Chapter 4. Vegetation Diversity

Beth Schulz

Introduction

Vegetation is the source of primary production and a fundamental determinant of habitat and wildfire fuel profile characterization. As such, changes in vegetation can have cascading effects through an ecosystem. While individual species can be important indicators of a site's potential productivity, economic value, and wildlife forage and shelter, changes in the composition and spatial arrangement of vascular plants in a forest may indicate the presence of chronic stresses such as discrete site degradation, climate change, and pollution. These stresses can lead to decline or local eradication of sensitive species, as well as the increase and dominance of opportunistic species, such as many invasive nonnative plants. Changes in species diversity, composition, and the abundance of nonnative species are national concerns, as reflected in international criteria for assessing sustainability of forestry practices (Forest Service, U.S. Department of Agriculture, 2004). Monitoring for change requires establishing an understanding of current conditions that can be reassessed in the future.

The vegetation diversity and structure indicator from the Forest Inventory and Analysis (FIA) Program of the Forest Service, U.S. Department of Agriculture, provides baseline data on forest vascular plant composition. The inventory is conducted with consistent methods across the vast array of forest types in the Nation. Permanent plots are established on a systematic grid in forests across the country and will be revisited in the future, providing a powerful means for change detection through time. The FIA phase 3 (P3) grid is geographically extensive with one plot every 96,000 acres. Therefore, while individual plot data characterize the changing conditions of sampled forest stands, population estimates are appropriate at regional and national scales.

This report focuses on attributes derived from the vascular plant composition data to describe the conditions of forest plant communities across the United States. Species composition data allow for analysis of diversity and individual species' distribution and abundance at several scales, from measured forest stands to large geographic areas, including assessments of the impacts of nonnative species on native plant communities.

Methods

The FIA program collects vegetation data on the systematically located P3 plots (fig. 4.1). All vascular plants rooted in or hanging over the four subplots are identified (see footnote 2, page 29, chapter 3). Plant identifications are recorded using plant symbols defined by the Natural Resource Conservation Service PLANTS Database (U.S. Department of Agriculture, Natural Resource Conservation Service 2000). For each species on the subplot, total percent canopy cover and canopy cover within three horizontal layers are estimated and recorded. Species rooted in or overhanging each of three permanently positioned 1-m^2 quadrats on each subplot are also recorded. Unknown species are collected near the plot, then pressed, dried, labeled, and identified later by an FIA vegetation specialist or submitted to a qualified herbarium.

The FIA sampling design is focused on accessible forested lands; this results in some plots with less area sampled than the four full subplots. These plots provide valuable information, but plot summaries and population estimations must be calculated and presented appropriately. Calculations for attributes that are dependent on fixed area measurements exclude sample units that are not 100 percent within accessible forest lands.

Ecological provinces, as described by Bailey (1995) and Cleland and others (2007), define areas with similar physical and biological features that influence vegetation and are useful for defining populations. Forest cover type is often highly correlated with understory species composition and is used as the primary grouping class within defined geographic areas. By grouping plots by ecological province and forest type, population estimate variability may be reduced. Forest type is assigned by mensuration field crews, and also derived by algorithm based on live-tree stocking of softwoods and

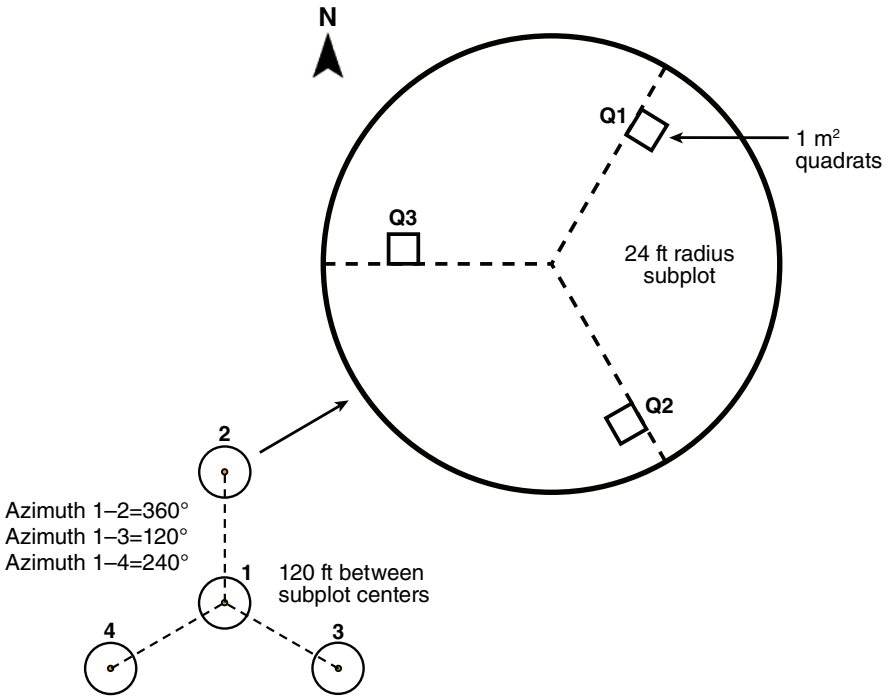

Figure 4.1—Vegetation indicator plot layout.

hardwoods (Forest Service, U.S. Department of Agriculture, 2006). In this report, a forest type within an ecological province will be referred to as a community type when summarizing and comparing population estimates.

The dataset includes 915 plots on the P3 grid collected from 2001 through 2004 from the States of Oregon, Washington, Utah, South Dakota, North Dakota, Kansas, Nebraska, Missouri, Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, and Pennsylvania; other States either do not collect vegetation data or the data are not available. Of those plots, 862 have at least one known 100-percent forested subplot, 583 plots are fully forested (four subplots), and 504 plots are fully forested in a single condition class. Condition class is determined by a number of attributes assigned to the plot such as forest type, stand-size class, and ownership. The type of results that can be presented vary by data subset (table 4.1). On the 504 fully forested, single-condition plots, there are 127 community types. Twelve of these community types are represented by 10 or more plots and are used in this report to demonstrate basic population estimates and comparisons. The 12 types are concentrated in areas with the longest history of vegetation indicator data collection.

Identification level rates and plant origin are determined by comparing the final vegetation species codes, after all identifications of unknown plants are complete, with the PLANTS Database. Species' nativities (native or introduced) are assigned based on information from the PLANTS Database. Note that not all introduced plants are invasive, and some native plants are invasive and/or noxious.

Species richness (alpha α) is a count of the number of unique plants recorded in each fully sampled (100-percent accessible forest land) plot. Gamma (γ) represents the number of unique species recorded across all samples in the population and represents the lower bound of the true number of species in a population. Any inventory that does not sample the entire population is expected to miss species (Colwell and others 2004, Heltshe and Forrester 1983). Given the expansive geographic range and low sample density of the P3 grid, it is assumed that many species are missed. To estimate the true number of species to be expected in the sampled community, nonparametric jackknife estimates are calculated (Heltshe and Forrester 1983, McCune and Grace 2002). Nonparametric estimates avoid assumptions about species distributions and discovery rates; most natural communities demonstrate patchiness and clumping of species. Plot-based samples are not random samples of individuals but random samples of space. These estimates are based on the number of species that are recorded on one or two plots across the sample. Jackknife estimates are calculated using the formulas:

Table 4.1—Summary of datasets and type of results presented

Number of plots (n)	Dataset characteristics	Results presented
915	Matching FIA P2 data available (including approximate plot locations)	Table 4.2—Identification rates and origin of species for all 915 plots Table 4.5—Distribution of selected native and introduced species Table 4.6—Top 25 most commonly recorded introduced species in all 915 plots Figure 4.5—Percentage of the number of and relative proportion cover of introduced plant species Figure 4.6—Distribution of three invasive grasses Figure 4.7—Distribution of five introduced herbs Figure 4.8—Distribution of three introduced shrubs
862	Plots with at least one known fully forested subplot	Figure 4.3—Average species richness for subplots in 100-percent accessible forested conditions
230	Fully forested, single-condition plots belonging to an ecological province/ forest-type pair represented by at least 10 plots	Table 4.3—Ecological province, forest type, identification rates, and origin of identified species for 12 community types Table 4.4—Species richness and differentiation for 12 community types Figure 4.2—Species area and distance curves for 12 community types Figure 4.4—Average plot, subplot, and quadrat alphas for 12 community types Appendix table A4.1—Top 5 percent most common species or genera for 12 community types

FIA = Forest Inventory and Analysis; P2 = phase 2.

1st order:

$$Jack_1 = S + \frac{r'(n-1)}{n}$$

where

S = the number of observed species

r' = the number of species occurring in only one sample unit

n = the number of sample units (plots)

2nd order:

$$Jack_2 = S + \frac{r'(2n-3)}{n} - \frac{r''(n-2)^2}{n(n-1)}$$

where

r″ = the number of species occurring in exactly two sample units

To quantify the sample's ability to characterize the species composition, species area and distance curves are used. Species area curves assessing sample adequacy are based on repeated subsampling of a fixed sample using species presence/absence (P/A). Distance curves describe the Sørensen distance (dissimilarity) between the species composition of a subsample of plots and the entire sample of plots, as a function of sample size (McCune and Grace 2002). Distance curves incorporate abundance information for each species. This is useful to determine a sample size (number of plots) that provides a consistent species composition as opposed to a consistent species list. These are produced using PC–ORD™ software (McCune and Medford 1999). Given the extent of the P3 grid and the concept of community type (forest type within an ecological province), it is expected that community types with high species richness require more samples to characterize their species composition.

Differential diversity, in its most basic sense, describes the extent to which species composition and abundance change from one place to another (Scheiner 2003, Whittaker and others 2001). It can be calculated a number of ways; in this report, it is simply:

$$\beta = \frac{\gamma}{\overline{\alpha}}$$

For community type beta, gamma is the total number of species for the community type and average alpha is the average number of species per plot. For plot-level beta, gamma is the total number of species observed on the plot and average alpha is the average number of species per subplot. Distribution of individual species are assessed using P/A data, which describes how the observed species are dispersed over an area of interest. This is useful in large-scale projects where vegetation composition changes dramatically across the area of interest (McCune and Grace 2002). The P/A data can be expressed as frequency and constancy; both are ratios of the number of sample or subsample units where a species was recorded to the number of total sample or subsample units visited. In this report, constancy is the percentage of the total number

of plots where the species has been observed, without the restriction of equal forested area plots. Frequency is used at subsample levels and is restricted to sample units of equal area, such as fully forested subplots or the standard 1-m^2 quadrats. Subplot and quadrat frequencies are valuable to describe fine-scale species distribution.

Quadrat frequency is compiled as:

$$F_s = \frac{\sum_{i}^{n}\sum_{j}^{4}\sum_{q}^{3}\delta_{ijq}\mathrm{I}_{ijqs}}{\sum_{i}^{n}\sum_{j}^{4}\sum_{q}^{3}\delta_{ijq}}$$

where

F_s = the frequency of species s on a quadrat basis for the population of interest

δ_{ijq} = a zero-one domain indicator function, which is 1 if quadrat q of subplot j of plot i is in accessible forest, 0 otherwise

I_{ijqs} = a zero-one species indicator function, which is 1 if species s is present on quadrat q of subplot j of plot i, 0 otherwise

Subplot frequency is computed as:

$$F_s' = \frac{\sum_{i}^{n}\sum_{j}^{4}\delta_{ij}I_{ijs}}{\sum_{i}^{n}\sum_{j}^{4}\delta_{ij}}$$

where

F_s' = the subplot frequency of species s for the population

δ_{ij} = a zero-one domain indicator function, which is 1 if subplot j of plot i is in 100-percent accessible forest, 0 otherwise

I_{ijs} = a zero-one species indicator function, which is 1 if species s is present on subplot j of plot i, 0 otherwise

The percentage number and relative proportion of cover of introduced species are calculated at the plot level; results are presented as mapped products. Percentage number of introduced species per plot is calculated by dividing the number of introduced species by the total number of unique species recorded on the plot (including plants not identified to species). Relative proportion of cover of introduced species is calculated by dividing the sum of all introduced plant species by the sum of all plant covers.

$$Rc_i = \frac{\sum_{j}^{4}\sum_{s'}c_{ijs'}}{\sum_{j}^{4}\sum_{s}c_{ijs}}$$

where

Rc_i = relative cover of all introduced species on plot i

$c_{ijs'}$ = canopy cover of introduced species s' on subplot j of plot i

c_{ijs} = canopy cover of species s on subplot j of plot i

s' = index for introduced species, a subset of s

s = index for any species

j = index for subplots

Results

Species Composition—Basic summaries of identification rates and species origin for the 915 plots provide insights to the nature of vascular plant composition in the forests of the 15 States that were sampled (table 4.2). Of all individual plant observations, 82 percent were identified to species. Of those identified to species, 93 percent are native. Of the unique plant codes recorded (γ), 89 percent of those identified to species are native. The origin of plants identified to species for each of the 12 community types are shown in table 4.3. In general, conifer community types have a higher percentage of native plants. However, the number of plants not identified to species (genus codes plus unknown codes) exceeds the number of identified introduced species for all groups in tables 4.2 and 4.3, and so the true extent of the number of introduced species remains uncertain.

The numbers of unknown codes underestimate the true number of species represented by plants recorded as such; there are numerous potential species for each genus and each symbol for unknown plants listed. The origin of plants identified to genus were estimated by evaluating all species of each recorded genus to determine what proportion of all species within the genus is native or introduced, with the assumption that species identified only to the genus had the same

Table 4.2—Identification rates and origin of species for all 915 plots

		Level of identification			Species by origin	
Type of record	n	Unknowns	Genus	Species	Native	Introduced
Individual plant observations (total)	35,980	1,624	4,830	29,491	27,418	2,108
Unique plant codes recorded (gamma)	2,975	33	345	2,595	2,318	279

Table 4.3—Ecological province, forest type, identification rates, and origin of identified species for 12 community types

Community type					Plants identified to species		
Ecological province (code)[a] and forest type (abbreviation)[b]	ID[c]	Plots (n)	Gamma[d]	Species	Native	Introduced	Unknowns[e]
			number of unique species codes				
Laurentian Mixed Forest (212)							
Northern white-cedar (Cedar)	A	13	270	231	221	10	39
Sugar maple/beech/birch (SMaple)	B	28	335	281	256	25	54
Hard maple/basswood (HMaple)	C	14	271	216	203	13	55
Aspen (Aspen)	D	33	438	364	325	39	74
Eastern Broadleaf Forest (221)							
White oak/red oak/hickory (Oak-Hic)	E	10	250	201	178	23	49
Sugar maple/beech/birch (SMaple)	F	11	201	149	135	14	52
Midwest Broadleaf Forest (222)							
White oak/red oak/hickory (Oak-Hic)	G	10	218	181	161	20	37
Central Interior Broadleaf Forest (223)							
White oak/red oak/hickory (Oak-Hic)	H	42	470	376	352	24	94
White oak (WOak)	I	10	262	210	199	11	52
Colorado Plateau Semi-Desert (313)							
Pinyon/juniper woodland (PJ)	J	12	98	81	76	5	17
Interior Semi-Desert and Desert (341)							
Pinyon/juniper woodland (PJ)	K	34	248	203	194	9	45
Nevada-Utah Mountain Semi-Desert Coniferous Forest (M341)							
Pinyon/juniper woodland (PJ)	L	13	100	79	78	1	21

[a] Used in figure 4.4 to simplify labels, as described by Cleland and others (2007).
[b] Used in figure 4.4 to simplify labels.
[c] Used in figure 4.2 to simplify labels.
[d] Gamma represents the total number of unique plant codes recorded in a community, including codes for plants identified to species, genus, and symbols for plants that cannot be identified to genus.
[e] Unknowns include both genus codes and symbols for unknown plants.

origin rate. For the 4,830 plant observations recorded as genera, origin is estimated to be 88 percent native and 12 percent introduced. Of the 12 communities, the highest percentage of introduced species, based on all plants identified to species, is also 12 percent (Eastern Broadleaf Forest—White oak/red oak/hickory).

Distance curves describing the Sørensen distance (dissimilarity) between subsample species composition and the entire sample species composition for each community type indicate how well the sample captured the overall species composition of the community types (fig. 4.2). Converging error curves representing plus or minus one standard deviation on graphs of community types identified in table 4.3 with more sampled plots indicate better representation of species composition. However, note that several types with smaller sample sizes are also fairly well represented (A. northern white cedar in the Laurentian Mixed Forest ecoprovince, and L. pinyon/juniper woodland in the Nevada-Utah Mountain Semi-Desert Coniferous Forest). There is no evidence that we have oversampled any community type; species area curves do not level off in any case. This is not surprising, given the extent of sampling design.

The approximate top 5 percent most frequently recorded species or genera codes recorded in each of the 12 community types are listed in appendix table A4.1. Constancy of 100 percent indicates the species was recorded on all plots representing that community. The abundance of most common species, listed in appendix table A4.1 as average cover, reveal an important characteristic in plant community composition; some species are extremely common (high constancy) but are present in low abundance (cover). Note that Canada mayflower (*Maianthemum canadense* Desf.) occurs often in all four forest types in the Laurentian Mixed Forest ecological province but with an average cover of < 1 percent. In the larger dataset of 915 plots, 56 percent of all species abundance records are equal to 1 percent canopy cover. Only three community types include an introduced species among the top 5 percent most common species.

Species Richness—Geographic patterns of species richness are shown in figure 4.3 as average subplot alpha ($\overline{\alpha}$). Mapped results include the 862 plots with at least 1 known fully forested subplot. The mesic forests of the Great Lakes States have higher subplot species richness, in general, than the arid semi-desert woodlands.

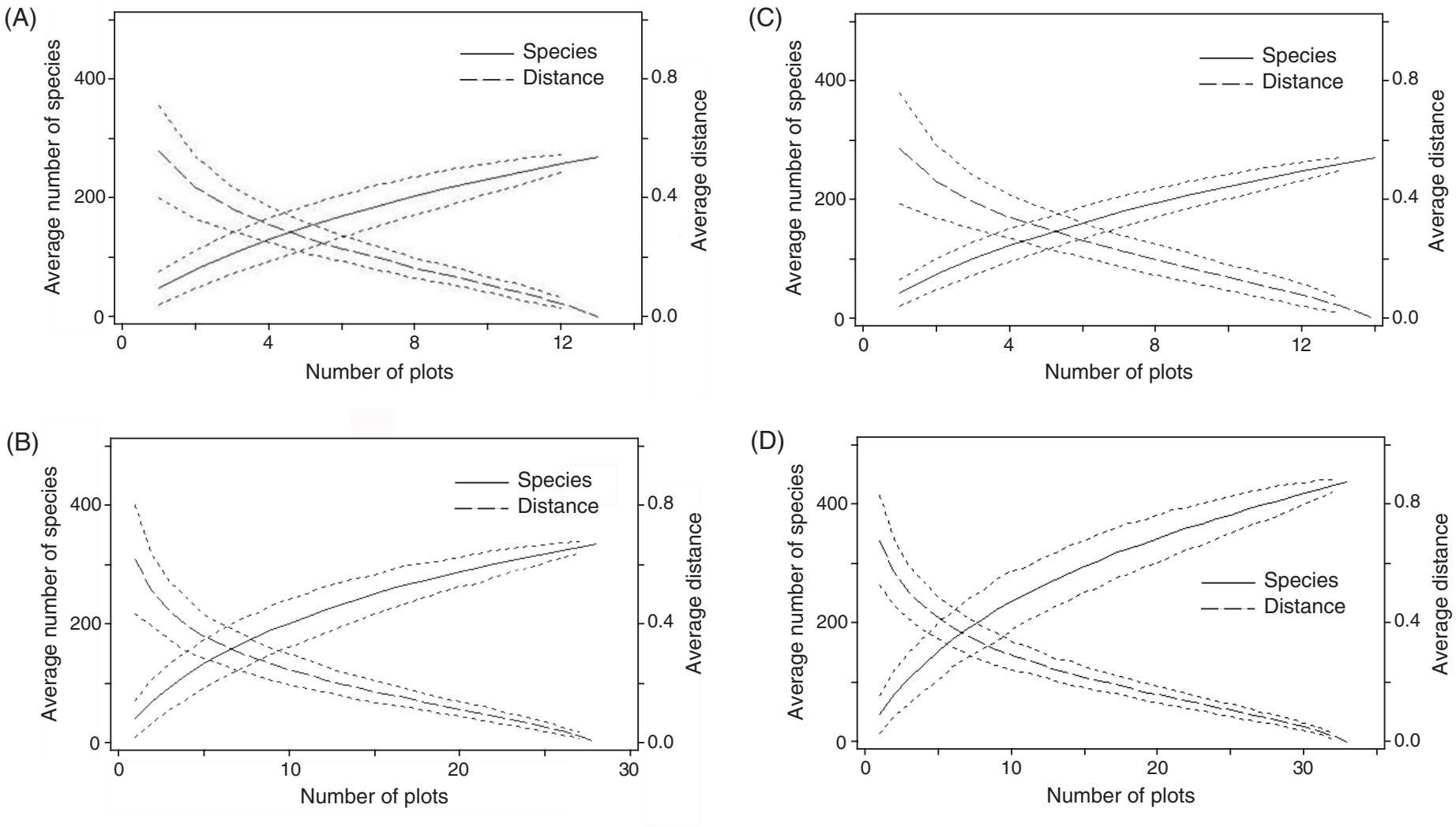

Figure 4.2—Species area and distance curves for 12 community types. Community types are identified by letters in table 4.3. Error curves represent plus and minus one standard deviation. (Data source: U.S. Forest Service Forest Inventory and Analysis Program) *(continued on next page)*

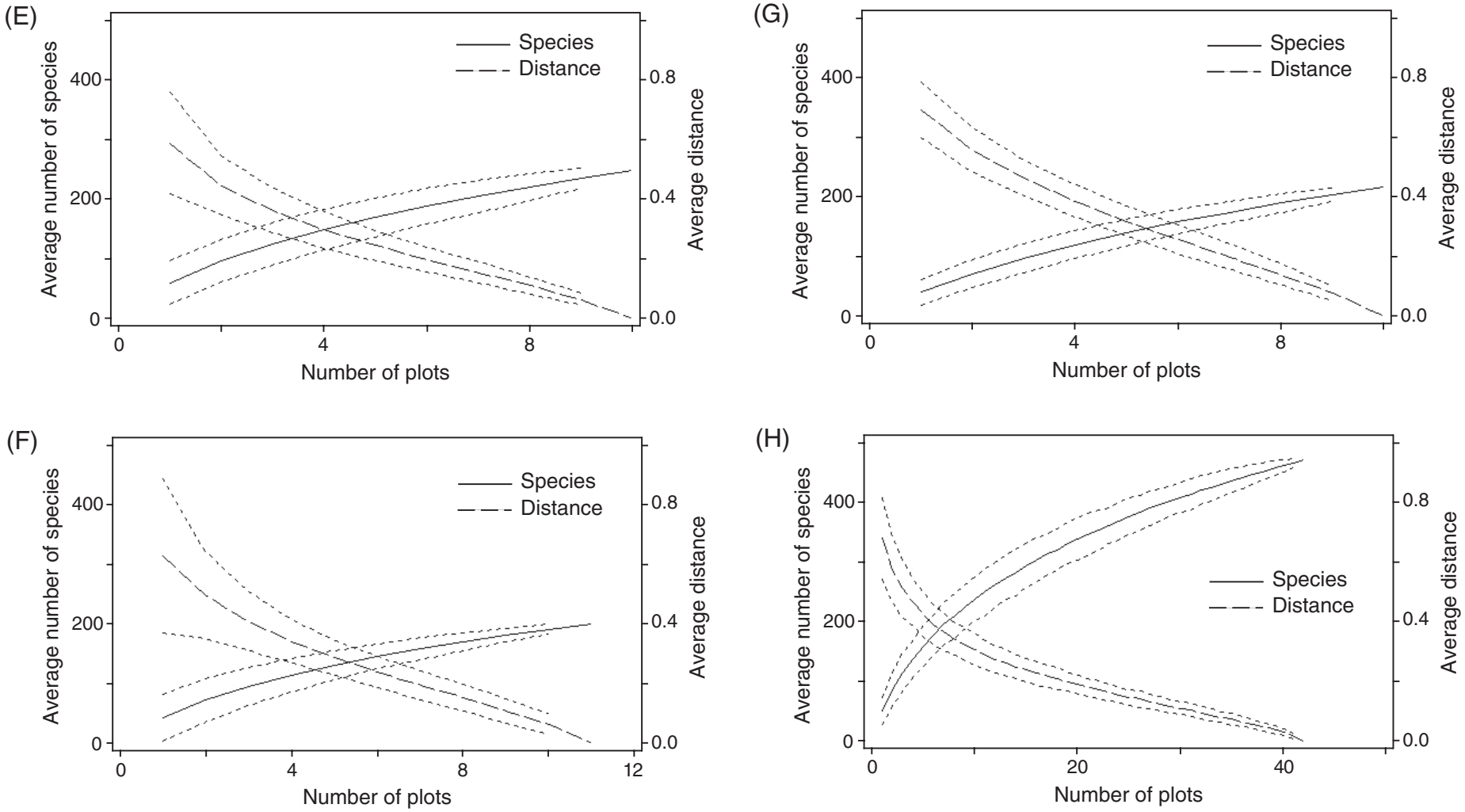

Figure 4.2 (continued)—Species area and distance curves for 12 community types. Community types are identified by letters in table 4.3. Error curves represent plus and minus one standard deviation. (Data source: U.S. Forest Service Forest Inventory and Analysis Program) *(continued on next page)*

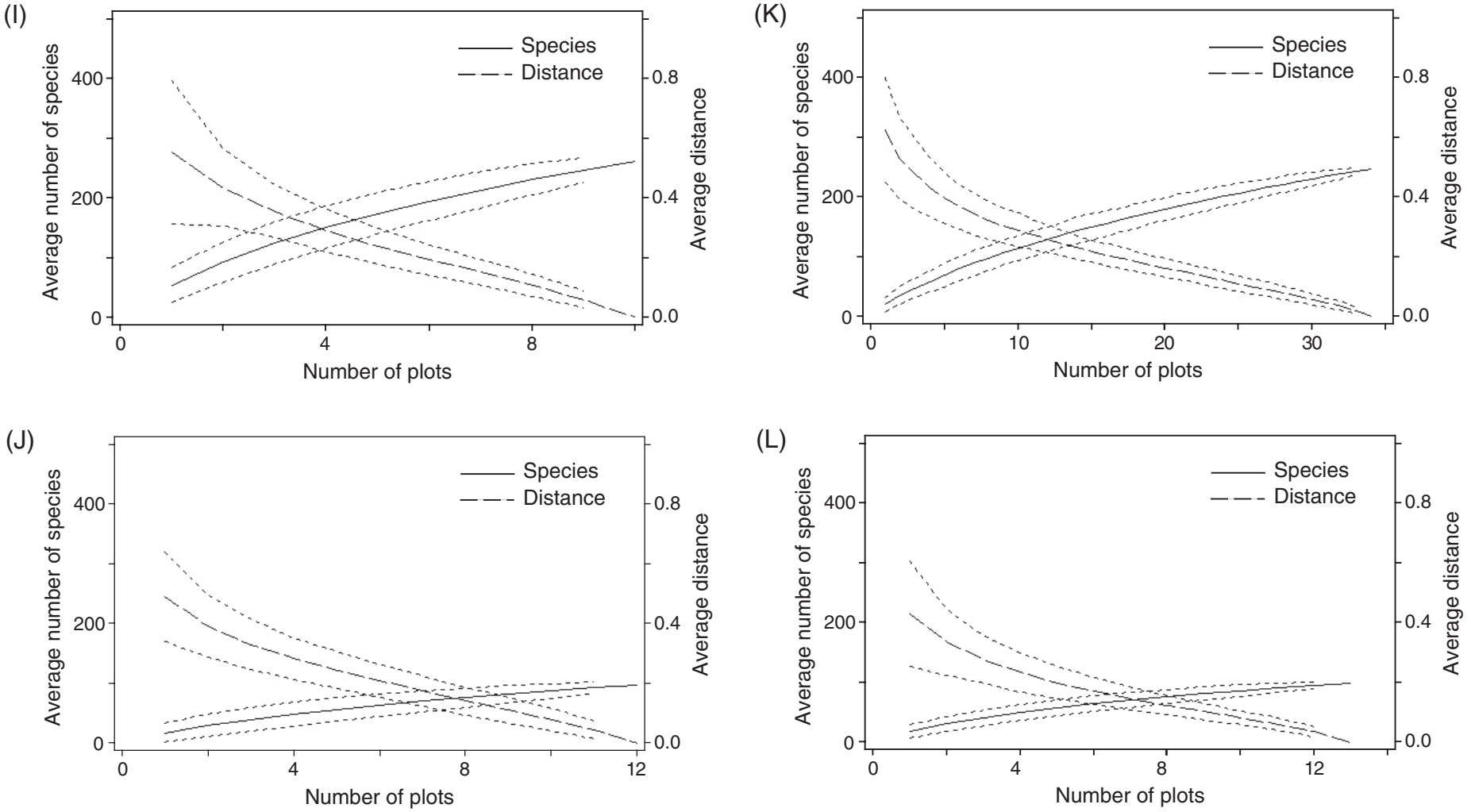

Figure 4.2 (continued)—Species area and distance curves for 12 community types. Community types are identified by letters in table 4.3. Error curves represent plus and minus one standard deviation. (Data source: U.S. Forest Service Forest Inventory and Analysis Program)

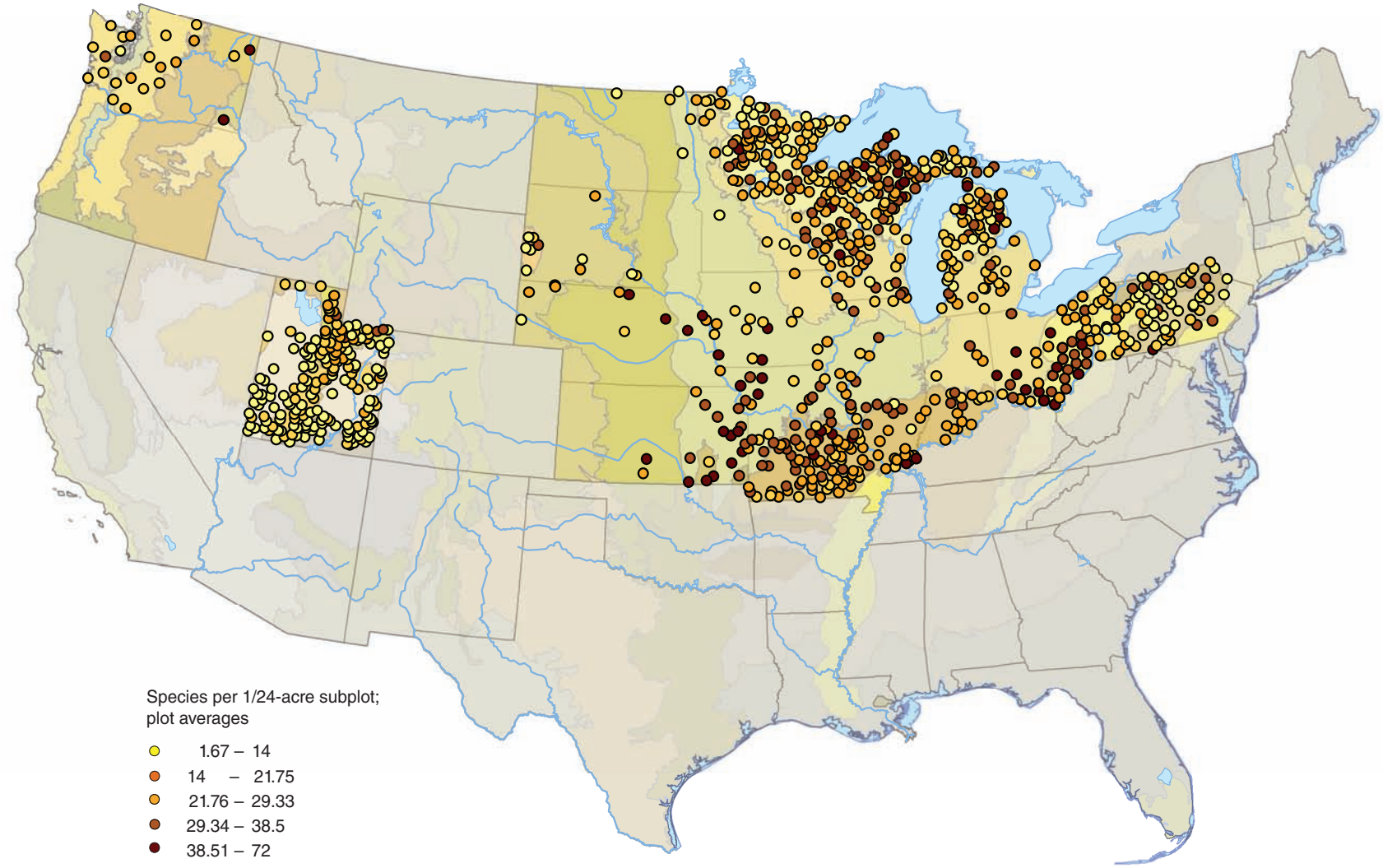

Figure 4.3—Average species alpha for subplots in 100 percent accessible forested conditions. Plot locations are approximate. Background colors correspond to ecological provinces. States with dulled colors have not been sampled. (Data source: U.S. Forest Service Forest Inventory and Analysis Program)

Population estimates of overall species richness by community type were calculated from fully forested plots in single-condition types, limited to 12 community types represented by at least 10 plots. Species area curves (fig. 4.2) indicate no community type is fully represented with the sample sizes available (species area curves do not level off). Some basic trends are supported, though. Most community types detect at least 200 species with 10 plots; the exceptions are the semi-desert, pinyon-juniper woodlands that only capture about 100 species with 10 plots (figs. 4.2J, 4.2K, and 4.2L). Population estimates for the 12 community types are summarized in table 4.4, including jackknife predictors of the true number of species. Most estimates included are highly dependent on sample size and should not be directly compared.

Population estimates of community average plot, subplot, and quadrat alphas reveal that the pinyon-juniper woodlands in the desert and semi-desert provinces (three community types to the far right-hand side of graph) support fewer species per plot than the other communities support on a single subplot [one-quarter of the area of the entire plot (fig. 4.4)]. The figure orders communities by average plot alpha descending order; note that average number of species per subplot and quadrat are not strictly proportional to the number of species observed at the plot level.

Direct comparison of communities should be limited to those with the same sample size. The northern white cedar (*Thuja occidentalis* L.) forest type in the Laurentian Mixed Forest province and the pinyon-juniper woodland in the Nevada-Utah Mountain Semi-Desert Coniferous Forest province are both represented by 13 plots (table 4.4). Independent sample t-tests of average plot, subplot, and quadrat alphas are significantly different (p value ≤ 0.00001 in all cases). The cool, moist northern white cedar forests support more species per unit area than the hot, dry pinyon-juniper forests. The higher species richness also includes a higher proportion of introduced species (3.7 percent) compared to the high desert pinyon-juniper (1 percent) (table 4.3). Forty-six percent of the northern white cedar plots had at least one introduced species, where only 23 percent of the pinyon-juniper plots had an introduced species. Differential diversity (β) at both the population level and the plots level were similar (table 4.4).

Table 4.4—Species richness and differentiation for 12 community types

Community type					Estimates of "true" gamma			
Ecological province and forest type	n	Average plot alpha[a]	(SE)	Beta	Gamma	1st order jackknife	2nd order jackknife	Average plot beta[b]
					number of species			
Laurentian Mixed Forest (212)								
Northern white-cedar (Cedar)	13	50.0	(4.53)	5.6	270	408.5	491.2	1.62
Sugar maple/beech/birch (SMaple)	28	42.8	(3.49)	8.3	335	475.8	558.6	1.74
Hard maple/basswood (HMaple)	14	44.9	(2.99)	6.3	271	416	517	1.84
Aspen (Aspen)	33	48.8	(2.91)	9.4	438	639.7	775	1.78
Eastern Broadleaf Forest (221)								
White oak/red oak/hickory (Oak-Hic)	10	62.6	(6.25)	4.1	250	375.1	458.6	1.82
Sugar maple/beech/birch (SMaple)	11	43.5	(6.37)	4.7	201	292.8	344.5	1.77
Midwest Broadleaf Forest (222)								
White oak/red oak/hickory (Oak-Hic)	10	41.8	(3.61)	5.4	218	339.5	421.2	1.85
Central Interior Broadleaf Forest (223)								
White oak/red oak/hickory (Oak-Hic)	42	53.3	(1.78)	9.4	470	657	753.9	1.93
White oak (WOak)	10	59.6	(5.08)	4.8	262	395	481	2.05
Colorado Plateau Semi-Desert (313)								
Pinyon/juniper woodland (PJ)	12	17.9	(2.36)	5.5	98	153	191	1.72
Interior Semi-Desert and Desert (341)								
Pinyon/juniper woodland (PJ)	34	20.5	(1.06)	12.3	248	387.8	485.9	1.74
Nevada-Utah Mountain Semi-Desert Coniferous Forest (M341)								
Pinyon/juniper woodland (PJ)	13	18.5	(1.54)	5.5	100	148.9	179.8	1.55

[a] Average number of species per 0.16-acre plot (four 0.04-acre subplots).

[b] Average plot beta $= \frac{\sum_{n}^{p=1} \frac{\gamma_{plot}}{\overline{\alpha}_{s}}}{n}$ and signified the average amount of species composition change across four subplots in a "homogenous" forest type.

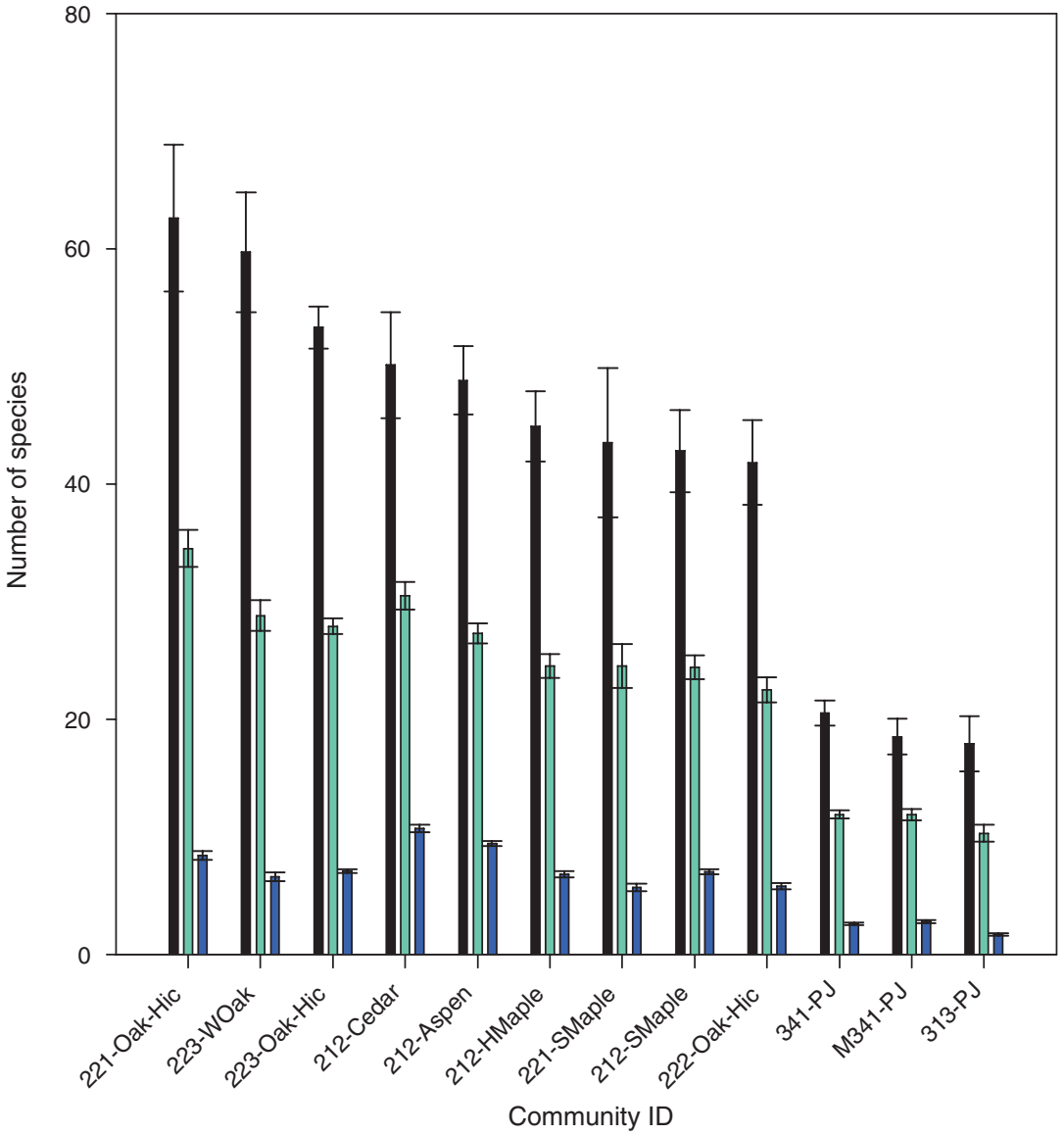

Figure 4.4—Average plot, subplot, and quadrat alphas for 12 community types. They are average plot-black; average subplot-green; average quadrat-blue. Community types are identified by ecological province codes and forest type abbreviations shown in table 4.3. Error bars show plus and minus one standard error. (Data source: U.S. Forest Service Forest Inventory and Analysis Program)

Species Distributions—The distribution of individual species at broad scales is described by constancy. The most common species by occurrence is Virginia creeper [*Parthenocissus quinquefolia* (L.) Planch.] (table 4.5). Other species shown were selected based on how common they appeared in the entire database for the 915 plots, and to provide some comparison of introduced and native species (table 4.5, I and N) with similar growth habits and constancies.

Species dominance is indicated by frequency, the proportion of standard area sample units where the species was recorded, and its abundance, recorded as canopy cover. Note that the native American fly honeysuckle (*Lonicera canadensis* Bart. ex Marsh.) was encountered on more plots than the introduced Japanese honeysuckle (*L. japonica* Thunb.), but Japanese honeysuckle has a much higher average cover and quadrat frequency on the plots where it does occur, indicating invasive plant tendencies.

Multiflora rose (*Rosa multiflora* Thunb.) and cheatgrass (*Bromus tectorum* L.) are the two most common introduced species found in the gamma analyses for all plots. They also are the only two introduced species listed in the top 5 percent most common species in the 12 plant communities (table A4.1). Both are considered to be invasive.

Invasive and Introduced Plant Species—Of the 915 plots included, 67 percent had at least 1 known introduced species identified. Of the 301 plots with no introduced species recorded at the time they were initially visited, 42 had all plants identified to species, with no unknowns. The percentage of introduced species with respect to the total number of species recorded and the relative proportion of introduced plant species cover for the included 915 plots is shown in figure 4.5. The top 10 most frequently recorded introduced species (table 4.6) are either considered to be noxious or invasive.

The broadscale geographic distribution of invasive species of interest, grouped by growth habit (grasses, forbs, and shrubs), are displayed in figures 4.6, 4.7, and 4.8. Reed canarygrass (*Phalaris arundinacea* L.) is a native species that is considered invasive; once widely used to restore roadbed cuts, this species has demonstrated the ability to quickly overtake wetland systems. Garlic mustard [*Alliaria petiolata* (M. Bieb.) Cavara & Grande] is an introduced forb that is highly shade tolerant, readily spreads in undisturbed forests, and has allelopathic properties to inhibit other plant growth. It has been recorded on many plots in the Great Lakes States, and its average cover and frequencies on subplots and quadrats (table 4.5) indicate its invasive tendencies. Invasive shrubs are well established in the North Central States; multiflora rose was handed out to the public free of charge for wildlife enhancement in the 1960s.

Table 4.5—Distribution of selected native and introduced species

Growth habit	Scientific name	Common name	Origin	All plots (n = 915) constancy	Plots where present		
					Average cover	Subplot frequency	Quadrat frequency
Vine	*Parthenocissus quinquefolia*	Virginia creeper	N	41.09	6.60	0.79	0.36
Tree	*Acer rubrum*	Red maple	N	35.41	15.15	0.77	0.33
Shrub, vine	*Toxicodendron radicans*	Eastern poison ivy	N	32.46	7.98	0.63	0.21
Tree	*Quercus rubra*	Northern red oak	N	29.95	10.50	0.59	0.09
Vine, shrub	*Rosa multiflora*	Multiflora rose	I	23.50	7.90	0.62	0.16
Tree, shrub	*Sassafras albidum*	Sassafras	N	17.38	8.98	0.72	0.21
Graminoid	*Achnatherum hymenoides*	Indian ricegrass	N	8.42	1.53	0.64	0.11
Graminoid	*Bromus tectorum*	Cheatgrass	I	8.42	4.47	0.72	0.33
Shrub	*Lonicera canadensis*	American fly honeysuckle	N	8.20	2.63	0.60	0.11
Subshrub, shrub	*Mahonia repens*	Creeping barberry	N	5.68	2.79	0.62	0.25
Vine	*Lonicera japonica*	Japanese honeysuckle	I	5.57	16.90	0.64	0.34
Forb/herb	*Daucus carota*	Queen Anne's lace	I	5.36	3.89	0.50	0.18
Forb/herb	*Phytolacca americana*	American pokeweed	N	5.36	3.57	0.46	0.07
Forb/herb	*Alliaria petiolata*	Garlic mustard	I	4.48	8.90	0.67	0.33
Forb/herb	*Apocynum androsaemifolium*	Spreading dogbane	N	4.48	1.71	0.50	0.16
Forb/herb	*Circaea lutetiana*	Broadleaf enchanter's nightshade	N	4.48	2.37	0.62	0.22
Forb/herb	*Leucanthemum vulgare*	Oxeye daisy	I	4.48	2.14	0.47	0.11
Forb/herb	*Sanguinaria canadensis*	Bloodroot	N	4.48	2.22	0.49	0.10

N = native species; I = introduced species.

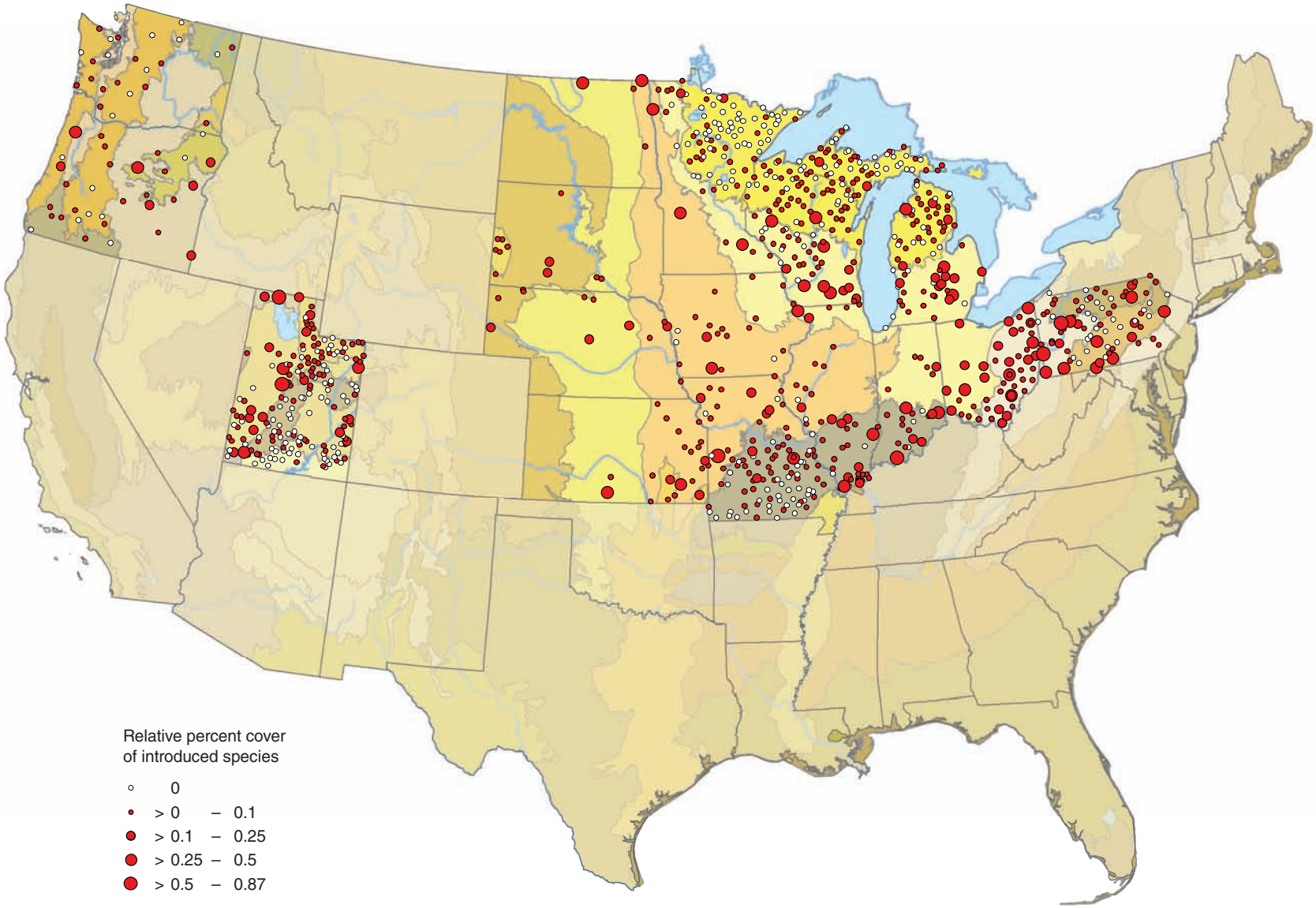

Figure 4.5—Relative percent cover of introduced plant species. White dots represent plots where no introduced plants were recorded, and red dot sizes correspond to increasing levels of infestation. Plot locations are approximate. Background colors correspond to ecological provinces. States with dulled colors have not been sampled at the time of report preparation. (Data source: U.S. Forest Service Forest Inventory and Analysis Program)

Table 4.6—Twenty-five most commonly recorded introduced species (n = 915)

Growth habit	Scientific name	Common name	Constancy
Vine, shrub	*Rosa multiflora*	Multiflora rose	23.50
Graminoid	*Bromus tectorum*	Cheatgrass	8.42
Vine	*Lonicera japonica*	Japanese honeysuckle	5.57
Forb/herb	*Daucus carota*	Queen Anne's lace	5.36
Forb/herb	*Hieracium aurantiacum*	Orange hawkweed	5.14
Vine, forb/herb	*Polygonum convolvulus*	Black bindweed	5.03
Forb/herb	*Leucanthemum vulgare*	Oxeye daisy	4.48
Forb/herb	*Alliaria petiolata*	Garlic mustard	4.48
Forb/herb	*Tragopogon dubius*	Yellow salsify	4.26
Graminoid	*Phleum pratense*	Timothy	4.04
Forb/herb	*Trifolium repens*	White clover	3.93
Forb/herb	*Polygonum persicaria*	Spotted ladysthumb	3.72
Forb/herb	*T. pratense*	Red clover	3.72
Forb/herb	*Glechoma hederacea*	Ground ivy	3.50
Graminoid	*Dactylis glomerata*	Orchardgrass	3.39
Subshrub, forb/herb	*Solanum dulcamara*	Climbing nightshade	3.28
Forb/herb	*Hypericum perforatum*	Common St. Johnswort	3.28
Forb/herb	*Arctium minus*	Lesser burdock	3.17
Forb/herb	*Cirsium arvense*	Canada thistle	3.17
Forb/herb	*Rumex acetosella*	Common sheep sorrel	2.95
Graminoid	*Poa compressa*	Canada bluegrass	2.95
Graminoid	*Lolium pratense*	Meadow fescue	2.84
Forb/herb	*Melilotus officinalis*	Yellow sweetclover	2.84
Tree, shrub	*Rhamnus cathartica*	Common buckthorn	2.84
Tree, shrub	*Morus alba*	White mulberry	2.84

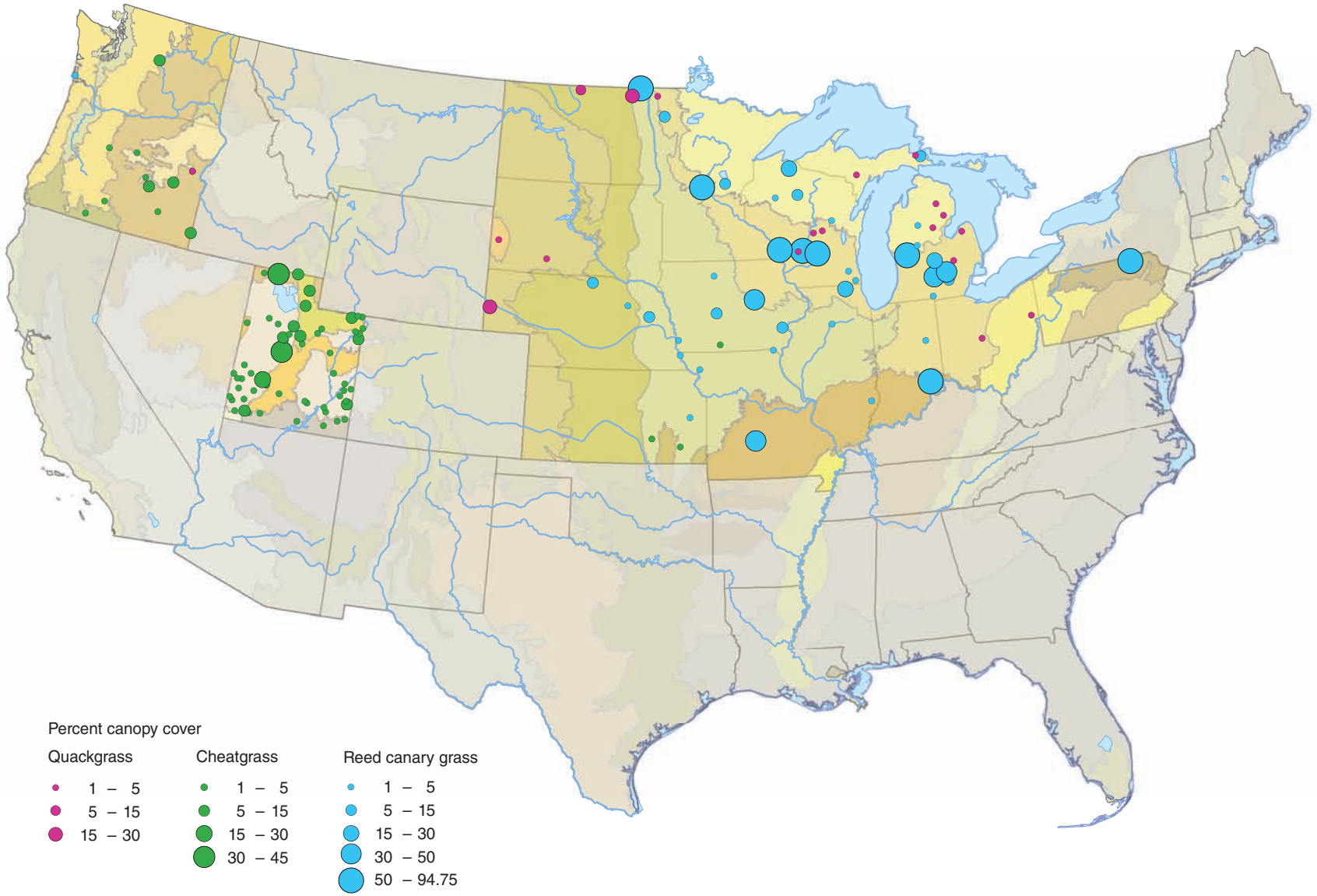

Figure 4.6—Broad scale distributions of three invasive grass species, with percent canopy cover. Plot locations are approximate. (Data source: U.S. Forest Service Forest Inventory and Analysis Program)

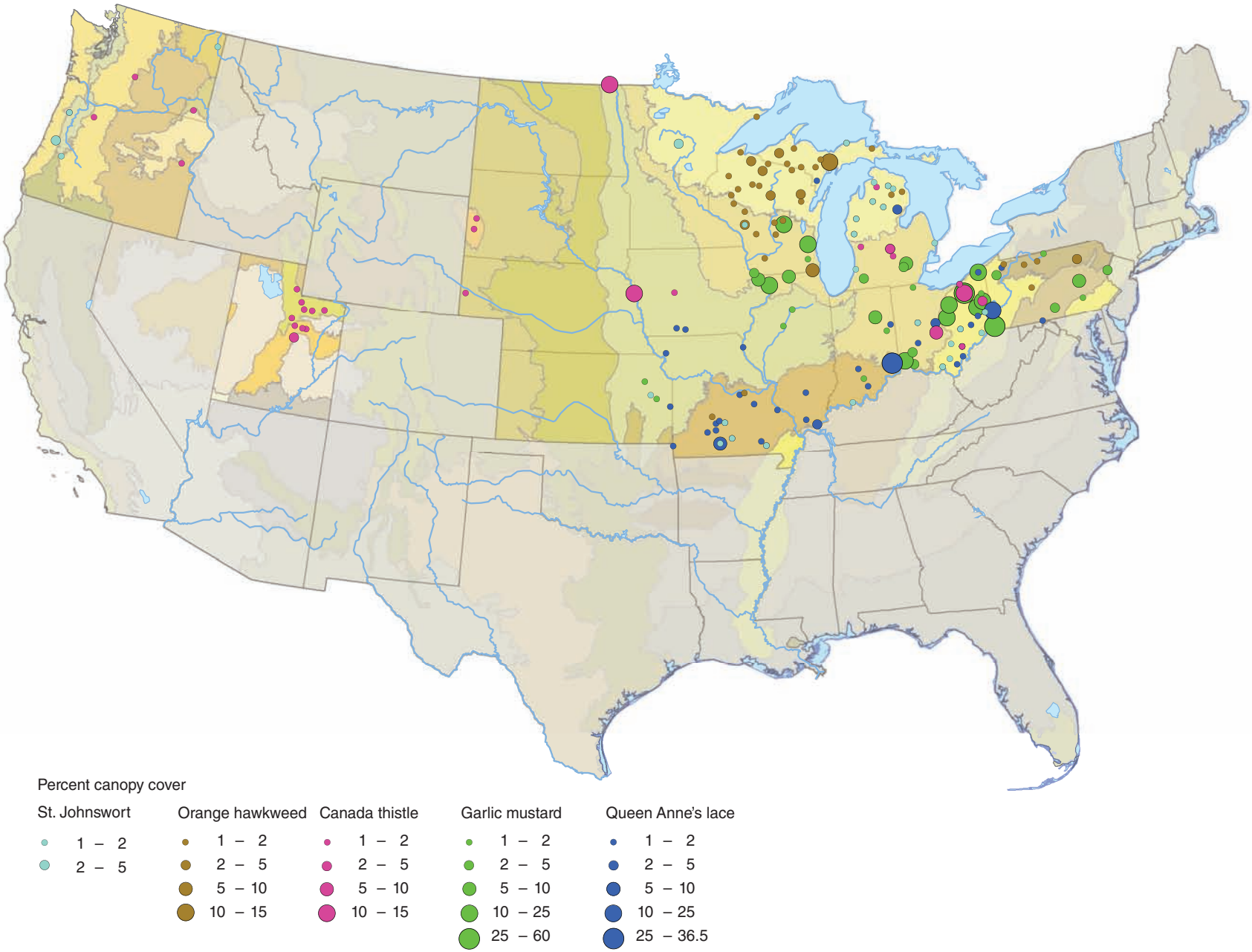

Figure 4.7—Broad scale distributions of five introduced herb species, with percent canopy cover. Plot locations are approximate. (Data source: U.S. Forest Service Forest Inventory and Analysis Program)

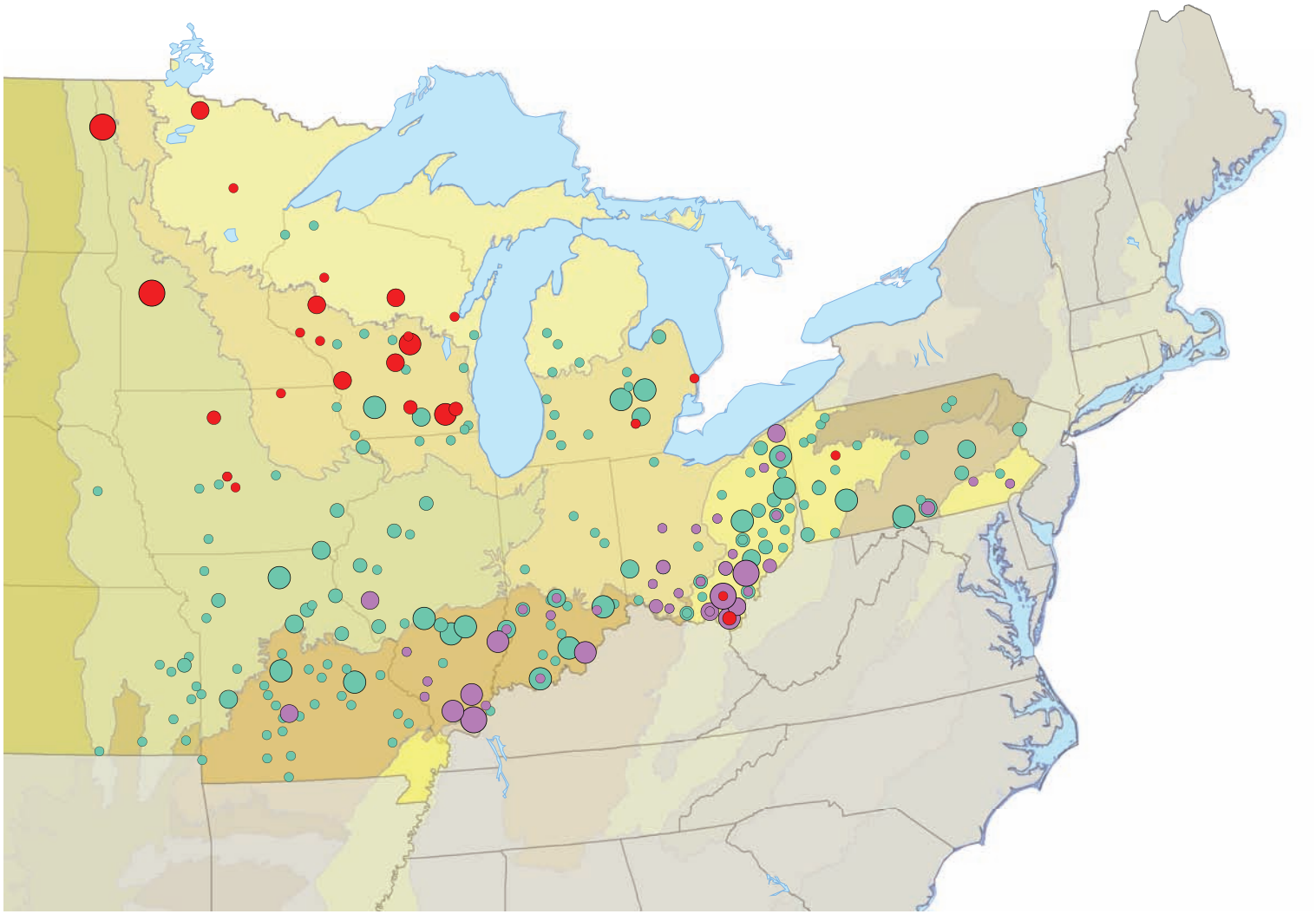

Figure 4.8—Broad scale distributions of three introduced, invasive shrub species, with percent canopy cover. Plot locations are approximate. (Data source: U.S. Forest Service Forest Inventory and Analysis Program)

Conclusions

Over the widely dispersed 915 plots, 2,975 unique plant codes were recorded, with 2,595 identified to species. The three most commonly recorded plant species are Virginia creeper, red maple (*Acer rubrum* L.), and poison ivy [*Toxicodendron radicans* (L.) Kuntze]. Across all 915 plots, only 7 percent of all individual plant observations recorded to species are introduced. Although 17 percent of all individual plant observations were not identified to species, examination of the genera identified suggest that the proportion of introduced species among the unidentified plants raises the estimate of percentage of introduced species by about 1 percent.

When assessing such an extensively dispersed plot network, many species are expected to be missed. Species composition data is more informative and less variable when grouped by ecological provinces and forest type to define communities. Community types defined with larger sample sizes are more thoroughly characterized. Some of the most commonly observed species in these communities are present in low abundance. Inventories that are limited to the most abundant species would have missed these species the majority of the time.

Number of species is a fundamental and easily interpretable measure of diversity. Species richness in itself is not an indicator of forest health; it is a technical characteristic of plant communities. However, when sample unit areas are standard, species richness trends over space and time can be assessed. Results from varied regions of the country quantify the intuitive impressions that forests in dry, hot climates support fewer species than cool, moist forests. An entire plot in the pinyon-juniper woodlands supports fewer species than found on a single subplot (one-fourth the area of a plot) in any of the other community types summarized.

Change or lack of change in species numbers does not reveal the entire story. Changes in species present on a site over time will reflect normal succession or changing conditions brought about by natural disturbance or management practices. Plant species composition data, along with information on site conditions

and disturbance history, allow researchers to hypothesize what forces are driving changes and predict future trends.

Of the 915 plots, 67 percent had at least 1 introduced plant species. The most commonly encountered introduced species is multiflora rose, with a constancy of 23.5 percent. The next most common introduced species recorded were cheatgrass and Japanese honeysuckle, with constancies of 8.42 and 5.57 percent, respectively. Each region of the country has plots with either no introduced species or a high percentage of introduced species numbers with high relative cover.

Species frequency and abundance together provide a clearer description of dominance across a sample unit than either alone. A species with a small growth habit may not contribute much in the way of canopy cover but may be widespread across a plot or population and have a high quadrat frequency. Conversely, a single large tree may provide the majority of canopy cover on a subplot but not be rooted in or overhanging any quadrats. Plants considered to be invasive often have higher frequencies than native species of the same growth habit.

Due to the extensive spatial scale of the P3 grid, the vegetation indicator cannot be expected to capture all species in any community type sampled. However, the indicator does allow for broadscale point-in-time estimates and will be a powerful tool for assessing change when plots are revisited. Because the vegetation indicator focuses on all vascular plants on the plot, all introduced species, not just a list of crisis species of the day, are monitored (Rudis and others 2006). Species that may become serious threats in the future—as well as today's species of concern that may become less important as invaders in the future—will be tracked through time.

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Appendix

Table A4.1—Top 5 percent most common species or genera for 12 community types

Community type	Scientific name	Common name	Origin	Constancy	Cover[a]
Laurentian Mixed Forest					
Northern white-cedar (n = 13)	*Thuja occidentalis*	Northern white cedar	N	100	28
	Viola	Violet	–	100	2
	Trientalis borealis	Starflower	N	100	1
	Abies balsamea	Balsam fir	N	92	13
	Coptis trifolia	Threeleaf goldthread	N	92	2
	Maianthemum canadense	Canada mayflower	N	92	1.2
	Cornus canadensis	Bunchberry dogwood	N	85	1.3
	Carex	Sedge	–	77	14
	Betula papyrifera	Paper birch	N	77	4.3
	Alnus incana ssp. *rugosa*	Speckled alder	N	69	25
	Fraxinus nigra	Black ash	N	69	8
	Rubus pubescens	Dwarf red blackberry	N	69	3.6
	Clintonia borealis	Bluebead	N	69	0.8
Sugar maple/beech/birch (n = 28)	*Maianthemum canadense*	Canada mayflower	N	93	1.7
	Acer saccharum	Sugar maple	N	89	45
	Abies balsamea	Balsam fir	N	86	8.7
	Trientalis borealis	Starflower	N	86	1.5
	Acer rubrum	Red maple	N	79	9
	Betula alleghaniensis	Yellow birch	N	68	8.3
	Carex	Sedge	–	68	6.8
	Lonicera canadensis	American fly honeysuckle	N	64	1.5
	Viola	Violet	–	64	1.45
	Dryopteris carthusiana	Spinulose woodfern	N	57	3.7
	Prunus serotina	Black cherry	N	57	2.4
	Pteridium aquilinum	Western brackenfern	N	46	17
	Tsuga canadensis	Eastern hemlock	N	46	6.5
	Populus tremuloides	Quaking aspen	N	46	3
	B. papyrifera	Paper birch	N	46	2.8
	Maianthemum racemosum ssp. *racemosum*	Feathery false lily of the valley	N	46	0.5
	Eurybia macrophylla	Bigleaf aster	N	43	10
	Picea glauca	White spruce	N	43	2.8
	Aralia nudicaulis	Wild sarsaparilla	N	43	1.5
	C. intumescens	Greater bladder sedge	N	43	1

continued

Table A4.1—Top 5 percent most common species or genera for 12 community types (continued)

Community type	Scientific name	Common name	Origin	Constancy	Cover[a]
Laurentian Mixed Forest (continued)					
Hard maple/basswood (n = 14)	*Tilia americana*	American basswood	N	100	11.6
	Ostrya virginiana	Hophornbeam	N	93	8.3
	Acer saccharum	Sugar maple	N	86	56
	Fraxinus americana	White ash	N	79	62
	Maianthemum canadense	Canada mayflower	N	79	1
	Arisaema triphyllum	Jack in the pulpit	N	79	0.6
	Aralia nudicaulis	Wild sarsaparilla	N	71	5.25
	Carex	Sedge	–	64	4.5
	Osmorhiza claytonii	Clayton's sweetroot	N	64	1.9
	Viola	Violet	–	64	1.2
	Eurybia macrophylla	Bigleaf aster	N	64	1
	Caulophyllum thalictroides	Blue cohosh	N	57	0.6
	F. nigra	Black ash	N	50	55
	Dryopteris carthusiana	Spinulose woodfern	N	50	2.25
	Athyrium filix-femina	Common ladyfern	N	50	1.75
	Trillium grandiflorum	White trillium	N	50	1.1
Aspen (n = 33)	*Maianthemum canadense*	Canada mayflower	N	97	1.5
	Populus tremuloides	Quaking aspen	N	94	28
	Eurybia macrophylla	Bigleaf aster	N	88	6.6
	Aralia nudicaulis	Wild sarsaparilla	N	76	4.6
	Trientalis borealis	Starflower	N	76	1
	Pteridium aquilinum	Western brackenfern	N	73	18.5
	Corylus cornuta	Beaked hazelnut	N	67	10.7
	Viola	Violet	–	67	1
	Clintonia borealis	Bluebead	N	64	2
	Abies balsamea	Balsam fir	N	61	8.3
	Solidago	Goldenrod	–	61	4
	Cornus canadensis	Bunchberry dogwood	N	61	3
	Rubus pubescens	Dwarf red blackberry	N	61	2
	Acer rubrum	Red maple	N	58	9
	Carex	Sedge	–	58	7.4
	Betula papyrifera	Paper birch	N	52	4.5
	R. idaeus ssp. *strigosus*	Grayleaf red raspberry	N	52	2
	Fragaria virginiana	Virginia strawberry	N	52	1.25

continued

Table A4.1—Top 5 percent most common species or genera for 12 community types (continued)

Community type	Scientific name	Common name	Origin	Constancy	Cover[a]
Laurentian Mixed Forest (continued)	*Prunus serotina*	Black cherry	N	45	6.7
Aspen (n = 33) (continued)	*Anemone quinquefolia*	Nightcaps	N	42	1
	P. virginiana	Chokecherry	N	39	1.8
	Thalictrum dioicum	Early meadow-rue	N	36	3
Eastern Broadleaf Forest					
White oak/red oak/hickory (n = 10)	*Quercus velutina*	Black oak	N	100	9
	Prunus serotina	Black cherry	N	100	7
	Parthenocissus quinquefolia	Virginia creeper	N	100	5.9
	Toxicodendron radicans	Eastern poison ivy	N	100	5.5
	Viola	Violet	–	100	1.65
	Rosa multiflora	Multiflora rose	I	90	8.3
	Q. alba	White oak	N	90	6.9
	Cornus florida	Flowering dogwood	N	90	6.75
	Sassafras albidum	Sassafras	N	90	6
	Fraxinus americana	White ash	N	90	4.3
	Acer rubrum	Red maple	N	80	18.75
	Ulmus americana	American elm	N	80	5.5
	Polystichum acrostichoides	Christmas fern	N	80	4.4
	Rubus occidentalis	Black raspberry	N	80	1.3
Sugar maple/beech/birch (n = 11)	*Acer rubrum*	Red maple	N	82	14.75
	Prunus serotina	Black cherry	N	82	8.8
	A. saccharum	Sugar maple	N	73	34.3
	Fagus grandifolia	American beech	N	73	21.2
	Fraxinus americana	White ash	N	73	7.4
	Parthenocissus quinquefolia	Virginia creeper	N	73	2.75
	Toxicodendron radicans	Eastern poison ivy	N	73	1.4
	Rosa multiflora	Multiflora rose	I	64	8.7
	Lindera benzoin	Northern spicebush	N	64	6.7
	Ulmus americana	American elm	N	64	5.5
	Carya cordiformis	Bitternut hickory	N	64	3.2
	Carex	Sedge	–	64	1.9
	Polystichum acrostichoides	Christmas fern	N	64	1.7
	Smilax rotundifolia	Roundleaf greenbrier	N	64	1
	Viola	Violet	–	64	1

continued

Table A4.1—Top 5 percent most common species or genera for 12 community types (continued)

Community type	Scientific name	Common name	Origin	Constancy	Cover[a]
Midwest Broadleaf Forest					
White oak/red oak/hickory (n = 10)	*Parthenocissus quinquefolia*	Virginia creeper	N	100	4.2
	Prunus serotina	Black cherry	N	90	10.87
	Quercus alba	White oak	N	90	8
	Ulmus americana	American elm	N	70	18
	Q. rubra	Northern red oak	N	70	13.1
	Populus tremuloides	Quaking aspen	N	70	4.7
	Ribes cynosbati	Eastern prickly gooseberry	N	70	4.6
	Carya ovata	Shagbark hickory	N	60	9.8
	C. cordiformis	Bitternut hickory	N	60	6.5
	Betula papyrifera	Paper birch	N	50	8.2
	Corylus americana	American hazelnut	N	50	3.1
	Rubus allegheniensis	Allegheny blackberry	N	50	2
	Circaea lutetiana	Broadleaf enchanter's nightshade	N	50	1.5
	Toxicodendron radicans	Eastern poison ivy	N	50	1
Central Interior Broadleaf Forest					
White oak/red oak/hickory (n = 42)	*Parthenocissus quinquefolia*	Virginia creeper	N	100	9.9
	Quercus alba	White oak	N	95	25.5
	Q. velutina	Black oak	N	81	17.1
	Sassafras albidum	Sassafras	N	81	8.7
	Toxicodendron radicans	Eastern poison ivy	N	71	8.7
	Prunus serotina	Black cherry	N	71	2
	Cornus florida	Flowering dogwood	N	67	17
	Symphoricarpos orbiculatus	Coralberry	N	64	3.5
	Desmodium nudiflorum	Nakedflower ticktrefoil	N	62	6.9
	Q. rubra	Northern red oak	N	60	7
	Vitis aestivalis	Summer grape	N	60	3
	Rhus aromatica	Fragrant sumac	N	52	2.7
	Carex	Sedge	–	50	2.9
	Q. stellata	Post oak	N	48	15.3
	Juniperus virginiana	Eastern redcedar	N	48	4
	Viola	Violet	–	48	1.4
	Acer rubrum	Red maple	N	45	11.25
	Nyssa sylvatica	Blackgum	N	43	8
	Vaccinium pallidum	Blue Ridge blueberry	N	43	5

continued

Table A4.1—Top 5 percent most common species or genera for 12 community types (continued)

Community type	Scientific name	Common name	Origin	Constancy	Cover[a]
Central Interior Broadleaf Forest (continued)	*Potentilla simplex*	Common cinquefoil	N	43	0.5
White oak/red oak/hickory (n = 42) (cont)	*Ulmus rubra*	Slippery elm	N	40	9.26
	Carya alba	Mockernut hickory	N	40	7.8
	Rubus	Blackberry	–	40	1.6
	Galium circaezans	Licorice bedstraw	N	40	1
White oak (n=10)	*Quercus alba*	White oak	N	100	39.25
	Sassafras albidum	Sassafras	N	100	4.5
	Parthenocissus quinquefolia	Virginia creeper	N	100	2.6
	Cornus florida	Flowering dogwood	N	90	9.5
	Q. velutina	Black oak	N	80	15.8
	Prunus serotina	Black cherry	N	80	1.4
	Antennaria plantaginifolia	Woman's tobacco	N	70	0.5
	Juniperus virginiana	Eastern redcedar	N	70	0.5
	Acer rubrum	Red maple	N	60	8.9
	Vaccinium pallidum	Blue Ridge blueberry	N	60	4.5
	Toxicodendron radicans	Eastern poison ivy	N	60	4.2
	Carex	Sedge	–	60	3.4
	Carya texana	Black hickory	N	60	3.29
	Vitis	Grape	–	60	1.4
	Rhus aromatica	Fragrant sumac	N	60	0.24
	C. cordiformis	Bitternut hickory	N	50	1.3
	Lespedeza virginica	Slender lespedeza	N	50	0.5
Colorado Plateau Semi-Desert	*Juniperus osteosperma*	Utah juniper	N	100	10.8
Pinyon/juniper woodland (n = 12)	*Pinus edulis*	Twoneedle pinyon	N	100	7.4
	Ephedra viridis	Mormon tea	N	75	1.3
	Gutierrezia sarothrae	Broom snakeweed	N	75	0.7
	Artemisia tridentata	Big sagebrush	N	58	1.9
	Amelanchier utahensis	Utah serviceberry	N	50	1.8
	Cercocarpus montanus	Alderleaf mountain mahogany	N	42	9.35
	Shepherdia rotundifolia	Roundleaf buffaloberry	N	42	4.5
	Opuntia polyacantha	Plains pricklypear	N	42	1.35
	Poa secunda	Sandberg bluegrass	N	42	1.35
	Achnatherum hymenoides	Indian ricegrass	N	42	0.6
	Penstemon	Beardtongue	–	42	0.4

continued

Table A4.1—Top 5 percent most common species or genera for 12 community types (continued)

Community type	Scientific name	Common name	Origin	Constancy	Cover[a]
Interior Semi-Desert and Desert					
Pinyon/juniper woodland (n = 34)	*Juniperus osteosperma*	Utah juniper	N	100	8.4
	Artemisia tridentata	Big sagebrush	N	71	2.6
	Opuntia polyacantha	Plains pricklypear	N	71	0.84
	Pinus edulis	Twoneedle pinyon	N	68	6.4
	Gutierrezia sarothrae	Broom snakeweed	N	68	1.1
	Ephedra viridis	Mormon tea	N	65	1.2
	Bromus tectorum	Cheatgrass	I	62	1.3
	Achnatherum hymenoides	Indian ricegrass	N	62	0.8
	Poa secunda	Sandberg bluegrass	N	38	1.4
	Pinus monophylla	Singleleaf pinyon	N	35	9
	Petradoria pumila	Grass-leaved rock goldenrod	N	32	0.9
	Cryptantha	Cryptantha	–	29	0.4
	Elymus elymoides	Squirreltail	N	26	0.72
	Purshia tridentata	Antelope bitterbrush	N	24	1.1
	Penstemon	Beardtongue	–	24	0.46
Nevada-Utah Mountain Semi-Desert Coniferous Forest					
Pinyon/juniper woodland (n = 13)	*Juniperus osteosperma*	Utah juniper	N	100	9.4
	Pinus edulis	Twoneedle pinyon	N	92	13.8
	Achnatherum hymenoides	Indian ricegrass	N	85	0.7
	Cercocarpus montanus	Alderleaf mountain mahogany	N	54	3.9
	Gutierrezia sarothrae	Broom snakeweed	N	54	0.9
	Poa secunda	Sandberg bluegrass	N	54	0.9
	Phlox austromontana	Mountain phlox	N	54	0.8
	Opuntia polyacantha	Plains pricklypear	N	46	1
	Artemisia tridentata	Big sagebrush	N	38	2.25
	Purshia tridentata	Antelope bitterbrush	N	38	1.6
	Ephedra viridis	Mormon tea	N	38	1.35
	Petradoria pumila	Grass-leaved rock goldenrod	N	38	1.1
	Cryptantha	Cryptantha	–	38	0.6

– = designations are not included for taxa identified as genera (blank cells); some species within genera may be either native or introduced; N = native species; I = introduced species.

[a] Cover is average cover over plots where species occurs. To determine average cover over entire community, multiply cover by (constancy/100 percent).