THE EXTENT OF SELECTED NONNATIVE INVASIVE PLANTS ON SOUTHERN FOREST LANDS

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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 detecting the spread of nonnative species. Better assessments of ongoing biological invasions are a primary research priority in the Southeast. As one method for addressing this need, a federal-state partnership initiated a survey of 33 invasive plant taxa in 2001 on all southern forest ownerships. Presence information and estimates of cover for these invasives are collected as part of the U.S. Forest Service, Southern Research Station, Forest Inventory and Analysis (FIA) program. Within the FIA program, the Southern Invasive Plant Indicator Program monitors and reports on plant invasions within southern forests; it also develops tools to detect emerging invasions and potentially threatening invasive plant populations. Results from data collected through the FIA program in the southern United States from 2001 to 2008 are described in this paper. Current distribution maps for selected nonnative invasive plants are presented, along with a discussion of the potential impacts of these species on native forests of the southern United States.

INTRODUCTION

Foresters and ecologists have noted the spread of nonnative invasive species onto United States forest land for decades. Billions of dollars have been dedicated to researching the physiological mechanisms of invasions, the environmental impacts of invasion, and site qualities that facilitate invasion, and to pursuing management and control efforts yearly, yet it is unclear how successful control programs have been, to date (Pimentel and others 2005). For example, Pimentel and others (2005) estimate expenditures of 3 to 6 million dollars annually on attempts to control the spread of the invasive tree *Melaleuca quinquenervia* in Florida, and Webster and others (2006) stated that more than 17,000 man-hours were spent treating invasive species over a 10-year period in the Great Smoky Mountains National Park in Tennessee and North Carolina. Annual costs of efforts to control nonnative plant species (including species that do not occur on forest land) nationally are estimated to be as high as $25 billion (Pimentel and others 2005).

Despite soaring costs and inestimable environmental impacts, nonnative invasive species continue to spread across managed and natural ecoregions, including forest land (Miller 2003). Southern forests are of particular concern because extended growing seasons and high site productivity, combined with relatively high disturbance rates and increasing forest land parcellization, may facilitate the growth and spread of hundreds of

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potentially noxious plants. Of the 31 terrestrial plants included on "100 of the World's Worst Invasive Alien Species" (Lowe and others 2000), 23 occur in the southern states. The U.S. Department of Agriculture, Forest Service (USFS) recognizes 53 noxious species that are deemed currently problematic and widespread enough on southern U.S. forest land to warrant constant monitoring through the USFS Southern Research Station (SRS) Forest Inventory and Analysis (FIA) program (USFS 2007).

Working with state forestry agents throughout the South, SRS-FIA began monitoring nonnative invasive plant species (NNIPS) in 2001 in response to a growing desire to track potential forest health threats on U.S. forest land. No other program in the United States provides a mechanism for monitoring the spread of common invasive species across both public and private lands on a regularly updated basis. The survey of invasive plant species was added to the timber resource surveys conducted since the 1930s. The NNIPS selected for survey are regionally recognized exotic pest trees, shrubs, vines, grasses, canes, forbs, and ferns known to invade interior forest stands and forest edges, canopy gaps, or stream-sides. SRS-FIA's Southern Invasive Plant Indicator Program (SIPIP) uses NNIPS presence information and estimates of cover to monitor and report on plant invasions within southern forests. Taking a proactive approach, SIPIP also develops tools to detect emerging invasions and potentially problematic invasive plant populations. This paper describes current results from data collected through the FIA program in the southern United States. from 2001 to 2008. The paper shows the current distribution of selected nonnative invasive plants, along with discussing the potential impacts of these species on Southern forests.

STUDY AREA

The Southern Research Station FIA program collects data on public and private land in 13 southern states and U.S. Territories: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, the U.S. Virgin Islands, and Puerto Rico. This paper includes data collected from 2001 to 2007 in all of the above except west Texas, Oklahoma, the U.S. Virgin Islands, and Puerto Rico. Collection dates for each state were: Alabama (2001 to 2005), Arkansas (2000 to 2005), Florida (2002 to 2007), Georgia (2005 to 2007), Kentucky (2000 to 2004), Louisiana (2001 to 2005), Mississippi (2006), North Carolina (2003 to 2007), South Carolina (2002 to 2006), Tennessee (2000 to 2004), east Texas (2004 to 2008), and Virginia (2002 to 2007).

METHODS

Field methods for the basic FIA program are well documented and interested users may refer to the SRS National Core Field Guide (USFS 2007) or to Bechtold and Patterson (2005) for detailed methodology. Briefly, the FIA program utilizes a nationally consistent systematic random sampling technique to locate sampling plots at three different geographic scales, referred to as "Phases." Phase 1 assigns points to land-use strata to determine the amount of forest land in a sample area while reducing sample variance by grouping like units (Bechtold and Patterson 2005). Phase 2, a subset of the Phase 1 points, consists of field-visit plots at a scale of roughly one plot to every 6,000 acres. Data collected on Phase 2 plots include all FIA National Variables, along with regional variables assigned to answer specific monitoring needs. The NNIPS survey is included among the regionally collected Phase 2 variables for the southern United States. Phase 3 plots are a subset of Phase 2 plots and receive additional, intensive sampling for certain forest health variables not discussed in this paper.

Phase 2 plots consist of four 1/24-acre subplots located approximately 120 feet apart at 120-, 240-, and 360-degree azimuths from a central subplot. In addition to a suite of mensuration variables, SRS-FIA collects information on nonnative plants on each subplot. Up to four nonnative invasive plants from a predetermined list of species known to be problematic in the South are recorded on the forested portion of each subplot (Table 1). In addition to presence/absence of up to four species, field personnel are instructed to select a range of abundance (in the form of percent cover) of each nonnative invasive plant recorded on the subplot. Percent cover categories are: Trace <01 percent; 1-10 percent; 11-50 percent; 51-90 percent; 91-100 percent. In the winter, personnel are instructed to treat percent cover values as though plants were in leaf-on condition. SRS-FIA collects regular mensuration data (e.g., height, diameter at breast height) on any NNIPS trees found on each subplot if the species is part of the SRS-FIA tree species measurement list. For a complete list of trees measured by SRS-FIA, see the Forest Inventory and Analysis SRS Core Field Guide: Volume 1: Field Data Collection Procedures for Phase 2 Plots (USFS 2007). Values from the field are transmitted to the SRS-FIA office, where they are processed through the National Information Management System.

Distribution maps for this paper were created by grouping all inventoried invasive species into their respective life-forms, and plotting presence/absence of an invasive species in a Phase 2 plot by life-form using a geographic information system. We also identified the overall number of Phase 2 plots in which each invasive species occurred to examine the extent of invasion across the South. A total of 33,534 forested plots were sampled.

RESULTS FROM THE SOUTHERN INVASIVE PLANT INDICATOR PROGRAM

The SRS-FIA program includes 12 invasive trees on the SIPIP survey list. Six of those trees are inventoried only in Florida. Invasive trees, as a life-form, were spread fairly evenly across the southern United States, with some dense concentrations along the Gulf Coast in east Texas, Louisiana, and Mississippi, where Chinese tallowtree (*Triadica sebifera*) is particularly problematic (Fig. 1a, Fig. 2). Chinese tallowtree was detected in more plots than any other invasive tree species, followed by tree-of-heaven (*Ailanthus altissima*), mimosa (*Albizia julibrissin*), and Chinaberry (*Melia azedarach*) (Fig. 2).

Shrubs are more densely concentrated across the South than are trees, particularly from the eastern bank of the Mississippi River across to the Atlantic Coastal Plain (Fig. 1b). Chinese and European privets (*Ligustrum* spp.) are by far the most common invasive shrubs, becoming fairly ubiquitous on forest land from Tennessee and Arkansas south to northern Florida (Fig. 3). Nonnative roses (*Rosa* spp.), particularly multiflora rose (*Rosa multiflora*), are problematic from Tennessee north through Kentucky and into western Virginia, while Brazilian pepper (*Schinus terebinthifolius*) is the most common invasive shrub in the Florida peninsula.

Vines are the most common invasive life-form detected by SRS-FIA in the southern United States and are present throughout the entire southeastern forested landscape north of Florida (Fig. 1c). Japanese honeysuckle (*Lonicera japonica*) is the most widespread invasive vine in forests in the entire Southeast, and occupies 55 times the number of FIA plots as the next most common invasive vine, kudzu (*Pueraria montana*, Fig. 4). In fact, Japanese honeysuckle is the single most common invasive species across all life forms in the Southeast.

Invasive grasses occupy fewer FIA plots than trees, shrubs, or vines, but are still commonplace in forests, particularly in Tennessee, Kentucky, and Virginia (Fig. 1d). The most commonly detected grasses on forest land were tall fescue (*Lolium arundinaceum*) and Nepalese browntop (*Microstegium vimineum*) (Fig. 5).

Table 1.—Southern Research Station Forest Inventory and Analysis (SRS-FIA) Nonnative Invasive Plants monitoring list. Each species is monitored on all standard SRS-FIA field plots. Species are grouped by life-forms, and were compiled from State and Federal noxious plant lists.

Common Name	Scientific Name
Trees	
Australian pine	*Casuarina equisetifolia*
Camphor tree	*Cinnamomium camphora*
Carrotwood	*Cupaniopsis anacardioides*
Chinaberry	*Melia azedarach*
Chinese tallowtree	*Triadica sebifera, Sapium sebiferum*
Java plum	*Syzygium cumini*
Melaleuca	*Melaleuca quinquenervia*
Mimosa, silktree	*Albizia julibrissin*
Princesstree, Royal Paulownia	*Paulownia tomentosa*
Russian olive	*Elaeagnus angustifolia*
Schefflera	*Schefflera actinophylla*
Tree-of-heaven	*Ailanthus altissima*
Shrubs	
Autumn olive	*Elaeagnus umbellate*
Bush honeysuckles	*Lonicera spp.*
Chinese / European privet	*Ligustrum sinense / L. vulgare*
Coral ardisia	*Ardisia crenata*
Japanese / glossy privet	*Ligustrum japonicum / L. lucidum*
Lantana	*Lantana camara*
Nonnative roses	*Rosa spp.*
Sacred bamboo, nandina	*Nandina domestica*
Silverthorn, thorny olive	*Elaeagnus pungens*
Winged burning bush	*Euonymus alata*
Vines	
Cat's-claw vine	*Macfadvena ungis-cati*
Chinese / Japanese wisteria	*Wisteria sinensis / W. floribunda*
English ivy	*Hedera helix*
Japanese honeysuckle	*Lonicera japonica*
Kudzu	*Pueraria Montana var. lobata*
Nonnative vincas, periwinkles	*Vinca minor / V. major*
Nonnative yams	*Dioscorea bulbifera / D. oppositifolia*
Oriental or Asian bittersweet	*Celastrus orbiculatus*
Rosary pea	*Abrus precatorius*
Skunk vine	*Paederia foetida*
Wintercreeper	*Euonymus fortunei*
Grasses	
Chinese silvergrass	*Miscanthus sinensis*
Cogongrass	*Imperata cylindrica*
Giant reed	*Arundo donax*
Napier grass	*Pennisetum purpureum*
Nepalese browntop	*Microstegium vimineum*
Nonnative bamboos	*Phyllostachys spp. / Bambus spp.*
Tall fescue	*Lolium arundinaceum*
Herbs	
Chinese lespedeza	*Lespedeza cuneata*
Garlic mustard	*Alliaria petiolata*
Hairy indigo	*Indigofera hirsuta*
Shrubby lespedeza	*Lespedeza bicolor*
Tropical soda apple	*Solanum viarum*
Ferns	
Japanese climbing fern	*Lygodium japonicum*
Old world climbing fern	*Lygodium microphyllum*
Sword fern	*Nephrolepis cordifolia*

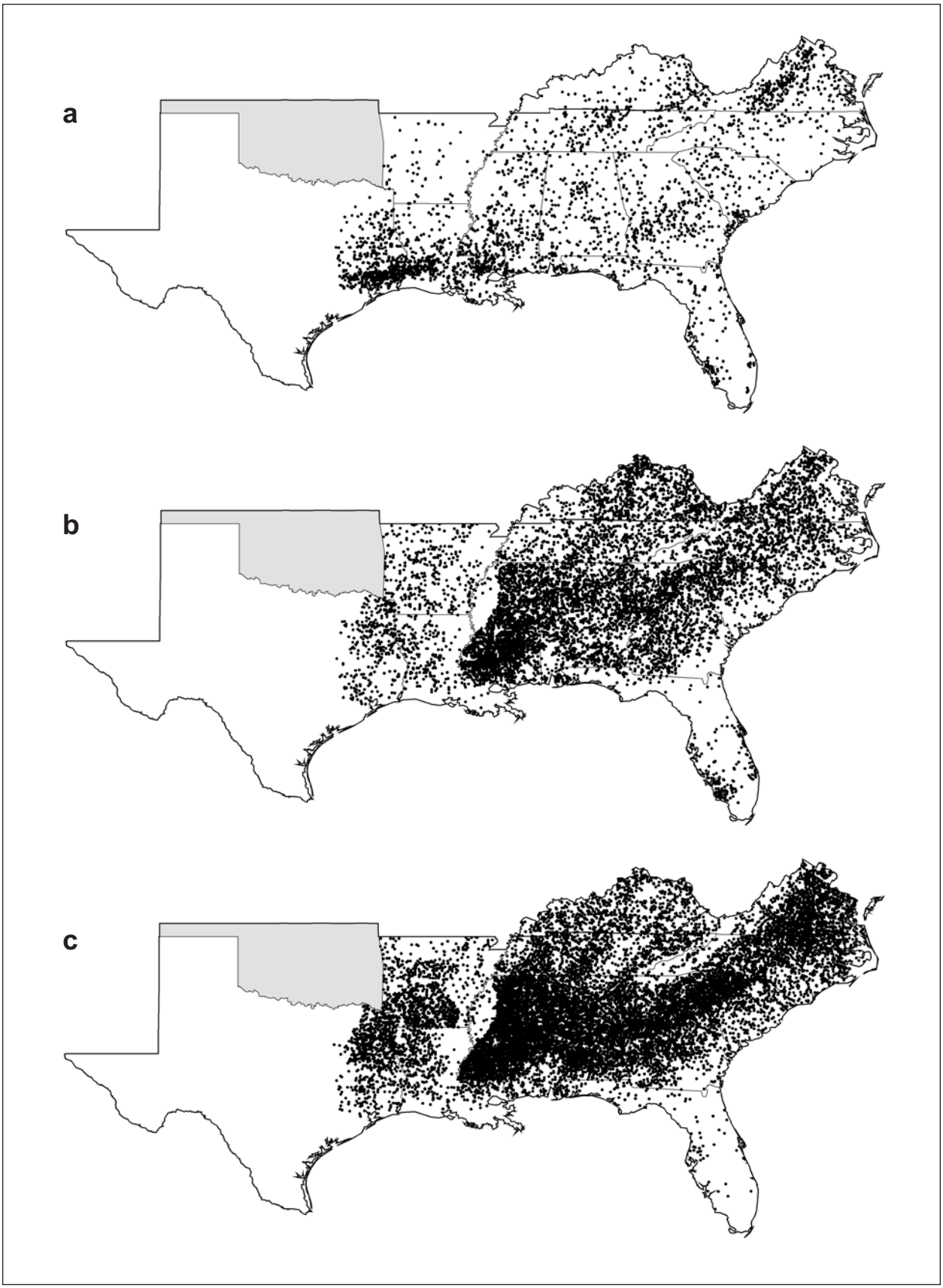

Figure 1.—Forest Inventory and Analysis plots containing invasive species in six life-forms from the FIA invasive species list in the southern United States (plot locations are approximate): (a) Trees, (b) Shrubs, (c) Vines, (d) Grasses, (e) Herbs, (f) Ferns. (Figure 1 continued on next page.)

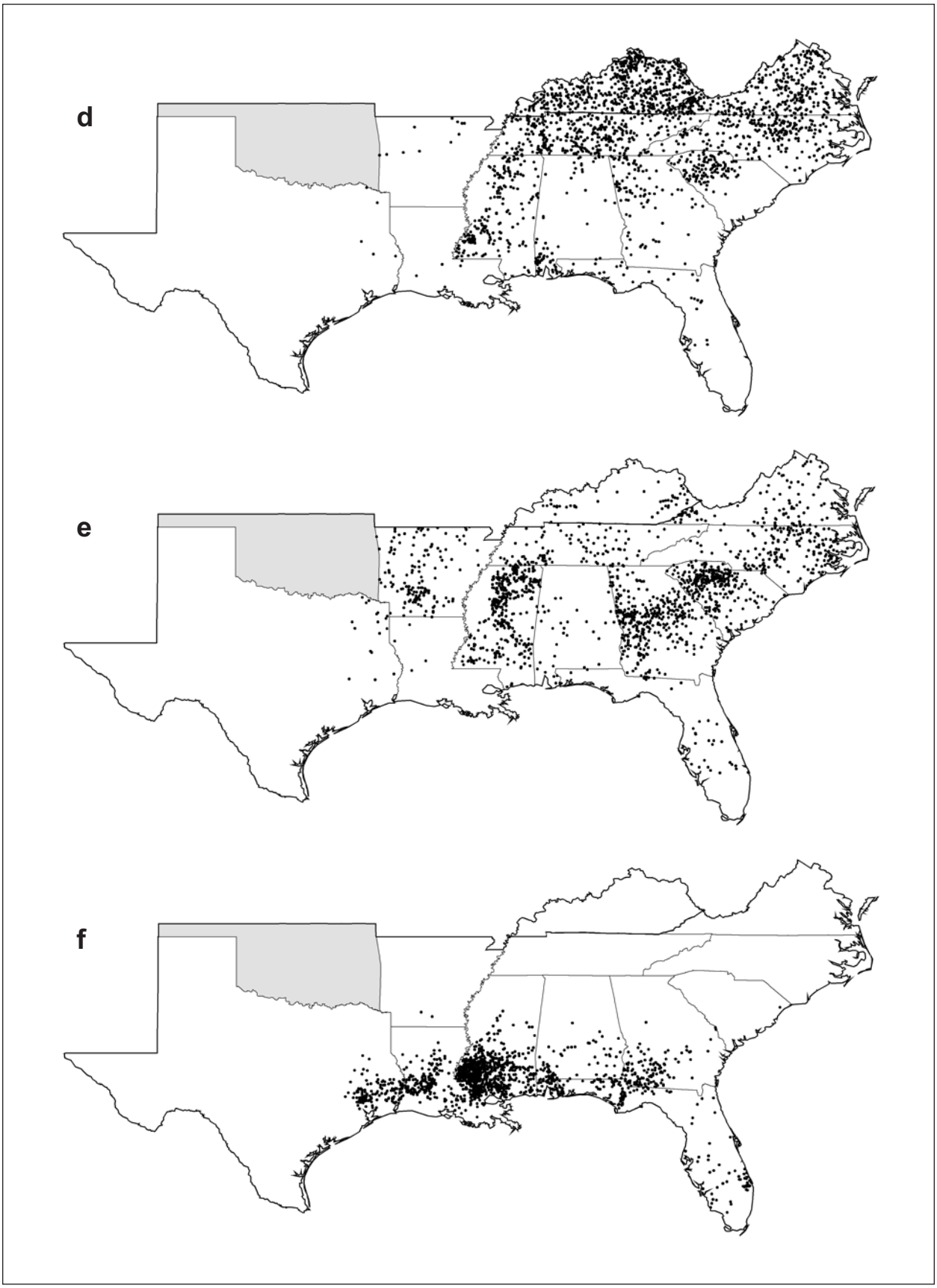

Figure 1 (continued).—Forest Inventory and Analysis plots containing invasive species in six life-forms from the FIA invasive species list in the southern United States (plot locations are approximate): (a) Trees, (b) Shrubs, (c) Vines, (d) Grasses, (e) Herbs, (f) Ferns.

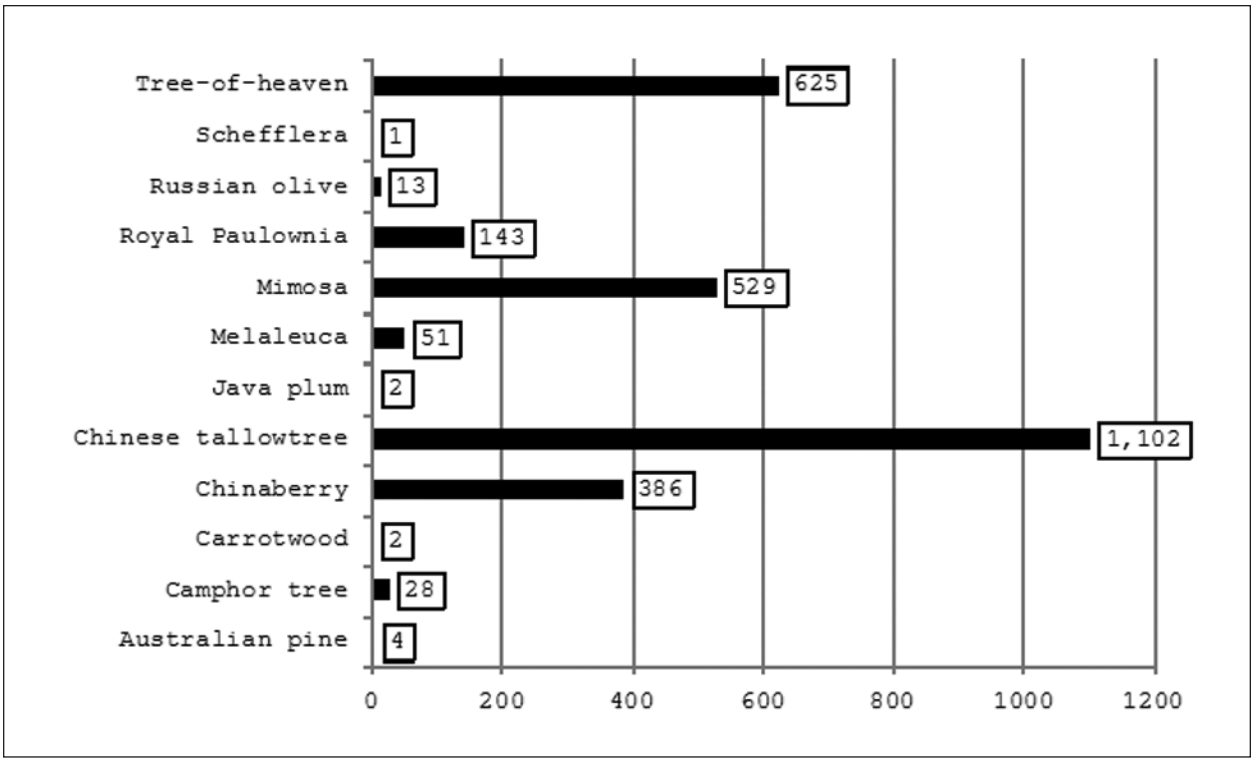

Figure 2.—Number of FIA plots containing invasive trees by species name. Plot counts are given at the end of each bar.

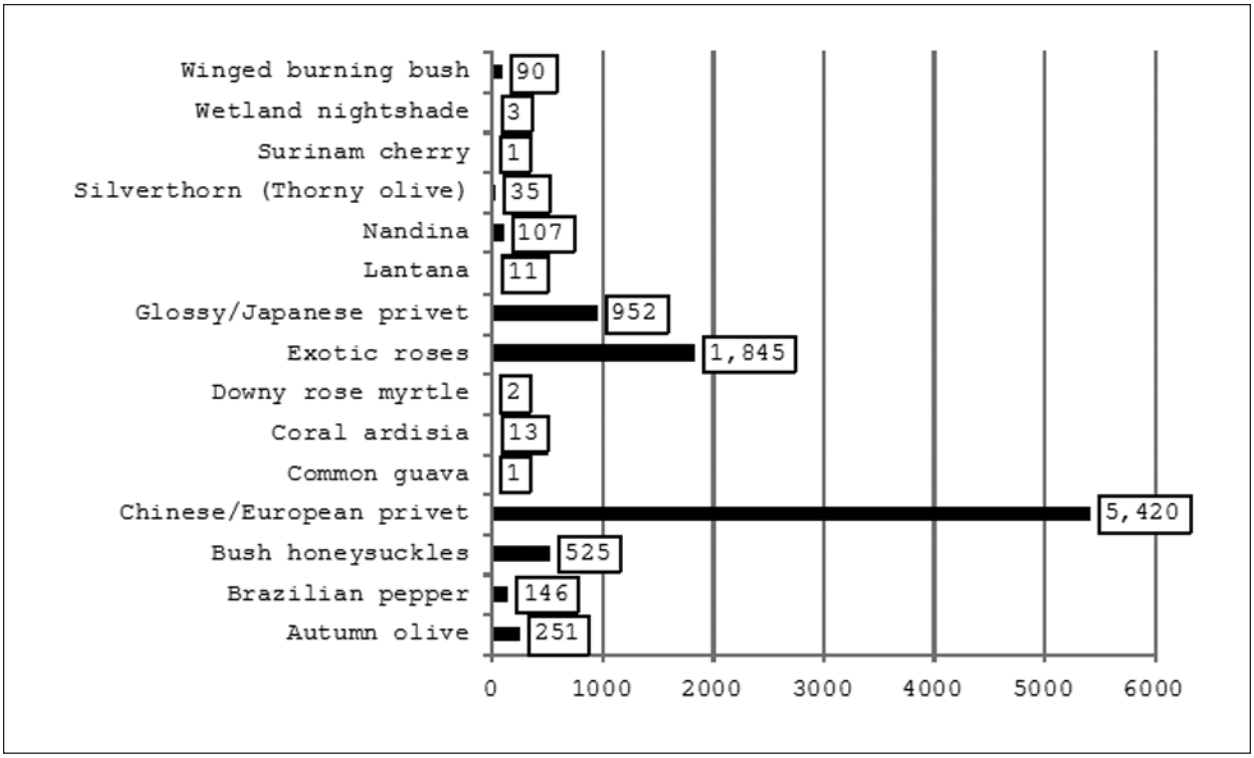

Figure 3.—Number of FIA plots containing invasive shrubs by species name. Plot counts are given at the end of each bar.

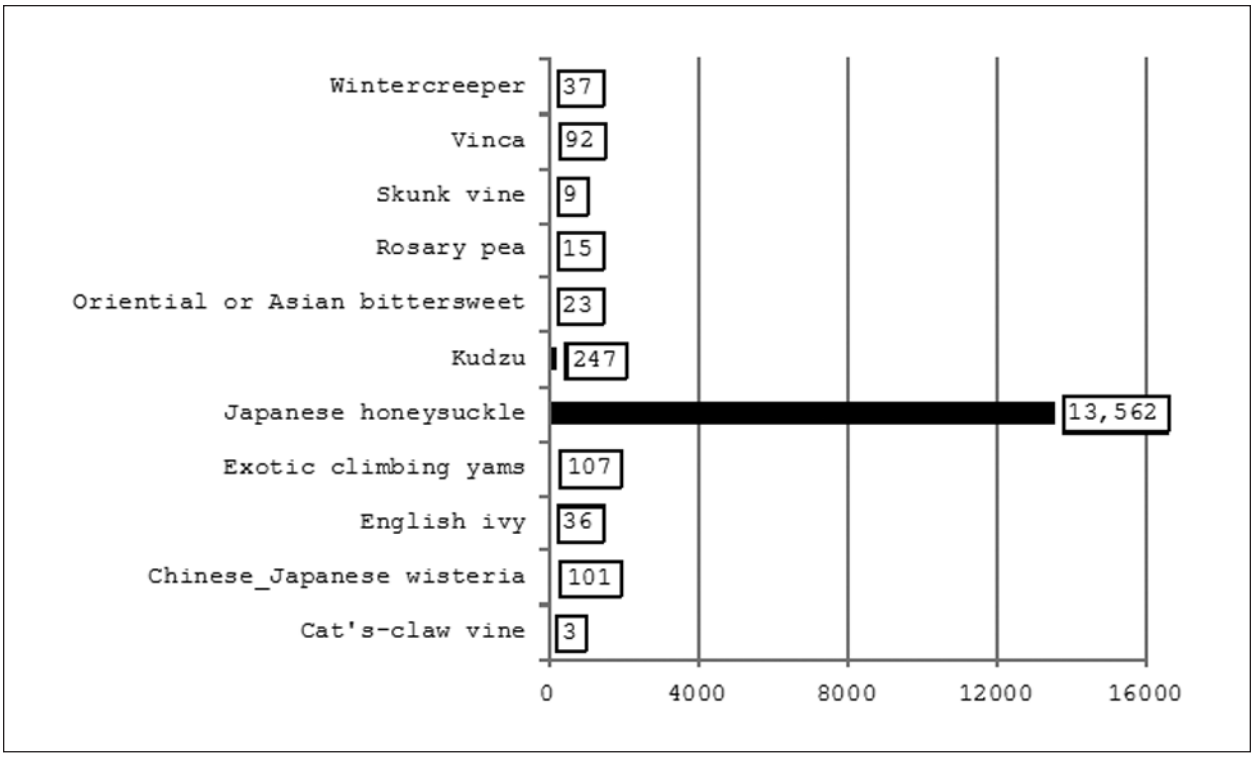

Figure 4.—Number of FIA plots containing invasive vines by species name. Plot counts are given at the end of each bar.

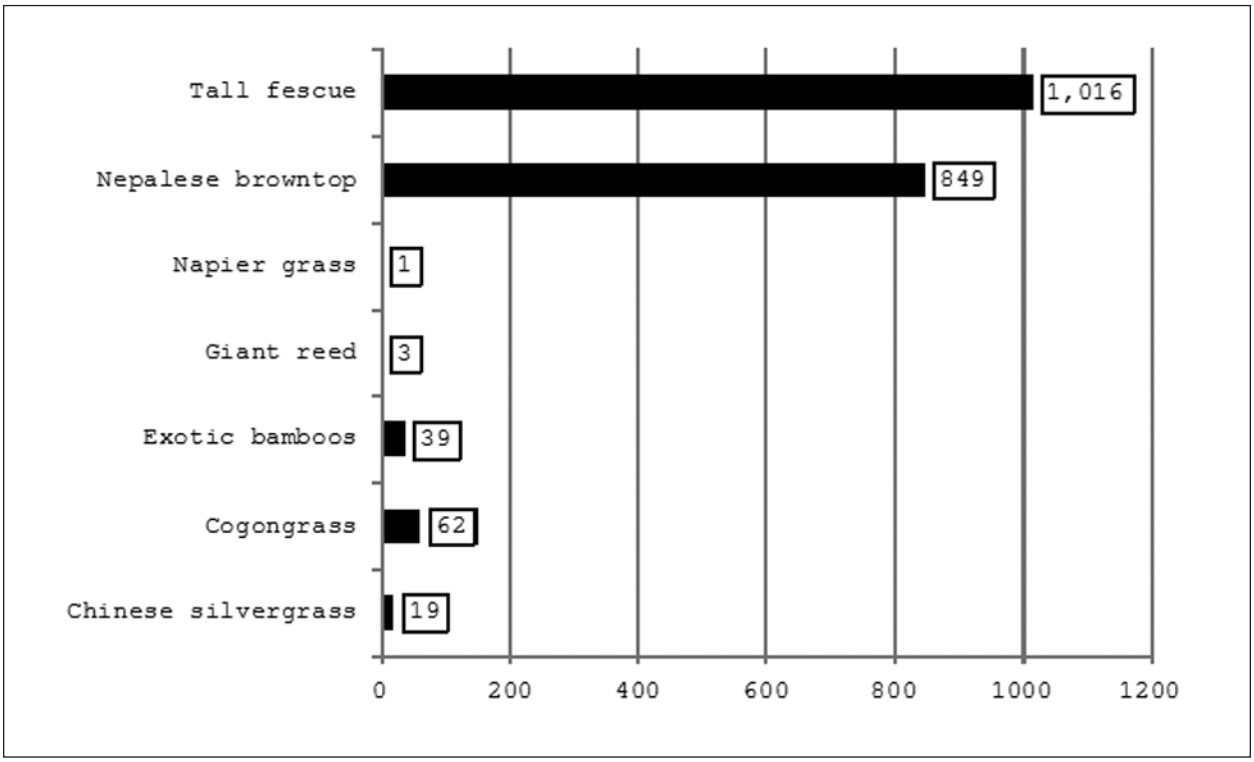

Figure 5.—Number of FIA plots containing invasive grasses by species name. Plot counts are given at the end of each bar.

Invasive herbs were not uniformly distributed across the South. Spatial aggregations tended to follow particular landscape features like roads or rivers (Fig. 1e). Lespedezas (*Lespedeza bicolor* and *L. cuneata*) were the herbs most commonly detected in the South, though garlic mustard (*Alliaria petiolata*) detection increased in the northernmost reaches of Kentucky and Virginia (Fig. 6).

Most nonnative invasive ferns do not survive the winter in areas outside the subtropical south. Therefore, it is not surprising that invasive ferns were most likely to be detected in forested plots of the Deep South (Fig. 1f). Japanese climbing fern (*Lygodium japonicum*) is the only species SRS-FIA monitors on forest land outside of Florida and not surprisingly, it was the most commonly detected invasive fern (Fig. 7).

OVERVIEW OF ONLINE PRODUCTS

The SIPIP team has utilized the SRS-FIA data to populate two publicly accessible online products, to date. The Nonnative Invasive Plant data tool (http://srsfia2.fs.fed.us/nonnative_invasive/Southern_Nonnative_Invasives.htm) provides user access to the raw subplot data collected in the field. The data have been compiled by state and species of interest, but has not been expanded to population levels. Users may select individual states or species to view tables of total species by subplot counts by county. Further drill-down selections allow users to access complete tables with state, county, plot, subplot, species, percent cover values, and control numbers used to link the NNIPS data with FIA field data obtained from other online sources. The raw tables provide subplot proportion information that users can apply to FIA plot data to expand NNIPS populations to large areas.

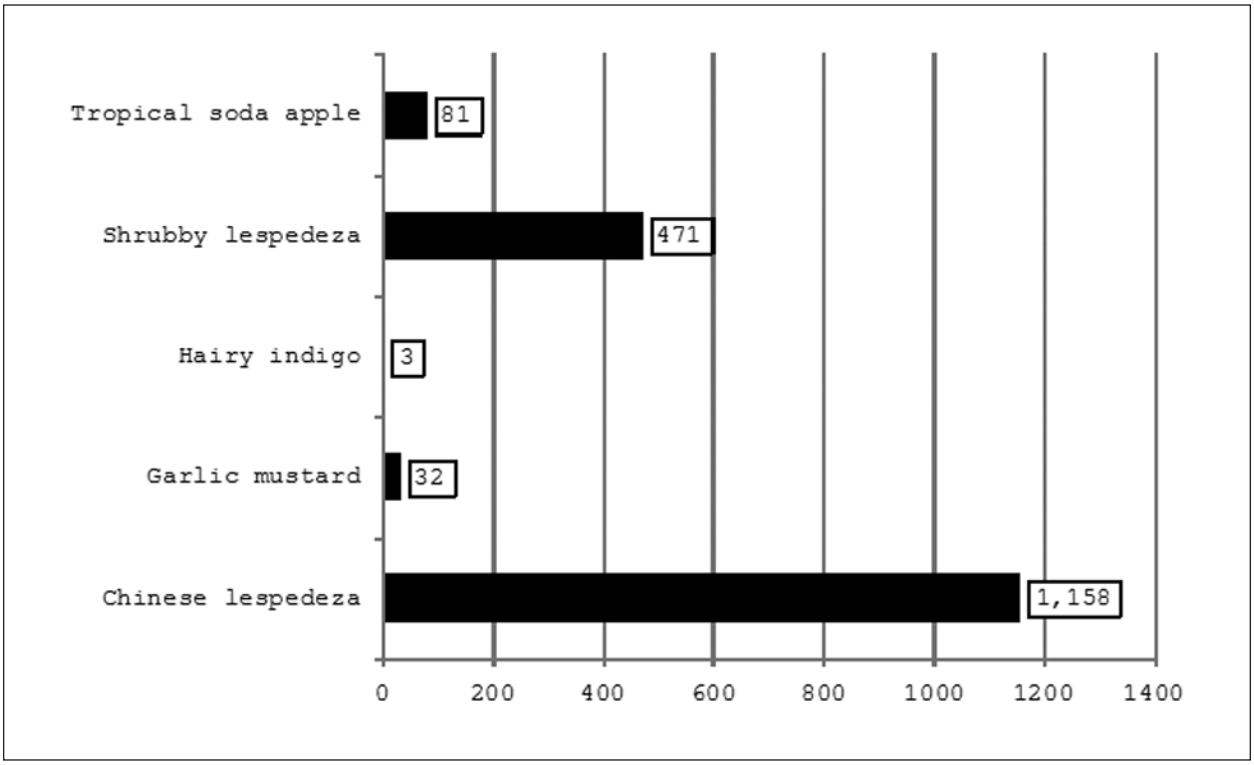

Figure 6.—Number of FIA plots containing invasive herbs by species name. Plot counts are given at the end of each bar.

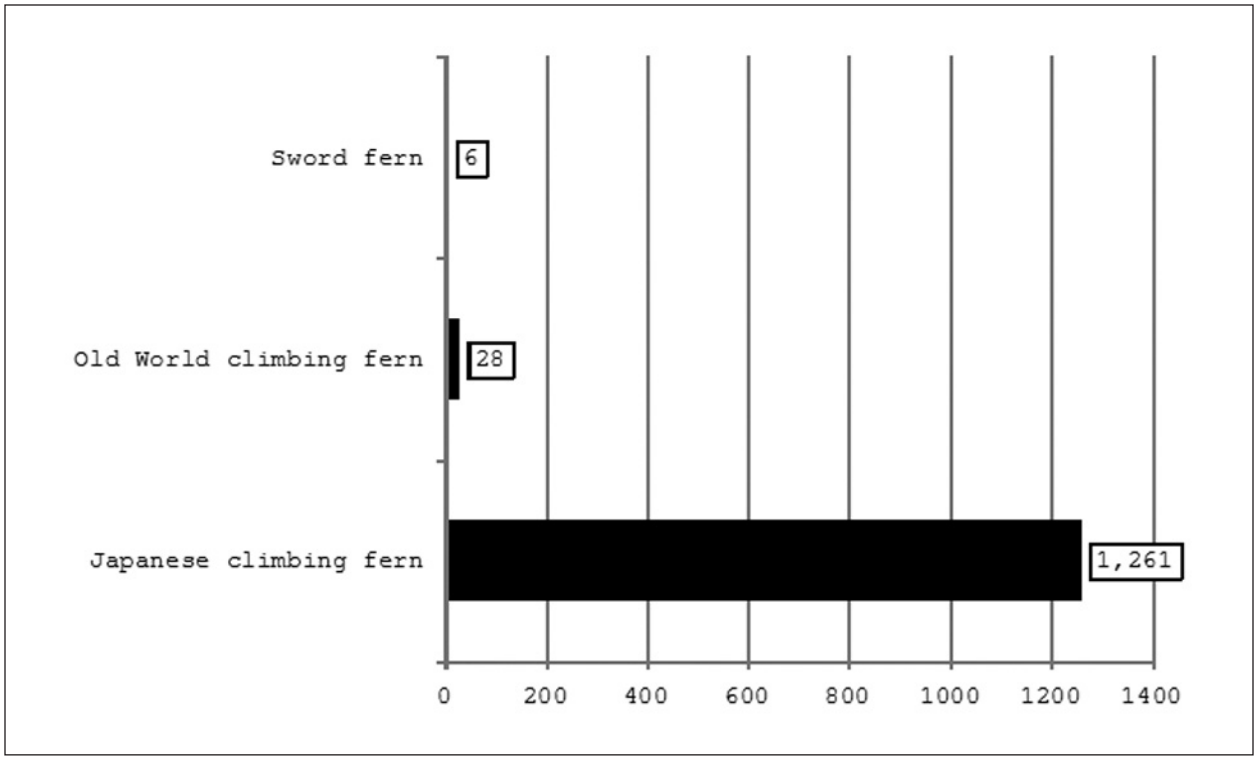

Figure 7.—Number of FIA plots containing invasive ferns by species name. Plot counts are given at the end of each bar.

In addition to the NNIPS data tool, the SIPIP team has created a series of Southern Invasive Plants Maps, which are southwide depictions of NNIPS detected in the most recent survey period available for each state (http://srsfia2.fs.fed.us/data_center/data_mapping.shtml). Species are grouped by life-form, and users may select a species to view chloropleth maps that depict the percentage of forested subplots containing that particular species in each county. These maps are useful for visualizing the extent and degree of infestation of a particular species across multiple states.

IMPLICATIONS

The latest surveys conducted by SRS-FIA illustrate how widespread nonnative plant invasions are on forests throughout the South. Japanese honeysuckle, originally introduced as an ornamental plant in the 1800s (and still sold and planted as an ornamental and for deer browse) is the most common of all forest-invasive nonnative species detected by SRS-FIA in the southern United States. Though the leaves, fruit, and nectar from Japanese honeysuckle are used by many wildlife species and insects, the species poses a threat to native plants and trees through competition, and may lower species diversity in areas where it has become established (Dillenburge and others 1993, Yurkonis and others 2005).

Chinese tallowtree, the most common tree species detected on SRS-FIA plots, encroaches on native coastal prairies and freshwater marshes in many southern states, including east Texas, Louisiana, and Mississippi, threatening conversion to near-monoculture forest land and disrupting entire ecosystems (Bruce and others 1995). A recent study conducted by Oswalt (in press) documented a Chinese tallowtree population expansion of more than 500 percent in Louisiana from 1991 to 2005, with similar increases of 445 percent in Mississippi from 1994 to 2006 and 174 percent in east Texas.

Chinese and European privets, both introduced as ornamental species and now widespread in forests throughout the Southeast, have the potential to severely impact forest understory species diversity and limit tree regeneration in invaded sites (Merriam and Feil 2002). While privets were once touted as important winter food for white-tailed deer in some areas (Stroymayer and others 1998), few (if any) studies exist that compare the relative value of privet as habitat and forage to the value of native species that evolved in conjunction with the wildlife species inhabiting the Southeast (Graham 2002). Furthermore, no studies appear to document the impacts of privet establishment in forests on habitat specialists who utilize native understory structure and components.

Like many nonnative invasive species, the impacts of the most common nonnative forest-invasive herb, Chinese lespedeza, are not well documented. Deep taproots and allelopathic characteristics enable the species to compete successfully against native species (Stevens 2002). However, most studies of the species have been conducted in grasslands and other open spaces, where it is most likely to colonize and become highly invasive. Thus, further research regarding the impacts of the species in forested conditions is necessary.

The second most common forest-invasive nonnative grass, Nepalese browntop, has been shown to impact species diversity and native woody species density in hardwood forests in the Southeast (Oswalt and others 2007). Similarly, Adams and Engelhardt (2009) found that Nepalese browntop impacted plant community structure in a way that could have long-term repercussions for site diversity.

Nonnative invasive ferns are problematic primarily in the Deep South. The most common species detected in forest areas by SRS-FIA, Japanese climbing fern, has the ability to grow over plants and trees much like kudzu, smothering native species and reducing plant diversity (Minogue and others 2009).

All of the nonnative species mentioned in detail above are continuing to spread across the southeastern United States, and much research is still needed to understand the full impact they are having on forest ecosystems and the wildlife associated with those systems. The NNIPS data and mapping tools identified, described, and exemplified in this paper provide a mechanism for monitoring these species through time and space. In addition, users have the ability to link the data to other SRS-FIA plot-level data, which could provide researchers with tools necessary to better understand the impacts of nonnative invasive species at a large scale.

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