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ASSESSMENT OF NONNATIVE INVASIVE PLANTS IN THE DOE OAK RIDGE NATIONAL ENVIRONMENTAL RESEARCH PARK

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Environmental Sciences Division

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ABSTRACT

The Department of Energy (DOE) National Environmental Research Park at Oak Ridge, Tennessee, is composed of second-growth forest stands characteristic of much of the eastern deciduous forest of the Ridge and Valley Province of Tennessee. Human use of natural ecosystems in this region has facilitated the establishment of at least 167 nonnative, invasive plant species on the Research Park. Our objective was to assess the distribution, abundance, impact, and potential for control of the 18 most abundant invasive species on the Research Park. In 2000, field surveys were conducted of 16 management areas on the Research Park (14 Natural Areas, 1 Reference Area, and Walker Branch Watershed) and the Research Park as a whole to acquire qualitative and quantitative data on the distribution and abundance of these taxa. Data from the surveys were used to rank the relative importance of these species using the "Alien Plant Ranking System, Version 5.1" developed by the U.S. Geological Survey. Microstegium *(Microstegium vimineum)* was ranked highest, or most problematic, for the entire Research Park because of its potential impact on natural systems, its tendency to become a management problem, and how difficult it is to control. Microstegium was present in 12 of the 16 individual sites surveyed; when present, it consistently ranked as the most problematic invasive species, particularly in terms of its potential impact on natural systems. Japanese honeysuckle (*Lonicera japonica)* and Chinese privet (*Ligustrum sinense)* were the second- and third-most problematic plant species on the Research Park; these two species were present in 12 and 9 of the 16 sites surveyed, respectively, and often ranked second- or third-most problematic. Other nonnative, invasive species, in decreasing rank order, included kudzu (*Pueraria montma),* multiflora rose (Rosa *multiflora),* Chinese lespedeza *(Lespedeza cuneara),* and other species representing a variety of life forms and growth forms. Results of this research can be used to prioritize management and research activities related to these invasive taxa on the Research Park as a whole and for specific Natural or Reference Areas. Additional research on the autecology and synecology of each species surveyed is suggested. In particular, research should focus on assessing the impacts of these species on the invaded plant and animal communities and ecosystems. Finally, this ranking system could be used to similarly rank the many other nonnative, invasive species present on the Research Park not included in this study.

1. INTRODUCTION

Invasive plants are defined in this document as plants that are not native to an area and that may potentially displace or otherwise adversely affect native plant and animal species (Bowen 1996). Plants that are novel to a particular site or region may successfully establish and maintain relatively dense populations for several reasons. First, there may be a lack of natural growth inhibitors, such as predators, parasites, and diseases, at the site of introduction, thus allowing the nonnative plant to spread (White 1997). Second, invasive plants are often prolific seed producers, with seeds that may disperse widely and that may remain viable in the soil for long periods of time (Rejmanek and Richardson 1996). Alternatively, invasive plants may reproduce asexually through extensive root growth, suckering, and resprouting (White 1997). Invasive plants are often capable of producing larger and higher quality fruit than native congeners, thus making them a better food source for animals and birds that may aid in their dispersal. For example, common hawthorn (*Crataegus monogyna*) has rapidly become established throughout portions of western Oregon because its seeds have been carried great distances by birds (Sallabanks 1993).

Invasive plants tend to be most problematic in disturbed areas (Vitousek 1990). Kudzu (*Pueraria montana*) is a notorious invader of roadsides and power transmission line rights-of-way in the southeastern United States, but it is seldom found in adjacent, lessdisturbed habitats (Plant Conservation Alliance 1997). In contrast, some invasive plants are capable of establishing in relatively undisturbed sites. For example, microstegium (*Microstegiurn virnineurn*) appears to invade forests that have been undisturbed for decades (Barden 1987, Redman 1995).

Invasive plants are often the target of management activities designed to eradicate them, or control their spread, in order to minimize their impact on existing ecological systems. However, management activities are often hampered by limited funds, time, and personnel. Even if adequate resources were available, managers may lack information about the natural history of the many different species in question and knowledge about the potential impacts that each species may have. Further, depending on the region and the management area in question, there may be numerous invasive species all deserving of management attention. For example, surveys of the flora at the Oak Ridge National Environmental Research Park in Tennessee have documented 167 nonnative, invasive species to date (Appendix A). Thus, managers need to prioritize their activities to focus on those species that may pose the greatest threat to existing management goals.

The 167 nonnative, invasive species on the Research Park (hereafter Research Park) are classified as "aggressive," "questionably aggressive," "passive," and "questionably passive" based on their abundance, distribution, and a qualitative assessment of their tendency to exclude native plant species (Awl et al. 1996). However, the relative importance of taxa within each classification has not been determined.

Forty-two of the 167 invasive species are classified as "aggressive" (listed in Appendix B). Awl (Tennessee Valley Authority, May 2000, personal communication) identified 10 of these aggressive invasive species for which basic information on the distribution and abundance were available for the Research Park. She then prioritized them in terms of management using a quantitative ranking system developed by the National Park Service (Table 1). Although purple loosestrife (*Lythrum salicaria*) was ranked relatively low in this original ranking because of its limited distribution, Awl moved it to the top of the list because of its potential to spread from its single location of Occurrence on the Research Park.

Table 1. The ten most aggressive invasive plants on the Research Park ranked by Awl **and Pounds** (unpublished manuscript)

Scientific name	Common name	Rank
Lythrum salicaria	Purple loosestrife	1
Pueraria montana	Kudzu	2
Elaeagnus umbellata	Autumn olive	3
Ligustrum sinense	Chinese privet	4
Ailanthus altissima	Tree-of-heaven	5
Celastrus orbiculatus	Oriental bittersweet	6
Microstegium vimineum	Microstegium (Japanese grass)	7
Lonicerajaponica	Japanese honeysuckle	8
Rosa multiflora	Multiflora rose	9
Sorghum halepense	Johnsongrass	10

The goal of our research was to determine the relative importance of 18 of the most abundant or widespread invasive species on the Research Park in terms of their potential impact on natural systems, their tendency to become management problems, and their potential for control. The 18 species ranked herein include nine of the ten taxa previously ranked by Awl (Tennessee Valley Authority, May 2000, personal communication) and nine additional species widely distributed throughout the Research Park (Table 2). Purple loosestrife was excluded from the analysis because it has been practically eradicated from the one site it occupied at the time of Awl's original investigation (Pounds, L. R., ORNL Consultant, 2000, personal communication). The nine species new to this analysis include Chinese yam ***(Dioscorea batatas)***, periwinkle ***(Vinca minor),*** field garlic ***(Allium vineale),*** Chinese lespedeza ***(Lespedeza cuneata),*** spearmint ***(Mentha spicatu),*** bull thistle ***(Cirsium vulgare)***, crown vetch ***(Coronilla varia)***, empress tree ***(Paulownia tomentosa),*** and watercress ***(Nasturtium officinale)***.

Table 2. Ranking of invasive species in each management area, including Natural Areas (NA), **Reference** Area **8 (RA8), and Walker Branch Watershed (WBW)** within **the Research Park**

Raw scores for each section of the ranking system (i.e., potential impact on natural systems, its tendency to become a management problem or pest, and how difficult it is to control) are summed to provide a total raw score. The final rank, where 1 is most problematic overall, was assigned based on the total raw score.

Area	Scientificname	Commonname	Impact	Pest	Control	Total	Rank
NA2	***Microstegium vimineum***	Japanese grass	56	71	24	151	1
	Ligustrum sinense	Chinese privet	33	70	24	127	2
	Lonicera japonica	Japanese honeysuckle	31	*60*	29	120	3
	Lespedeza cuneata	Chinese lespedeza	*22*	59	16	97	4
	Celastrus orbiculatus	Oriental bittersweet	31	30	19	80	5
	Ailanthus altissima	Tree-of-heaven	13	48	13	74	6
	Elaeagnus umbellata	Autumn olive	9	51	13	73	7

Table 2 (continued)

Area	Scientificname	Commonname	Impact	Pest	Control	Total	Rank
NA4	*Microstegium vimineum*	Japanese grass	56	71	24	151	1
	Ligustrum sinense	Chinese privet	33	70	21	124	2
	Lespedeza cuneata	Chinese lespedeza	31	49	32	112	3
	Dioscorea batatas	Chinese yam	44	37	11	92	4
	Paulownia tomentosa	Empress tree	11	54	9	74	5
	Coronilla varia	Crown vetch	13	17	7	37	6
NA8	*Lespedeza cuneata*	Chinese lespedeza	36	59	32	127	1
	Lonicera japonica	Japanese honeysuckle	29	60	21	110	2
	Ligustrum sinense	Chinese privet	18	70	20	108	3
	Pueraria montana	Kudzu	45	35	24	104	4
NA9	*Microstegium vimineum*	Japanese grass	64	67	37	168	1
	Lonicera japonica	Japanese honeysuckle	29	56	24	109	2
NA10	*Microstegium vimineum*	Japanese grass	64	67	37	168	1
	Lespedeza cuneata	Chinese lespedeza	36	59	32	127	2
	Lonicera japonica	Japanese honeysuckle	29	56	24	109	3
	Dioscorea batatas	Chinese yam	35	37	11	83	4
	Paulownia tomentosa	Empress tree	11	54	9	74	5
NA11	*Microstegium vimineum*	Japanese grass	51	63	16	130	1
	Rosa multiflora	Multiflora rose	29	54	27	110	2
	Lonicera japonica	Japanese honeysuckle	29	56	24	109	3
	Ligustrum sinense	Chinese privet	18	65	20	103	4
NA13	*Microstegium viminewn*	Japanese grass	64	71	37	172	1
	Lonicera japonica	Japanese honeysuckle	29	56	24	109	2

Table 2 (continued)

Area	Scientificname	Commonname	Impact	Pest	Control	Total	Rank
	Lespedeza cuneata	Chinese lespedeza	25	54	20	99	3
	Dioscorea batatas	Chinese yam	49	38	4	91	4
	Elaeagnus umbellata	Autumn olive	18	51	13	82	5
	Vinca minor	Periwinkle	29	13	11	53	6
NA18	***Microstegium vimineum***	Japanese grass	***64***	71	37	172	**1**
	Lespedeza cuneata	Chinese lespedeza	36	48	32	116	2
	Lonicera japonica	Japanese honeysuckle	29	56	24	109	3
	Paulownia tomentosa	Empress tree	11	49	9	69	4
	Vinca minor	Periwinkle	29	13	7	49	5
	Cirsium vulgare	Bull thistle	9	27	4	40	6
NA20	***Microstegium vimineum***	Japanese grass	45	71	20	**136**	1
	Ligustrum sinense	Chinese privet	36	70	20	126	2
	Lespedeza cuneata	Chinese lespedeza	27	48	23	98	3
	Rosa multiflora	Multiflora rose	25	48	24	97	**4**
	Pueraria montana	Kudzu	45	35	17	97	5
	Ailanthus altissima	Tree-of-heaven	16	51	15	82	6
	Dioscorea batatas	Chinese yam	35	32	11	78	7
	Vinca minor	Periwinkle	29	13	8	50	8
	Cirsium vulgare	Bull thistle	9	24	4	37	9
	Sorghum halepense	Johnsongrass	9	8	4	21	10
NA 21a	***Microstegium vimineum***	Japanese grass	56	67	37	160	1
	Ligustrum sinense	Chinese privet	47	70	40	157	2
	Lonicera japonica	Japanese honeysuckle	45	60	33	138	3
	Rosa multiflora	Multiflora rose	35	60	31	126	4
	Elaeagnus umbellata	Autumn olive	29	37	24	90	5
NA24	***Mentha spicata***	Spearmint	29	25	13	67	1

Table 2 (continued)

Area	Scientificname	Commonname	Impact	Pest	Control	Total	Rank
NA42	***Microstegium vimineum***	Japanese grass	56	67	37	160	1
	Lonicera japonica	Japanese honeysuckle	45	56	33	134	2
	Rosa multiflora	Multiflora rose	35	60	31	126	3
	Dioscorea batatas	Chinese yam	53	43	24	120	4
	Lespedeza cuneata	Chinese lespedeza	35	51	29	115	5
NA43	***Ligustrum sinense***	Chinese privet	31	70	29	130	1
	Rosa multiflora	Multiflora rose	35	60	31	126	2
	Lespedeza cuneata	Chinese lespedeza	33	51	36	120	3
	Lonicera japonica	Japanese honeysuckle	36	56	23	115	4
	Allium vineale	Field garlic	45	29	28	102	5
	Elaeagnus umbellata	Autumn olive	22	37	17	76	6
	Nasturtium oflcinale	Watercress	13	21	7	41	7
NA47	***Microstegium vimineum***	Japanese grass	58	67	40	165	1
	Ligustrum sinense	Chinese privet	47	70	40	157	2
	Lonicera japonica	Japanese honeysuckle	55	52	33	140	3
	Rosa multiflora	Multiflora rose	35	63	31	129	4
	Dioscorea batatas	Chinese yam	53	43	24	120	5
	Lespedeza cuneata	Chinese lespedeza	36	51	32	119	6
	Ailanthus altissima	Tree-of-heaven	22	59	21	102	7
	Elaeagnus umbellata	Autumn olive	22	37	17	76	8
	Vinca minor	Periwinkle	29	21	21	71	9
	Nasturtium oflcinale	Watercress	13	21	7	41	10
	Cirsium vulgare	Bull thistle	9	27	4	40	11
RA8	***Lespedeza cuneata***	Chinese lespedeza	45	51	32	128	1

Table 2 (continued)

Area	Scientificname	Commonname	Impact	Pest	Control	Total	Rank
	Ligustrum sinense	Chinese privet	22	67	27	116	2
	Allium vineale	Field garlic	25	41	24	90	3
	Sorghum halepense	Johnsongrass	9	8	15	32	4
WBW	***Microstegium vimineum***	Japanese grass	56	67	37	160	1
	Lonicera japonica	Japanese honeysuckle	45	51	28	124	2
	Lespedeza cuneata	Chinese lespedeza	33	51	28	112	3
	Vinca minor	Periwinkle	29	21	24	74	4

The research objectives were to rank these 18 species for (1) the entire Research Park and (2) each of 16 important management areas on the Research Park. Data for ranking were collected using field surveys and a review of the literature. We used a different ranking system than that previously employed by Awl (Tennessee Valley Authority, May 2000, personal communication) ***that*** was developed by the U.S. Geological Survey and termed the "Alien Plant Ranking System" (APRS Implementation Team 2000).

2. METHODS

2.1 RESEARCH PARK SITE DESCRIPTION

The Oak Ridge National Environmental Research Park is located on the 13,860 ha (34,241 acre) Department of Energy Oak Ridge Reservation in Anderson and Roane counties, Tennessee (Fig. 1). The Research Park is situated within the Ridge and Valley Province west of the Appalachian Mountains (ORNL 2002). This region is characterized by roughly parallel ridges and valleys formed within the folds of Paleozoic sediments. The ridge and valley topography results from differential erosion of alternating layers of resistant sandstone and less-resistant limestone (McKnight 1997). This geologic pattern results in the many caves and sinkholes that can be found on the Research Park.

The Ridge and Valley Province is located within the Temperate Mesophytic Forest Region (Daubenmire 1978). Upland sites are characterized by second- and third-growth oak-hickory forest stands, with *Quercus* spp., *Carya* spp., and *Acer* spp. the dominant overstory species. Stands of pines (*Pinus echinata*, *P. virginiana*, *P. taeda*) occupy ridges, abandoned agriculture fields, and pine plantations. Mesophytic hardwoods (*Tilia*, *Liriodendron*) dominate the lower slopes.

Climate in this region is characterized by cold winters and long frost-free summers. Mean annual temperature is about 14°C, and mean annual precipitation is about 1300 mm (Hanson et al. 1998). Soils are generally acidic and well weathered and are classified primarily as typic paleudults (Hanson et al. 1998).

2.2 MANAGEMENT AREAS ON THE RESEARCH PARK

A total of 16 management areas, including Research Park Natural Areas, a Research Park Reference Area, and the Walker Branch Watershed, were selected for detailed field surveys (Fig. 1). Research Park Natural Areas were established to protect state-listed or federally listed rare species that occur on the Oak Ridge Reservation (Pounds, Parr, and Ryon 1993). Fourteen areas, representing a variety of habitats distributed throughout the Research Park, were selected for the survey. Natural Areas surveyed included mesic deciduous forest, palustrine forested wet-lands, a palustrine emergent marsh, limestone outcrops, and power transmission line rights-of-way.

Research Park Reference Areas are vegetational communities representative of the southern Appalachian region or sites that possess unique biotic features ((Pounds, Parr, and Ryon 1993). The single Reference Area surveyed in this study, a cedar glade or barren on a limestone outcrop, was selected because it is a unique example of this plant community type on the Research Park and because it contains plant taxa uncommon to the region (e.g., *Yucca* spp. and *Opuntia* spp.).

Walker Branch Watershed is a research watershed that consists of two subcatchments with a total area of approximately 100 ha. Similar to other upland sites on the Research Park, the watershed is dominated by second- and third-growth oak-hickory, pine, and mesophytic hardwood forests that have established on former pastures or croplands. The underlying soils are acidic, very cherty, infertile, and quite permeable to water. There is a long and relatively well-known history of anthropogenic disturbance and research on the site, which is one of a few sites in the world characterized by long-term, intensive environmental studies at the watershed scale (Johnson and Van Hook 1989). Taxonomic nomenclature is from Wofford and Kral (1993).

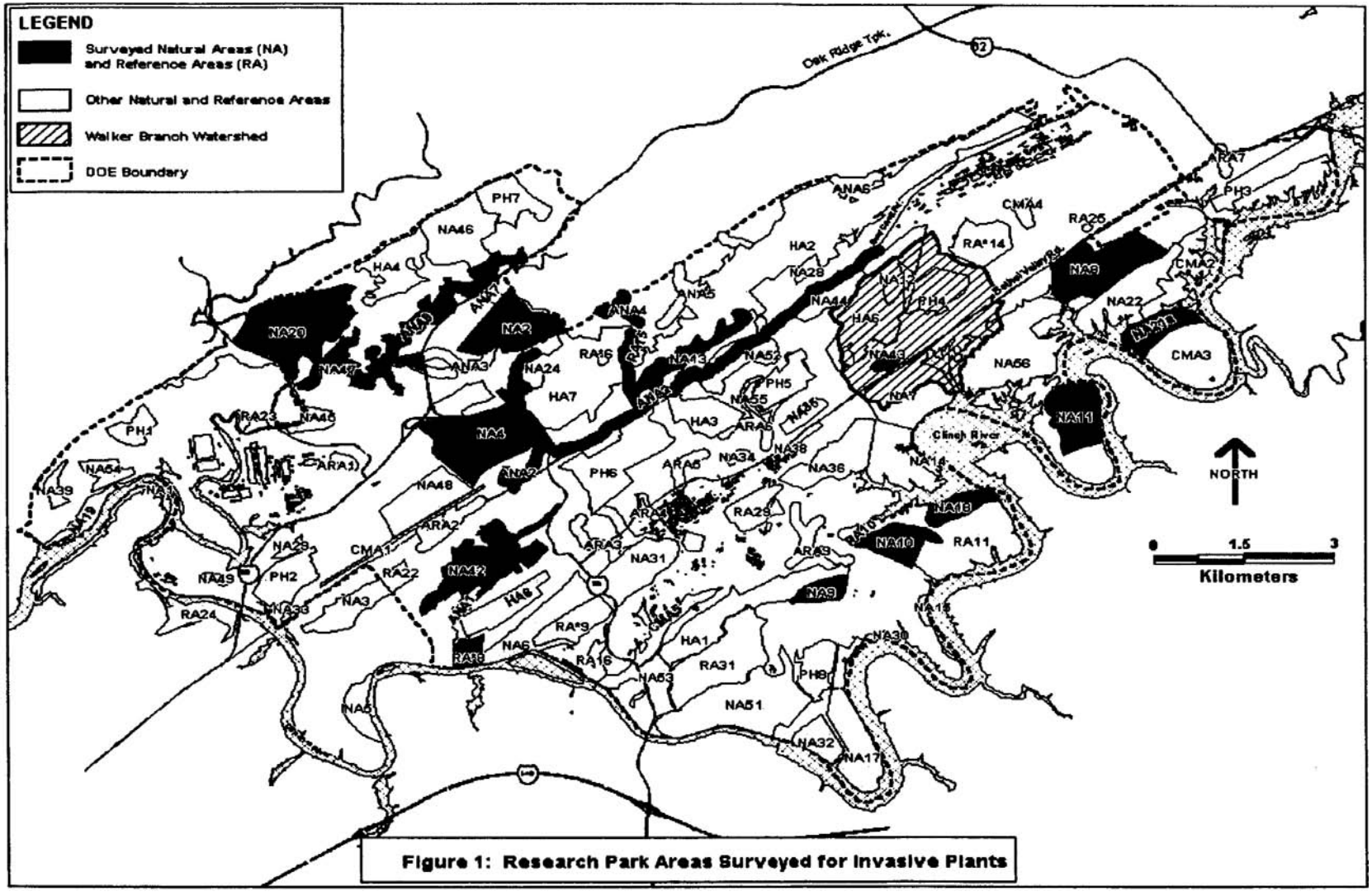

Fig. 1. Research Park Areas surveyed for invasive plants.

2 3 INDIVIDUAL MANAGEMENT AREA SITE DESCRIPTIONS

23.1 Natural Area 2

Natural Area 2 is located along U.S. Highway 95 between Hot Yard Road and Midway Turnpike (Fig. 1). This moist woodland contains a variety of tree species, including basswood (*Tilia americana*), beech (*Fagus grandifolia*), and maple (*Acer* spp.). Natural Area 2 contains goldenseal (Hydrastis *canadensis*) and Canada lily (*Lilium canadense*) (Pounds, Parr, and Ryon 1993; Cunningham et al. 1993), which are listed as "Threatened Species" by the Tennessee Department of Environment and Conservation (TDEC). Microstegium is abundant throughout the site and forms a dense mat in the understory of this mid-successional forest. Chinese lespedeza (*Lespedeza cuneata*) and Japanese honeysuckle (*Lonicera japonica*) grow all along the length of the road. Japanese honeysuckle is especially abundant along the northeastern boundary of the Natural Area where a fence separates the Research Park from an adjacent neighborhood. Autumn olive (*Elaeagnus umbellata*), tree-of-heaven (*Ailanthus altissima*), and Chinese privet (*Ligustrum sinense*) also grow along the road but occur in smaller patches. Removal of a patch of oriental bittersweet (*Celastrus orbiculatus*) was initiated in July 2000 and continued in July 2001 by groups of high school teachers through the Appalachian Regional Commission Summer Research Program. The plants were either pulled up by hand or cut with a saw and treated with a glyphosate herbicide.

2 3 3 Natural Area 4

Natural Area 4, or Rein-Orchid Swamp, is a forested wetland at the intersection of Highway 95 and the Oak Ridge Turnpike (Fig. 1). The wetland is bordered by streams, a highway, and a power transmission line right-of-way that could each facilitate plant invasions. The wetland contains the northern tubercled rein-orchid (*Platanthera flava* var. *herbiola*), which is listed by TDEC, and the golden club (*Orontiurn aquaticurn*), which is uncommon to wetlands of the region (Pounds, Parr, and Ryon 1993; Cunningham et al. 1993). Microstegium, Chinese yam (*Dioscorea batatas*), and Chinese privet are abundant throughout the Natural Area but occur in larger patches along the stream that bisects the area. Several empress trees (*Paulownia tomentosa*) are present along the road. Chinese lespedeza is also abundant along the road as well as within the power transmission line right-of-way. Crown vetch (*Coronilla varia*) occurs for many meters along the grassy margin between the Natural Area and Highway 95.

233 Natural Area 8

Natural Area 8 is located in the McCoy Branch Embayment "Barren," just northwest of Freel's Bend (Fig. 1). The southern portion of this embayment consists of secondary forest. Invasive plants include a large patch of kudzu (*Pueraria montana*), which grows along the road, and Japanese honeysuckle, which occurs throughout this area. Chinese privet is present but uncommon. The northern portion of this embayment consists of a power transmission right-of-way that is mowed annually. Also a registered State Natural Area, this site contains the TDEC-listed endangered tall larkspur (*Delphinium exaltatum*) (Pounds, Parr, and Ryon 1993; Cunningham et al. 1993). The only invasive plant observed in the right-of-way was Chinese lespedeza, which grew amongst and adjacent to the tall larkspur.

23.4 Natural Area 9

Natural Area 9, or Cesium Forest Orchid Area, is located on Copper Ridge. This immature, mesic forest is dominated by tulip poplar (*Liriodendron tulipifera*). The uncommon lesser

ladies'-tresses orchid (*Spiranthes ovalis*) is present in one of the sinks in this area (Pounds, Parr, and Ryon **1993).** Invasive plants include large and dense patches of microstegium and Japanese honeysuckle that occur throughout the Natural Area.

23.5 Natural Area 10

Natural ***Area* 10,** known as Lazy Beaver Forest, is located on Copper Ridge in both Roane and Anderson counties. This Natural Area is a mesic forest dominated by tulip poplar and contains a TDEC threatened species, goldenseal (Hydrastis ***canadensis)*** as well as the uncommon lesser ladies'-tresses orchid (Pounds, Parr, and Ryon **1993).** Dense carpets of microstegium and Chinese yam were observed near the roads. Empress tree and Chinese lespedeza are quite abundant in sunny areas. Japanese honeysuckle is present throughout the site in small amounts but is not a significant problem in this Natural Area.

23.6 Natural Area 11

Natural Area **11,** or Bull Bluff, is a steep, limestone bluff with many cave entrances and sinkholes. This wooded slope contains the TDEC threatened species, Appalachian bugbane (*Cimicifuga rubifolia*) and northern bush-honeysuckle (***Diervilla lonicera)*** (Pounds, Parr, and Ryon; Cunningham et al. **1993).** This Natural Area contains very few invasive plant species. Dense thickets of multiflora rose ***(Rosa multiflora)*** occur along the road adjacent to the site but are not expected to spread into the Natural Area because they require large amounts of sunlight. Microstegium also occurs in dense patches along the road and extends into the Natural Area for a few meters in several places. Honeysuckle was found throughout the site but in very minimal numbers. A single privet plant found on a tree root tip-up mound was removed during the survey in June 2000.

23.7 Natural Area 13

Natural Area **13** is located on Pine Ridge, east of Gum Branch Road and north of Bear Creek Road. Small streams that flow perpendicular to the area bisect Natural Area **13,** which is characterized by forested floodplains and wetlands. A gravel road extends into the area and ends at a small cemetery where a patch of periwinkle ***(Vinca minor***) can be found. TDEC-listed species that occur here include Canada lily and the northern tubercled rein-orchid (Pounds, Parr, and Ryon **1993;** Cunningham et al. **1993).** Extensive amounts of microstegium occur in the area and were observed growing alongside the northern tubercled rein-orchid.

23.8 Natural Area 18

Natural Area **18** is located on the eastern end of Copper Ridge and is bordered by a gravel road on one side and Melton Hill Lake on the other. This limestone outcrop area is rocky, and contains many sinkholes and caves (Pounds, Parr, and M. G. Ryon **1993).** Microstegium, Chinese lespedeza, and periwinkle are most abundant along the road and waterfront but extend into the forest in smaller amounts. Microstegium is not present within the higher points of this area. In contrast, Japanese honeysuckle is abundant at these higher points, although it is scattered throughout the entire Natural Area. Several empress tree and bull thistle ***(Cirsium vulgare)*** populations occur in the road margins.

23.9 Natural Area 20

Natural Area 20 is located on the slope of Black Oak Ridge along Poplar Creek. This area contains a few small limestone cliffs and is registered as a State Natural Area through a DOE/TDEC agreement. Many of the species that occur here are not common to the Research Park; they include spider lily (*Hymenocallis ocidentalis*) and fringe tree (*Chionanthus virginicus*). TDEC-listed species include pink lady's-slipper (Cypripedium *acaule*), which is considered threatened because it has experienced high levels of harvesting, and the threatened spreading false-foxglove (*Aureolaria patula*) (Pounds, Parr, and Ryon 1993; Cunningham et al. 1993). Chinese yam, privet, and multiflora rose grow along the road but have not apparently established within the Natural Area proper. There are dense stands of Chinese lespedeza, microstegium, and Johnson grass (Sorghum *halepense)* along the road. Bull thistle, tree-of-heaven, and kudzu were also noted along the road, and periwinkle is present in small amounts within the Natural Area. The North Boundary Road Greenway, open to the public, passes through a portion of this Natural Area.

23.10 Natural Area 21a

Natural Area 21a, or Rainy Knob Bluff, is located near Freel's Bend along Melton Hill Lake. This forested Natural Area is located on a hill and contains a large open limestone sinkhole. Carey saxifage (*Saxifraga careyana*) grows on the walls of the sinkhole. This species was recently removed from the list of species of special concern because its population has increased in recent years. Microstegium is especially abundant throughout the forest, whereas Chinese privet and multiflora rose, while still abundant, are less so than microstegium. The Chinese privet that is present is quite young and could easily be removed. Autumn olive was most abundant along the road at the edge of the Natural Area; however, several autumn olive plants were observed growing in the forest. Japanese honeysuckle is present in the Natural Area, but in minimal numbers.

23.11 Natural Area 24

Natural Area 24, or Hembree Marsh, is located between U.S. Highway 95 and Old County Road. This palustrine, emergent marsh is formed by perennial seeps and deep groundwater springs and is dominated by tall grasses, sedges, rushes, and other plants typical of such wetland systems in the region. It contains the fen orchid (*Liparis loeselii*), which is listed by TDEC as endangered (Pounds, Parr, and Ryon 1993; Cunningham et al. 1993). Hembree Marsh is part of the Bear Creek/McNew Hollow Floodplain, a registered State Natural Area. The only invasive species present in the marsh is a large patch of spearmint (Mentha *spicatu),* which occurs throughout the marsh.

23.12 Natural Area 42

Natural Area 42, known as New Zion Boggy Area, is located west of the intersection of Bethel Valley Road and Highway 95 on Chestnut Ridge near New Zion Cemetery. This 152-ha forested wetland is maintained by springs and often has patches of standing water throughout the year. TDEC-listed species that occur here include Pink lady's-slipper, Canada lily, and heavy sedge (Carex *gravida).* It was listed as RA20 until the TDEC-listed species were discovered there (Pounds, Parr, and Ryon 1993; Cunningham et al. 1993). Invasive species in the area include Chinese yam, microstegium, lespedeza, honeysuckle, and multiflora rose, especially on small upland islands and peninsulas throughout the wetland.

23.13 Natural Area 43

Natural Area 43 is located along a power transmission line right-of-way, west of Walker Branch watershed and north of Bethel Valley Road. This area contains the state-listed tall larkspur (*Delphinium exaltatum*) that grows along the hillside (Pounds, L. R., ORNL Consultant; P. D. Parr and M. G. Ryon, Oak Ridge National Laboratory; 2001, personal communication). Routine right-of-way maintenance includes periodic mowing to reduce the shoot extension of trees. Field garlic and Chinese lespedeza are abundant throughout the Natural Area, while Chinese privet, Japanese honeysuckle, autumn olive, and multiflora rose are abundant along the edges of the area and along the roadside. A small patch of watercress (*Nasturtium officinale*) occurs within a perennial stream crossing.

23.14 Natural Area 47

Natural Area 47 is located along the floodplain of East Fork Poplar Creek. This Natural Area encompasses 171 ha and contains canebreaks, which are patches of river bank dominated by native river cane (*Arundinaria gigantea*). The majority of the area contains a floodplain hardwood forest dominated by box elder, sycamore, and ash (Pounds, L. R., ORNL Consultant; P. D. Parr and M. G. Ryon, Oak Ridge National Laboratory; 2001, personal communication). Species listed by TDEC as threatened that occur in this area include golden seal, pink lady's-slipper, and ginseng (*Panax quinquefolium*). Numerous invasive plant species were observed in this Natural Area, including dense stands of Chinese privet. Other common invasive plant species that are abundant throughout the area include microstegium, Japanese honeysuckle, and Chinese yam. Chinese lespedeza, bull thistle, multiflora rose, and tree-of-heaven are profuse along the road. Autumn olive and periwinkle occur in small numbers throughout the area, and watercress was present in one location along a stream bank.

23.15 Reference Area 8

Reference Area 8 is a cedar barren limestone outcrop near Raccoon Creek. The area is very sunny, and the soil is thin and rocky, especially on steeper slopes. Red cedar (*Juniperus virginiana*), yucca (*Yucca filamentosa*), and prickly pear cactus (*Opuntia humifusa*) are present (Pounds, Parr, and Ryon 1993). Chinese lespedeza is present in small numbers within the area, but it forms small, dense patches along the road. Johnson grass forms dense clumps along the road, and Chinese privet and field garlic are present along the road in smaller numbers.

23.16 Walker Branch Watershed

Walker Branch Watershed contains fewer invasive plants than many of the Natural Areas. Microstegium is present but is relatively uncommon; it is largely confined to access roads but forms small, scattered patches along ephemeral to perennial watercourses. Periwinkle forms dense stands along floodplains and at abandoned homesites. Lespedeza grows along many of the access roads, and Japanese honeysuckle is particularly prevalent in pine plantations.

2.4 RANKING PROCEDURE

A semiquantitative ranking system developed by the U.S. Geological Survey (APRS Implementation Team 2000) was used to rank the 18 nonnative subject species in this study. Generally, the "Alien Plants Ranking System" uses a query system to compile information about the characteristics of each invasive species, as well as the attributes of the invaded community.

The rationale behind this approach is based on limited evidence that the invasion of a community by a nonnative plant species is controlled by the biological characteristics of the species in question, the number of propagules entering the community, and the susceptibility of the community to invasion (Lonsdale **1999).** In turn, the susceptibility of a plant community to invasion is likely influenced by its disturbance regime, the competitive abilities of native species, and the prevailing climatic conditions (Lonsdale **1999).**

The query list for each species consists of **23** "multiple-choice" questions arranged in three sections (Appendix C). Section I, "Significance of Threat or Impact (Site Characteristics)," is designed to determine the relative distribution and abundance of each species and its potential effect on native communities. Section II, "Innate Ability to Become a Pest," determines the autecological characteristics of the plant, and Section 111, "Difficulty of Control," describes the feasibility and effects of control measures. Responses to queries for the Research **Park** as a whole, and for each management area, **are** in Appendices D and E, respectively. Species abstracts are in Appendix F.

Queries in Section I (Significance of Threat or Impact and Site Characteristics) include the following:

1. Distribution relative to disturbance regime
2. Areal extent of populations
3. Numerical dominance of species within a community
4. Association with native community
5. Hybridization with native species
6. Degree of threat and impact
7. Effects on management goals

These queries were answered based on field surveys, interviews with managers knowledgeable about the sites and species, aerial photograph interpretation, and reviews of existing literature. Field surveys and interviews were conducted during the **2000** growing season. Field surveys were conducted primarily to estimate the distribution and abundance of each species in each management area for queries 1 through **3.** Field surveys were relatively extensive; more systematic, intensive surveys (e.g., transects) were utilized as necessary in order to provide information sufficient to answer each query for each species. Species distributions relative to disturbance regimes were determined based on the distribution of each species relative to the **type,** intensity, scale, and history of disturbance in the subject area. For example, microstegium and Japanese honeysuckle were often found in areas that have not been disturbed for at least 50 years, whereas Chinese lespedeza and field garlic were found growing in areas that are more disturbed by either roads or power line clearings.

Areal extents and numerical dominance were determined by estimating the proportion of each site occupied by each species. When determining the association of each species with native community, the response that best indicated the successional level of that portion of the management area that contained the species in question was selected. In contrast, when ranking each species within the Research Park as a whole, the response that best indicated the stand at the *latest* successional stage occupied by that species on the Research Park was selected. The potential for hybridization with native species was answered for each species based on reviews of the literature. **Threats,** impacts, and effects of each species on management goals were determined based on conversations with managers and scientists familiar with the **area,** coupled with observations of the density and distribution of each species at each site.

Section II (Innate Ability to Become a Pest) includes the following ten questions:

8. Mode of reproduction
9. Vegetative reproduction
10. Frequency of sexual reproduction for mature plant
11. Number of seeds per plant
12. Dispersal ability
13. Germination requirements
14. Seedbanks
15. Competitive ability
16. Ecological effects
17. Known level of impact in natural areas

Answers to the first nine questions were based on reviews of the scientific literature. However, for most of our subject species, there is a paucity of data on competitive ability. Therefore we answered "unknown" for all species except kudzu. Similarly, the effects and impacts of these invasive species on native ecosystems are largely unknown, which mirrors the general dearth of scientific understanding of effects of invasive plants worldwide (Parker et al. 1999). Nonetheless, we estimated ecological effects and impacts based on reviews of the literature and our knowledge of the autecology and synecology of these species.

Section III (Difficulty of Control) includes the following six questions:

18. Likelihood of successful control
19. Saturation in surrounding region
20. Effectiveness of community management
21. Vegetative regeneration
22. Biological control
23. Side effects of control measures

These questions were answered through reviews of the literature, field observations, and interviews with managers familiar with physical, chemical, and biological control techniques.

3. RESULTS AND DISCUSSION

3.1 SPECIES RANKS FOR THE RESEARCH PARK

Out of the 18 species ranked in this study, microstegium was identified as the most problematic nonnative, invasive plant on the Research Park as a whole (Table 3). Microstegium was ranked highest, or most problematic, because of its potential impact on natural systems, its tendency to become a management problem, and the difficulty of its control. Microstegium is present in numerous, dense stands across the Research Park, in both disturbed, early-successional habitats as well as relatively undisturbed, late-successional forest communities. In addition, it was present across a broad range of environmental conditions, from shallow flowing-water habitats to margins of gravel roads along dry ridge tops.

Table 3. Nonnative, invasive plants on the Research Park ranked by this study

Raw scores for each section of the ranking system (i.e., potential impact on natural systems, its tendency to become a management problem or pest, and how difficult it is to control) are summed to provide a total raw score. The final rank, where 1 is most problematic overall, was assigned based on the total raw score.

Scientific name	Commonname	Impact	Pest	Control	Total	Rank
Microstegium vimineum	Japanese grass	60	67	44	171	1
Lonicera japonica	Japanese honeysuckle	58	60	40	158	2
Ligustrum sinense	Chinese privet	44	70	33	147	3
Pueraria Montana	Kudzu	58	41	48	147	4
Rosa multiflora	Multiflora rose	36	59	35	130	5
Lespedeza cuneata	Lespedeza	36	59	33	128	6
Dioscorea batatas	Chinese yam	53	43	24	120	7
Ailanthus altissima	Tree-of-heaven	27	52	24	103	8
Allium vineale	Field garlic	24	38	31	93	9
Elaeagnus umbellate	Autumn olive	29	37	24	90	10
Celastrus orbiculatus	Oriental bittersweet	35	30	21	86	11
Paulownia tomentosa	Empress tree	18	46	19	83	12
Sorghum halepense	Johnsongrass	20	41	21	82	13
Vinca minor	Periwinkle	29	21	24	74	14
Mentha spicata	Spearmint	29	25	13	67	15
Nasturtium officinale	Watercress	22	21	7	50	16
Cirsium vulgare	Bull thistle	9	27	4	40	17
Coronilla varia	Crown vetch	13	17	7	37	18

Although there is little published information about the effect that microstegium has on native plants and natural ecosystems, it has been suggested that it may exclude native plants or prevent them from becoming established (Barden 1987). Microstegium may become even more problematic in the near future; because it can reproduce vegetatively and from seed, it produces large number of seeds each year, and its seeds may remain viable in the soil for 3 or more years (USDA, NRCS 2001). In addition, control of microstegium populations is relatively difficult; successful control will likely require multiple applications of herbicide or labor-intensive hand pulling. However, small patches of microstegium have reportedly been controlled through a combination of herbicide application, mowing, and hand removal (K. Johnson, Great Smoky Mountains National Park, personal communication, 2001). Additional information on the autecology and synecology of microstegium is in Appendix F.

Our ranking of microstegium is similar to other recent qualitative assessments of this particular species as a problematic invasive plant. For example, managers at the Great Smoky Mountains National Park in Tennessee and North Carolina have qualitatively ranked microstegium highest in potential impacts on natural ecosystems in the Park (out of a total of 35 problematic nonnative, invasive plants) and lowest in feasibility of control because so little is known of its autecology or synecology (National Park Service 1999). Similarly, 18 of 35 governmental and private agencies in the Southern Appalachian region reported that out of a total of 218 invasive plant species, microstegium was one of their greatest ongoing or potential management problems, behind only kudzu and multiflora rose (which were reported by 21 and 19 agencies, respectively) (Kuppinger 2000). Finally, the Tennessee Exotic Pest Plant Council considers microstegium in its "Rank 1, Severe Threat" category, which includes a total of 24 "exotic plant species which possess characteristics of invasive species and spread easily into native plant communities and displace native vegetation; includes species which are or could become widespread in Tennessee" (Tennessee Exotic Pest Plant Council 1996).

Japanese honeysuckle was ranked as the second-most problematic nonnative, invasive plant on the Research Park (Table 3). Japanese honeysuckle was present in numerous, dense stands across the Research Park in early-successional to mid-successional habitats. It was relatively uncommon on recently disturbed (e.g., bladed) habitats and was only patchily distributed in closed-canopy, later-successional forest communities. It was a common ground cover in more open habitats, such as decadent pine stands, along road margins, and in canopy gaps. Of the three ranking subcategories—potential impact on natural systems, tendency to become a management problem, and difficulty of control—it ranked second, second, and third highest in impact, management, and control, respectively.

Japanese honeysuckle is widely recognized as a problematic invasive plant throughout the region. It is in the Tennessee Exotic Pest Plant Council "Rank 1, Severe Threat" category (Tennessee Exotic Pest Plant Council 1996) and was reported by 17 of 35 management agencies in the Southern Appalachian region as an ongoing or potential management problem (Kuppinger 2000). Additional information on the natural history and control of Japanese honeysuckle is in Appendix F.

The third-most problematic plant surveyed on the Research Park was Chinese privet (*Ligustrum sinense*). It was most abundant along margins of gravel and paved roads, where it could form dense, unpenetrable stands with relatively dark understories. Although it can persist in shaded understory habitats, it was less abundant in relatively undisturbed, later-successional stands on the Research Park. It was also common in floodplains adjacent to streams and smaller watercourses but was occasionally present on drier upland sites. Chinese privet reproduces both vegetatively and by seed and produces copious quantities of fruits and seeds that are consumed and spread by birds. Although it vigorously resprouts from roots and cut stumps, it can be eradicated though a combination of top removal and application of glyphosate herbicide to the stump. Chinese privet is a "Rank 1, Severe Threat" species (Tennessee Exotic Pest Plant Council 1996) and was reported as a management problem by 16 of 35 management agencies in the Southern Appalachian region (Kuppinger 2000). Additional information on this and other invasive species ranked in this study is in Appendix F.

Kudzu was ranked the fourth-most problematic invasive plant on the Research Park (Table 3). This species is not widespread on the Research Park; in fact, it was present in only two management areas. However, it was ranked highest in terms of how difficult it is to control, largely because of its deep and extensive root system and tendency to resprout after physical

manipulation. In addition, it ranked second-highest in terms of its potential impact on natural systems, because it is capable of overgrowing and decimating mature stands of trees. Because of this obvious tendency to overtop even tall vegetation, we assigned it a high competitive ability (query # 15), whereas all other species were considered to have "unknown" competitive abilities because of insufficient data. In contrast with its potential impact and difficulty of control, it ranked relatively low (i.e., 10") for its tendency to become a management problem, because it does not tend to spread from site to site without human intervention. Further, it produces few viable seed, so it has little potential for long-distance dispersal outside of human activities.

Kudzu was the most commonly reported plant management problem (by 21 out of 35 management agencies) in the Southem Appalachian region, likely because of its widespread distribution, its obvious impact on natural systems, and its difficult nature to control (Kuppinger 2000). It is a "Rank 1, Severe Threat" species (Tennessee Exotic Pest Plant Council 1996).

Multiflora rose was the fifth-most problematic plant (Table 3). This species was present along fence rows and in early to mid-successional habitats. Although it is somewhat shade-intolerant, small populations were present within closed-canopy forest. It was present across a broad range of edaphic and environmental conditions (i.e., dry ridges to mesic floodplains). When present, it often formed dense, impenetrable thickets. Its seeds are dispersed by wildlife, particularly birds, and its seeds remain viable in the soil for up to 20 years. Once established, it can resprout readily after top removal and can reproduce from roots and by layering. As such, it ranked relatively high in terms of its tendency to spread rapidly and become a management problem. Multiflora rose was reported as a management problem by resource managers in the Southern Appalachians more often than Japanese honeysuckle and microstegium, perhaps because its upright and clumped growth form make it relatively apparent on landscapes (Kuppinger 2000). It is classified as a noxious weed in several of the United States and is ranked as a "Severe Threat" to natural ecosystems in Tennessee (Tennessee Exotic Pest Plant Council 1996).

Chinese lespedeza ranked sixth in our survey of invasive plants on the Research Park. Similar to field garlic (9") and Johnsongrass (13th), Chinese lespedeza tends to establish only in early successional sites with abundant sunlight. As such, it was present along roads, power transmission line rights-of-way, along waterfronts, and in other natural and human-made clearings and openings. When present, it can form dense thickets that may exclude small-statured (e.g., herbaceous) native plant species. Chinese lespedeza produces abundant seeds that are dispersed by wildlife, and its seeds remain viable in the soil for many years (Plant Conservation Alliance 1997). As such, it ranked relatively high in terms of its tendency to become a management problem. Field garlic and Johnson grass both received a high rank for tendency to become a management problem as well. All three of these species are difficult to control because they are so widespread; however, Chinese lespedeza is much more prevalent across the Research Park than either field garlic or Johnson grass.

Chinese yam received an overall rank of seven and had a relatively high rank for impact because it is a climbing vine that spreads rapidly. It can reproduce both vegetatively and through aerial bulbils, which is another reason for its high rank in impact. However, Chinese yam received a low rank for control because it occurs in relatively few locations on the Research Park. Chinese yam was mostly found along roadsides and the edges of management areas. In these areas it often forms large clumps and completely covers native vegetation.

Rankings for tree-of heaven (8") and empress tree (12") were affected by their tendency to become a management problem because their seeds are capable of widespread dispersal. Both

tree-of-heaven and empress tree were found growing only along roadsides; however, tree-of-heaven usually occurs in clumps, while empress tree often occurs as an individual.

Although bull thistle (17'') produces abundant seed that is readily dispersed by wind, it ranked low in impact because its seeds are not capable of widespread dispersal. Bull thistle occurs in minimal numbers along roadsides and fields and is not a threat to management areas. Spearmint (15th), on the other hand, ranked high in impact because it occurs throughout Hembree Marsh Natural Area. Although it should not be considered a management concern on the Research Park as a whole, it is important in Hembree Marsh because of its abundance therein.

Autumn olive ranked tenth and is mostly a problem along roadsides. Although it was found in minimal numbers within management areas, it is generally requires disturbance and ample sunlight for establishment and growth. Similar to autumn olive, crown vetch (18'') also occurs in areas with high solar insolation. Crown vetch was found in only one location on the Research Park and should not be considered a management problem. It was included in the ranking simply because the population was observed and was thought to have the potential to become a problem in the future.

Oriental bittersweet (11'') and periwinkle (14'') both received their highest score in impact because they are both vines and are capable of overtopping and thereby excluding native vegetation. Oriental bittersweet received a low score for control because it was found in only one location on the Research Park and removal has been initiated from that location. In contrast, periwinkle was found in several locations and was observed to form dense mats in the understory of second-growth forest stands.

Finally, watercress (16'') ranked low for control because the populations observed were small and could be easily removed by hand. It was only found in areas where running water and ample sunlight were available. Watercress should not be considered a management concern because it has a low impact in native communities and can easily be controlled.

3.2 SPECIES RANKS FOR EACH MANAGEMENT AREA

The relative rank of invasive plant species present within each management area tended to mirror the ranking for the Research Park as whole. For example, the most problematic plant for the Research Park as a whole—microstegium—was ranked first in each of the 12 management areas in which it was present. The four management areas in which microstegium was not present included two power transmission rights-of-way (Natural Areas 8 and 43), a marsh dominated by emergent vegetation (Natural Area 24), and a cedar barren (Reference Area 8). Although microstegium could conceivably become established in each of these management areas, they do not represent habitats typically invaded by this plant (Barden 1987, Redman 1995).

Japanese honeysuckle was present in 12 of the 16 management areas surveyed. Similar to microstegium, it was ranked second in each of these management areas, as it was for the Research Park as a whole. It was particularly abundant in Natural Area 9, where large clumps of vines reminiscent of kudzu hung from trees. In other Natural Areas, it was mostly present along fence rows and roadsides.

Chinese privet was present in 8 of the 16 management areas surveyed. It ranked second in 6 of those 8 management areas, even though it ranked third on the Research Park as a whole. The

management areas in which Chinese privet was found were all areas where privet was expected to be found because of their close proximity to streams or roadsides.

Chinese lespedeza ranked number one in Reference Area 8 (Racoon Creek Cedar Barren) whereas it ranked sixth on the Research Park as a whole. In contrast with adjacent stands of closed-canopy deciduous forest on more mesic sites, solar insolation at ground level within the cedar barren is relatively high. These high levels of sunlight tend to favor the establishment and growth of lespedeza. In all other management areas where it was present, lespedeza was ranked relatively low.

Natural Area **24,** or Hembree Marsh, contains a large, dense population of spearmint that could potentially affect native wetland plants. No other invasive species examined as part of this survey were found within Hembree Marsh, probably because the perennially high water tables preclude the establishment of species less tolerant of periodic or permanent inundation. Thus, spearmint ranked first in this Natural Area.

4. CONCLUSIONS

4.1 RANKING NONNATIVE, INVASIVE PLANTS ON THE RESEARCH PARK

The National Environmental Research Park and its component management areas contain a total of 167 nonnative invasive plants that may have potential negative effects on native plant and animal communities. These invasive plants are not unique to the Research Park; indeed, they are present throughout the entire southern Appalachian region of the United States. Of the 18 species surveyed in this study, microstegium, Japanese honeysuckle, Chinese privet, kudzu, and multiflora rose are among the most problematic invasive plants on the Research Park and its component management areas. These species are abundant throughout the southern Appalachian region and have all been ranked as particular management problems in other qualitative and semiquantitative rankings of nonnative, invasive plants in the region (Tennessee Exotic Pest Plant Council 1996, Kuppinger 2000). However, results of this research can be used to prioritize management and research activities related to these invasive taxa on the Research Park as a whole and for specific Natural or Reference Areas.

Overall, the U.S. Geological Survey ranking system was relatively straightforward and contained the components thought to provide an adequate assessment of the impact of invasive plants: abundance, impact per individual, and total area occupied (Parker et al. 1999). However, the ranking system does have some flaws. For example, in all but one case, it allows only one answer to be chosen for each question. In particular, this was a problem for the question "Distribution relative to disturbance regime," in which the options early, mid-, or late successional sites could be chosen. For plants such as microstegium and Japanese honeysuckle, more than one answer would have been appropriate. We dealt with this specific problem by selecting the option that portrayed the latest successional stage in which a particular species could be found.

4.2 THE NEED FOR ADDITIONAL RESEARCH

As we gathered information from the literature about the traits and characteristics of individual species, it became apparent that basic autecological information on many invasive species is not readily available. This was particularly true for the less-abundant and least-problematic taxa, but even basic quantitive information on the more common taxa was sometimes lacking. In particular, data on species competitive ability, the number of seeds produced per plant, the viability and longevity of the seedbank, and the difficulty of control were often difficult to procure. Additional information on these topics would improve our ability to rank these species.

In addition, quantitative data on the effects of these species on the invaded plant and animal communities and ecosystems were seldom available. This is not a new problem in the field of invasion biology or plant ecology, nor is it specific to the particular species in question, the Research Park, or the region. In fact, scientists seldom collect basic data directed at quantification of effects of plant invasions on native ecological systems, and most of the discussion of ecological effects of invaders is anecdotal (Parker et al. 1999). In fact, Parker et al. (1999), in a recent review of scientific assessments of ecological impacts of invasions, stated that "Despite the considerable attention invasive species receive, our lamentable paucity of data on impacts leaves us largely ignorant about the ecological changes they have brought about." Obviously, additional research focused on the general effects of individual invasive species on individuals, populations, communities, and ecosystems is much needed.

In addition, there is a great need and potential to learn more about invasive plants in the various management areas on the Research Park, in the Ridge and Valley Province, and in the southern Appalachian region as a whole. Future research should focus on individual plant characteristics and the effects of invasive plants on native communities; research priorities could be guided by the results of the ranking conducted herein. For example, an ongoing study of microstegium is focused on constraints to its distribution and abundance, and its response to interacting environmental variables (Patrice Cole, University of Tennessee, July 2001, personal communication). In addition, an ongoing study of the effects of elevated atmospheric concentrations of CO_2 on entire plant communities dominated by invasive plants (including microstegium and Japanese honeysuckle) will shed light on potential interactions between plant invasions and global change (Belote, Travis, University of Tennessee, 2001, personal communication).

Similarly, studies of the effects of disturbance (e.g., logging, roads, and construction and maintenance of power line rights-of-way) could yield important information on the ways in which invasive plants establish and spread. Research on different control methods could aid in implementing management strategies for eradication of invasive plants. In all, additional research will yield information necessary to further prioritize management activities related to different invasive plant species. Finally, this ranking system could be used to similarly rank the many other nonnative, invasive species present on the Research Park that we did not include in this study.

4 3 DEVELOPMENT OF MANAGEMENT STRATEGIES FOR THE RESEARCH PARK

Results of this study and other research can be used to develop a management strategy for the most problematic invasive species on the Research Park and its component management areas. Strategies for management could take one or both of two non-mutually excusive approaches. First, management priorities could be site-specific (i.e., focused on particular management areas most threatened by a suite of invasive species). For example, sites that include large populations or many species of invasive plants, or sites with species of special concern, may be targets for particular management activities. Second, management priorities could be species-specific — focusing on a particular invasive (or native) plant of special concern — across a variety of sites. Management activities should also probably be focused on invasive plant populations that are feasible to control. For example, eradication of microstegium from an area as extensive as the Research Park may represent a Sisyphean task.[1] However, intensive monitoring and control efforts may prevent the establishment and spread of other nonnative species before they become ecological or management problems.

[1] Sisyphus, a legendary king of Corinth, was condemned to roll a heavy rock up a hill in Hades and have it roll down again as it approached the top.

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APPENDIX A

NONNATIVE PLANT SPECIES ON THE RESEARCH PARK

Table A.l. Nonnative plant species on the Research Park (Awl et al. 1996)

Scientific name	Common name
Abutilon theophrasti	Velvet leaf
Agrostemma githago	Corncockle
Agrostis stolonifera	Creeping bentgrass
Ailanthus altissima	Tree-of-heaven
Albizia julibrissin	Mimosa
Allium ampeloprasum	Garlic
Allium vineale	Field garlic
Amaranthus hybridus	Amaranth
Amaranthus spinosus	Spiny amaranth
Anagallis arvensis	Pimpernel
Anthoxanthum odoratum	Sweet vernal grass
Arabidopsis thaliana	Mouse-ear cress
Arctinium minus	Burdock
Arenaria serpyllifolia	Thyme-leaf sandwort
Arthraxon hispidus	Jointed grass
Asparagus officinalis	Asparagus
Barbarea verna	Early winter-cress
Barbarea vulgaris	Yellow rocket
Belamcanda chinensis	Blackberry lily
Berberis thunbergii	Japanese barberry
Brassica rapa	Rape mustard
Bromus commutatus	Common brome grass
Bromus hordeaceus	Soft chess
Bromus japonicus	Japanese chess
Bromus tectorum	Brome grass
Buglossoides arvense	---
Buxus sempervirens	Boxwood
Calamintha nepeta	Basil-thyme
Capsella bursa-pastons	**Sheperd's purse**
Cardamine hirsute	**Hairy** bittercress
Cardamine parviflora	**---**
Catalpa binonioides	Catalpa
Celastrus orbiculatus	Oriental bittersweet
Centaurea cyanus	Bachelor's button
Centaurea maculosa	Bachelor's button
Cerastium fontanum	Mouse-ear chickweed
Cerastium glomeratum	Mouse-ear chickweed
Chaennorrhinum minus	Lesser toadflax
Chenopodium album	White goosefoot
Chenopodium ambrosioides	Fragrant goosefoot
Chrysanthemum leucanthemum	Daisy
Cichorium intybus	chicory
Cirsium arvense	Canada thistle
Cirsium vulgare	Bull thistle

Table A.1 (continued)

Scientific name	Common name
Commelina communis	Common dayflower
Consolida ambigua	Rocket larkspur
Convallaria majalis	Lily-of-the-valley
Coronilla varia	Crown vetch
Crepis pulchra	Hawk's beard
Cynodon dactylon	Bermuda grass
Dactylis glomerata	Orchard grass
Datura stramonium	Jimson weed
Daucus carota	Queen Anne's lace
Dianthus armera	Deptford pink
Digitaria ischaemum	Smooth crabgrass
Digitaria sanguinalis	Crabgrass
Dioscorea batatas	Chinese yam
Dipsacus fullonum	Teasel
Draba verna	Whitlow grass
Duchesnea indica	Barren strawberry
Echinochloa crusgalli	Bamyard grass
Elaeagnus pungens	Thorny autumn olive
Elaeagnus umbellate	Autumn olive
Eleusine indica	Goosegrass
Eragrostis cilianensis	Lovegrass
Eragrostis curvula	South African lovegrass
Erysimum cheiranthoides	Worm-seed mustard
Festuca arundinacea	Meadow fescue
Festuca pratensis	Fescue
Festuca rubra	Red fescue
Galium parisiense	---
Galium pedamontanum	Narrow bedstraw
Geranium columbinum	Longstalk crane's-bill
Glechoma hederacea	Ground-ivy, Gill-over-the-ground
Hedera helix	English ivy
Hemerocallis fulva	Day-lily
Hibiscus trionum	Flower of an hour
Holcus lanatus	Velvet grass
Holosteum umbellatum	Jagged chickweed
Hypericum perforatum	Common St. John's-wort
Ipomoea coccinea	Scarlet morning-glory
Ipomoea hederacea	Ivy-leaved morning-glory
Ipomoea purpurea	Purple morning-glory
Iris germanica	German iris
Iris pseudocorus	Yellow European ins
Kummerowia stipulacea	Korean bush-clover
Kummerowia striata	Japanese clover

Table A.1 (continued)

Scientific name	Common name
Lactuca saligna	Willow-leaved lettuce
Lactuca serriola	Prickly lettuce
Lamium amplexicaule	Henbit
Lamium purpureum	Purple dead-nettle
Lathyrus latifolia	Everlasting pea
Leonurus cardiaca	Motherwort
Lepidium campestre	Cow-cress
Lespedeza bicolor	Shrubby bush-clover
Lespedeza cuneata	Chinese lespedeza
Ligustrum sinense	Chinese privet
Ligustrum vulgare	Privet
Linaria vulgaris	Butter-and-eggs
Lolium multiflorum	Italian ryegrass
Lolium perenne	Perennial ryegrass
Lonicerajaponica	Japanese honeysuckle
Lonicera maackii	Bush honeysuckle
Lotus comiculatus	Birdfoot trefoil
Lysimachia nummularia	Moneywort
Lythrum salicaria	Purple loosestrife
Maclura pomifera	Osage-orange
Mahonia bealei	Oregon grape
Malus pumila	Apple
Medicago lupulina	Black medick
Medicago sativa	Alfalfa
Melilotus alba	White sweet-clover
Melilotus officinalis	Yellow sweet-clover
Mentha spicata	Spearmint
Mentha x piperita	Peppermint
Microstegium vimineum	Microstegium **(Japanese grass)**
Mollugo verticillata	Carpet-weed
Mosla dianthera	---
Murdannia keisak	---
Myriophyllum spicata	Eurasian water-milfoil
Narcissus pseudonarcissus	Daffodil
Nasturtium officinale	Watercress
Nicandra physalodes	Apple-of-Peru
Omithogalum umellatum	Star of Bethlehem
Paspalum dilatatum	---
Paulownia tomentosa	Empress tree
Perilla frutescens	Beefsteak plant
Phleum pratense	Common timothy
Plantago lanceolata	Plantain
Poa annua	Annual bluegrass
Poa compressa	Bluegrass

Table A.1 (continued)

Scientific name	Common name
Poa pratensis	Kentucky bluegrass
Polygonum cespitosum	Smartweed
Polygonum cuspidatum	Japanese knotweed
Polygonum hydropiper	Water-pepper
Polygonum persicaria	Smartweed
Poncircus trifoliata	Trifoliate orange
Populus alba	Silvery poplar
Populus x jackii	---
Potamogeton crispus	Curly pondweed
Potentilla recta	Rough-fruited cinquefoil
Prunella vulgaris	Heal-all
Pueraria montana	Kudzu
Ranunculus acris	Common buttercup
Ranunculus bulbosus	Bulbous buttercup
Ranunculus parviflorus	Small-floweredbuttercup
Ranunculus repens	Creeping buttercup
Ranunculus sardos	---
Rosa multiflora	Multiflora rose
Rubus phoenicolasius	Wineberry
Rumex acetosella	Shep sorrel
Rumex conglomeratus	Clustered dock
Rumex crispus	Curled dock
Rumex obtusifolius	Bitter dock
Salix alba	White willow
Salix babylonica	Weeping willow
Saponaria officinalis	Soapwort
Secale cereale	Rye
Senna obtusifolia	Sickle-pod
Setaria faberi	Foxtail
Setaria pumila	Foxtail
Setaria viridis	Green foxtail
Sherardia arvensis	Field-madder
Sida spinosa	Prickly mallow
Sonchus asper	Prickly sow-thistle
Sorghum bicolor	Milo
Sorghum Mepense	Johnsongrass
Spiraea douglasii	Spiraea
Spirodela punctata	Duckweed
Sporobolus indicus	Smutgrass
Stellaria media	Common chickweed
Taraxacum oficinale	Common dandelion
Thlaspi perfoliatum	Thoroughwort penny-cress
Tragopogon dubius	---
Trifolium campestre	Low hop-clover

Table A.1 (continued)

Scientific name	Common name
Trifolium hybridum	Alsike clover
Trifolium pratense	Red clover
Trifolium repens	White clover
Triticum x aestivum	Wheat
Tussilago farfara	Coltsfoot
Urtica dioica	Stinging nettle
Valerianella locusta	European corn salad
Verbascum blattaria	Moth mullein
Verbascum thaspus	Mullein
Veronica agrestis	Field speedwell
Veronica arvensis	Corn speedwell
Veronica hederaefolia	Ivy-leaved speedwell
Veronica officinalis	Common speedwell
Veronica serpyllifolia	Thyme-leaved speedwell
Vicia augustifolia	Narrow-leaved vetch
Vicia villosa	Hairy vetch
Vinca minor	Common periwinkle
Vitex agnus-castus	---
Vulpia myuros	Rat-tail fescue

APPENDIX B

AGGRESSIVE INVASIVE PLANT SPECIES ON THE RESEARCH PARK

Table B.l. Aggressive invasive plant species on the Research Park
(Awl et al. 1996)

Scientific name	Common name
Ailanthus altissima	Tree-of-heaven
Allium vineale	Field garlic
Amaranthus hybridus	Green amaranthus
Arthraxon hispidus	Jointed grass
Celastrus orbiculatus	Oriental bittersweet
Cirsium vulgare	Bull thistle
Coronilla varia	Crown vetch
Dioscorea batatas	Chinese yam
Echinochloa-crusgalli	Barnyard grass
Elaeagnus pungens	Thorny autumn olive
Elaeagnus umbellata	Autumn olive
Glechoma hederacea	Gill-over-the-ground, ground ivy
Kummerowia stipulacea	Korean bush clover
Kummerowia striata	Japanese clover
Kyllinga brevifoliodes	---
Lespedeza bicolor	Shrubby bush clover
Lespedeza cuneata	Chinese lespedeza
Ligustrum sinense	Chinese privet
Lonicera japonica	Japanese honeysuckle
Lysimachia nummularia	Moneywort
Lythrum salicaria	Purple loosestrife
Mahonia bealei	Oregon grape
Mentha spicata	Spearmint
Mentha x piperita	Peppermint
Microstegium vimineum	Microstegium (Japanese grass)
Myriophyllum spicata	Eurasian water-milfoil
Nasturtium oflcinale	Watercress
Paulownia tomentosa	Empress tree
Plantago lanceolata	Common plantain
Poa pratensis	Kentucky bluegrass
Polygonum cuspidatum	Japanese knotweed
Polygonum persicaria	Smartweed
Potamogeton crispus	Curly pondweed
Pueraria montana	Kudzu
Rosa multiflora	Multiflora rose
Rumex conglomeratus	Clustered dock
Sorghum halepense	Johnsongrass
Urtica dioica	Stinging nettle
Veronica arvensis	Corn speedwell
Veronica officinalis	Common speedwell
Veronica serpyllifolia	Thyme-leaved speedwell
Vicia villosa	Hairy vetch
Vinca minor	Common periwinkle

APPENDIX C

ALIEN PLANTS RANKING SYSTEM, VERSION 5.1

Alien Plants Ranking System, Version 5.1
(APRS Implementation **Team** 2000)

I. Significance of threat or impact (site characteristics)

1. Distribution relative to disturbance regime
   a. Found only within sites disturbed within the last 3 years or sites regularly disturbed
   b. Found in sites disturbed within the last 10 years
   c. Found in mid-successional sites disturbed 11 to 50 years before present
   d. Found in late-successional sites disturbed 51 to 100 years before present
   e. Found in high quality natural areas with no known major disturbance for 100 years
   f. Unknown

2. Areal extent of populations
   a. Not in site, but in adjacent areas
   b. Found in less than 5% of site
   c. Found in between 5% and 10% of site
   d. Found in between 10% and 25% of site
   e. Found in more than **25%** of site
   f. Unknown

3. Numerical dominance of species within a community
   a. Not found on site
   b. Usually observed as a single individual (or fewer than **5** per 5 m^2)
   c. Usually observed in numbers less than the 2 or 3 most common native species in the community (but more than 5 per 5 m^2)
   d. Usually observed in numbers approximately equivalent to the most common native species in the community
   e. Usually observed in numbers greater than the most common native species in the community
   f. Unknown

4. Association with native community
   a. Associated with weedy (early successional) species
   b. Associated with mid-successional species
   c. Associated with dominant (late-successional) species
   d. Displaces native plant community
   e. Unknown

5. Hybridization with native species
   a. Not known to hybridize with native species
   b. Known to hybridize with native species
   c. unknown

6. Degree of threat and impact
   a. Little or no increase in numbers of individuals and populations and no invasion of native communities
   b. Present in native communities, but static or decreasing
   c. Moderate rate of increase in numbers of individuals and populations; little or no invasion of native communities
   d. Moderate rate of increase in numbers of individuals and populations; invading native plant communities
   e. High rate of increase of numbers of individuals and populations; invading and replacing or highly modifying native plant communities
   f. Unknown

7. Effects on management goals
   a. No effect
   b. Little impact on site management goals
   c. Moderate impact on site management goals
   d. Large impact on site management goals
   e. Unknown

11. Innate ability to become a pest

8. Mode of reproduction
   a. Rarely, if ever, reproduces in area
   b. Reproduces almost entirely by vegetative means
   c. Reproduces only by seed
   d. Reproduces vegetatively and by seeds
   e. Unknown

9. Vegetative reproduction
   a. No vegetative reproduction
   b. Vegetative reproduction rate maintains population
   c. Vegetative reproduction rate results in moderate increase in population size
   d. Vegetative reproduction rate results in rapid increase in population size
   e. Unknown

10. Frequency of sexual reproduction for mature plant
   a. Almost never reproduces sexually in area
   b. Once every 5 or more years
   c. Every other year
   d. One or more times a year
   e. Bursts of sexual reproduction in response to environmental stimulus
   f. Unknown

11. Number of seeds per plant
   a. Rarely, if ever, produces seed in area
   b. Few (0–10)
   c. Moderate (11–1000)
   d. Many (>1000)
   e. Unknown

12. Dispersal ability
    a. Little potential for long-distance dispersal
    b. Great potential for long-distance dispersal
    c. Unknown

13. Germination requirements
    a. Requires open soil and disturbance to germinate
    b. Can germinate in vegetated areas but in a narrow range or in special conditions
    c. Can germinate in existing vegetation in a wide range of conditions
    d. Unknown

14. Seedbanks
    a. Seeds remain viable in the soil for less than 1 year
    b. Seeds remain viable in the soil for 1 to 5 years
    c. Seeds remain viable in the soil for more than 5 years
    d. Unknown

15. Competitive ability
    a. Poor competitor
    b. Moderately successful competitor
    c. Highly successful competitor
    d. Unknown

16. Ecological effects (select all that apply)
    a. Produces persistent litter or shade that affects germination or growth of native species
    b. Produces allelochemicals
    c. Affects availability of soil nutrients
    d. Affects water availability to native plants
    e. Changes natural fire regime
    f. None of the above
    g. Unknown

17. Known level of impact in natural areas
    a. Not known to cause impacts in any other natural area
    b. Known to cause impacts in natural areas, but with different habitats and climate zones
    c. Known to cause low impact in natural areas with similar habitats and climate zones
    d. Known to cause moderate impact in natural areas with similar habitats and climate zones
    e. Known to cause high impact in natural areas with similar habitats and climate zones and/or on the list of most invasive alien plants for the region
    f. unknown

III. Difficulty of control

18. Likelihood of successful control
    a. This species has been eradicated in a natural area
    b. Control (populations declining) of *this* species has been achieved in a natural area

c. Limited control (species is no longer spreading, but persists near pre-control levels) of this species has been achieved in a natural area
d. Control of this species has never been achieved in a natural area
e. Unknown

19. Saturation in surrounding region
a. Not present in areas surrounding the site
b. Present in few areas surrounding the site
c. Present in several areas but not entirely surrounding the site
d. Present in most areas surrounding the site
e. Unknown

20. Effectiveness of community management
a. Protection from disturbance effectively controls target species
b. Cultural techniques (burning, flooding) can be used to control target species
c. Restoration or preservation practices effectively control target species
d. The above options are not effective
e. Unknown

21. Vegetative regeneration
a. No resprouting following removal of aboveground growth
b. Sprouts from roots or stumps
c. Any plant part is a viable propagule
d. Unknown

22. Biological control
a. Biological control feasible
b. Potential may exist for biological control
c. Biological control not feasible (not practical, possible, or probable)
d. Unknown

23. Side effects of control measures
a. Control measures have little potential to affect native communities
b. Control measures are likely to cause moderate impacts on communities
c. Control measures are likely to cause major impacts on communities
d. Side effects of control unknown
e. Unknown

APPENDIX D

RESPONSES TO EACH RANKING SYSTEM QUESTION (QUESTIONS 1 THROUGH 23) FOR EACH SPECIES ON EACH MANAGEMENT AREA (MA) SURVEYED ON THE RESEARCH PARK

Table D.1. Responses to Each Ranking System Question (Questions 1 through 23) for Each Species on Each Management Area (MA) Surveyed on the Research Park

MA	Species"	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2	*Mivi*	c	d	d	b	a	e	d	d	B	D	c	b	c	b	d	a,d	e	e	d	c	a	d	c
	Lisi	c	c	b	b	a	d	c	d	D	D	d	b	c	d	d	**a,d**	e	e	c	b	b	b	c
	Loja	c	d	d	b	a	b	c	d	B	D	c	b	c	d	d	**a**	e	e	d	b	b	d	c
	Lecu	a	a	a	a	a	c	c	c	A	D	e	b	c	c	d	**c**	e	e	d	b	d	d	c
	Ceor	c	a	a	b	b	c	c	d	C	F	e	a	d	d	d	**a**	e	b	b	b	b	d	b
	Aial	a	a	a	a	a	c	c	c	A	D	d	b	a	d	d	**b**	e	e	c	b	b	d	b
	Elum	a	b	b	a	a	a	b	c	A	D	e	b	c	d	d	**a,c**	e	e	b	b	b	d	b
4	*Mivi*	c	d	d	b	a	e	d	d	A	d	c	b	c	b	d	**a,d**	e	e	d	c	a	d	c
	Lisi	c	c	b	b	a	d	c	d	D	d	d	b	c	d	d	**a,d**	e	e	c	b	b	b	c
	Lecu	a	c	d	a	a	c	d	c	A	d	d	b	b	c	d	c	e	e	d	b	d	d	c
	Diba	c	c	c	b	a	e	d	b	D	a	a	b	d	d	d	a	e	e	c	c	d	d	c
	Pato	a	a	b	a	a	c	b	d	C	d	d	b	d	d	d	g	e	e	b	b	b	d	b
	Cova	a	a	a	a	c	c	c	d	C	f	e	a	d	d	d	g	d	e	d	a	d	d	a
8	*Lecu*	a	c	d	a	a	d	d	d	B	d	d	b	b	c	d	c	d	e	d	e	d	d	e
	Loja	c	d	c	b	a	d	c	e	D	d	c	b	d	d	d	a	e	e	d	e	b	d	e
	Lisi	c	b	b	b	a	a	b	d	D	d	d	b	b	d	c	a,d	e	e	c	e	b	d	c
	Pumo	a	a	e	a	a	e	d	b	D	a	a	a	a	a	c	**a**	e	e	c	e	d	d	e
9	*Mivi*	c	e	e	b	a	e	d	d	B	d	c	b	c	b	c	**a,d**	e	e	d	e	a	d	e
	Loja	c	d	c	b	a	d	c	d	D	d	e	b	d	d	d	**a**	e	e	d	e	b	d	e
10	*Mivi*	c	e	e	b	a	e	d	d	B	d	c	b	c	b	c	**a,d**	e	e	d	e	a	d	e
	Diba	a	c	c	a	a	e	d	b	D	a	a	b	d	d	b	**a**	e	e	c	e	d	d	e
	Pato	a	a	b	a	a	c	b	d	C	d	d	b	d	d	d	**a**	c	e	b	e	b	d	e
	Lecu	a	c	d	a	a	d	d	c	A	d	d	b	b	c	d	**c**	d	e	d	e	d	d	e
	Loja	c	d	c	b	a	d	c	d	D	d	c	b	d	d	d	**a**	e	e	d	e	b	d	e
11	*Romu*	c	c	c	b	c	d	c	d	D	d	e	b	d	c	d	**a**	e	e	c	e	b	d	e
	Mivi	c	b	c	b	a	e	d	d	B	d	c	b	c	b	c	**a,d**	e	e	d	e	a	d	e
	Lisi	c	b	b	b	a	a	a	d	D	d	d	b	b	d	c	**a,d**	e	e	c	e	b	d	c
	Loja	c	d	c	b	a	d	c	d	D	d	c	b	d	d	d	**a**	e	e	d	e	b	d	e
13	*Mivi*	c	e	e	b	a	e	d	d	B	d	d	b	b	b	d	**a,d**	e	e	d	c	a	d	c
	Loja	c	d	c	b	a	c	c	d	B	d	e	b	c	d	d	**a**	e	e	d	b	b	d	c
	Diba	c	b	b	b	a	e	b	b	C	a	a	b	d	d	d	**a**	e	e	b	c	d	d	c
	Lecu	a	b	b	a	a	c	d	c	A	d	d	b	b	c	d	**c**	e	e	b	b	d	d	c
	Elum	c	b	b	b	a	a	b	c	A	d	e	b	c	d	d	**a,c**	e	e	b	b	b	d	b
	Vimi	c	c	c	b	a	c	c	b	C	a	a	a	d	d	d	**a**	d	e	c	b	d	b	b
18	*Mivi*	c	e	e	b	a	e	d	d	B	d	c	b	c	b	d	**a,d**	e	e	d	c	a	d	c
	Lecu	a	c	d	a	a	d	d	c	A	d	d	b	b	c	d	**c**	e	e	d	b	d	d	c
	Vimi	c	c	c	b	a	c	c	b	C	a	a	a	d	d	d	**a**	d	e	e	b	d	b	b
	Loja	c	d	c	b	a	e	c	d	B	d	c	b	c	d	d	**a**	e	e	d	b	b	d	c
	Pato	a	a	b	a	a	c	b	d	C	d	d	b	d	d	d	**g**	e	e	b	b	b	d	b
	Civu	a	b	b	a	a	a	b	c	A	d	d	a	d	a	d	**g**	d	e	b	a	d	d	a
20	*Diba*	a	c	c	a	a	e	d	b	D	a	a	b	d	d	d	**a**	e	e	c	c	d	d	c
	Lisi	c	a	a	b	a	d	d	d	D	d	d	b	c	d	d	**a,d**	e	e	c	b	b	b	c
	Romu	a	c	c	a	c	d	c	d	B	d	e	b	d	c	d	**a**	e	e	c	b	b	d	b
	Lecu	a	a	a	a	a	d	d	c	A	d	d	b	b	c	d	**a**	e	e	d	b	d	d	c

Table D.1 (Continued)

MA	Species[a]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	Mivi	c	c	d	b	**a**	d	d	d	B	d	c	b	c	b	d	a,d	e	e	d	c	**a**	d	c
	Soha	**a**	**a**	**a**	**a**	**a**	c	b	e	E	f	e	c	d	d	d	g	d	e	c	c	d	d	b
	Civu	**a**	b	b	**a**	**a**	a	b	c	A	d	d	a	d	a	d	g	c	e	b	a	d	d	a
	Aial	**a**	**a**	c	**a**	**a**	c	c	d	C	d	d	b	a	d	d	a,b	e	e	c	b	b	d	b
	Vimi	c	c	c	b	**a**	c	c	b	C	a	a	a	d	d	d	a	d	e	b	b	d	b	b
	Pumo	**a**	**a**	e	**a**	**a**	e	d	b	D	a	a	a	a	a	c	a	e	c	c	c	d	d	c
21a	***Mivi***	c	d	d	b	**a**	e	d	d	B	d	c	b	c	b	d	a,d	e	e	d	c	**a**	d	c
	Lisi	c	d	d	b	**a**	d	d	d	D	d	d	b	c	d	d	a,d	e	e	c	b	b	b	c
	Elum	c	c	c	b	**a**	c	c	e	E	d	e	c	b	d	d	a,c	e	e	c	b	b	d	b
	Romu	c	c	c	b	c	d	c	d	C	d	e	b	c	c	d	a	e	e	c	b	b	d	b
	Loja	c	d	c	b	a	e	c	d	D	d	c	b	c	d	d	a	e	e	d	b	b	d	c
24	***Mesp***	c	b	c	b	b	a	b	d	E	d	e	a	b	d	d	g	d	e	b	b	d	d	b
42	***Diba***	c	c	c	b	**a**	e	d	b	D	a	a	b	c	d	d	a	e	e	c	c	d	d	c
	Mivi	c	d	d	b	**a**	e	d	d	B	d	c	b	c	b	d	a,d	e	e	d	c	**a**	d	c
	Lecu	a	c	c	a	a	d	d	c	A	d	d	b	b	c	d	c	d	e	d	b	d	d	c
	Loja	c	d	c	b	a	e	c	d	B	d	c	b	c	d	d	a	e	e	d	b	b	d	c
	Romu	c	c	c	b	c	d	c	d	C	d	e	b	c	c	d	a	e	e	c	b	b	d	b
43	***Alvi***	a	d	c	**a**	a	e	d	d	B	d	c	a	a	a	d	g	d	e	c	c	d	d	c
	Lecu	a	d	d	a	c	d	d	c	A	d	d	b	b	c	d	c	d	e	d	b	d	d	c
	Elum	c	**a**	**a**	b	**a**	c	c	e	E	d	e	c	b	d	d	a,c	e	e	c	b	b	d	b
	Romu	c	c	c	b	c	d	c	d	C	d	e	b	c	c	d	a	e	e	c	b	b	d	b
	Lisi	c	b	b	b	**a**	d	c	d	D	d	d	b	c	d	d	a,d	e	e	c	b	b	b	c
	Loja	c	a	a	b	a	e	c	d	B	d	c	b	c	d	d	a	e	e	d	b	b	d	c
	Naof	**a**	b	b	e	**a**	c	b	e	E	d	e	a	b	d	d	a	c	e	b	b	a	d	a
47	***Lisi***	c	d	d	b	**a**	d	d	d	D	d	d	b	c	d	d	a,d	e	e	c	b	b	b	c
	Naof	**a**	b	b	e	**a**	c	b	e	E	d	e	a	b	d	d	a	c	e	b	b	a	d	a
	Mivi	b	c	e	b	**a**	e	d	d	B	d	c	b	c	b	d	a,d	e	e	d	c	a	d	c
	Loja	c	d	c	b	a	e	d	d	C	d	c	b	c	d	d	a	e	e	d	b	b	d	c
	Elum	c	**a**	**a**	b	**a**	c	c	e	E	d	e	c	b	d	d	a,c	e	***e***	c	b	b	d	b
	Diba	c	c	c	b	**a**	e	d	b	D	a	a	b	c	d	d	a	e	e	c	c	d	d	c
	Lecu	a	c	d	a	a	d	d	c	A	d	d	b	b	c	d	c	d	e	d	b	d	d	c
	Civu	**a**	b	b	**a**	**a**	**a**	b	c	A	d	d	a	a	a	d	g	d	e	b	a	d	d	a
	Romu	c	c	c	b	c	d	c	d	D	d	e	b	c	c	d	a	e	e	c	b	b	d	b
	Vimi	c	c	c	b	**a**	c	c	b	C	a	a	a	b	d	d	a	d	e	b	b	d	b	b
	Aial	**a**	**a**	c	**a**	**a**	d	c	d	C	d	d	b	a	d	d	a,b	e	e	c	b	**b**	d	b
RA8	*Lecu*	a	c	d	a	a	e	d	c	A	d	d	b	b	c	d	c	d	e	d	b	d	d	c
	Soha	a	a	a	a	a	c	b	e	E	f	e	c	d	d	d	g	d	e	c	c	d	d	b
	Alvi	**a**	c	c	**a**	**a**	d	c	d	D	a	c	b	a	a	d	g	d	e	c	c	d	d	c
	Lisi	c	**a**	**a**	b	**a**	c	c	d	D	d	d	b	b	d	d	a,d	e	***e***	c	b	b	b	c

Table D.l (Continued)

MA	Species"	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
WBW	*Mivi*	c	d	d	b	a	e	d	d	B	d	c	b	c	b	c	a,d	e	e	d	e	a	d	e
	Vimi	c	c	c	b	a	c	c	b	C	a	a	a	d	d	b	a	d	e	e	e	d	d	e
	Lecu	a	b	c	a	a	d	d	c	A	d	d	b	d	c	d	c	d	e	d	e	d	d	e
	Loja	c	d	c	b	a	d	c	D	D	d	c	b	d	d	d	a	e	e	d	e	b	d	e

"Mivi = Microstegium vimineum; Diba = Dioscorea batatas; Lecu = Lespedeza cuneata; Alvi = Allium vineale; Elum = Elaeagnus umbellata; Lisi = Ligustrum sinense; Naof = Nasturtium officinale; Loja = Lonicera japonica; Pumo = Pueraria montana; Vimi = Vinca minor; Aial = Ailanthus altissima; Civu = Cirsium vulgare; Mesp = Mentha spicata; Soha = Sorghum halepense; Ceor = Celastrus orbiculatus; Romu = Rosa multiflora; Pato = Paulownia tomentosa; Cova = Coronilla varia

APPENDIX E

RESPONSES TO EACH RANKING SYSTEM QUESTION (QUESTIONS 1 THROUGH 23) FOR EACH SPECIES SURVEYED IN THE NATIONAL ENVIRONMENTAL RESEARCH PARK

Table E.1. Responses to each ranking system question (Questions 1 through 23) for each species surveyed in the National Environmental Research Park

Species[a]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mivi	c	e	d	b	a	e	d	d	b	d	c	b	c	b	d	a,d	e	e	d	c	a	d	c
Diba	c	c	c	b	a	e	d	b	d	a	a	b	c	d	d	a	e	e	c	c	d	d	c
Lecu	a	d	c	a	a	d	d	c	a	d	d	b	b	c	d	c	e	e	d	b	d	d	c
Alvi	a	b	c	a	a	d	c	d	b	d	c	a	a	b	d	g	d	e	b	c	b	d	c
Elum	c	c	c	b	a	c	c	e	e	d	e	c	b	d	d	a,c	e	e	c	b	b	d	b
Lisi	c	c	c	b	a	d	d	d	d	d	d	b	c	d	d	a,d	e	e	c	b	b	b	c
Naof	a	b	b	e	b	c	b	e	e	d	e	a	b	d	d	a	c	e	b	b	a	d	a
Loja	c	e	c	b	a	e	d	d	d	d	c	b	c	d	d	a	e	e	d	b	b	d	c
Pumo	c	c	e	b	a	e	d	b	d	a	a	a	c	a	c	a	e	c	c	c	b	d	c
Vimi	c	c	c	b	a	c	c	b	c	a	a	a	b	d	d	a	d	e	c	b	d	b	b
Aial	b	c	c	a	a	d	c	c	a	d	d	b	a	d	d	a,b	e	e	c	b	b	d	b
Civu	a	b	b	a	a	a	b	c	a	d	d	a	a	a	d	g	d	e	b	a	d	d	a
Mesp	c	b	c	b	b	a	b	d	e	d	e	a	b	d	d	g	d	e	b	b	d	d	b
Soha	a	c	c	a	a	c	c	d	c	d	e	b	a	d	d	g	e	e	c	c	d	d	b
Ceor	c	b	b	b	b	c	c	d	c	f	e	a	d	d	d	a	e	b	b	b	b	d	b
Romu	c	d	c	b	c	d	c	d	b	d	e	b	c	c	d	a	e	e	c	b	b	d	b
Pato	a	c	b	a	a	c	c	d	c	d	d	b	d	d	d	a	d	e	b	b	b	d	b
Cova	a	a	a	a	c	c	c	d	c	f	E	a	d	d	d	g	d	e	d	a	d	d	a

[a]Mivi = Microstegium vimineum; Diba = Dioscorea batatas; Lecu = Lespedeza cuneata; Alvi = Allium vineale; Elum = Elaeagnus umbellata; Lisi = Ligustrum sinense; Naof = Nasturtium officinale; Loja = Lonicera japonica; Pumo = Pueraria montana; Vimi = Vinca minor; Aial = Ailanthus altissima; Civu = Cirsium vulgare; Mesp = Mentha spicata; Soha = Sorghum halepense; Ceor = Celastrus orbiculatus; Romu = Rosa multiflora; Pato = Paulownia tomentosa; Cova = Coronilla varia

APPENDIX F

SPECIES ABSTRACTS FOR EACH SPECIES SURVEYED IN THIS STUDY

COMMON NAME:	Tree-of-heaven
SCIENTIFIC NAME:	*Ailanthus altissima* (Mill.) Swingle
DESCRIPTION:	Tree-of-heaven is a small deciduous tree with smooth, gray bark. Leaves are compound and alternate with 15 to 27 lanceolate leaflets. These leaflets often have 1 to 5 rough teeth near their base. Flowers are green and occur in panicles near the ends of the branches (Radford et al. 1968). Seeds are contained within a pod called a samara. Samaras are shaped such that they can be twirled about and carried great distances by wind. Female trees can produce up to 350,000 seeds per year, while male trees produce a distinctive "burnt peanut" odor. Tree-of-heaven produces a toxin that accumulates in the soil and prevents other plants from establishing there (Virginia Native Plant Society 2000). Tree-of-heaven is considered a Rank 1 "Severe Threat" plant, which means that it "possesses characteristics of invasive species and spreads easily into native plant communities and displaces native vegetation" (Tennessee Exotic Pest Plant Council 1996).
HABITAT:	Tree-of-heaven can be found in a wide variety of disturbed habitats and is unusually tolerant of polluted environments (Conservation New England 1998). It is mostly found along roadsides, fence rows, and vacant city lots (Virginia Native Plant Society 2000).
INTRODUCTION:	Tree-of-heaven is native to Asia and was first introduced to Europe in 1751. It was brought to the United States by a man from Philadelphia in 1784 (Conservation New England 1998).
OCCURRENCE ON ORR:	Tree-of-heaven can be found along nearly all roadsides throughout the Oak Ridge Reservation.
CONTROL:	Tree-of-heaven should be cut at ground level twice per year and a glyphosate herbicide applied to the stump. The herbicide should be applied late in the growing season so as to be translocated into the roots by the plant itself (Virginia Native Plant Society 2000).

REFERENCES:

Conservation New England. 1998. Available on-line [http://omega.cc.umb.edu/~conne/jennjim/ailanthus.html]. Cited Aug. 23, 2000.

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Tennessee Exotic Pest Plant Council. 1996. Available on-line [http://www.se-eppc.org/doc.cfm?id=473]. Cited Mar. 9, 2001.

Virginia Native Plant Society. 2000. Available on-line [http://www.vnps.org/invasive/invloni.htm]. Cited Aug. 23 2000.

COMMON NAME:	Field garlic
SCIENTIFIC NAME:	***Allium vineale*** L.
DESCRIPTION:	Field garlic is a perennial that reproduces sexually with aerial seeds, asexually with aerial bulbils, and asexually with underground offsets, which are analogous to the garlic cloves that we eat (Ronsheim **1996).** These offsets can remain dormant underground for **5** years (Ronsheim **1997).** Field garlic is considered a Rank 2 "Significant Threat" species, meaning that it may "possess some invasive characteristics, but have less impact on native plant communities; may have the capacity to invade natural communities along disturbance comdors, or to spread from stands in disturbed sites into undisturbed areas" (Tennessee Exotic Pest Plant Council **1996).**
HABITAT:	Field garlic grows in fields, roadsides, and can even grow in bottomland forests and pine woods (Ronsheim **1996).**
INTRODUCTION:	Field garlic was introduced to the United States from Central and Western Europe. It can now be found along the East coast from Georgia to Michigan (Ronsheim **1994).**
OCCURRENCE ON ORR:	Field garlic is found in most power line cuts and along **most sunny roadsides on the Oak Ridge Reservation.**
CONTROL:	Control is difficult because field garlic possesses variable bulb dormancy. This trait allows field garlic to emerge over long periods of time (Leys and Slife **1988).**

REFERENCES:

Leys, A. R., and F. W. Slife. **1988.** Absorption and translocation of ^{14}C-Chlorsulfuron and ^{14}C-Metasulfuron in wild garlic ***(Allium vineale).*** Weed Sci. **36:1–4.**

Ronsheim, M. L. **1994.** Dispersal distances and predation rates of sexual and asexual propagules of ***Allium vineale*** L. ***Am.*** Midland Nat. **131:55–64.**

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Ronsheim, M. L. **1997.** Distancedependent performance of asexual progeny in ***Allium vineale*** (Liliaceae). ***Am.*** J. Bot. **84:1279–1284.**

Tennessee Exotic Pest Plant Council. **1996.** Available on-line [http://www.se-eppc.org/doc.cfm?id=473]. Cited Mar. **9, 2001.**

COMMON NAME:	Oriental bittersweet (Asian bittersweet)
SCIENTIFIC NAME:	*Celastrus orbiculatus* Thunb.
DESCRIPTION:	Oriental bittersweet is a deciduous, climbing vine with round to oblong leaves. Inflorescences have few flowers, which are small and green and occur in clusters. A capsule surrounding the seed turns orange when the seed ripens (PCA Alien Plant Working Group 2000). Oriental bittersweet is considered a **Rank** 2 "Significant Threat" species by the Tennessee Exotic Pest Plant Council (1996).
HABITAT:	Oriental bittersweet grows in disturbed areas including roadsides and old homesites. It grows in alluvial woods and is capable of spreading into undisturbed mesic forests (PCA Alien Plant Working Group 2000).
INTRODUCTION:	Oriental bittersweet is native to Asia and was brought to the United States in the mid-1800s. It can be found as far north as Maine, south to Georgia, and west to Iowa (PCA Alien Plant Working Group 2000).
OCCURRENCE ON ORR:	Oriental bittersweet has been found to occur in only one location on the **Oak** Ridge Reservation. Eradication procedures were carried out in July 2000.
CONTROL:	Oriental bittersweet can be controlled through cutting and stump treatment with a glyphosate herbicide (PCA Alien Plant Working Group 2000).

REFERENCES:

PCA Alien Plant Working Group. 2000. Available on-line [http://www.nps.gov/plants/alien/fact/ceor1.htm]. Cited Mar. 5,2001.

Tennessee Exotic Pest Plant Council. 1996. Available on-line [http://www.se-eppc.org/doc.cfm?id=473]. Cited Mar. 9,2001.

COMMON NAME:	Bull thistle
SCIENTIFIC NAME:	*Cirsium vulgare* (Savi) Ten.
DESCRIPTION:	Bull thistle is a biennial plant that may produce up to 8000 seeds. These seeds germinate in both autumn and spring. Seeds are dispersed from July through September (Klinkhamer et al. 1988). Seeds are usually viable in soil for less than a year but have been found on occasion to be viable for 3 years. Seed dispersal is extremely limited, and seeds do not require light to germinate (Doucet and Cavers 1996). Bull thistle is considered a Rank 2 "Significant Threat" by the Tennessee Exotic Pest Plant Council (1996).
HABITAT:	Bull thistle occurs mainly in temperate regions. It can be found in such disturbed areas as roadsides, fields, and quarries. It can also be found along the banks of streams and rivers (Doucet and Cavers 1996).
INTRODUCTION:	Bull thistle was introduced to North America, New Zealand, Australia, and Chile from Europe, Africa, and western Asia (Doucet and Cavers 1996).
OCCURRENCE ON ORR:	Bull thistle can be found in several places on the Oak Ridge Reservation, including fields and sunny places along roads.
CONTROL:	**Control methods are unknown.**

REFERENCES:

Doucet, C., and P. B. Cavers. 1996. A persistent seed bank of the bull thistle *Cirsium vulgare*. Can. J. Bot. 74:1386–1391.

Klinkhamer, P. G. L., T. J. De Jong, and E. Van Der Meijden. 1988. Production, dispersal and predation of seeds in the Biennial *Cirsium vulgare*. J. Ecol. 76:403–414.

Tennessee Exotic Pest Plant Council. 1996. Available on-line [http://www.se-eppc.org/doc.cfm?id=473]. Cited Mar. 9, 2001.

Nomenclature taken from: Wofford, B. E., and R. Kral. 1993. Checklist of the Vascular Plants of Tennessee.

COMMON NAME:	Chinese yam (Air potato)
SCIENTIFIC NAME:	Dioscorea ***batatas*** Decne.
DESCRIPTION:	Chinese yam is a vine with opposite leaves that may sometimes occur in alternate or 3-leaf whorls. Stems climb by curling from left to right, as opposed to the native yam (Dioscorea ***villosa),*** whose stems curl from right to left. Chinese yam produces miniature aerial bulbils within the leaf axils. These bulbils are produced from August through October and then fall to the ground, re-sprouting the following spring. Chinese yam rarely produces flowers in the United States and inflorescences rarely mature (Nabors 1996). It is considered a Rank 2 "Significant Threat" by the Tennessee Exotic Pest Plant Council (1996).
HABITAT:	Chinese yam can be found growing in alluvial woods, fence rows, roadsides, and other disturbed areas. It primarily occurs in the piedmont and mountain areas of the southeastern United States (Radford et al. 1968).
INTRODUCTION:	Chinese yam was originally introduced from China to Europe in the mid-1800s as an alternative food crop during the potato blight. It is believed to have been brought to the United States by European settlers. Chinese yam is used in China, Japan, Korea, and Taiwan as a food crop. The yam is useful if allowed to grow for at least 3 years, at which point, the tuber may reach up to a meter in length. The Chinese yam is often used in Europe and the United States as a decorative ground cover and climbing vine (Nabors 1996).
OCCURRENCE ON ORR:	Chinese yam is found throughout the National Environmental Research Park. It is most prevalent along roads and in disturbed areas.
CONTROL	Chinese yam resprouts from its bulbils. The yam must be pulled from the ground, thus removing its underground tubers as well as its aboveground bulbils. The resulting material must be disposed of properly in order to assure that no resprouting will occur. Larger stems may be cut treated with a glyphosate herbicide.

REFERENCES:

Nabors, Pamela J. 1996. The current status and potential spread of an invasive exotic species: Chinese yam (Dioscoreu ***batatas)*** in the Great Smoky Mountains National Park. M.S. thesis. University of Tennessee, Knoxville, Tenn.

Radford, A. E., H. E. Ahles, and C. R. Bell. 1968. Manual of the Vascular mora of the Carolinas. The University of North Carolina Press, Chapel Hill, N.C.

Tennessee Exotic Pest Plant Council. 1996. Available on-line [http://www.se-eppc.org/doc.cfm?id=473]. Cited Mar. 9,2001.

COMMON NAME:	Autumn olive
SCIENTIFIC NAME:	***Elaeagnus umbellata***
DESCRIPTION:	Autumn olive is a deciduous shrub with alternate leaves that are oval and untoothed. The underside of the leaves are covered with silvery-white scales. Small, yellow leaves occur late in the growing season and round reddish-pink fruits are produced in great quantities. Autumn olive has nitrogen-fixing root nodules, which allow it to thrive in poor soils (Paschke et al. **1989).** It is considered a Rank 1 "Severe Threat" by the Tennessee Exotic Pest Plant Council **(1996).**
HABITAT:	Autumn olive tends to prefer disturbed areas including roadsides, forest edges, and pastures. It has, however, been spotted on at least one occasion within an undisturbed forest.
INTRODUCTION:	Autumn olive was introduced to the United States from in the **1830s.** It was brought from East Asia and can now be found throughout the eastern and central United States. Autumn olive was used to re-vegetate disturbed areas (Virginia Native Plant Society 2000).
OCCURRENCE ON ORR:	Autumn olive can be found growing along most roadsides and power-line cuts. It is especially dense along Bethel Valley Road.
CONTROL:	The best method for control of autumn olive is to cut the shrub and treat the stump with a glyphosate herbicide. The stump must be treated because otherwise resprouting will occur and the problem may become worse. Hand-pulling is effective for removing seedlings if the roots are removed as well (Virginia Native Plant Society 2000).

REFERENCES:

Paschke, M. W., J. O. Dawson, and M. B. David. **1989.** Soil nitrogen mineralization in plantations of ***Juglans nigra*** interplanted with actinorhizal ***Elaeagnus umbellata*** or ***Alnus glutinosa.*** Plant Soil 118:33–42.

Tennessee Exotic Pest Plant Council. **1996.** Available on-line [http://www.se-eppc.org/doc.cfm?id=473]. Cited Mar. **9, 2001.**

Virginia Native Plant Society. 2000. Available on-line [http://www.dcr.state.va.us/dnh/fselum.pdf]. Cited Aug. **28,** 2000.

COMMON NAME:	Chinese lespedeza (sericea lespedeza)
SCIENTIFIC NAME:	*Lespedeza cuneata* (Dum. Cours.) G. Don
DESCRIPTION:	Chinese lespedeza is a member of the pea family. It is an herbaceous to woody perennial with compound leaves, each with three leaflets. Leaflets are cuneate and flowers are white with purple veins and can be found at the base of the upper leaves. Chinese lespedeza alters the soil nutrient content by adding nitrogen (Virginia Native Plant Society 2000). Lespedeza seeds can remain viable in the soil for up to 20 years, making scarification necessary for germination (Plant Conservation Alliance 1998). Lespedeza has deep roots that allow it to thrive on *dry* slopes and abandoned mines. It was used regularly in the past couple of decades to stabilize slopes (Guernsey 1970). Chinese lespedeza is considered a Rank 1 "Severe Threat" by the Tennessee Exotic Pest Plant Council (1996).
HABITAT:	Chinese lespedeza appears to prefer open, sunny areas. It can be found along roads, power line cuts, cedar barrens, and waterfronts on the Oak Ridge Reservation (ORR).
INTRODUCTION:	Chinese lespedeza was introduced to the United States from Asia (Virginia Native Plant Society 2000). It has been introduced for use as a forage crop and is now a significant food source for bob white quail who make it from 1.5% to 86.8% of their annual diet (Plant Conservation Alliance 1998). It can now be found throughout the southern United States and in parts of the Midwest (Virginia Native Plant Society 2000).
OCCURRENCE ON ORR:	Chinese lespedeza occurs along nearly every road on the ORR. It can also be found in power line rights-of-way, abandoned fields, and lake edges.
CONTROL:	According to the Virginia Native Plant Society, the best method for controlling Chinese lespedeza is to mow it during the period of time when it is flowering. It is during this time that root reserves are low. This process should be repeated for 3 to 4 years in order to reduce the intensity of growth (Virginia Native Plant Society 2000). Prescribed burning may be the most effective method for long-term control. Fire will force lespedeza seeds to germinate, and, when followed by mowing, can reduce the number of years in which the procedure must be repeated. Foliar herbicide application is not recommended because of its inability to target a particular species (Virginia Native Plant Society 2000).

REFERENCES:

Guernsey, Walter J. 1970. Sericea Lespedeza: Its use and management. U.S. Department of Agriculture Farmers' Bulletin No. 2245.

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Plant Conservation Alliance, Alien Plant Working Group. 1998. Available on-line [http://www.nps.gov/plants/alien/fact/lecu1.htm]. **Cited Aug.** 10, 2000.

Virginia Native Plant Society. 2000. Available on-line [http://www.vnps.org/invasive/invfslesp.htm]**Cited Aug.** 10, 2000.

COMMON NAME:	Chinese privet (privet)
SCIENTIFIC NAME:	***Ligustrum sinense*** Lour.
DESCRIPTION:	Chinese privet is a semideciduous shrub that can grow up to 10 meters in height. Leaves are opposite and elliptic in shape (Cuda and Zeller 2000). Twigs are pubescent (Gleason and Cronquist 1963). Chinese privet produces small white flowers that bloom from June to July and dark blue fruits that are often eaten by birds and thus spread to surrounding areas (Cuda and Zeller 2000). Each fruit contains 1 to 4 seeds that ripen during September and October. Each individual plant is capable of producing hundreds of fruit (Tennessee Exotic Pest Plant Council 1996a). Chinese privet is considered a Rank 1 "Severe Threat" by the Tennessee Exotic Pest Plant Council (1996b).
HABITAT:	Chinese privet resides in disturbed areas along roads and in abandoned fields. It also grows readily along stream banks (Cuda and Zeller 2000). It does not prefer high elevations and is not found above 3000 feet. Privet is shade tolerant and can be found living in forests; however, it does not often produce fruit in low-light conditions (Tennessee Exotic Pest Plant Council 1996a).
INTRODUCTION	Chinese privet was introduced from Asia to the United States in 1852. By 1932, it had become naturalized throughout the southeastern United States (Cuda and Zeller 2000).
OCCURRENCE ON ORR:	Chinese privet is found in many areas at ORR. Chinese privet is troublesome because unlike most of the other invasive plant species, it is found within Natural Areas.
CONTROL:	Chinese privet will resprout upon cutting, thus it is necessary to use an herbicide glyphosate on stumps in order to kill the roots. According to Cuda and Zeller, a biological control of Chinese privet may already be occurring. The seed weevil ***Ochyromera ligustri*** has been observed feeding on privet stands in Florida. The weevil feeds on the leaves, thus weakening them. It lays its eggs inside the fruit, which subsequently destroys the seeds when the larvae hatch and begin to feed on them (Cuda and Zeller 2000).

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COMMON NAME:	Japanese Honeysuckle
SCIENTIFIC NAME:	***Lonicera*** japonica Thunb.
DESCRIPTION:	Japanese honeysuckle is a climbing vine with hairy stems on its younger branches and hollow stems when the branches get older. Leaves are normally oblong but can be toothed or lobed. Japanese honeysuckle can grow up to 30 feet long. It flowers throughout summer and flowers are white with a pinkish interior when young and a yellow interior when older. Honeysuckle produces black bemes that contain many seeds in autumn. The vine produces stolons that can root when they come into contact with soil (Virginia Native Plant Society 2000). Japanese honeysuckle is considered a Rank 1 "Severe Threat" by the Tennessee Exotic Pest Plant Council (1996).
HABITAT:	Japanese honeysuckle prefers disturbed areas, such as fields, fence rows, and roadsides (Virginia Native Plant Society 2000). The vine, however, can often be found throughout undisturbed areas.
INTRODUCTION:	Japanese honeysuckle was introduced to the United States from Asia in 1862. It is now well established throughout the eastern and central United States (Virginia Native Plant Society 2000).
OCCURRENCE ON ORR:	Japanese honeysuckle has been noted in almost every Research Park Natural Area and Reference Area surveyed in this study. It is usually more dense along forest edges and fence rows but can be seen in small numbers throughout undisturbed areas as well.
CONTROL:	Hand-pulling is most effective for small populations of honeysuckle. Prescribed burning is effective where large populations occur (Virginia Native Plant Society 2000).

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COMMON NAME:	Spearmint
SCIENTIFIC NAME:	***Mentha*** spicata L.
DESCRIPTION:	Spearmint has terminal spike-like inflorescences with white flowers. Female plants can occur alongside hermaphroditic plants and can be distinguished by the absence of the anther. Spearmint is well adapted to drought conditions. It flowers from July through September. ***Mentha*** spicatu is thought to be a hybrid of ***Mentha suaveolens*** and ***Mentha longifolia*** (Kokkini and Vokou **1989).** There is evidence that spearmint may reproduce vegetatively (Hirata et al. **1990).** Spearmint is considered a Rank **3** "Lesser Threat" by the Tennessee Exotic Pest Plant Council which means that it "seems to principally spread and remain in disturbed comdors, not readily invading natural areas" (Tennessee Exotic Pest Plant Council **1996).**
HABITAT:	Spearmint grows in wet areas.
INTRODUCTION:	Spearmint is native only to the Balkan Peninsula Northwestern Turkey. It has been introduced and naturalized in the United States, Europe, and throughout the Mediterranean (Kokkini and Vokou **1989).** It has been widely used as a culinary herb (Hirata et al. **1990).**
OCCURRENCE ON ORR:	***An*** extensive patch of spearmint has been found in Hembree Marsh.
CONTROL:	Control methods are unknown.

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COMMON NAME:	Microstegium (Japanese grass, Nepal grass, wiregrass)
SCIENTIFIC NAME:	*Microstegiurn virnineurn* (Trin.) A. Camus
DESCRIPTION:	Microstegium is a C_4 annual grass with stems that may grow up to 40 inches long and are capable of rooting at the stem nodes (Barden 1987). Its leaves are tapered at both ends and are generally 4 to 5 inches in length and a half-inch wide. Each plant may produce between 100 and 1000 seeds that may remain viable in the soil for 3 to 5 years (Virginia Native Plant Society 2000). Inflorescences are terminal with spike-like racemes, and stalks are pubescent (Godfrey and Wooten 1979). Microstegium is considered a Rank 1 "Severe Threat" by the Tennessee Exotic Pest Plant Council (1996).
HABITAT:	Microstegium is shade tolerant and can grow in variable light conditions because of its low-light compensation points and low-dark respiration rates. These allow the plant to continue to assimilate CO_2 in the darkness of the understory (Horton and Neufeld 1998). In fact, microstegium has been observed growing in areas that receive only 5% full sunlight (Barden 1987). Although microstegium is often found in shady environments, it has been noted to grow in full sunlight. Microstegium appears to prefer moist soils and can often be found in low woods, floodplains, stream banks, roadsides, and woodland borders (Virgina Native Plant Society 2000).
INTRODUCTION:	Microstegium was first introduced to the United States in 1919 in Knoxville, Tennessee. It is native to Korea, Malaysia, India, and Japan (Virginia Native Plant Society 2000). It can now be found throughout the Southeastern United States (Horton and Neufeld 1998).
OCCURRENCE ON ORR:	Microstegium is found throughout the ORR. It appears to be the most problematic invasive plant found on the ORR. Although it is most often associated with disturbed areas, it is not restricted to these areas. In many instances, it was observed growing in undisturbed areas.
CONTROL:	The best method of control of microstegium is hand removal just before seed production of the next growing season. According to the Virginia Native Plant Society, this procedure must be repeated for at least seven years because of the longevity of seed viability in the soil (Virginia Native Plant Society 2000). Burning and mowing are not effective because they do nothing to remove the seed bank. A glyphosate herbicide will work effectively against microstegium; however, it works effectively against all green vegetation and is not recommended because of the possibility of losing native species (Virginia Native Plant Society 2000).

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Virginia Native Plant Society. 2000. Available on-line [http://www.dcr.state.va.us/dnh/fsmivi.pdfl. Cited Aug. 26, 2000.

COMMON NAME:	Watercress
SCIENTIFIC NAME:	*Nasturtium officinale* R.Br.
DESCRIPTION:	Watercress is a perennial, succulent plant that obtains nitrogen directly from the water in which it grows (Shear 1970). It is a macrophyte that lives in north temperate regions. It is an amphibious crucifer, meaning that it is a member of the Cruciferae family (Kerfoot et al. 1998). Watercress is also a helophyte with perennating buds below the surface of the marsh (Bornette et al. 1994). It is considered a Rank 2 "Significant Threat" by the Tennessee Exotic Pest Plant Council (1996).
HABITAT:	Watercress lives mostly in streams, ditches, and other areas where moving water may be present. It prefers a cooler climate but grows very well in the hilly southern states (Shear 1970).
INTRODUCTION:	Watercress was introduced to the United States from Europe in the 1700s (Kerfoot et al. 1998).
OCCURRENCE ON ORR:	Watercress was found in two different Natural Areas on the ORR. It was observed growing within a stream in Natural Area 43 and beside a stream in Natural Area 47.
CONTROL:	Options for biological control of watercress include the watercress sowbug, which chews through the underwater stems of the plant and causes the plants to drift downstream. Muskrats also feed on watercress and burrow in the soil which disturbs rooting (Shear 1970).

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Nomenclature taken from: Wofford, B. E., and R. Kral. 1993. Checklist of the Vascular Plants of Tennessee.

COMMON NAME:	Empress tree (Princess tree)
SCIENTIFIC NAME:	***Paulownia tornentosa*** (Thunb.) Steud.
DESCRIPTION:	The empress tree is a rapidly growing tree that can easily invade disturbed areas, especially areas that have a higher soil pH, like abandoned strip mines (Turner et al. **1988).** The empress tree produces prolific amounts of winged seeds that are shade intolerant, requiring sunlight to germinate. A single tree can produce up to $2 * 10^7$ seeds (GrubiSic and Konjevic **1992).** Each seed capsule usually contains 2,000 seeds that are left behind after the fall leaves are shed and often rattle in wind, giving the empress tree its nickname rattlebox. The flowers are tubular and a pale violet color. Leaves are opposite and heart-shaped (Sand **1992).** The empress tree reproduces not only by seed but by root suckering as well. In fact, root sprouts may grow up to **15** feet per season (Plant Conservation Alliance **1998).** The empress tree is considered a Rank **1** "Severe Threat" by the Tennessee Exotic Pest Plant Council **(1996).**
HABITAT:	The empress tree prefers a mild, temperate climate (Hui-jun and Ingestad **1984).** It grows well on poor soils, making it common in disturbed areas (GrubiSic and Konjevic **1992).** The empress tree can be found in such disturbed areas as roadsides and abandoned strip mines. It can also be found growing along stream banks and forest edges (Plant Conservation Alliance **1998).**
INTRODUCTION:	The empress tree was introduced to Europe from China and was introduced to the United States in **1845.** It can now be found from New York to Florida and as far west as Texas (Sand **1992).** The purpose for introduction was for use as a park tree (GrubiSic and Konjevic **1992).**
OCCURRENCE ON ORR:	The empress tree can be found in several areas on the Oak Ridge Reservation but mostly in disturbed areas, such as roadsides.
CONTROL:	Hand pulling is the best method of control for young plants as long as all of the roots are removed to prevent resprouting. Cutting at ground level is effective for removing larger trees. Stumps must be treated with a glyphosate herbicide to prevent resprouting.

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COMMON NAME:	Kudzu
SCIENTIFIC NAME:	Pueruriu *montana* (Willd.) Ohwi
DESCRIPTION:	Kudzu is a leguminous perennial vine that spreads locally through vegetative reproduction. It is rarely spread by seed because of poor seedling establishment. Kudzu is high-climbing and can completely blanket existing vegetation (Sasek and Strain 1989).
HABITAT:	Kudzu grows in disturbed areas such as roadsides and abandoned fields. It can often be seen encroaching onto adjacent forest margins.
INTRODUCTION:	Kudzu was introduced to the Eastern United States in 1876 (Sasek and Strain 1989).
OCCURRENCE ON ORR:	Kudzu occurs in few places on the ORR. It can be found growing in power line cuts and other disturbed areas.
CONTROL:	Kudzu is very difficult to control but can be managed through manual removal and stump treatment with a glyphosate herbicide (Tennessee Exotic Pest Plant Council 1996).

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Nomenclature taken from: Wofford, B.E., and R. Kral. 1993. Checklist of the Vascular Plants of Tennessee.

COMMON NAME:	Multiflora rose
SCIENTIFIC NAME:	Rosa *multiflora* Thunb. ex Murray
DESCRIPTION:	Multiflora rose is a perennial shrub with stems that are trailing and can root at the tip. The leaves are compound, alternate, and toothed (Virginia Native Plant Society 2000). Flowers are white and bloom in May or June (Szafoni 1991). Multiflora rose seeds are photoblastic and sensitive to light (Yambe et al. 1995). Fruits are red hips that are eaten by birds and thus, spread rapidly. Multiflora rose produces dense thickets that are highly competitive for soil nutrients and can shade out native plants (Virginia Native Plant Society 2000). It reproduces both vegetatively through layering and by seed. Seeds are viable in soil for 10 to 20 years (National Park Service 2000). Multiflora rose is considered a Rank 1 "Severe Threat" by the Tennessee Exotic Pest Plant Council (1996).
HABITAT:	Multiflora rose can be found growing not only in such disturbed areas as agricultural lands and pastures, but also in natural areas, such as savannas, prairies, and open woodlands (Szafoni 1991).
INTRODUCTION:	Multiflora rose is native to Japan and other areas in northeastern Asia. It was introduced to the United States on several occasions within the last 200 years (Epstein et al. 1997).
OCCURRENCE ON ORR:	Multiflora rose can be found growing along roads and forest edges on the ORR. Large populations can be found growing along the edge of the Bull Bluff Natural Area.
CONTROL:	Multiflora rose can be controlled by pulling plants from the soil. It is important to remove all roots from the soil, as they will resprout. Cutting the plant at ground level is also effective if a glyphosate herbicide is applied to the stump. Routine prescribed burning can also be effective in preventing the growth of multiflora rose. No known effective biological controls exist at this time. Rose rosette disease is a viral disease that can destroy multiflora rose, but is not recommended as a control because it may also affect native and ornamental roses (Szafoni 1991).

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Nomenclature taken from: Wofford, B. E., and R. Kral. 1993. Checklist of the Vascular Plants of Tennessee.

COMMON NAME:	Johnsongrass
SCIENTIFIC NAME:	***Sorghum halepense*** (L.) Pers.
DESCRIPTION:	Johnsongrass grows by seed, branched rhizomes, and fleshy rhizomes (Smeda et al. **1997).** It is considered a Rank 1 " Severe Threat" by the Tennessee Exotic Pest Plant Council **(1996).**
HABITAT:	Johnsongrass is a problem in the croplands of **58** countries (Smeda et al. **1997).**
INTRODUCTION:	Johnsongrass is considered to be the **fifth** most problematic pest plant in the southeastern United States (Barrentine and McWhorter **1988).**
OCCURRENCE ON ORR:	Johnsongrass is found along almost every road edge on the Oak Ridge Reservation.
CONTROL:	One study found that Johnsongrass rhizomes could be controlled by spraying sethoxydim, quizalofop, and haloxyfop in paraffin oil on the plant (Barrentine and McWhorter **1988).**

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Nomenclature taken from: Wofford, B. E., and R. Kral. **1993.** Checklist of the Vascular Plants of Tennessee.

COMMON NAME:	Greater periwinkle
SCIENTIFIC NAME:	***Vinca minor*** L.
DESCRIPTION:	Periwinkle is an herbaceous evergreen that is very cold-tolerant. It is an angiosperm with leaves that develop in spring and summer (Huner et al. 1988). Periwinkle produces blue flowers in the spring and disperses its seeds throughout the summer; however, vegetative reproduction seems to dominate (Schulz and Thelen 2000). It is considered a Rank 2 "Significant Threat" by the Tennessee Exotic Pest Plant Council (1996).
HABITAT:	Periwinkle is a shade-tolerant plant and is a good competitor in shade (Hottes 1947).
INTRODUCTION:	Periwinkle was introduced to the United States from Asia and southern Europe. It can now be found throughout the eastern and central United States (Schulz and Thelen 2000).
OCCURRENCE ON ORR:	Periwinkle can often be found in areas where a cemetery or old homesite can be found. It is prevalent in Walker Branch and can be found growing together with microstegium.
CONTROL:	Foliar application of 2,3,6-trichlorobenzoic acid is effective if used to the point of being washed into the soil. A glyphosate herbicide will not work because it is unable to penetrate periwinkle's thick outer cuticle (The Nature Conservancy 2000). Periwinkle has been found to be susceptible to foliar diseases caused by ***Phoma exigua*** and ***Colletotrichum gloeosporioides*** (Koelsch et al. 1995).

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