Fruit Production in Mature and Recently Regenerated Forests of the Appalachians

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ABSTRACT Fleshy fruit is a key food resource for both game and nongame wildlife, and it may be especially important for migratory birds during fall and for resident birds and mammals during winter. Land managers need to know how land uses affect the quantities and species of fruit produced in different forest types and how fruit production varies seasonally and as young stands mature. During June 1999–April 2004, we quantified fleshy fruit abundance monthly in 31 0.1-ha plots in 2 silvicultural treatments: 1) young 2-age stands with low basal area retention, created by shelterwood-with-reserves regeneration cuts (R; harvested 1998–1999); and 2) uncut mature closed-canopy stands (M) in 2 common southern Appalachian, USA, forest types (upland hardwood and cove hardwood [CH] forests). Over the 5-year study period, total dry pulp biomass production was low and relatively constant in both M forest types ($\bar{x} = 0.5$–2.0 kg/ha). In contrast, fruit production increased each year in R, and it was 5.0 to 19.6 times greater in R than in M stands beginning 3–5 years postharvest. Two disturbance-associated species, pokeweed (*Phytolacca americana*) and blackberry (*Rubus allegheniensis*), produced a large proportion of fruit in R but showed different patterns of establishment and decline. Huckleberry (*Gaylussacia ursina*) recovered rapidly after harvest and was a major producer in both silvicultural treatments and forest types each year. Several herbaceous species that are not associated with disturbance produced more fruit in CHR. Few species produced more fruit in M than in R. Fruit production by most tree species was similar between R and M, due to fruiting by stump sprouts in R within 1–3 years postharvest. Fruit availability was highest during summer and early fall. American holly (*Ilex opaca*), sumac (*Rhus* spp.), and greenbriar (*Smilax* spp.) retained fruit during winter months but were patchy in distribution. In the southern Appalachians, young recently regenerated stands provide abundant fruit compared to mature forest stands and represent an important source of food for wildlife for several years after harvest. Fruit availability differs temporally and spatially because of differences in species composition, fruiting phenology, and the dynamic process of colonization and recovery in recently harvested stands. Land managers could enhance fruit availability for many game and nongame species by creating or maintaining young stands within forests. (JOURNAL OF WILDLIFE MANAGEMENT 71(2):321–335; 2007)

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Fleshy fruit is a key food resource for both game and nongame wildlife (Martin et al. 1951). Also termed soft mast, fleshy fruit is available most of the year, and the vast majority of birds and mammals consume it at least occasionally (Martin et al. 1951, Willson 1986). Because fruit is often abundant, easily captured, and high in energy, it can be a critical resource in the fall for migratory birds (Willson 1986) and for resident birds in winter (McCarty et al. 2002, Borgmann et al. 2004, Kwit et al. 2004) when arthropods and other forest food sources are scarce (Greenberg and Forrest 2003, Whitehead 2003). Fruit consumption has also been linked to mammalian survival and reproductive success (Rogers 1976, Eiler et al. 1989).

Despite the importance of fruits to wildlife, relatively little is known about spatial or temporal patterns of fruit production in the southeastern United States, especially in the southern Appalachians. Several studies have shown that fruit production is much greater in forest openings caused by natural (e.g., Blake and Hoppes 1986) or silvicultural (e.g., Perry et al. 1999) disturbance than in closed-canopy forest. Increased fruit production may continue for several years after disturbance because of higher light conditions and reduced competition. However, most studies of fruit production are of only limited utility to land managers because they include only a few species, small sample sizes, single seasons, few forest types or age classes, or are too short term to provide an accurate picture of how fruit availability changes spatially and temporally.

Because fruit is important to wildlife, land managers need information on both short- and long-term changes in fruit production in response to common silvicultural practices such as regeneration (or reproduction) cutting. Specifically, managers need to know how forest management activities affect the quantities and species of fruit produced in different forest types and how fruit production varies seasonally and as young stands mature.

We quantified fruit abundance monthly in 2 silvicultural treatments: 1) young 2-age stands created by recent shelterwood-with-reserves regeneration cutting (R), and 2) uncut, mature closed-canopy stands (M) in 2 common southern Appalachian forest types, upland hardwood (UH) and cove hardwood (CH) forests. Our objective was to examine spatial and temporal variation in fruit production and composition between the 2 silvicultural treatments and 2 forest types during the first 5 years after harvest (Jun 1999–Apr 2004).

STUDY AREA

Our study plots were located throughout the Pisgah and Grandfather range districts of the Pisgah National Forest in

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Buncombe, Haywood, McDowell, and Transylvania counties, North Carolina, USA. Study plot elevations ranged from about 500 m to 1,250 m. Average annual rainfall in the region ranged from approximately 135 cm to 229 cm and was evenly distributed throughout the year. Soils were predominantly Dystrochrepts and Hapludults (Pittillo et al. 1998). Mature forest ranged from 80 years to 100 years in age. Cove hardwood forests were dominated by yellow poplar (*Liriodendron tulipifera*) and northern red oak (*Quercus rubra*), and they also included magnolia (*Magnolia* spp.), white ash (*Fraxinus americanus*), beech (*Fagus grandifolia*), hemlock (*Tsuga canadensis*), and silverbell (*Halesia carolina*). Upland hardwood forests were dominated by scarlet oak (*Q. coccinea*), chestnut oak (*Q. montana*), and black oak (*Q. velutina*). Blackgum (*Nyssa sylvatica*) and sourwood (*Oxydendrum arboreum*) were common midstory trees. Red maple (*Acer rubrum*), hickories (*Carya* spp.), flowering dogwood (*Cornus florida*), and white oak (*Q. alba*) were common in both forest types (Pittillo et al. 1998).

METHODS

We randomly established one 20 × 50-m (0.1-ha) plot in each of 31 stands of 2 forest types (CH and UH) and 2 silvicultural treatments (R and M) in a 2 × 2 factorial design. We selected R study sites based on availability of stands that met our age, forest type, and silvicultural treatment criteria and were ≤2 hours' drive from our office. We attempted to locate M study sites near R sites for logistical reasons and to minimize variability between young and mature stands attributable primarily to location or topography. We had 6–9 stands per forest type–silvicultural treatment combination: CHR, CHM, UHR, and UHM (the first 2 letters denote the forest type and the third letter denotes silvicultural treatment [age structure]). Young stands resulted from harvests conducted during 1998–1999 using a shelterwood-with-reserves regeneration method. This method entails retention of about 15–20% of the original basal area of mature trees, typically scattered oaks and hickories, to help ensure initiation and development of tree regeneration while retaining a heterogeneous stand structure and hard mast production (acorns and hickory nuts) for wildlife (T. Oprean, Pisgah National Forest, personal communication). Forest types (cove [type 56] or upland hardwood [type 53]) were determined by the United States Forest Service (USFS; *Southern Region Silvicultural Examination and Prescription Field Book*, for Continuous Inventory of Stand Conditions version 4.02, unpublished report) based on tree species composition at the stand level. Young regenerated stand sizes ranged from 3.2 ha to 10.5 ha ($\bar{x} = 7.0$ ha) and were generally the same age as mature study stands when they were harvested (80–100 yr old). All regenerated stands were site-prepared within a year of harvesting. This entailed cutting all stems 2.5–20 cm diameter at breast height (Pisgah district) or 5–25 cm diameter at breast height (Grandfather district) and ≥1.4 m tall. The cut surface of the stumps of red maple, flowering dogwood, silverbell, sourwood, yellow poplar, sassafras (*Sassafras albidum*), black locust (*Robinia pseudoacacia*), Fraser magnolia (*M. fraseri*), blackgum, rhododendron (*Rhododendron* spp.), and mountain laurel (*Kalmia latifolia*) were treated with herbicide (Garlon 3A, 50–50 mix; Dow AgroSciences, Indianapolis, IN).

Beginning in June 1999, we counted all fruit within plots monthly for 5 years. We categorized fruits as ripe, unripe, or damaged. We counted fruits of trees, nonclonal shrubs, and vines in the whole plot; we sampled fruits of herbaceous species and clonal shrubs in a 4 × 50-m subplot that extended along the 50-m centerline of each plot. If >10 individuals of a species were fruiting within a plot, we sampled a random subset ($n = 10$ plants) and applied their average number of fruits to the other fruiting individuals within that plot. Counting methods varied among species. For species with clusters of fruit (e.g., flowering dogwood, sumac [*Rhus* spp.], and fox grape [*Vitis aestivalis*]), we counted clusters (by large, medium, and small size class) and multiplied the number of clusters by the mean number of fruits per cluster, based on counts of fruits on several clusters for that month. We counted fruits of canopy trees by estimating the fruits on portions of the crown that were visible when lying on the ground and expanding that number to the estimated crown size. Because visibility was limited for some individuals (e.g., large black cherry trees [*Prunus serotina*]), our estimates for those species were likely conservative. Fruit counts of some species were most reliable when fruits ripened (e.g., blackgum and flowering dogwood) or leaves fell off in the fall (e.g., fox grape); we used these counts to adjust earlier counts as needed.

We report fruit production in units of dry edible biomass (g/ha) to standardize across species for differences in water, seed, and pulp mass, and because fruit pulp is the portion of the fruit that is digested by the majority of fruit-eating vertebrates. To calculate estimates of biomass, we collected 10 ripe fruits from each of approximately 10 off-plot locations for each species. We weighed fruits of each sample, dried them at 60° C to constant mass, and weighed them again with and without seeds. We calculated fruit production for each species by multiplying the average dry pulp weight of one fruit (based on $n = 10$ samples of 10 fruits each; Table 1) by the number of fruits counted within a plot and extrapolating to grams per hectare.

We elected to separate the effects of silvicultural treatment (2 treatments) and forest type (2 types) in our analyses, rather than lump them as 4 treatment combinations, to better tease apart the relative influence of each on fruit production. We used the interaction term between those variables to assess the degree to which effects of silvicultural treatment and forest type were unrelated to each other. We used 2-way, repeated-measures analysis of variance (ANOVA) for between-subject effects ($RMA_{between}$) to test for 1) differences in dry pulp biomass (total, monthly, and by plant form and species) between forest types and silvicultural treatments or 2) an interaction between those factors; for these analyses we did not include time as a variable of interest. We also used 2-way ANOVA on repeated

Table 1. Ripening patterns[a] of fleshy fruit-producing plant species in young 2-age stands and mature closed-canopy stands in upland hardwood and cove hardwood forest types of the southern Appalachian Mountains, USA, June 1999–April 2004. We also give dry pulp weight ($\bar{x}$ and SE; mg) per fruit and number of samples processed.

	Month												Dry pulp weight (mg)		
Species[b]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	$\bar{x}$	SE	n[c]
Serviceberry					g	g,**R**,d	g,r,d	g,d	d	d			85.5[d]		0
Jack-in-the-pulpit					g	g,d	g,d	g,r,d	g,**R**,d	r,d	r,d	r,d	25.6	5.3	10
Devil's walkingstick								g	g,**R**,d				3.9	0.5	10
Blue cohosh	d	d				g,r,d	g,r,d	g,**R**,d	g,r,d	r,d	r,d	d	31.1	1.4	10
Speckled wood-lily	d	d	d			g,r,d	g,r,d	g,r,d	g,**R**,d	g,r,d	r,d	d	9.0	1.5	3
Flowering dogwood	d	d	d	d	g	g,r,d	g,r,d	g,r,d	g,**R**,d	g,r,d	r,d	r,d	46.4	3.4	10
Yellow mandarin					g	g,r,d	g,r,d	g,r,d	g,**R**,d	r,d	d		25.4	1.1	10
Strawberry bush					g	g	g	g,r,d	g,**R**	**R**,d	r		6.7	0.9	12
Huckleberry[e]	d				g,r,d	g,r,d	g,**R**,d	g,**R**,d	g,rd	g,r,d	d	d	33.1	2.5	13
Deciduous holly						g	g,r,d	g,r,d	g,**R**,d	r,d	r,d	d	26.7	1.9	6
American holly	g,r,d	g,r,d	g,r,d	g,r,d	g,r,d	g,r,d	g,r,d	g,r,d	g,r,d	g,**R**,d	g,**R**,d	g,**R**,d	66.9	6.0	10
Spicebush	r,d	d	d	d	d	g,d	g,d	g,R,d	g,**R**,d	g,r,d	r,d	r,d	50.2	2.1	10
Fraser magnolia	d	d				g	g	g,**R**,d	g,r,d	d	d	d	210.4	16.8	7
Indian cucumber-root						g,r,d	g,r,d	g,**R**,d	g,r,d	r,d	d	d	8.5	1.5	11
Partridgeberry						g	g	g	**R**	r			10.0	0.8	12
Blackgum	d	d	d	d	g	g,r,d	g,r,d	g,r,d	g,**R**,d	g,**R**,d	r,d	r,d	95.9	8.0	10
Ginseng						g	g,r	g,**R**	r,d				6.9	1.3	8
Pokeweed	d	d				g	g,r,d	g,**R**,d	g,**R**,d	g,**R**,d	g,r,d	r,d	19.1	1.6	10
Solomon's seal[f]	d	d	d	d	g	g,r,d	g,r,d	g,**R**,d	g,r,d	r,d	d	d	57.3	7.9	10
Fire cherry						g	**R**,d						25.4	0.6	10
Black cherry	d	d			g	g,r,d	g,**R**,d	g,**R**	g,**R**	g,r,d	d	d	85.5	14.9	10
Buffalo nut						g,d	g,d	g	g				689.1	122.1	10
Winged sumac	d	d	d	d	d	d	r,d	r,d	**R**,d	**R**	d	d	2.6	0.4	9
Smooth sumac	d	d	d	d			g,r	g,r	**R**	**R**	d	d	8.6	0.7	10
Blackberry						g,r,d	g,**R**,d	g,r,d	g,r,d	d	d		49.7	4.7	9
Raspberry[g]						g	g,r,d	g,**R**,d	g,r,d	r,d	d		63.1	5.9	10
Sassafras					g	g,r,d	g,r,d	g,**R**	g,r,d	r			77.3	6.2	8
Horse sugar						g	g	g	g,**R**,d	g,r,d	d		26.0	14.0	2
False Solomon's seal	d	d	d	d		g,d	g,r,d	g,r,d	g,**R**,d	r,d	r,d	r,d	19.0	2.2	10
Biltmore greenbriar	r,d	r,d	d	d		g	g	g,r	g,**R**,d	**R**,d	r,d	r,d	42.5	9.0	10
Glaucous greenbriar	r,d	r,d	d	d	d	g,d	g	g,r,d	g,r,d	g,**R**,d	r,d	r,d	48.3	3.9	8
Herbaceous greenbriar						g	g	g,r,d	**R**,d	d	d		61.0		1
Round-leafed greenbriar	r,d	r,d	r,d	r,d	g,r,d	g,r,d	g,r,d	g,r,d	g,r,d	g,**R**,d	r,d	r,d	22.9	1.5	10
Trillium[h]						g,**R**	g,**R**	r					33.0[i]		0
Highbush blueberry					g	g,**R**,d	g,**R**,d	g,r,d	g,r,d	g,r,d	d		36.0	4.0	10
Deerberry						g,d	g,**R**,d	g,r,d	g,r,d	g,r,d			68.5	6.4	10
Lowbush blueberry					g	g,r,d	g,**R**,d	gr,d	g,r,d	r,d	d		17.9	2.0	10
Maple-leaf viburnum	d	d	d	d	d	g,d	g,d	g,r,d	g,**R**,d	g,r,d	r,d	d	16.4	1.7	10
Fox grape	d	d	d	d	d	g,d	g,r,d	g,**R**,d	g,**R**,d	g,**R**,d	r,d	r,d	69.5	11.6	10

[a] g = green; r = ripe; d = damaged; **R** indicates peak ripeness.
[b] See Appendix for scientific names.
[c] Each sample (usually 10 samples) contained 10 fruits in most cases.
[d] We did not process any *Amelanchier arborea* samples; we used mean wt for *Prunus serotina* in analyses.
[e] Includes *Gaylussacia ursina* (predominantly) and *G. baccata*. Dry pulp wt presented and used in data analyses is for *G. ursina*.
[f] Includes *Polygonatum biflorum* and *P. pubescens*. The dry pulp wt presented and used in data analyses is for both (no distinction made for weighing).
[g] Includes *Rubus odoratus* (predominantly) and *R. phoenicolasius*. The dry pulp wt presented and used in data analyses is for *R. odoratus*.
[h] Includes *Trillium vaseyi*; possibly also *T. catesbei* and *T. cernuum*, as they occurred in plots but may have been recorded (lumped) as *Trillium* spp. in data.
[i] We did not process any *Trillium* samples. We used mean dry pulp wt of 33 mg/fruit as calculated from data in Lapointe (1998) for *T. erectum*.

measures for within-subject effects (RMA_{within}) to test for temporal differences in dry pulp biomass over the 5 years and for silvicultural treatment × year, forest type × year, and silvicultural treatment × forest type × year interactions. We used Greenhouse–Geisser Epsilon adjusted probability values, which provide the greatest penalty for the lack of sphericity (the assumption that differences between forest types or silvicultural treatments are identical through time) in our data. We also assessed each year separately using 2-way ANOVA to determine whether dry pulp biomass differed between forest types, silvicultural treatments, or as an interaction between those factors. We performed post hoc tests using Tukey's Studentized Range tests for pairwise comparisons. For all ANOVAs we used the Type III sum of squares and associated mean squares as the error term for main effects. We natural log–transformed our data to reduce heteroscedasticity. We considered $P < 0.10$ as statistically significant due to the patchy distribution of fruit-producing plants and high variability in fruit production among our stands. For each species, we used the month of highest average fruit production (including ripe, unripe, and damaged fruit) for interannual comparisons. We calculated

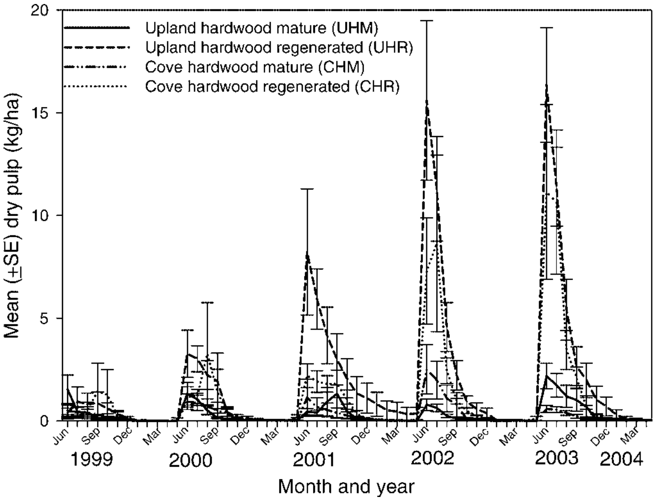

Figure 1. Mean (±SE) monthly total dry pulp biomass (kg/ha) of soft mast in young 2-age stands created by shelterwood-with-reserves regeneration cuts (harvested 1998–1999) and uncut mature closed-canopy stands in upland hardwood and cove hardwood forest types of the southern Appalachian Mountains, USA, June 1999–April 2004.

total annual biomass by summing the month of maximum production for each species. In some cases, such as when species were difficult to distinguish in the field (e.g., Solomon's seal [*Polygonatum pubescens* and *P. biflorum*]), we combined species within genera for analyses.

RESULTS

During our 5-year study period, 42 species produced fruit (Table 1). Several other fruit-producing species, including poison ivy (*Rhus radicans*), Virginia creeper (*Parthenocissus quinquefolia*), baneberry (*Actaea pachypoda*), wild sarsaparilla (*Aralia nudicaulis*), barberry (*Berberis thunbergii*), alternate-leaved dogwood (*Cornus alternifolia*), persimmon (*Diospyros virginiana*), cucumber tree (*M. acuminata*), and may-apple (*Podophyllum peltatum*), occurred in some stands but never fruited.

Overall, total dry pulp biomass was significantly greater in R than in M (RMA$_{between}$ $P_{silv} = 0.0004$) and marginally greater in the UH than in the CH forest type ($P_{for} = 0.097$), with no silvicultural treatment × forest type interaction ($P = 0.857$; Fig. 1, Appendix). Within-year ANOVAs indicated that total dry pulp production was greater in UH than in CH forest (controlled for silvicultural treatment) but only during 2000 ($P_{for} = 0.053$), 2001 ($P_{for} = 0.036$), and 2003 ($P_{for} = 0.052$). This corresponded with years of high fruit production by blackgum, an upland hardwood species.

Fruit production was highly dynamic in R over the 5-year study period (RMA$_{within}$ $P_{yr \times silv} = 0.013$; Fig. 1, Appendix). During 1999 and 2000, average fruit production was low in R (range: 1.5 ± 0.8 kg dry pulp/ha to 4.9 ± 1.5 kg/ha) and did not differ between the 2 silvicultural treatments either year (within-year ANOVA $P_{silv} \geq 0.220$). During the third year postharvest (2002), fruit production increased dramatically in R of both forest types (within-year ANOVA $P_{silv} < 0.0001$ during 2001–2003). Dry pulp biomass production in UHR increased more than 10-fold, from a low of 1.5 ± 0.8 kg/ha in 1999 to a high of 16.0 ± 2.8 kg/ha in 2003 (Figs. 1, 2; Appendix). In contrast, annual average (±SE) dry pulp biomass in M (both forest types) was relatively low and constant, ranging from 0.5 ± 0.3 kg/ha to 2.0 ± 0.9 kg/ha during 1999–2003 (Figs. 1, 2; Appendix).

Most species produced fruit in only a few plots. However, some species that exhibited spatially patchy fruit production nonetheless contributed substantially to total fruit production, at least within a given forest type or silvicultural treatment. Others, such as American holly (*Ilex opaca*), greenbriar (*Smilax* spp.), and sumac, were additionally important because they retained fruit during winter. A few species dominated fruit production, but their relative importance differed among forest types, silvicultural treatments, and years (Fig. 2; Appendix). Fruit production in UHM was dominated by huckleberry (*Gaylussacia ursina*), blackgum, and flowering dogwood, and in CHM it was dominated by spicebush (*Lindera benzoin*), flowering dogwood, huckleberry, and fox grape.

In young regenerated stands, the majority of fruit was produced by species that proliferate in recently disturbed areas, such as pokeweed (*Phytolacca americana*) and blackberry (*Rubus allegheniensis*). Neither of these species produced any fruit in either M forest type. Overall, fruit production by these species was similar in young regenerated stands of both forest types (RMA$_{between}$ pokeweed $P_{for} = 0.331$, RMA$_{between}$ blackberry $P_{for} = 0.958$); within-year ANOVAs indicated that pokeweed production was greater in CHR than UHR during 2002 ($P_{for} = 0.091$; Appendix). In R, both pokeweed (RMA$_{within}$ $P_{yr \times silv} = 0.001$) and blackberry (RMA$_{within}$ $P_{yr \times silv} < 0.0001$) showed different patterns of fruit production among the 5 years studied. Pokeweed produced fruit during the first year postharvest, peaked during the second and third years postharvest, and reached its lowest levels in 2003 (Fig. 2; Appendix). In contrast, blackberry did not produce substantial amounts of fruit until the third year postharvest (2001) and reached peak production during 2002 and 2003 (Fig. 2; Appendix).

The impact of disturbance by harvesting on fruit production was less apparent for other important fruit-producing species. Overall, huckleberry (predominantly *G. ursina*) fruit production did not differ between silvicultural treatments or forest types, nor was there a silvicultural treatment × forest type interaction (RMA$_{between}$ $P \geq 0.113$; Appendix). Within-year ANOVAs further indicated that huckleberry fruit production was similar in M and in R during all years (P_{silv} range: 0.379–0.861). However, relatively low *P*-values for forest type effects in both RMA$_{between}$ ($P_{for} = 0.113$) and within-year ANOVAs (P_{for} range: 0.088–0.142), with a significant *P*-value during 2002, suggests that huckleberry fruit production tended to be greater in the UH forest type (regardless of silvicultural treatment) and that with greater replication we would likely have detected significant differences between UH and CH forest types. RMA$_{within}$ (with yr as a variable) detected a significant effect of time ($P_{yr} = 0.012$) and a significant time × silvicultural treatment interaction ($P_{yr \times silv} = 0.067$), indicat-

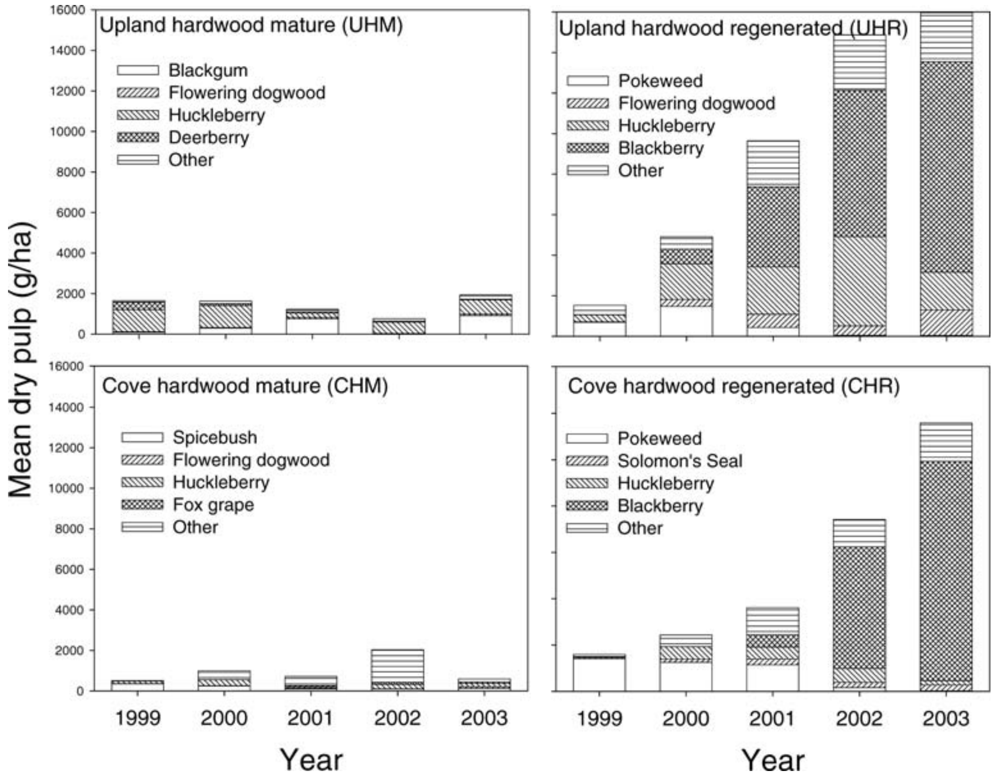

Figure 2. Mean total dry pulp biomass (g/ha) of major soft mast–producing species in young 2-age stands created by shelterwood-with-reserves regeneration cuts (harvested 1998–1999) and uncut mature closed-canopy stands in upland hardwood and cove hardwood forest types of the southern Appalachian Mountains, USA, 1999–2003.

ing that huckleberry fruit production varied among years and that production patterns differed between M and R.

Several species that are not specifically associated with disturbance nonetheless produced more fruit in young recently regenerated stands, most commonly in CHR. Maple-leaf viburnum (*Viburnum acerifolium*) produced more fruit in CHR than in other silvicultural treatments or forest types (RMA$_{between}$ $P_{silv} = 0.011$, $P_{for} = 0.0575$, $P_{silv\times for} = 0.062$). Fruit production increased over time (RMA$_{within}$ $P_{yr\times silv\times for} = 0.050$); production was greater in CHR the third year postharvest and remained high thereafter ($P \leq 0.009$; Appendix). Among herbaceous species, jack-in-the pulpit (*Arisaema triphyllum*; RMA$_{between}$ $P_{silv} = 0.002$, $P_{for} = 0.002$, $P_{silv\times for} = 0.002$), mandarin (*Disporum lanuginosum*; RMA$_{between}$ $P_{silv} = 0.097$, $P_{for} = 0.008$, $P_{silv\times for} = 0.033$), Solomon's seal (RMA$_{between}$ $P_{silv} = 0.027$, $P_{for} = 0.016$, $P_{silv\times for} = 0.077$), and trillium species (*Trillium* spp.; RMA$_{between}$ $P_{silv} = 0.021$, $P_{for} = 0.059$, $P_{silv\times for} = 0.097$) produced more fruit in both the young regenerated and mature CH stands than in either UH silvicultural treatment and generally produced more fruit biomass in CHR than in CHM (Fig. 3; Appendix). No herbaceous species produced more fruit in M than in R.

Fruit production by most tree species, including flowering dogwood, American holly, Fraser magnolia, black cherry, and sassafras, was similar between forest types and silvicultural treatments (RMA$_{between}$ $P > 0.10$) due to fruiting by stump sprouts in young regenerated stands. Blackgum produced more fruit in UHM than in other treatment combinations (RMA$_{between}$ $P_{silv} = 0.280$, $P_{for} = 0.032$, $P_{silv\times for} = 0.090$) but also fruited from stump sprouts in R.

Few other species produced more fruit in M than in R. During the first 2 years postharvest, lowbush blueberry (*Vaccinium vacillans*) produced more fruit in UHM than in UHR ($P_{silv} \leq 0.091$) but subsequently produced similar amounts of fruit in the UH forest type, regardless of silvicultural treatment; overall this species produced more fruit in the UH than in the CH forest type (RMA$_{between}$ $P_{silv} = 0.189$, $P_{for} = 0.059$, $P_{silv\times for} = 0.265$). Spicebush occurred only in CHM plots and hence produced more fruit in that habitat (RMA$_{between}$ $P_{silv} = 0.030$, $P_{for} = 0.030$, $P_{silv\times for} = 0.030$; Appendix).

Fruit (including unripe, ripe, and damaged) was available from June through December, and dry pulp production was greater in R than in M during those months (RMA$_{between}$ P_{silv} range <0.0001 in Jul to 0.061 in Dec; Fig. 1). Within-year ANOVAs indicated that differences between the 2 silvicultural treatments were evident beginning the third year postharvest (2001). During 2001–2003 fruit was consistently greater in R from June through December than in M (within-year ANOVA P_{silv} range: <0.0001–0.076). Differences between silvicultural treatments were greatest in summer. For example, in R the average ($\pm$SE) biomass in July 2003 was 11.4 ± 1.9 kg/ha (UHR) and 10.7 ± 3.5 kg/ha (CHR), but in M averages ranged from only 1.7 ± 0.6 kg/ha (UHM) to 0.6 ± 0.1 kg/ha (CHM). During winter and spring months, dry pulp biomass was low and did not

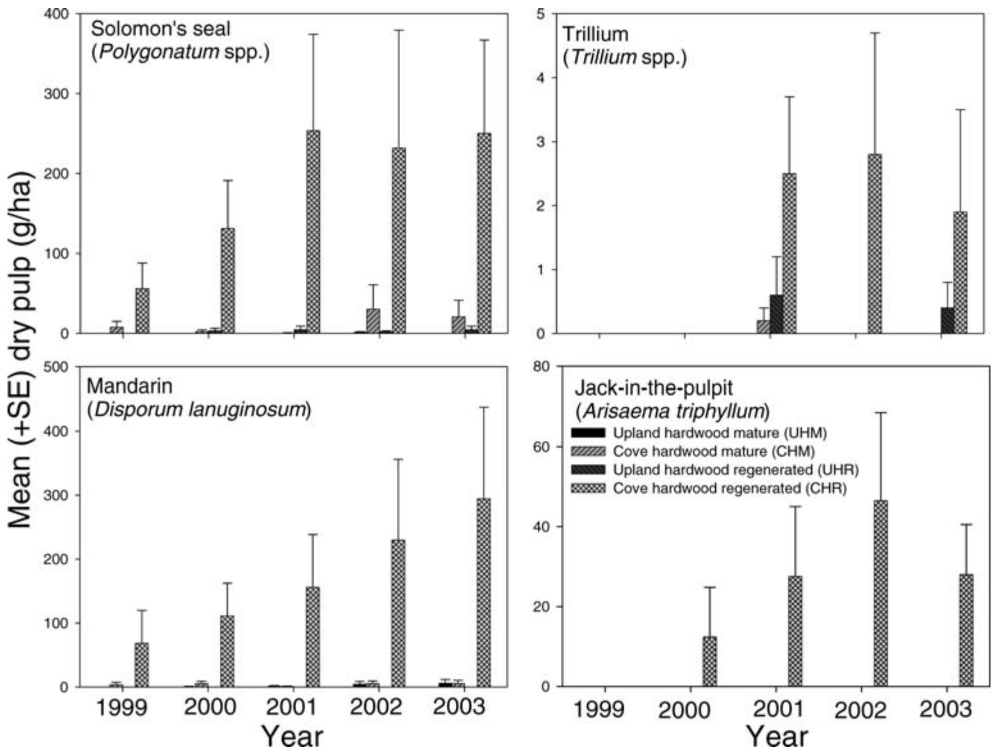

Figure 3. Mean (+SE) total dry pulp biomass of select herbaceous plant species that are not typically associated with disturbance, in young 2-age stands created by shelterwood-with-reserves regeneration cuts (harvested 1998–1999) and uncut mature closed-canopy stands in upland hardwood and cove hardwood forest types of the southern Appalachian Mountains, USA, 1999–2003.

differ among the silvicultural treatments or forest types (e.g., Jan 2004 range 0.05 $\pm$ 0.03 kg/ha in CHM to 0.29 $\pm$ 0.26 kg/ha in UHR; Fig. 1). Total fruit availability each month (except May) differed among years ($\text{RMA}_{\text{within}}$ P_{yr} range: $<$0.0001–0.004). A significant year $\times$ silvicultural treatment interaction during June, July, August, and November indicated fruit production increased over time within R, primarily during summer months ($\text{RMA}_{\text{within}}$ $P_{\text{yr}\times\text{silv}}$ range: 0.0002–0.048; Fig. 1).

Overall, fruit production was similar between UH and CH forest types during all months ($\text{RMA}_{\text{between}}$ $P_{\text{for}} = 0.107$). However, within-year ANOVA indicated that production was greater in the UH forest type during July of 2000 ($P_{\text{for}} = 0.035$), 2001 ($P_{\text{for}} = 0.082$), and 2003 ($P_{\text{for}} = 0.077$), which coincided with years of greater blackgum fruit production.

Peak availability differed between the 2 silvicultural treatments and forest types because of differences in species composition, fruiting phenology, and the dynamic process of colonization and recovery in R (Table 1; Figs. 2, 4). For example, total blackberry fruit production peaked in June, with peak ripeness in July, but blackberries occurred only in R beginning the third year. Pokeweed also fruited only in R but produced its maximum fruit crop in August and September, largely during the first 3 years. Huckleberry reached peak fruit production in June, peak ripeness in July, and was largely gone by September. Flowering dogwood produced unripe fruits as early as June, and peak fruit ripeness was in September (Table 1; Fig. 4). Several species, such as pokeweed, ripened asynchronously, thus prolonging the length of time fruit was available on plants. Fruits of most summer-ripening species disappeared rapidly, although individuals of several species retained small amounts of damaged fruit during winter months. In contrast, late-ripening species such as American holly, sumac, and greenbriar tended to retain substantial amounts of fruit through the winter months (Table 1; Fig. 4). However, their contribution to winter fruit availability was limited by their patchy distribution.

DISCUSSION

In our 5-year study, dry pulp biomass of fleshy fruit was 5.0–19.6 times greater in young regenerated stands 3–5 years postharvest than in mature closed-canopy forest. Fruit production in mature stands was relatively low and constant, and interannual changes in the relative contribution by species to total fruit production were due to differences in the amount of fruit produced by the same individuals and (or) roughly the same number of plants each year. In contrast, shifts in the relative contribution by species to total fruit production in young regenerated stands was largely due to the dynamic process of plant recovery through stump sprouting, regrowth of clonal shrubs such as huckleberry, and site colonization by disturbance-adapted species such as pokeweed and blackberry. With few exceptions, all plant species produced more fruit or similar amounts of fruit in young regenerated stands than in mature closed-canopy forest during the first 5 years postharvest.

Of the 30 genera of fruiting plants in our study, 10 (*Rubus*, *Prunus*, *Cornus*, *Vitis*, *Vaccinium*, *Amelanchier*, *Rhus*, *Smilax*, *Nyssa*, and *Ilex*) are documented of high value to many game

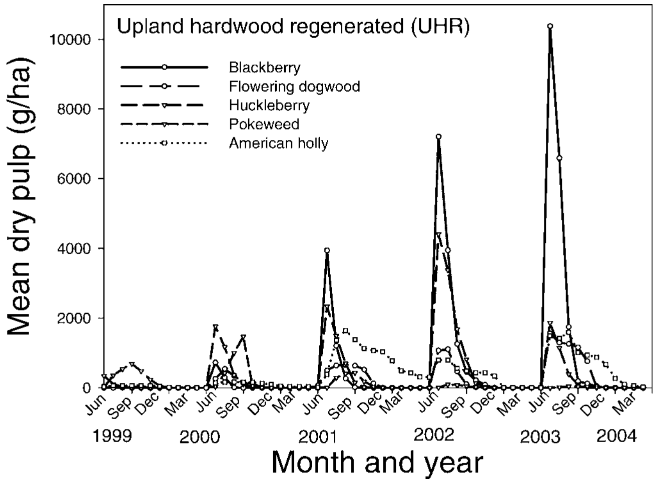

Figure 4. Mean monthly dry pulp biomass (g/ha) of select soft mast–producing species in young 2-age stands created by shelterwood-with-reserves regeneration cuts (harvested 1998–1999) and uncut mature closed-canopy stands in upland hardwood and cove hardwood forest types of the southern Appalachian Mountains, USA, June 1999–April 2004.

and nongame wildlife species (20–56 documented consumers in the Northeast region, including the southern Appalachian Mountains), and an additional 11 (*Aralia*, *Arisaema*, *Gaylussacia*, *Lindera*, *Magnolia*, *Mitchella*, *Phytolacca*, *Sassafras*, *Polygonatum*, *Smilacina*, and *Viburnum*) are reported as being consumed by at least a few vertebrate species (Martin et al. 1951).

Several studies show that fruit production is much greater in forest openings caused by natural disturbance (Thompson and Willson 1978, Blake and Hoppes 1986, Levey 1990) or by silvicultural disturbance such as harvesting (e.g., Johnson and Landers 1978, Campo and Hurst 1980, Stransky and Roese 1984, Perry et al. 1999, Mitchell and Powell 2003) compared to closed-canopy conditions. Abundant light, soil disturbance, and reduced competition created by reductions in tree basal area provide optimal conditions for fruit production by many species and for colonization by disturbance-associated species such as pokeweed and blackberry that are prolific fruit producers. In the Ouachita Mountains of Arkansas and Oklahoma, USA, fruit production was negatively correlated with stand basal area 3 and 5 years postharvest (Perry et al. 1999).

Other studies have also shown 1–3-year delays in increased fruit production following disturbance. Basinger (2003) reported a sharp increase in fruit production during the second year posttreatment in 4 silvicultural treatments compared to controls, although differences were not significant due to high variability among sites. In pine (*Pinus* spp.) plantations of the southeastern United States, maximum fruit production is reached when stands are about 4–5 years old (Lay 1961, Johnson and Landers 1978, Campo and Hurst 1980). Perry et al. (1999) reported similar levels of fruit production among harvested mixed pine–hardwood stands (clearcut, shelterwood, group selection, and single-tree selection) and controls during the first year postharvest but much greater fruit production in all harvested treatments by year 3. Fruit production in clearcuts and shelterwood cuts, where basal area reduction was heaviest, remained high during year 5 compared to controls and other silvicultural treatments (Perry et al. 1999).

In our study, fruit production in R of both forest types was dominated by pokeweed and blackberry, 2 species that proliferate after disturbance. However, the relative contribution of each shifted over the 5-year study period. During 1999 pokeweed composed 45.2% of total dry pulp biomass in UHR and 88.7% in CHR (blackberry composed 0.0% and 0.8%, respectively), whereas in 2003 pokeweed composed 0.2% in both young regenerated stand treatments, and blackberry composed 65.0% in UHR and 81.7% in CHR. Perry et al. (1999) reported similar interannual patterns of fruit production, with pokeweed fruit composing the majority of total biomass in young regenerated stands for the first few years but disappearing by the fifth year, with blackberry becoming the dominant producer during the fifth year postharvest (Perry et al. 1999).

Huckleberry recovered rapidly after harvest; fruit production in R was similar to production in M beginning the first year postharvest. Huckleberry fruit production was highly variable among stands and years. Although fruit production did not differ statistically between CH and UH forest types, relatively low P_{for}-values suggest that huckleberry tends to produce more fruit in the UH forest type, and greater replication would have yielded statistical significance. Further, crude stand-level (rather than plot-level) forest type classifications may have obscured some differences between the CH and UH forest types.

Fruiting by stump sprouts in young regenerated stands resulted in average fruit yields similar to that in mature stands for several common tree species. In our study, several tree species, including flowering dogwood, American holly, Fraser magnolia, and blackgum fruited within 1–2 years postharvest, and others (e.g., black cherry, sassafras) fruited within 3 years. Campo and Hurst (1980) reported that flowering dogwoods fruited in 6–7-year-old pine plantations. Potential fruit production by stump sprouts of species, including flowering dogwood, blackgum, and sassafras, may have been reduced by the herbicide treatment after harvest.

Fruits of herbaceous species (with the exception of pokeweed) composed a small proportion of total dry pulp biomass but nonetheless may be important to some wildlife species. In our study, many herbaceous species that are not typically associated with disturbance produced more fruit in R than in M stands, especially in CHR, indicating that regeneration cutting did not adversely affect their reproductive output, at least in the short term.

Our estimates of total fruit production were generally lower than estimates in other studies. For example, Perry et al. (1999) estimated 80–100 kg/ha dry fruit biomass in regenerated and clearcut stands 5 years after harvest, whereas our estimates were 16.0 kg/ha (UHR) and 11.6 kg/ha (CHR), in young regenerated stands 5 years after harvest. This large discrepancy is likely in part because we based our estimates on dry edible pulp only, whereas their (and most other) results were based on whole dry fruits, including seeds. However, we believe that reporting dry edible pulp provides a more practical estimate of fruit production for land managers, as seeds of fleshy fruit are not generally digested by frugivorous wildlife (with the exception of seed predators).

Geographic and site differences may also have contributed to differences in total fruit production because these factors influence the presence and relative abundance of fruit-producing species. For example, at the Savannah River Site (SRS), located between the Piedmont and Coastal Plain in South Carolina, USA, deerberry (*Vaccinium stamineum*) produced an average of 14.9 kg dry edible pulp/ha in longleaf pine (*Pinus palustris*) plantation and young (<5-yr-old) clearcuts (McCarty et al. 2002), whereas it was a relatively minor producer in the southern Appalachians ($\leq$0.4 kg/ha/yr in UHM). Flowering dogwood produced >6.3 kg dry pulp/ha in upland hardwood forest at the SRS but <0.1 kg/ha/year in UHM in our study. The presence of dogwood anthracnose on many of our study trees, especially in some UHM plots (C. H. Greenberg, USFS, personal observation), may have reduced fruit production by flowering dogwoods (Rossell et al. 2001). American holly, which retains fruit during winter, produced 2.4 kg dry pulp/ha in upland and bottomland hardwoods at the SRS but a maximum of about 0.01 kg/ha in a somewhat equivalent habitat type (CHC) in our study (but 1.4 kg/ha was produced in UHR). Winged sumac (*Rhus copallina*), also an important winter fruit species, produced 3.7 kg dry pulp/ha in young clearcuts at the SRS (McCarty et al. 2002) but a maximum of 0.2 kg/ha in our study.

In our study, spatial variation in fruit production was influenced primarily by conditions created by low basal area retained within the young regeneration cuts, and less so by the influence of forest type on plant species composition. However, the sporadic distribution of some plant species among our study stands also affected our estimates of fruit production. For example, American holly and black cherry are common in southern Appalachian hardwood forests. Their low occurrence in our study plots was likely due to somewhat clumped distributions of these species across the landscape (C. H. Greenberg, personal observation). The high variability in occurrence and abundance, hence fruit production, by these and some other species among plots likely led to underestimation of their relative contribution to total fruit production at a larger landscape level and potentially obscured detection of statistically significant differences among silvicultural treatments and forest types.

Fruit production by several species varied among years. This was clearly due to patterns of establishment and growth in young regenerated stands for species such as blackberry and pokeweed. For others, such as flowering dogwood and huckleberry, production varied among years even within mature stands. This suggests that intrinsic factors, such as prior-year fruiting, or edaphic factors, such as climate, influence fruit production, at least in some species. Powell and Seaman (1990) also reported high temporal and spatial variability in huckleberry production in the southern Appalachians.

Fruit availability varied spatially and temporally primarily due to differences in species composition, fruiting phenology, and the dynamic process of colonization and recovery in R. In R, patterns of establishment, fruit production, and ripening patterns by pokeweed and blackberry affected fruit availability over the 5-year study period. Fruits of some other species, such as flowering dogwood and huckleberry, were more widely distributed among treatments but fruits ripened during different months (flowering dogwood in fall; huckleberry in summer).

Winter fruit availability in our study was low in both silvicultural treatments and forest types. Average January dry pulp biomass ranged from 0.2 $\pm$ 0.2 g/ha (UHM in 2003) to 814.4 $\pm$ 579.2 g/ha (UHR in 2002) among years and treatments. In contrast, Kwit et al. (2004) reported January dry pulp biomass ranging from 100g/ha to 2,900 g/ha during 1996–2002 in bottomland hardwood habitat at the SRS, primarily from American holly fruits (see McCarty et al. 2002). In our study, only a few species, including American holly, greenbriar, and sumac, retained substantial amounts of ripe fruit during winter, although some individuals of several other species retained small amounts of damaged fruits during winter months. Average dry pulp biomass of these species was relatively small, perhaps in part reflecting their clumped or erratic distribution across the landscape. Nonetheless, where they occur these species may be important to birds and mammals during winter, when other food resources such as arthropods (Greenberg and Forrest 2003, Whitehead 2003), foliage, and hard mast are scarce.

MANAGEMENT IMPLICATIONS

In the southern Appalachians, young regenerated stands produce abundant fruit compared to mature unharvested forest and represent important wildlife food patches. In our 5-year study, dry pulp biomass of fleshy fruit was similar in young 2-age stands and mature forest during the first 2 years postharvest, and it was 5.0 to 19.6 times higher in young stands than in mature forest during years 3–5 postharvest. Disturbance-associated species, pokeweed and blackberry, were major fruit producers in young regenerated stands. However, many other species that are not typically associated with disturbance, including several herbaceous species, huckleberry, and stump sprouts of fruit-producing tree species, produced similar amounts or more fruit in young recently regenerated stands than in mature forest. Flowering dogwood, American holly, Fraser magnolia, black cherry, sassafras, and blackgum all produced fruit from stump sprouts within 1–3 years postharvest. Fruit production by these tree species could likely be increased if land managers left some as reserve trees and (or) avoided herbicide treatment of stump sprouts (while ensuring that the density of these species did not impede other stand-regeneration objectives). Fruit availability was highest during summer and early fall as different species reached peak production. Land managers could enhance winter fruit availability by retaining American holly, sumac, and greenbriar, which retain fruit during winter months. Fruit availability differs temporally and spatially between young regenerated stands and mature forest due to differences in species composition, fruiting phenology, and the dynamic process of colonization and recovery in recently harvested stands. Land managers could enhance fruit availability for many game and nongame species by creating or maintaining patches of young openings within forests.

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Appendix. Mean (±SE) annual soft mast production (g dry pulp/ha) by plant species,[a] plant form (herbaceous, tree, shrub, vine), and total in young 2-age stands created by shelterwood-with-reserves regeneration cuts (R; harvested 1998–1999) and uncut mature closed-canopy stands (M) in upland hardwood (UH) and cove hardwood (CH) forest types of the southern Appalachian Mountains, USA (2 forest types × 2 silvicultural treatments: UHM, CHM, UHR, CHR), during 1999–2003.

		Forest type and silvicultural treatment											Repeated-measures ANOVA[c]			
		UHM (n = 8)		CHM (n = 8)		UHR (n = 9)		CHR (n = 6)		2-way ANOVA (/yr)[b]			P_{silv}	P_{for}	$P_{silv \times for}$	
Species	Yr	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	P_{silv}	P_{for}	$P_{silv \times for}$	P_{yr}	$P_{yr \times silv}$	$P_{yr \times for}$	$P_{yr \times silv \times for}$
Herbaceous species																
Devil's walkingstick (*Aralia racemosa*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.2026	0.2026	0.2026	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.2026	0.2026	0.2026	0.2026
	2001	0.0	0.0	0.0	0.0	0.0	0.0	95.5	95.5	0.2026	0.2026	0.2026				
	2002	0.0	0.0	0.0	0.0	0.0	0.0	11.2	11.2	0.2026	0.2026	0.2026				
	2003	0.0	0.0	0.0	0.0	0.0	0.0	61.6	61.6	0.2026	0.2026	0.2026				
Jack-in-the- pulpit (*Arisaema triphyllum*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.0019	0.0019	0.0019	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	12.4	12.4	0.2026	0.2026	0.2026	0.0565	0.0565	0.0565	0.0565
	2001	0.0	0.0	0.0	0.0	0.0	0.0	27.5	17.5	0.0487	0.0487	0.0487				
	2002	0.0	0.0	0.0	0.0	0.0	0.0	46.5	22.0	0.0072	0.0072	0.0072				
	2003	0.0	0.0	0.0	0.0	0.0	0.0	28.0	12.5	0.0070	0.0070	0.0070				
Blue cohosh (*Caulophyllum thallictroides*)	1999	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477	0.9593	0.1123	0.9593	
	2000	0.0	0.0	0.8	0.8	0.0	0.0	3.1	3.1	0.5920	0.1174	0.5920	0.1238	0.0969	0.1238	0.0969
	2001	0.0	0.0	2.5	2.5	0.0	0.0	0.3	0.3	0.5932	0.2078	0.5932				
	2002	0.0	0.0	2.7	2.7	0.0	0.0	0.5	0.5	0.7312	0.1724	0.7312				
	2003	0.0	0.0	2.3	2.3	0.0	0.0	2.6	1.6	0.5080	0.0406	0.5080				
Speckled wood-lily (*Clintonia umbellulata*)	1999	1.4	1.4	1.5	1.5	0.0	0.0	5.1	5.1	0.9319	0.3742	0.3816	0.5809	0.1027	0.1878	
	2000	2.1	2.1	1.5	1.5	0.0	0.0	7.4	5.4	0.6463	0.1847	0.1488	0.4006	0.5178	0.2513	0.6794
	2001	0.0	0.0	4.3	4.3	0.0	0.0	14.8	9.8	0.2988	0.0353	0.2988				
	2002	0.9	0.9	2.0	2.0	0.0	0.0	8.9	7.1	0.5588	0.1176	0.1883				
	2003	3.3	3.3	6.2	6.2	0.0	0.0	16.9	11.0	0.6643	0.1450	0.1939				
Yellow mandarin (*Disporum lanuginosum*)	1999	0.0	0.0	3.8	3.6	0.0	0.0	68.4	51.3	0.0748	0.0056	0.0748	0.0972	0.0076	0.0325	
	2000	0.6	0.6	5.4	3.7	0.0	0.0	111.1	51.2	0.1316	0.0062	0.0594	0.0318	0.6500	0.5232	0.1097
	2001	1.1	1.1	0.8	0.6	0.0	0.0	156.0	82.4	0.0455	0.0111	0.0134				
	2002	4.3	4.3	5.4	4.0	0.0	0.0	229.7	126.2	0.1951	0.0100	0.0503				
	2003	0.6	0.6	5.4	5.1	0.0	0.0	294.3	143.2	0.1255	0.0170	0.0274				
Indian cucumber-root (*Medeola virginiana*)	1999	0.0	0.0	0.2	0.2	0.0	0.0	6.5	6.5	0.2986	0.1488	0.2986	0.1520	0.0625	0.4738	
	2000	0.0	0.0	0.7	0.4	0.2	0.2	2.6	1.2	0.0671	0.0058	0.1955	0.0061	0.7303	0.6697	0.7329
	2001	0.1	0.1	1.2	0.7	1.5	1.5	2.4	1.6	0.2989	0.0994	0.9317				
	2002	0.2	0.2	1.5	1.5	1.6	1.4	4.6	3.4	0.1369	0.2051	0.6453				
	2003	0.5	0.4	4.2	3.7	1.3	0.9	7.8	4.9	0.2504	0.1143	0.5625				
Partridgeberry (*Mitchella repens*)	1999	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1609	0.1609	0.1609	0.1609	0.1609	0.1609	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.1609	0.1609	0.1609	
	2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
Ginseng (*Panax quinquefolium*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.5136	0.0917	0.5136	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.2026	0.2026	0.2026	0.2335	0.2930	0.2335	0.2930
	2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2002	0.0	0.0	0.1	0.1	0.0	0.0	1.0	1.0	0.3847	0.1305	0.3847				
	2003	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477				
Pokeweed (*Phytolacca americana*)	1999	0.0	0.0	0.0	0.0	691.1	482.5	1,411.4	1,383.6	0.0019	0.9240	0.9240	<0.0001	0.3306	0.3306	
	2000	0.0	0.0	0.0	0.0	1,472.4	1,398.7	1,258.3	1,105.4	<0.0001	0.3287	0.3287	0.0013	0.0013	0.3861	0.3861

Appendix. Continued.

Species	Yr	Forest type and silvicultural treatment: UHM (n = 8) $\bar{x}$	UHM SE	CHM (n = 8) $\bar{x}$	CHM SE	UHR (n = 9) $\bar{x}$	UHR SE	CHR (n = 6) $\bar{x}$	CHR SE	2-way ANOVA (/yr)[b] P_{silv}	P_{for}	$P_{silv \times for}$	Repeated-measures ANOVA[c] P_{silv} / P_{yr}	P_{for} / $P_{yr \times silv}$	$P_{silv \times for}$ / $P_{yr \times for}$	$P_{yr \times silv \times for}$
	2001	0.0	0.0	0.0	0.0	433.3	267.2	1,145.4	772.8	<0.0001	0.1262	0.1262				
	2002	0.0	0.0	0.0	0.0	44.1	17.5	159.5	81.7	<0.0001	0.0906	0.0906				
	2003	0.0	0.0	0.0	0.0	37.8	27.0	27.1	25.7	0.0064	0.7376	0.7376				
Solomon's seal (*Polygonatum* spp.	1999	0.0	0.0	7.5	7.5	0.0	0.0	55.9	32.0	0.0861	0.0081	0.0861	0.0269	0.0156	0.0771	
[*P. biflorum* and *P. pubescens*])	2000	0.0	0.0	2.2	2.2	3.2	3.2	131.3	59.9	0.0189	0.0200	0.0791	0.1412	0.1761	0.7876	0.6938
	2001	0.0	0.0	0.4	0.4	4.5	4.5	253.6	120.5	0.0088	0.0229	0.0427				
	2002	1.1	1.1	30.4	30.4	1.9	1.4	231.9	147.4	0.0776	0.0428	0.1394				
	2003	0.0	0.0	20.7	20.7	4.5	4.5	250.2	116.7	0.0424	0.0203	0.1409				
Biltmore greenbriar (*Smilax biltmoreana*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.3477	0.3477	0.3477	
	2000	3.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477	0.3477	0.3477	0.3477	0.3477
	2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2002	1.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477				
	2003	11.4	11.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477				
Herbaceous greenbriar (*Smilax herbacea*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.1616	0.9545	0.9545	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.1804	0.1804	0.4624	0.4624
	2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2002	0.0	0.0	0.0	0.0	1.1	1.1	0.0	0.0	0.4067	0.4067	0.4067				
	2003	0.0	0.0	0.0	0.0	0.6	0.6	3.5	3.5	0.1318	0.5258	0.5258				
False Solomon's seal (*Smilacina racemosa*)	1999	9.2	9.2	0.7	0.7	0.00	0.00	1.9	1.9	0.6120	0.8651	0.3090	0.6478	0.4383	0.0825	
	2000	12.5	12.5	0.0	0.0	0.00	0.00	165.6	148.2	0.1127	0.1127	0.0115	0.0800	0.0091	0.0904	0.0114
	2001	15.0	15.0	0.0	0.0	0.00	0.00	126.5	126.5	0.6346	0.6346	0.1172				
	2002	13.2	13.2	0.0	0.0	0.00	0.00	103.4	103.4	0.6368	0.6368	0.1172				
	2003	28.8	28.8	1.8	1.4	0.00	0.00	4.6	3.7	0.7001	0.4978	0.2698				
Trillium (*Trillium* spp. [*T. vaseyi*,	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.0205	0.0590	0.0967	
T. catesbei, *T. cernuum*])	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.0140	0.0217	0.0785	0.1698
	2001	0.0	0.0	0.2	0.2	0.6	0.6	2.5	1.2	0.0096	0.0893	0.0893				
	2002	0.0	0.0	0.0	0.0	0.0	0.0	2.8	1.9	0.1259	0.0347	0.1259				
	2003	0.0	0.0	0.0	0.0	0.4	0.4	1.9	1.6	0.0554	0.2792	0.2792				
Total herbaceous	1999	10.9	10.5	15.2	10.9	691.1	482.5	1,549.1	1,358.4	0.0063	0.1572	0.5365	0.0001	0.0215	0.1715	
	2000	18.7	12.9	10.4	5.1	1,475.7	1,401.8	1,692.1	1,042.2	0.0016	0.1963	0.2259	0.2794	0.0621	0.6221	0.8727
	2001	16.2	16.1	9.2	4.3	439.9	271.5	1,824.3	689.1	<0.0001	0.0182	0.1946				
	2002	20.9	19.5	42.5	35.3	48.6	18.6	799.9	262.4	0.0002	0.0029	0.1079				
	2003	50.0	38.6	40.9	30.1	44.2	26.4	698.1	256.3	0.0426	0.0706	0.2886				
Tree species																
Serviceberry (*Amelanchier arborea*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.9635	0.4338	0.5608	
	2000	0.0	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477	0.0087	0.7203	0.6079	0.0720
	2001	0.0	0.0	1.2	1.2	0.7	0.7	0.0	0.0	0.8489	0.8489	0.2135				
	2002	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2026	0.2026	0.2026				
	2003	5.9	3.9	2.8	2.8	0.6	0.6	18.5	14.2	0.7610	0.4868	0.1335				
Flowering dogwood (*Cornus florida*)	1999	26.7	25.6	8.2	6.7	20.3	20.3	0.0	0.0	0.3132	0.5407	0.7000	0.5069	0.1994	0.1253	
	2000	30.9	29.7	20.2	16.7	344.6	151.1	10.3	10.3	0.3536	0.2153	0.1179	0.0002	0.1996	0.5223	0.2824
	2001	72.3	54.2	47.7	27.9	655.8	279.9	131.3	131.3	0.5726	0.1279	0.1262				
	2002	13.2	11.6	9.3	4.8	465.8	394.7	169.1	169.1	0.2150	0.2687	0.1787				
	2003	71.2	46.4	80.1	60.0	1,257.8	759.3	270.7	270.7	0.5234	0.3465	0.1329				

Appendix. Continued.

		Forest type and silvicultural treatment											Repeated-measures ANOVA[c]			
		UHM ($n = 8$)		CHM ($n = 8$)		UHR ($n = 9$)		CHR ($n = 6$)		2-way ANOVA (/yr)[b]			P_{silv}	P_{for}	$P_{silv \times for}$	
Species	Yr	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	P_{silv}	P_{for}	$P_{silv \times for}$	P_{yr}	$P_{yr \times silv}$	$P_{yr \times for}$	$P_{yr \times silv \times for}$
American holly (*Ilex opaca*)	1999	0.0	0.0	0.0	0.0	65.0	43.0	0.0	0.0	0.2134	0.2134	0.2134	0.3043	0.3043	0.1603	
	2000	0.0	0.0	0.1	0.1	160.9	106.9	0.0	0.0	0.2343	0.2343	0.1953	0.1589	0.6463	0.6463	0.1589
	2001	0.0	0.0	10.6	10.6	1,366.4	1,148.9	0.0	0.0	0.4158	0.4158	0.1380				
	2002	0.0	0.0	7.0	7.0	793.9	562.3	0.0	0.0	0.3983	0.3983	0.1385				
	2003	0.0	0.0	0.5	0.5	1,419.7	979.9	0.0	0.0	0.2682	0.2682	0.1751				
Fraser magnolia (*Magnolia fraseri*)	1999	0.0	0.0	0.0	0.0	399.8	399.8	0.0	0.0	0.4067	0.4067	0.4067	0.4067	0.4067	0.4067	
	2000	0.0	0.0	0.0	0.0	310.9	310.9	0.0	0.0	0.4067	0.4067	0.4067	0.4067	0.4067	0.4067	0.4067
	2001	0.0	0.0	0.0	0.0	32.3	32.3	0.0	0.0	0.4067	0.4067	0.4067				
	2002	0.0	0.0	0.0	0.0	781.8	781.8	0.0	0.0	0.4067	0.4067	0.4067				
	2003	0.0	0.0	0.0	0.0	279.8	279.8	0.0	0.0	0.4067	0.4067	0.4067				
Blackgum (*Nyssa sylvatica*)	1999	88.1	86.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2001	0.2001	0.2001	0.2798	0.0320	0.0903	
	2000	290.5	225.8	0.0	0.0	18.7	13.3	0.0	0.0	0.6009	0.0670	0.6009	0.1633	0.4699	0.2673	0.1540
	2001	747.7	715.5	0.0	0.0	23.9	20.2	0.0	0.0	0.3907	0.0368	0.3907				
	2002	8.6	7.5	0.0	0.0	6.0	6.0	7.5	7.5	0.7594	0.5177	0.2915				
	2003	916.6	579.7	0.0	0.0	0.9	0.7	32.0	32.0	0.1681	0.0830	0.0175				
Fire cherry (*Prunus pensylvanica*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.4067	0.4067	0.4067	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.4067	0.4067	0.4067	0.4067
	2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2002	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.4067	0.4067	0.4067				
	2003	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.4067	0.4067	0.4067				
Black cherry (*Prunus serotina*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.8764	0.2646	0.6152	
	2000	0.0	0.0	11.5	11.5	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477	0.0870	0.6566	0.2740	0.7775
	2001	0.0	0.0	27.8	27.8	2.2	2.2	25.8	25.8	0.6323	0.2647	0.8701				
	2002	0.0	0.0	618.5	618.5	1.1	1.1	14.3	12.9	0.8306	0.1591	0.8420				
	2003	0.0	0.0	23.5	23.5	22.5	22.5	199	1.9	0.7360	0.6450	0.4276				
Sassafras (*Sassafras albidum*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.4485	0.1273	0.7610	
	2000	51.5	51.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477	0.0265	0.0468	0.3353	0.4259
	2001	11.1	11.1	0.0	0.0	31.5	31.5	0.0	0.0	0.9454	0.2206	0.9454				
	2002	2.7	2.7	0.0	0.0	161.5	143.3	0.2	0.1	0.4116	0.1435	0.4116				
	2003	9.3	9.3	0.0	0.0	91.3	65.0	22.5	22.5	0.0740	0.1628	0.5437				
Total tree	1999	114.8	111.8	8.2	6.7	485.1	391.4	0.0	0.0	0.7822	0.0564	0.2283	0.5443	0.0376	0.1488	
	2000	372.9	217.3	32.7	18.4	835.2	304.9	10.3	10.3	0.9297	0.0145	0.2209	<0.0001	0.2736	0.3456	0.3726
	2001	831.1	705.4	87.3	32.3	2,112.7	1,197.8	157.1	128.7	0.9568	0.0648	0.1781				
	2002	24.6	14.8	634.8	616.2	2,210.2	986.5	191.0	174.2	0.1364	0.3734	0.0467				
	2003	1,003.0	571.1	106.9	59.9	3,072.9	1,092.6	345.6	294.9	0.4399	0.0667	0.6732				
Shrub species																
Strawberry bush (*Euonymous americanus*)	1999	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.4067	0.4067	0.4067	0.9559	0.9559	0.2198	
	2000	0.0	0.0	0.4	0.4	1.2	1.2	0.0	0.0	0.7906	0.7906	0.2396	0.2976	0.6309	0.6309	0.2976
	2001	0.0	0.0	0.3	0.3	0.3	0.3	0.0	0.0	0.9708	0.9708	0.2155				
	2002	0.0	0.0	0.3	0.3	0.1	0.1	0.0	0.0	0.7262	0.7262	0.2188				
	2003	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477				

Appendix. Continued.

Species	Yr	Forest type and silvicultural treatment											Repeated-measures ANOVA[c]			
		UHM (n = 8)		CHM (n = 8)		UHR (n = 9)		CHR (n = 6)		2-way ANOVA (/yr)[b]			P_{silv}	P_{for}	$P_{silv \times for}$	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	P_{silv}	P_{for}	$P_{silv \times for}$	P_{yr}	$P_{yr \times silv}$	$P_{yr \times for}$	$P_{yr \times silv \times for}$
Huckleberry (*Gaylussacia* spp. [*G. ursina* and *G. baccata*])	1999	1,094.8	523.3	131.8	88.0	339.8	228.4	36.1	36.1	0.3791	0.1121	0.9741	0.5963	0.1132	0.8761	
	2000	1,086.7	523.0	293.2	188.7	1,763.3	1,139.0	541.2	541.2	0.4656	0.1375	0.9918	0.0115	0.0666	0.6424	0.3775
	2001	224.7	112.4	62.3	42.9	2,340.0	1,308.0	516.9	516.9	0.8612	0.1415	0.8343				
	2002	571.0	304.0	220.7	158.6	4,408.2	2,723.1	595.0	595.0	0.8068	0.1146	0.6911				
	2003	703.4	333.6	163.4	105.5	1,865.7	1,183.7	182.9	182.9	0.5453	0.0876	0.8413				
Deciduous holly (*Ilex ambigua*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.5645	0.8828	0.1817	
	2000	1.1	1.1	0.0	0.0	0.0	0.0	6.7	6.7	0.5503	0.5503	0.1182	0.1040	0.6790	0.6980	0.2744
	2001	4.7	4.7	0.0	0.0	0.3	0.3	22.7	22.7	0.5336	0.7872	0.1723				
	2002	21.9	21.9	0.0	0.0	0.9	0.9	8.5	8.5	0.7792	0.7984	0.2428				
	2003	2.2	2.2	0.0	0.0	0.8	0.8	11.1	11.1	0.4324	0.8927	0.2569				
Spicebush (*Lindera benzoin*)	1999	0.0	0.0	349.6	279.9	0.0	0.0	0.0	0.0	0.0699	0.0699	0.0699	0.0297	0.0297	0.0297	
	2000	0.0	0.0	240.4	159.2	0.0	0.0	0.0	0.0	0.0231	0.0231	0.0231	0.5649	0.5649	0.5649	0.5649
	2001	0.0	0.0	99.1	64.4	0.0	0.0	0.0	0.0	0.0244	0.0244	0.0244				
	2002	0.0	0.0	97.2	63.8	0.0	0.0	0.0	0.0	0.0249	0.0249	0.0249				
	2003	0.0	0.0	126.0	65.2	0.0	0.0	0.0	0.0	0.0339	0.0339	0.0339				
Buffalo nut (*Pyrularia pubera*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.9230	0.2226	0.9230	
	2000	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477	0.4078	0.5008	0.4078	0.5008
	2001	0.0	0.0	0.0	0.0	3.8	3.8	0.0	0.0	0.4067	0.4067	0.4067				
	2002	1.7	1.7	0.0	0.0	1.5	1.5	0.0	0.0	0.9409	0.2144	0.9409				
	2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
Winged sumac (*Rhus copallina*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.1887	0.2186	0.2186	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.1854	0.1854	0.2265	0.2265
	2001	0.0	0.0	0.0	0.0	0.0	0.0	23.8	84.4	0.2026	0.2026	0.2026				
	2003	0.0	0.0	0.0	0.0	0.2	0.2	226.4	226.4	0.1710	0.2476	0.2476				
Smooth sumac (*Rhus glabra*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.4067	0.4067	0.4067	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.4067	0.4067	0.4067	0.4067
	2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2003	0.0	0.0	0.0	0.0	17.9	17.9	0.0	0.0	0.4067	0.4067	0.4067				
Raspberry (*Rubus* spp. [*R. odoratus* and *R. phoenicolasius*])	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.0800	0.6068	0.6068	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.0675	0.0675	0.2585	0.2585
	2001	0.0	0.0	0.0	0.0	11.2	11.2	0.0	0.0	0.4067	0.4067	0.4067				
	2002	0.0	0.0	0.0	0.0	5.6	5.6	38.4	26.0	0.0386	0.2311	0.2311				
	2003	0.0	0.0	0.0	0.0	6.3	6.3	52.6	52.6	0.1323	0.5802	0.5802				
Blackberry (*Rubus allegheniensis*)	1999	0.0	0.0	0.0	0.0	12.4	12.4	0.0	0.0	0.4067	0.4067	0.4067	<0.0001	0.9580	0.9580	
	2000	0.0	0.0	0.0	0.0	723.0	634.9	2.1	2.1	0.1363	0.3707	0.3701	<0.0001	<0.0001	0.4569	0.4569
	2001	0.0	0.0	0.0	0.0	3,943.1	3,392.0	517.4	385.6	<0.0001	0.8254	0.8254				
	2002	0.0	0.0	0.0	0.0	7,207.8	3,562.0	5,252.9	2,124.1	<0.0001	0.4797	0.4797				
	2003	0.0	0.0	0.0	0.0	10,379.7	3,027.8	9,468.4	4,088.6	<0.0001	0.5506	0.5506				
Horse sugar (*Symplocos tinctoria*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.4839	0.1032	0.4839	
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.0941	0.5092	0.0941	0.5092
	2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2002	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.4067	0.4067	0.4067				
	2003	2.9	2.9	0.0	0.0	12.5	11.3	0.0	0.0	0.5031	0.0952	0.5031				

Appendix. Continued.

		Forest type and silvicultural treatment											Repeated-measures ANOVA[c]			
		UHM (n = 8)		CHM (n = 8)		UHR (n = 9)		CHR (n = 6)		2-way ANOVA (/yr)[b]			P_{silv}	P_{for}	$P_{silv \times for}$	
Species	Yr	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	P_{silv}	P_{for}	$P_{silv \times for}$	P_{yr}	$P_{yr \times silv}$	$P_{yr \times for}$	$P_{yr \times silv \times for}$
Highbush blueberry (*Vaccinium corymbosum*)	1999	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477	0.4365	0.4793	0.1070	
	2000	0.2	0.2	0.0	0.0	0.0	0.0	132.9	132.9	0.2640	0.2640	0.1617	0.1522	0.3707	0.3313	0.2155
	2001	5.0	5.0	0.0	0.0	0.0	0.0	150.5	150.5	0.5063	0.5063	0.1199				
	2002	0.0	0.0	0.0	0.0	0.0	0.0	47.5	47.5	0.2026	0.2026	0.2026				
	2003	12.1	10.9	0.0	0.0	0.0	0.0	153.6	153.6	0.7025	0.8824	0.0967				
Deerberry (*Vaccinium stamineum*)	1999	357.9	290.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1589	0.1589	0.1589	0.1366	0.1366	0.1366	
	2000	101.0	66.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1044	0.1044	0.1044	0.3922	0.3922	0.3922	0.3922
	2001	54.8	54.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3477	0.3477	0.3477				
	2002	50.1	34.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1569	0.1569	0.1569				
	2003	27.8	25.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1839	0.1839	0.1839				
Lowbush blueberry (*Vaccinium vacillans*)	1999	31.9	21.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0907	0.0907	0.0907	0.1890	0.0589	0.2649	
	2000	28.0	18.1	0.5	0.5	0.2	0.2	0.0	0.0	0.0729	0.1041	0.1711	0.2933	0.5047	0.3836	0.5762
	2001	58.4	30.3	0.0	0.0	29.1	29.1	0.0	0.0	0.3071	0.0487	0.3071				
	2002	11.2	8.7	0.0	0.0	15.7	15.7	0.0	0.0	0.5454	0.0763	0.5454				
	2003	81.7	69.0	1.1	1.1	29.0	29.0	0.0	0.0	0.2668	0.1054	0.5116				
Maple-leaf viburnum (*Viburnum acerifolium*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	5.5	5.5	0.2026	0.2026	0.2026	0.0113	0.0575	0.0615	
	2000	0.0	0.0	0.0	0.0	2.8	2.8	31.7	31.7	0.1318	0.5232	0.5232	0.0091	0.0103	0.0449	0.0498
	2001	0.0	0.0	0.0	0.0	0.4	0.4	328.9	297.2	0.0089	0.0173	0.0188				
	2002	0.0	0.0	0.1	0.1	9.6	9.6	109.2	68.0	0.0090	0.0573	0.0691				
	2003	0.0	0.0	0.0	0.0	19.4	19.4	204.1	98.5	0.0075	0.0606	0.0606				
Total shrub	1999	1,485.3	711.9	481.4	273.6	352.4	226.4	41.7	35.4	0.1244	0.2108	0.7992	0.0527	0.2256	0.8786	
	2000	1,217.9	567.4	534.4	220.3	2,490.4	1,174.4	714.6	539.1	0.6978	0.2129	0.3948	<0.0001	<0.0001	0.4242	0.1983
	2001	347.5	171.9	161.7	68.9	6,328.3	3,311.3	1,560.3	610.0	0.0221	0.1950	0.9405				
	2002	655.9	312.9	318.3	159.3	11,649.6	3,876.8	6,135.8	2,669.6	<0.0001	0.6069	0.9261				
	2003	830.1	348.0	290.6	124.9	12,331.9	2,668.7	10,299.1	4,104.7	<0.0001	0.2779	0.3826				
Vines																
Glaucous greenbriar (*Smilax glauca*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA						
	2000	0.0	0.0	0.0	0.0	58.6	58.6	0.0	0.0	0.4067	0.4067	0.4067	0.4067	0.4067	0.4067	
	2001	0.0	0.0	0.0	0.0	25.8	25.8	0.0	0.0	0.4067	0.4067	0.4067	0.4067	0.4067	0.4067	0.4067
	2002	0.0	0.0	0.0	0.0	106.9	106.9	0.0	0.0	0.4067	0.4067	0.4067				
	2003	0.0	0.0	0.0	0.0	99.3	99.3	0.0	0.0	0.4067	0.4067	0.4067				
Round-leafed greenbriar (*Smilax rotundifolia*)	1999	40.1	40.1	4.2	4.0	0.0	0.0	0.7	0.7	0.2981	0.9320	0.6004	0.8631	0.3881	0.6004	
	2000	24.2	24.2	29.9	21.4	0.0	0.0	15.6	15.3	0.4512	0.2444	0.7456	0.0120	0.1075	0.2593	0.6940
	2001	27.7	27.7	9.7	8.2	0.9	0.9	15.5	15.2	0.7662	0.4546	0.6467				
	2002	60.0	60.0	11.3	7.4	4.3	4.3	197.3	191.1	0.7702	0.3070	0.4379				
	2003	43.9	43.0	21.8	16.2	8.6	6.0	174.7	167.2	0.6304	0.4030	0.7041				
Fox grape (*Vitis aestivalis*)	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA			0.5221	0.8086	0.2097	
	2000	0.0	0.0	385.0	385.0	46.9	43.8	0.0	0.0	0.9849	0.9849	0.1441	0.0292	0.4393	0.7159	0.3242
	2001	0.0	0.0	450.4	450.4	737.3	491.4	60.1	60.1	0.3693	0.9159	0.3472				
	2002	0.0	0.0	1,026.2	825.0	852.5	572.6	102.9	102.9	0.6864	0.5648	0.2093				
	2003	0.0	0.0	134.4	129.6	406.0	327.6	70.3	70.3	0.3171	0.8929	0.2284				

Appendix. Continued.

		Forest type and silvicultural treatment											Repeated-measures ANOVA[c]			
		UHM (n = 8)		CHM (n = 8)		UHR (n = 9)		CHR (n = 6)		2-way ANOVA (/yr)[b]			P_{silv}	P_{for}	$P_{silv \times for}$	
Species	**Yr**	$\bar{x}$	**SE**	$\bar{x}$	**SE**	$\bar{x}$	**SE**	$\bar{x}$	**SE**	P_{silv}	P_{for}	$P_{silv \times for}$	P_{yr}	$P_{yr \times silv}$	$P_{yr \times for}$	$P_{yr \times silv \times for}$
Total vine	1999	40.1	40.1	4.2	4.1	0.0	0.0	0.7	9.7	0.2996	0.9316	0.5985	0.4281	0.7075	0.5862	
	2000	24.2	24.2	415.0	404.5	105.4	68.2	15.7	15.3	0.8111	0.9648	0.3510	0.0007	0.0702	0.4920	0.4627
	2001	27.7	27.7	460.1	458.5	764.0	487.7	75.7	58.9	0.2852	0.9355	0.5874				
	2002	60.1	60.1	1,037.6	829.4	963.8	564.8	300.2	197.4	0.3887	0.4308	0.5461				
	2003	43.0	43.0	153.2	144.8	513.9	332.6	245.0	167.3	0.1556	0.6366	0.6672				
Total	1999	1,651.1	689.1	509.0	268.1	1,528.6	834.4	1,591.5	1,350.2	0.7427	0.4009	0.9458	0.0004	0.0967	0.8574	
	2000	1,633.6	532.6	992.4	398.6	4,906.8	1,455.9	2,432.6	994.5	0.2200	0.0527	0.6737	<0.0001	0.0130	0.3501	0.5478
	2001	1,222.5	667.3	718.3	450.7	9,644.9	3,137.7	3,617.4	935.6	<0.0001	0.0358	0.9082				
	2002	761.4	294.8	2,033.1	917.3	14,872.1	4,078.5	7,426.9	2,633.4	<0.0001	0.8476	0.3236				
	2003	1,926.0	508.2	591.6	154.1	15,963.3	2,793.6	11,587.8	4,198.1	<0.0001	0.0515	0.1946				

[a] Species that were lumped for analysis are noted in the species column.
[b] P-values for 2-way analysis of variance (ANOVA), using silvicultural treatment (R or M; silv) and forest type (UH or CH; for) as main effects, are given separately for each yr.
[c] Repeated-measures P-values for between-subject effects (holding yr constant) include silvicultural treatment, forest type, and silvicultural treatment × forest type interaction (first line). Repeated measures P-values for within-subject effects (analyzing effect of yr) include yr, silvicultural treatment × yr, forest type × yr, and silvicultural treatment × forest type × yr interactions (second line).