

DISTRIBUTION AND OCCUPANCY OF INTRODUCED SPECIES: A BASELINE INVENTORY FROM PHASE 3 PLOTS ACROSS THE COUNTRY

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Abstract.—Invasive plant species have significant negative impacts in many ecosystems and are found in many forests around the world. Although not all introduced species become invasive, there are numerous examples of species escaping cultivation and invading natural ecosystems years or even decades after their initial introduction. Regional distributions of invasive species are influenced by climatic and physical conditions; within the landscape, fragmentation, disturbance, and surrounding land use are important factors. Inventory data can help describe the distribution (reported as constancy) and occupancy, (reported as relative richness and cover of introduced species) in forested ecosystems. Vegetation data from 1690 Phase 3 forest inventory plots collected by the U.S. Forest Service’s Northern and Pacific Northwest Research Stations’ FIA units are used to examine and compare the distribution and occupancy of introduced species. Introduced species were common in forests; 388 species were recorded and 61 percent of all plots had at least one introduced species. Where introduced species occurred, their mean relative richness was 10.7 percent and mean relative cover was 8 percent. However, this varied across regions, level of fragmentation, and distance from roads. Regions with high proportions of forest edge plots had higher overall constancy and occupancy of introduced species. The most commonly recorded introduced species in our analysis was multiflora rose, however, common species varied by ecological region. The most commonly recorded species are highlighted by region, with examples of how these results can inform managers who have limited budgets for invasive plant control.

INTRODUCTION

Tens of thousands of plant species have been introduced to the United States, often intentionally. Although the majority of introduced species are not problematic, many have escaped cultivation to become invasive, producing reproductive offspring at a distance from their original introduction (e.g., >328 ft. in less than 50 years for taxa spreading by seed) (Mack 2003, Richardson et al. 2000). A

subset of invasive plant species can have significant negative impacts on ecosystems and are found in many forests around the world. These species are capable of transforming the ecosystems by excluding native species via competition or by exuding substances toxic to other plants, and altering water, nutrient, and fire regimes, and are hence referred to as “transformers” (Richardson et al. 2000). Direct effects on native plant populations have cascading indirect effects on other biota in the invaded communities.

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Although not all invasive species become ecosystem transformers, many naturalized introduced species (capable of reproduction without further human cultivation, but not spreading beyond original site) can become invasive years or even decades after

their initial introduction. (Mack 2003). Initially benign species can slowly expand their presence without notice or recognizable impacts. Once they are widespread, control of these species becomes difficult and expensive.

Many surveys are conducted to monitor for known transformer species. These surveys are often implemented along roadsides, trails, waterways, and areas subjected to disturbance—both human-induced and natural. Focusing on species that are new to the area and have been evaluated for invasive/transforming properties ensures that managers make the most efficient use of limited resources available for invasive species control. From year to year, the list of species may change as more is learned about the distribution and invasiveness of individual species. These surveys are invaluable, but cannot provide a systematic measure of the distribution throughout the range of forested ecosystems of the United States. A regional perspective can help land managers evaluate their local conditions and prioritize projects for effectiveness.

The distribution of invasive species in forests is influenced by the proximal ecosystem and land use patterns, disturbance intensity and distribution, and climate. Forest inventory data can help define the distribution and occupancy of such species in forested ecosystems. Introduced and invasive species are common in the forests of the northeastern United States. Schulz and Gray (in press) found two-thirds of Phase 3 plots in the U.S. Forest Service's Forest Inventory and Analysis (FIA) inventory had at least one introduced species present. Fragmentation and ecological province were important predictors of the occupancy (percent richness and cover) of introduced species. We expand upon those analyses to include data from the Pacific Northwest to further examine and compare the distribution of introduced species in relation to forest fragmentation, distance from improved roads, and ecological divisions. The most abundant species are highlighted by region.

STUDY AREA

Twenty-four states in the northeastern and midwestern regions of the United States and three states in the Pacific Northwest are included in the study area. Data collected on 1,690 Phase 3 plots were used in this analysis. Approximate plot locations in the contiguous United States are shown in Figure 1. (Alaska plots are not shown.)

METHODS

Data were collected by the Northern (NRS) and Pacific Northwest (PNW) Research Stations' FIA Programs between 2001 and 2008 as part of the Phase 3 (P3) Vegetation Diversity and Structure Indicator (VEG). VEG includes a complete census of vascular plants on the forested portion of each subplot (Schulz et al. 2009). Field crews certified for VEG data collection record each plant species and estimate percent cover over the entirety of each of four 24-ft radius subplots. Cover of each unknown species is also estimated and samples are collected for later identification. Some plants remain unidentified if they were present in very early or late stages of development or only a few individual plants were on site. Plants not ultimately identified to the species level were not included in this analysis; we assume that the proportions of native to introduced species among unknown plants are similar to that for known species.

Species origins were assigned according to the Natural Resource Conservation Service's PLANTS database (USDA NRCS 2010). Ecological divisions, as described by Cleland et al. (1997) were used to distinguish regions with broad climatic and physiographic zones. The systematic random sample design of the FIA inventory results in some plots straddling multiple vegetation conditions defined by significant differences in land use, forest type, stand size class, and forest/nonforest condition (Bechtold and Patterson 2005). Each plot was assigned one of three levels of fragmentation based on the number

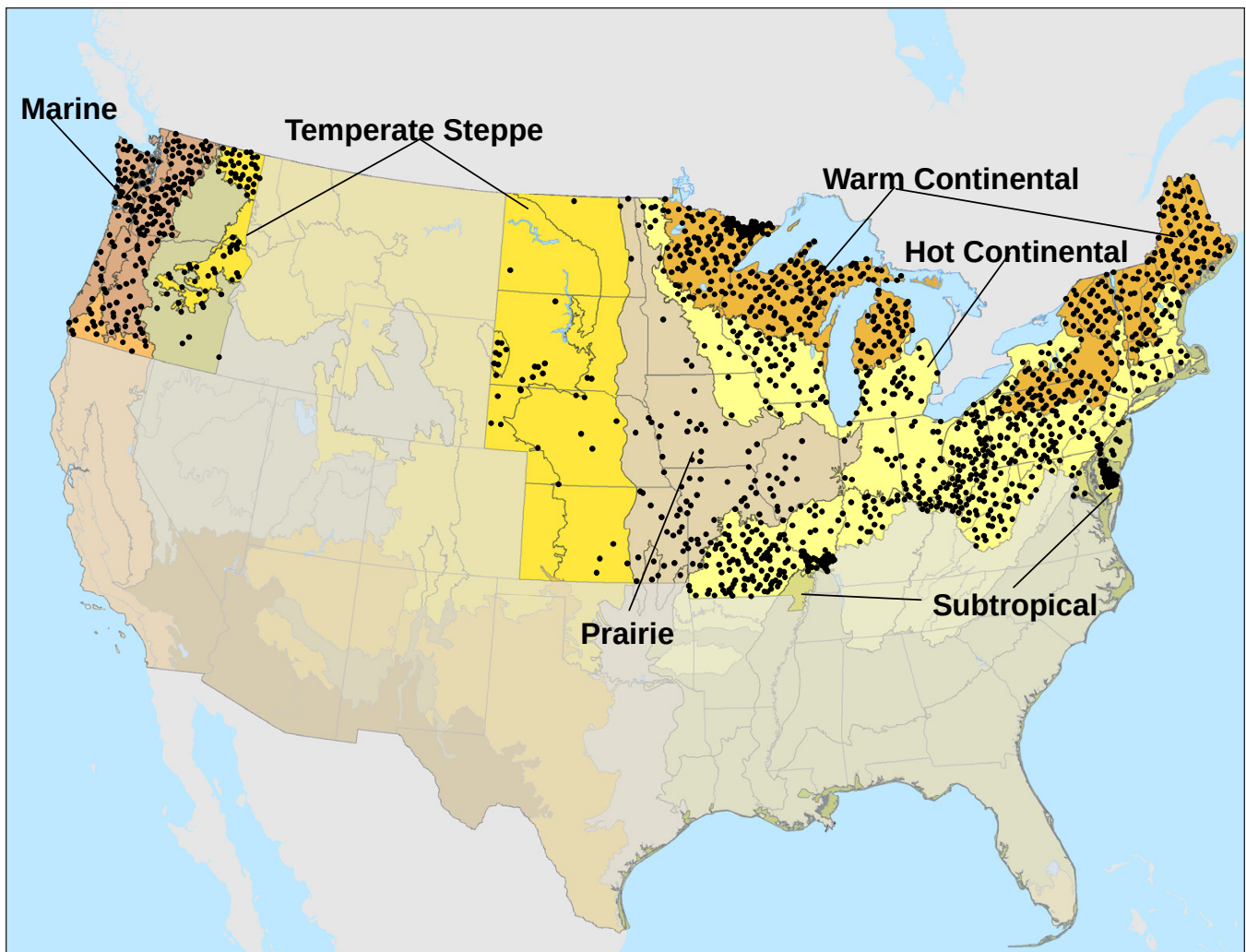


Figure 1.— Approximate location of FIA Phase 3 plots where VEG has been collected in the contiguous United States with an initial visit from 2001 through 2008. Shaded areas of map represent labeled ecological divisions.

and types of condition classes assigned. If the plot was 100 percent forest and was determined to be a single condition, it was designated as an “intact” stand. Plots that were 100 percent forest, but had more than one condition assigned, were designated as “multiple condition.” Plots that were less than 100 percent forest were designated as “forest edge”, although only forested portions of these plots were sampled, their proximity to nonforest land increases their potential exposure to introduced plant species flourishing on nonforested lands. This assignment creates a coarse filter for fragmentation in that some “intact” forest may, in fact, be adjacent to forest edge or be contained within small parcels of remnant forest and the forest in

some plots labeled “edge” could be adjacent nonforest plant communities unaffected by invasive species. Other variables considered included distance from improved roads, latitude, and longitude.

The numbers of native and introduced species per fully forested subplot were compiled for all plots regardless of level of fragmentation. Constancy (the presence of at least one introduced species) and measures of occupancy (relative richness and relative cover of introduced species) were computed at the plot level at the site. The relative richness is simply the number of introduced species divided by the total number of all species identified to species per plot. The relative

cover of introduced species is the sum of subplot cover of all introduced species divided by the sum of subplot cover of all species. Estimates and variances for each category were computed using the ratio of means methods described in Schulz et al. (2009).

RESULTS

Sixty-one percent of the 1690 plots had at least one introduced species. Where introduced species occurred, their mean relative richness was 10.7 percent, and their mean relative cover was 8 percent. We found 386 species of nonnative plants. We included two native grasses—reed canarygrass (*Phalaris arundinacea* L.) and common reed (*Phragmites australis* (Cav.) Trin. ex Steud.)—because invasive populations are genetically distinct from relatively rare native populations (Olson and Cholewa 2009).

The distribution of introduced species on Phase 3 inventory plots varied by ecological division (Table 1). The Warm Continental Division had the lowest constancy and occupancy of introduced species and the highest proportion of intact plots. The Prairie Division, with the highest proportion of edge plots, had the highest constancy and relatively high occupancy. Constancy and occupancy varied predictably with distance from improved roads (Fig. 2). Results from Alaska differed substantially from other regions: constancy of introduced species was only 4.4 percent, and when they occurred, their mean relative richness average was 2.2 percent, and mean relative cover of less than 1 percent; 74 percent of all plots were greater than 1 mile from an improved road. Comparisons between the Pacific Northwest and the northeastern United States were limited to the lower 48 States.

Table 1.—Ecological divisions represented in the sample, with total number of plots, number of plots by level of fragmentation, overall constancy of introduced plant species, and mean occupancy when introduced species are present.

Division	Level of Fragmentation				Constancy percent	Occupancy	
	Total	Intact	Multi	Edge		Mean relative richness (SE)	Mean relative cover (SE)
		number of plots				percent	percent
Warm Continental	538	352	64	122	48.7	7.7 (0.4)	4.0 (0.6)
Hot Continental	571	296	46	229	77.8	12.0 (0.4)	10.9 (0.7)
Subtropical	70	33	4	33	64.3	8.6 (0.9)	6.5 (1.6)
Marine ^a	173	96	21	56	60.7	11.7 (1.0)	6.3 (1.3)
Prairie	87	27	5	55	86.2	10.9 (0.9)	10.0 (1.6)
Temperate Steppe	93	55	10	28	82.8	13.8 (1.0)	9.2 (1.7)

^a Washington and Oregon only

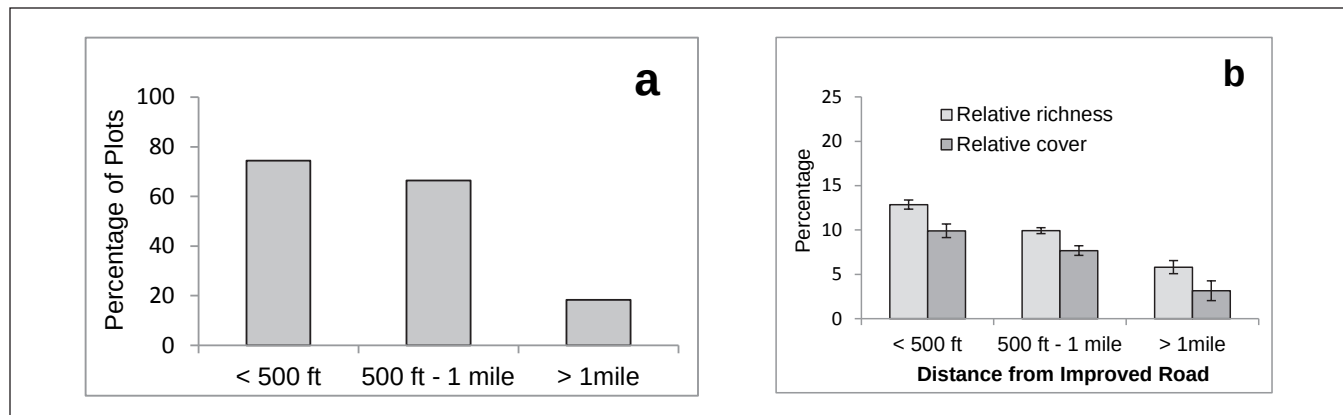


Figure 2.— Constancy (a) and occupancy (b) as a function of the distance of plots from improved roads; error bars represent plus and minus one standard error.

Despite not being found west of the Rocky Mountains, multiflora rose (see Table 2 for scientific and common names) remained the most commonly recorded species in this expanded analysis, with a constancy of over 20 percent of all 1690 plots. When the data were compiled regionally at the ecological-division level, there were some surprises among the most commonly recorded species (Table 2). Although many of the listed species are known to be problematic transformers, several, including broadleaf helleborine and wall-lettuce, are naturalized species considered benign in the past.

DISCUSSION

Full species census provides opportunities to monitor any species present on FIA plots. Our results find introduced species to be quite common in the forests of the lower 48 United States. Although some species were widely planted (e.g., multiflora rose) most of these species can be considered invasive, in that it is unlikely that they were planted in most of the stands sampled by FIA. Although many known transformer

species were captured in the Phase 3 VEG sample, there were some surprises concerning the most common species by ecological region compiled. For example, orange hawkweed is found on forest edge plots of many forest types, but in intact forests, it is found most often in aspen stands; broadleaf helleborine was found most often in intact sugar maple stands in the Adirondack Mountain province. These results could inform the development of lists of species to target in local and other list-based invasive species efforts, such as the national FIA inventory, and focus research attention to invasive species considered to be benign but are more widespread than previously thought.

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Table 2.—The three most commonly recorded introduced species by ecological division with constancies (percentage of plots in each division where the species was recorded)

Ecological Division	N plots	Scientific Name	Common Name	Division Constancy (percent)
Warm Continental	538	<i>Hieracium aurantiacum</i> L.	orange hawkweed	8.0
		<i>Phleum pretense</i> L.	timothy	4.8
		<i>Epipactis helleborine</i> (L.) Crantz	broadleaf helleborine	4.6
Hot Continental	571	<i>Rosa multiflora</i> Thunb.	multiflora rose	49.4
		<i>Lonicera japonica</i> Thunb.	Japanese honeysuckle	16.8
		<i>Alliaria petiolata</i> (M. Bieb.) Cavara & Grande	garlic mustard	13.7
Subtropical	70	<i>Lonicera japonica</i> Thunb.	Japanese honeysuckle	48.6
		<i>Rosa multiflora</i> Thunb.	multiflora rose	17.1
		<i>Microstegium vimineum</i> (Trin.) A. Camus	Japanese stiltgrass	8.6
Marine ^a	173	<i>Mycelis muralis</i> (L.) Dumort.	wall-lettuce	28.9
		<i>Rubus laciniatus</i> Willd.	cutleaf blackberry	16.2
		<i>Digitalis purpurea</i> L.	purple foxglove	15.6
Prairie	87	<i>Rosa multiflora</i> Thunb.	multiflora rose	47.1
		<i>Morus alba</i> Michx.	white mulberry	17.2
		<i>Torilis arvensis</i> (Huds.) Link	spreading hedgeparsley	16.1
Temperate Steppe	93	<i>Tragopogon dubius</i> Scop.	yellow salsify	39.8
		<i>Bromus tectorum</i> L.	cheatgrass	23.6
		<i>Hypericum perforatum</i> L.	common St. Johnswort	19.3

^a Washington and Oregon only

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