THE DISTRIBUTION OF EXOTIC WOODY PLANTS AT CUMBERLAND GAP NATIONAL HISTORICAL PARK

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THE DISTRIBUTION OF EXOTIC WOODY PLANTS

AT CUMBERLAND GAP NATIONAL HISTORIC PARK

Research/Resources Management Report No. 52

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INTRODUCTION

In the 1980 Report to Congress (NPS 1980) on the state of the national parks, encroachment of exotic species was listed as a major threat to park resources. A total of 120 exotic plant threats were reported. In a survey of botanical problems of Southeastern national parks, Bratton et al. (in press) found that 17 parks reported kudzu, 14 reported Japanese honeysuckle, 8 reported mimosa, 3 reported princess tree, and 2 reported tree of heaven as prominent exotics. The purpose of this study was to locate and quantify populations of woody exotic plants in Cumberland Gap National Historical Park and to determine their effects on the native vegetation.

History of Human Impact

Cumberland Gap National Historical Park (CUGA), established in 1955, is administered by the National Park Service (U.S. Department of the Interior). Located at the common corner of Virginia, Tennessee, and Kentucky, the 8,000 ha park includes historic buildings, forested mountain slopes, limestone cliffs and caves, and a major highway.

At the time of establishment, CUGA already had a long history of human impact. Prior to European colonization, Indians had trails running through the area and hunted in the surrounding mountains. The "discovery" of the gap is credited to Dr. Thomas Walker, who was surveying for a suitable settlement site. Later, Daniel Boone helped blaze a wagon trail along some of the same routes that the Indians used. Soon pioneers traversed the area as part of the general western migration. Because of the importance of the gap in trade, the land was quickly settled. Slopes were cleared for farming and homes although, according to records of the day, very little of the timber came from the steep ridges now designated as part of the park, but

rather from the surrounding area.

The Civil War caused a dramatic change in the vegetation of Cumberland Gap. Because of its strategic location, both Union and Confederate forces strived to control the critical "Wilderness Road" and the area changed hands several times. The gap itself was stripped of all trees, and surrounding slopes were cut and cleared in order to make visible any advancing troops and better secure the garrisons built there (Hinkle 1975).

In the late 1800's, with the introduction of the railroad, commercial loggers began harvesting the remaining slopes that contained large stands of virgin timber. Mining soon became prevalent in the mountains, and the area experienced its first economic boom. Eventually all virgin stands of timber were removed. Fires may have affected the vegetation; however, since 1956 only 32 small fires have been reported in the park and none were hot enough to enter the forest canopy (Hinkle 1975).

In addition to clearing the forest, European settlers introduced exotic plants. Some non-native plants were originally cultivars, including crops, fruit trees, and ornamentals in early homesites. Others were probably accidentally introduced as weeds. Under park administration, the homesites have either been maintained as points of historic significance, such as Hensley Settlement, or have been abandoned and are being allowed to revegetate to the natural woodland. In allowing this revegetation, little or no emphasis has been placed on the removal of exotic plant species. Populations of woody exotics have persisted and are encroaching upon the native vegetation to varying degrees.

Determining the locations of exotic plant populations is important for three reasons. First, exotic plants threaten to invade and dominate niches occupied by native plants. This could theoretically lead to the elimination

of some species of local flora. Second, as an historical park, CUGA has an obligation to preserve and represent the natural historic setting. Care must be taken to define "appropriation exotics" and distinguish them from more recent additions. Third, the existence of non-native species tends to obscure the native flora, giving the visitor to the park a false image of the area's natural vegetation. In a landscape of Southern Highland forests, thickets of kudzu and Japanese honeysuckle are aesthetic intrusions.

METHODS

Sampling was conducted from July 1 through July 22, 1980. An attempt was made to survey all occurrences of woody exotics within the park boundaries. All roads and trails in the park were walked at least once, and observations were recorded each time a woody exotic was encountered. A total of 97 km was surveyed, 28 on roads and 69 km on trails and in wooded areas. The first half of each data sheet contained environmental data which was collected once for each site, regardless of the number of exotics present. Each site was coded with a four-digit number and an area index for the geographic section of the park and marked on a topographic map. A "site" was defined subjectively by a continuous population of at least one woody exotic species and/or uniform environmental parameters. Thus, the size of the sites varied greatly, ranging from 10 m^2 to 20,000 m^2.

The longitude and latitude for each site were recorded to the nearest 0.01 km, using Universal Transverse Mercator (UTM) coordinates on USGS topographic maps. Elevation (determined from topographic maps) was recorded to the nearest 20 feet. The slope of each site was determined with a Brunton pocket transit. The slope values refer to the microenvironment

of about 10 m on each side of the site. The aspect of each site was recorded in degrees from magnetic north, except in flat areas. The topography of the site was classified into 10 categories ranging from ridgetops to middle slope positions to bottomlands. A special topographic code was used for Hensley Settlement.

Developments such as roads, trails, homesites, and monuments were coded 1 when present or 2 if present but abandoned. Other environmental information, including blowdowns, cliffs, burn scars, marshes, or steep banks were coded as present where appropriate. The distance in meters from the nearest road with public access was recorded, both as a measure of accessibility and of dispersion of the exotics. All distances were in reference to the part of the population nearest the road.

The surrounding plant community was surveyed for forest type, understory type, and successional stage. The forest types were classified as one of the 15 types outlined by Hinkle (1975) (see Table 7). A tulip tree-sycamore (successional) forest type was added to the list. The understory was classified as mesic herb, xeric herb, hydric herb, and old field or roadside weed. In addition, the successional stage of the forest was recorded on a scale of 0 to 3, from old fields through virgin forests (see Table 6). The canopy closure was subjectively rated on a scale of 1 to 6 from closed canopy or semi-open due to recent disturbance to nearly devoid of vegetation. In addition, the basal area was measured using a one-factor basal area prism. The percent canopy cover was estimated and recorded; sites at the forest edge, such as along roadsides, were given a maximum canopy cover of only 50 percent.

Based on a map, in the park files, of proposed management areas, sites were designated D for developed areas, H for locations of historic

significance, and N for proposed natural or wilderness areas.

Species Data

Each exotic species at a site was surveyed to determine its quantity and its impact on the surrounding vegetation. The degree of spread was subjectively rated on a scale of 0 to 4, from no evidence of spread to plants overcoming adjoining plants and dispersing from the site. The impact of the exotics on each of three vegetation layers (herbs, shrubs, and overstory) was rated from 0, no impact, to 4, engulfing the site and killing shrubs and trees, or 5, 100 percent cover. A separate note was made if the exotic was actually killing trees or opening the canopy.

The total area of cover for each woody exotic species was determined by dividing the spread into three categories: (1) scattered, where the exotic had less than 20 percent cover, (2) dominant, where the exotic had from 20 to 90 percent cover, and (3) areas where the exotic had more than 90 percent cover. The area covered in each category was paced off and recorded. The totals were computed separately for occurrences on the ground and occurrences in the canopy, and the two layers often overlapped. Finally, an estimate of the total cover for the whole site was obtained by summing the absolute cover of each category. For instance, if a plant covered 10 m^2 on the ground with a 50 percent cover, and 10 m^2 in the trees with 10 percent cover, the total would be 10 x 50% + 10 x 10%, or 6 m^2 for the site.

For tree and shrub species, stem counts were taken in four classes: seedlings, saplings with stems less than 1 cm at breast height, small trees with diameters at breast height (dbh) equal to or greater than 1 cm but less than 10 cm, and trees with dbh's 10 cm or greater. The diameters were

recorded for each stem greater than 1 cm dbh.

Data Analysis and Random Points

To facilitate analysis, the aspect values were divided into aspect units 1 to 8 based on 45° sections of the compass. Some species were clumped by genus, such as roses (Rosa spp.) or privet (Ligustrum spp.). Apples (Pyrus) and peaches (Prunus) were also clumped through much of the analysis.

To establish baseline data for several physical environment variables, 194 points were randomly selected after blocking USGS 7-1/2 minute topographic maps into 1 km x 1 km squares. A random numbers table was used to select first the numbered block and then the "latitude and longitude" within this block. Elevation, aspect, slope, and topography were recorded for each point directly from the topographic map.

Data were analyzed using SAS statistical computer program packages (SAS Institute 1979) and CALFORM mapping packages (Laboratory for Computer Analysis and Spatial Graphics 1972). SAS programs included MEANS for totals and averages, FREQ for frequency tables, and Chi-square tests and CORR for product-moment correlation.

RESULTS

A total of 20 woody exotic species were located and surveyed in Cumberland Gap National Historical Park. Three hundred and thirty-five recordings were taken at 153 sites (Table 1). Japanese honeysuckle (Lonicera japonica) was by far the most prevalent exotic species, covering an estimated total of 136,759 m^2 of the park. Its 100 sightings accounted for 30 percent of the sightings and comprised 67 percent of the total

Table 1. List of exotic species found at Cumberland Gap National Historical Site, with frequency and percent of total.

	Frequency	Percent of Total
Lonicera japonica, Japanese honeysuckle	101	30
Rosa spp., Roses	61	18
Albizzia julibrissin, Mimosa	36	11
Pyrus malus, *Prunus persica*/Apple, peach	31	9
Pueraria lobata, Kudzu	23	7
Ligustrum spp., Privet	24	7
Vinca minor, Periwinkle	12	4
Paulownia tomentosa, Princess tree	11	3
Ailanthus altissima, Tree of heaven	9	3
Yucca filamentosa, Yucca	9	3
Populus alba, White poplar	5	1
Cornus sp.	3	1
Hedera helix, English ivy	2	1
Catalpa sp.	2	1
Castanea mollissima, Chinese chestnut	1	.03
Ginkgo biloba, Ginkgo	1	.03
Quercus sp.	1	.03
Salix sp., Willow	1	.03
Spiraea sp.	1	.03
Ulmus sp.	1	.03
TOTAL	335	100

square meters of exotics in the park. The six most common species, which include Japanese honeysuckle, roses (Rosa spp.), mimosa (Albizzia julibrissin), apples (Pyrus malus), privet (Ligustrum spp.), and kudzu (Pueraria lobata), account for over 80 percent of the sightings. However, in terms of square meters of cover, two species, honeysuckle and kudzu, account for 90 percent of the total area covered by all exotics (Table 2).

The exotic species tend to be found clustered around Cumberland Gap itself, between the Visitor's Center and the wilderness road campground. With the exception of the artificially maintained environment of Hensley Settlement, only two sites of exotics were located east of Gibson Gap (Fig. 1). Detailed maps of the western half of the park (Figs. 2-5) reveal patterns of high exotic concentration along roadsides and developed areas. The frequency of sightings along the ridge trail was only 0.17 sightings per kilometer surveyed, compared to 17.95 sites per kilometer along Highway 58.

The environmental factors related to exotic occurrence can be best observed by summarizing and comparing data from 194 randomly chosen sites. From the random points, the mean elevation of the park is 2190 ft above sea level. The mean elevation of exotic sightings (1470 ft) is significantly less than this value ($p > t = .0006$). Although some exotics were found throughout the range of elevations in the park, the unequal variances suggest a clumping of exotics at the lower elevations.

Comparison of mean random slope values with slopes found at exotic sites reveals a strong tendency for exotics to be found in areas with little or no slope. Over half of the exotics sites (53 percent) were found on slopes less than 5°. None of the randomly selected sites had slopes under 5°, although such slopes do exist at scattered locations in the park.

To facilitate evaluation, aspect values were divided into nine subunits,

Table 2. List of species (in order of magnitude) by cover (m^2).

Species	Meters squared	Percent of total
Honeysuckle	136,928	67
Kudzu	47,112	23
Roses	9,406	5
Mimosa	1,816	1
Privet	1,576	1
Princess tree	720	.04
Trce of heaven	907	.04
Other	4,893	2
TOTAL	203,358	100

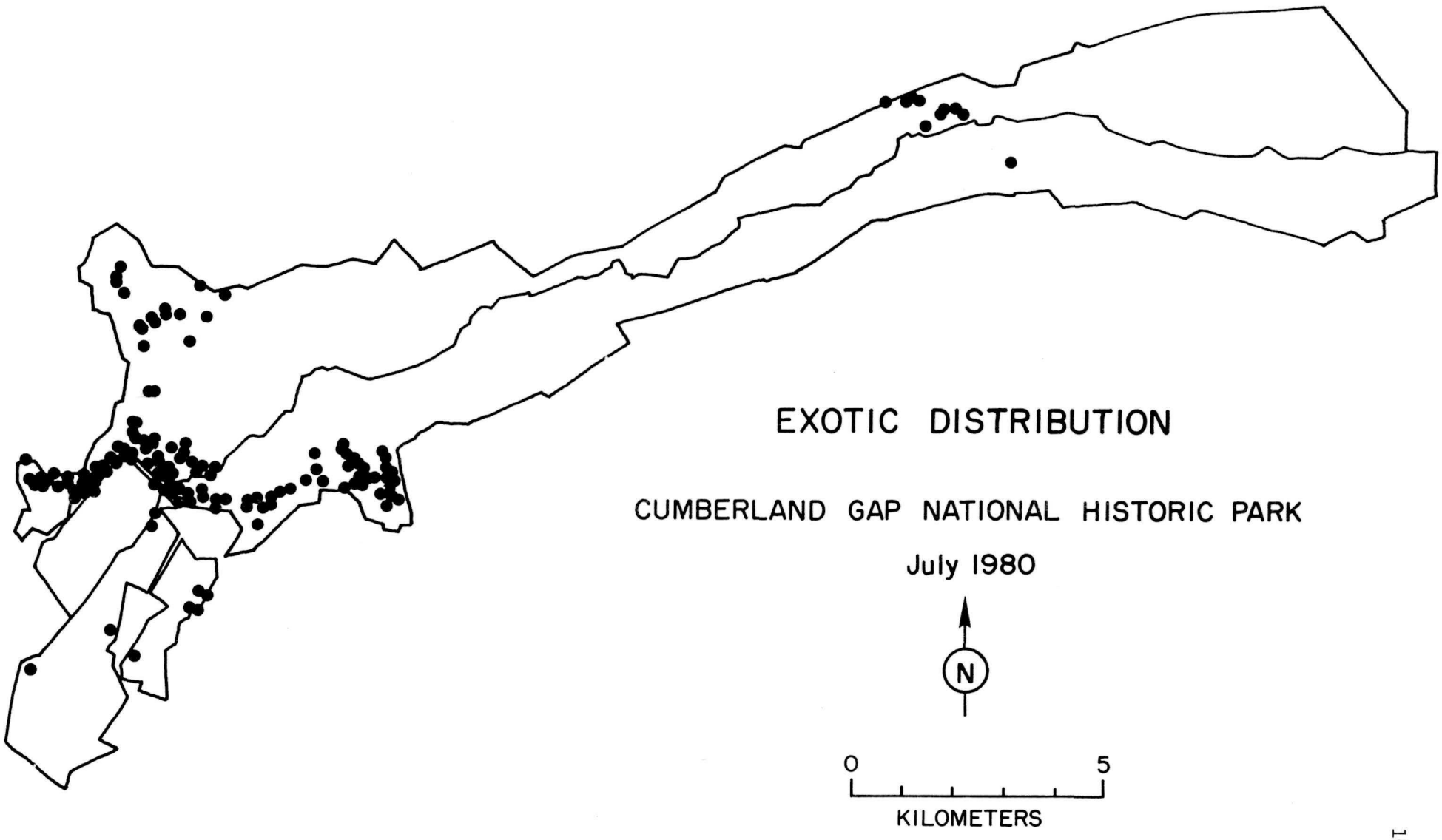

Figure 1. Distribution of exotic woody plants.

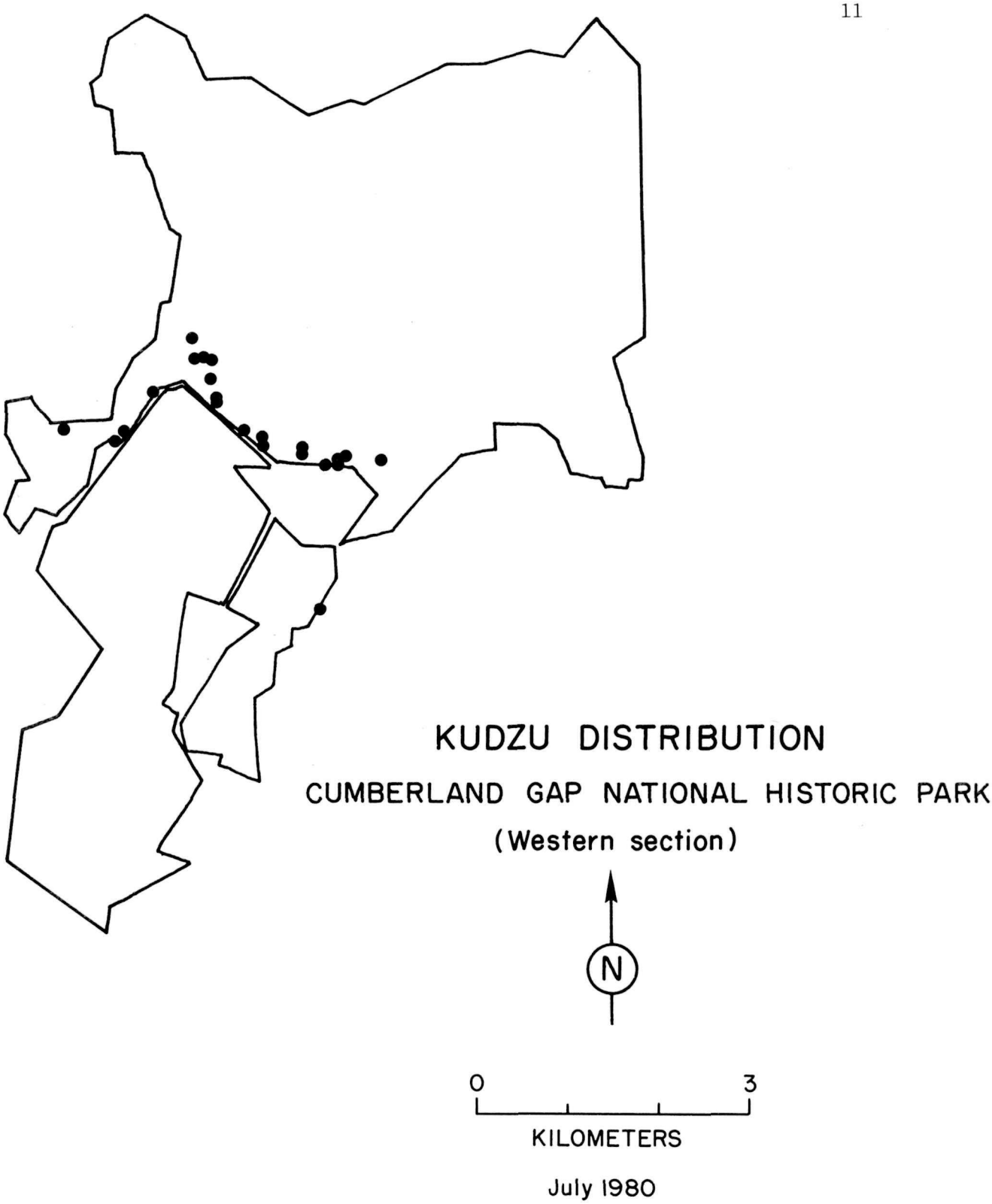

Figure 2. Distribution of kudzu. No kudzu was found in the eastern section of the park.

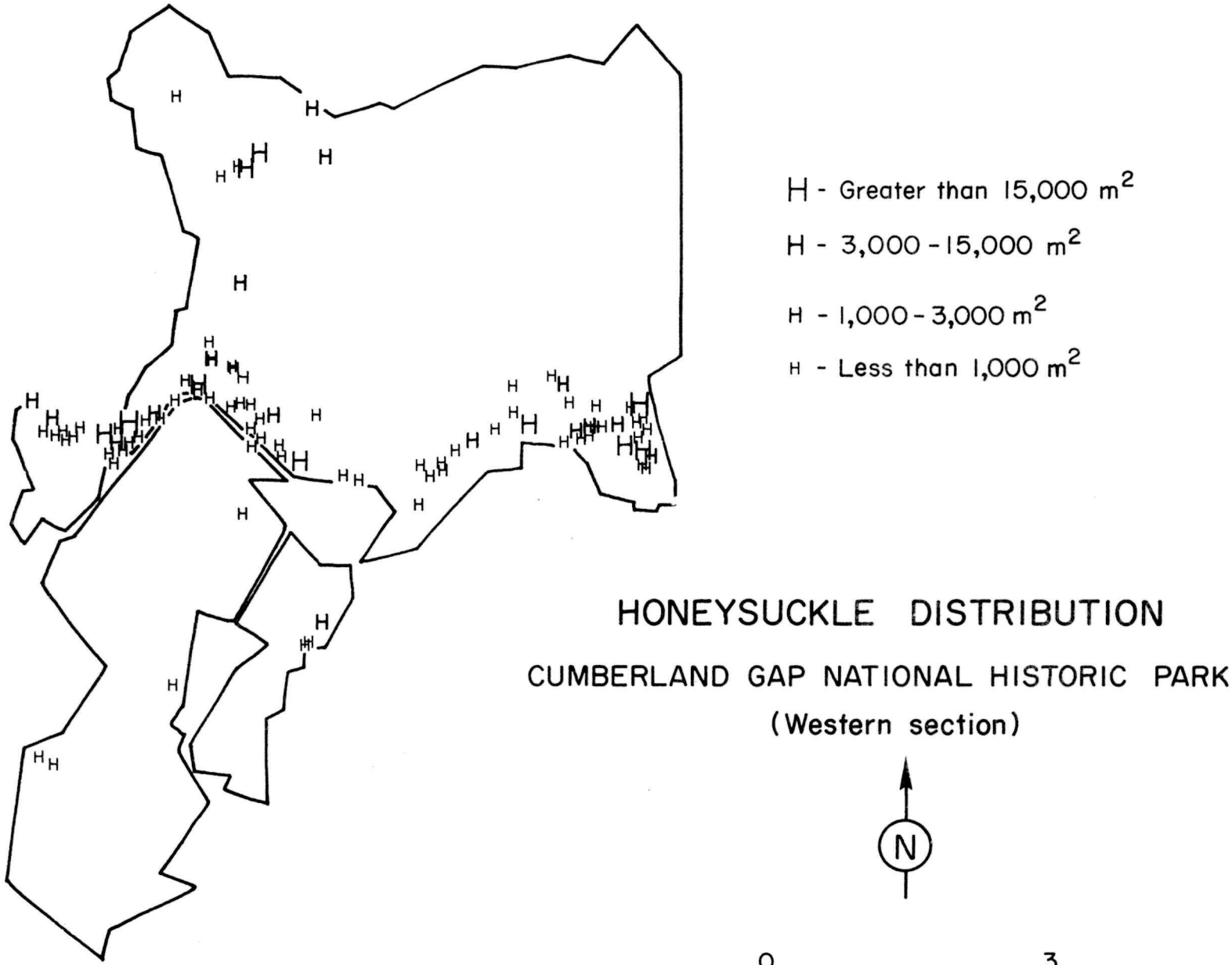

Figure 3. Distribution of honeysuckle. No honeysuckle was found in the eastern section of the park.

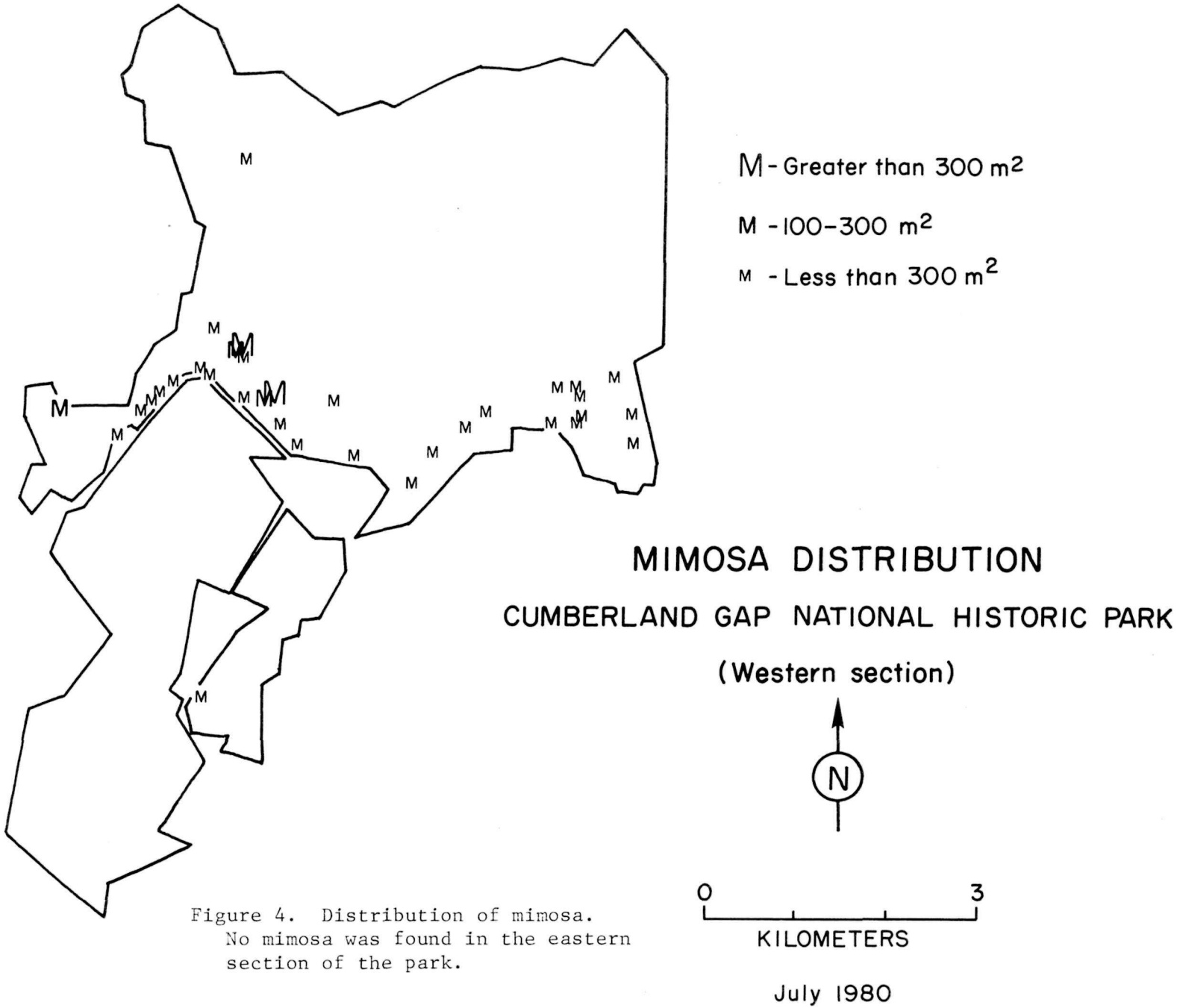

Figure 4. Distribution of mimosa. No mimosa was found in the eastern section of the park.

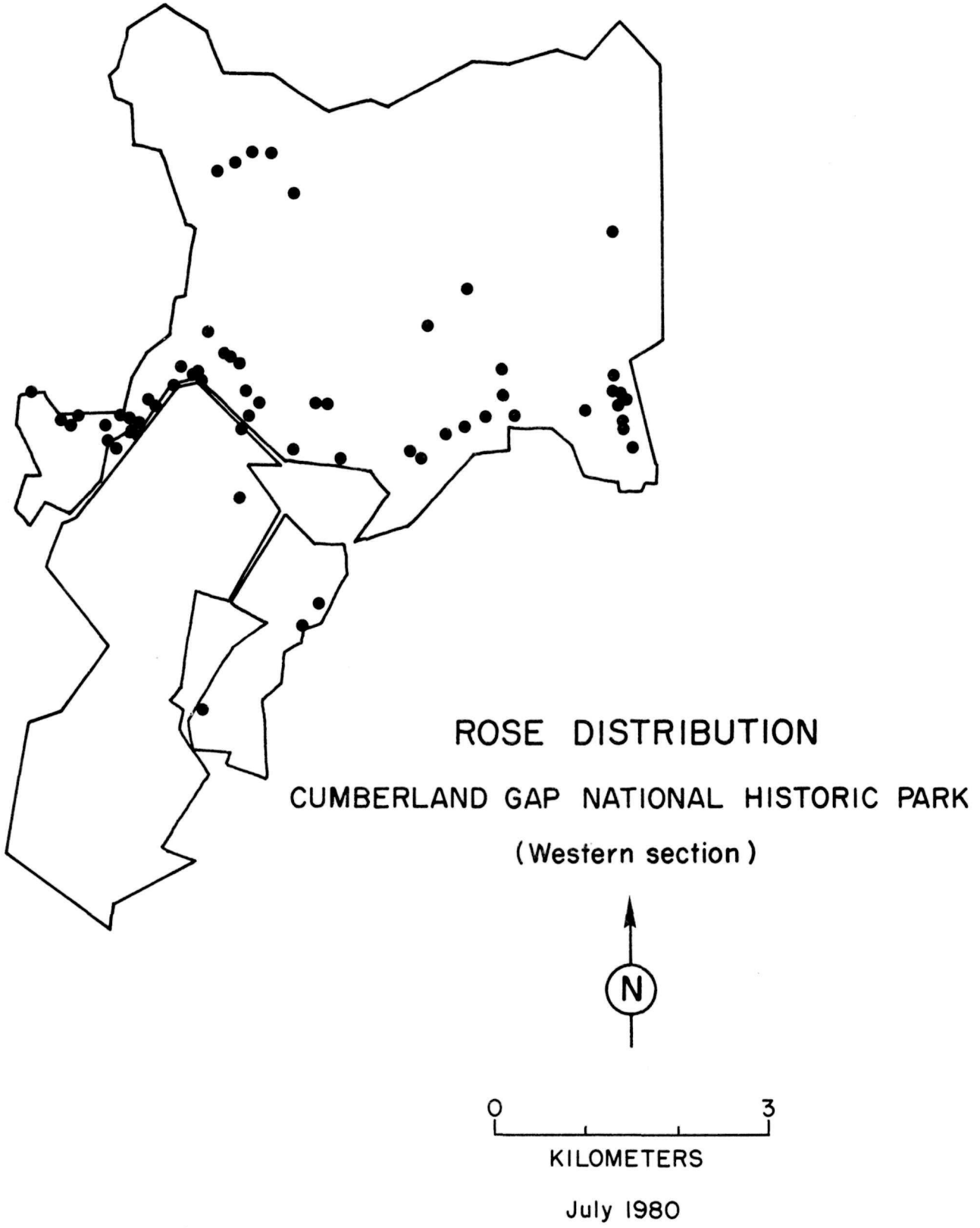

Figure 5. Distribution of roses. No roses were found in the eastern section of the park.

from driest to wettest, based on probable amounts of solar radiation (Table 3). Frequency and percentages of the random points, exotic sites, and the square meters of cover in each solar (aspect) unit are listed (see Table 3). Immediately apparent is the deviation of the random distribution from that of exotics in areas with no aspect defined. Dry south and southeast facing slopes are also under-represented among the exotic locations, as are shaded north to northeast faces (Table 4).

The tendency toward flatter terrain is further supported by comparing the topographic classes of the exotic and random sites. The distribution of exotics parallels the random points through most of the topographic classes; over half of the exotics and half of the random sightings occupied middle slope positions. However, the increased frequency of exotics in flat bottomlands and the corresponding decreased frequency of sightings in ravines shows a significant deviation away from the random distribution (Table 5; chi sq. - 97.7; $p = 0.0001$).

Forest Type

Most of the exotics found occurred in successional areas. Only 9 percent of the sightings were classified as mature forests. Most were either in young, secondary growth forests or old fields (Table 6).

In general, exotics preferred more mesic forest types. Honeysuckle was unique in showing a significant positive correlation with the dry forest types. Almost all of the exotic cover, 95 percent, was found in three major forest types: mixed pine, tulip-oak, and tulip-sycamore (Table 7). All are considered successional communities and represent early stages of a mature hardwood forest. Six major exotics (kudzu, privet, roses, mimosa, tree of heaven, and princess tree) were most prevalent in the tulip-sycamore

Table 3. Distribution of exotics and random points by aspect.

	Subunit	Range degrees	Random sites Freq.	%	Exotic Freq.	%	Exotic m^2	%
Most sunlight (driest)	1	180-225	28	(15)	21	(6)	12,848	(6)
	2	135-180	25	(24)	23	(7)	9,711	(5)
	3	225-270	12	(6)	27	(8)	8,681	(4)
	4	90-135	11	(6)	21	(6)	35,822	(18)
	5	270-315	18	(9)	38	(11)	14,178	(7)
	6	45-90	8	(4)	20	(6)	15,942	(8)
	7	315-360	35	(18)	41	(12)	10,267	(5)
Most shade (wettest)	8	0-45	34	(18)	16	(5)	13,838	(7)
	9	No aspect (flat)	0	(0)	131	(39)	81,423	(40)

Table 4. Cover (m^2) of major exotics by aspect unit.

	Aspect								No Aspect
	Driest							Wettest	
Species	1	2	3	4	5	6	7	8	9
LNC JPN	2	5	5	18	6	7	5	5	47
PRRLBT	19	--	--	23	12	8	3	14	20
LGS sp.	--	--	2	.4	2	--	21	12	63
ROS sp.	12	30	2	.4	2	--	4	1	48
ALB JLL	2	.1	31	1	9	14	27	3	13
ALH ALT	3	29	7	--	23	26	7	6	--
PLW TMN	6	1	1	--	6	42	1	29	15
Other	1	8	12	3	1	24	3	1	40

Table 5. Topographic distribution of random and exotic sites.

	Frequency	(%)	Frequency	(%)
Hensley	2	(1)	8	(2)
Ridgetop	13	(7)	28	(8)
Gap	21	(11)	9	(3)
Open/Sheltered slope	106	(56)	198	(59)
Draw	29	(15)	0	(0)
Ravine	11	(6)	3	(1)
Xeric flat	6	(3)	6	(2)
Bottomland	2	(1)	86	(25)
Sink hole	0	(0)	0	(0)
TOTAL	190	(100)	338	(100)

Table 6. Frequency of exotics by successional stage.

	Open Successional	(%)	Young Semiclosed	(%)	Older Successional forest	(%)	Total
Honeysuckle	29	(25)	65	(34)	7	(23)	101
Kudzu	9	(8)	11	(6)	3	(10)	23
Roses	17	(15)	35	(19)	9	(29)	61
Mimosa	10	(9)	22	(12)	4	(13)	35
Privet	4	(3)	19	(10)	1	(3)	25
Princess tree	6	(5)	4	(2)	1	(3)	11
Tree of heaven	5	(4)	4	(2)	0	(0)	9
Fruit trees	21	(18)	10	(5)	0	(0)	31
Periwinkle	5	(4)	6	(3)	1	(3)	12
Other	10	(9)	13	(7)	5	(16)	28
TOTAL	116	(100)	189	(100)	31	(100)	

Table 7. Forest types from Hinkle (1975) and frequency of exotic occurrence.

Forest Type	Frequency
I - Hemlock-rhododendron (HR)	2
II - Red maple-black gum-hemlock (MG)	4
III - Tulip-hemlock-mixed oak (TH)	9
IV - Tulip-mixed oak-hickory (TO)	80
V - Northern red oak-hickory (RH)	6
VI - Northern red oak-chestnut oak (RC)	2
VII - White oak-northern red oak (WR)	6
VIII - White oak-hickory (WH)	0
IX - White oak-black oak (WB)	0
X - Chestnut oak (CO)	2
XI - Chestnut oak-black oak (CB)	0
XII - Chestnut oak-black gum (CG)	0
XIII - Black oak-sand hickory (BH)	0
XIV - Scarlet oak-black oak-chestnut oak (SB)	2
XV - Pitch pine-Virginia pine (PV)	29
XVI - Tulip sycamore (TS)	60

community, and two (honeysuckle and periwinkle) were found most commonly in tulip-oak woods. Apple, peach, and pear trees, found predominantly at Hensley Settlement, were most commonly associated with oak-hickory forest types (Table 8).

Comparisons of exotic cover to basal area (BA) of forest cover per hectare indicate differing degrees of encroachment on native vegetation among exotic species (Table 9). For all exotics, mean BA values were low compared to mature forest in the Southern Appalachians, where 40-50 m^2/ha is not uncommon. However, the presence of honeysuckle, roses, and privet in areas with BA as high as 35 m^2/ha shows a high degree of shade tolerance in these species. Positive correlation coefficients reinforce these findings (Table 9). Four other species, mimosa, kudzu, tree of heaven (Ailanthus altissima), and princess tree (Paulownia tomentosa), show lower mean BA's, narrower BA ranges, and negative correlation to BA, indicating less of a shade tolerance/preference.

The degree of spread varied considerably between species. Sightings of honeysuckle and kudzu were most often given high spread ratings (Tables 10 and 11), with populations overcoming adjoining plants and dispersing from the site. On the other hand, sightings of princess tree and fruit trees showed little, if any, spread. The degree of dispersal is also reflected by the density of the population; sightings where individuals were scattered over the site without any dense clumps of mature growth probably reflect populations dispersing from parent populations. Mimosa and roses tended to be highly dispersed; 67 percent of the mimosa sightings and 33 percent of the rose sightings had only scattered individuals, whereas kudzu (9 percent scattered) stayed in more dense clumps (Table 12). Honeysuckle was intermediate, with 18 percent of its populations containing only scattered individuals. In the case of trees and shrubs, a similar index of dispersion was constructed by sorting for sites that had seedlings without mature trees

Table 8. Percent total area of exotics per forest type.

Forest Type	Percent
Tulip-mixed oak-hickory (TO)	35
Tulip-sycamore (TS)	33
Pitch pine-Virginia pine (PV)	26
Tulip-hemlock-mixed oak (TH)	4
Scarlet/black/chestnut oak (SB)	1
Others	1

Table 9. Exotic species response to canopy cover.

Exotic	$\bar{x}$BA	Product-moment correlation - cover vs. BA	Basal area range m^2/ha 0 5 10 15 20 25 30 35	
Honeysuckle	8.3	+.335	++++++++++++++++++++++++++++	(0-35)
Privet	9.3	+.226	++++++++++++++++++++++++++	(2-35)
Roses	9.3	+.137	++++++++++++++++++++++++++++	(0-35)
Mimosa	6.3	-.082	++++++++++++	(0-16)
Kudzu	4.7	-.204	+++++++++++++++	(0-20)
Tree of heaven	5.1	-.124	++++++++++++	(0-16)
Princess tree	3.7	-.149	++++++	(0-9)

Table 10. Square meters of each exotic by spread unit.

Species	Spread Unit (1) Little or no spread	(2) Clump growing in size	(3) Plant dispersing from site	(4) Plant engulfing site and dispersing	TOTAL
Honeysuckle	92	4,883	27,202	100,026	136,928
Kudzu	25	1,288	4,550	38,494	47,117
Roses	10	2,245	560	3,036	9,407
Mimosa	29	392	868	--	1,814
Privet	4	132	507	682	1,575
Princess tree	320	205	--	--	690
Tree of heaven	90	332	445	--	907
Other	28	1,190	2,608	550	4,479

Table 11. Percent of each exotic by spread unit.

Species	Spread Unit (1) Little or no spread	(2) Clump growing in size	(3) Plant dispersing from site	(4) Plant engulfing site and dispersing
Honeysuckle	< 1	4	20	73
Kudzu	< 1	3	10	82
Roses	< 1	24	6	32
Mimosa	2	22	48	0
Privet	< 1	8	32	43
Princess tree	46	30	0	0
Tree of heaven	10	37	49	0
Other	1	27	58	12

Table 12. Square meters of each exotic by density classification.

Species	ON THE GROUND						IN TREES						Un-adjusted total
	Scattered (<20% cover)	(%)	Dominant (20-90% cover)	(%)	>90% Cover	(%)	Scattered (<20% cover)	(%)	Dominant (20-90% cover)	(%)	>90% Cover	(%)	
Honeysuckle	8,899	(3)	133,556	(51)	6,413	(2)	42,966	(16)	68,436	(16)	1,931	(2)	262,201
Kudzu	100	(<1)	11,345	(20)	30,575	(54)	210	(<1)	10,040	(18)	4,350	(8)	56,620
Roses	4,715	(25)	12,928	(69)	1,068	(6)	15	(<1)	40	(<1)	95	(1)	18,861
Mimosa	1,079	(24)	2,936	(65)	3	(<1)	0	(0)	504	(11)	10	(<1)	4,532
Privet	4,301	(73)	1,165	(20)	398	(7)	0	(0)	0	(0)	0	(0)	5,864
Princess tree	0	(0)	50	(4)	4	(<1)	50	(4)	1,056	(89)	31	(3)	1,191
Tree of heaven	85	(5)	50	(3)	0	(0)	0	(0)	1,445	(91)	0	(0)	1,580
Other	1	(<1)	4,213	(65)	2,055	(32)	2	(<1)	0	(0)	231	(4)	6,502

present. Only two species were found; mimosa had 5 sightings while privet had only 2.

Most of the tree species appear to be replacing themselves with new seedlings or young trees and show a fairly stable population structure (Fig. 6). Princess tree has the least reproductively dispersing population, with only 6 seedlings (10 percent) observed. The exceptionally large number of mimosa seedlings indicate an ability for rapid colonization as new habitats become available. The relatively low number of mature mimosas could be indicative of an expanding population. The fruit tree populations should eventually decline due to low sapling replacement. The tree of heaven shows an even distribution among seedlings, first year trees, and young trees, suggesting, again, an expanding population.

Means for total impact (all exotics) showed the herb layer to be the most influenced, with a mean impact rating of 3.8 on a scale of 0 to 5 (Fig. 7), where 5 is the greatest possible impact. The shrub layer averaged 3.3, while impact on trees had an average rating of 2.9. Within the herb category, woody vines had the heaviest impact. Over half of the honeysuckle (64 percent), and 83 percent of the kudzu were found in classes 4 and 5. Average values were 4.3 and 3.6 for kudzu and honeysuckle, respectively. All (100 percent) of the periwinkle sighted was found in categories 3 and 4, giving an average herbal impact of 3.8. Roses, privet, and mimosa were found to influence herbs to a lesser degree, with average values of 2.7, 1.9, and 1.1, respectively. The larger tree species, princess tree, tree of heaven, and apples and pears had little or no impact on herbs.

Honeysuckle and kudzu showed the most impact in the shrub layer (3.2 and 3.9), while periwinkle, predominant as a ground cover, dropped to the no-impact rating (0.0). Privet and roses had mean impact values of 2.5 and 2.7,

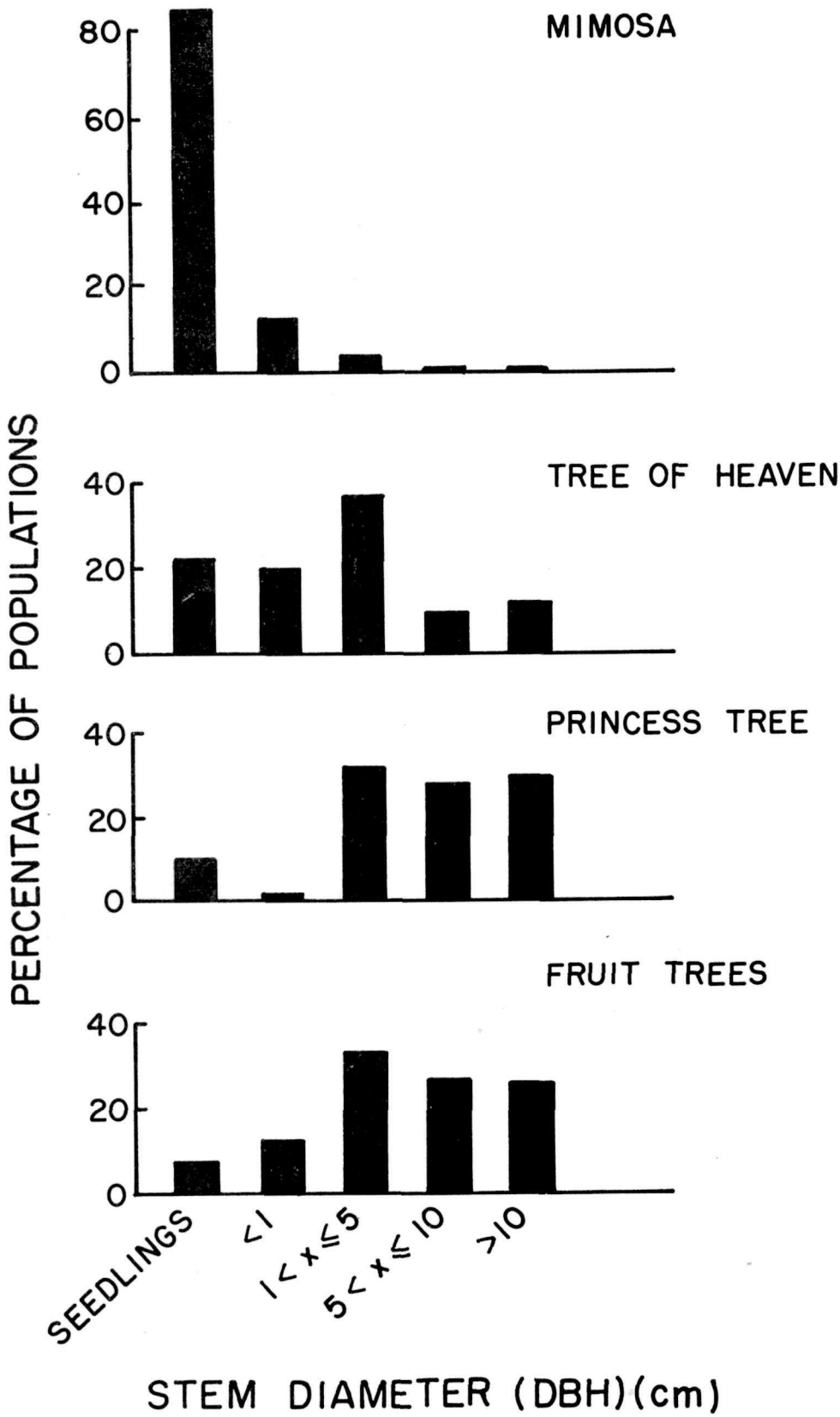

Figure 6. Distribution of stem diameter in four exotic tree species. Diameters were measured in centimeters at breast height.

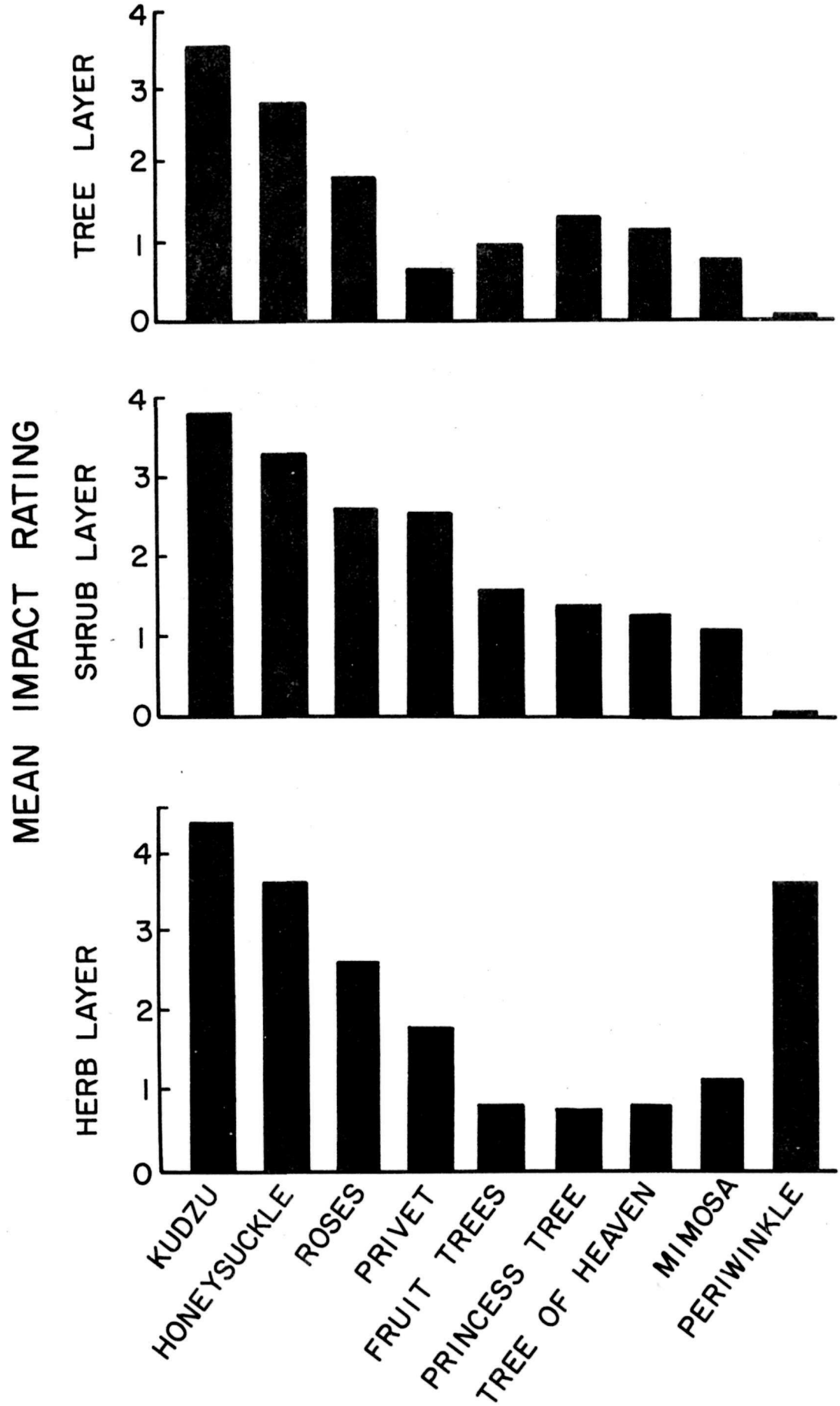

Figure 7. Mean impact ratings for major exotic species on the surrounding trees, shrubs, and herbs. Impact ratings range from 0, no impact, to 5, 100 percent cover.

while the larger tree species again had little or no impact (Fig. 7).

Kudzu had the highest impact on the overstory (tree) layer of CUGA's vegetation. Two-thirds (68 percent) of the total square meters in trees were found in impact class 4 for this species. Honeysuckle had less of an impact but remained a heavy influence, with 56 percent and a total mean impact value of 2.8 for this category. No other species showed a significant influence in thr tree layer.

Most of the exotics were found along roadsides (Table 13). Tree of heaven and princess tree were restricted to roadsides, with a mean distance of approximately 4 meters from the road. Other species were much less restricted; roses, for example, had a mean distance of 347 meters from roads. Highway 58 had the most frequent sightings of exotics, with nearly 18 sightings per kilometer. Trails had by far the fewest, with only 1.36 sightings per kilometer.

Approximately half of the total cover of woody exotics occurs in developed areas (Table 14), the remainder being equally split between historic and natural areas. A much larger percentage of the historic and developed areas are covered with exotics (Table 14). Nearly two-thirds of both honeysuckle and privet is in developed areas, while kudzu is nearly absent. Roses and mimosa are nearly equally distributed between the three areas. The less common species ("other") tend to occur in historic and natural areas.

Analysis of meters squared per acre reveal recreational and developed areas to be regions of major exotic encroachment (Rec. and developed: 123 m^2/acre, 50 m^2/hectare; cultural and historical: 55.5 m^2/acre, 23 m^2/hectare; and natural: 3.2 m^2/acre, 1.3 m^2/hectare).

Table 13. Total area (m^2) of each exotic per road type. Km walked is given as a measure of sampling intensity.

Exotic	Major highway	County road	Park/ visitor	Park/ maint. primitive	Not road (incl. trail)	Total
Honeysuckle	5,084	12,342	31,684	25,457	62,357	136,928
Kudzu	37,792	2,889	4	3,025	3,400	47,112
Roses	1,325	119	1,083	2,384	4,488	9,406
Privet	325	30	167	62	992	1,576
Mimosa	391	59	1,287	94	55	1,816
Tree of heaven	525	322	60	0	0	907
Princess tree	345	295	79	0	0	720
Other	51	184	1,005	1,991	1,662	4,893
TOTAL	45,838 (23%)	16,240 (8%)	35,369 (17%)	33,013 (16%)	72,954 (36%)	203,414
TOTAL KM WALKED	4.8 (5%)	4.8 (5%)	12.2 (12%)	6.7 (7%)	69.1 (70%)	97.6

Table 14. Exotic distribution by management codes

Species	Developed Recreational	%	Cultural & Historic	%	Natural	%
Honeysuckle	94,833	(69)	7,990	(6)	33,936	(25)
Kudzu	--	(0)	29,754	(63)	17,363	(37)
Privet	1,074	(68)	25	(2)	476	(30)
Roses	2,261	(24)	3,902	(41)	345	(34)
Mimosa	451	(26)	514	(30)	748	(44)
Tree of heaven	--	(0)	350	(39)	557	(61)
Princess tree	85	(12)	109	(15)	526	(73)
Other	332	(7)	2,009	(41)	2,550	(52)
Total	99,036	(49)	44,653	(22)	59,401	(29)

Analysis of meters squared per acre reveals recreational and developed areas to be regions of major exotic encroachment (Rec and dev: 123 m^2/acre, 50 m^2/hectare; Cult and hist: 55.5 m^2/acre, 23 m^2/hectare; and Natural: 3.2 m^2/acre, 1.3 m^2/hectare). These are based on available acreage values.

Perhaps the most significant correlation, however, is with the degree of human impact. Sightings were clumped according to areas with high or low human disturbance (Table 15). Approximately 90 percent of the exotics surveyed were in areas classified as high human impact. Sampling intensity was approximately equal in both high and low impact areas.

DISCUSSION

Woody exotic plants in Cumberland Gap National Historic Park tended to be found in open environments at low elevations. While this may reflect environmental limitations, it may also suggest direct human influence. Baron et al. (1975), in an exotic plant survey at Great Smoky Mountains National Park, found no non-native woody species above 3400 ft. All of CUGA (highest elevation 3300 ft) lies below this upper limit. Correspondingly, some woody exotics were found at all elevations at Cumberland Gap. Species such as tree of heaven and princess tree, which had lower elevational limits at Great Smoky Mountains National Park (1700 ft), had similarly low thresholds at Cumberland Gap (1750 ft), even though suitable roadside habitats were found at higher elevations in the park.

Within CUGA, the tendency toward low elevations may reflect the distribution of old homesites. The mean elevation of exotics at homesites found during the course of this study (excluding Hensley Settlement) was 1395 ft. Also, developed areas around the Visitor Center and the wildnerness road campground were at low elevations.

Exotics tended to be most successful in open, more recently disturbed areas and appeared to be more easily out-competed in later stages of succession. The tendency toward open environments can be seen in the fact that most exotics were negatively correlated with basal area. Honeysuckle

Table 15. Frequency of exotics in areas of high and low human impact. The number of killometers walked per area is given as a measure of sampling intensity.

		Frequency	Km walked
High human impact:* (subjective rating)	Visitor Center	25	2.58
	Wilderness Road Campground	20	4.49
	Highway 25-E	66	4.84
	Highway 58	35	1.95
	Highway 988	12	2.87
	Davis Hollow	11	2.00
	Hensley Settlement	16	11.94
	Iron Furnace	10	1.02
	Lewis Hollow	9	3.91
	Pinnacle Road	65	5.53
	Railroad	6	1.8
	Sugar Run	10	4.97
	Station Creek	22	3.81
	TOTAL:	296	51.71
Low human impact: (subjective rating)	Banner Field	2	2.16
	Chadwell Gap Trail	2	2.32
	Fitness Trail	2	1.70
	Gibson Gap Trail	2	6.68
	LMU Trail	8	2.80
	Martins Fork	1	0.87
	Ridge Trail	4	23.55
	Tri-State Trail	7	1.95
	Woodson Gap Trail	0	2.00
	TOTAL:	28	44.03

*These are areas with continuing disturbance, such as roadsides or visitor center. The list also includes areas with a high concentration of old homesites (i.e., Lewis Hollow, Davis Hollow).

was unique in its significant positive correlations with basal area.

The occurrence of honeysuckle under closed canopies is hard to explain. Thomas (1980) reported that in Theodore Roosevelt Island National Park, shading is a limiting factor in the growth of honeysuckle. The limit of "vigorous" growth occurred at about 27 percent of full sunlight, and "good" growth was found only at 47 percent of full sunlight or above. Average values of sunlight intensity in a mature deciduous forest in summer range from 23 to 29 percent. While the mean basal areas for honeysuckle sites was low (8.3 m^2/ha), the maximum (35 m^2/ha) is typical of mature successional forests.

A possible explanation for honeysuckle's persistence in the understory is winter growth. Honeysuckle in Tennessee was found to start vegetative growth in the middle of January, long before the canopy leaves emerge (Thomas 1980). Highest light intensity in winter averages 80 to 90 percent of full sunlight or very optimal conditions. Rates of winter growth are low, however, and may not completely account for its widespread presence.

An examination of variables, such as road type, management area, successional stage, and presence or absence of old homesites, shows that exotics are most successful in areas of heaviest human impact, and this factor outweighs environmental variables such as elevation and slope. Even though past disturbances, including logging and homesites, have influenced variables such as forest type, successional stage, and openness, present disturbance was a factor in most of the exotic sightings. Highway clearances, campground openings, and trail cutting all seem to be

contributing significantly to the success of exotic encroachment.

Among the 21 species of woody exotics found in CUGA, only a few appear to have much impact on the native flora. Some of these "problem" species are so abundant and highly dispersed that control would be difficult. The other species can be divided according to high, medium, and low priority groups based on their impact and ability to spread. Proposed groupings for management are:

I - Control difficult under present management constraints:
Honeysuckle, roses

II - Control practical under present management constraints:
High priority: Kudzu
Medium priority: Mimosa, privet
Low priority: Poplars, tree of heaven, princess tree, fruit trees

III - Other species were represented primarily by isolated individuals or small clumps that had little or no impact on the surrounding vegetation.

Honeysuckle, the most common woody exotic in the park, was found in a variety of habitats, in both developed areas and on relatively undisturbed forest floor. It also occurred in the canopy and was found killing trees. Because honeysuckle can persist under a closed canopy and can spread easily, it may be very difficult to control. (Controlled spring burning may be effective in slowing its rate of spread.) Cutting the vines by hand in dense populations where it is killing trees may be useful, but complete elimination of honeysuckle from the park is probably not possible at present.

Roses were not found in as dense clumps as honeysuckle, yet they had the second highest frequency of occurrence. They tend to occur in openings in the canopy, at homesites or blowdowns. The roses found along the ridge trail represent the farthest encroachment of any exotic away from roads or homesites. The impact of roses is not as great as honeysuckle, yet because they are so highly dispersed and already show evidence of invading the backcountry, they should be monitored.

Of the three species with high impact, kudzu is unique in that it is localized along Highway 25E. Although it has extremely high impact where it occurs (up to 100 percent cover and killing trees), it appears to spread almost entirely by vegetative means and remains near the parent population. Thus it should be possible to control its spread and keep it out of the backcountry. Eradication methods are currently being studied at Cumberland Gap.

Mimosa shows an ability for long distance dispersal (seedlings were found at several sites where there were no mature trees nearby), yet it still remains primarily restricted to disturbed areas along roadsides, showing a preference for an open environment that is relatively free of competitors.

Mimosa can spread rapidly and thousands of seedlings were found, yet there were relatively few large trees. A large portion of the mimosa seedlings were located on mowed highway easements. Although this appears to be an optimum environment for semination, the regular mowing will probably keep these seedlings from surviving to maturity. Several dead mimosas were observed, probably as a result of the mimosa blight that is entering the area. The seedlings are presently not much of a threat, and the blight may reduce the number of mature trees. The large seed

bank suggests that if new areas are opened up, mimosas can quickly invade.

Privet has a high impact on the herb and shrub layers where it occurs, yet it tends to be in dense localized clumps without much long distance dispersal. It is concentrated in the developed areas around the Visitor Center, where it can be easily cut out. Similarly, fruit trees are common and are reproducing, yet the populations do not appear to be expanding. The young individuals were without exception at the same site as a mature tree. Most of the fruit trees are in maintained areas such as the Hensley Historic District; however, they are also able to persist as part of second growth forests at old homesites. Because of their historical appropriateness, the fruit trees around Hensley Settlement should be maintained. Other fruit trees are not threatening the native vegetation, and removal is not urgent.

Tree of heaven and princess tree were found only along roadsides and thus appear to be restricted to highly disturbed open areas. Since very few seedlings or young trees were found, neither species is actively expanding its range. They both have low impact on the native vegetation and are presently not much of a threat. Because they are localized near the roads, it is possible to completely eradicate these species.

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