	4.67	73.36	56.52	10.4	23
Appalachians		8.27	12.75	20.25	65.17	2.5	90.86	27.58	20.17	29
Combined Ecological		7.35	10.72	27.06	66.73	3.46	83.12	40.38	15.86	52
Ozarks	*R. multiflora*	6.12	10.25	41.75	65.37	3.75	58.87	61.62	6.12	20
Appalachians		3.39	6.42	20.08	66.07	9.73	89.37	41.60	9.10	28
Combined Ecological		4.53	8.02	29.11	65.78	7.23	76.66	49.94	7.86	48

Table A4: Mean value for each soil nutrient. Sampled were combined across both ecoregions to obtain a large enough sample size

Species	Organic Matter (%)	N (N/acre)	S (ppm)	P (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	K (mg/kg)	Na (mg/kg)	N
A. petiolata	7.40	105.92	14.07	26.92	5408.53	181.07	104.07	21.69	13
L. cuneata	5.84	102	11.8	35	1774.5	301.7	118	25	10
L. japonica	6.06	103.6	13	26.9	3108	165.4	140	24.3	10
M. vimineum	7.09	107.68	14.7	35.10	3283.36	202.31	131.05	27.73	19
R. multiflora	6.63	105.64	13.41	29.76	2327.17	154.35	114.47	19.52	17

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