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# Assessing Recreational User Impacts, Motivations, and Knowledge on the Spread of Invasive Plant Species in a Managed, Multiple-Use Forest Ecosystem

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# ASSESSING RECREATIONAL USER IMPACTS, MOTIVATIONS, AND KNOWLEDGE ON THE SPREAD OF INVASIVE PLANT SPECIES IN A MANAGED, MULTIPLE-USE, FOREST ECOSYSTEM

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A Thesis
Presented to
the Graduate School of
Clemson University

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In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Forest Resource Management

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by
Crystal Strickland
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Accepted by:
Dr. Jessica A. Hartshorn, Committee Chair
Dr. Donald Hagan
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Dr. Mysha Clarke

ABSTRACT

The spread of invasive plants is ecologically and economically detrimental to native ecosystems, animals, and humans. Recreation is one factor that may influence plant dispersal. The impacts of recreation on invasive plant spread are multifaceted and include the physical act of spreading and transporting seeds and vegetation to new areas on clothes, pets, and equipment, as well as the social aspect of outreach and education. Therefore, I used a multifaceted approach to assess the impact of human trafficked areas where recreational activities frequently occur on four known invasive plant species in the Clemson Experimental Forest (CEF) in South Carolina: *Microstegium vimineum*, *Ligustrum. sinense, Lespedeza cuneata,* and *Lonicera japonica*. To address the ecological component, I quantified the distribution of these species along transects at recreation trails in the CEF. To address the social component, I distributed a survey to CEF trail users that assessed their knowledge of, and attitude towards, common invasive plants.

Increasing distance from trailhead and trail edge was correlated with a decreased percent cover of *M. vimineum*, *L. sinense,* and *L. cuneata* but not *L. japonica*. Increases in litter and canopy cover significantly decreased the percent cover of *M. vimineum* but not *L. sinense*, *L. cuneata*, or *L. japonica*. This supports previous research demonstrating a positive relationship between areas of increased disturbance (i.e., trailheads) and invasive plant spread, but also suggest areas of future research regarding canopy and litter cover effects on invasive plants.

My research on social awareness indicated that survey participants were knowledgeable about the status of plants from the CEF as either native or invasive. Most

participants reported an awareness of invasive plant impacts, a belief in personal responsibility for the prevention of invasive plant spread, and a desire to purchase native plants for their own use, with Extension services often being the educational delivery method that led to a desire to participate in behaviors that help curb invasive plant spread.

Together, these results demonstrate a link between increased disturbance at recreational areas and invasive plant distribution and spread. Future research should aim to better understand the effects of microclimates, seeds banks, propagule pressure, residence time, and other environmental factors on invasive plant response to disturbance.

Additionally, research that looks at plant purchase motivations for varying property size owners' and the ability of these owners to properly identify known invasives, creating invasive education that engages the non-traditional audience, factors that may be inhibiting ecologically friendly plant production in the horticulture industry, and how to better engage minorities in ecological decision making may have a positive impact on mitigating spread by empowering forest users and landowners to contribute positively to the resources they enjoy.

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To my children, you are the most important people on this earth to me, and the reason for everything I do. You make me a better person. I love you.

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CHAPTER ONE

# ASSESSING THE SPREAD OF INVASIVE PLANT SPECIES IN A MANAGED, MULTIPLE-USE FOREST

## Introduction

The Department of the Interior's Invasive Species Advisory Committee designate an invasive species as "a non-native species whose introduction does, or is likely to cause, economic or environmental harm or harm to human health" (Beck et al., 2008). Invasive plants are often introduced as ornamentals, for food or for fiber, while others are transported accidentally through global trade, commerce, and recreational activities (Reichard and White 2001, Pimentel et al. 2005, Meyerson and Mooney 2007, Adams and Engelhardt 2009, Pyšek et al. 2012, Montagnani et al. 2022). Human connectivity continues to increase the network of available pathways to invasion, which can lead to ecosystem degradation (Chapman et al. 2019, Pyšek et al. 2020). Of the ~20,000 plants currently found in ecosystems around the United States, approximately 23% are invasive species introduced by human activities, both intentional and unintentional, however this number could be severely underestimated as we currently do not know how many invasive plants have yet to be recorded (Pimentel et al. 2005, Qian and Ricklefs 2006) and no recent updates have been made on these estimates.

Recreational activities can precipitate the spread of invasive plants in forest ecosystems through trail use by creating satellite colonies as plants are moved from trailhead to trailhead on foot, hoof, paw, or tire tread (Wallinga et al. 2002, Pickering et al. 2007, Allen et al. 2009), and through soil disturbance which promotes opportunity for invasion (Presotto et al. 2020). Regardless of the introduction method, not all escaped non-native species will become invasive, as they must pass certain barriers to become problematic. The Tens Rule is a hypothesis that states, for each barrier to invasion between introduction and establishment, 10% of non-native plants will successfully overcome each barrier and pass into the next stage of invasion (Williamson et al. 1986). That results in approximately 0.01% of non-native introductions becoming invasive (Williamson and Fitter 1996, Richardson et al. 2000). The Tens Rule, however, underscores the seriousness of invasive species because even one species that manages to overcome all the barriers to become invasive within a community can have disastrous ecological and economic impacts as they dominate the surrounding community (Williamson and Fitter 1996, Richardson et al. 2000, Jarić and Cvijanović 2012, Brewer et al. 2018).

While the Tens Rule attempts to address the likelihood of a successful invasion occurring, it does not give weight to the various mechanisms of invasive plant spread or their impacts on native ecosystems (Adams and Engelhardt 2009). As the science of invasion ecology grows, having clear definitions helps create a universal framework for understanding plant invasions (Blackburn et al. 2011). Plant invasion occurs when non-native plants are introduced to a new area, begin to reproduce, and their progeny begin to invade surrounding areas (Williamson and Fitter 1996, Richardson et al. 2000). The economic costs associated with non-native invasive species is estimated at $1.288 trillion dollars in the United States alone, but this amount could be underestimated since nearly half of these species have not been evaluated and described regarding economic loss

(Zenni et al. 2021). Invasive plants have the capability of being one of the greatest natural disasters, with long-lasting implications on economic and ecological stability, and biodiversity conservation around the world (Elton 1933, Coblentz 1990, Aronson and Handel 2011, Crystal-Ornelas et al. 2021).

*Spread and Ecology of Invasive Plants*

Invasive plants are frequently spread through human activities with invasion most likely to occur in areas with high population densities and areas of disturbed soils on the edges of forest ecosystems (Williamson and Fitter 1996, Yates et al. 2004, Loewenstein and Loewenstein 2005). Roadways contribute to plant dispersal through increased levels of traffic, altered hydrology, and fragmentation of natural ecosystems (Loewenstein and Loewenstein 2005, Trombulak and Frissell 2000). The fragmentation of habitats creates access points for plant species to invade (Flory and Clay 2009; Flory and Clay 2010). Invasive plant species spread easily along roads as they provide optimal light and frequent disturbance (Hansen and Clevenger 2005).

Invasive trees, shrubs, herbs, grasses, and forbs have been expanding their range across North America at alarming rates due to human development and travel (Moser et al. 2009, Pyšek et al. 2020) and have been recorded causing ecological impacts on native communities. For example, *Alliaria petiolata* (M. Bieb.) Cavara and Grande), a shade tolerant and highly proliferative invasive plant found in disturbed areas on forest edges and closed-canopy ecosystems, alters the functional capacity of arbuscular mycorrhizal fungi by disrupting their germination, which leads to slower growth of native hardwood trees (Stinson et al. 2006). *Microstegium vimineum* (Trin.) was found to induce declines in species richness of native species during the peak growing season of *M. vimineum* when they overtake native plants in height, precipitating long-term consequences to native biodiversity (Adams and Engelhardt 2009). In New England, *Fallopia japonica* (Houtt.) has invaded roadsides and riparian areas, and has altered species diversity, above ground biomass, and nitrogen concentrations, while leading to drastically altered monocultures (Aguilera et al. 2010). Removing invasive species can increase native species diversity, such as native bee diversity in the southeastern United States with the removal of *Ligustrum sinense* (Hanula and Horn 2011).

Invasive plants pose a wide range of problems on forest ecosystems and can cause a significant impact on the health and function of the surrounding plant communities, potentially causing bottom-up effects on herbivores and wildlife (Aguilera et al. 2010, Aronson and Handel 2011, Pyšek et al. 2012). Their establishment can alter ecosystems in ways that result in biotic homogeneity by negatively impacting the growth and fitness of native plants, causing a loss of species diversity, abundance, and native biomass (McKinney 2004, Vilá and Weiner 2004, Qian and Ricklefs 2006, Vilá et al. 2018). Plant invasions also contribute to a decrease in both fitness and abundance of reptiles, invertebrates, and higher trophic animal levels when invasive impacts alter the primary productivity of an ecosystem. (Gibbons et al. 2000, Gerber et al. 2008, Vilá et al. 2011).

Plant invasions impact soil composition and nutrient cycles, with the magnitude of impact at least somewhat depending on the morphological and phenological similarity between the invading species and those it replaces (Ehrenfeld 2003, Vanderhoeven et al. 2005, Ashton et al. 2005). Depending on the native soil type, plant invasions frequently increase biomass and net primary production, which has greater impacts on soil composition and nutrient cycling (Ehrenfeld 2003). Impacts on soil chemistry through changes in nitrogen availability, soil pH, phosphorous, aluminum concentration and nutrients because of invasive plants can alter forest biota, lower microarthropod diversity and ultimately, forest succession (McLendon and Redente 1992, McGrath and Binkley 2009).

Plant invasions can change microbial communities, with the greatest changes occurring after multiyear successions, leading to the potential for disrupted ecosystem fitness and function (Batten et al. 2006, Rodrigues et al. 2015). Soil bacteria and fungi was changed by the invasion of *Lespedeza cuneata* with increased intensity based on length of invasion (Yannarell et al. 2011). In areas where there have been long-lasting plant invasions, the impacts to soil biota and chemistry can persist for many years after invasive plants have been removed, disrupting the ability for native plants to progress through native seral stages, especially in areas where invasive plants have caused extirpation of native species (Corbin and D'Antonio 2004, Flory and Clay 2010, Corbin and D'Antonio 2012). The invasion of *Imperata cylindrica* (L.), a non-native invasive plant spreading across the southeastern United States, did not produce significant changes in soil nitrate availability between invaded and uninvaded control plots, however, eradication did produce short-lasting significant changes on soil nutrient cycling (Hagan et al. 2013a). *Imperata cylindrica* has allelopathic exudates that disrupt the mycorrhizal symbiosis and inhibit fine root development (Hagan et al. 2013b).

Plant evolution has given rise to a wide array of seed and fruit dispersal methods; for example, hooks and barbs allow seeds to attach to passing animals, plumes, and wings (Ray and Bordolui 2021). High surface to volume ratio allows for wind dispersal, surface tension for water transport, and edible flesh entices animals to consume fruit and later deposit seeds at other locations, containing seeds via their excrement (Howe and Smallwood 1982). Soil seed banks can last for years, allowing for continued dispersal of invasive plants (Ray and Bordolui 2021).

*Forest Use and Management*

Silviculture is the foundation of forest management around the world, and the United States Forest Service definition, "the science of controlling the establishment, growth, composition, health, and quality of the forests and woodlands to meet the diverse needs and values of landowners and society, such as wildlife habitat, timber, water resources, restoration, and recreation on a sustainable basis," paints the picture of a multiple use forestry model (USDA Forest Service 2022). The Multiple Use – Sustained Yield Act of 1960 was the first attempt at regulating silviculture within United States National Forest land but gave little guidance on what multiple use meant (Wilkinson and Anderson 1985). These acts were followed by The Forest and Rangeland Renewable Resources Planning act of 1974 and its amendment, the National Forestry Management Act of 1976, which gave more guidance about managing forests for sustainable harvesting, wildlife, and recreational use (Wilkinson and Anderson 1985). These acts paved the way for the modern multiple use model of forest management, which requires federal forest managers to take into consideration the impacts of timber harvest on wildlife, human recreational activities, hunting, and water flow, while providing a place for recreation, scenic viewing, scientific research, and historical value (Bowes and Krutilla 1985).

According to the U.S. Forest Service there were nearly 150 million visitors to our National Forests every year from 2014 through 2018, with the primary reason being recreational activities (USDA Forest Service 2020). This number increased to approximately 161 million visitors by 2020 as Americans sought outdoor activities in the covid world (Outdoor Foundation 2021). Of these visits, 46.7% are utilizing the forest for hiking/walking, 5.3% use the forest for biking, and 0.7% of users are on horseback (USDA Forest Service 2020; Table 1.1). Approximately 24 million of these visits happen in National Forests in the southeastern United States, and they require a large network of roads and trails to provide access for visitor access (USDA Forest Service 2020).

The Clemson Experimental Forest (CEF) is state land managed by Clemson University and has similar recreational use to federally managed forests. As gateways to the forest, trailheads are the areas with the most activity, and create the greatest chance for plant invasion to occur (Flory and Clay 2009, Minor and Gardner 2011). Trailheads and areas of elevated human activity experience high levels of invasive plants, with activities such as motorized vehicle use (Yang et al. 2018), horseback riding, and hiking increasing levels of plants and their invasion potential (Barros and Pickering 2014).

*Non-native Invasive Plant Species of Concern in South Carolina*

First discovered in 1919 by entomologist George G. Ainslie along Third Creek in Knoxville, Tennessee (Fairbrothers and Gray 1972), *Microstegium vimineum* (Trin.) is a non-native Asiatic grass that has been found with increasing frequency and density across many landscapes in the eastern United States after presumably arriving in the United States through packing materials (Fairbrothers and Gray 1972, Loewenstein and Loewenstein 2005, Michigan Invasive Species Program 2022). It has the capacity to grow in a wide range of site conditions and can be found on riverbanks, lawns, fields, swamps, roadsides, edge habitat and deep canopied forest (Fairbrothers and Gray 1972). *Microstegium vimineum* is tolerant of light conditions from 5% to full sun and grows well in light conditions where other species fail to thrive, which gives it a competitive advantage (Winter et al. 1982). It does not spread as easily in undisturbed sites but has the capacity to rapidly invade periodically disturbed areas and completely replace ground vegetation by year five of invasion on fertile mesic sites (Barden 1987, Bowen et al. 2002).

Invasion of *M. vimineum* reduces native biomass and lowers the species richness and diversity of native plants, lowering the ability of native plant communities to rebound through restoration efforts (Flory and Clay 2010). Its range expands slowly on its own, and the rapid dispersal on trails and roads may be human mediated (Rauschert et al. 2010). Seeds can lay dormant for up to five years, and a persistent seed bed may develop, making eradication nearly impossible (Barden 1987, Gibson et al. 2002). Increased abundance of *M. vimineum* reduces species richness, lowers the reproductive potential of the forest canopy, negatively impacts overstory regeneration, and has long-lasting impacts on biodiversity (Loewenstein and Loewenstein 2005, Adams and Engelhardt 2009, Aronson and Handel 2011). *Microstegium vimineum* density physically prevents establishment of other species' seedlings and reduces the rate at which competing species grow; this can slow the rate of succession in forest ecosystems (Marshall et al. 2009, Flory and Clay 2010).

*Ligustrum sinense* (Lour.) is native to China, Taiwan, and Vietnam and was brought to the United States in 1852 for ornamental purposes (Dirr 1983), had become naturalized by 1932 (Small 1933), and is now considered invasive across the southeast (Dirr 1983). *Ligustrum sinense* grows aggressively in disturbed sites such as floodplains, riparian areas, plowed fields, ditches, and forest edges with abundant light (Merriam and Feil 2002). However, it also creates dense cover in interior forest sites and can grow in a variety of site conditions, with leaf litter and canopy closure being a strong predictor of invasion (Hagan et al. 2014). It establishes well-stocked seed banks that are frequently transported by birds and can grow in the understory of undisturbed forests due to its shade tolerant characteristics (Brown and Pezeshki 2000, Panetta 2000, Grove and Clarkson 2005). Its shade tolerance and ruderal characteristics allow *L. sinense* to choke out the understory, preventing light from reaching the forest floor, lowering native species richness and abundance (Merriam and Feil 2002, Wilcox and Beck 2007, Green and Blossey 2012). Once established, *L. sinense* is very difficult to eradicate, but removal has been found to increase bee diversity and richness (Hanula and Horn 2011), while simultaneously improving native plant communities by promoting the growth of diverse native species that drive secondary succession (Hudson et al. 2013, Hudson et al. 2014). With minimal success in the eradication of *L. sinense*, biological controls, such as the introduction of lace bugs (*Corythucha ciliata* (Say)) and the sap sucking tingid bug

(*Leptoypha hospita*) were being studied as methods of mitigation (Zhang et al. 2011, Zhang et al. 2013), but to date research continues to seek additional methods of successful eradication.

*Lespedeza cuneata* ((Dum-Cours) G. Don.) is native to Asia and was introduced to the United States in 1896 by McCarthy with the North Carolina Agricultural Station (McCarthy 1896). Experimental plantings of *L. cuneata* in 1900 escaped cultivation and were found in remote areas surrounding the Arlington Experiment Farm in Virginia by 1925 (United States Department of Agriculture 1950). By the 1940's it was promoted for erosion control, wildlife food and cover, and cattle forage (Smith 2008, United States Department of Agriculture 2011, Cummings et al. 2017). *Lespedeza cuneata* can be found growing from Ohio through the southeastern United States and westward towards Texas (Duncan and Clark 2005, United States Department of Agriculture 2011). It escapes from cultivated sites and spreads into forested areas with abundant water, displacing native species (Silliman and Maccarone 2005, United States Department of Agriculture 2011, Cummings et al. 2017). As a nitrogen fixing legume, it is often one of the first species to take hold in disturbed sites (Ritchie and Tilman 1995). The most common method of transport is through animal movement due to the lack of morphological characteristics seen in species that travel by air or water (Blocksome 2006). *Lespedeza cuneata* is a drought tolerant species that does well in poor soil conditions and grows in many different habitats, such as forests, fields, and swamps (Isely 1948, Miller 2006, Cummings et al. 2017). Its competitive nature prevents the reestablishment of desirable native species and threatens the health of varying habitats by releasing allelopathic chemicals into the soil and changing soil chemistry (Kalburtji and Mosjidis 1993, Eddy et al. 2003, Zedler and Kercher 2004, Silliman and Maccarone 2005, United States Department of Agriculture 2011). It grows best in abundant light, which does slow the spread under native canopy, but seed banks persist and can take hold when disturbance increases light availability (Brandon et al. 2004). Eradication efforts have shown limited success on established plants, and in some areas prescribed fire and mowing has shown to increase plant abundance (Brandon et al. 2004, Wong et al. 2012, Cummings et al. 2017).

*Lonicera japonica* (Thunb.) is a non-native semi-woody vine from China and Japan (Bor and Raizada 1943) that was introduced for ornamental cultivation in the 1800's (Rehder 1903). It escaped cultivation and was later found along the Potomac River (Hardt 1986, Schierenbeck 2004). Having the ability to spread through both seed (sexual) and vegetative (asexual) reproduction, it has become established in 45 states and remains one of the most invasive species in the southeastern United States, thriving in forests, fields, and disturbed lands (Schierenbeck 2004, Wang et al. 2012, Bravo 2019). *Lonicera japonica* will increase its seed dispersal investment by as much 60% to ensure success in competing against native species (Murray and Phillips 2009). It has a wide range of tolerance for soil pH levels, with the ability to establish in acidic soils with a pH of 4 and alkaline soils with a pH of 8 (Schierenbeck 2004). It thrives best in mesic soils but is intolerant of saturated soil conditions (Schierenbeck 2004). As marginal populations evolve to withstand colder temperatures, *L. japonica* will continue to spread to northern latitudes (Kilkenny and Galloway 2016).

*Lonicera japonica* can be a severe problem in forestry as it dominates the understory and smothers tree seedlings, preventing them from establishing, and strangling overstory trees as they climb in competition for light (Cain 1985, Webster et al. 2006). There is also evidence that suggests *L. japonica* is allelopathic (Skulman et al. 2004, Ladwig et al. 2012). Systemic herbicides have been effective at controlling the spread of *L. japonica*, but unintended impacts on other plants must be considered when using herbicides for invasive control (Bravo 2019).

*Objectives*

My overall goal was to assess the effects of recreation on the distribution of four non-native invasive plant species of concern in South Carolina (i.e., *M. vimineum*, *L. sinense*, *L. cuneata*, and *L. japonica*). My objectives were to determine the effects of 1) distance to trailhead and trail edge and 2) canopy cover and litter cover on distribution and abundance of these four species. I hypothesize that 1) percent cover of all four species will decrease with increased distance from trailheads and trail edges and that 2) canopy cover and litter cover will negatively affect percent cover of these four species due to reduced light availability and access to the soil bed.

## Methods

*Site Description*

The research area is located within the Clemson Experimental Forest (CEF) (34.738017, -82.841439), which spans 7,081 hectares surrounding Clemson University, in Oconee, Pickens, and Anderson Counties in South Carolina (Clemson Public Service and Agriculture 2022; Figure 1.1). Elevations range between 198 and 304 meters above sea level. The predominant soil within the CEF is Pacolet (fine, kaolinitic, thermic Typic Kanhapludults) but Catula (fine, kaolinitic, thermic Oxyaquic Kanhapludults) and Cecil (fine, kaolinitic, thermic Typic Kanhapludults) can also be found in certain areas (USDA Web Soil Survey 2021). Since 1991, monthly rainfall ranged between 8.8 cm to 12.47 cm, with monthly low temperatures ranging between 0.89°C to 21.06°C and monthly high temperatures ranging between 11.06°C to 31.5°C (National Oceanic and Atmospheric Administration 2021; Table 1.2). Among the various forest types in the CEF, there are 2690 hectares of planted pine, 1268 hectares of cove hardwood, 1142 hectares of upland hardwood, 918 hectares of pine-hardwood mix, and 878 hectares of natural pine, with the remaining 185 hectares in unplanted fields or bodies of water (Clemson University Office of Land Management 2008, Clemson Public Service and Agriculture 2022; Table 1.3). Three trail systems are divided among three areas: Todd's creek 29 kilometers long), Fants Grove (64 kilometers long), and Issaqueena/Keowee Heights (76 kilometers long), with dozens of formal and informal trailheads dispersed throughout the CEF (Figure 1.2).

*Experimental Design*

In September and October of 2015, a group of undergraduate students used geographic information systems (GIS) and field surveys to identify potential study sites within the CEF for analyzing the distance from trailhead and trail edge that herbaceous non-native invasive plants had spread. Fourteen trails (Figure 1.3) were identified that met the following criteria:

- Directly connected to an improvement (paved or maintained) road or trailhead

- No evidence of recent maintenance or repair (mowing, grading, etc.)
- No streams, other roads, or trail intersections in the first 100 meters of the trail
- At least 25 meters (to the side) from the nearest trail or stream

At each of the fourteen trailheads identified, five transects were established, starting at the edge of the trail, at distances of 0, 5-, 10-, 25-, and 50-meters from the trailhead. Each transect consisted of four plots at 0, 2, 4, and 12 meters from the transect beginning (Figure 1.4). Each plot was created using a 2 x 1-meter portable PVC frame, totaling 20 sample plots per trailhead. Within each frame, the four non-native invasive plants were identified and counted (Figure 1.5), percent litter, cover, and soil exposure were estimated, and canopy cover was estimated using a convex spherical densitometer (Figure 1.6) to measure the degree of darkness (optical density) from the center of each sampling plot.

*Statistical Analyses*

To assess the relationship between distance to trailhead, distance to trail edge, and the percent cover of the four recorded non-native invasive species, binomial regression was conducted for each focal species individually and for the total invasives recorded at each site. In the binomial regression, percent cover of native species or bare ground was considered the "success" while percent cover of the invasive was the "failure". To determine the relationship between canopy cover and litter cover, and the percent cover of four recorded non-native invasive plants, a generalized linear regression model was created for each variable (litter cover and canopy cover) for each invasive species, as well as for the total invasives recorded at each site. All statistics were completed using R statistical software Version 4.1.3 (R Core Team 2020).

**Results**

*Distance to Trailhead and Trail Edge*

As distance from trailhead increased, the percent cover of *M. vimineum* (z = -10.56, p<0.0001), *L. sinense* (z = -9.95, p<0.0001), and *L. cuneata* (z = -10.03, p<0.0001) significantly decreased but percent cover of *L. japonica* was not affected (z = 1.18, p=0.237; Figure 1.7). As distance from trail edge increased, there was a significant decrease in the percent cover of *M. vimineum* (z = -8.33, p<0.0001), *L. sinense* (z = -3.43, p<0.0006), and *L. cuneata* (z = -4.27, p<0.0001), but not of *L. japonica* (z = -0.12, p = 0.905; Figure 1.8). A significant interaction did exist between trailhead and trail edge, with *M. vimineum* percent cover decreasing as distance from both increased (z = -8.25, p = <0.0001). When including the interaction term of trailhead and trail edge, there was a significant decrease in *M. vimineum* percent cover with increasing distance from trailhead (z = -2.26, p = 0.0238), but the main effect of trail edge no longer existed (z = -0.53, p = 0.5930). There was no significant interaction between trailhead and trail edge on *L. sinense* (z = -1.12, p = 0.2635) or *L. cuneata* (z = -0.34, p = 0.7372).

*Canopy and Litter Cover*

As litter cover increased, there was no effect on the percent cover of *L. sinense* (t = 0.99, p = 0.325), *L. cuneata* (t = -0.25, p = 0.801), or *L. japonica* (t = 1.01, p =0.316), but an increase in litter cover significantly decreased the percent cover of *M. vimineum* (t = -6.19, p = <0.0001; Figure 1.9). As canopy cover increased, there was no effect on the percent cover of *L. sinense* (t = 1.80, p = 0.0735), *L. cuneata* (t = 1.55, p = 0.1224), or *L. japonica* (t = -0.07, p =0.9470), but an increase in canopy cover significantly decreased the percent cover of *M. vimineum* (t = -3.29, p = <0.0012; Figure 1.10).

**Discussion**

Trailheads and edges experience frequent disturbance and highly eroded soils (Salesa and Cerdà 2020), which create opportunities for invasion by invasive plants (e.g., Silliman and Maccarone 2005). Distance from trailheads and trail edges showed a significant relationship between percent cover of *M. vimineum*, *L. sinense*, and *L. cuneata*, but not *L. japonica*. *Microstegium vimineum* moves into areas that other grasses are unable to inhabit but its methods of spread are still poorly understood (Winter et al. 1982). Since *M. vimineum* lacks certain characteristics that often facilitate invasive plant spread (e.g., wind dispersal, attachment to animals) and its spread has been associated with small scale flooding events (Miller and Matlack 2010), this suggests that it most likely spreads by gravity and soil disturbance (Christen and Matlack 2008). If gravity is a primary means of *M. vimineum* seed dispersal, movement of soils following disturbance that occurs with human recreation could be a catalyst for accelerated spread (Rauschert et al. 2010). Soil disturbance, in turn, increases water movement, which has also been shown to facilitate the spread of *M. vimineum* (Tekiela and Barney 2013). *Ligustrum sinense*' ability to grow in disturbed sites (Merriam and Feil 2002) means that it may have an advantage in areas of high human traffic (i.e., recreation trails). *Lespedeza cuneata* is a light loving species (Brandon et al. 2004) and thrives in areas where frequent disturbance keeps overstory light competition at bay (Erfanian et al. 2021). As a nitrogen fixing legume, once soil disturbance has occurred, it quickly takes hold, outcompeting native species (Ritchie and Tilman 1995). While *L. japonica* is frequently associated with disturbance from anthropogenic activities as well as land use and management (Wang et al. 2012), it is also found in late successional forests with little disturbance (Drake et al. 2003).

Areas of dense overstory and increased litter create areas of low light penetration, impacting vegetation cover and species composition. Recreational trails and areas of high human activities create open corridors of available light, facilitate soil disturbance, and diminish litter cover, with the most significant impacts seen in soil surface organic matter where most seed banks are found (Zabinski et al. 2000). Increases in canopy cover and litter cover significantly decreased *M. vimineum* cover but had no effect on *L. sinense*, *L. cuneata*, or *L. japonica*. Previous studies have found that *M. vimineum* can grow 4.5 times faster in areas where litter has been removed (Oswalt and Oswalt 2007). Conversely, *L. sinense* thrives in riparian forests in highly disturbed sites with abundant light (Merriam and Feil 2002) but can also grow deep within forest interiors with low light availability and disturbance (Hagan et al 2014). While my results do not suggest a significant impact of canopy or litter cover on *L. cuneata*, other studies have found the opposite (e.g., Lázaro-Lobo et al. 2021). However, this study utilized data from different site types that were collected in a different manner. These contradictory results suggest that other factors may mediate the response of *L. cuneata* to canopy and litter cover, and this may affect its spread and distribution. *Lonicera japonica* exhibits a lot of plasticity and responds differently to varying microclimates, possibly explaining the lack of a significant effect by any variable tested (West et al. 2010).

The interaction between trailhead and trail edge had significant effects only on *M. vimineum* but not *L. sinense*, *L. cuneata*, or *L. japonica*. However, when viewing an interaction between trailhead and trail edge, the main effect of distance from trail edge was lost for *M. vimineum*. These changes in main effects may indicate other factors that may be influencing *M. vimineum* spread and abundance. For example, site factors that impact light availability, percent slope, and soil type can affect *M. vimineum* abundance (Mikhailova et al. 2017). It may be a combination of these site factors that caused the change in relationship between trail edge and trailhead in *M. vimineum* cover.

Our results, in conjunction with previous research showing greater *M. vimineum* dispersal and growth near roadsides (e.g., Huebner 2007), support a strong positive relationship between human activities (i.e., recreation) and percent cover of *M. vimineum* (Schramm and Ehrenfeld 2012, Campbell and Gibson 2001, Potito and Beatty 2005). Conversely, the other species examined, can be found both in shaded areas regardless of site location (e.g., Hagan et al. 2014) and in highly disturbed areas (e.g., Drake et al 2003). Dense overstory vegetation may help keep invasive plants from rapidly spreading, but invasion can occur further away from trailheads and edges when disturbance opens opportunity for increased light to understory seed banks (Brandon et al. 2004).

**Conclusion**

Invasive species tend to have characteristics that allow them to rapidly invade disturbed sites, and recreation activities create prime opportunities for that disturbance which is evident with the greater abundance of non-native invasive species along recreational trails (Schramm and Ehrenfeld 2012). Trailheads experience continuous human activity that declines over a gradient as distance from trailhead increases, but the same declining gradient of human activity is not seen as distance from trail edges increase, potentially slowing the spread of invasive plants away from trail edges (Yates et al. 2004, Potito and Beatty 2005). Human activity tramples vegetation (Erfanian et al. 2021) and exposes soils (Manning 1979, Deluca et al. 1998, Marion et al. 2016) leading to increased soil run-off during rain events (Grierson and Oades 1977, Scanlan et al. 1996, Wallin and Harden 1996), magnifying the potential for seed bank dispersal into areas absent of invasive plants.

Controlling and reducing the spread of invasive plants relies on mitigating human behaviors that facilitate disturbance and influence the spread of these species at hubs of recreational activity (Pyšek et al. 2012). Human mediated movement of invasive plants allows for their spread much faster and further than would otherwise occur through natural dispersal by wind, water, or air (Horvitz et al. 2017). These species, once present, are very difficult or impossible to eradicate, sometimes leading to huge economic loss with limited success (Falcão et al. 2022). Research suggests invasive species may undergo adaptive evolution in introduced areas, allowing them to overcome environmental barriers and develop increased resistance to methods of control (Ziska et al. 2015, Smith et al. 2020).

Further research is warranted to explore complex mechanisms of invasive plant spread as well as the impacts of microclimates on their response to disturbance. Our study shows that there is a higher prevalence of certain invasive plants at trailheads and along trail edges, however, observations alone do not show causation. Experimental studies that look deeper into the underlying mechanisms of invasive plant invasion help shed light on the path to invasion (Stricker et al. 2015). Studies performed in a controlled greenhouse setting, such as research on soil disturbance and seed banks (Leischman and Thomson 2005), can give additional insight to the invasion process, but will struggle to replicate all natural processes found in a forest ecosystem. Studies that introduce invasive species to an area could allow researchers to monitor the invasion process from the onset and tease out mechanisms that drive the invasion process for target species (Leischman and Thomson 2005, Kempel et al. 2013).

Recreationists can contribute to the spread of invasive plants in both positive (e.g., spreading knowledge, hand-pulling invasives) and negative (e.g., tracking seeds, disturbing soil) ways. Therefore, factors that influence behaviors and activities of recreationists are important to better understand how to improve invasive plant management and control while promoting the responsible use of our forests.

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# CHAPTER TWO

# ASSESSING RECREATIONISTS' KNOWLEDGE ON INVASIVE PLANT SPREAD AND MOTIVATIONS TO MANAGE

## Introduction

### *Recreational impacts on invasive plants and the environment*

Human movement and connectivity may have an impact on the expansion of invasive species (Chapman et al. 2019, Falcão et al. 2022) through forest road management (Rauschert et al. 2009), recreation (Dickens et al. 2005), and agricultural activities (Montagnani et al. 2022). Roadside plant communities, especially trailheads and trail destinations where there are elevated levels of human activity, experience increased levels of invasive plants that threaten native biodiversity (Moser et al 2009, Manee et al. 2015, Yang et al. 2018, Falcão et al. 2022). Recreational trails are a major corridor for invasive plant dispersal with areas of high motorized vehicle use, horseback riding, and hiking experiencing heightened plant invasion, even in protected natural areas (Barros and Pickering 2014, Yang et al. 2018). Recreational activities have a strong influence on the spread of invasives, in part due to the connections that human activities create between areas that would normally have been separated by natural barriers (Chapman et al. 2019), with human activities spreading invasives at a much greater distance than natural dispersal methods (Horvitz et al. 2017). Additionally, recreation activities increase soil erosion (Salesa and Cerdà 2020) which impact invasive plant dispersal (Truscott et al. 2006), especially following rain events (Mohamadi and Kavian 2015, Wen et al. 2015).

*Invasive plant impacts on human wellbeing and health*

While there has been significant research on the ecological impacts of invasive species (Ehrenfeld 2003, Stricker et al. 2015), a growing number of scientists aim to establish a better understanding of the social, emotional, physical, and financial impacts on communities surrounded by ecosystems that have been negatively impacted by environmental change (MacKerron and Mourato 2009, Jones 2017). Human connection to the natural environment has positive effects on overall mental and physical well-being (MacKerron and Mourato 2009, Hartig et al 2014). Invasive plants negatively impact humans by decreasing mental and physical wellbeing (MacKerron and Mourato 2009, Donovan et al. 2013, Hartig et al 2014, Marselle et al. 2019, Shackleton et al. 2019a, de Vries and Snep 2019). Not all introduced plants change our natural environment in a way that creates negative ecological, financial, or social-emotional change (Schlaepfer et al. 2011, Aerts et al. 2018), which makes plant invasion a science of human dimensions (Epanchin-Niell et al. 2010) as we seek to understand the driving factors of human perception on invasive plant species (Pejchar and Mooney 2009).

*Invasive Species' Impact on Mental Wellbeing*

It is not enough to just consider the ecological factors at play when combatting plant invasions, as there are many factors that influence environmental decision making at the individual level, with finances and human health being strong predictors of environmental behavior (Gifford and Nilsson 2014). Finances and human health have broader implications to human values because they impact areas of human wellbeing not related to environmental concerns (Gifford and Nilsson 2014) which may require education aimed at utilizing social influence, feelings of independence, and the tangibility of actions associated with environmental actions (White et al. 2019). Humans often seek a sense of self, well-being, and mental clarity by utilizing nature (Brymer et al. 2020), with forests and recreation being positively associated with better overall health and mental happiness (Jones 2017, Aerts et al. 2018, Nowak et al. 2018, Stier-Jarmer et al. 2021) but also with the unintentional spread of invasive plants (Chapman et al. 2019, Pyšek et al. 2020). The degradation of environmental quality then impacts people's mental and physical health (Donovan et al. 2013, Marselle et al. 2019, Shackleton et al. 2019a, de Vries and Snep 2019).

*Human Dimensions of Invasion*

Reducing the spread of invasive species hinges on human values, public perceptions, and stakeholders' willingness to purposefully maintain actions that inhibit invasive spread (McLeod et al. 2015). Unfortunately, research regarding the human dimensions of invasive species is growing but still limited in comparison to the number of ecological studies (Estevez et al. 2015), but a recent study looking to understand effective outreach on invasive species found that raising awareness may be one of the key approaches in modifying human behavior (Solano et al. 2022) The negative impacts on people's mental and physical well-being alone may not equate to environmental action, as perceptions and attitudes towards invasive management vary among stakeholders, creating a significant barrier to invasive species management (García-Llorente et al. 2008). This lack of support is also fueled by a lack of understanding about human perceptions, behaviors, and attitudes in decision making processes (Andreu et al. 2009, Kapitza et al. 2019). Invasive species management has long used science and policy to mitigate the spread of invasive species, but often does not consider the social dimensions behind invasive species prevention and spread, thus causing pushback from the public (Bremner and Park 2007, Sievanen et al. 2012, Crowley et al. 2017, Head 2017).

Humans may instinctively push back against policies that utilize harsh tactics towards compliance (Koslowsky et al. 2001, Schwarzwald et al 2001, Kapitza et al. 2019) and leave the stakeholder with the belief that their freedoms have been restricted (Jakobsson et al. 2000). Policies surrounding invasive species control may struggle to gain traction due to the publics' opinion on governmental credibility (Warner and Kinslow 2013). While most members of the scientific community may view a species as invasive and damaging, there may also be other scientists and non-expert public who may perceive the same species as beneficial to individuals or communities, creating conflict when these social, cultural, and emotional beliefs are not considered in policy making processes (Davis et al. 2011, Schlaepfer et al. 2011, Shackleton et al. 2019b).

People of Color are severely underrepresented in outdoor recreation due to the privilege that the education and income of their White counterpart's experience (Schultz et al. 2019, Davis 2019). There is also a system of bias and discrimination for minorities that has persisted since the middle of the 20$^{th}$ century (Stanfield et al. 2005). The number of ethnic minorities and Caucasians will continue to narrow, with less than half of the U.S. population projected to be white by the middle of the 21$^{st}$ century (Colby and Ortman 2015). Parks and recreation currently struggle to meet the needs of this changing demographic (Davis 2019), and with different minority groups having different values, it may require different management strategies for recreational areas (Ordóñez-Barona 2017). Previous research has shown there are differences in the type of recreation preferred by minorities and whites (Virden and Walker 1999, Buijs et al. 2009), and a different preference for where the recreation occurs in wildlife and urban settings (Kaplan and Talbot 1988, Yoon and Lee 2019), often because of historical oppression (Johnson et al. 2004). With a growing understanding that a sense of place may drive environmental decision making, environmental education is lacking in the use of this method of connection to nature (Thomashow 2002, Kudryavtsev et al. 2010).

*Motivations and Responsibility*

Self-efficacy, the belief that you can be successful when completing a task (Bandura 1997), may alter the way people perceive their personal responsibility in invasive species management. There are many drivers, such as cultural identity, natural resource stewardship, decision-making autonomy, socio-cultural context, benefits, and costs that influence perceived behavioral control on conservation actions (Shackleton et al. 2019b, Perry and Davenport 2020). If there is a belief that personal actions will have no influence or create negative impacts, self-efficacy and motivation may remain low (Perry and Davenport 2020) thwarting attempts at invasive plant management (Clarke et al. 2021a). Increased self-efficacy can be acquired through successfully completed actions or personal observations of others completing tasks correctly (Zulkosky 2009) which may translate to the belief that one’s actions may have an impact on invasive species management (Pradhananga and Davenport 2022). This further demonstrates the need to better understand factors affecting self-efficacy and sense of responsibility which can be used to motivate people to actively manage invasive species (McLeod et al. 2015).

Invasive plant knowledge is gained through education, extension services, friends, family, citizen science, volunteer groups, the news, and other forms of social media (Krasny and Lee 2002, Crall et al. 2015, Blood 2016, Clarke et al. 2019, Pinkerton et al. 2019). Social media usage is growing at an unprecedented rate and is significant source of connectivity between people (Twenge et al. 2019, Abi-Jaoude et al 2020). Younger generations of people are actively engaged in social media, making it a useful mechanism for generating pro-environmental education and behavioral changes (Fischer et al. 2023). Diverse groups of people are active on social media with many using these platforms to share personal experiences, both positive and negative (Laudy et al. 2020, Koen and Newton 2021, Vitale et al. 2021). Social media frequently uses message framing to reach target audiences (Radler et al. 2020), with images that illicit gut reactions having effects on their decision-making process (Shaw et al. 2021). Social media may provide a platform for sharing invasive species education for a broad audience of people (Blood 2016). Media coverage of invasive plants influences public and stakeholder perceptions in a way that may create conflict with managers, indicating that there is a greater need for the study of educational delivery methods that will reduce misinformation and increase public support for invasive plant management (Sharp et al. 2011).

Social norms are the influence of perceived social pressure to conform to a certain accepted standard (Cialdini and Goldstein 2004, Hong and Kacperczyk 2009, Mollen et al. 2010), which can influence a person’s receptiveness to environmental policy and behavioral changes (Minato et al. 2010, De Groot and Schuitema 2012, Niemiec et al. 2016, Collado et el. 2019, Lubeck et al. 2019). Social norms, how one may perceive other people as acting towards a situation, can influence personal norms, and be a predictor of altruistic environmentally conscious behaviors (Schwartz 1977, Dwyer et al. 2015). Social norms can help predict ecological behaviors (Schwartz 1977, Dwyer et al. 2015) and the use of social media to influence social norms may increase public willingness to act on the suppression of invasive plants (Gharis et al. 2014). Social norms can be changed with active engagement through social media and extension services (Gharis et al. 2014, Koen and Newton 2021). A propensity towards conformity of social norms may be influenced by positive landowner interactions and may help facilitate collective action for invasive plant management (Niemiec et al 2016, Clarke et al. 2021b).

*Horticulture and Invasive Plant Spread*

The horticulture industry has long been a doorway for invasive species introduction, with many policies on the import of invasives being outdated (Reichard and White 2001, Drew et al. 2010, Liebhold et al. 2012). While only a small portion of plants in the horticulture industry escape cultivation, approximately 61% of plants sold by the horticulture industry are invasive plants that have catastrophic impacts on native plants, biodiversity, and ecosystems (Reichard and White 2001, Baskin 2002, Mack and Erneberg 2002, Beaury et al. 2021, Clarke et al. 2021b). Increases in personal wealth often correlate with increased spending on horticultural products (Posadas et al. 2021), and the 2019 Census of the Horticultural Specialties report showed the industry had grown to $13.8 billion in the United States (United States Department of Agriculture

2020). Ornamental non-native plants purchased for home properties can escape through natural dispersal methods into native forests, replacing native plant species and reducing food web complexity (Burghardt et al. 2010, Narango et al. 2017, Padayachee et al. 2017), with some studies reporting up to 33% of plant species along rural-to urban gradients being non-native (Loewenstein and Loewenstein 2005).

Willingness to prevent the spread of invasive plants can be increased through education (Crall et al. 2013), but there can be a complacency in prevention strategies where people believe invasion is a natural part of an ecosystem (Bardsley and Edwards-Jones 2006). Invasive plants continue to be sold as ornamentals, with new exotics being introduced as the industry grows (Gagliardi and Brand 2007, Drew et al. 2010). Habituation, the diminishing of a physiological or emotional response to repeated stimuli, of invasive species through the horticulture industry can negatively impact the public's awareness and willingness to combat invasive species (Kalnicky et al. 2014). Posadas et al. 2021 used voluntary surveys over a five-year period that showed 93% of people given education through extension services later applied the information learned to their home practices.

Education aimed at helping consumers understand the impacts of invasive plants on local ecosystems may help combat plant invasion (Drew et al. 2010). A lack of knowledge related to invasive species and how human activity may influence invasive plant dispersal patterns have been identified as predictors of non-use of preventative behaviors (Drake et al. 2014, Nanayakkara et al. 2017). Individuals with knowledge of invasive issues show higher levels of support for eradication programs, demonstrating that awareness may be tied to action (Bremner and Park 2007). Greater education about environmental issues also increases the likelihood that an individual will enact environmentally proactive behaviors (Levine and Strube 2012, Robelia and Murphy 2012). A focus on public awareness to increase knowledge of invasive plant impacts can, therefore, increase overall public support towards actions aimed at reducing invasive plant spread (Novoa et al. 2017).

Humans contribute to both the spread and management of invasive plants through recreation and agricultural activities (Dickens et al. 2005, Rauschert et al. 2009, Montagnani et al. 2022). Understanding human perceptions towards invasive species management and recognizing the drivers to behavioral change will allow for development of programs that initiate lasting changes among recreationists to help mitigate invasive species spread (Kollmuss and Agyeman 2010, McLeod et al. 2015).

*Objectives*

The overall goal of my research was to assess the knowledge and awareness of recreational trail users about invasive plant species present in the Clemson Experimental Forest (CEF). To address this goal, I surveyed recreationists to evaluate 1) their ability to correctly identify invasive plant species present in the CEF, 2) sources of invasive plant knowledge, 3) where trail users purchase plants for personal use, and 4) personal beliefs regarding invasive plant prevention and management. I hypothesized that recreationists within the CEF will 1) have limited ability to correctly identify invasive plant species present in the CEF, 2) gain their invasive plant knowledge through communication through social media and with friends and family, 3) purchase most plants for personal use from big box retail stores, and 4) have high personal belief and motivation with regards to preventing and managing for invasive plants.

**Methods**

*Site Description*

The research area is located within the Clemson Experimental Forest (CEF) (34.738017, -82.841439), which spans 7,081 hectares surrounding Clemson University, in Oconee, Pickens, and Anderson Counties in South Carolina (Clemson Public Service and Agriculture 2022; Figure 1.1). Elevations range between 198 and 304 meters above sea level. The predominant soil within the CEF is Pacolet (fine, kaolinitic, thermic Typic Kanhapludults) but Catula (fine, kaolinitic, thermic Oxyaquic Kanhapludults) and Cecil (fine, kaolinitic, thermic Typic Kanhapludults) can also be found in certain areas (United States Department of Agriculture 2022). Since 1991, monthly rainfall ranged between 8.8 cm to 12.47 cm, with monthly low temperatures ranging between 0.89 °C to 21.06°C and monthly high temperatures ranging between 11.06°C to 31.5°C (National Oceanic and Atmospheric Administration 2022; Table 1.2). Among the various forest types in the CEF, there are 2690 hectares of planted pine, 1268 hectares of cove hardwood, 1142 hectares of upland hardwood, 918 hectares of pine-hardwood mix, and 878 hectares of natural pine, with the remaining 185 hectares in unplanted fields or bodies of water (Clemson University Office of Land Management 2008, Clemson Public Service and Agriculture 2022; Table 1.3). Three trail systems are divided among three areas: Todd’s creek (29 kilometers long), Fants Grove (64 kilometers long), and Issaqueena/Keowee

Heights (76 kilometers long), with dozens of formal and informal trailheads dispersed throughout the CEF (Figure 1.2).

*Survey Design and Data Collection*

We developed a survey questionnaire during the summer of 2020 to assess recreationists' knowledge, perceptions, and actions towards invasive plants in the CEF. The survey was distributed using Qualtrics (Qualtrics, Provo, UT), an online survey tool, that is widely used to collect electronic survey data. The survey had a total of 46 questions (Appendix C) and was broken into eight sections: 1) visit to the CEF, 2) knowledge and awareness of invasive plants, 3) current and past actions related to invasive plant management, 4) perceptions of responsibility towards the CEF, 5) invasive plants on their own properties, 6) future actions, 7) learning and education – recreationists motivations to learn more, and 8) socio-demographics of respondents. Respondents were given a map so that they could select the areas of the CEF they visited and shown images of native and invasive species found within the CEF to determine their ability to identify species accurately. The survey was approved by the Clemson Institutional Review Board (IRB220-205). Recreationists could take the survey at trailheads through QR codes, printed paper surveys placed at recreational trailheads around the CEF along with a waterproofed box to collect the completed questionnaires, or a web link to take the survey from a web browser. The survey was active between 28 September and 30 November 2020.

Eleven sites were chosen in the Fants Grove area in the southern Clemson Experimental Forest and fourteen locations were chosen in along the Issaqueena trail and

Todds Creek recreation areas in the northern CEF (Figure 2.1). These sites were chosen based on their use as frequently utilized trailheads. QR codes were created so that trail users could quickly access the survey online and take it through their cellular devices, and printed copies of the survey were placed at trailheads with the most frequent use and access to a covered area.

*Analyses*

Between 28 September 2020 and 30 November 2020, a total of 186 forest users responded to the survey through the Qualtrics software system. Of these surveys, 128 (69%) were completed through QR code, 50 (27%) through anonymous web links, and 8 (6%) were sent in through paper surveys. If respondents started a survey but did not answer all questions, the data from the questions answered was used on that portion of the analyses. To assess each of our four objectives, we examined response percentages for each survey question. We also created cross-tabulations through Qualtrics to quantify the effects of certain self-reported variables (e.g., familiarity with invasive plants) on responses (e.g., reported motivations and personal responsibility regarding management of invasive plants).

**Results**

*Demographics*

Of survey respondents, there were roughly an equal number of male and female respondents. Race demographics showed most respondents were Caucasian. The most common annual gross income level was <$49,999. Most respondents were employed. The highest percent of respondents had a bachelor’s degree. The most common age range of trail users was 35-44. The most common community that trail users spent their childhood in was a city with 5,000-30,000 people (Table 2.1).

*Reasons to visit the Clemson Experimental Forest*

Many trail users reported multiple reasons for visiting the CEF with the most common being exercise, enjoying scenery and aesthetics, and enhancing mental health. Fewer trail users identified spending time with friends and family, observing wildlife, and spiritual benefits as their main reasons for visiting the CEF trails (Table 2.2). Many trail users (20%) also visited other forests or wooded recreational areas, presumably for similar reasons. The most popular times of year trail users visited the CEF were fall and spring, with more than three-quarters selecting these two seasons as their primary times for visiting. Most trail users were visiting the Lake Issaqueena area (40%) or Fants Grove (19%) at the time of taking the survey.

*Ability to Correctly Identify Invasive Plants*

Most forest users indicated they were at least a little familiar with invasive species, with 11% reporting as ‘very familiar’. Still, more than a quarter felt they were ‘not familiar’ with invasive plants (Figure 2.2). Trail users who reported that they were ‘very familiar’ performed better on the identification section of the survey with 100% of respondents able to identify *M. vimineum*, *L. sinense*, *Triadica sebifera*, and *Hedera helix* as invasive and between 83% and 95% of respondents able to correctly identify the remaining invasive species of *L. japonica*, *Elaeagnus pungens*, *L. cuneata*, and *Albizia julibrissin* (Table 2.3).

Higher education levels reported that they were ‘very familiar’ with invasive plants, with recreationists that did not feel familiar with invasive plants having a wide range of education levels (Table 2.4). There was no clear correlation between recreationists’ education levels and their ability to correctly identify invasive plants (Table 2.5).

The size of property owned and managed was positively correlated with the ability of recreationists to correctly identify invasive species, with 100% of those that manage 20 or more acres able to identify the known invasive species in the CEF (Figure 2.3).

*How recreationists obtained information about invasive plants*

Respondents obtained information about invasive plants from a variety of sources, with the most common methods being through family, friends, and news media. Fewer trail users obtained information directly from educational signs posted in the CEF or from the Clemson Extension service, with the smallest percentage of people reporting a formal classroom and social media as their primary means of obtaining information about invasive plants (Figure 2.4). There was an overall trend towards the use of extension services increasing the likelihood that recreationists could correctly identify invasive plants. A classroom education was strongly linked to identifying more common invasive plants found in the CEF (Table 2.6). Recreationists who reported that they were ‘very familiar’ with invasive plants were more likely to have acquired their invasive plant knowledge from the formal classroom, while those who indicated ‘familiar’ got their information primarily from extension services, and recreationist who reported a ‘little familiar’ primarily obtained their information from family or friends (Table 2.7).

Recreationists that ‘Agree’ or ‘Strongly agree’ that they choose plants for their property that are native were more likely to get their information on invasive plants from the classroom, news media, or extension services. Recreationists that ‘Agree’ or ‘Strongly agree’ that they choose plants for their property to help increase native diversity were more likely to get their information on invasive plants from extension services. Recreationists that ‘Agree’ or ‘Strongly agree’ that they choose plants for their property to attract wildlife species were more likely to get their information on invasive plants from the classroom, extension services, from family and friends, social media, and news media. Recreationist that either ‘Agree’ or ‘Strongly agree’ that they will not buy plants that are classified as invasive plants in South Carolina were more likely to obtain their information on invasive plants from the classroom, extension services, and friends and family (Table 2.8).

*Plant Purchase*

Most of the recreationists obtained plants for their own home, with most believing it was ‘Important’ to ‘Very important’ for the plants purchased to be non-invasive, and very few believing the invasiveness of the plant to be not important (Figure 2.5). Almost half of the recreationists researched plants prior to purchase to determine whether the plant is invasive, with a large portion reading labels to determine invasiveness (Figure 2.6). Most recreationists purchased plants for their property from “big box stores”, with nearly a third choosing “local home and garden centers,” and the rest of the purchases being made from “other” or “online” (Figure 2.7). The most common place for home plant purchase came from horticulture centers like Lowes, Walmart, and Home Depot. Most recreationists that purchase plants for their home could identify the known invasive species in the CEF, with slight identification weakness in *E. pungens*, *A. julibrissin*, and *L. cuneata* (Table 2.9). Most recreationists that obtained plants for their homes also take actions to prevent or control invasive plants on their property (Table 2.10) For recreationists that obtained plants for their home, the area of land currently managed for invasive plants most often was on average 0.5 to 1 acre in size, followed in size by zero to 0.5 acres, one to five acres, five to twenty acres, and the smallest percentage owning twenty acres or more (Figure 2.8).

*Motivations and Responsibility for Prevention and Spread of Invasive Plants*

Most recreationists, regardless of their familiarity with invasive species, ‘Agree’ or ‘Strongly agree’ in a personal responsibility to reduce the spread of invasive plants. Recreationists that felt they were ‘Very familiar’ with invasive species have a much stronger sense of self responsibility than those who were “Not familiar’ with invasive species. Regardless of self-reported familiarity with invasive species, most recreationists believed that it was Clemson University’s responsibility to reduce the spread of invasive species (Table 2.11).

Most recreationists take actions to prevent the spread of invasive plants in the CEF, with the highest percentage reporting the action taken as cleaning their shoes, their recreational equipment, or their pets, while the smallest percentage reported cleaning their tires (Table 2.12). For the recreationists that use other actions to prevent the spread of invasive plants in the CEF, they all reported pulling rogue plants as the action taken.

A vast majority of recreationists take action to prevent the spread of invasive species in the CEF because they understood the impact invasive plants have on native plants, they wanted to make a positive impact on the environment, or because they felt it was the right thing to do. A smaller percentage of recreationists reported taking action to prevent the spread of invasive species in the CEF because they thought it was easy to do, they had read or heard about invasive impacts on native plants through media, extension, or publication, or family and friends told them to do it. Still less were the recreationist that take no action to prevent the spread of invasive plants in the CEF (Figure 2.9).

Recreationists that take no action did so primarily because they did not know what actions to take (44%), did not know that they should take action (36%), did not believe their actions impact the spread of invasive species in the CEF (9%), did not believe invasive plants are an issue in the CEF (3%), believe it takes too much time (2%), they sometimes forget (1%), or reported as other reason not specified (6%; Figure 2.10). When responding to 'Please explain' under the 'Other' category, people said they did not take action because "I'm on vacation" (1), "I'm running" (2), "I do not know if Clemson cares if the plants are there or not" (1), and "not familiar enough with invasive plants" (1).

Most recreationists responded that they would like to learn more about invasives because 'I want to preserve the native habitats of the CEF for wildlife purposes,' 'The CEF is more aesthetically pleasing without invasive plants,' 'Invasive plants are detrimental to native areas and wildlife,' 'I want to find our more cost-effective ways to manage invasive plants on my own property,' or 'Other' (Figure 2.11). The most common reason for recreationists not wanting to learn more about invasive species was their belief that it takes too much time. The other common reasons were that they don't plant invasives, so they have no control over their spread, they do not believe their actions impact the spread of invasive plants in the CEF, and they do not know where to go to learn more about invasive species (Figure 2.12).

**Discussion**

The aim of our research was to understand the awareness and knowledge of recreational trail users by looking at their current knowledge on known invasive plants in the CEF, determine how they acquired their current knowledge, where their personal plants are purchased, and investigate their motivations regarding the prevention and management of invasive plants. Most people in the study could identify invasive species found within the CEF, regardless of their reported familiarity or their education level. Education on invasive plants most often came from friends and family, but also many people gained awareness of invasive species through news media and signs posted in the CEF.

Recreational trail users in the CEF had a strong sense of personal responsibility towards the prevention of invasive plants, but also believed that Clemson University shared a large part of the responsibility. These findings are not novel but support previous research that demonstrates the need for a better understanding of human dimensions (Andreu et al. 2009, Pejchar and Mooney 2009, Kapitza et al. 2019) and how they impact recreational user beliefs and actions, as this may be important to preventing invasive plant transport, establishment, and spread (McLeod et al. 2015). Our research also asked questions about invasive plants that allowed us to gain additional insight to role of recreationists and their beliefs concerning invasive plant species that may help channel future research in the social dynamics of invasion ecology.

Nearly three-fourths of recreational users primarily visit the CEF in the fall and spring. About 20% of recreational users also visited other forests or wooded recreational areas. Many of the invasive plants found in the CEF and surrounding forests and wooded recreational areas are in peak seed production or vegetative growth during the spring and fall (Judge et al. 2005, Hidayati et al. 2000, Urbatsch and Skinner 2000, Ervin et al. 2019). Recreational trail users frequently move invasive species from trailheads along trail edges deeper into the forest, but also between trailheads of different recreational areas, creating new satellite colonies (Pickering et al. 2007, Allen et al. 2009, Eagleston and Marion 2018). Programs like Leave No Trace (LNT) aim to reduce recreational impacts (Leave No Trace 2022, Dolman and Marion 2022), however the success of programs like LNT may rely on recreationists having the ability to correctly identify invasive plant species and understand their morphological and physiological characteristics. Many of the survey respondents reported taking actions in the CEF to prevent invasive spread, which could lead to less movement of viable seeds and propagules if recreation is a facilitating factor.

Most recreationist had a basic understanding of invasive species, and even those who reported that their knowledge was not strong could still identify most plants as either invasive or native correctly. The most common methods for obtaining information for those that indicated ‘least familiar’ was family, friends, and news media, and may imply a significance to the passing of accurate information through these non-formal educational pathways, which demonstrates the significance of social interaction in combatting the spread of invasive plants (Clarke et al. 2021a). Extension services increased both confidence in identification skills and actual identification abilities. Extension services can contribute to an understanding and potentially lead to applied practices that mitigate the introduction and spread of invasive species (Drew et al. 2010, Posadas et al. 2021). Recreationists in the CEF that had been exposed to extension services and formal classroom settings were more likely to not buy plants that are known invasives in South Carolina.

Most recreationists in the CEF managed an acre or less of land for invasive species (Figure 2.8). As property size increased, so did the ability to recognize the invasive species, although those with 20 acres or more was only represented by 7% of survey respondents and may not give a strong representation of ability to identify based on property size managed (Figure 2.3), so future research should look for any connection to property size and ability to identify invasive species. Future research should also investigate land use patterns by property size. Family forests, large tracts of land owned and managed by individual families, and agricultural lands, may be managed for profit, giving the landowner greater incentive to manage for invasive plants that may reduce financial gains. Smaller properties using ornamentals from the horticulture industry may pose greater risks to invasive management, yet recreationists managing these smaller property sizes have less knowledge of invasive plants. Extension education traditionally targeted property managers with larger tracts of land due to their land use and associated degradation. More research should go into creating programming that targets individuals managing smaller tracts of land, and how to best reach those property managers.

Ma et al. (2018) showed that a small portion of landowners have knowledge of invasive species and only a small fraction actively manage for invasive species on their property, with homeowners in urban and suburban areas having even less awareness of invasive species issues. Barriers to invasive species management may hinge on the lack of community cooperation and desire for autonomy (Ma et al. 2018). Education can facilitate awareness, which can lead to increased perceptions of self-efficacy, and ultimately environmental action (Story and Forsyth 2008). Integrating the social and emotional perceptions of recreationists into education geared towards management of invasive plants is an important factor in changing personal actions (Potgieter et al. 2019). Public willingness to participate in the management of invasive species may be increased by using an educational approach that incorporates user beliefs on their socio-economic and ecological sustainability (Bardsley and Edwards-Jones 2006).

Most recreationists in the CEF purchase plants for their personal properties in ‘big box” stores. Majority of these respondents believed that the plants purchased should be non-invasive, and almost half attempting to determine the invasiveness of plants prior to purchase through personal research or labels. As invasive species pass barriers to introduction and establishment, the costs associated with their ecosystem degradation, eradication, and control grow exponentially (Jarić and Cvijanović 2012, Fletcher et al.

2015, Zenni et al. 2021). The horticulture industry is a vector of invasion (Reichard and White 2001, Drew et al. 2010), with minimal regulation and cultivars of known invasives being introduced at an alarming rate (Drew et al. 2010). The invasive species found in the CEF that recreationists had the hardest time identifying as invasive were those most often sold in garden centers as ornamentals or shrubs. People can also become habituated to the presence of common invasive species sold through ornamental horticultural practices in a way that they may no longer have the emotional reaction needed to combat their spread in natural systems (Kalnicky et al. 2014).

Programs aimed at removing invasive species introduced by the horticulture industry are reactive and costly and may be a last-ditch effort to stop ecosystem degradation by established invasive species (Clemson Cooperative Extension; US Forestry Commission 2022, NC State Extension 2022). With approximately one-third of recreationists in the CEF reading labels to determine the invasiveness of a plant, regulations on the horticulture industry aimed at providing accurate information on known invasive qualities of species being sold to the public may slow the spread of invasives and promote a culture within the horticultural industry of selling plants that are not known for their invasive characteristics. Recreationists using the CEF seem to have a strong desire to prevent the use and spread of known invasive species, therefor, education and policy regulation that target the horticulture industry may be an effective means at reducing invasive species introductions (Oele et al. 2015, Hulme et al. 2018).

The horticulture industry has an incomparable contribution to the spread of invasive plants through intentional cultivars and ornamental plants (Mack 1991, Mack and

Erneberg 2002, Drew et al 2010). Our research demonstrates that most recreational users in the CEF frequent big box stores for their plant purchases. Big box stores contribute to the mass sale of cultivated and ornamental plants to property owners (Miller 2001). A lack of knowledge about the possible invasiveness of big box store plants sold by inexperienced sales floor personnel, or purchased by self-service clientele, intensifies invasive potential (Drew et al. 2010). Currently around the United States, legislation is being passed that bans the sell, import, or planting of invasive species, but to date there has been limited stakeholder support (Barbier et al. 2013, Hulme et al. 2018). Public pressure has been a driving force behind many policy changes. Creating effective educational programs that increase public support of policies that prevent the spread of invasives could help curtail the unchecked sale of existing invasives and new cultivars in the horticulture industry that may have disastrous ecological impacts to native ecosystems. Surveys that look at the emotional forces behind the purchase choices of landowners may shed light on effective educational strategies to drive ecologically conscious choices for future plant purchases.

Minorities may struggle to have a sense of place where they have traditionally felt excluded. Our research targeted recreationists in the CEF, which typically sees hikers, mountain bikers, and horseback riders, in areas of dense vegetation. Clemson University demographics are like those in the overall state of South Carolina, which may mean that the recreational activities typically sought after in the CEF may not be the type of activities that minorities seek. This means a lost chance of understanding minority values and beliefs concerning native ecosystems and plant invasions in the Clemson area. Many educational approaches use a binary system of good versus evil to educate and perpetuates xenophobic expression rather than ethical decision-making (Maggiulli 2022) Looking at educational programming that targets minorities at a grade school level and helps foster a sense of place may encourage future generations to feel safer in areas like the CEF. Changing policies to create a sense of inclusion may help facilitate feeling of acceptance for minorities within recreational areas. Future research should look at questionnaires that target minority communities to get a better understanding of the current barriers preventing them from utilizing forested lands, what type of educational methods may facilitate increased feelings of safety with use of forested lands. Research looking at urban recreation preferences (Yoon and Lee 2019) and recreation motivation and preference for minorities (Whiting et al. 2017) help increase our understanding of recreational behaviors. Black family forest owners may have a greater understanding of the ecological need to protect the forests, but many do not have the same level of forestry knowledge (Schelhas et al. 2017, Schelhas et al. 2021), but there is little research on the beliefs and values of minorities on the topic of invasive species and ecosystem degradation. Future research should find a way to target minorities, possibly in urban settings, with questionnaires that help gain a better understanding of their beliefs on invasive species to facilitate the creation of programs targeted at minorities to help increase their knowledge on recreational dispersal and purchasing impacts in invasion ecology.

**Study Limitations**

Our research was done in Clemson University managed land, where the demographics are not necessarily representative of the general population. There was a large percentage of recreationists with a higher-education degree. Clemson University is also a land-grant institution that focuses on scientific research, which may lend to a larger portion of those recreating in the CEF to have a better understanding of ecological benefits of native ecosystems. Performing this same type of research study, questioning recreationists that use public forest lands in areas not surrounding a land-grant research institution, may yield results more indicative of the general public.

One issue with the data surrounding the ability for survey-respondents to accurately identify species as invasive or native was the use of common names for many of the species in association with the image on the survey. Common names could have cultural designations attached, leading to response bias if the name listed another country or region, even if the country listed in the common name was not where the species originated.

For some survey questions on responsibility, there may be response bias from people who perceive themselves as doing the right thing regarding invasives, or report themselves as such because of social pressure (Randall and Fernandes 1991).

The recreationists in the CEF were not representative of race demographics for the general population of South Carolina. Of those recreating in the CEF, 95% reported as Caucasian, but the 2021 government census shows that 15% of respondents in Clemson South Carolina are minorities (Table 2.13). The demographics for Clemson

University are more reflective of the overall population of South Carolina (College Factual 2023; Table 2.14).

**Conclusion**

Humans are an influential force in the transport, and management of, of invasive species around the globe (Pimentel et al. 2005, Qian and Ricklefs 2006, Montagnani et al. 2022). Often, invasion is the unintended consequences of human actions, but the impacts are no less devastating to the ecological health of native ecosystems (Stinson et al. 2006, Adams and Engelhardt 2009, Aguilera et al. 2010, Vilá et al. 2011), and human mental and physical wellbeing (MacKerron and Mourato 2009, Donovan et al. 2013, Hartig et al 2014, Marselle et al. 2019, Shackleton et al. 2019a, de Vries and Snep 2019). These results provide insight into the beliefs, and actions, or recreationists living in and around Clemson University regarding non-native plant invasion. However, these results are not reflective of the broader population in the surrounding areas of upstate South Carolina.

Reaching a more inclusive demographic will give greater insight to the beliefs of those from all socio-economic statuses and cultural beliefs. Education increases the likelihood that recreationists will have the ability to identify invasives, which can influence environmental actions and potentially change social norms. So much of what we learn comes from social interaction and having strong foundational education in the form of public outreach through extension programs and other educational resources will help increase accurate information being disseminated throughout our communities.

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APPENDICES

Appendix A

Tables

**Table 1.1 Participation by activity within National Forests based on survey by the U.S. Forest Service for fiscal year 2014 through fiscal year 2018.**

| Activity | % Participated |
|---|---|
| Camping | 10.9 |
| Viewing Wildlife | 28.2 |
| Viewing Natural Features | 44.5 |
| Relaxing, escaping heat or noise | 31.7 |
| Motorized Trail Activity | 2.9 |
| Fishing/Hunting/Foraging | 17.7 |
| Hiking/Walking | 46.7 |
| Backpacking | 1.8 |
| Horseback Riding | 0.7 |
| Bicycling | 5.3 |

**Table 1.2 NOAA average monthly temperature and precipitation for Clemson in Pickens and Anderson County SC, between 1991 and 2020.**

| Month | Max Temp (°C) | Min Temp (°C) | Avg Temp (°C) | Precipitation (cm) |
|---|---|---|---|---|
| **January** | 11.06 | 0.88 | 5.94 | 11.45 |
| **February** | 13.17 | 2.38 | 7.77 | 10.56 |
| **March** | 17.72 | 5.83 | 11.77 | 11.86 |
| **April** | 22.22 | 9.88 | 16.05 | 9.6 |
| **May** | 26.11 | 14.72 | 20.44 | 8.86 |
| **June** | 29.61 | 18.88 | 24.27 | 11.17 |
| **July** | 31.50 | 21.05 | 26.27 | 9.27 |
| **August** | 30.72 | 20.44 | 25.55 | 12.47 |
| **September** | 27.77 | 17.50 | 22.66 | 9.34 |
| **October** | 22.39 | 11.00 | 16.72 | 9.14 |
| **November** | 16.83 | 5.44 | 11.11 | 9.24 |
| **December** | 12.11 | 2.33 | 7.22 | 11.43 |

**Table 1.3 Tree species by forest-type within the Clemson Experimental Forest in Clemson, South Carolina.**

| Planted Pine | Upland Hardwood | Pine-hardwood | Cove Hardwood |
|---|---|---|---|
| *Pinus taeda* | *Quercus falcata* | *Pinus elliottii* | *Tilia americana* |
| *Pinus echinata* | *Quercus alba* | *Pinus strobus* | *Liriodendron tulipifera* |
| | *Quercus stellata* | *Pinus pungens* | *Acer saccharum* |
| | *Quercus rubra* | *Pinus virginiana* | *Acer rubrum* |
| | *Quercus montana* | *Pinus taeda* | *Betula alleghaniensis* |
| | *Quercus coccinea* | *Pinus echinata* | *Fagus grandifolia* |
| | *Carya ovata* | *Quercus falcata* | *Fraxinus americana* |
| | *Carya tomentosa* | *Quercus alba* | *Magnolia macrophylla* |
| | *Carya glabra* | *Quercus stellata* | *Carya cordiformis* |
| | *Nyssa sylvatica* | *Quercus rubra* | *Tsuga canadensis* |
| **Natural Pine** | *Liquidambar styraciflua* | *Quercus montana* | *Halesia carolina* |
| *Pinus elliottii* | *Liriodendron tulipifera* | *Quercus coccinea* | *Cersis canadensis* |
| *Pinus strobus* | *Acer rubrum* | *Carya ovata* | |
| *Pinus pungens* | *Ulmus* spp | *Carya tomentosa* | |
| *Pinus virginiana* | *Fraxinus* spp. | *Carya glabra* | |
| | *Oxydendrum arboreum* | *Nyssa sylvatica* | |
| | *Sassafras albidum* | *Liquidambar styraciflua* | |
| | | *Liriodendron tulipifera* | |
| | | *Acer rubrum* | |
| | | *Ulmus* spp | |
| | | *Fraxinus* spp. | |
| | | *Oxydendrum arboreum* | |
| | | *Sassafras albidum* | |

**Table 2.1 Self-reported demographic Information for the Clemson Experimental Forest in Anderson and Oconee County, South Carolina**

| **Race** | **Percent Reporting** | **Frequency** |
|---|---|---|
| Caucasian | 95.35% | 123 |
| Asian | 3.10% | 4 |
| Alaskan Native | 0.78% | 1 |
| Black | 0.00% | 0 |
| Native American | 0.78% | 1 |
| **Gender** | | |
| Male | 46.88% | 60 |
| Female | 51.66% | 66 |
| Non-binary/Gender Fluid | 0.78% | 1 |
| Prefer not to say | 0.78% | 1 |
| **Age Range** | | |
| 18 - 24 | 22.66% | 29 |
| 25 - 34 | 21.88% | 28 |
| 35 - 44 | 24.22% | 31 |
| 45 - 54 | 19.53% | 25 |
| > 55 | 11.72% | 15 |
| **Gross Income** | | |
| < $49,999 | 32.28% | 41 |
| $50,000 - 99,999 | 31.50% | 40 |
| $100,000 - 149,999 | 14.17% | 18 |
| $150,000 - 199,999 | 7.09% | 9 |
| $200,000 - 249,999 | 1.57% | 2 |
| > $250,000 | 2.36% | 3 |
| Prefer not to answer | 11.02% | 14 |
| **Employment Status** | | |
| Employed | 51.56% | 66 |
| Self-employed | 7.03% | 9 |
| Retired | 7.81% | 10 |
| Full-time Student | 28.13% | 36 |
| Unemployed | 5.47% | 7 |
| **Education Level** | | |
| Less than high school or GED | 0.76% | 1 |
| High school or GED | 8.40% | 11 |
| Technical or Trade | 2.29% | 3 |
| Some college (no degree) | 14.50% | 19 |
| Associates | 6.87% | 9 |
| Bachelors | 22.14% | 44 |
| Masters | 22.14% | 29 |
| Doctorate | 9.92% | 13 |
| Other Terminal Degree | 1.53% | 2 |

**Table 2.2 Recreationist's reasons for visiting the Clemson Experimental Forest in Clemson, South Carolina.**

| **Reason for visit** | **# Reporting of 186** |
|---|---:|
| Scenery/aesthetics | 139 (77%) |
| Observe wildlife | 78 (42%) |
| Spiritual benefit | 56 (31%) |
| Spend time with family or friends | 81 (45%) |
| Enhance mental health | 101 (56%) |
| Exercise | 151 (83%) |
| Forage for food | 7 (4%) |
| To find a sense of place | 43 (24%) |
| Other | 29 (16%) |

**Table 2.3 Cross-tabulation showing the relationship between survey participants' ability to correctly identify invasive plants and their self-reported familiarity with invasive plants on a 4-point Likert scale.**

| | **Not familiar** | **A little familiar** | **Familiar** | **Very familiar** |
|---|---|---|---|---|
| **Invasive Species** | **% correctly identified** | | | |
| *M. vimineum* | 80.0 | 95.7 | 96.6 | 100.0 |
| *L. sinense* | 88.9 | 93.0 | 96.6 | 100.0 |
| *L. japonica* | 63.2 | 86.4 | 89.7 | 94.7 |
| *E. pungens* | 50.0 | 48.7 | 75.0 | 88.9 |
| *T. sebifera* | 83.3 | 84.2 | 86.2 | 100.0 |
| *H. helix* | 72.7 | 76.0 | 92.9 | 100.0 |
| *L. cuneata* | 57.9 | 59.5 | 61.5 | 93.8 |
| *A. julibrissin* | 50.0 | 41.5 | 75.0 | 83.3 |

**Table 2.4 Cross-tabulation showing the relationship between survey participants' self-reported education level and their self-reported familiarity with invasive plants on a four-point Likert scale.**

| Education | Not familiar | A little familiar | Familiar | Very familiar |
|---|---|---|---|---|
| | % of each self-reported education level | | | |
| Less than high school or GED | 0.0 | 0.0 | 3.6 | 0.0 |
| High school or GED | 10.3 | 9.6 | 7.1 | 5.3 |
| Technical, trade, or vocational program | 6.9 | 0.0 | 3.6 | 0.0 |
| Some college (no degree) | 17.2 | 17.3 | 17.9 | 0.0 |
| Associates degree (2-year degree) | 6.9 | 9.6 | 0.0 | 10.5 |
| Bachelor's degree (4-year degree) | 31.0 | 32.7 | 32.1 | 47.4 |
| Masters (M.S., M.A., M.B.A.) | 24.1 | 21.2 | 25.0 | 21.1 |
| Doctorate (J.D., Ph.D.) | 6.9 | 7.7 | 17.9 | 10.5 |
| Other terminal degree (e.g. M.F.A.) | 0.0 | 1.9 | 0.0 | 5.3 |

**Table 2.5 Cross-tabulation showing the relationship between survey participants' self-reported education level and their correct identification of known invasive plants.**

| Invasive Species | HS or GED | Tech, trade, voc. | Some college | Assoc. degree | Bach. Degree | Masters (M.S., M.A., M.B.A.) | Doctorate (J.D., Ph.D.) | Other term. degree (e.g. M.F.A.) |
|---|---|---|---|---|---|---|---|---|
| | % of each self-reported education level | | | | | | | |
| *M. vimineum* | 87.5 | 50.0 | 92.9 | 100.0 | 88.9 | 100.0 | 92.3 | 100.0 |
| *L. sinense* | 87.5 | 100.0 | 92.9 | 85.7 | 93.5 | 100.0 | 84.6 | 100.0 |
| *L. japonica* | 75.0 | 100.0 | 78.6 | 100.0 | 78.1 | 87.0 | 76.9 | 100.0 |
| *E. pungens* | 83.3 | 100.0 | 71.4 | 60.0 | 57.6 | 66.7 | 38.5 | 50.0 |
| *T. sebifera* | 100.0 | 100.0 | 78.6 | 80.0 | 82.8 | 86.4 | 100.0 | 100.0 |
| *H. helix* | 66.7 | 100.0 | 58.3 | 100.0 | 75.7 | 100.0 | 84.6 | 100.0 |
| *L. cuneata* | 75.0 | 100.0 | 83.3 | 40.0 | 68.8 | 63.2 | 45.5 | 0.0 |
| *A. julibrissin* | 62.5 | 100.0 | 66.7 | 50.0 | 51.4 | 57.1 | 66.7 | 100.0 |

**Table 2.6 Cross-tabulation showing the relationship between survey participants' self-reported source of invasive plant knowledge and their ability to correctly identify invasive species.**

| Invasive Species | Social media | News media | Extension Service | Classroom | Family or friends | Signs in the CEF |
|---|---|---|---|---|---|---|
| | % able to identify by knowledge source | | | | | |
| *M. vimineum* | 92.3 | 97.4 | 97.1 | 96.7 | 97.8 | 100 |
| *L. sinense* | 86.4 | 97.3 | 97.1 | 96.3 | 93.2 | 96.9 |
| *L. japonica* | 84 | 89.2 | 94.3 | 89.3 | 88.1 | 93.5 |
| *E. pungens* | 52.4 | 62.2 | 78.8 | 61.5 | 61.5 | 60 |
| *T. sebifera* | 77.3 | 82.9 | 90.6 | 88.9 | 89.2 | 86.7 |
| *H. helix* | 77.8 | 85 | 91.4 | 92.9 | 91.3 | 80 |
| *L. cuneata* | 57.9 | 67.7 | 67.7 | 76 | 63.9 | 65.4 |
| *A. julibrissin* | 45.5 | 52.6 | 64.7 | 76.9 | 52.4 | 51.6 |

**Table 2.7 Cross-tabulation showing the relationship between survey participants' self-reported familiarity and their self-reported invasive plant information source on a three-point Likert scale.**

| | **Level of Familiarity** | | |
|---|---|---|---|
| **Information Source** | *A little Familiar* | *Familiar* | *Very Familiar* |
| Social Media | 31.1 | 18.8 | 21.1 |
| News Media | 42.6 | 43.8 | 26.3 |
| Extension Service | 24.6 | 53.1 | 36.8 |
| Classroom | 19.7 | 34.4 | 52.6 |
| Family or friends | 50.8 | 40.6 | 42.1 |
| Signs in the CEF | 44.3 | 31.3 | 21.1 |
| Other | 3.3 | 28.1 | 36.8 |

**Table 2.8 Cross-tabulation showing the relationship between where survey respondents acquired their invasive plant knowledge and survey participants' self-reported plant purchase motivation on a five-point Likert scale.**

| | | Social media | News media | Extension Service | Classroom | Family or friends | Signs in the CEF |
|---|---|---|---|---|---|---|---|
| | | % of each self-reported invasive knowledge source | | | | | |
| I choose plants for my property that are native | Strongly Disagree | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Disagree | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 26.3 | 26.9 | 19.2 | 6.7 | 29.4 | 36.0 |
| | Agree | 42.1 | 53.8 | 50.0 | 60.0 | 47.1 | 48.0 |
| | Strongly Agree | 31.6 | 19.2 | 26.9 | 33.3 | 23.5 | 16.0 |
| I choose plants for my property that help increase native diversity | Strongly Disagree | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Disagree | 0.0 | 7.7 | 0.0 | 6.7 | 8.8 | 8.0 |
| | Neutral | 42.1 | 26.9 | 23.1 | 20.0 | 26.5 | 48.0 |
| | Agree | 26.3 | 46.2 | 50.0 | 46.7 | 41.2 | 28.0 |
| | Strongly Agree | 31.6 | 19.2 | 26.9 | 26.7 | 23.5 | 16.0 |
| I choose plants for my property that attract wildlife species | Strongly Disagree | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Disagree | 0.0 | 0.0 | 7.7 | 6.7 | 8.9 | 12.0 |
| | Neutral | 21.1 | 15.4 | 7.7 | 13.3 | 6.0 | 16.0 |
| | Agree | 63.2 | 53.8 | 46.2 | 40.0 | 58.8 | 48.0 |
| | Strongly Agree | 15.8 | 26.9 | 38.5 | 40.0 | 26.5 | 24.0 |
| I will not buy plants that can are classified as invasive plants | Strongly Disagree | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 |
| | Disagree | 0.0 | 7.7 | 0.0 | 6.7 | 2.9 | 12.0 |
| | Neutral | 31.6 | 26.9 | 0.0 | 6.7 | 20.6 | 36.0 |
| | Agree | 26.3 | 30.8 | 34.6 | 40.0 | 38.2 | 24.0 |
| | Strongly Agree | 42.1 | 34.6 | 57.7 | 46.7 | 38.2 | 24.0 |

**Table 2.9 Cross-tabulation showing the relationship between survey participants' that self-reported purchasing plants for their home and their ability to correctly identify eight known invasive plants in the Clemson Experimental Forest.**

| **Invasive Species** | **% Purchase and can identify as invasive** |
|---|---|
| *M. vimineum* | 91.9 |
| *L. sinense* | 92.8 |
| *L. japonica* | 84.7 |
| *E. pungens* | 56.7 |
| *T. sebifera* | 86.2 |
| *H. helix* | 83.8 |
| *L. cuneata* | 65.1 |
| *A. julibrissin* | 62.9 |

**Table 2.10 Cross-tabulation showing the relationship between survey respondents self-reported action to prevent invasive plants on their property on a two-point Likert scale and survey respondents self-reported home plant purchases on a two-point Likert scale**

| | | *Purchase Plants for Home* | |
|---|---|---|---|
| | | **Yes** | **No** |
| *Prevent Invasives Plants on Property* | **Yes** | 78.0 | 43.8 |
| | **No** | 22.0 | 56.3 |

**Table 2.11 Cross-tabulation showing the relationship between survey respondents self-reported beliefs of responsibility for invasive plant spread on a four-point Likert scale and survey participants' self-reported level of familiarity with invasive plants on a four-point Likert scale.**

| | | **Not Familiar** | **A Little Familiar** | **Familiar** | ***Very Familiar*** |
|---|---|---|---|---|---|
| *I believe it is my responsibility to reduce the spread of invasive plants* | **Strongly Disagree** | 6.3 | 1.7 | 3.3 | 0 |
| | **Disagree** | 28.1 | 20.7 | 13.3 | 5.3 |
| | **Agree** | 56.3 | 62.1 | 46.7 | 36.8 |
| | **Strongly Agree** | 9.4 | 15.5 | 36.7 | 57.9 |
| *I believe it is Clemson University's responsibility to reduce the spread of invasive plants* | **Strongly Disagree** | 0 | 1.7 | 0 | 0 |
| | **Disagree** | 6.3 | 3.4 | 3.4 | 0 |
| | **Agree** | 68.8 | 60.3 | 55.2 | 16.7 |
| | **Strongly Agree** | 25 | 34.5 | 41.4 | 83.3 |

**Table 2.12 Survey respondents self-reported actions taken to prevent the spread of invasive species in the Clemson Experimental Forest.**

| **Action taken** | **% who take action** |
|---|---:|
| Clean my shoes | 58.8 |
| Clean my pets | 23.5 |
| Clean my tires | 8.8 |
| Clean my recreational equipment | 35.3 |
| I do not take action | 8.8 |
| Other | 23.5 |

**Table 2.13 Survey demographics from the Clemson Experimental Forest compared to demographics from the 2021 United States Census.**

| Race | Survey Respondents | Clemson (Census) |
|---|---:|---:|
| Caucasian | 95.4% | 82.3% |
| Asian | 3.1% | 8.0% |
| Alaskan Native | 0.8% | 0.0% |
| Black | 0.0% | 6.8% |
| Native American | 0.8% | 0.0% |

**Table 2.14 College Factual demographics for Clemson University in Clemson, South Carolina.**

| **Race** | **Percent Reporting** | **Frequency** |
|---|---:|---:|
| Caucasian | 81% | 20196 |
| Asian | 3% | 666 |
| Alaskan Native | 0% | 0 |
| Black | 6% | 1609 |
| Native American | 0% | 0 |
| International | 5% | 1295 |
| Multi-ethnic | 4% | 950 |
| Unknown | 1% | 169 |
| Native Hawaiian | 0% | 19 |

Figures


**Figure 1.1 South Carolina map with coordinates of Clemson University.**

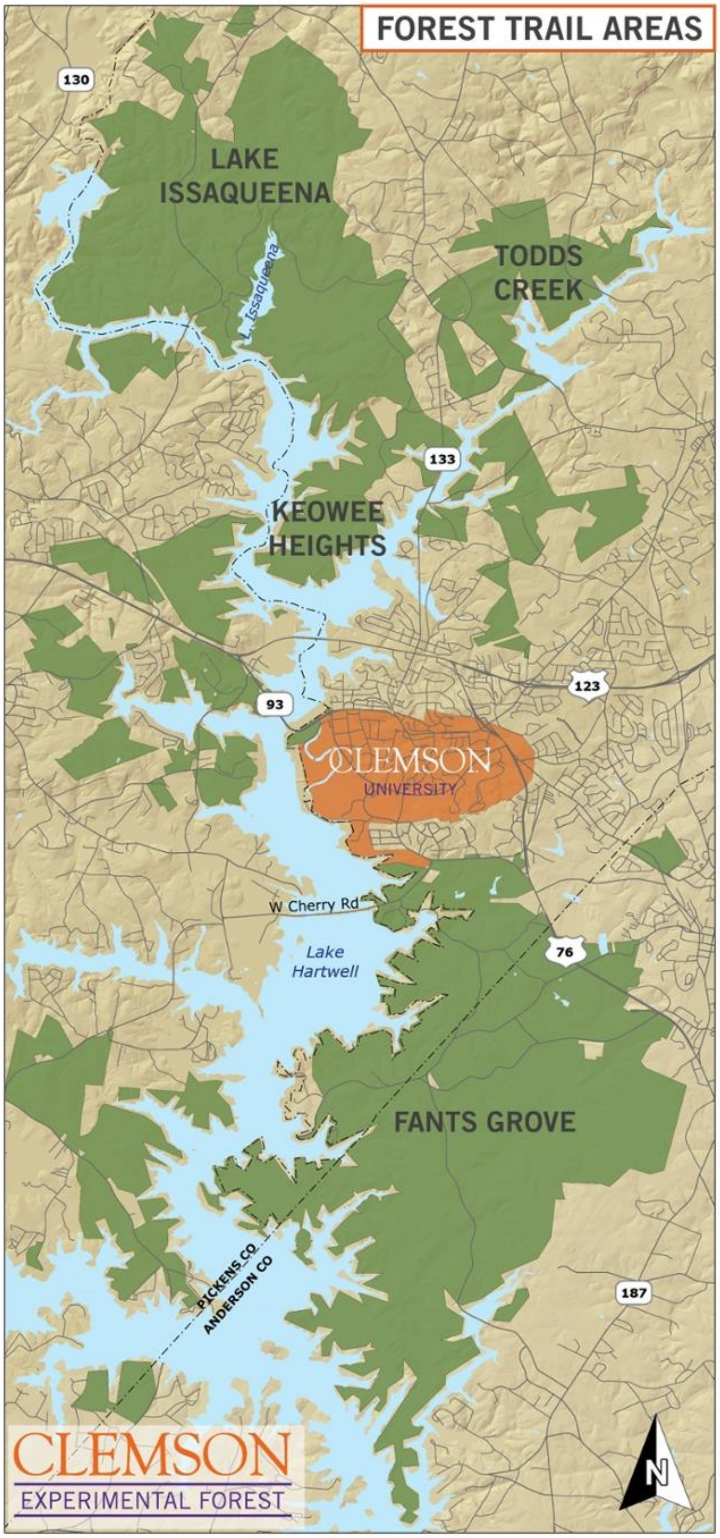

FOREST TRAIL AREAS
130
LAKE
ISSAQUEENA
L. Issaqueena
TODDS
CREEK
133
KEOWEE
HEIGHTS
123
93
CLEMSON
UNIVERSITY
W Cherry Rd
Lake
Hartwell
76
FANTS GROVE
PICKENS CO
ANDERSON CO
187
CLEMSON
EXPERIMENTAL FOREST
N

**Figure 2.2 Map overview of the four recreational areas within the Clemson Experimental Forest in Pickens and Anderson Counties in upstate South Carolina.**

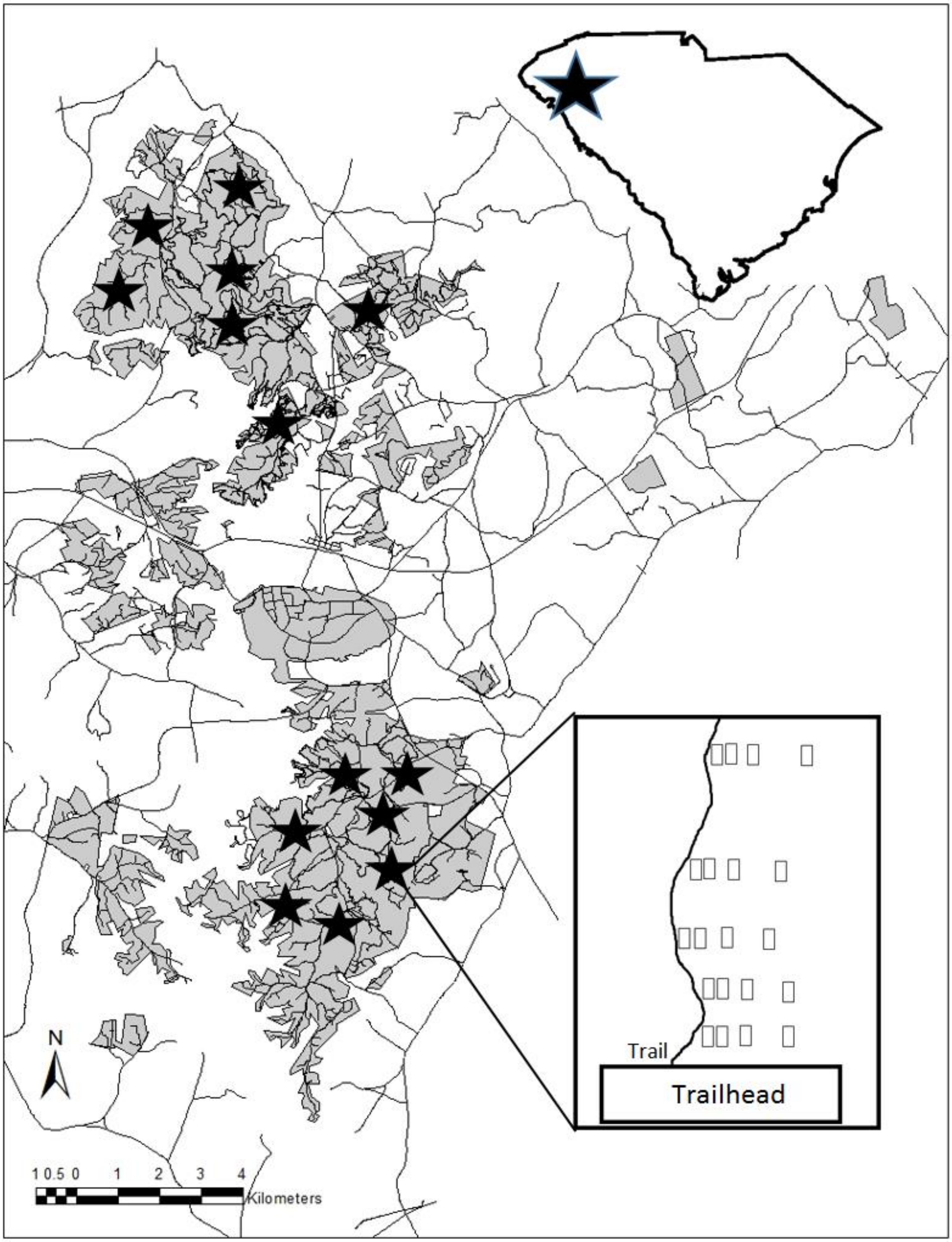


**Figure 3 1.3 Fourteen trailheads within the Clemson Experimental Forest that met specified criteria. Inset image shows the placement of research plots at interval distances of 5, 5, 10, 25, and 50 meters from trailhead and 0, 2, 4, and 12 meters from trail edge.**


**Figure 4 1.4 Experimental design of transect and plot layout for assessing the relationship between distance to trailhead and trail edge for invasive plants.**


a
UGA2308028
b
5408389
c
5496811
d
UGA1150069

**Figure 5 1.5 Species of concern quantified along transects at Clemson Experimental Forest trailheads and trail edges; a) Microstegium vimineum (Trin.) photo by Chuck Bargeron, University of Georgia, Bugwood.org; b) Ligustrum sinense (Lour.) photo by Karen A. Rawlins, University of Georgia, Bugwood.org; c) *Lespedeza cuneata* (Dum-Cours) G. Don.) photo by Katherine Russell, Bugwood.org; and d) *Lonicera japonica* (Thunb.) photo by Chuck Bargeron, University of Georgia, Bugwood.org.**


**Figure 6 1.6 Image demonstrating light availability using a spherical densitometer at one of the fourteen trailheads within the Clemson Experimental Forest**

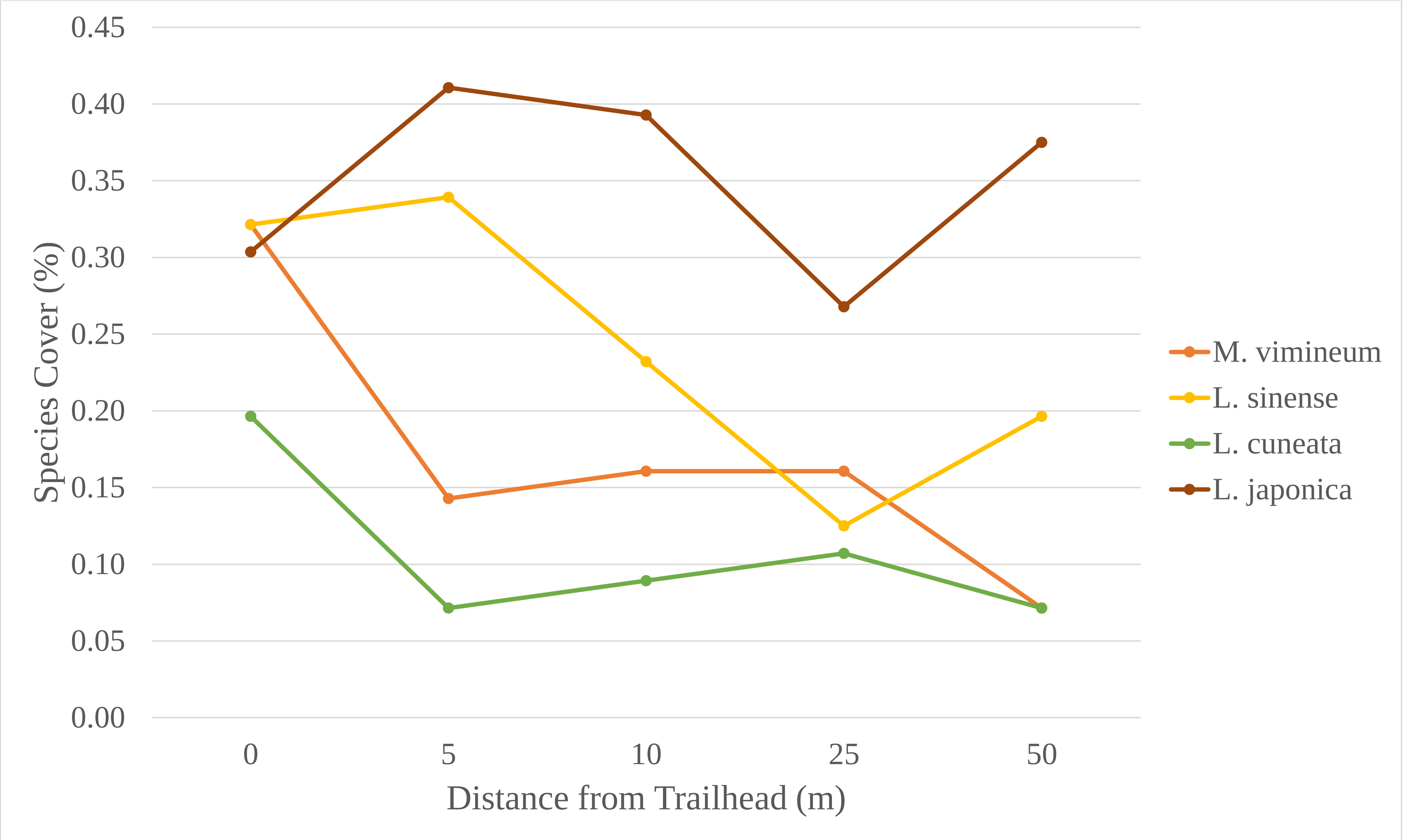



**Figure 7 1.7 The percent cover of M. vimineum, L. sinense, L. cuneata, and L. japonica as distance from trailhead increases in the Clemson Experimental Forest.**

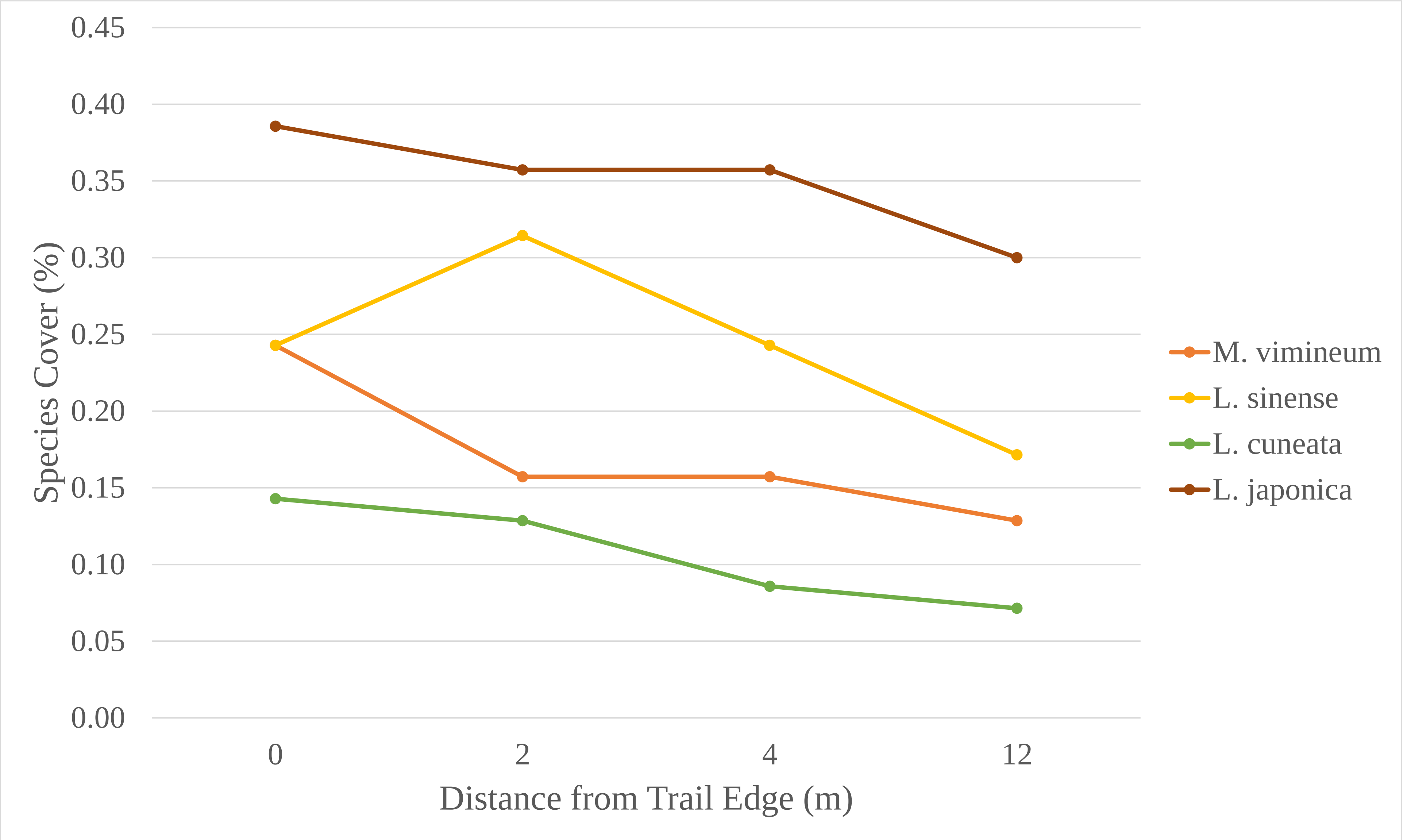



**Figure 8 1.8 The average percent cover of M. vimineum, L. sinense, L. cuneata, and L. japonica as distance from trail edge increases in the Clemson Experimental Forest.**

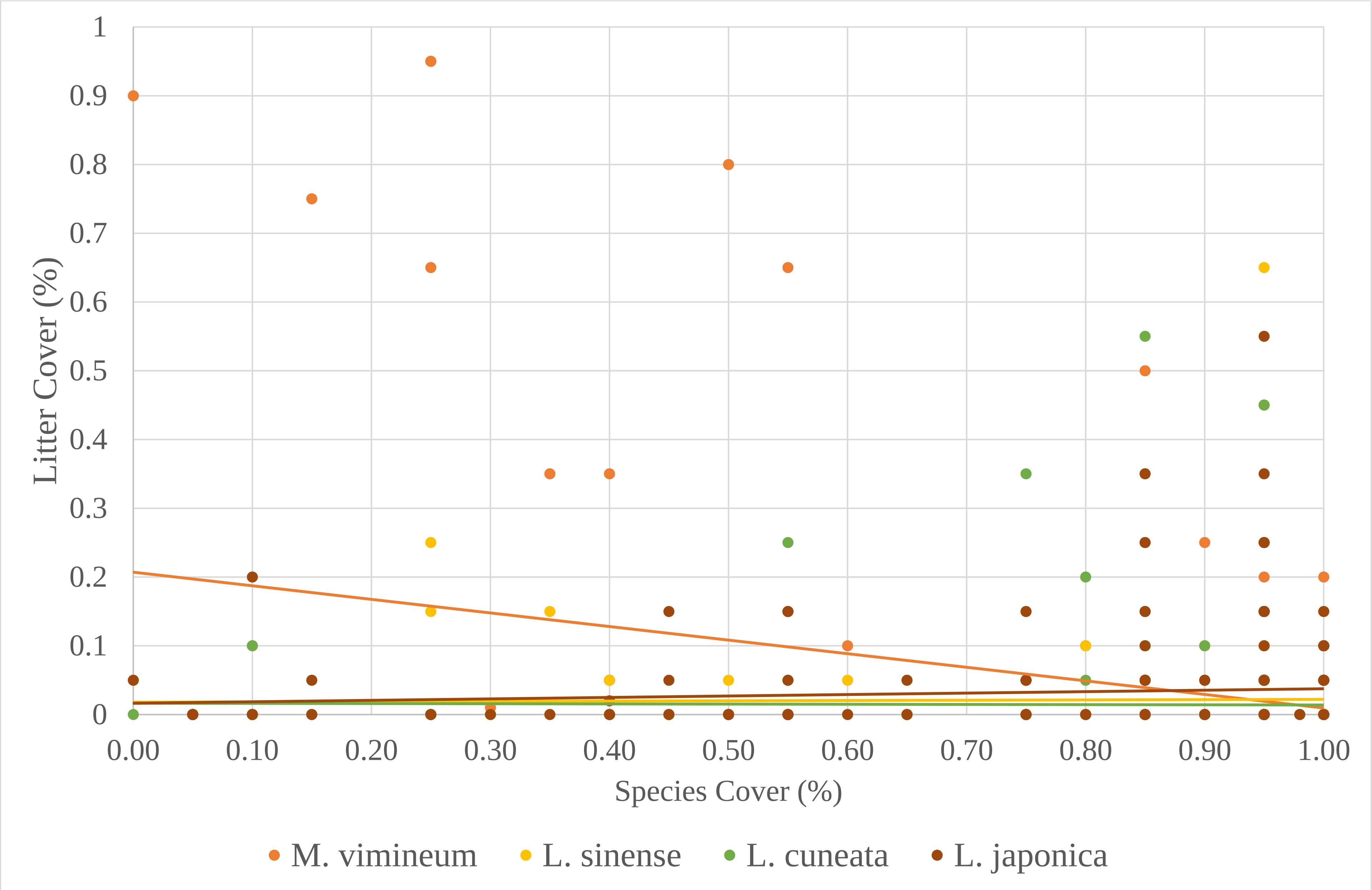
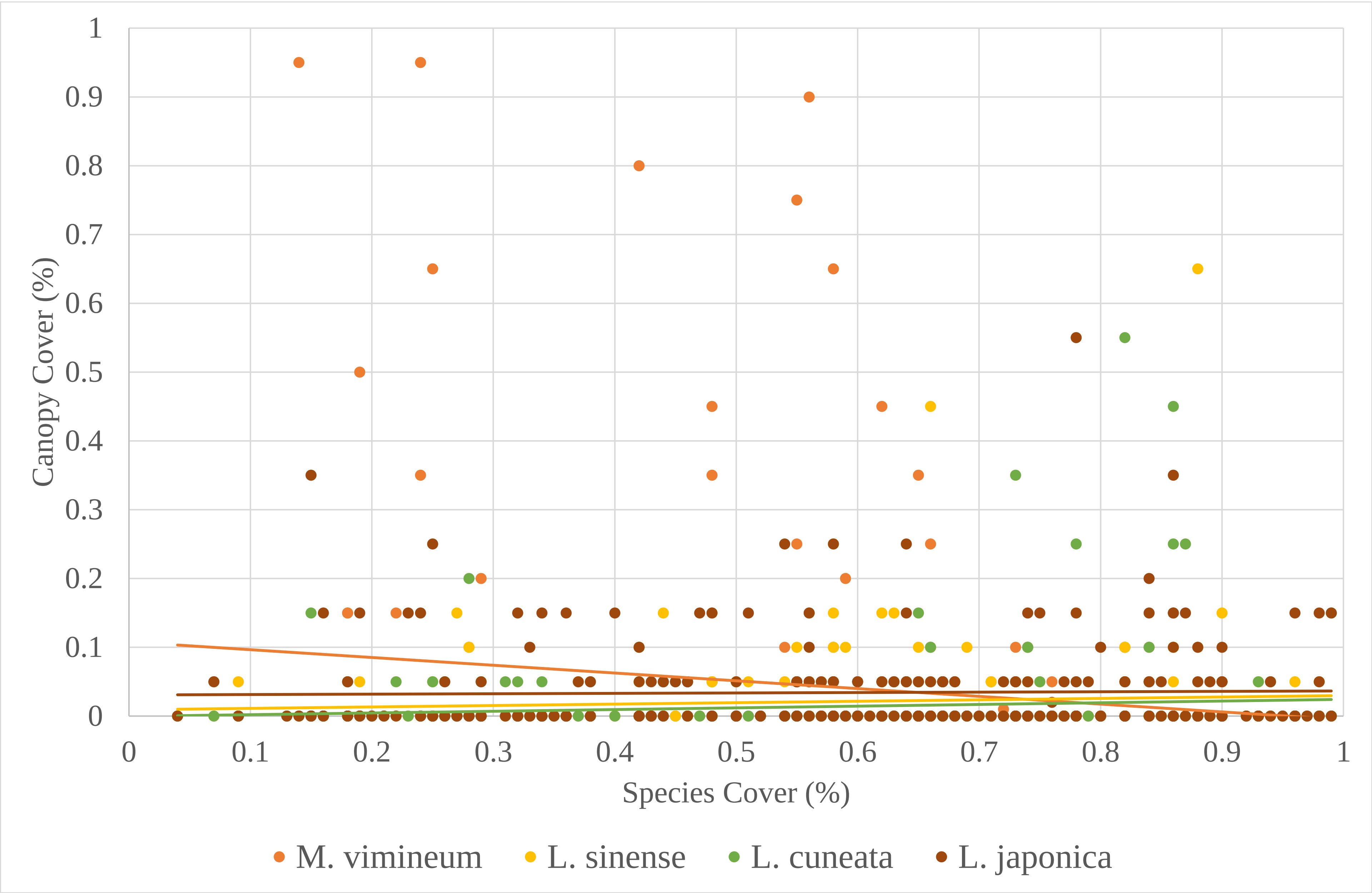



**Figure 9 1.9 The average percent cover of M. vimineum, L. sinense, L. cuneata, and L. japonica in relation to percent litter cover in the Clemson Experimental Forest.**



Canopy Cover (%)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Species Cover (%)
M. vimineum
L. sinense
L. cuneata
L. japonica

**Figure 10 1.10 The average percent cover of M. vimineum, L. sinense, L. cuneata, and L. japonica in relation to percent canopy cover in the Clemson Experimental Forest.**

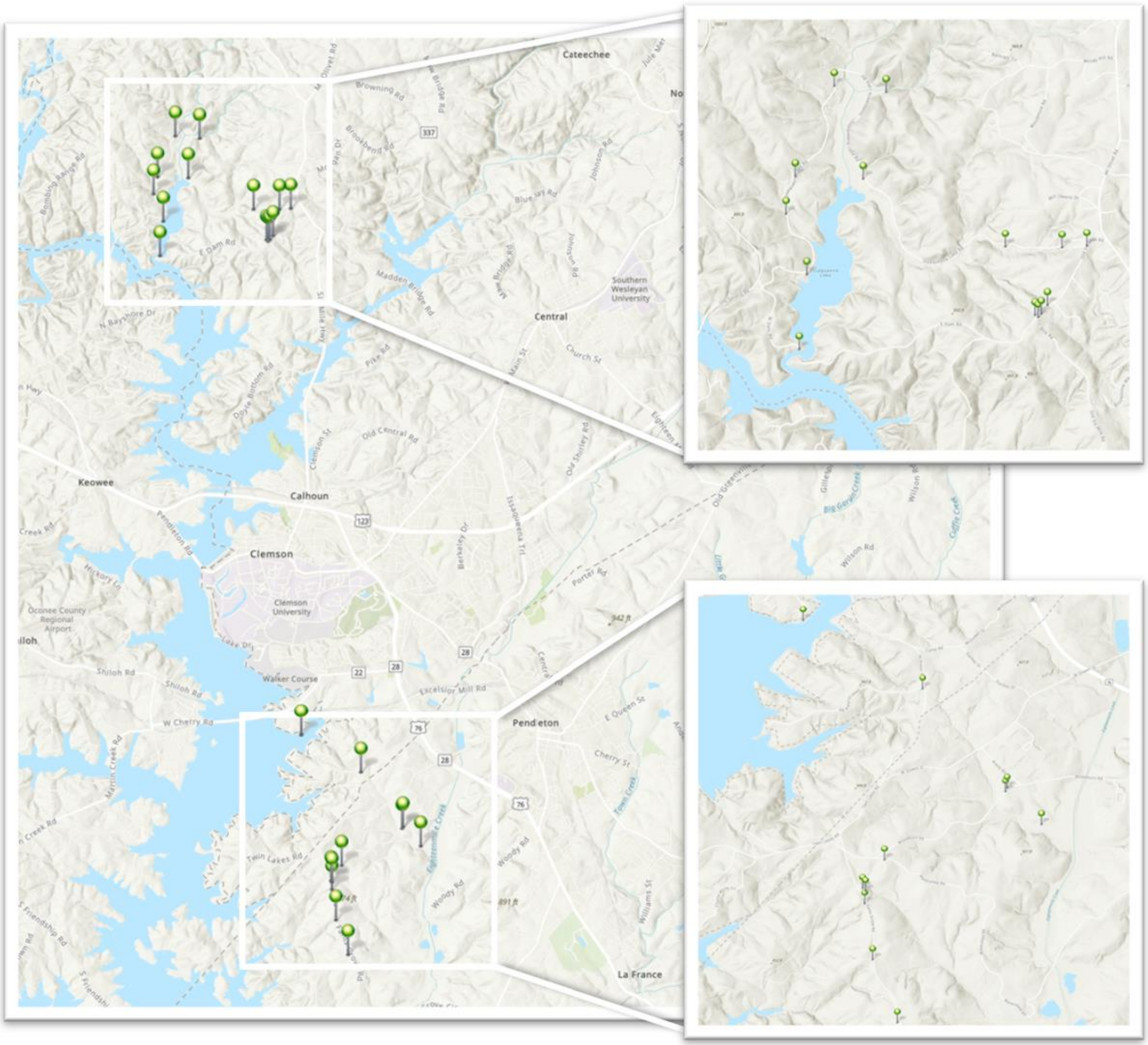

Cateechee
Central
Southern Wesleyan University
Keowee
Calhoun
Clemson
Clemson University
Oconee County Regional Airport
Walker Course
Pendleton
La France
Madden Bridge Rd
Blue Jay Rd
Church St
Old Central Rd
Doyle Bottom Rd
N Bayshore Dr
Issaqueena Trl
Berkeley Dr
Excelsior Mill Rd
W Cherry Rd
Shiloh Rd
Twin Lakes Rd
Martin Creek Rd
Woody Rd
Williams St
Cherry St
E Queen St
Wilson Rd
Porter Rd
E Dam Rd

**Figure 11 2.1 Recreational survey placements at eleven trailheads in Fants Grove in the southern Clemson Experimental Forest and fourteen trail heads along Issaqueena trail and Todds Creek in the northern Clemson Experimental Forest.**

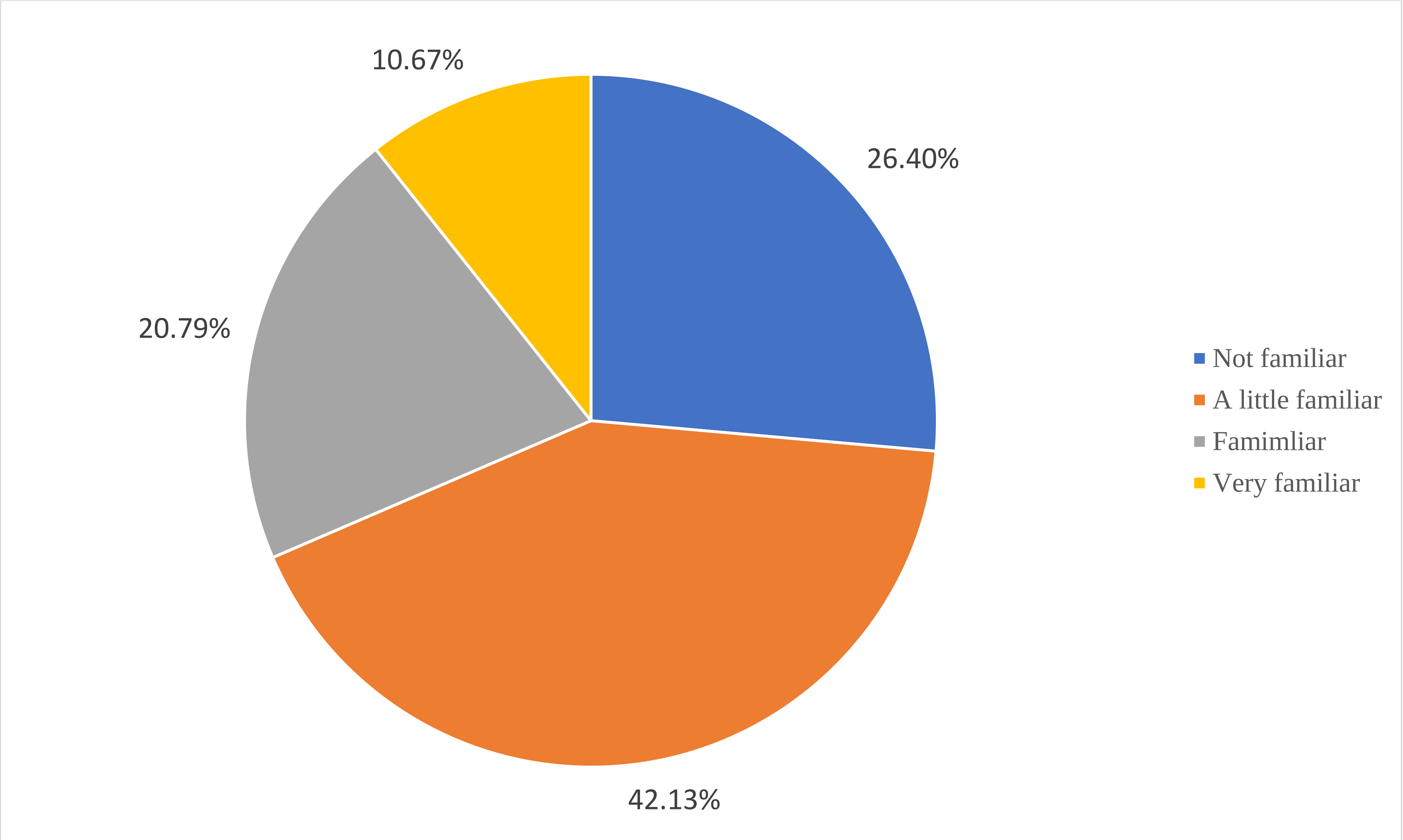


**Figure 12 2.2 Self-reported level of familiarity with invasive plants in the Clemson Experimental Forest in Anderson and Oconee counties in South Carolina.**

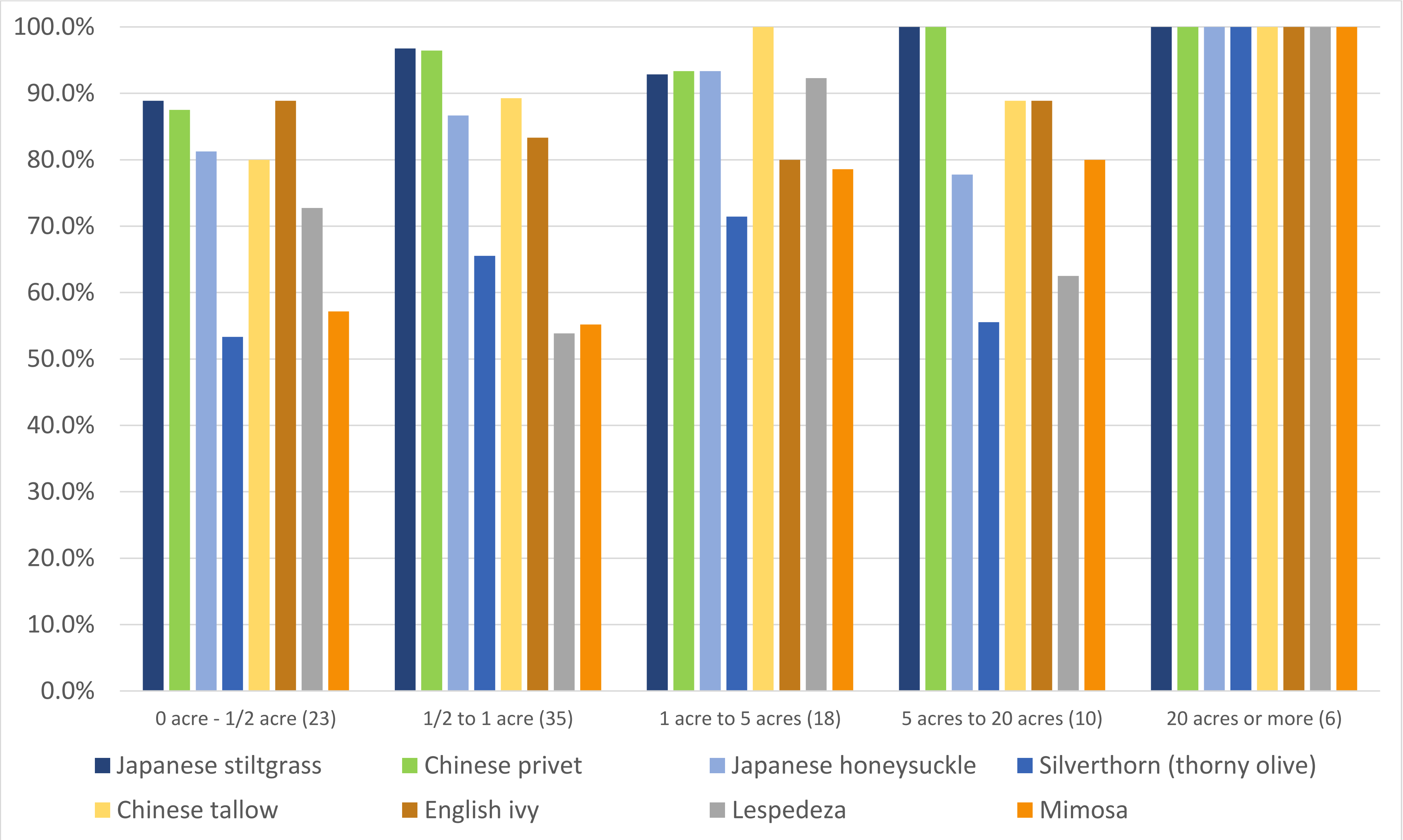



**Figure 13 2.3 Self-reported property size managed by recreationists in the CEF compared to their ability to accurately identify eight invasive species found in the Clemson Experimental Forest.**

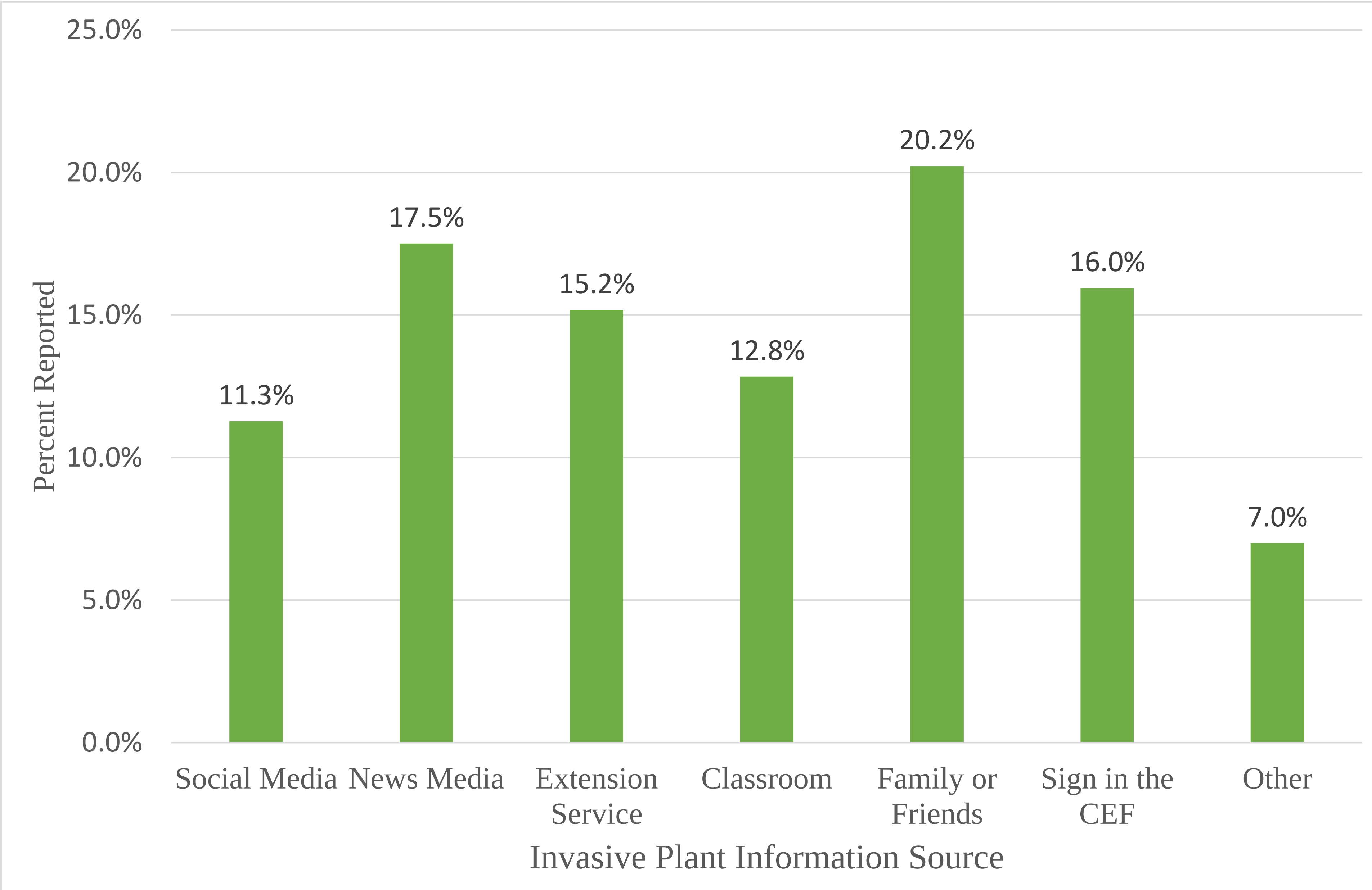

25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Percent Reported
11.3%
17.5%
15.2%
12.8%
20.2%
16.0%
7.0%
Social Media
News Media
Extension Service
Classroom
Family or Friends
Sign in the CEF
Other
Invasive Plant Information Source

**Figure 14 2.4 Self-reported source of information on invasive plants.**

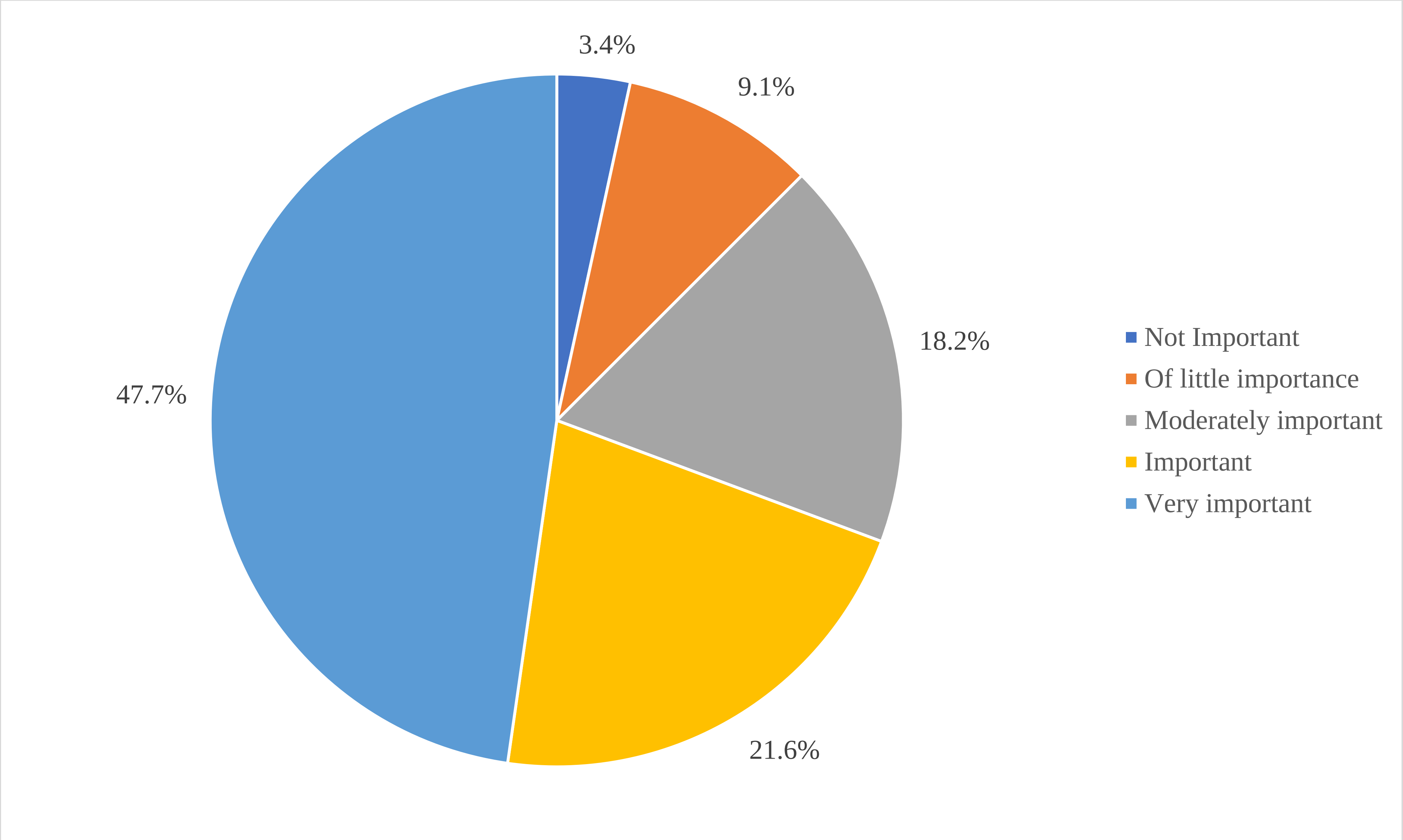



**Figure 15 2.5 Self-reported breakdown to the query, "If you purchase plants to plant on your own property, how important is it that they are not classified as invasive?"**

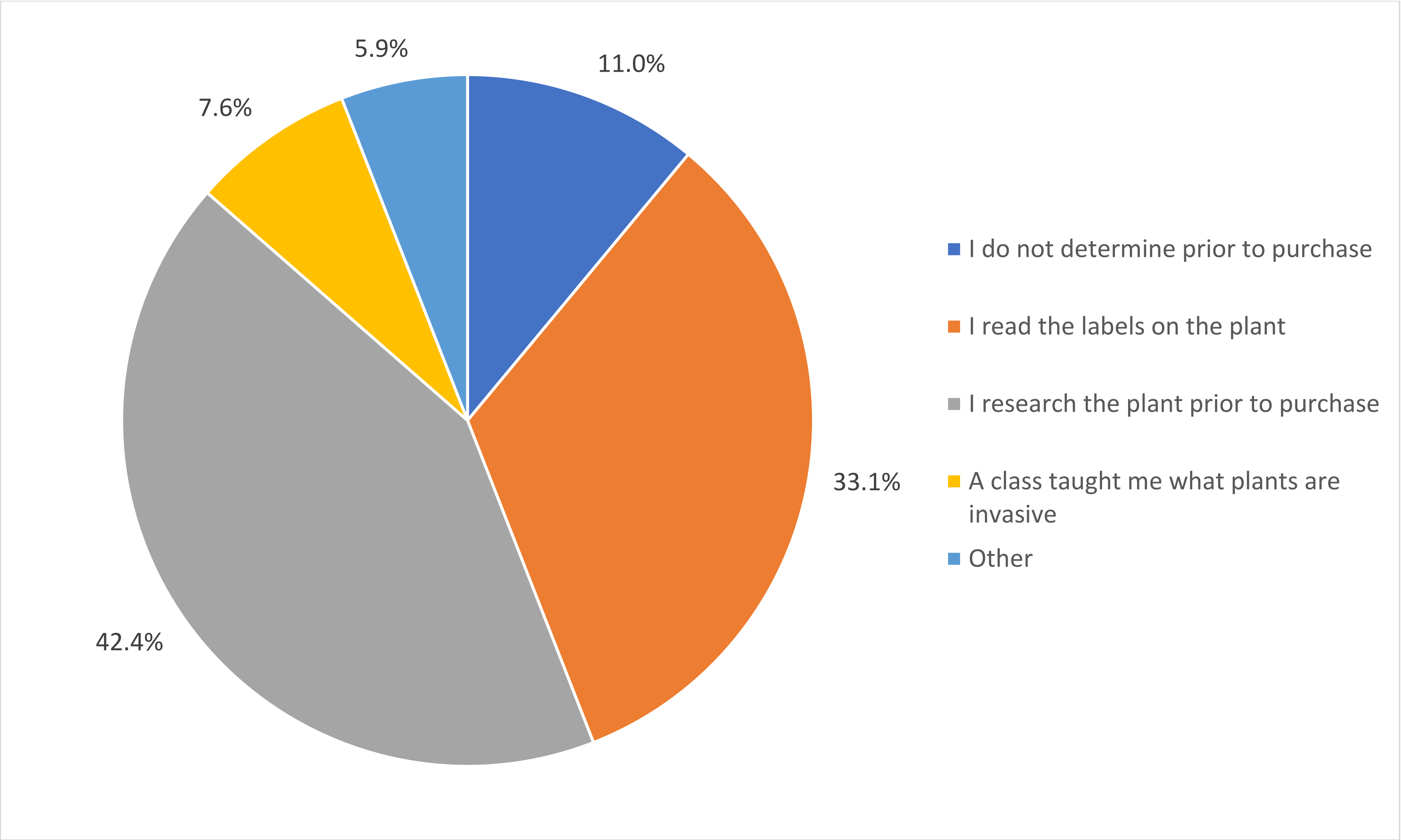



**Figure 16 2.6 Self-reported most often used method for determining plants are invasive prior to purchase.**

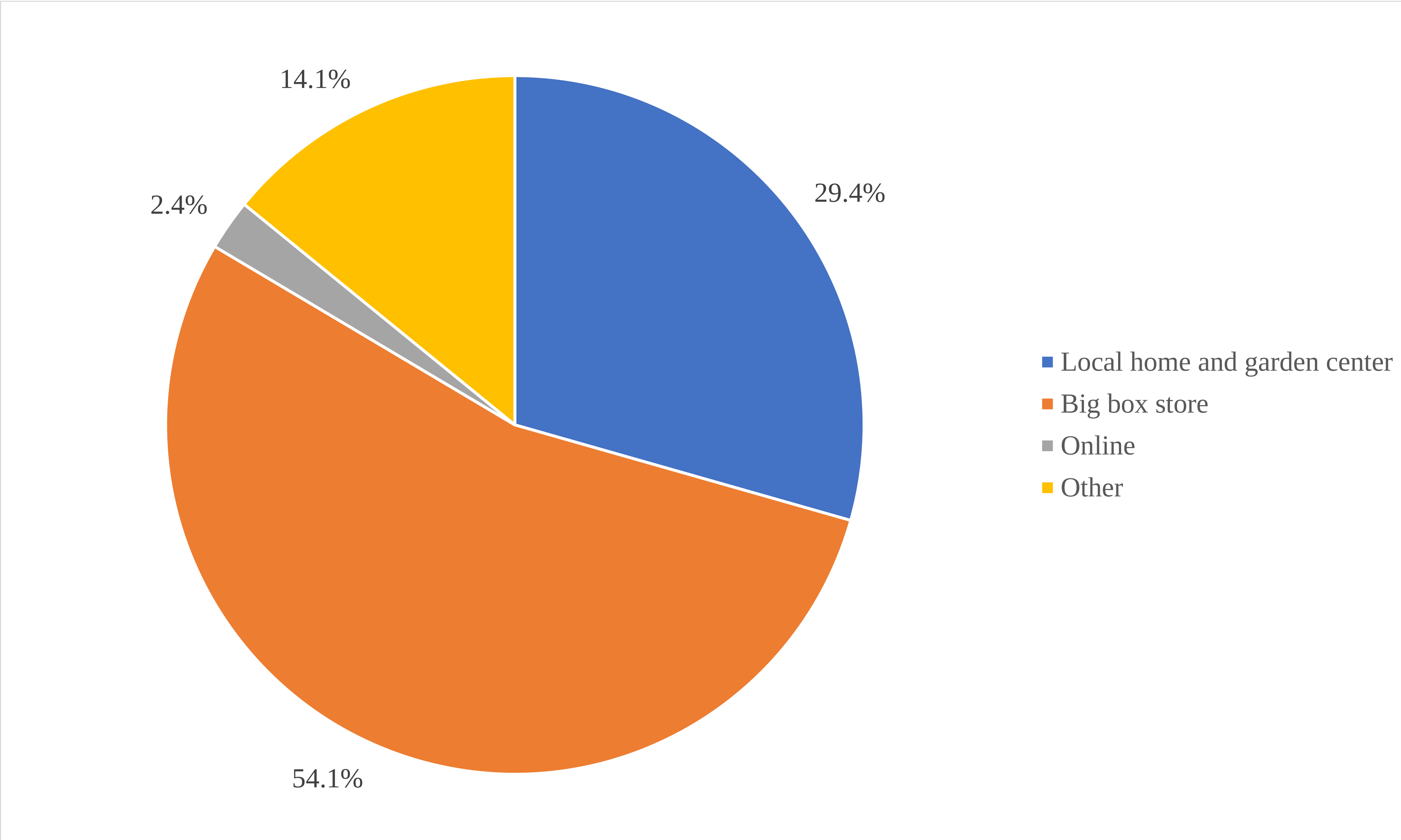



**Figure 17 2.7 Self-reported most often used place of purchase for plants used on managed properties, with big box stores listed as, "Lowes, Home Depot, Walmart, and Tractor Supply," and "Other" being reported as, "Native plant sales," and "Clemson Botanical Gardens."**

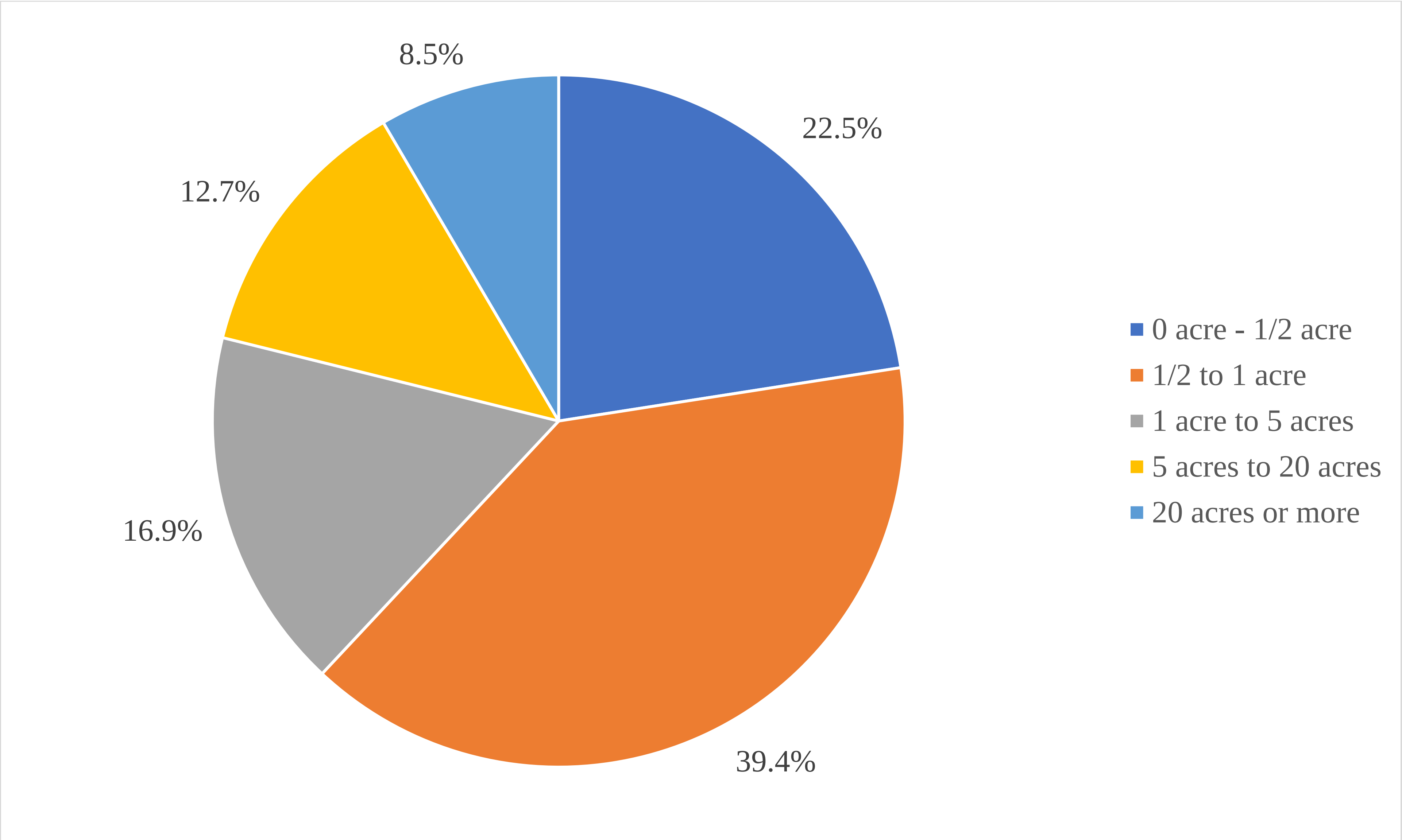



**Figure 18 2.8 Self-reported size of property managed for invasive plants by recreationist that obtain plants for their home.**

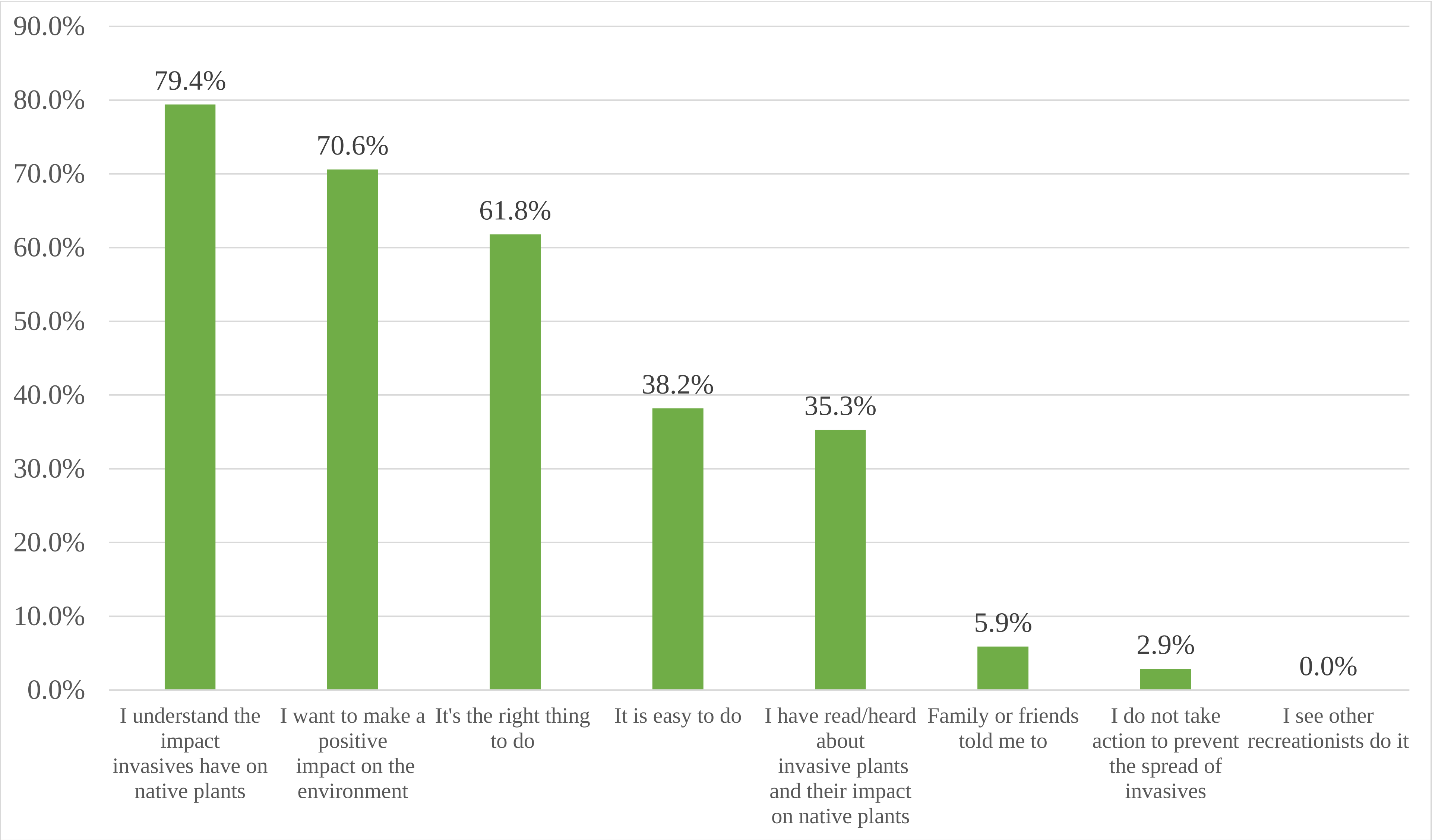



**Figure 19 2.9 Self-reported reasons for taking action to prevent the spread of invasive plants in the Clemson Experimental Forest.**

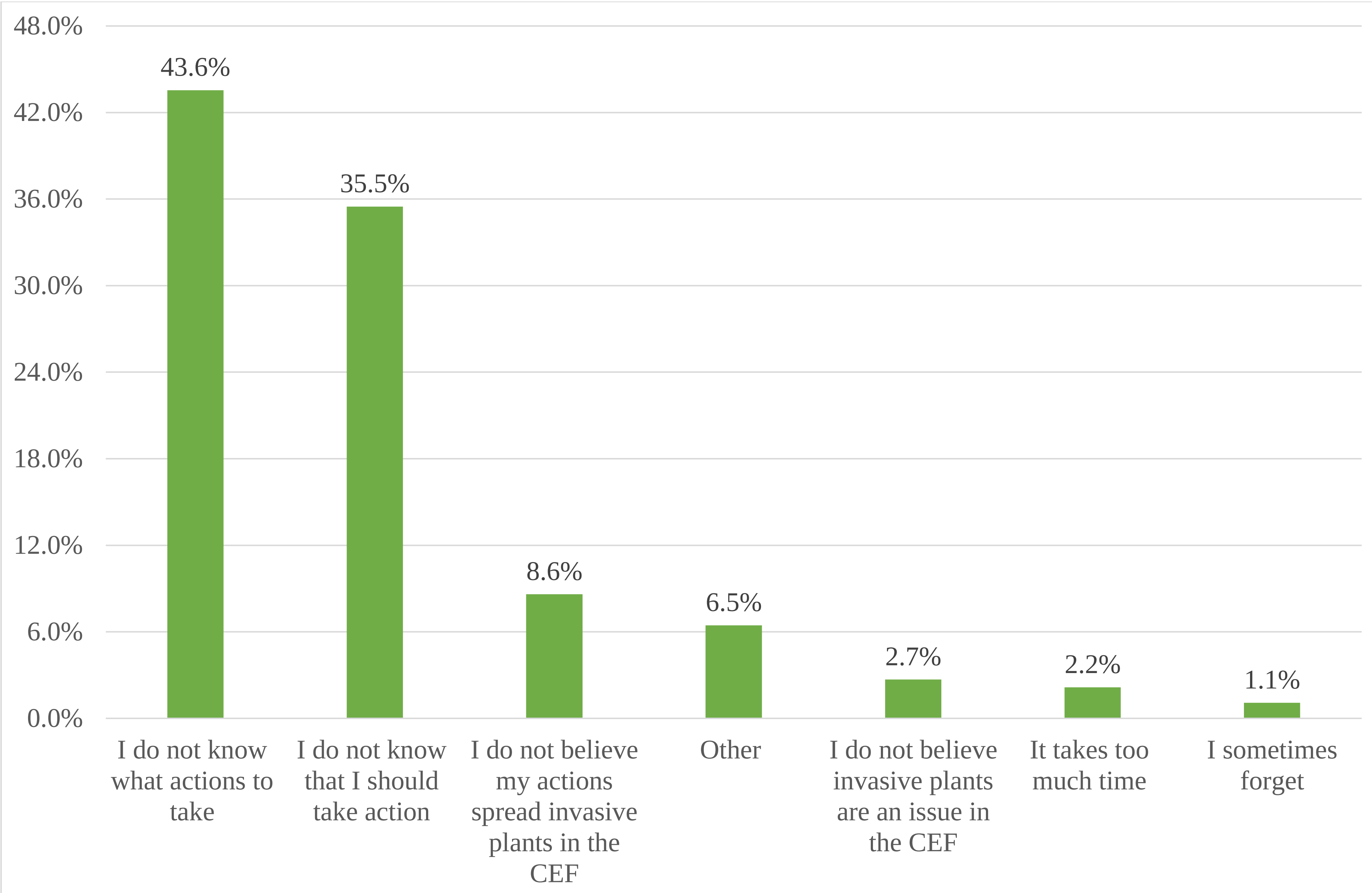



**Figure 20 2.10 Self-reported reasons for not taking actions to prevent the spread of invasive plants in the Clemson Experimental Forest.**

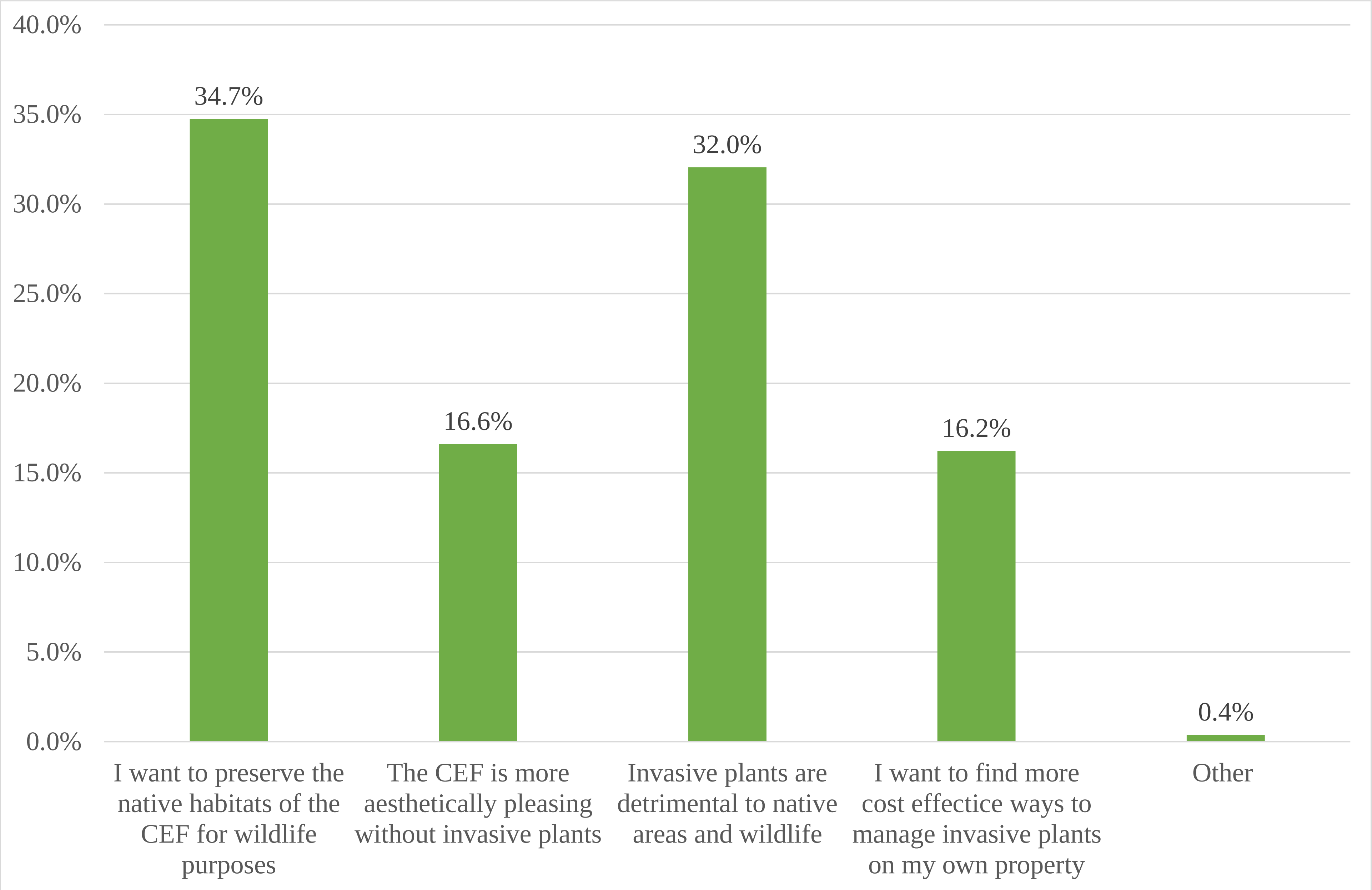



**Figure 21 2.11 Self-reported reasons for recreationists wanting to learn more about invasive plants.**

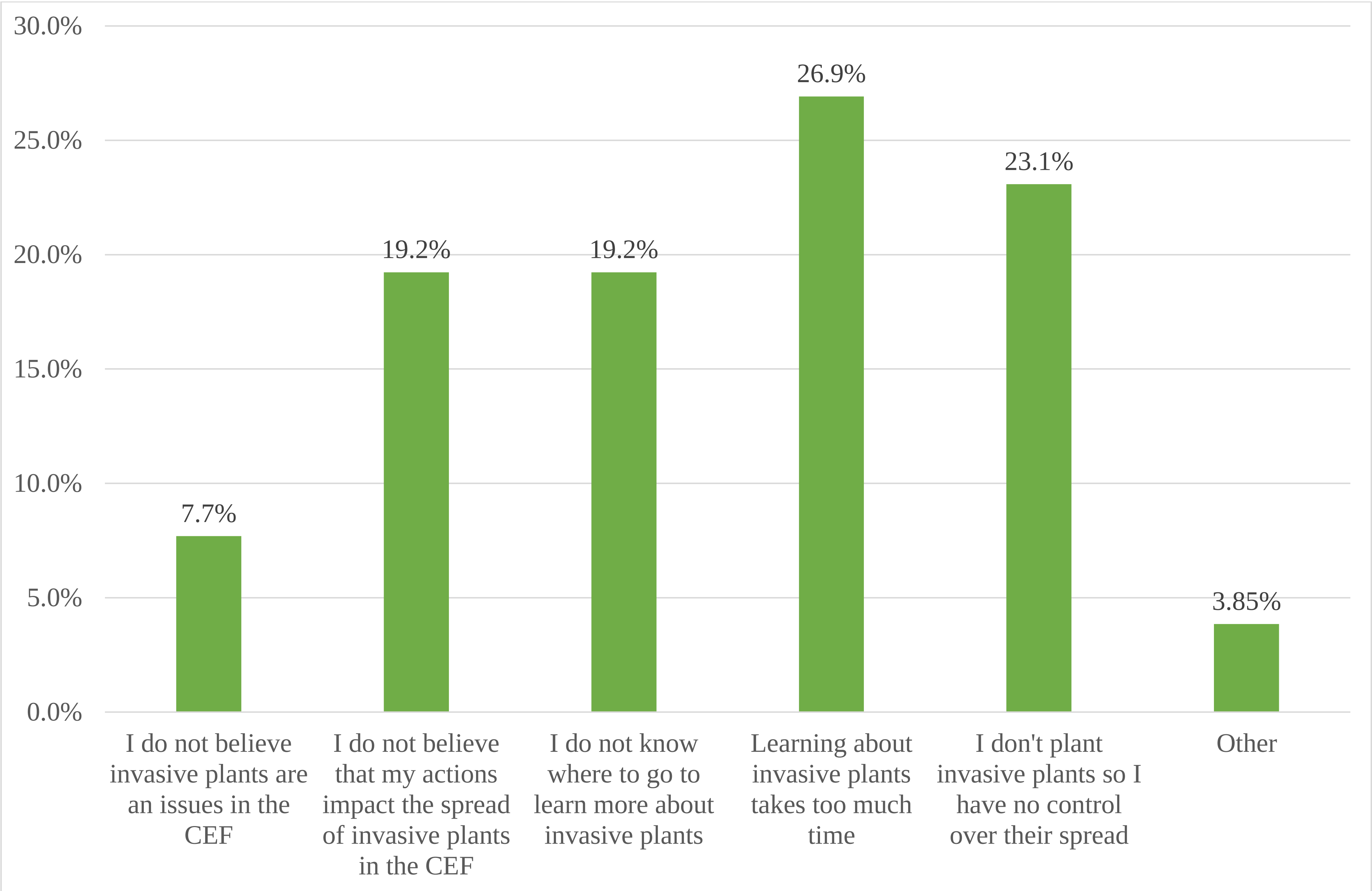

30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
7.7%
19.2%
19.2%
26.9%
23.1%
3.85%
I do not believe invasive plants are an issues in the CEF
I do not believe that my actions impact the spread of invasive plants in the CEF
I do not know where to go to learn more about invasive plants
Learning about invasive plants takes too much time
I don't plant invasive plants so I have no control over their spread
Other

**Figure 22 2.12 Self-reported reasons for not wanting to learn more about invasive plants.**

Appendix C

Survey Tool

# Recreationists' perceptions and actions towards invasive plants in the Clemson Experimental Forest

**Survey Purpose:** This survey is part of a research project conducted by the Department of Forestry and Environmental Conservation at Clemson University. The purpose of this survey is to better understand recreationists' knowledge about invasive plants, their perceptions towards invasive plant control, their recreational activities within the Clemson Experimental Forest (CEF), and the amount of invasive plant management they have done in the past or are willing to do in the future. All responses will remain anonymous. This survey should take approximately 14 minutes to complete.

**Your visit to the Clemson Experimental Forest:** In this section of the survey, we want to know about your time in the CEF. We are looking at the reasons and time of year for forest use, and which areas of the Clemson Experimental Forest are being used most.

1. Why are you visiting the CEF today? (Check all that apply)

   - ☐ To enjoy the scenery/aesthetics
   - ☐ To observe wildlife
   - ☐ For spiritual benefits
   - ☐ To spend time with family or friends
   - ☐ To enhance mental health (example to clear my head)
   - ☐ To exercise
   - ☐ To forage for food (example mushrooms, herbs etc.)
   - ☐ To find a sense of place
   - ☐ Other, please specify ______________________________________________

2. Please rank the following in order of months when you visit the CEF (1 = most often and 4 = least often).
______ Spring (March - May)
______ Summer (June - August)
______ Fall (September - November)
______ Winter (December - February)

3. Do you visit other forests or wooded recreational areas?

Yes, please specify ________________________________________________

No

4. Please select the area(s) of the CEF that you visit. If this is your first visit to the Clemson Experimental Forest, please check the area you are visiting today.

☐ Lake Issaqueena

☐ Todds Creek

☐ Keowee Heights

☐ Fants Grove

**Knowledge and awareness of invasive plants:** These survey questions look to quantify the level of knowledge users of the CEF have about invasive plant species. For the purposes of this study, we define "invasive plants" as plants from places outside of North America that are causing harm either economically or environmentally. Please refer to this definition throughout the rest of the survey.

5. What is your level of familiarity with invasive plants? (Check one)

Not familiar

A little familiar

Familiar

Very familiar

*Skip To: Q8 If What is your level of familiarity with invasive plants? (Check one) = Not familiar*

Q7 Where do you get information about invasive plants? (Check all that apply)

- ▢ Social media (e.g. Facebook, Twitter, Instagram, etc.) (1)
- ▢ News media (e.g. print, online, television, radio) (2)
- ▢ Extension Service (e.g. workshops, podcasts, etc.) (3)
- ▢ Classroom (4)
- ▢ Family or friends (5)
- ▢ Signs in the Clemson Experimental Forest (6)
- ▢ Other, please specify (8) ________________________________________________

Q8 Which of these plants have you noticed in the Clemson Experimental Forest? (Check all that apply)

| Plant Species | Which of these plants have you seen in the Clemson Experimental Forest? | | | Which of these plants is native or invasive? | |
|---|---|---|---|---|---|
| | Have seen | Have not seen | Do not know this plant | Native | Invasive |
| *A. rubrum* | | | | X | |
| *M. vimineum* | | | | | X |
| *L. sinense* | | | | | X |
| *L. japonica* | | | | | X |
| *Q. falcata* | | | | X | |
| *E. pungens* | | | | | X |
| *T. sebifera* | | | | | X |
| *C. canadensis* | | | | X | |
| *L. tulipifera* | | | | X | |
| *H. helix* | | | | | X |
| *L. cuneata* | | | | | X |
| *A. julibrissin* | | | | | X |
| *P. quinquefolia* | | | | X | |

**End of Block: Knowledge and awareness of invasive plants**

**Start of Block: Current and past actions related to invasive plant management**

Current and past actions related to invasive plant management: In this section of the survey, we aim to measure your current and past actions in dealing with invasive species within the Clemson Experimental Forest.

Q57 Do you take actions to prevent the spread of invasive plants in the Clemson Experimental Forest?

Yes (1)

No (2)

*Skip To: Q11 If Do you take actions to prevent the spread of invasive plants in the Clemson Experimental Forest? = Yes*

*Skip To: Q12 If Do you take actions to prevent the spread of invasive plants in the Clemson Experimental Forest? = No*

*Display This Question:*

*If Do you take actions to prevent the spread of invasive plants in the Clemson Experimental Forest? = Yes*

Q11 What actions have you taken to prevent the spread of invasive plants in the Clemson Experimental Forest? (Check all that apply)

- ▢ Clean my shoes (1)
- ▢ Clean my pets (2)
- ▢ Clean my tires (3)
- ▢ Clean my recreational equipment (4)
- ▢ I do not take action to prevent the spread of invasive species in the Clemson Experimental Forest (5)
- ▢ Other, please explain (6) ________________________________________________

Q10 Why do you take action to prevent the spread of invasive plants in the Clemson Experimental Forest? (Check all that apply)

- ▢ I want to make a positive impact on the environment (1)
- ▢ It is easy to do (2)
- ▢ It's the right thing to do ethically (3)
- ▢ My family or friends told me to do it (4)
- ▢ I see other recreationists do it (5)
- ▢ I understand the impact that invasive plants have on native plants (6)
- ▢ I have read/heard about invasive plants and their impact on native plants (TV, Radio, Extension class/publication, News article) (11)
- ▢ I do not take any action to prevent the spread of invasive plants in the Clemson Experimental Forest (8)

---

*Display This Question:*

*If Do you take actions to prevent the spread of invasive plants in the Clemson Experimental Forest? = No*

Q12 Why do you NOT take action to prevent the spread of invasive plants in the Clemson Experimental Forest? (Check all that apply)

- ▢ I do not think that invasive plants are an issue in the Clemson Experimental Forest (1)
- ▢ I do not believe that my actions impact the spread of invasive plants in the Clemson Experimental Forest (2)
- ▢ It takes too much time (3)
- ▢ I sometimes forget (4)
- ▢ I do not know that I should take action (5)
- ▢ It costs too much (6)
- ▢ I do not know what actions to take (7)
- ▢ Other, please explain (8) ________________________________________________

**End of Block: Current and past actions related to invasive plant management**

---

**Start of Block: Feelings of responsibility/self-efficacy towards the Clemson Experimental Forest**

Q63 Invasive plants in the Clemson Experimental ForestIn this section, we aim to assess the beliefs and feelings of individuals, and how those individuals perceive other users of the Clemson Experimental Forest.

---

Q13 How much do you agree with the following statements? (Scale = Strongly Disagree (1), Disagree (2), Agree (3), Strongly Agree (4)).

- I believe it is my responsibility to reduce the spread of invasive plants.
- I believe it is Clemson University's responsibility to reduce the spread of invasive plants.
- I believe recreationists and other users have a responsibility to reduce the spread of invasive plants.
- I believe that my actions can have a direct impact on the spread of invasive plants in the Clemson Experimental Forest.
- I believe it is my responsibility to educate myself and others about invasive plants in the Clemson Experimental Forest.
- I believe that invasive plants pose a real threat to the local ecosystems of the Clemson Experimental Forest.
- I believe cleaning my gear and equipment will prevent the spread of invasive plants in the Clemson Experimental Forest.
- I believe cleaning my pets will prevent the spread of invasive plants in the Clemson Experimental Forest.

**End of Block: Feelings of responsibility/self-efficacy towards the Clemson Experimental Forest**

---

**Start of Block: Invasive plants on your property**

Q64 Invasive plants on your property: In this section, we aim to assess which, if any, actions you take concerning invasive species on your own property and your motivations for your choices.

---

Q58 Do you take actions to prevent or control invasive plants on your property?

Yes (1)

No (2)

*Skip To: Q46 If Do you take actions to prevent or control invasive plants on your property? = No*

---

*Display This Question:*

*If Do you take actions to prevent or control invasive plants on your property? = Yes*

Q14 What actions do you take to prevent or control invasive plants on your property? (Check all that apply)

- ▢ I use chemical treatments (1)
- ▢ I cut and pull invasive plants (2)
- ▢ I use biological control tactics (e.g., using goat grazing to control invasive plants) (3)
- ▢ Other, please specify (5) ________________________________________________

---

Q18 What size is your property where you currently manage invasive plants?

- 0 acre - 1/2 acre (1)
- 1/2 to 1 acre (2)
- 1 acre to 5 acres (3)
- 5 acres to 20 acres (4)
- 20 acres or more (5)

---

Q46 Do you obtain plants for your home?

- Yes (1)
- No (2)

*Skip To: End of Block If Do you obtain plants for your home? = No*

---

*Display This Question:*

*If Do you obtain plants for your home? = Yes*

Q15 If you purchase plants to plant on your property, how important is it that they are not classified as invasive plants? (Check one)

- Not important (1)
- Of little importance (2)
- Moderately important (4)
- Important (5)
- Very important (6)

---

Q16 How do you determine that the plants you are purchasing for your property are known invasive plants for your area? (Check one)

- ☐ I research the plant prior to purchase (1)
- ☐ I read the labels on the plant (2)
- ☐ I took a class that taught me what plants are invasive to my area (3)
- ☐ I do not determine this prior to purchasing plants for my property (4)
- ☐ Other, please specify (5) ________________________________________________

---

Q17 From where do you most often purchase your plants?

Local home and garden center, please specify (1)

________________________________________________

Big box store (Lowe's, Home Depot, Walmart, Tractor Supply) (2)

Online (6)

Other, please specify (7) ________________________________________________

---

Q19 How much do you agree with the following statements? (Choose Neutral if you do not purchase plants for your property)(Scale = Strongly Disagree (1), Disagree (2), Neutral(3), Agree (4), Strongly Agree (5)).

- I choose plants for my property that are native.
- I choose plants for my property that help increase native diversity.
- I choose plants for my property that attract wildlife species.
- I choose plants for my property that increase property value.
- I choose plants for my property that are aesthetically pleasing.
- I will not buy plants that can are classified as invasive plants in South Carolina.

End of Block: Invasive plants on your property

---

Start of Block: Future Actions

Q65 Future actions: In this section, we aim to identify which, if any, actions you will take in the future regarding invasive plants control and education, and willingness to spread invasive plant information.

---

Q20 How much do you agree with the following statements? (Scale = Strongly Disagree (1), Disagree (2), Agree (3), Strongly Agree (4)).

- I will further my education about invasive plants.
- I will plant only native species on my own property to help reduce the spread of invasive plants.
- I will educate others about invasive plants and their spread to our local area and the Clemson Experimental Forest.
- I will take measures to prevent the spread of invasive plants in the Clemson Experimental Forest.
- I will share information about invasive plants on my social media platforms.
- I believe my sharing of information through social media will influence others' decisions about buying and planting invasive plants.

End of Block: Future Actions

---

Start of Block: Learning and education - Recreationists' motivations to learn more

Q66 Learning and education - Recreationists' motivations to learn moreIn this section of the survey, we aim to measure your interest in learning about invasive plants and why you feel this way.

---

Q59 Would you like to learn more about invasive plants?

Yes (1)

No (3)

*Skip To: Q22 If Would you like to learn more about invasive plants? = No*

---

*Display This Question:*

*If Would you like to learn more about invasive plants? = Yes*

Q21 I would like to learn more about invasive plants because (Check all that apply)

▢ I want to preserve the native habitats of the Clemson Experimental Forest for wildlife purposes (1)

▢ The Clemson Experimental Forest is more aesthetically pleasing without invasive plants (2)

▢ Invasive plants are detrimental to native areas and wildlife (3)

▢ I want to find more cost effective ways to manage invasive plants on my own property (4)

▢ I do not want to learn more about invasive plants (5)

▢ Other, please specify (6) ________________________________________________

---

Q53 What type of educational delivery methods do you enjoy most? (Rank the following in order of preference with 1 - most preferred and 7 as least preferred)
______ Indoor classroom instruction (1)
______ Outdoor, interactive, hands-on lessons (2)
______ Short educational videos (3-5 minutes long) (3)
______ Webinars (up to 60 minutes) (4)
______ Outdoor signs at trail heads (5)
______ Written media (6)
______ News (print and online) (7)

---

*Display This Question:*

*If Would you like to learn more about invasive plants? = No*

Q22 I would NOT like to learn more about invasive plants because (Check all that apply)

- ▢ I do not think that invasive plants are an issue in the Clemson Experimental Forest (1)
- ▢ I do not believe that my actions impact the spread of invasive plants in the Clemson Experimental Forest (2)
- ▢ I don't know where to go to learn about invasive plants (3)
- ▢ Learning about invasive plants takes too much time (4)
- ▢ Learning about invasive plants costs too much money (5)
- ▢ I don't plant invasive plants so I have no control over their spread (6)
- ▢ Other, please specify (7) ________________________________________________

**End of Block: Learning and education - Recreationists' motivations to learn more**

---

**Start of Block: Demographics**

Q67 Demographics We ask that you complete the following questions to help us create a detailed understanding of people that use the Clemson Experimental Forest. This information will help us inform future decision making and educational efforts. All responses will be kept confidential and no identifiable information will be linked to you or your responses.

---

Q44 What is your gender?

- Male (1)
- Female (2)
- Non-binary/Gender fluid (3)
- Prefer not to answer (4)

---

Q45 What is your age?

- 18-24 (1)
- 25-34 (2)
- 35-44 (3)
- 45-54 (4)
- 55-64 (5)
- 65+ (6)

---

Q56 Do you identify as Hispanic or Latino?

- Yes (1)
- No (2)

---

Q46 What is your race? (Check all that apply)

- ☐ African American/Black (1)
- ☐ Alaska Native (2)
- ☐ Asian (3)
- ☐ Native American/American Indian (4)
- ☐ Native Hawaiian or other Pacific Islander (5)
- ☐ White/Caucasian (6)
- ☐ Other, please specify (7) ________________________________________________

---

Q47 What is your household annual gross income level?

- $0 - $49,999 (1)
- $50,000 - $99,999 (2)
- $100,000 - $149,999 (3)
- $150,000 - $199,999 (4)
- $200,000 - $249,999 (5)
- Over $250,000 (6)
- Prefer not to answer (7)

---

Q48 What is your employment status?

- Employed (1)
- Self-employed (2)
- Retired (3)
- Disabled (4)
- Full-time student (5)
- Currently unemployed (6)

---

Q49 What type of community(ies) did you spend your time living in between the ages of birth and eighteen? (Check all that apply)

- ☐ Rural farm or lived out of town (1)
- ☐ Small town with up to 5,000 people (2)
- ☐ City with between 5,000 and 30,000 people (3)
- ☐ City with between 30,000 and 65,000 people (4)
- ☐ City with between 65,000 and 100,000 people (5)
- ☐ City with 100,000 people or more (6)

---

Q50 What is your highest level of education completed? (check one)

- ▢ Less than high school or GED (1)
- ▢ High school or GED (2)
- ▢ Technical, trade, or vocational program (3)
- ▢ Some college (no degree) (4)
- ▢ Associates degree (2-year degree) (5)
- ▢ Bachelor's degree (4-year degree) (6)
- ▢ Masters (M.S., M.A., M.B.A.) (7)
- ▢ Doctorate (J.D., Ph.D.) (8)
- ▢ Other terminal degree (e.g. M.F.A.) (9)

---

Q51 If you received a degree(s), please specify the field(s) of study for each degree completed.

________________________________________________________________

---

Q47 Would you like to be entered for a drawing for a $50 Visa gift card? There will be two winners picked from those who complete the survey. Submit your email address for your chance to win!

________________________________________________________________

---

Q52 Thank you for taking the time to complete our survey! Do you have any other comments you would like to add?

________________________________________________________________

**End of Block: Demographics**

| | | What is your level of familiarity with invasive plants? | | | | |
|---|---|---|---|---|---|---|
| | | Not familiar | A little familiar | Familiar | Very familiar | **Total** |
| Which of these plants is invasive or native? | | 23.0 | 52.0 | 30.0 | 19.0 | 124.0 |
| *A. rubrum* | Invasive | 30.0% | 8.3% | 6.9% | 0.0% | 10.3% |
| | Native* | 70.0% | 91.7% | 93.1% | 100.0% | 89.7% |
| *M. vimineum* | Invasive* | 80.0% | 95.7% | 96.6% | 100.0% | 93.9% |
| | Native | 20.0% | 4.3% | 3.4% | 0.0% | 6.1% |
| *L. sinense* | Invasive* | 88.9% | 93.0% | 96.6% | 100.0% | 94.4% |
| | Native | 11.1% | 7.0% | 3.4% | 0.0% | 5.6% |
| *L. japonica* | Invasive* | 63.2% | 86.4% | 89.7% | 94.7% | 84.7% |
| | Native | 36.8% | 13.6% | 10.3% | 5.3% | 15.3% |
| *Q. falcata* | Invasive | 26.3% | 4.1% | 3.3% | 0.0% | 6.9% |
| | Native* | 73.7% | 95.9% | 96.7% | 100.0% | 93.1% |
| *E. pungens* | Invasive* | 50.0% | 48.7% | 75.0% | 88.9% | 63.1% |
| | Native | 50.0% | 51.3% | 25.0% | 11.1% | 36.9% |
| *T. sebifera* | Invasive* | 83.3% | 84.2% | 86.2% | 100.0% | 87.3% |
| | Native | 16.7% | 15.8% | 13.8% | 0.0% | 12.7% |
| *C. canadensis* | Invasive | 21.1% | 9.8% | 16.7% | 10.5% | 13.8% |
| | Native* | 78.9% | 90.2% | 83.3% | 89.5% | 86.2% |
| *L. tulipifera* | Invasive | 5.6% | 8.2% | 0.0% | 5.6% | 5.3% |
| | Native* | 94.4% | 91.8% | 100.0% | 94.4% | 94.7% |

| | | | | | | |
|---|---|---|---|---|---|---|
| *H. helix* | Invasive* | 72.7% | 76.0% | 92.9% | 100.0% | 83.1% |
| | Native | 27.3% | 24.0% | 7.1% | 0.0% | 16.9% |
| *L. cuneata* | Invasive* | 57.9% | 59.5% | 61.5% | 93.8% | 65.3% |
| | Native | 42.1% | 40.5% | 38.5% | 6.3% | 34.7% |
| *A. julibrissin* | Invasive* | 50.0% | 41.5% | 75.0% | 83.3% | 58.9% |
| | Native | 50.0% | 58.5% | 25.0% | 16.7% | 41.1% |
| *P. quinquefolia* | Invasive | 50.0% | 46.5% | 17.2% | 0.0% | 32.1% |
| | Native* | 50.0% | 53.5% | 82.8% | 100.0% | 67.9% |