Inventory of Invasive Exotic Flora at George Washington Carver National Monument

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Summary

A survey of invasive exotic and problematic plants was conducted in prairie and forest habitats at George Washington Carver National Monument in the summer of 2001. One hundred and seventy-one 100 m^2 plots were sampled for the presence, cover, and dispersion of seven targeted exotic and seven problematic species throughout the park. Seven invasive exotic species were encountered; tall fescue (*Festuca arundinacea*) and bull thistle (*Cirsium vulgare*) were most abundant-both species found predominately in prairie habitat. Seven potentially problem species were encountered; horse nettle (*Solanum carolinense*) and dewberry (*Rubus trivialis*) were most abundant-both also found in prairie habitats. In addition, 43 of the 171 plots were surveyed for plant species dominance and physical habitat characteristics. Big blue stem (*Andropogon gerardii*) and switch grass (*Panicum virgatum*) were the most dominant (both native) occurring in 62% of the plots. Five exotic species were found to be dominant in at least one plot. No apparent relationships between species dominance, physical habitat, and frequency of exotic or problematic species were observed. Spatial and temporal variation in sampling of each prairie unit and forest habitat confounds the interpretation of patterns in the abundance and distribution of exotic species. However, some clear patterns are apparent and are discussed. In sum, the inventory establishes baseline data that can be used to administer control measures and monitor patterns of invasion.

Acknowledgments

I thank Dr. Wendy B. Anderson at Drury University and Doug Aubrey at Southwest Missouri State University for help in the field. I thank Dr. Michelle Bowe at Southwest Missouri State University for help in positively identifying plants and LeAnn Aubrey for help with developing the database and entering data. I thank the Heartland Network Inventory and Monitoring Program of the National Park Service for funding this inventory, the staff of George Washington Carver National Monument with logistical support, and Michael H. Williams, Inventory Specialist of the Heartland Network Inventory and Monitoring Program for generating all maps.

Introduction

In 1998 Congress passed the National Parks Omnibus Management Act in response to concerns about the condition of natural resources within the national parks. The act requires each park to gather baseline inventory data on pertinent natural resources, data that will provide a pivotal step toward establishing an effective monitoring program furthering the ability to effectively manage and protect park resources. The National Park Service (NPS) responded with the Natural Resource Challenge program, including the establishment of biome-based inventory and monitoring networks. The Heartland Network, as part of the NPS Inventory and Monitoring (I&M) program, has undertaken inventories of vascular plants and vertebrates within fifteen parks in eight Midwestern states.

Stemming from this challenge and a widespread concern regarding the status of invasive exotic plant populations at George Washington Carver NM, an inventory was deemed necessary to determine patterns of species presence and distribution.

Invasive plants can negatively impact ecosystems by altering fire regimes, nutrient cycling, hydrology, and energy budgets, while negatively impacting communities by diminishing the abundance and persistence of native species (Hobbs and Humphries 1995; Mack et al. 2000). Some invasive plants are exotics, while others are native but not desirable in a given habitat. In addition, not all exotic plants are necessarily invasive (Westman 1990), where invasive indicates a negative impact on an ecosystem or community. One of the first steps in assessing the impact of potentially invasive plants is to establish patterns in the abundance and distribution of those plants.

The inventory described in this report describes the distribution and composition of potentially invasive exotic flora, and of potentially invasive ("problematic") native flora at George Washington Carver NM. This inventory is a first step in understanding the abundance and distribution of potentially invasive species at the park as it 1) pinpoints some areas that should be monitored closely, and 2) establishes baseline data for understanding population dynamics of the target exotic and problematic species. The inventory also initiates sampling of vegetative and physical variables that may be associated with the distribution and abundance of the target species. Probably the most important products are "permanent" plots and a database, upon which data collected in the future can be used to more completely understand the dynamics of invasion in the park and assess management strategies.

Study Area

George Washington Carver NM is located in Newton County, MO in the Springfield plateau in the southwest corner of the state (Figure 1). Topography consists of gently rolling uplands dissected by stream channels that carry water from natural springs and excess water during rainy periods. A soil covering of several feet in thickness is present nearly everywhere, with Hagerstown and Eldon silt loams and Baxter gravelly loam being predominant in the park (USDA 1989). The park is roughly rectangular-shaped encompassing approximately 85 ha (210 ac). Habitat is dominated by xeric prairie and hardwood forest. Approximately 53 ha (130 ac) are in various stages of restoration to native tallgrass prairie. The park's woodlands are small in area, with the total acreage being approximately 32 ha (79 ac). The remaining areas are in the "development subzone" and encompass areas surrounding the administrative/housing and visitor center/maintenance complexes. Three small streams occur in the park; Carver, Harkins, and Williams. The latter two flow into Carver Branch, which is a tributary of Shoal Creek. Several areas of the park experience wet conditions throughout much of the year. The south central, west central and east central (just east of Williams pond) portions often have standing water during the winter and spring. Some of the water results from runoff, while much of it results from groundwater seepage. In comparison to the surrounding area, the land within the park does not stand out in distinct contrast. The surrounding farmlands all possess somewhat of a mosaic pattern: alternating grassland pastures and forest. Management efforts of approximately 80 acres for restoration to native prairie include seeding, planting, mowing, haying, and prescribed burning. In the past three years, restoration efforts have consisted mainly of mowing, haying, and prescribed burning. These areas are now in a variety of stages of restoration to native prairie. Control of exotic species in both the park's woodland and prairie areas is also a large concern.

Materials and Methods

One hundred and seventy-one 100 m^2 plots were sampled for the presence, cover and dispersion of seven exotic and seven problematic species (Table 1) throughout George Washington Carver NM during the summer of 2002 (July 18-20, August 14, September 15 & 28). An eighth possible exotic species, Kentucky blue grass (*Poa pratensis*), was not encountered in an identifiable state (i.e., flowering) and is not referred to in the results of this report.

Thirteen transect points (Appendix A) were randomly generated using Minitab 13.31 (Minitab, 2000) based on the assumption that the southern border of the park is 780 m. Assuming there were 73.4 ha (181.4 acres) that could be surveyed in the park (i.e., not surveying the "development subzone"), and that the target of surveying 170 5x20m plots was met, plots were evenly spaced at 65 m intervals along each transect (i.e., 65 m between the center of each plot; see figure 4). These assumptions were valid, and 171 plots were sampled. Therefore 1.71 ha (4.22 acres) or 2.3 % of the total area of the park was sampled.

Transects began at the southern boundary of the park (east-west baseline) and were oriented north-south and plots were systematically placed along the transect line. Plots were numbered consecutively according to date and order sampled and the center of the first plot began on the baseline. The first seven transects (plots 1-46) were interrupted by the "development subzone"; therefore, a second transect baseline was placed north of the development zone (plots 47-140) (Figure 2).

Plots were temporarily marked by walking due north 55, 65 and 75 m from the center of the previous plot using a global positioning system (GPS), transect tape, and compass marking each distance with a flag (the center of the plot is 65 m from the previous plot center). The center of the first plot of every transect line was placed along the transect line (Figure 3). Note that in cases where a development zone or obstruction (e.g., pond or stream) would have been included in a plot, the plot center was moved north at 10 m intervals until a plot could be established.

From each of the three flags, additional flags were placed 2.5 m due east and west of the transect using a compass and transect tape to delineate the plot area (5 x 20 m; 100m^2). Plots that started or ended a transect, or were sampled for dominance and physical structure ("full plots" see below) were permanently marked with a 30 cm nail and aluminum tag (transect number and plot number; e.g. T1-Plot 1). Nails were left 2-4 cm above ground.

Forty-three of the 171 plots were randomly chosen and sampled for dominant species and a number of additional biotic and physical variables (e.g., elevation, slope, physiognomy). Up to five dominant species were listed for each subset plot, where a dominant species has at least a cover of 5-25%. Species were ranked according to dominance, with a dominance value of 1 receiving a rank value of 5. Therefore rank values range between 1-5, with, for example, a species with rank 5 being more dominant than a species with rank 4. If there were fewer than five species with cover of at least 5-25%, then the number of dominant species is less than five. Ranks are simply based on estimates of cover, with the species with the greatest cover the most dominate, and so on. Data is presented as frequency and mean rank value, where the higher the rank value the greater the mean coverage across plots where the species was encountered.

A GPS coordinate was recorded for the center of every plot (the 65 m midpoint of the plot, see Figure 4) using a Garmin GPS II Plus (position accuracy 1-5 m). Species identification follows Kucera (1967) and Steyermark (1963).

While walking the transect line between plots, the presence of target and problematic species was noted and dispersion (clumped, random, uniform) and cover (by cover class) was recorded along with other plot notes.

See Table 4 for the number of plots that were sampled within each subzone except 7A and 2. Subzones follow National Park Service (1992) boundaries. For subzone 7A (forest), there were 36 plots sampled and, in subzone 2 only 1.

Target and problematic exotic species frequencies and mean cover were summarized from all plots (n=171, Tables 2 and 7), by habitat strata (n=135, prairie; n=36, forest, Tables 3 and 8), prairie subzone (n=7, Tables 4 and 9), and date (n=6, Tables 5 and 10). Target and problematic exotic species frequency and mean cover between plots were also summarized (Tables 6 and 11). Frequency (or presence) is reported as the percent of plots where species was encountered; mean coverage is reported as the average cover class across plots where the species was encountered. Cover classes are as follows: 1 < 1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6= 75-95%, 7 = 95-100%. Dominant species and dominant targeted exotic and problematic species (cover of 5-25% and found in at least 5 of the 43 subset plots) were then summarized by frequency, mean rank value, and subzone (Tables 12 and 13).

A picture of each plot was taken with a Nikon CoolPix 950 digital camera and stored as a .jpg file labeled by plot number. Pictures were taken from eye level at a distance of 5 m from the southern baseline of the 5 x 20 m plots, with the photographer standing midway between the eastern and western border of the plot (i.e., 2.5 m from each border, standing along the transect line, facing north). For orientation, a person was standing in the middle of the plot for each picture (15 m due north of photographer). The picture for plot 124 was not recorded.

Results

Invasive Exotic Species

The most frequently encountered target exotic species was tall fescue, followed closely by bull thistle each being found in over 20% of the plots (Table 2); however, tall fescue had a much greater coverage than bull thistle. Japanese honeysuckle (*Lonicera japonica*), Johnson grass (*Sorghum halepense*), and wild rose (*Rosa multiflora*) were each found in 12-19% of plots with Japanese honeysuckle having the greatest cover (Table 1). Sericea lespedeza (*Lespedeza cuneata*) and crown vetch (*Coronilla varia*) were found in less than 6% of plots and had very low cover (<2%).

The exotic species that were encountered most frequently in prairie habitat were tall fescue, bull thistle, and Johnson grass; while Japanese honeysuckle and wild rose were most prevalent in forest habitat (Table 3). While Japanese honeysuckle was widespread in the forest plots (24 of 36 plots), it covered only between 1-5% of a 100 m^2 plot; however, in prairie habitats it was uncommon (7 of 135 plots), but covered between 5-25% of a plot (Table 3). While all exotic species surveyed were found in the prairie habitats, three species (crown vetch, tall fescue, and Johnson grass) were not found in forest habitats.

There were clear differences in the presence and coverage of exotic species by "unit" or subzone of the park (Table 4, Figure 5). However, any patterns are confounded by both space and time. Some subzones are small, while others are large; although, relative sampling area in each is approximately the same. Some subzones were sampled in July, some in August, and some in September (see Table 5). However, important spatial patterns exist. For example, sericea lespedeza was only found in subzones 3, 4, and 7 – and most importantly was found in plots that were very close to the park border, or, in the case of subzone 4, along an interior road. Subzone 7 has the greatest number of exotic species, six, compared to four or fewer for every other subzone (except 7B with five species). Subzone 7b, although very small, is surrounded by forest and had five exotic species, with Japanese honeysuckle having an average coverage of 50-75%.

Examining species frequencies by date illustrates two general patterns, patterns related to time and patterns related to space since different plots were sampled at different time intervals (Table 5). In addition, in some cases, spatial inferences within subzones can be made (i.e., sampling within a subzone occurred on more than one date). Some observed patterns are as follows. Tall fescue was not observed in either of the September sampling dates. It is probably safe to assume that it may be in those plots and was not observed due to being past anthesis (Burns and Chamblee 1979) and not identifiable, than to it not being present. Johnson grass frequency apparently decreases throughout the season (Table 5), probably due to flowering phenology (Warwick and Black 1983). However it has been observed in subzone 6 (NPS 1992), and was probably not captured in this survey due to the date of sampling in that subzone. On the other hand, crown vetch was only observed on the last sampling date in September. However, its flowers should have been conspicuous during the July and August sampling dates.

Patterns in the presence and coverage of exotic species encountered along transects (i.e., between plots) (Table 6) were generally similar to those found in plots (Table 2). The percentage of

transect segments where exotics were encountered was on average 10% lower than the percentage of plots with a particular species. However, two notable exceptions were found. Sericea lespedeza was encountered at about the same frequency as in plots, while tall fescue was only encountered in 3.2 % of the inter-plot areas. It is important to note that data were collected while walking a transect for the major purpose of marking plots; therefore, inter-plot data were collected with much less rigor and validation than in plots.

Problematic Species

Target problematic species occurred with a frequency between 2 and 50% (Table 7). Cover was generally low with values < 3%. Horse nettle (*Solanum carolinense)* and dewberry (*Rubus trivialis*) were the most frequently encountered, whereas coralberry (*Symphoricarpos orbiculatus*) and Osage orange (*Maclura pomifera*) were encountered at lower frequencies.

There were clear differences between prairie and forest habitat and the frequency of particular species (Table 8, Figure 6). Poison ivy (*Toxicodendron radicans*) occurs more frequently in forest habitat, while horse nettle and dewberry occur more frequently in prairie habitat.

Table 9 provides frequency and coverage data by subzone and Table 10 provides frequency and coverage data by sample date. Frequency and coverage data for species encountered between plots (i.e., along transects) is provided in Table 11.

Osage orange was only found in the northeast corner of subzone 7. Winged sumac (*Rhus copallinum*) was common (occurred in over 50% of all plots) in subzones 1, 3, and 4. Dewberry was common in subzones 1, 3, 4, 6, and 7. Bristly catbiar (*Smilax tamnoides*) was common in subzone 3 and 7B, as well as forested habitat (subzone 7A, Table 7). Horse nettle was common in subzones 1, 4, 5, 6, and 7. Coralberry was never found in frequency above 50% and poison ivy was only common in subzone 7B, where only 4 plots were sampled and which is adjacent to forest habitat.

Dominant Species

A total of 39 species were listed as dominant in at least one plot. Table 12 lists the species that were listed as dominant in at least 5 out of the 43 subset plots. Table 13 lists the target exotic and problematic species that were dominant in at least 1 out of 43 plots. By far the most dominant species were big blue stem (*Andropogon gerardii*) and switch grass (*Panicum virgatum*), followed by Indian grass (*Sorghastrum nutans*) and daisy fleabane (*Erigeron annuus*) (Table 11). The only target exotic species that was found in at least 5 of the subset plots was tall fescue, while two target problematic species were also found in at least 5 of the subset plots. However, four target exotic and three target problematic species were found to be dominant in at least 1 of these plots (Table 13).

In general, physical and biotic sampling revealed that elevation difference between plots was minimal with a range in elevation between 314 and 329 m. Slope never varied by more than 5 degrees and variation was very low. Surface water was present in only one plot and, for the majority of plots, the hydrological regime was designated as upland. Physiognomy was

herbaceous or forest with few exceptions; grass litter was generally 95-100%; woody debris minimal; and herbaceous phenology generally perennial.

Discussion

This survey provides information of the current distribution and relative abundance of a set of exotic and problematic species at George Washington Carver NM. Habitats can change greatly from year to year, even without major disturbances (Meffe et al. 1997). Therefore, this inventory combined with other historical floral data for the park, provides a monitoring database for which conservation management can be continued, implemented and/or assessed.

Invasive Exotic Species

The two targeted exotic grass species, tall fescue and Johnson grass, considered to be abundant and widespread in 1992 (NPS 1992) and requiring immediate action, were found in 24% and 16% of plots surveyed, respectively. Tall fescue had a relatively high coverage within plots (5-25%) while Johnson grass was lower (<1%). Neither was found in forest habitats. Johnson grass is probably a problem in every prairie subzone, even though it was not recorded in the subzones in the southwest corner of the park. In the 1992 survey, it was considered problematic in subzone 6. Both of these species continue to be invasive in the park, and given the size of the park and prevalence of these species in the matrix (Meffe et al. 1997) their invasiveness will continue to be problematic. In 1992, crown vetch was found in one large clump in subzone 1 (NPS 1992). Today it is found in subzones 4 and 6 (5 plots) but in low densities (< 1%). Based on this information it appears that the species has become more prevalent in the park. Japanese honeysuckle was of concern in 1992 in four subzones (3, 4, 5, & 7) and during this inventory was found in subzones 3, 6, 7,7B and most extensively in the forest subzone (7B). It continues to invade the prairie from forest habitat. Wild rose and sericea lespedeza were of little concern in 1992 and its occurrence by subzone was not known. The former was found in every subzone but 4, found in about 13% of plots, and had a coverage ranging from <1 to 5% whereas the latter was found at very low density and frequency in four subzones (3, 4, 7,7A). Musk thistle (*Carduus nutans*) was considered in the 1992 study but bull thistle was not. In this study musk thistle was not documented yet bull thistle was found to be the second most common species, found in all subzones, and as would be predicted was clumped but not dense (i.e., < 1% coverage). Bull thistle is considered problematic in grazed prairie (Mitich 1998) and in a number of National Parks (Forcella and Randall 1994). Management of the species at George Washington Carver NM is probably warranted if the species is considered an undesirable exotic as it is certainly becoming invasive. Kentucky blue grass was not found flowering in initial informal surveys of the park in March, nor was it found flowering in this inventory (mid July through September).

Problematic Species

Three target problematic species mentioned in the 1992 survey were surveyed in this study: winged sumac, poison ivy, and Osage orange. Actually the 1992 survey only mentions smooth sumac (*Rhus glabra*), but this species was not encountered very often – especially in relation to the occurrence of winged sumac (winged sumac was very common, especially in subzones 1, 3, 4). Poison ivy is found on the margins of prairie habitat while being common in the forest habitat. Osage orange was considered of medium urgency in a 1992 report, especially in subzone 7 (NPS 1992). This survey does not indicate that the species has expanded into prairie

habitat as prescribed burning has effectively controlled seedling expansion into the prairie. These species continue to be problematic at the park.

Problematic species were generally more common than target exotic species, but always occurred at low densities. Management strategies of these species really depend on the goals of the park, as it is arguable whether these species are problematic.

Dominant Species

The three most dominant species, big blue stem, switch grass, and Indian grass, are all considered important prairie species (Tarr et al. 1980). These species were widespread and generally the most dominant species in the plots. This is a very positive result. On the other hand, five of the seven target exotic species were dominant in at least one plot and dominant in up to five plots (2.3-14.0% of the 43 plots surveyed). No obvious relationships between dominance of "desirable" and exotic species was found. For example, it was just as likely (67%) to find exotics in plots where big blue stem was dominant, then it was to find exotics in plots where big blue stem was not dominant (67%). However, the sample size of 43 plots and the amount of variation between plots limits any formal statistical analysis at this point.

In prairie habitat the dominant species changed very little from that reported in Table 12. This is most easily explained by the fact that 37 of the subset plots were in the prairie; therefore, the patterns in Table 12 are generally the patterns for prairie habitat. However, the percentage of plots that big blue stem, switch grass, and Indian grass were encountered increased by approximately 8% when the six forest plots are excluded from the analysis. In the six forest plots coralberry was the most frequent dominant species, followed by tick trefoil (*Desmodium canescens*), Canada goldenrod (*Solidago canadensis),* and slippery elm (*Ulmus rubra*). Big blue stem and switch grass were only dominant in 1 of the 6 forest subset plots.

There were no obvious patterns between physical or biotic variables and the distribution and abundance of exotic or problematic species. In part this is due to the qualitative nature of the data collected, and the fact that all plots within prairie or forest habitat are very similar based on the data collected. There are obvious differences between prairie and forest habitat such as physiognomy and ground cover – and these differences are related to the presence and abundance of exotic and problematic species as described above. In addition, subzone and sampling date were much more important for understanding patterns than physical or biotic variables. There were no obvious patterns between distance from the edge of the park or sampling date and physical or biotic variables, although no formal statistical analysis was performed.

Conclusion

This survey establishes baseline patterns in the distribution and abundance of exotic and potentially problematic species at George Washington Carver NM. Following are some recommendations for future surveys and management.

Tall fescue is probably well established and invading from surrounding agricultural and old-fields. The urgency ranking for this species in 1992 was "high", and this survey indicates that it is still a problem. Subzone 5 in the southeast corner of the park is of particular concern, while surveying for tall fescue in July in subzone 4 is warranted to see if it was controlled based on its prevalence in that subzone in 1992. In 1992 tall fescue was "particularly evident" in the northeast corner of subzone 7; however, in this survey tall fescue was found in only 1 plot in the northeast corner of subzone 7. If control measures were implemented they appear to be successful. Bull thistle, the second most frequent exotic species, is found throughout the park at low densities and randomly dispersed, mostly as single individuals. Since the park is not grazed it may not be a "problem". However, it is indicative of the fact that the park is easily invaded given its large perimeter to area ratio – and should be continued to be monitored even if just for heuristic value. Japanese honeysuckle continues to occur at a high frequency in forest habitat and invade prairie habitat, and management should continue or be implemented to keep the population low. Johnson grass management is prevalent in the prairie units surveyed in July indicating that it is successfully invading the park.

Crown vetch, which in 1992 was found only in the very northeastern portion of the park ("unit 1"), is now found in patches in the southwestern portion of the park (subzones 4 and 6). The species does not appear to have spread into the northeastern portion of the park, indicating management, if any, was successful. Wild rose was unknown in the park in 1992, but is found virtually throughout the entire park. Current prescribed burns are not apparently keeping the species in check and the park is apparently susceptible to invasion by the species. Detailed plant and physical habitat associations are probably warranted to assess why it is invading and how best to manage to keep the population from spreading. Sericea lespedeza is apparently being controlled successfully. It was "unknown" in 1992, and is still relatively uncommon. However, this species is very invasive, and any occurrence is of concern.

Kentucky blue grass should be included in future studies as it may still be a problem in the park. It was noted in subzone 4 (south-central prairie unit) in 1992 but not encountered in this survey, but that may be due to flowering phenology. Conversely, Osage orange, which was listed in the 1992 report as of "medium urgency" and as an exotic (which is a debated point) does not appear to be encroaching into prairie habitat. Current management appears to be successful (and would be expected given the growth habit of this species), and the species should only be of ancillary interest in future surveys.

Problematic species need to be considered for control after the park establishes that they are undesirable. For example, keeping poison ivy out of "developed zones" and from surrounding trails would entail control within forest habitat, which is where it is prevalent and spreads into prairie habitat.

To develop management strategies and programs considering only the invasive species themselves is analogous to curing symptoms and not the disease (Meffe et al. 1997). It is generally understood that invasive species grow, reproduce, and compete extremely well in relatively novel habitats – and this is due, in part, to the physical and biotic environment. It is important to note that the target species in this survey, except for one, are considered "naturalized" (Yatskievych and Turner 1990) and a large literature based on the biology and management of the species exists. However, the physical and biotic variables related to their success are not entirely understood. This survey does not add to any knowledge of the physical and biotic variables associated with the target exotic (or problematic) species abundance and distribution. Much more detailed and extensive sampling would be required. For example, measurements of leaf area index at different levels in the canopy, soil moisture, and plant diversity would be required. However, the recorded data is useful for a long-term record of the current physical and biotic structure of the park – and will be useful for comparing to data collected in the future, evaluating current management practices in each prairie subzone, and making immediate decisions about control measures that should be undertaken.

The park is especially vulnerable to invasion due to its high perimeter to area ratio. The matrix surrounding the park probably contains much habitat for species likely to invade both prairie and forest habitat. Conversely, the habitat within the park appears to be highly managed to promote native grasses and forbs, with three native grasses, big blue stem, switch grass, and Indian grass being dominant in much of the prairie habitat. Management will probably have to be ongoing, and the park is a good model for parks with high perimeter to area ratios and problems with invasive exotic species. The small area of the park makes it easy for extensive spatially explicit surveys. Spatially explicit surveys are recommended to record the spread of individual patches of exotic species and correlate their spread with species diversity, composition, and habitat conditions.

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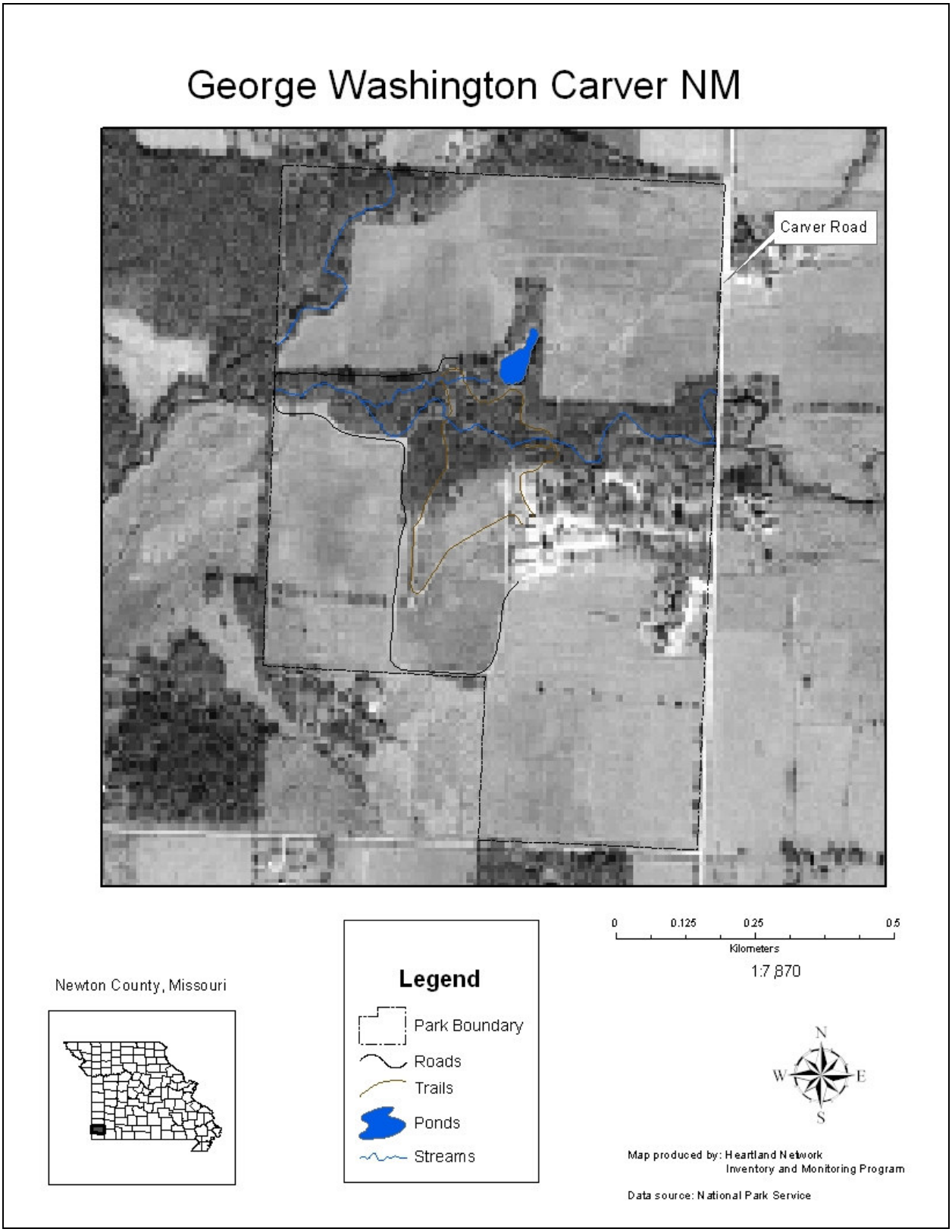

Figure 1. Location of George Washington Carver NM.

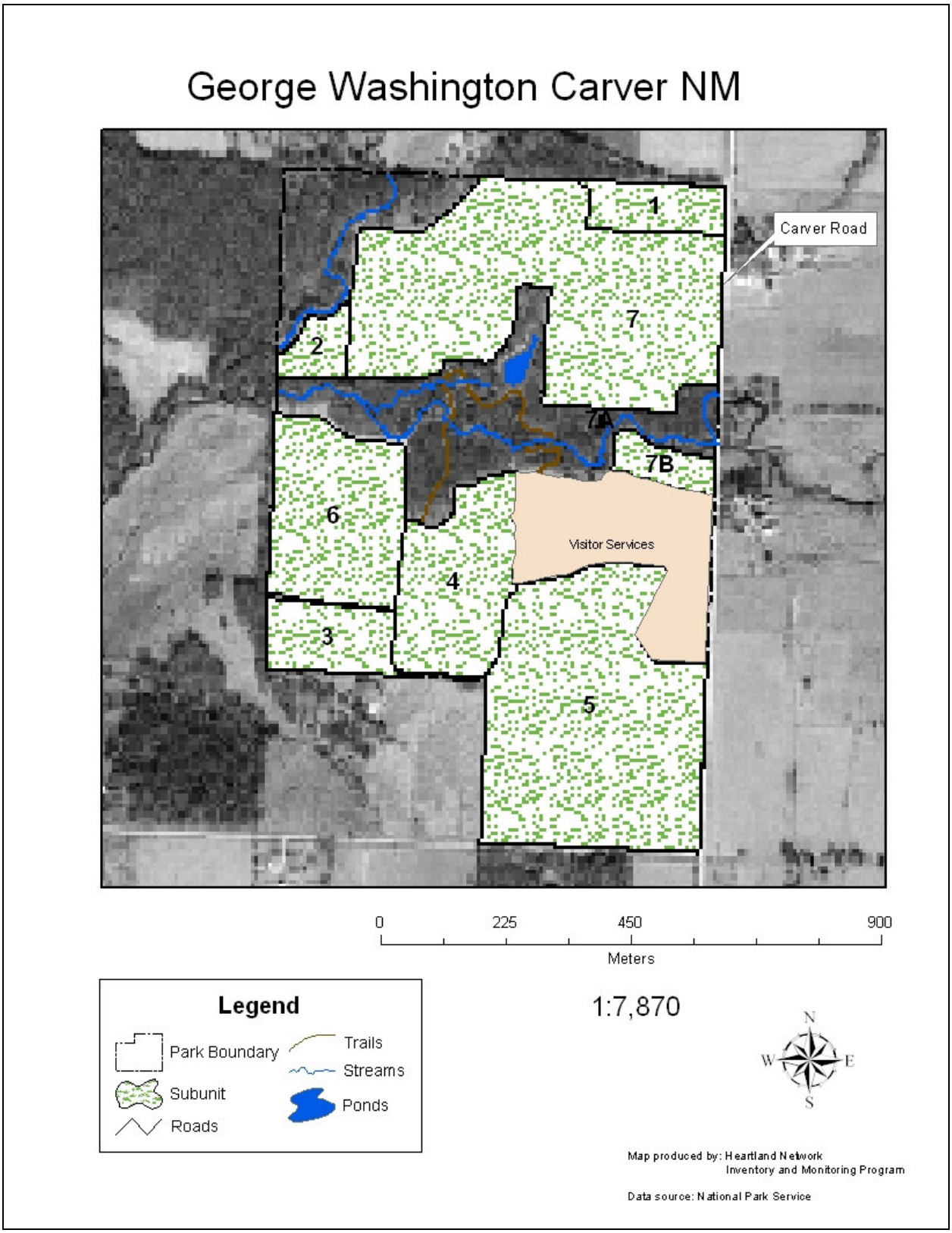

Figure 2. Map of George Washington Carver NM indicating subunits.

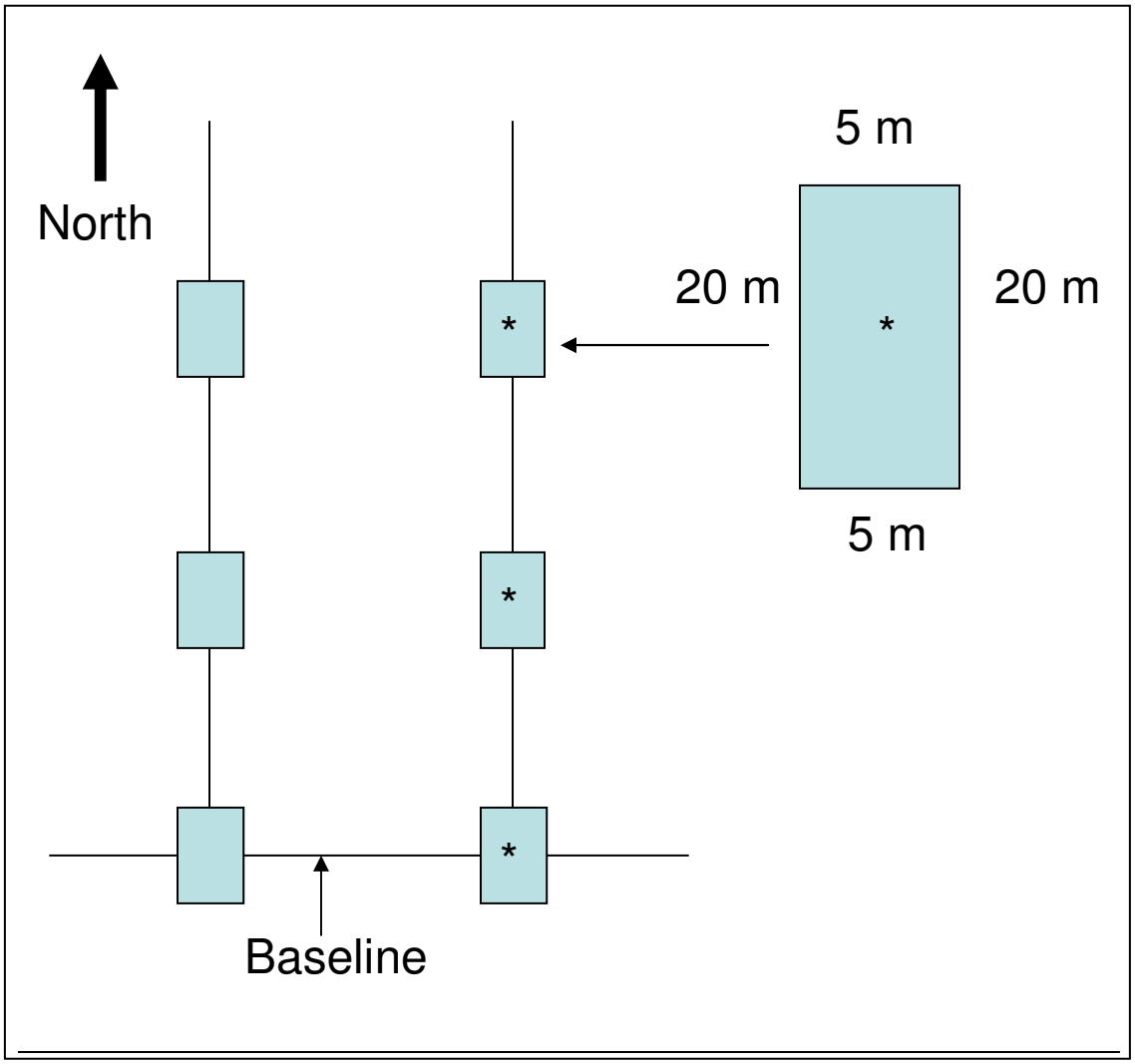

Figure 3. Layout of plots within George Washington Carver NM.

The distance between plots along the baseline was random, whereas the distance between the center of plots (denoted by *) was 65 m.

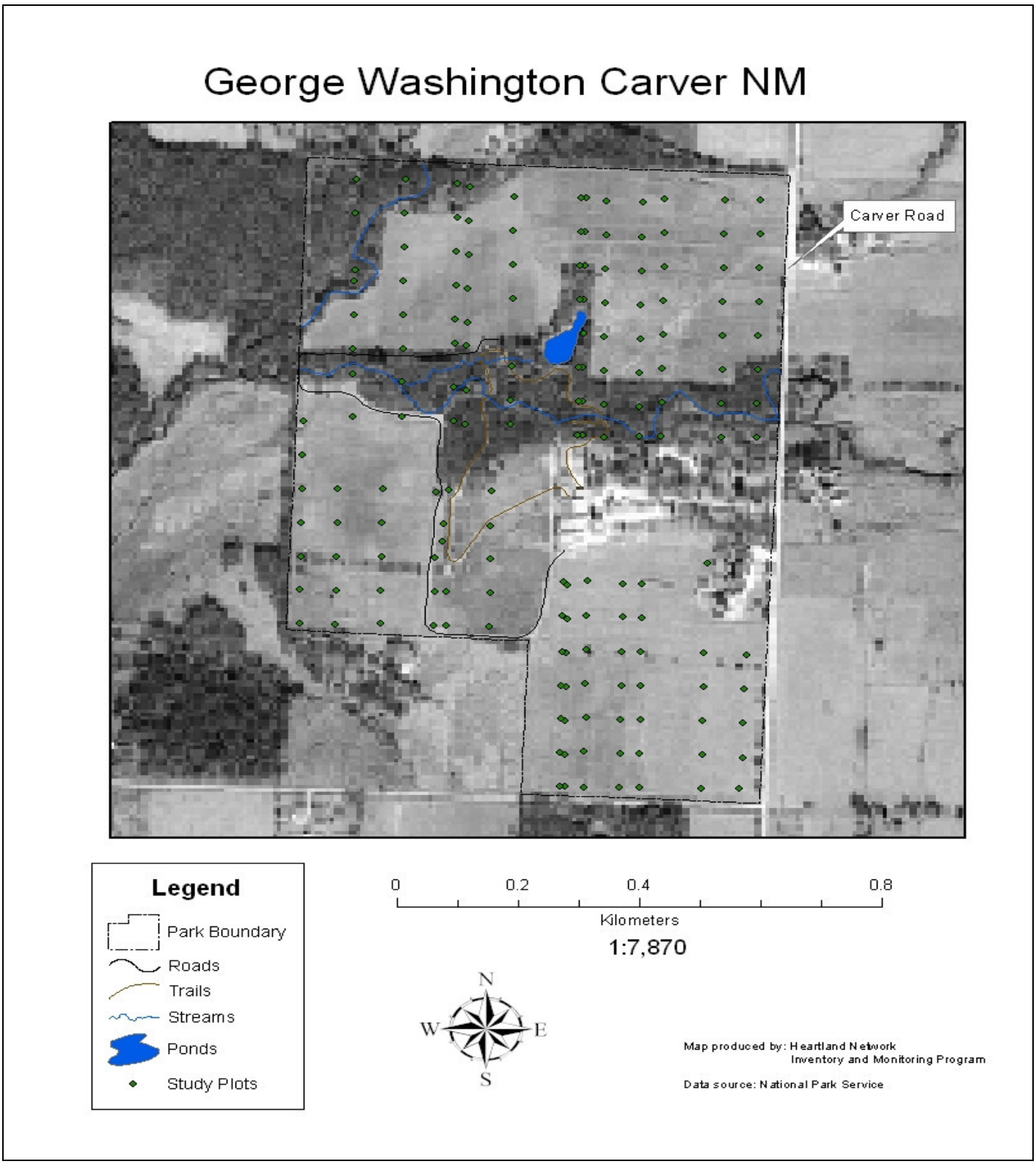

Figure 4. Map of George Washington Carver NM indicating study plots.

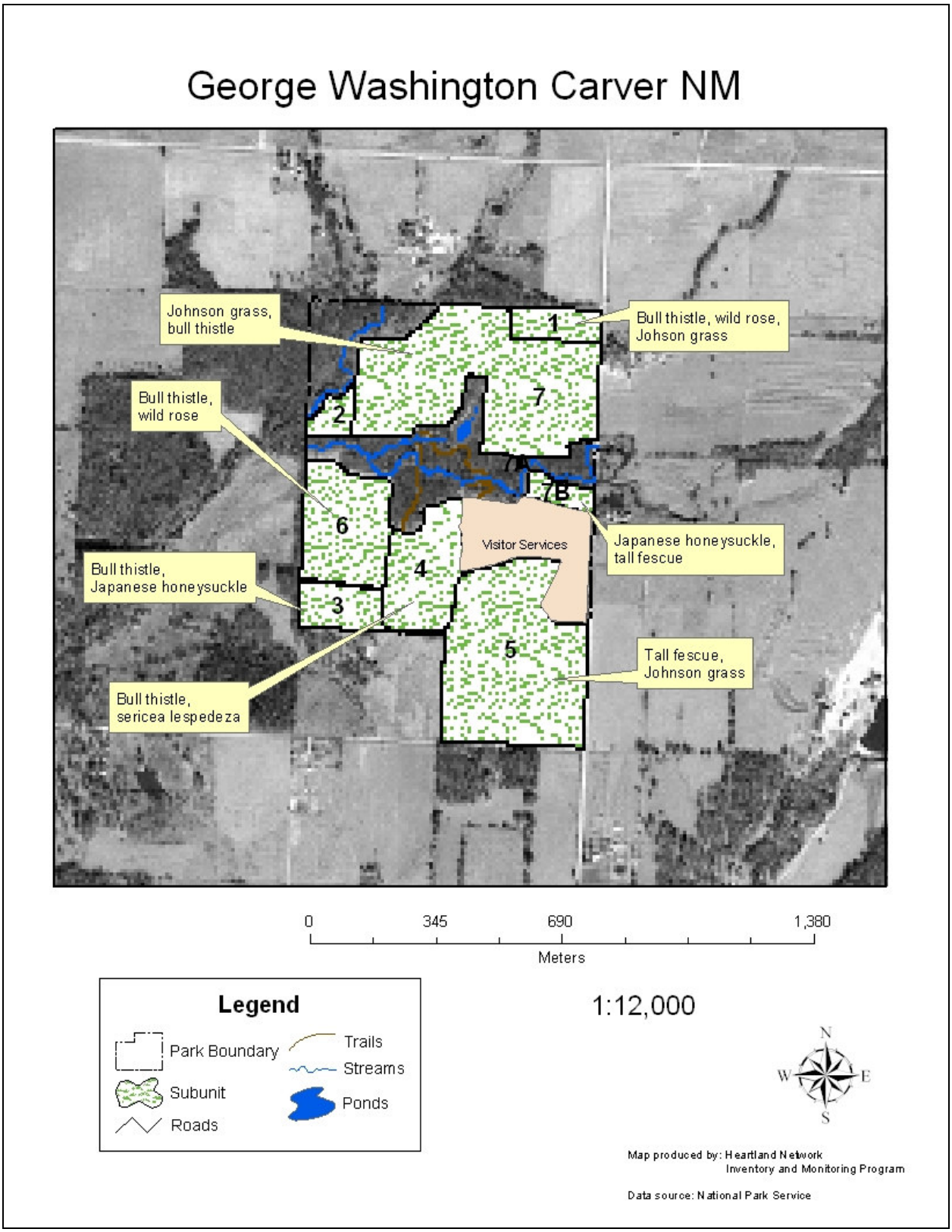

Figure 5. Map indicating subunits and most frequent invasive exotic plants.

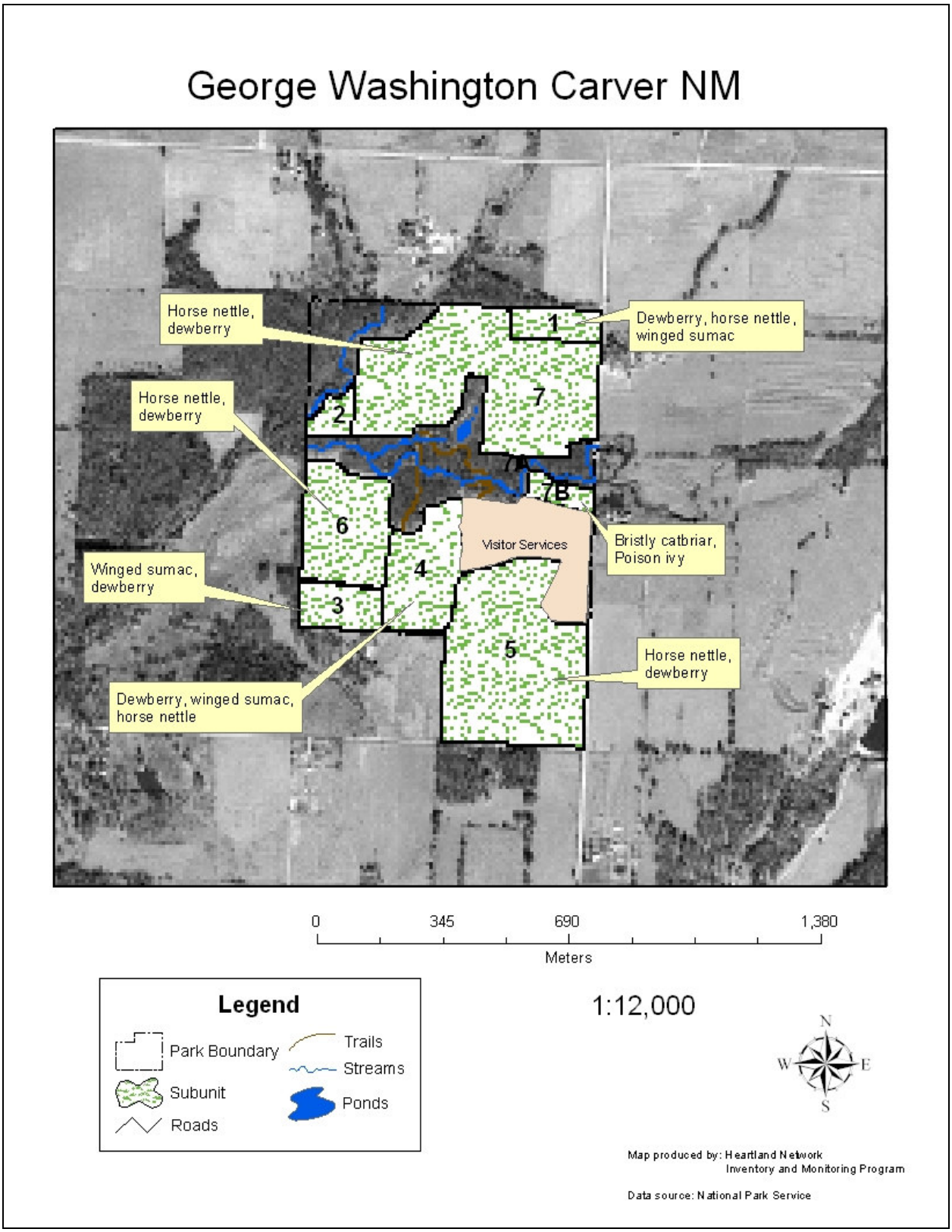

Figure 6. Map indicating subunits and most frequent problematic plants.

Table 1. List of target exotic and problematic species surveyed at George Washington Carver NM in 2001.

Exotic Species		Problematic Species	
Scientific Name	**Common Name**	**Scientific Name**	**Common Name**
Cirsium vulgare	Bull thistle	Maclura pomifera	Osage orange
Coronilla varia	Crown vetch	Rhus copallinum	Winged sumac
Festuca arundinacea	Tall fescue	Rubus trivialis	Dewberry
Lespedeza cuneata	Sericea lespedeza	Smilax tamnoides	Bristly catbiar
Lonicera japonica	Japanese honeysuckle	Solanum carolinense	Horse nettle
Poa pratensis	Kentucky blue grass	Symphoricarpos orbiculatus	Coralberry
Rosa multiflora	Wild rose	Toxicodendron radicans	Poison ivy
Sorghum halepense	Johnson grass		

Note that Kentucky blue grass was never encountered (i.e., identified in a flowering state) in sampling, probably due to time of year, and thus was excluded from survey results.

Table 2. Frequency and mean cover class of invasive exotic species at George Washington Carver NM (number of plots = 171).

Scientific Name	Common Name	Frequency (%)	Mean Cover Class
Festuca arundinacea	Tall fescue	24.6	2.6
Cirsium vulgare	Bull thistle	22.8	1.3
Lonicera japonica	Japanese honeysuckle	18.1	2.6
Sorghum halepense	Johnson grass	16.4	1.4
Rosa multiflora	Wild rose	12.9	1.8
Lespedeza cuneata	Sericea lespedeza	5.8	1.4
Coronilla varia	Crown vetch	2.9	1.0

Table 3. Frequency and mean cover class of invasive exotic species by habitat type.

Habitat Type	Scientific Name	Frequency (%)	Mean Cover Class
Prairie (n=135 plots)	Festuca arundinacea	31.1	2.6
	Cirsium vulgare	25.9	1.3
	Sorghum halepense	20.7	1.5
	Rosa multiflora	8.1	1.6
	Lespedeza cuneata	6.7	1.4
	Lonicera japonica	5.2	3.1
	Coronilla varia	3.7	1.0
Forest (n=36 plots)	Lonicera japonica	66.7	2.4
	Rosa multiflora	30.6	2.0
	Cirsium vulgare	11.1	1.3
	Lespedeza cuneata	2.8	1.0
	Sorghum halepense	2.8	1.0
	Coronilla varia	-	-
	Festuca arundinacea	-	-

(-) species was absent from all plots

Table 4. Frequency (%) and mean cover class (C) of invasive exotic species by prairie subzone.

Scientific Name	**Prairie Subzone** (number of plots within subzone)													
	1 (3)		3 (6)		4 (13)		5 (46)		6 (13)		7 (49)		7b (4)	
	%	C	%	C	%	C	%	C	%	C	%	C	%	C
Cirsium vulgare	33.3	1.0	66.7	1.5	69.2	1.1	6.5	1.0	23.1	1.3	28.6	1.6	25.0	1.0
Coronilla varia	-	-	-	-	30.8	1.0	-	-	7.7	1.0	-	-	-	-
Festuca arundinacea	-	-	-	-	-	-	76.1	2.8	-	-	10.2	1.2	50.0	2.5
Lespedeza cuneata	-	-	16.7	3.0	46.2	1.3	2.2	1.0	-	-	2.0	1.0	-	-
Lonicera japonica	-	-	33.3	1.5	-	-	-	-	7.7	2.0	2.0	3.0	75.0	4.7
Rosa multiflora	33.3	1.0	16.7	1.0	-	-	6.5	1.7	15.4	2.0	6.1	1.3	25.0	3.0
Sorghum halepense	33.3	1.0	-	-	-	-	23.9	1.5	-	-	30.6	1.5	25.0	1.0

(-) indicates species was absent from all plots

Table 5. Frequency (%) and mean cover class (C) of invasive exotic species by date.

Scientific Name	**Date** (number of plots within subzone)											
	July 18 (11)		July 19 (35)		July 20 (24)		August 14 (38)		September 15 (32)		September 28 (31)	
	%	C	%	C	%	C	%	C	%	C	%	C
Cirsium vulgare	9.1	1.0	5.7	1.0	41.7	1.5	21.1	1.5	6.3	1.0	51.6	1.3
Coronilla varia	-	-	-	-	-	-	-	-	-	-	16.1	1.0
Festuca arundinacea	45.5	2.4	85.7	2.9	12.5	2.0	10.5	1.3	-	-	-	-
Lespedeza cuneata	-	-	2.9	1.0	-	-	2.6	1.0	3.1	1.0	22.6	1.6
Lonicera japonica	-	-	-	-	20.8	4.0	36.8	2.1	28.1	2.9	9.7	1.7
Rosa multiflora	-	-	8.6	1.7	12.5	3.0	15.8	1.3	21.9	1.9	9.7	1.7
Sorghum halepense	36.4	2.3	20.0	1.1	4.2	1.0	36.8	1.4	6.3	1.5	-	-

(-) indicates species was absent from all plots

Table 6. Frequency and mean cover class of invasive exotic species encountered between plots. (number of transect segments = 126, coverage over 100m^2 area)

Scientific Name	Common Name	Frequency (%)	Mean Cover Class
Cirsium vulgare	Bull thistle	10.3	1.1
Rosa multiflora	Wild rose	4.8	1.0
Lonicera japonica	Japanese honeysuckle	4.0	3.0
Festuca arundinacea	Tall fescue	3.2	1.3
Lespedeza cuneata	Sericea lespedeza	3.2	4.6
Coronilla varia	Crown vetch	0.8	3.2
Sorghum halepense	Johnson grass	-	-

(-) indicates species was not recorded between plots

Table 7. Frequency and mean cover class of problematic species at George Washington Carver NM. (number of plots = 171)

Scientific Name	Common Name	Frequency (%)	Mean Cover Class
Solanum carolinense	Horse nettle	49.1	1.3
Rubus trivialis	Dewberry	44.4	1.6
Toxicodendron radicans	Poison ivy	27.5	1.6
Smilax tamnoides	Catbriar	21.1	1.5
Rhus copallinum	Winged sumac	19.3	2.3
Symphoricarpos orbiculatus	Coralberry	11.1	2.2
Maclura pomifera	Osage orange	2.3	2.5

Table 8. Frequency and mean cover class of problematic species by habitat type.

Habitat Type	Scientific Name	Frequency (%)	Mean Cover Class
Prairie (n=135 plots)	Solanum carolinense	59.3	1.3
	Rubus trivialis	54.1	1.6
	Rhus copallinum	23.7	2.3
	Toxicodendron radicans	16.3	1.7
	Smilax tamnoides	8.9	1.6
	Symphoricarpos orbiculatus	2.2	1.7
	Maclura pomifera	0.7	3.0
Forest (n=36 plots)	Toxicodendron radicans	69.4	1.6
	Smilax tamnoides	66.7	1.5
	Symphoricarpos orbiculatus	44.4	2.3
	Solanum carolinense	11.1	1.5
	Maclura pomifera	8.3	2.3
	Rubus trivialis	8.3	2.0
	Rhus copallinum	2.8	1.0

Table 9. Frequency (%) and mean cover class (C) of problematic species by prairie subzone.

	Prairie Subzone (number of plots within subzone)													
Scientific	1 (3)		3 (6)		4 (13)		5 (46)		6 (13)		7 (49)		7b (4)	
Name	%	C	%	C	%	C	%	C	%	C	%	C	%	C
Maclura pomifera	-	-	-	-	-	-	-	-	-	-	2.0	3.0	-	-
Rhus copallinum	66.7	1.5	66.7	3.3	84.6	2.5	2.2	1.0	10.9	1.5	22.4	2.7	-	-
Rubus trivialis	100	1.0	66.7	2.5	92.3	1.7	37.0	1.5	61.5	1.4	57.1	1.8	-	-
Smilax tamnoides	-	-	50.0	2.0	15.4	1.5	-	-	15.4	1.5	4.1	1.0	75.0	1.7
Solanum carolinense	66.7	1.5	33.3	1.0	76.9	1.0	60.9	1.5	61.5	1.0	61.2	1.2	-	-
Symphoricarpos orbiculatus	-	-	16.7	1.0	7.7	1.0	-	-	-	-	-	-	25.0	3.0
Toxicodendron radicans	-	-	33.3	1.0	30.8	1.5	10.9	2.5	38.5	1.4	8.2	1.5	50.0	2.5

(-) indicates species was absent from all plots

Table 10. Frequency (%) and mean cover class (C) of problematic species by date.

	Date (number of plots within subzone)											
Scientific	July 18 (11)		July 19 (35)		July 20 (24)		August 14 (38)		September 15 (32)		September 28 (31)	
Name	%	C	%	C	%	C	%	C	%	C	%	C
Maclura pomifera	-	-	-	-	-	-	-	-	12.5	2.5	-	-
Rhus copallinum	-	-	2.9	1.0	25.0	1.2	18.4	3.0	6.3	1.5	54.8	2.6
Rubus trivialis	18.2	1.5	42.9	1.5	54.2	1.4	44.7	2.1	18.8	1.2	74.2	1.7
Smilax tamnoides	-	-	-	-	25.0	1.7	28.9	1.4	37.5	1.4	22.6	1.7
Solanum carolinense	63.6	1.4	60.0	1.5	50.0	1.4	44.7	1.3	25.0	1.0	61.3	1.3
Symph-oricarpos orbiculatus	-	-	-	-	12.5	3.3	13.2	1.2	28.1	2.6	6.5	1.0
Toxic-odendron radicans	-	-	14.3	2.2	20.8	2.2	50.0	1.6	21.9	1.3	35.5	1.4

Table 11. Frequency and mean cover class of invasive exotic species encountered between plots. (number of transect segments = 126, coverage over 100m^2 area)

Scientific Name	Common Name	Frequency (%)	Mean Cover Class
Rhus copallinum	Winged sumac	15.9	3.2
Rubus trivialis	Dewberry	6.3	2.0
Symphoricarpos orbiculatus	Coralberry	2.4	4.6
Smilax tamnoides	Catbriar	1.6	2.5
Solanum carolinense	Horse nettle	1.6	1.0
Toxicodendron radicans	Poison ivy	0.8	2.0
Maclura pomifera	Osage orange	0.6	1.0

Table 12. Frequency and dominance of most common dominant species.

Scientific Name	Common Name	Frequency (%)	Mean Rank Value	Subzones
Andropogon gerardii	Big blue stem	62.8	4.4	3,4,5,6,7,7A
Panicum virgatum	Switch grass	62.8	3.7	3,4,5,7,7A
Sorghastrum nutans	Indian grass	25.6	4.3	3,4,6,7
Erigeron annuus	Fleabane	23.3	3.4	4,5,6,7
Trifolium pratense	Clover	16.3	3.0	5,7
Festuca arundinacea*	Tall fescue	14.0	4.3	5,7B
Rhus copallinum**	Winged sumac	14.0	4.2	3,4,7
Rubus trivialis**	Dewberry	14.0	3.0	3,7,7A
Desmodium canescens	Tick trefoil	11.6	3.6	5,7,7A

* Target exotic species; ** Target problematic species

Table 13. Additional target exotic and problematic species that were dominants

Scientific Name	Common Name	Frequency (%)	Mean Rank Value	Plots
Symphoricarpos orbiculatus**	Coralberry	7.0	4.0	71,138,139
Smilax tamnoides**	Catbriar	7.0	2.7	21,138,166
Sorghum halepense*	Johnson grass	4.7	4.0	30,76
Cirsium vulgare*	Bull thistle	4.7	2.0	66,81
Toxicodendron radicans**	Poison ivy	2.3	5.0	30
Lespedeza cuneata*	Sericea lespedeza	2.3	4.0	160
Rosa multiflora*	Wild rose	2.3	4.0	30

* Exotic species; ** Problematic species

Appendix 1. Distances between transects and subset plot numbers.

Distances between transects (m)	29 93 194 225 286 317 326 449 520 541 631 707 765
Subset Plot numbers	9 15 17 18 22 24 30 33 38 39 42 46 47 50 60 61 66 69 70 71 76 81 82 85 94 101 103 115 116 125 127 129 138 139 142 143 148 149 159 160 1651 163 166

Distances between transects 1-13, and 14-25, where baselines run east to west. Transects 1-13 start at the south-east corner of the park, and transects 14-25 start north of the development zone and run east to west. Plot numbers where additional vegetation data was obtained (subset plots).