

POTENTIAL IMPACTS OF YEAR-ROUND SAMPLING ON MONITORING PRESENCE-ABSENCE OF INVASIVE FLORA IN THE SOUTHERN UNITED STATES

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ABSTRACT

Studies suggest that the southern United States is an area of primary concern with regards to the spread of nonnative invasive plant species. Recent data show that species such as Japanese honeysuckle (*Lonicera japonica*) and Nepalese browntop (*Microstegium vimineum*) are invading forests and displacing native species throughout the southern United States. Monitoring on large spatial scales is among the most important mechanisms for the detection and prevention of the spread of nonnative species.

Accurate assessments of on-going biological invasions are a primary research priority in the Southeast. As one method for addressing this need, the US Forest Service Southern Research Station (SRS), in partnership with State forestry agencies across the South, initiated a southern region survey of 33 invasive plant taxa in 2001 on all forest ownerships as part of the SRS Forest Inventory and Analysis (FIA) program. Currently in the southern United States, presence-absence data is collected for select invasive flora throughout the calendar year. Little is known about the impacts of year-round sampling on the quality of invasive flora data collection. In this study we investigate the implications of year-round sampling on presence-absence data collected by the southern FIA program for states east of the Mississippi river. Chinese and European privets (*Ligustrum* spp) are observed on FIA plots most often between February and May, and least often between September and December. Exotic roses (*Rosa* spp) and Japanese honeysuckle follow a similar trend.

Nepalese browntop, however, is observed more often between August and October. Moreover, Nepalese browntop is observed more than four times as often during peak months than it is during the period between December and April. These results suggest that plant apparency may be impacting the quality of presence-absence data collected by the SRS-FIA program. While the systematic nature of the FIA sampling design minimizes the impact to population estimates of sampled invasive flora, year-round sampling may be impacting attempts to accurately portray the geographical distribution of a given plant.

Keywords: forest inventory, invasive species, exotic plants, sampling bias, plant survey

INTRODUCTION

Nonnative invasive plant species (NNIPS) are threats to southern forests through the displacement of native species (Mooney and Cleland 2001), the alteration of soil physical

and chemical properties (Bruce and others 1995, Jose and others 2002), and the disruption of successional pathways (Oswalt and others 2007) among other potential impacts (Gordon 1998, Jose and others 2002). Environmental impacts coupled with attempts to control and/or eradicate NNIPS are costly, as exemplified by the estimated \$3 to \$6 million spent annually by the State of Florida to manage the highly invasive Chinese tallowtree (*Melaleuca quinquenervia*; Pimentel and others 2005). Because of the environmental and ecological burdens posed by these species, NNIPS inventory and monitoring is considered a priority in the South.

Effective inventory and monitoring programs depend on reliable data. Monitoring vegetation on a large scale can be challenging, however. The potential effects of observer-bias in vegetation monitoring have been documented and include species misidentification and missed species occurrences, along with widely varying interpretations of area cover, all of which can result in inaccurate representations of species' abundances and spread (Archaux and others 2006, Leps and Hadincova 1992, Gotfryd and Hansell 1985, Hall and Okali 1978). Additionally, species diversity and abundance estimates are closely correlated with the seasonal sampling period, particularly as pertains to herbaceous ground flora, and single-season sampling may result in underestimates (Small and McCarthy 2002). Typically, vegetation surveys in the deciduous forests of the north and southeast are conducted during the growing season when flora are in leaf-on condition and/or are flowering. In some cases, however, overarching monitoring goals may result in sampling during the dormant season, as with the USDA Forest Service Southern Research Station Forest Inventory and Analysis (SRS-FIA) program.

Currently, the increase in the number of plots surveyed for invasive plants by using the FIA Phase 2 plots provides significant additional data over using the FIA Phase 3 plots.

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While Phase 3 plots are only surveyed during the growing season months, the sample intensity is 1/16th of the Phase 2 plots. Moreover, the added logistical challenges of sampling a subset of the Phase 2 plots along with the fact that the invasive plant survey is a secondary goal render such an option untenable.

The SRS-FIA program began tracking forest health threats, including NNIPS, on forestland in 2001. The NNIPS-monitoring component provides a mechanism for monitoring the spread of common (known) invasive plants on both public and private land at a large scale by utilizing the existing FIA system of forest inventory plots. Data collection occurs year-round in all southern states, regardless of the expressed phenology of the vegetation (i.e., leaf-on, withered, brown, etc...).

The impacts of this year-round sampling on the quality of NNIPS flora data collection have not been quantified. In this study we investigate the implications of year-round sampling on presence-absence data collected by the southern FIA program for states east of the Mississippi river with the specific objective of quantifying the impact of year-round sampling on the SRS-FIA invasive plant data.

METHODS

DATA COLLECTION

The FIA program collects data on plots distributed in a random, systematic fashion on both private and public land across the United States. The plot design consists of four 1/6-acre fixed-radius subplots arranged in a “tri-areal” configuration (Bechtold and Patterson 2005). A number of environmental conditions, tree-level variables, and abiotic measures are recorded on each subplot. Detailed explanations of the FIA plot design and sampling phases are given in Bechtold and Patterson (2005).

Nonnative invasive plant species are among the variables sampled on all FIA plots in the Southern region. The NNIPS program was implemented in 2001 to meet the needs of State forestry agencies and other partners for tracking the emergence and spread of species known to cause ecological problems in southern forests. Observers are trained in the detection of 33 species classified into 6 life forms (trees, shrubs, herbs, grasses, vines, and ferns) from a pre-developed list of NNIPS (Table 1).

Additional NNIPS are recorded in Florida; however, for the purposes of this study the species analyzed were limited to those sampled in all southern states. Observers are instructed to note the presence/absence and percent cover (< 01 percent, 01-10 percent, 11-50 percent, 51-90 percent, and 91-100 percent) of (up to) the four most abundant species found on the forested portion (condition) of

each sampled subplot. Sampling occurs year-round, and observers are instructed to record an estimate of percent cover as though plants are in leaf-on condition when sampling occurs during the dormant season. Studies suggest that observer bias may be minimized by consistent and frequent calibration (training) and quality control procedures (Kercher, Frieswyk, and Zedler 2003). Standard FIA quality assurance procedures apply to the NNIPS program, and include randomly-selected plots subjected to checks by certified quality control personnel.

DATA ANALYSIS

We used 29,558 SRS-FIA plots from 9 southern States to examine the impact of year-round sampling (Figure 1). States included in the analysis were Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia. We calculated the relative occurrence for each NNIPS at the plot level by the month in which the data were collected. Plots-by-month were grouped into season for analysis (Spring – March to May, Summer – June to August, Fall – September to November, and Winter – December to February) and subjected to a one-way analysis of variance (ANOVA) with Tukey mean separation to determine if differences in relative occurrence existed among sample seasons.

Additionally, we calculated the relative occurrence and estimate of cover for each NNIPS by subplot and month. We share those preliminary results graphically.

Results – Nonnative invasive plants from the predetermined list were detected on 15,720 (53 percent) of the sampled plots. Japanese honeysuckle was the most frequently observed species, while giant reed was least common (Table 2). Observers noted 3 or fewer species on most (92 percent) of the plots containing NNIPS, though 2 plots contained at least 8 species from the list (Table 3).

While inter-seasonal detection differences were found for 9 of the 33 species surveyed ($p < 0.05$; Table 4), four species appeared to exhibit the most notable differences (mimosa, Nepalese browntop, Chinese lespedeza, and shrubby lespedeza). The time of observation bias differed depending on the individual species and its phenotypic expression. For example, mimosa is a tree that presents an easily recognizable flower in the summer months and, indeed, detection rates were higher in the summer than in any other season (Figure 2a). Winter detections were least common for mimosa, when the plant is in leaf-off phase. Nepalese browntop was most frequently detected in summer and fall (Figure 2b), when foliage is most noticeable because of its height. Chinese and shrubby lespedeza exhibited similar patterns wherein relative occurrence was extremely low in the winter and highest in the summer and fall periods (Figure 2c and 2d, respectively).

Preliminary graphs of relative subplot occurrence by month indicate that detection differences appear to exist for species in each life form (Figure 3) with the exception of vines (Figure 3c) and possibly shrubs (Figure 3b). Mimosa detections occurred most often from April through July, the flowering period for the species, and Chinese tallowtree was most often detected from June through August (Figure 3a).

Shrubs and vines showed little monthly variation in relative occurrence, though ANOVA indicated that seasonal variation in detection did exist for privet species, which may be detected more frequently in the winter simply because it is an evergreen and perhaps more likely to be correctly identified during the months when other species are dormant. Two of the 6 grasses varied in their monthly detection rates (Figure 3d).

Microstegium detection rates peaked in July, August, and September, while tall fescue detection rates were highest from May through November—the typical growing season in the southern states. Ferns and other herbaceous species exhibited some monthly differences in detection rates (Figure 3e). Detection rates for both lespedeza species were highest from June through September, with peaks in August, while detection rates for Japanese climbing fern peaked in July.

Inter-seasonal differences in relative occurrence appeared strongest in the smaller cover classes. For example, the range in monthly relative occurrence of Chinese lespedeza was greatest for the <01 percent cover class, followed by the 01-10 percent, 11-50 percent, and 51-90 percent cover classes and was smallest for the >90 percent cover class (Figure 4a and 4b). Concomitantly, the overall relative occurrence was greatest for the smaller cover classes (Figure 4c). Moreover, the monthly mean relative occurrence deviated very little from the annual mean relative occurrence for the larger cover classes (Figure 4d). This pattern was similar for the majority of the species that exhibited a significant inter-seasonal bias.

DISCUSSION

Preliminary results from our study indicate that seasonal detection bias occurs for some species on the SRS-FIA NNIPS list. Species are most likely to be detected during the peak of the southern growing season (late spring, summer, early fall), or when some distinct characteristic (e.g. flowers, herb height, etc...) increases visibility in the forest understory. Seasonal detection bias may result in false negatives on FIA plots, thus underestimating invasion rates. Bias appears to be limited to the winter months, suggesting that sampling during the winter is less effective than sampling during the other three seasons for a limited number of species collected. In addition to underestimating invasion

rates, seasonal biases in estimates of percent cover add error to modeled representations of invasion threats on the ground. Underestimating invasion rates and/or extents may prevent managers from directing resources to appropriate areas for control and eradication efforts.

The most surprising result was that of seasonal differences in the relative occurrence of some tally tree species. For example, mimosa exhibited a five-fold increase in mean relative occurrence from winter to spring. Seasonal differences in relative occurrence among tally trees may suggest a need for increased winter identification training. Moreover, such results suggest that this analysis has potential for use within the quality control program of FIA in order to identify potential additional training needs.

The results of this study suggest that SRS-FIA may want to reconsider sampling during winter months, limiting sampling to the growing season. If sampling continues year-round, the study results suggest that additional measures are needed to train observers to recognize NNIPS during the dormant season, and that quality assurance personnel may need to pay extra attention to the NNIPS component of sampled variables during the winter months.

Data reliability is a key component of inventory and monitoring programs. The preliminary results of this study indicate that measures may need to be taken to ensure high quality NNIPS data are available year-round in the south. Further research is needed to quantify the impact of potential false-negatives to invasive plant distribution modeling using SRS-FIA invasive plant data. In addition, further research is needed to better understand this bias through multiple plots visits within a given year.

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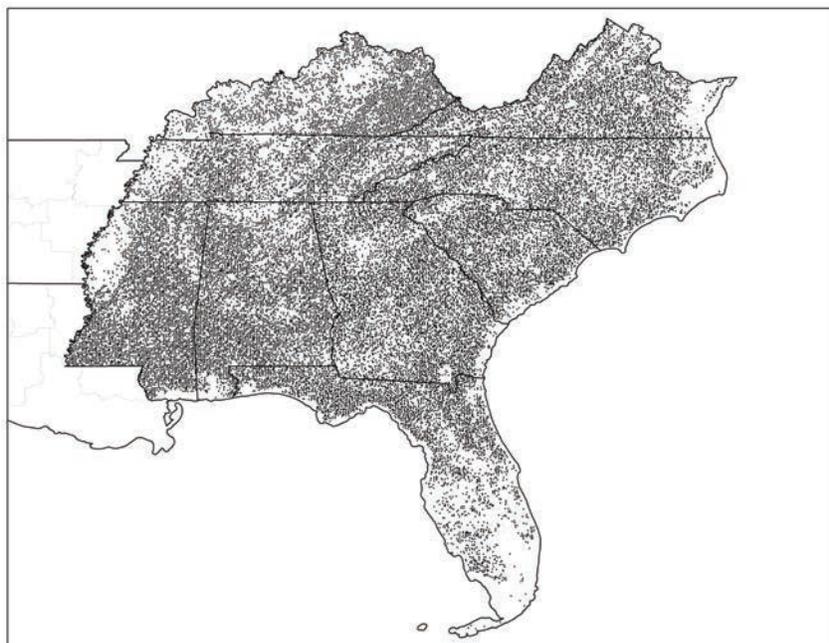


Figure 1—Approximate plot locations of forested plots where invasive plant data was collected by the Southern Research Station Forest Inventory and Analysis program between roughly 2002 and 2007.

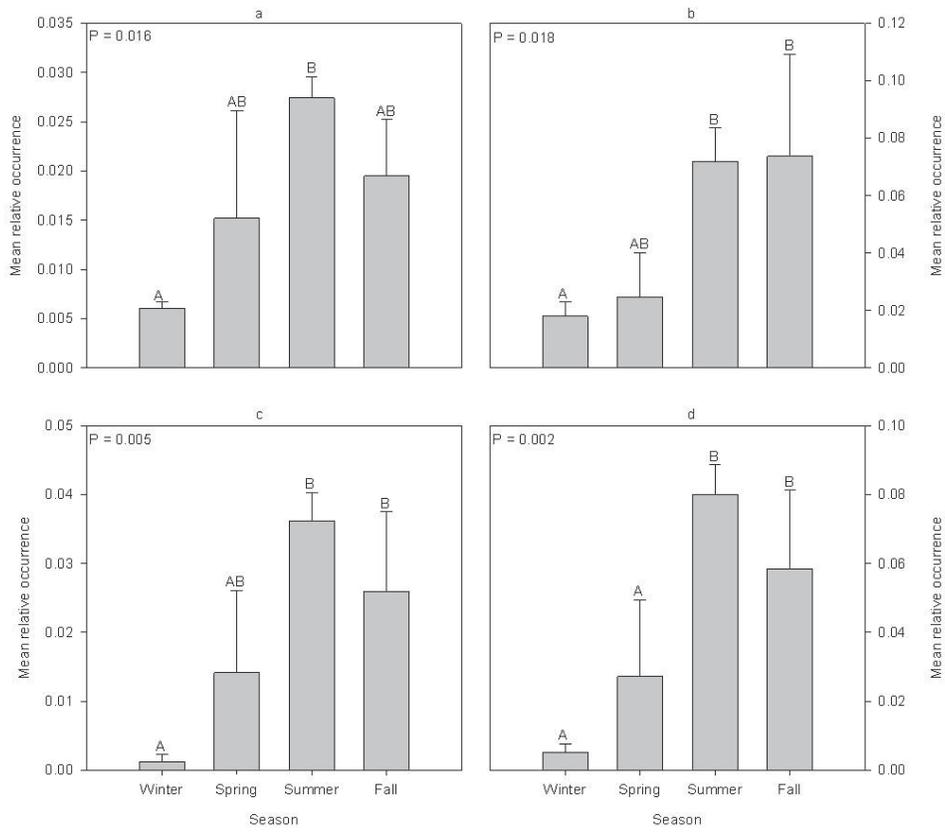


Figure 2—Mean relative occurrence of (a) mimosa, (b) microstegium, (c) Chinese lespedeza, and (d) shrubby lespedeza across four seasonal categories. Bars with different lettering indicates significant inter-seasonal differences (alpha 0.05).

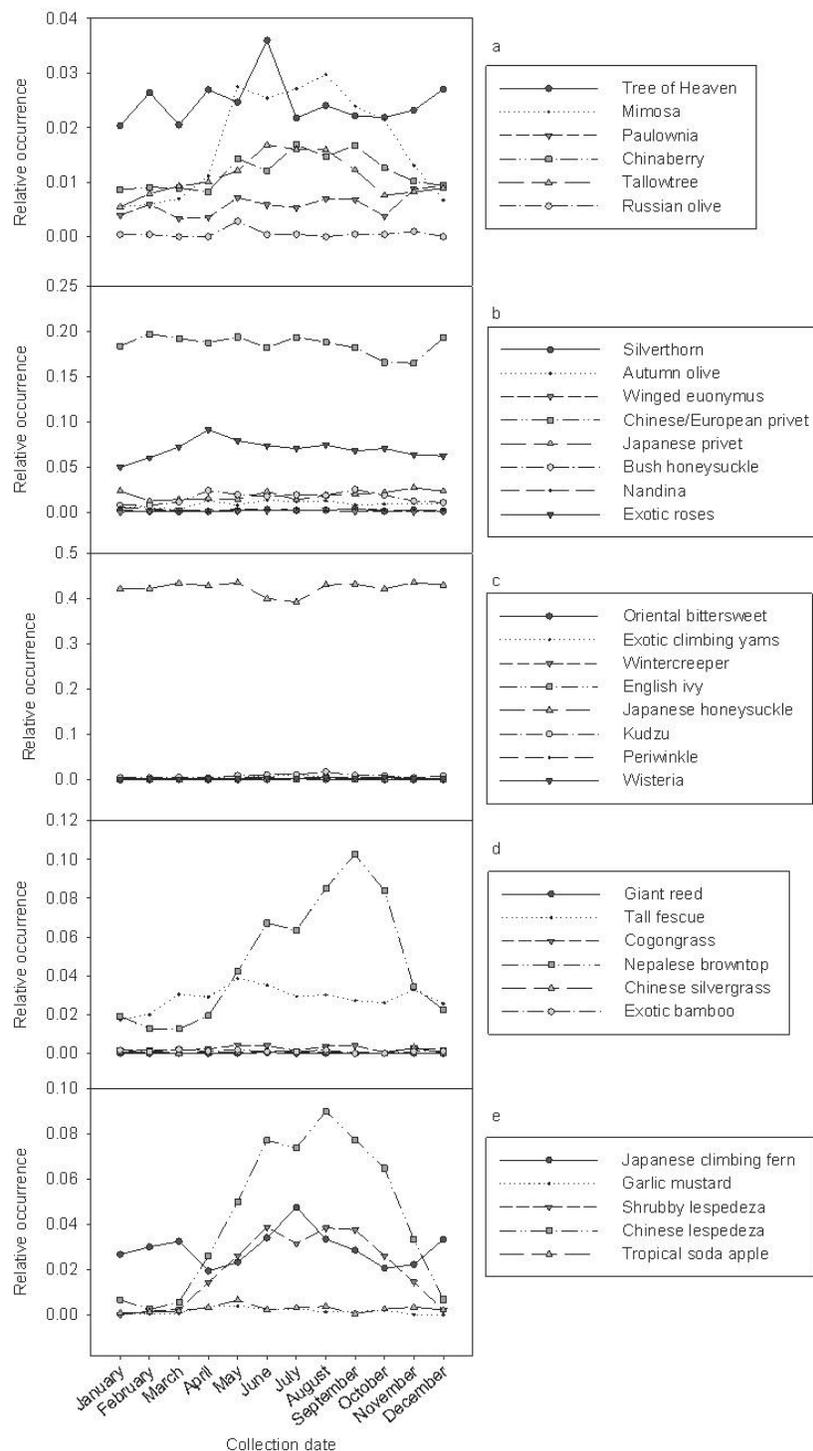


Figure 3—Monthly relative occurrence for invasive (a) trees, (b) shrubs, (c) vines, (d) grasses, and (e) ferns, forbs and other herbaceous plants collected by the Southern Research Station Forest Inventory and Analysis program between roughly 2002 and 2007.

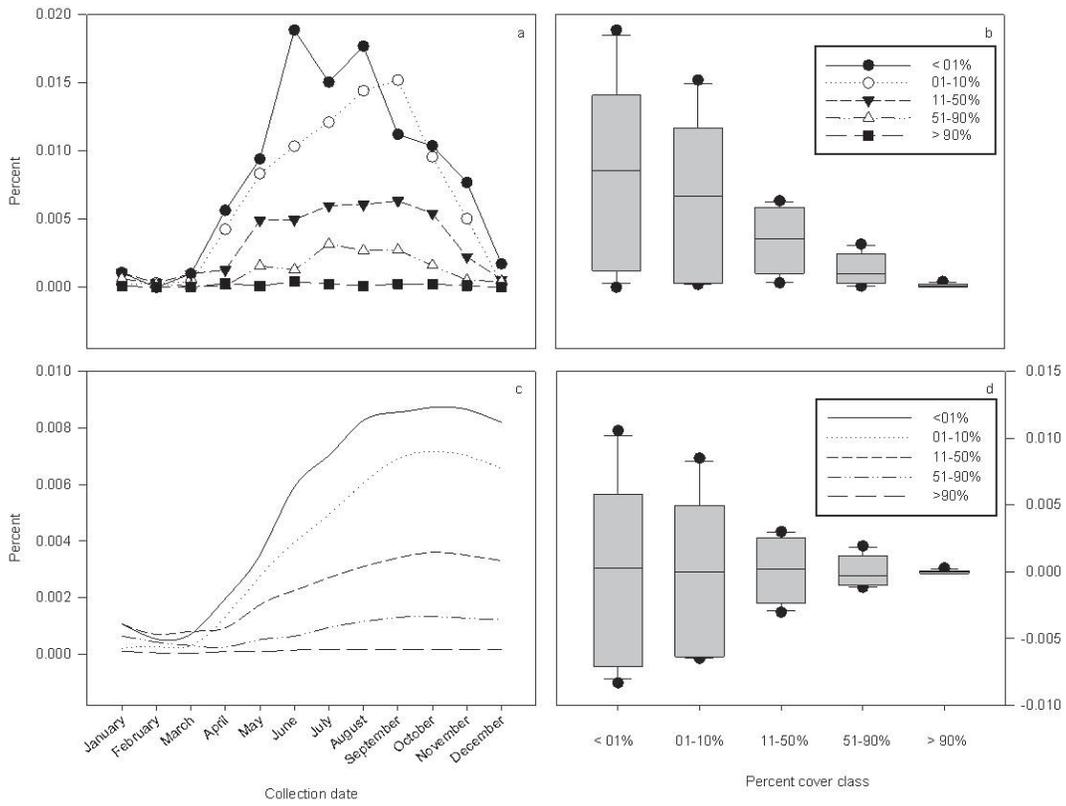


Figure 4—Estimates of (a) monthly relative occurrence, (b) boxplot for annual mean of monthly relative occurrence, (c) cumulative relative occurrence, and (d) boxplot of average monthly deviation from the annual mean for Chinese lespedeza across four cover classes.

Table 1—List of common and scientific names of each invasive plant collected in all states by the Southern Research Station Forest Inventory and Analysis program

Trees		Vines	
Tree of heaven	<i>Ailanthus altissima</i> (Mill.) Swingle	Oriental bittersweet	<i>Celastrus orbiculatus</i> Thunb.
Mimosa	<i>Albizia julibrissin</i> Durazz.	Nonnative-yams	<i>Dioscorea</i> Spp.
Paulownia	<i>Paulownia tomentosa</i> (Thunb.) Sieb. & Zucc. ex Steud.	Wintercreeper	<i>Euonymus fortunei</i> (Turcz.) Hand.-Maz.
Chinaberry	<i>Melia azedarach</i> L.	English Ivy	<i>Hedera helix</i> L.
Tallowtree	<i>Triadica sebifera</i> (L.) Small	Japanese honeysuckle	<i>Lonicera japonica</i> Thunb.
Russian-olive	<i>Elaeagnus angustifolia</i> L.	Kudzu	<i>Pueraria montana</i> var. <i>lobata</i> (Willd.)
Grasses		Nonnative vincas	<i>Vinca</i> Spp.
Giant reed	<i>Arundo donax</i> L.	Wisteria	<i>Wisteria</i> Spp.
Tall fescue	<i>Festuca arundinacea</i> Schreb.	Shrubs	
Cogongrass	<i>Imperata cylindrica</i> (L.) P. Beauv.	Silverthorn	<i>Elaeagnus pungens</i> Thunb.
Nepalese browntop	<i>Microstegium vimineum</i> (Trin.) A. Camus	Autumn olive	<i>Elaeagnus umbellata</i> Thunb.
Chinese silvergrass	<i>Miscanthus sinensis</i> Anderss.	Winged euonymus	<i>Euonymus alatus</i> (Thunb.) Sieb.
Nonnative bamboos	<i>Bambusa</i> spp.	Chinese/European privet	<i>Ligustrum sinense</i> Lour.
Ferns, Forbs/Other Herbaceous			<i>Ligustrum vulgare</i> L.
Japanese climbing fern	<i>Lygodium japonicum</i> (Thunb. ex Murr.) Sw.	Japanese/Glossy privet	<i>Ligustrum japonicum</i> Thunb.
Garlic mustard	<i>Alliaria petiolata</i> (M. Bieb.) Cavara & Grande		<i>Ligustrum lucidum</i> W.T. Aiton
Shrubby lespedeza	<i>Lespedeza bicolor</i> Turcz.	Bush honeysuckle	<i>Lonicera</i> Spp.
Chinese lespedeza	<i>Lespedeza cuneata</i> (Dum.-Cours.) G. Don	Sacred-bamboo nandina	<i>Nandina domestica</i> Thunb.
Tropical soda apple	<i>Solanum viarum</i> Dunal	Nonnative roses	<i>Rosa</i> spp.

Table 2—Number of individual plots and percent of total forested plots sampled on which each invasive plant was observed by the Southern Research Station Forest Inventory and Analysis program during time period covering roughly 2002-2007

Life Form	Plant species	Plot Occurrences	Percent Occupied
Trees	Tree of Heaven	726	2.46
	Mimosa	501	1.69
	Paulownia	169	0.57
	Chinaberry	346	1.17
	Tallowtree	321	1.09
	Russian olive	16	0.05
Shrubs	Silverthorn	60	0.20
	Autumn olive	271	0.92
	Winged euonymus	49	0.17
	Chinese/European privet	5,484	18.55
	Japanese privet	553	1.87
	Bush honeysuckle	482	1.63
	Nandina	88	0.30
	Exotic roses	2,077	7.03
Vines	Oriental bittersweet	25	0.08
	Exotic climbing yams	123	0.42
	Wintercreeper	32	0.11
	English ivy	69	0.23
	Japanese honeysuckle	12,524	42.37
	Kudzu	255	0.86
	Periwinkle	99	0.33
	Wisteria	104	0.35
Grasses	Giant reed	1	0.00
	Tall fescue	845	2.86
	Cogongrass	73	0.25
	Nepalese browntop	1,356	4.59
	Chinese silvergrass	16	0.05
	Exotic bamboo	32	0.11
Ferns, Forbs/Other Herbaceous	Japanese climbing fern	859	2.91
	Garlic mustard	48	0.16
	Shrubby lespedeza	567	1.92
	Chinese lespedeza	1,242	4.20
	Tropical soda apple	77	0.26

Table 3—Number of plots by the number of unique invasive plant species that was observed by the Southern Research Station Forest Inventory and Analysis program during the time period covering roughly 2002-2007

Nonnative Plant Count	Plots (no.)
1	6,794
2	5,326
3	2,394
4	904
5	246
6	49
7	5
8	2

Table 4—F-test statistic and associated p-value for one way analysis of variance testing for inter-seasonal differences in relative occurrence of each invasive plant species collected by the Southern Research Station Forest Inventory and Analysis program during the time period covering roughly 2002-2007

Species	F	P
Autumn olive	2.409	0.142
Bush honeysuckle	3.539	0.068
Chinaberry	2.715	0.115
Chinese lespedeza	12.121	0.002
Chinese silvergrass	0.660	0.600
Chinese/European privet	6.205	0.018
Cogongrass	0.476	0.708
English ivy	2.004	0.192
Exotic bamboo	3.778	0.059
Exotic climbing yams	3.712	0.061
Exotic roses	7.629	0.010
Garlic mustard	2.789	0.109
Giant reed	1.000	0.441
Japanese climbing fern	3.831	0.057
Japanese honeysuckle	3.109	0.089
Japanese privet	1.936	0.202
Kudzu	4.655	0.036
Nepalese browntop	6.469	0.016
Mimosa	6.085	0.018
Nandina	0.770	0.543
Oriental bittersweet	2.185	0.168
Paulownia	0.427	0.739
Periwinkle	1.434	0.303
Russian olive	0.438	0.732
Shrubby lespedeza	9.353	0.005
Silverthorn	1.866	0.214
Tall fescue	4.962	0.031
Tallowtree	14.581	0.001
Tree of Heaven	0.586	0.641
Tropical soda apple	1.480	0.292
Winged euonymus	2.790	0.109
Wintercreeper	1.340	0.328
Wisteria	1.664	0.251