INVASIVE PLANT MANAGEMENT PLAN FOR THE DUKE FOREST, DURHAM, NC

by

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Masters project submitted in partial fulfillment of the

requirements for the Master of Environmental Management and Master of Forestry

degrees in

the Nicholas School of the Environment of

Duke University

2009

Abstract

Recently, populations of invasive plants are increasing in the Duke Forest and detrimentally affecting the growth of *Pinus taeda* (loblolly pine) and natural forest communities. To effectively control the spread of invasives, the Duke Forest Resource Manager needs to know what invasive plants are located throughout the Forest, where they are located and what factors are associated with their presence. Therefore, a sample of the invasive plant population was recorded using a GPS unit. This data was then used to model the distribution of each of the invasive plants throughout the Forest. I used Maxent to create these predicted distributions.

Ailanthus altissima, *Lonicera japonica*, and *Microstegium vimineum* are the dominant invasive species present. Of the 15 invasive plants recorded, most species were found along roads and streams. The management activity that was most correlated with presence of invasive plants was harvesting, though no specific harvesting technique (i.e. seed-tree, salvage, selective or clear cut) predicts invasive plant presence than any other.

The predicted distribution maps will be used to complete a targeted inventory of invasive plants throughout the Duke Forest. The inventory process should begin in Natural Heritage areas predicted to have high priority species and multiple invasive species. When feasible, control treatments should be applied at the same time as inventorying particularly on small, peripheral populations. In addition, the Duke Forest Manager can prevent future invasions through monitoring and early removal of plants in areas where soil disturbing management activities have taken place.

Acknowledgments

I would like to thank my advisor, Dr. Dean Urban for all his help throughout this process. I would also like to thank Judd Edeburn, Marissa Hartzler, and Mike Burke at the Office of the Duke Forest for providing the support and funding for this project. In addition, I would like to thank Dr. Lynne Maguire for assistance in developing a sampling design. Finally, thank you to all my colleagues at the Nicholas School, friends and family for your support and a great learning experience.

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I. INTRODUCTION

A. Background

The United States Department of Agriculture defines an invasive species as a non-native species which causes ecological or economic harm or threatens human health (Clinton 1999). For this management plan, an invasive plant is an exotic plant that was introduced either directly or indirectly by humans to a new range (the Duke Forest) in which the plant flourished, spread rapidly, and persisted (adapted from Mack et al. 2000). Invasive plants alter the species composition of a community, frequently forming dense monocultures (Merriam and Feil 2002, Chornesky and Randall 2003). They can also change the ecosystem processes by altering soil conditions, hydrology, nutrient cycling, succession, and trophic processes (Bratton 1982, D'Antonio and Vitousek 1992, Gordon 1998, Merriam and Feil 2002, Davis et al. 2005). In managed systems, such as the Duke Forest, invasive plants may have an economic effect as well. Invasive plants can impede the growth of desirable species and impose costs for removal (Pimentel et al. 2000).

Anecdotal evidence suggests that the abundance and diversity of invasive plants has increased over the last 10 years in the Duke Forest. The Duke Forest staff have noticed an increase in the abundance of invasive plants such as *Ailanthus altissima* (tree-of-heaven) and *Microstegium vimineum* (Japanese stiltgrass) in managed areas of the Duke Forest (J. Edeburn, personal communication). In addition, Taverna et al. (2005) documented a greater occurrence of exotic species between 1977 and 2000, noting that the exotic species were present not only in hurricane damaged stands but also in relatively intact stands. There is concern regarding the ecological and economic impacts these weeds may be having on the production of *Pinus taeda* (loblolly pine) as well as the regeneration of native trees and shrubs. In Natural Heritage Areas within the Duke Forest, there are also concerns regarding the impacts non-native plants are having on the herbaceous layer and the animals, such as butterflies, that rely on specific species to survive (J. Pippen, personal communication).

To effectively control the spread of invasives, the Duke Forest Resource Manager needs to know what invasive plants are located throughout the Forest, where they are located and what factors are associated with their presence.

The objective of my research is to provide some baseline information in order to assist the Duke Forest Resource Manager in determining which species and/or locations should be prioritized for management. Specifically, my research is designed to address the follow questions:

- Which invasive species are present in the Duke Forest?
- Where are the invasive species present?
- What is the extent of invasion?

In addition, I will also determine if there is a correlation of invasive plant presence with various forest management techniques, including harvesting, thinning, herbicidal treatment, mechanical soil preparation, and fire. Finally, based upon the information collected through my research, I will make management recommendations.

B. Management Setting

Duke Forest is a 7,060 acre teaching and experimental forest located on the eastern edge of the piedmont plateau in Durham, Orange and Alamance counties (Figure 1). The Forest is comprised of 6 divisions – Durham, Korstian, Blackwood, Hillsboro, Dailey and Eno. Prior to purchase by Duke University, the Forest was used for agriculture and timber harvesting. A variety of forest cover types and communities, including upland hardwoods, lowland hardwood, pine, and mixed pine-hardwood communities, are present in the forest. In addition, the Duke Forest contains several unique communities designated as Natural

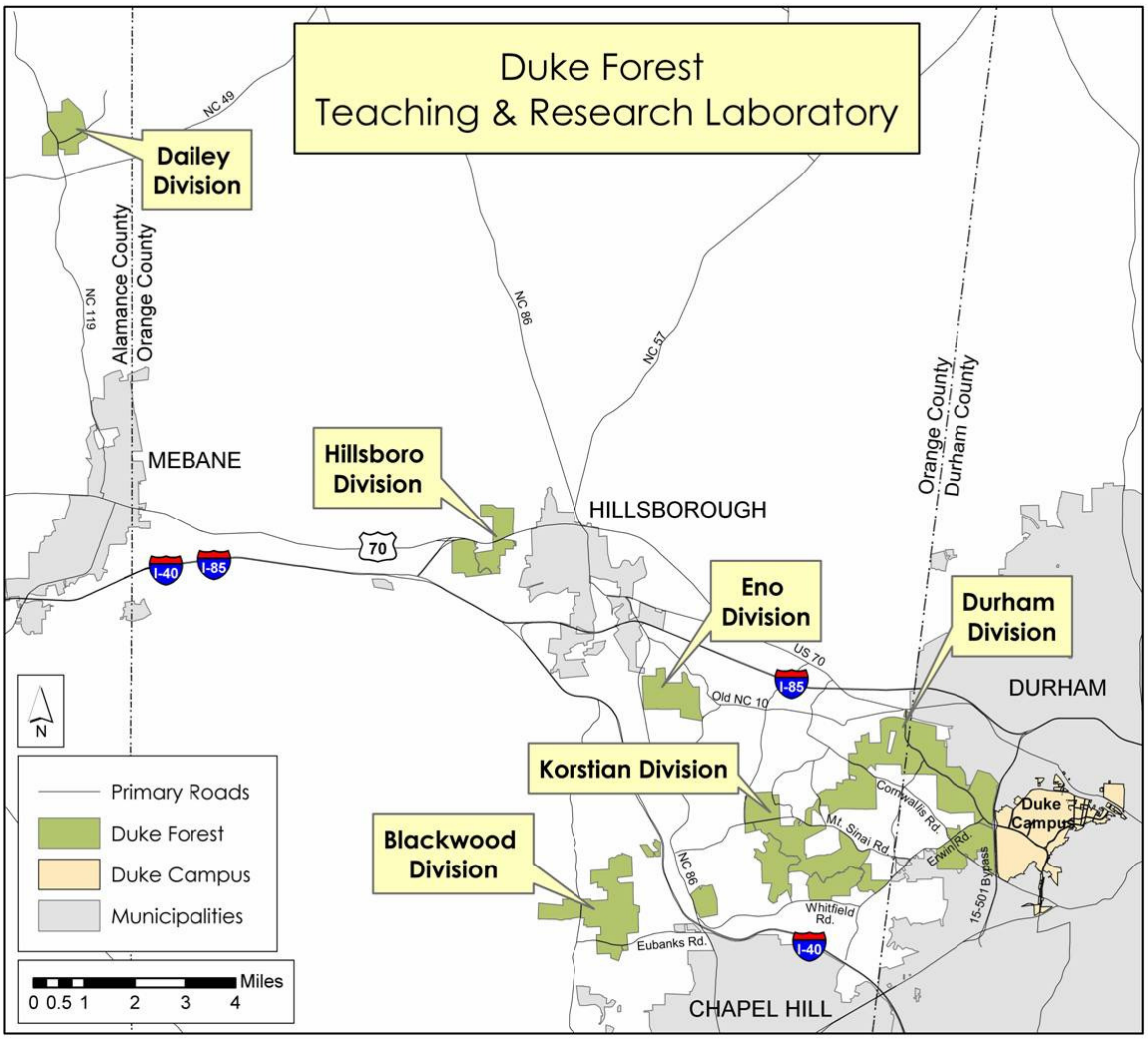

Figure 1: General location map of the Duke Forest, North Carolina

Heritage areas. The forest has been intensively managed since 1931 for multiple purposes including timber, biodiversity, wildlife, aesthetics, and recreation. The current mission of the Duke Forest is "to (1) facilitate research that addresses fundamental and applied questions concerning forest and aquatic ecosystems; (2) aid in the instruction of students so that they will be informed citizens and stewards of our natural resources" (Edeburn and Broadwell, 2004).

The Duke Forest is a challenging landscape to manage in part due to its discontinuous distribution. Some divisions are located in rural areas surrounded by agricultural fields, while others are in more urban areas with high-density apartment complexes as neighbors. This dissimilarity in locations and neighboring land uses means that any management plan must be adaptable to all divisions.

Along the borders of each division, the management and activities of neighboring properties affect the Duke Forest. For example, an invasive species planted on a neighboring property can become established in the area of the Forest abutting the property. In managing the Forest, these neighbors and their reactions to management activities need to be considered.

The size and purpose of Duke Forest also make it a challenge to manage. There are many disturbances, both natural and anthropogenic, which affect management, including hurricanes, ice storms, wind storms, and logging. In addition, recreational users hike off trail, allow dogs off leash, and leave trash in the Duke Forest. The Forest is also used by researchers, causing varying degrees of disturbance. All of these disturbances have effects on whether an invasive plant will establish, which invasive plants will establish, whether they will persist, and what ecological effects these plants will have on the surrounding natural community.

II. DISTRIBUTION OF INVASIVE PLANTS IN THE DUKE FOREST

A. Methods

Data Collection

I compared lists of invasive plants for North Carolina from various sources including the United States Department of Agriculture (USDA) Natural Resources Conservation Service (USDA NRCS 2007), The Nature Conservancy (2005), the National Park Service (2005), a previous Nicholas School Master's Project (Bickel 2001) and several books (Evans et al 2006, Kaufman and Kaufman 2007, Miller 2006, and Palmer 1990). Only those plants which were listed by at least 4 sources as being present and invasive in North Carolina were examined for this study (Table 1).

Table 1: List of study species

Scientific Name	Common Name	Source*
Ailanthus altissima	Tree-of-Heaven	2, 3, 5, 6, 7, 8
Albizia julibrissin	Mimosa tree	3, 5, 6, 7, 8
Alliaria petiolata	Garlic mustard	2, 3, 5, 6, 7
Celastrus orbiculatus	Oriental bittersweet	1, 2, 3, 5, 6, 7, 8
Elaeagnus pungens	Thorny olive	5, 6, 7, 8
Elaeagnus umbellata	Autumn olive	2, 5, 6, 7, 8
Hedera helix	English ivy	2, 3, 4, 5, 6, 7, 8
Lespedeza bicolor	Bicolor lespedeza	1, 2, 5, 6, 7, 8
Lespedeza cuneata	Chinese lespedeza	1, 2, 3, 4, 5, 6, 7, 8
Ligustrum sinense	Chinese privet	1, 2, 4, 5, 6, 7, 8
Lonicera japonica	Japanese honeysuckle	2, 3, 4, 5, 6, 7, 8
Lonicera fragrantissima, Lonicera maackii, Lonicera morrowii, Lonicera tatarica, & Lonicera x bella	Bush honeysuckles	2, 3, 5, 6, 7, 8
Microstegium vimineum	Japanese stiltgrass	2, 3, 4, 5, 6, 7, 8
Nandina domestica	Sacred bamboo	5, 6, 7, 8
Paulownia tomentosa	Princess tree	2, 3, 5, 6, 7, 8
Pueraria montana	Kudzu	5, 6, 7, 8
Rosa multiflora	Multiflora rose	2, 3, 5, 6, 8
Sorghum halepense	Johnsongrass	2, 5, 6, 7, 8
Vinca minor	Periwinkle	1, 2, 4, 5, 6, 7, 8
Wisteria sinensis	Chinese wisteria	2, 3, 5, 6, 7, 8

*The sources that list the specific plant as invasive and present in North Carolina. The source codes are as follows: 1= USDA NRCS 2007; 2= The Nature Conservancy 2005; 3= National Park Service 2005; 4= Bickel 2001; 5= Evans et al 2006; 6= Kaufman and Kaufman 2007; 7= Miller 2006; and 8= Palmer 1990.

A second list of species to watch was created. The species on this watch list are plants that have a range including North Carolina according to some of the above resources, have been spotted in the Piedmont region by experts (N. Christensen, personal communication and R. Wilbur, personal communication), but have not yet established in the Duke Forest.

Since the Duke Forest totals 7,060 acres, it was not feasible to inventory the entire area. Instead a sample of the invasive plant population was recorded and used to interpolate the population of the Forest as a whole.

Sampling areas were selected in order to increase the chances of locating invasive plants. Therefore, areas adjacent to roads, streams, and disturbed soils or vegetative cover were chosen. More specifically, ¼ of all roads in the Forest and any stream which was crossed by a road were selected. In addition, areas having received only one forest management treatment (Table 2) in the last 10 years were selected. Areas that had received more than one treatment were removed from the sampling in order to reduce potential confounding factors in the analysis. That is, if an invasive plant is located in an area with multiple treatment types it would be more difficult to determine which treatment(s) are associated with invasive presence.

Table 2: Forest Management Techniques

Management Activity	Definition
Herbicide treatment	Application of herbicide to kill undesirable species.
Mechanical treatment	Physical preparation of a site for planting. Techniques typically involve removing logging debris and loosening the soil. The Duke Forest uses windrowing, disking, and drum chopping.
Clear cut harvest	The cutting and removal of all merchantable trees in a stand.
Selective harvest	The logging of specific trees or groups of trees within an area, leaving the remaining trees standing.
Salvage harvest	The removal of dead or damaged trees due to a hurricane, ice storm, wind storm, or beetle infestation.
Seed-tree harvest	The logging of all trees in an area, except a few desirable individuals which provide seed for regeneration of the stand.
Pre-commercial thinning	The removal of low quality trees and undesirable species to reduce competition and promote better growing stock.
Commercial thinning	The removal of a percentage of trees within a stand to reduce crowding and promote growth.
Fire	Prescribed burns for understory vegetation control or wildfire

Road segments and streams were sampled by walking 500 feet along the road or stream and recording any invasive plants seen. Areas receiving forest management treatment were sampled by walking around the perimeter and recording any invasive plants seen within the area. If invasive plants were noticed outside of the area, they were recorded as well.

The occurrence of invasive plants was assessed in predetermined sampling areas and documented using a portable GPS unit. Individual plant occurrences were recorded as points, while lines or polygons (depending on the population pattern) were used for plant populations. For polygons and lines, percent coverage of the total area was estimated for each species present. Using Hawth's tools (Beyer 2007) in ArcMap (ESRI 2007), random points were

generated within each polygon at frequencies corresponding to field-observed density levels. The randomly generated points were used to represent species abundance within population polygons; when combined with individual plant occurrence points recorded in the field, the total distribution and abundance of each species was determined.

Model

There are a variety of species distribution models which could be used to predict the range of each species in the Forest. In a previous study, I compared the results of three models, Maxent, classification and regression tree (CART), and generalized linear model (GLM), on a subset of the data to be used in this analysis in order to determine which model is the most appropriate for the current study. I found that Maxent generally performed better than CART and GLM in predicting distributions across the Forest. In addition, Maxent does not require the use of species absence points (which I do not have) or pseudo-absence points. Both GLM and CART require either absence or pseudo-absence points in order to create a distribution range. Therefore, I used Maxent to model the distribution of each of the invasive plants.

Maxent is a mathematical algorithm which uses species presence points and environmental layers as inputs. Maxent works to find a distribution of presence points with maximum entropy (i.e. most similarity) across the environmental variables (Phillips et al 2004, Phillips et al 2006). The environmental variables used for this analysis are listed in Table 3.

Table 3: Environmental predictor variables used in developing probability distributions of species presence

Layer	Source	Resolution
Elevation	USGS DEM	30 meter
Slope	Calculated from DEM	30 meter
Aspect	Calculated from DEM	30 meter
Soil type	SSURGO	1:20,000
Stand cover type	Digitized from paper maps	1:9600
Distance from roads	Calculated from digitized maps	1:9600
Distance from streams	Calculated from digitized maps	1:9600
Distance from railroads	Calculated from digitized maps	1:9600
Distance from power lines	Calculated from digitized maps	1:9600

Additionally management variables were included in the model. The management variables were calculated as the Euclidean distance from the management activities listed previously in Table 2. Elevation, slope, aspect, and soil type significantly control plant community composition (Whittaker 1967). It is

generally assumed that invasive plants establish in areas that have been disturbed, either naturally or anthropogenically. Roads, streams, railroads, power lines, and active management are the major vectors of disturbance in the Duke Forest. The Euclidean distance from each of these vectors was used as a predictor variable, assuming that the likelihood of invasive plant community establishment would decrease further away from disturbances. Stand cover type is also an indicator of disturbance in the case of the Duke Forest since some stands, such as loblolly pine stands, are managed actively and others, such as mixed hardwood stands, are more passively managed.

In order to compute the maximum entropy distribution, Maxent uses an iterative process which updates the weights of each variable one by one (Phillips et al, 2004). Therefore, Maxent can identify those variable(s) most likely to determine species presence. This feature was used to determine if species presence is correlated with any of the forest management activities.

Maxent produces a probability distribution. Therefore, it is necessary to determine a threshold probability above which a species will be considered present at a location and below which it a will be considered absent. The threshold was determined by the "Balance threshold" as identified by Maxent for each species. The "Balance threshold" minimizes the omission rate of known invasive species presence.

In addition, an overlay of all species distributions was used to locate areas within the Duke Forest which may have a high number of invasive plants.

B. Results and Discussion

Ailanthus altissima, *Lonicera japonica*, and *Microstegium vimineum* are the dominant invasive species present throughout the Duke Forest as well as in Natural Heritage areas and loblolly pine stands (Table 4). *Alliaria petiolata*, *Celastrus orbiculatus*, *Hedera helix*, *Nandina domestica*, and *Sorghum halepense* were not found through sampling and thus were not included in the analysis. These species are listed as species to watch for potential future invasion (see Appendix B). Maps depicting the predicted distribution of each plant species are presented in Appendix C. Only 3 occurrences of *Lespedeza bicolor* were documented. The resulting probability distribution as a result substantially overestimated the present infestation of *L. bicolor*. Thus these maps were disregarded when developing recommendations for management. When more occurrences are recorded, the model should be rerun.

Table 4: Amount of area predicted to be infested with invasive plants in Natural Heritage areas, loblolly pine stands, and the Duke Forest overall The Duke Forest Total is the total land area infested with invasive plants within each category, taking into account overlapping populations.

Scientific name	Common Name	Full Extent (acres)	Natural Heritage Areas (acres)	Loblolly Pine Stands (acres)
Ailanthus altissima	Tree-of-heaven	2746	633	1595
Albizia julibrissin	Mimosa tree	1286	272	897
Elaeagnus pungens	Thorny olive	268	106	158
Elaeagnus umbellata	Autumn olive	1768	390	1030
Lespedeza cuneata	Chinese lespedeza	2029	407	1145
Ligustrum sinense	Chinese privet	1724	418	827
Lonicera japonica	Japanese honeysuckle	3417	858	1993
Lonicera spp	Bush honeysuckles	1073	355	460
Microstegium vimineum	Japanese stiltgrass	3423	907	1644
Paulownia tomentosa	Princess tree	1590	393	925
Pueraria montana	Kudzu	116	1	87
Rosa multiflora	Multiflora rose	2442	493	1042
Vinca minor	Periwinkle	102	24	56
Wisteria sinensis	Wisteria	1499	432	815

Most species were found along roads, both forest roads and public roads, and streams, primarily permanent and intermittent streams. *Elaeagnus pungens* was only found in the Triassic Basin and was the only species to be specific to the Triassic Basin. Otherwise there were no trends across species in regards to correlations with soil type. Stand type was not a significant predictor variable for presence of any invasive species, indicating that all plants studied can be found in pine, hardwood, or mixed stands.

The management activity that was most correlated with presence of invasive plants was harvesting, though no specific harvesting technique (i.e. seed-tree, salvage, selective or clear cut) predicts invasive plant presence than any other.

The predicted distributions generated by Maxent did misclassify some areas where invasive plants were located as not being likely to contain invasives. The predicted distributions also classified some areas where invasives were not found as being likely to contain invasive plants. However, overall the Maxent predictions were generally consistent with field observations.

These predictor maps will be used to complete a targeted inventory of invasive plants throughout the Duke Forest as described in Section III. After the inventory is complete, the data will be used to create new predictions of where invasive plants may spread. An analysis of potential vectors for infestation would add to these future predictions. In addition, complete information on the location of old homestead sites and adjacent residential properties would improve invasive plant presence predictions.

III. MANAGEMENT PLAN

A. Management Targets

Invasive plant control is part of the overall management of the Duke Forest. The focus of this plan is to enable the Duke Forest to meet its overall management goals including academic research, timber management, protection of rare species and unique ecosystems, wildlife management, water quality protection, history and archeology, and recreation and aesthetics (Edeburn and Broadwell 2004), rather than only eliminating weeds. In the long run, invasive plant management should include preventative programs to keep the Forest free of species that have not yet established as well as programs to control or eliminate weeds that are already established in the Forest and have negative impacts on the Duke Forest. The Duke Forest should implement control programs when the negative impacts of leaving an exotic invasive in place outweigh the ecological impacts of controlling it with available methods.

B. Setting Priorities

Initial priorities are should be set to minimize the time and effort needed to inventory the invasive plant populations within the Duke Forest. Future priorities may shift to minimize the time, effort, and costs of controlling populations.

The priority-setting process can be difficult, partly because so many factors need to be considered. The Nature Conservancy prioritization method (TNC 2005b) groups these factors into four categories:

a. Current extent of the species on or near the site;
b. Current and potential impacts of the species;
c. Value of the habitats/areas that the species infests or may infest; and
d. Difficulty of control.

Categories A, C, and D will be used to set priorities of the invasive plants in the Duke Forest. Current and potential impacts within the Duke Forest have not been studied yet. Category b should be used in future priority assessments. While I use the same general categories as the Nature Conservancy to prioritize species, I did modify the factors under each category to reflect the management goals of the Duke Forest and the data available. The National Park Service (Hiebert 2001) uses a similar strategy for invasive species prioritization.

Category A. Current extent of the species**:** Under this category, priorities are assigned to species in order to first, prevent large infestations from expanding, second, eliminate small infestations, and finally to prevent new weeds from establishing.

1. Species covering a large extent of the Forest (>1000 acres)
2. Species covering an extent ranging from 300 to 800 acres
3. Species covering an extent ranging from 100 to 300 acres

4. Species covering a small extent of the Forest (<100 acres)

Category B. Current and potential impacts of the species:

1. Species that alter ecosystem processes such as fire frequency, sedimentation, nutrient cycling, or other ecosystem processes.
2. Species that outcompete natives and dominate otherwise undisturbed native communities.
3. Species that do not outcompete dominant natives but:
   a. prevent or depress recruitment or regeneration of native species; OR
   b. reduce or eliminate resources used by native animals; OR
   c. promote populations of invasive non-native animals by providing them with resources otherwise unavailable in the area.
4. Species that overtake and exclude natives following natural disturbances such as fires, floods, or hurricanes, thereby altering succession, or that hinder restoration of natural communities. Note that species of this type should be assigned higher priority in areas subject to repeated disturbances.

Category C. Value of the habitats/areas the species infests or could infest:

1. Infestations that occur in the most highly valued habitats or areas of the site - especially areas that contain rare or highly valued species. These communities are identified as Natural Heritage Areas
2. Infestations that occur in economically valuable areas. These areas are stands identified as containing loblolly pine.
3. Infestations that occur in less valued portions of the site.

Category D. Difficulty of control and establishing replacement species:

1. Species likely to be controlled or eliminated with available technology and resources and which desirable native species will replace with little further input.
2. Species likely be controlled but will not be replaced by desirable natives without an active restoration program requiring substantial resources.
3. Species difficult to control with available technology and resources and/or whose control will likely result in substantial damage to other, desirable species.
4. Species unlikely to be controlled with available technology and resources.

Table 5: Prioritized List of Invasive Plants*

Scientific Name	Common Name	**Priority**	Category A	Category C	Category D	Total
Ailanthus altissima	Tree-of-heaven	**High**	1	1	1	3
Elaeagnus umbellata	Autumn olive	**High**	2	2	1	5
Microstegium vimineum	Japanese stiltgrass	**High**	1	1	3	5
Paulownia tomentosa	Princess tree	**High**	2	2	1	5
Lonicera japonica	Japanese honeysuckle	**Medium**	1	1	4	6
Albizia julibrissin	Mimosa tree	**Medium**	3	3	1	7
Lespedeza cuneata	Chinese lespedeza	**Medium**	2	2	3	7
Ligustrum sinense	Chinese privet	**Medium**	2	3	2	7
Rosa multiflora	Multiflora rose	**Medium**	2	2	3	7
Elaeagnus pungens	Thorny olive	**Medium**	4	3	1	8
Lonicera spp	Bush honeysuckles	**Medium**	3	3	2	8
Wisteria sinensis	Wisteria	**Low**	3	3	3	9
Pueraria montana	Kudzu	**Low**	4	4	2	10
Vinca minor	Periwinkle	**Low**	4	4	2	10

*Plants were ranked on a scale of 1-4, with 1 being high priority and 4 being low priority for each category. The sum of rankings across the categories resulted in the final ranking of each plant species (lower totals indicating higher priority). Category A is the extent of spread, Category C is the value of the infested habitat, and Category D is the difficulty of control.

C. Inventory and Monitoring

An effective strategy for inventorying invasive plants is to start in areas where the probability of locating populations is highest (Rew et al. 2006). Areas in which invasive plants may have more negative impacts, such as areas with rare or endangered species, should also be targeted to minimize these negative impacts. Therefore, the inventory process should begin in Natural Heritage areas predicted to have high priority species and multiple invasive species. The inventory process should then continue to areas with high priority species, but fewer numbers of species, then to timber management areas with high priority

species, and finally to areas with lower priority species. The predicted distribution maps can guide the inventory process.

Literature on effective control of invasive plants recommends focusing treatment on small, rapidly growing populations (Moody and Mack 1988, Hobbs and Humphries 1995). During the inventory process, when feasible, control treatments should be applied at the same time (this may require a team of at least 2 people) particularly on small, peripheral populations.

Maps of invasive populations should be continually updated. It is particularly important to identify the boundaries of populations in order to track the rate of expansion. Annual monitoring can help determine which populations are expanding and the rate of expansion. Then priorities can be adjusted to target rapidly expanding populations first.

In addition, treatment applications should be recorded and data on population size and percent cover should be compared to previous years to determine the effect of management on populations. Several database options exist for tracking data on invasive plant management activities and their effects. These include the Weed Information Management System (WIMS) developed by The Nature Conservancy, GeoWeed developed by the Sonoma Ecology Center, and a custom addition to the current Duke Forest database tracking other forest management activities.

After the initial inventory is complete, new data can be incorporated into the species distribution models to determine areas to watch for the establishment of new invasive plant populations.

D. Prevention

Preventing new populations from establishing is an important and effective part of any weed management plan. In the Duke Forest, there are several actions that can be taken to prevent new populations from establishing.

- Powerwashing equipment, vehicles, and shoes after working in infested areas of the Forest;
- Ensuring that equipment, vehicles, and shoes do not have any foreign seeds or plant material on them when entering off-road areas;
- Ensuring that seedlings are free of weeds and weed seeds prior to planting.

In the future it may be useful to identify potential vectors of invasive plant introduction. By understanding these vectors, the Duke Forest may more effectively and efficiently prevent new population from establishing.

E. Early Detection and Rapid Response

Early detection and rapid response is an important component of any weed management plan. When new infestations are detected early, they can be eradicated quickly with little ecological or economic impacts.

Early detection requires regular monitoring of managed areas and the boundaries of the Duke Forest. In particular, areas which have been disturbed or are near roads or streams should be monitored with vigilance as these are most likely to be infested. Specific recommendations include:

- Monitor harvested and thinned stands for 2 growing seasons immediately afterwards and remove or control any invasive plants found.
- Remove or control any invasive plants along boundary lines as boundary lines are being marked. Note these areas and return annually to monitor and re-treat as needed.
- Make note of any invasive plants on neighboring property near the boundary line. Monitor these areas frequently.

F. Education, Outreach, and Training

There are many stakeholders in the management of the Duke Forest, including researchers, students, neighbors, and recreationalists. These stakeholders can be an effective part of the invasive plant management. They can assist with early detection, prevention, control and tracking of populations.

G. Minimum Staffing Requirements

One full-time staff equivalent with herbicide application certification should be dedicated to implement the management plan during the active control seasons. Student interns can assist with control activities in the summer months.

H. Weed Management Plan Implementation Schedule

Cutting herbaceous species with a mower, weed whacker, bush hog, or other instrument in late summer prior to seed set will prevent the growth of the seed bank. Since it is not feasible to mow in riparian areas or forest stands, mowing is only recommended for roadside populations.

Hand pulling of herbaceous species in early spring when the soil is loose is another option for areas where mowing is not appropriate. However, it should be noted that hand pulling is labor intensive as all parts, including tiny roots, must be removed from the site. Also, hand pulling disturbs the soil and may allow other invasive plants to gain a foothold, increasing the diversity of invasive plants (J. DeMeester, personal communication).

Cut stump, basal bark, and hack and squirt treatments should be applied, in accordance with label instructions, to woody plants when plant carbohydrates, essential minerals, et cetera are being pulled down into the roots. This will enable the herbicide to kill the roots, thus killing the entire plant. Only those Forest Stewardship Council approved herbicides recommended in the specific

control plans (Appendix A) should be used. It should be noted that basal bark and hack and squirt treatments will leave the plant standing as it is dying, potentially resulting in unappealing aesthetics. If this is a concern, then the cut stump technique may be more appropriate.

To minimize impacts on surrounding vegetation, winter is the ideal time to apply foliar herbicide to *L. japonica* because it is evergreen. Foliar herbicide would be more effective in controlling *L. japonica* during the summer growing season. However, most other surrounding vegetation would also be in its growing season and thereby affected. In addition, children like to suck on the honeysuckle flower in the summer months and could be negatively affected if herbicide was applied to the plants during that time.

Note: All treatments once started, must be monitored and repeated on at least an annual basis in order to ensure success. If there is no follow-up, the treatments may not only be ineffective but could actually cause an increase in weed density. For example, a population of *A. altissima* was treated using a cut stump technique near Gate 22 in 2004 No follow-up treatment occurred. When surveyed in 2008, multiple stems were growing from one stump, increasing overall density and seed production.

Table 6: Seasonal Implementation Schedule

Season	Species	Actions
Spring (March – June)	*Ailanthus altissima* *Albizia julibrissin* *Elaeagnus pungens* *Elaeagnus umbellata* *Ligustrum sinense* *Lonicera spp* *Paulownia tomentosa* *Pueraria montana* *Rosa multiflora* *Wisteria sinensis*	Apply basal bark treatments.
Summer (July/August)	*Microstegium vimineum* *Lespedeza cuneata*	Mow prior to seed set
Fall (August – November)	*Ailanthus altissima* *Albizia julibrissin* *Elaeagnus pungens* *Elaeagnus umbellata* *Ligustrum sinense* *Lonicera spp* *Paulownia tomentosa* *Pueraria montana* *Rosa multiflora* *Wisteria sinensis*	Apply cut stump or hack and squirt treatments
Winter	*Lonicera japonica*	Apply foliar herbicide spray

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V. APPENDICES

A. Specific Control Plans for Priority Weed Species

Ailanthus altissima – Tree of Heaven
Updated: 2007

PRIORITY
High

DESCRIPTION
Life History
- Allelopathic
- Root sprouts
- Wind and water dispersed seeds
- Seed can be produced by 2-3 year old plants (from sprout)
- Flowers April to June
- Fruit and seeds July to February
- Can produce as many as 325,000 seeds per year

Habitat and Range
- Tolerant of poor soils, including acidic, compacted, and nutrient deficient
- Both drought and flood tolerant
- Commonly invades disturbed areas
- Shade intolerant
- Alleys, sidewalks, parking lots, and streets
- Fields, roadsides, fencerows, woodland edges, and forest openings
- Recently planted fields and rocky, untillable areas

History and Use
- Introduced in 1784 from Europe
- Originally from China
- Used for mine reclamation

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Rapid growing, forming dense thickets
- Dense clonal thickets displace native species
- Can rapidly take over fields and meadows, restricting light to the understory
- Allelopathic properties aid in displacing other species
- Aggressive root system can damage sewage pipes and foundations

MANAGEMENT OPTIONS
Viable control options include manual, mechanical, and chemical methods. Manually young seedlings may be pulled or dug up when soil is moist, removing the entire plant including root fragments. Mechanically, cutting trees repeatedly may

exhaust the plants reserves over time. Plants would need to be cut several years in a row. The initial cut should be in early summer when root reserves are lowest. Subsequent cuts should occur as soon as new sprouts develop to prevent production of more plant reserves.

- Hack and squirt
  - Midsummer best, late winter somewhat less effective
  - 1 hack cut for each inch of diameter plus 1 cut
  - Leave 1 to 2 inches of uncut tissue between each cut
    - Triclopyr
    - Pathfinder II
    - Imazapyr
    - Accord Concentrate or Glypro Plus undiluted or dilute 1 to 1 with clear water
  - Girdling and frilling are not recommended
- Cut stump
  - Best in summer
    - Triclopyr, either 20% mixture with oil to entire stump or 100% solution to outer 1/3 of stump
    - Pathfinder II
    - Imazapyr
    - Accord Concentrate or Glypro Plus undiluted or dilute 1 to 1 with clear water
- Basal bark
  - Late winter, early spring best
  - Used for trees less than 6 inches dbh
  - Apply triclopyr as a 15-25% solution in available herbicidal oil with a penetrant to young bark as a basal spray
  - Pathfinder II
- Foliar
  - June or July to October
  - Imazapyr as a 1-2% solution in water with ¼-½% surfactant
  - Fosamine as a 15% solution in water with a surfactant
  - Triclopyr as a 2% solution in water with a surfactant
  - Mesulfuron at 1 ounce per acre in water with a surfactant
  - Accord Concentrate in clear water can also be used. It is registered for wetland sites
  - For small infestations or follow-up spraying 2-3 ounces imazapyr in 1 gallon water
- Annual follow-up treatments should begin no earlier than June
- Target large female trees to control seed production
- Establish a thick cover of native trees or grasses to shade out seedlings

<u>RECOMMENDED ACTIONS</u>

The hack and squirt and basal bark treatments are recommended for use in the Duke Forest. These treatments are applied directly to the plants to be controlled

and therefore have little to no impact on surrounding vegetation. According to the literature, these are also more effective than cut stump treatments. However, in areas where aesthetics are important, cut stump treatment should be used.

Several different herbicide solutions are suggested for each treatment. If a particular herbicide is on hand and can be used for multiple purposes, such as pine release and invasive control, this may be most efficient. Testing various herbicide solutions to determine effectiveness and cost-efficiency is also an option.

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Albizia julibrissin – Silktree, Mimosa
Updated: 2007

PRIORITY
Medium

DESCRIPTION
Life History
- Root sprouts
- Animal and water dispersed seeds
- Nitrogen fixer
- Seeds remain viable for several years
- Flowers May to July
- Fruits and seeds June to February
- Pods ripen August to September
- Seeds remain viable for up to 50 years

Habitat and Range
- Dry to wet sites
- Forest edges
- River floodplains
- Drought, wind and salt tolerant
- Range of soil types
- Spreads along stream banks
- Prefers open conditions
- Can persist in shade
- Seldom found above 3,000 feet
- Roadsides, open vacant lots, and riparian areas

History and Use
- Introduced from Asia in 1745
- Native from Iran to Japan

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Dense stands reduce light and water available to other plants
- Increase soil nitrogen levels
- Short-lived and weak wood
- Easily infested and die as a result of a fungal disease, fusarium wilt

MANAGEMENT OPTIONS
Viable control options are:
- Mechanical
  - Cut at ground level
  - Requires repeated cutting or herbicide use for effective control

- Girdling with follow-up of foliar herbicide
- Hand pull young seedlings, including all root fragments

♦ Foliar spray
- Triclopyr as a 2% solution (July to October)
- Glyphosate herbicide as a 2% solution (July to October)
- Clopyralid as a 0.2 – 0.4 % solution (July to September)
- Use 0.5% non-ionic surfactant

♦ Hack and Squirt
- Anytime except March and April
- Imazapyr
- Triclopyr

♦ Basal bark
- Triclopyr as a 20-25% solution in herbicidal oil
- Undiluted Pathfinder II

♦ Cut stump
- Cut while flowering
- Cut near ground
- Apply 25% solution of glyphosate or triclopyr and water covering out 20% of stump

RECOMMENDED ACTIONS

The hack and squirt and basal bark treatments are recommended for use in the Duke Forest. These treatments are applied directly to the plants to be controlled and therefore have little to no impact on surrounding vegetation. According to the literature, these are also more effective than cut stump treatments. However, in areas where aesthetics are important, cut stump treatment should be used.

Several different herbicide solutions are suggested for each treatment. If a particular herbicide is on hand and can be used for multiple purposes, such as pine release and invasive control, this may be most efficient. Testing various herbicide solutions to determine effectiveness and cost-efficiency is also an option.

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Elaeagnus pungens – Thorny Olive
Updated: 2007

PRIORITY
Medium

DESCRIPTION
Life History
- Fast-growing
- Animal-dispersed seeds
- Stem sprouts
- Can climb into trees
- Flowers October to December
- Fruit and seeds March to June

Habitat and Range
- Shade, drought, and salt tolerant

History and Use
- Introduced from China and Japan in 1830
- Used in hedgerows, on highway right-of-ways, and landscaping

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Increases soil nitrogen concentrations
- Shrubs can out-compete other species
- Can reduce diversity of plant community

MANAGEMENT OPTIONS
Viable control options are:
- Foliar spray
  - Imazapyr as a 1% solution in water with a surfactant
  - Dicamba as a 1% solution in water with a surfactant
  - Triclopyr as 2% solution
- Basal bark
  - Apply triclopyr as a 20% solution in herbicidal oil with a penetrant
  - January to February or May to October
- Cut stem
  - Imazapyr as a 10% solution in water with a surfactant
  - Glyphosate herbicide as a 20% solution in water with a surfactant
  - In late summer
- Hand pull seedlings when soil is moist

RECOMMENDED ACTIONS

The basal bark treatment is recommended for use in the Duke Forest. The treatment is applied directly to the plant to be controlled and therefore has little to no effect on surrounding vegetation. The majority of *E. pungens* individuals in the Duke Forest are small diameter and thus basal bark treatment will be effective. For those stems that are larger in diameter (>2 inches), cut stem treatment will be more appropriate. In addition, cut stem treatment will be more appropriate when aesthetics are a concern.

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Elaeagnus umbellata – Autumn Olive
Updated: 2007

PRIORITY
High

DESCRIPTION
Life History
- Animal-dispersed seeds
- Nitrogen fixer
- Flowers February to June
- Fruit and Seeds August to November
- Stump sprouts

Habitat and Range
- Prefers drier sites
- Shade tolerant
- Invades old fields, woodland edges, forest openings, pastures, road sides, rights-of-way, and other disturbed areas
- Open forests
- Prairies
- Floodplains
- Grows in sandy, loamy, and somewhat clayey soils
- Grows in slightly acidic to neutral pH soils

History and Use
- Introduced from China and Japan in 1830
- Used for wildlife habitat, strip mine reclamation, and shelterbelts
- Ornamentals

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Forms dense thickets, creating a monocultural shrub layer
- Displaces native species
- Reduces biodiversity
- Alters successional states
- Restricts light availability to understory layers in meadows and forest openings
- Alters soil nitrogen availability
- Alters ecosystems that are adapted to infertile soils

MANAGEMENT OPTIONS
Viable control options are:
- Foliar spary
  - Imazapyr as a 1% solution in water with a surfactant

- Dicamba as a 1% solution in water with a surfactant
- Triclopyr as 2% solution

♦ Basal bark
- Apply triclopyr as a 20% solution in herbicidal oil with a penetrant
- January to February or May to October

♦ Cut stem
- In late summer
- Imazapyr as a 10% solution in water with a surfactant
- Glyphosate herbicide as a 20% solution in water with a surfactant

♦ Hand pull seedlings when soil is moist

RECOMMENDED ACTIONS

The basal bark treatment is recommended for use in the Duke Forest. The treatment is applied directly to the plant to be controlled and therefore has little to no effect on surrounding vegetation. The majority of *E. umbellata* individuals in the Duke Forest are small diameter and thus basal bark treatment will be effective. For those stems that are larger in diameter (>2 inches), cut stem treatment will be more appropriate. In addition, cut stem treatment will be more appropriate when aesthetics are a concern.

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Lespedeza cuneata – Chinese lespedeza, Sericea lespedeza
Updated: 2007

PRIORITY
Medium

DESCRIPTION
Life History
- Nitrogen fixer
- Seeds remain viable for decades
- Re-sprouts from root crowns
- Flowers July to September
- Fruit and seeds October to March
- Perennial semi-woody forb
- A single plant can persist for 20 years

Habitat and Range
- Occurs in forest openings, dry upland woodlands to moist savannas, old fields, right of ways, and cities
- Meadows, prairies, pastures, roadsides
- Flood tolerant
- Thrives on nutrient poor sites
- Prefers sunny locations
- Can grow in sandy, sandy-loam, and clayey soils
- Can grow in strongly acidic to neutral pH soils
- Drought tolerant
- Shade intolerant

History and Use
- Introduced from Asia in 1899
- Used for erosion control, quail food, soil stabilization, and grazing

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Dense thickets form through spreading root systems
- Spreads rapidly
- Displaces native vegetation
- Alters species diversity
- Alters wildlife suitability
- Alters fire regimes
- Tannins and allelopathic chemicals inhibit growth of other plant species
- Older plants unpalatable to grazers

MANAGEMENT OPTIONS

Viable control options are:

- Foliar spray
  - July to September
  - Triclopyr as a 2% solution in water with a surfactant
  - Mesulfuron methyl at three-fourths of an ounce per acre in water with a surfactant
  - Clopyralid as a 0.2-0.5% solution in water with a surfactant
  - Glyphosate as a 2% solution in water with a surfactant
  - Hexazinone as a 2% solution in water with a surfactant
  - Early to mid-summer
  - Prior to flowering
  - Mowing 1 to 3 months before herbicide applications can assist control.
- Mechanical
  - Mowing 2-3 consecutive years in the flower bud stage

RECOMMENDED ACTIONS

Mowing or cutting with another instrument is the recommended control method. Foliar spray may have negative impacts on native vegetation, insects, and amphibians. If mowing or cutting for 2-3 consecutive years does not result in containment or decrease in *L. cuneata* populations, experiments with the various recommended herbicide solutions may be required to determine which is most cost-effective.

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Ligustrum sinense – Chinese privet
Updated: 2007

PRIORITY
Medium

DESCRIPTION
Life History
- Root sprouts
- Bird and animal dispersed seeds
- Single plant or thicket forming
- Flowers April to June
- Fruit and seeds July to March
- Semi-evergreen to evergreen

Habitat and Range
- Invade both lowland and upland habitats
- More prevalent in lowlands
- Shade tolerant
- Present along fencerows, forest edges, fields, and rights of way, abandoned home sites, lots, and farmlands
- Floodplains, riparian forests, upland forests
- Tolerant of occasional drought
- Invades wide variety of soil types, nutrient availability, moisture, and pH
- Grows best in mesic soil and abundant sunlight

History and Use
- Introduced from China in 1852
- Used as ornamental and hedgerows

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Forms dense impenetrable thickets
- Shade and displace native understory and shrub species
- Mid-canopy trees and developing seedlings and saplings can be replaced or restricted from establishing
- Large scale ecosystem modification
- Push native species closer to extinction

MANAGEMENT OPTIONS
Viable control options are:
- Chemical
  - Foliar spray
    - August to February
    - Glyphosate herbicide as a 3-5% solution in water with a surfactant

        - Imazapyr as a 1% solution in water with a surfactant
        - Mesulfuron methyl at 1 ounce per acre plus 0.25% non-ionic surfactant
    - Basal bark
        - January to February or May to October
        - Triclopyr as a 20% solution in herbicidal oil
        - Undiluted Pathfinder II
    - Cut stem
        - Imazapyr as a 10% solution in water with a surfactant
        - Hexazinone as a 10% solution in water with a surfactant
        - Krenite (mixed 50-50 with water)
        - Triclopyr as a 20% solution in water with a surfactant
        - Glyphosate as a 20% solution in water with a surfactant
- Mechanical
    - Hand pull young plants
    - Repeatedly cut shrubs

RECOMMENDED ACTIONS

The basal bark treatment is recommended for use in the Duke Forest. The treatment is applied directly to the plant to be controlled and therefore has little to no effect on surrounding vegetation. The majority of *L. sinense* individuals in the Duke Forest are small diameter and thus basal bark treatment will be effective. For those stems that are larger in diameter (>2 inches), cut stem treatment will be more appropriate. In addition, cut stem treatment will be more appropriate when aesthetics are a concern.

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Lonicera japonica – Japanese honeysuckle
Updated: 2007

PRIORITY
Medium

DESCRIPTION
Life History
- Spreads by rooting at vine nodes and through rhizomes
- Animal dispersed seeds
- Remains at low densities in mature forest until an opening occurs
- Flowers April to August
- Fruit and seeds June to March
- Stump sprouts
- Evergreen

Habitat and Range
- Occurs along forest margins, right-of-ways, under dense canopies, on forest floors, flood plains, roadsides, fence rows, old fields, wetlands, arbors high in canopies, roadsides, field edges, and disturbed areas
- Shade tolerant
- Flood tolerant
- Drought tolerant

History and Use
- Introduced from Japan in 1806
- Used for erosion control, deer browse, and as an ornamental

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Girdles shrubs and small saplings
- Forms dense mats in the canopies of shrubs and trees
- Shades understory and mid-story species
- Forms dense thickets on forest floor
- Inhibits growth of native understory species
- Inhibits tree seedling establishment
- Can create a "living wall" of vegetation
- Reduces variety of food and shelter for animals

MANAGEMENT OPTIONS
Viable control options are:
- Chemical
  - Foliar spray
    - June to August
      - Apply mesulfuron 2 to 4 ounces per acre in water with a surfactant

        - July to October or during warm days in early winter
            - Glyphosate herbicide as a 2-2.5% solution in water with a surfactant
            - Triclopyr as a 2-5% solution in water with a surfactant
    - Cut stem
        - July to October
        - Glyphosate herbicide as a 20-25% solution in water with a surfactant
        - Triclopyr as a 20-25% solution in water with a surfactant
- Manual and Mechanical
    - Repeated pulling of entire vines and root systems
    - Monitor frequently and remove any new plants
    - Cut and remove twining vines to prevent girdling
    - Cut vine stems low to ground
    - Mowing large patches repeatedly (mid-July and mid-September)
    - Grazing by goats
- Fire
    - Clears above ground vegetation
    - Does not kill rhizomes
    - Will continue to sprout
    - Makes herbicide treatments more effective

RECOMMENDED ACTIONS

Since *L. japonica* has become naturalized in many areas of the Duke Forest, is widespread, and difficult to remove without damaging surrounding vegetation, it may be best to leave existing, well established patches. New, expanding or small patches, however, may be controlled to prevent the further spread of *L. japonica*. The use of foliar spray in winter when potential damage to surrounding vegetation will be minimized is recommended. Prescribed fire is also recommended for control of *L. japonica* when it coincides with prescribed fire plans for the Duke Forest generally.

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Lonicera fragrantissima, L. maackii, L. morrowii, L. tatarica, L. xbella – Bush honeysuckles
Updated: 2007

PRIORITY
Medium

DESCRIPTION
Life History
- Deciduous shrubs
- Forms dense thickets
- Root sprouts
- Bird and animal dispersed
- Seeds long-lived in the soil
- Flowers February to June
- Fruit and seeds June to February

Habitat and Range
- Present in open forests, forest edges, abandoned fields, pastures, roadsides, thickets, floodplains, maritime forests and open upland
- Shade and sun tolerant
- Wet and dry sites
- Calcareous soils

History and Use
- Introduces from Asia in the 1700's and 1800's
- Used as ornamentals and wildlife plants

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Limit ability of forests to re-grow
- Reduces seedling establishment
- Reduces herb species richness in forests
- Forms dense thickets
- Keep native species from establishing
- Crowds and shades native species
- Decrease light availability
- Deplete soil moisture and nutrient availability
- Possibly allelopathic
- Reduce native honeysuckle seed set by competing for pollinators
- Reduces food availability for migratory birds

MANAGEMENT OPTIONS

Viable control options are:

- Chemical
  - Foliar spray
    - Glyphosate herbicide as a 1-2% solution in water with a surfactant
    - August to October
  - Basal bark
    - Triclopyr as a 20% solution in herbicidal oil
    - Undiluted Pathfinder II
  - Cut stems
    - Imazapyr as a 10% solution in water with a surfactant
    - Glyphosate herbicide as a 20% solution in water with a surfactant
- Fire
  - Can work in open habitats
- Mechanical
  - Hand pull small infestations
  - Clip at ground level in shaded forest habitats repeatedly in spring and fall
  - Repeat yearly
- Biological
  - Goats and deer control honeysuckles by browsing

RECOMMENDED ACTIONS

The basal bark treatment is recommended for use in the Duke Forest. The treatment is applied directly to the plant to be controlled and therefore has little to no effect on surrounding vegetation. The majority of bush honeysuckle individuals in the Duke Forest are small diameter and thus basal bark treatment will be effective. For those stems that are larger in diameter (>2 inches), cut stem treatment will be more appropriate. In addition, cut stem treatment will be more appropriate when aesthetics are a concern. Prescribed fire is also recommended for control of bush honeysuckles when it coincides with prescribed fire plans for the Duke Forest generally.

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Microstegium vimineum – Japanese stiltgrass, Nepalese browntop
Updated: 2007

PRIORITY
High

DESCRIPTION
Life History
- Annual grass
- Water dispersed seed
- Prolific seeding
- Seeds viable in soil for 3-5 years
- Spreads on human clothes and shoes
- Flowers July to October
- Seeds July to December
- Roots at stem nodes
- Individuals produce 100-1000 seeds
- Self and cross-pollinating

Habitat and Range
- Flood tolerant
- Prefers alluvial floodplains and stream sides
- Also present at forest edges, roadsides, trail sides, damp fields, swamps, lawns, and ditches
- Occurs up to 4,000 feet
- Shade tolerant
- Associated with disturbed areas including those subject to regular mowing, tilling, foot traffic, and other soil disturbing activities
- Present on moist, sandy or loamy soils
- Present on mildly acidic or neutral pH soils
- Open woods, floodplain forests, wetlands, paths, clearings, and utility corridors
- Prefers high nitrogen soils

History and Use
- Introduced from Asia in 1919
- Used for ground cover and packing material for porcelain

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Forms thick monocultural stands within 5 years
- Changes communities
- Replaces native herbaceous vegetation
- Alters litter composition
- Alters pH levels (increases)

- Alters organic soil horizon (increases)
- Reduces growth in establishing seedlings
- Displaces vegetation native to floodplains
- Provides increased habitat for rats that prey on ground nesting birds' eggs
- Overabundance of deer can cause soil disturbance and encourage spread of stiltgrass

MANAGEMENT OPTIONS

Viable control options are:

- Repeat treatments for several years to control abundant germinating seeds.
- Chemical
  - Pre-emergent herbicide, imazapyr with no surfactant at 4oz per acre beginning in March and throughout summer during peak growth
  - Apply a glyphosate herbicide as a 2% solution in water with a surfactant in summer.
  - Spray with imazameth (will not kill most native competitors)
- Manual
  - Hand pull throughout the growing season
  - When soil is moist
  - Remove entire plant including roots
  - Dehydrate on site
  - May expose seed from previous seasons
  - Repeat for many seasons until seed bank is exhausted
- Mechanical
  - Mow in late summer (August through September)
  - Before seed is produced
  - Cutting late in season avoids regrowth
  - Repeat for many seasons

RECOMMENDED ACTIONS

Mowing or cutting with another instrument is the recommended control method. Foliar spray may have negative impacts on native vegetation, insects, and amphibians. Mowing or cutting may not be feasible in riparian areas or within forest stands. Therefore, experiments with the various recommended herbicide solutions may be required to determine which is most cost-effective.

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Paulownia tomentosa – Princess tree
Updated: 2007

PRIORITY
High

DESCRIPTION
Life History
- Wind and water dispersed seeds
- Root sprouts
- Flowers April to May
- Fruit and seeds June to April
- Seeds mature in autumn
- Deciduous tree
- Rapid growth – up to 15 ft per year
- Survives fire, cutting and bulldozing
- Single tree can produce 20 million seeds
- Trees mature in 8-10 years

Habitat and Range
- Found around old homes, roadsides, riparian areas, and forest margins
- Can tolerate infertile, shallow, rocky, alkaline to acidic or very dry soils
- Shade intolerant
- Prefers highly disturbed areas
- Clearcuts, burns and storm blowdowns
- Stream banks, forests, steep rocky slopes, previously burned areas
- Drought tolerant

History and Use
- Introduced to Europe from Asia in 1830s
- Introduced to US from Europe in mid to late 1800's
- Used as an ornamental and wood export to Japan

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Ability to re-sprout after fire, creates problems when managing species that require fire for regeneration
- Ability to colonize marginal habitats threatens rare plants that require these habitats

MANAGEMENT OPTIONS
Viable control options are:
- Mechanical
  - Hand pull seedlings when ground is moist, removing all root fragments
  - Cut trees at ground level when they have begun to flower

- Cutting will require repetition or herbicide to control resprouting

♦ Chemical
  - Foliar spray
    - July to October
    - Imazapyr as a 1% solution in water with a surfactant
    - Glyphosate herbicide as a 2% solution in water with a surfactant
    - Triclopyr as a 2% solution in water with a surfactant
  - Hack and Squirt
    - Cut through bark encircling base of tree 6 inches above ground
    - Will kill top of tree, but not root system
    - May require follow-up with foliar herbicide
  - Cut stump
    - 50% solution of glyphosate or triclopyr and water to cut stump, covering outer 20% of stump
  - Basal bark
    - 20-25% triclopyr in horticultural oil to base of trunk

RECOMMENDED ACTIONS

The hack and squirt and basal bark treatments are recommended for use in the Duke Forest. These treatments are applied directly to the plants to be controlled and therefore have little to no impact on surrounding vegetation. According to the literature, these are also more effective than cut stump treatments. However, in areas where aesthetics are important, cut stump treatment should be used.

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Pueraria montana – Kudzu
Updated: 2007

PRIORITY
Low

DESCRIPTION
Life History
- Colonizes by vines rooting at nodes
- Wind animal and water dispersed seeds
- Nitrogen fixer
- Flowers June to September
- Fruit and seed September to January
- Few seeds are viable

Habitat and Range
- Occurs along right-of-ways and stream banks
- Forms dense mats over the ground, debris, shrubs, and mature trees

History and Use
- Introduced from Japan and China in early 1900s
- Used for erosion control, livestock feed, and folk art

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Grows rapidly, up to 1 ft per day
- Grows over ground, tops of trees, and onto power lines
- Roots penetrate 10 ft into ground
- Shade out native species

MANAGEMENT OPTIONS
Viable control options are:
- Biological
  - Graze with goats or pigs
- Mechanical
  - Mow close to the ground on a monthly basis for at least 2 years
- Chemical
  - Foliar spray
    - July to September
    - Tordon 101 as a 3% solution
    - Tordon K as a 2% solution
    - Mesulfuron methyl at 3 to 4 ounces per acre in water or when safety to surrounding vegetation is desired
    - Clopyralid as a 0.5% solution in water
    - Cut vines that are not controlled after herbicide treatment

    - Repeat for successive years
    - Triclopyr as a 4% solution in water with a surfactant (partial control)
    - Glyphosate herbicide as a 4% solution in water with a surfactant (partial control)
- Cut stem
    - Triclopyr
    - Glyphosate
- Basal bark
    - January to April
    - For vines less than 2 inches in diameter.
    - Triclopyr as a 20% solution in herbicidal oil
    - Undiluted Pathfinder II

RECOMMENDED ACTIONS

The current populations of *P. montana* are small and are not in highly valued areas of the Duke Forest. Therefore it is recommended that *P. montana* be monitored for rate of spread, but no active control be implemented at this time.

If active control is determined to be appropriate in the future, basal bark and cut stem treatments are recommended as these treatments are applied directly to the plants, minimizing negative impacts on surrounding vegetation.

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Rosa multiflora – Multiflora rose
Updated: 2007

PRIORITY
Medium

DESCRIPTION
Life History
- Root sprout
- Vegetative rooting
- Animal dispersed seed
- Flowers April to June
- Fruit and seeds July to December
- Seeds can survive in soil for up to 20 years
- One plant can produce 1 million seeds per year

Habitat and Range
- Found along right-of-ways, in new forests, and forest margins
- Colonizes gaps in woodland, prairies, and old fields
- Often climb into trees
- Shade tolerant
- Open woodlands, dense woods, stream banks, roadsides, and pastures

History and Use
- Introduced from Japan in 1866
- Used as ornamentals, livestock containment, wildlife habitat, erosion control and "living fences"

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Form impenetrable thickets
- Excludes native plants
- Canes can add weight to tree branches, making them vulnerable to breaking in windstorms
- Disrupts livestock grazing

MANAGEMENT OPTIONS
Viable control options are:
- Mechanical
  - Repeated cutting or mowing 3-6 times per growing season for 2-4 years
- Chemical
  - Herbicide treatment will likely need to be repeated
  - Foliar spray
    - Escort at 1 ounce per acre in water (April to June, at or near the time of flowering)

- Imazapyr as a 1% solution (August to October)
- Mesulfuron methyl at 1 ounce per acre in water (August to October)
- Repeated applications of a glyphosate herbicide as a 4% solution in water, a less effective treatment that has no soil activity to damage surround plants (May to October).
- Spray foliage with fosamine during summer

♦ Basal bark
  - January to February or May to October.
  - Triclopyr as a 20% solution in herbicidal oil
  - Undiluted Pathfinder II

♦ Cut stem
  - Imazapyr as a 10% solution in water with a surfactant
  - Glyphosate herbicide as a 20% solution in water with a surfactant

RECOMMENDED ACTIONS

The cut stem treatment is recommended for control of *R. multiflora* in the Duke Forest. Both cut stem and basal bark treatments are applied directly to the plant, minimizing negative impacts on surrounding vegetation. However, due to the growth patterns of *R. multiflora* the application of cut stem treatments will likely be more efficient than basal bark treatments.

Two herbicide solutions are suggested for the cut stem treatment. If a particular herbicide is on hand and can be used for multiple purposes, such as pine release and invasive control, this may be most efficient. Testing various herbicide solutions to determine effectiveness and cost-efficiency is also an option.

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Vinca minor – Periwinkle
Updated: 2007

PRIORITY
Low

DESCRIPTION
Life History
- Evergreen to semi-evergreen vines
- Forms mats by rooting at nodes
- Flowers April to May
- Fruit and seeds May to July

Habitat and Range
- Found around old home sites and open to dense canopied forests
- Requires part shade and moisture
- On well drained to poorly drained soils
- Calcareous, alkaline to slightly acidic soils
- Medium textured to fine textured soils
- Rich, moist soils

History and Use
- Introduced from Europe in 1700s
- Used as ornamental ground cover, erosion control
- Historically used for herbal medicine and aphrodisiac

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Shades the ground, excluding other plants
- Displaces food sources for wildlife
- Leaves toxic to most grazers

MANAGEMENT OPTIONS
Viable control options are:
- Manual
  - Hand pull, removing all roots
- Chemical
  - Foliar
    - July to October for successive years
      - Tordon 101 as a 3% solution in water with a surfactant
      - Tordon K as a 2% solution in water with a surfactant
      - Triclopyr as a 4% solution in water with a surfactant
    - During the growing season, repeated applications
      - Triclopyr as a 2% solution in water with a surfactant
      - Glyphosate herbicide as a 2% solution in water with a surfactant

RECOMMENDED ACTIONS

The current populations of *V. minor* are small and are not in highly valued areas of the Duke Forest. Therefore it is recommended that *V. minor* be monitored for rate of spread, but no active control be implemented at this time.

If active control is determined to be appropriate in the future, foliar herbicide application is recommended. The herbicide should be applied during the winter months in order to minimize negative impacts on surrounding vegetation.

Note: Since *V. minor* tends to be associated with old homestead sites, an inventory of this species could assist in documenting sites of historical significance throughout the Duke Forest.

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Wisteria sinensis – Chinese wisteria
Updated: 2007

PRIORITY
Low

DESCRIPTION
Life History
- Deciduous vine
- Nitrogen fixer
- Runners root at nodes
- Water dispersed seeds
- Flowers March to May
- Fruit and seeds July to November
- Lives more than 50 years

Habitat and Range
- Occur on wet to dry sites
- Cover trees and shrubs
- Shade tolerant
- Prefers moist soil
- Forest edges, roadsides, ditches, right-of-ways, old homesites

History and Use
- Chinese wisteria introduced from Asia in 1816
- Used for shade on porches, trellises, and gazebos

CURRENT DISTRIBUTION ON THE SITE
(Refer to maps, Appendix C)

DAMAGE & THREATS
- Kills individual shrubs and trees by shading or strangling them
- Forms thickets which exclude native plants
- Roots damage foundations, siding, and roofs
- Alters soil nitrogen

MANAGEMENT OPTIONS
Viable control options are:
- Mechanical
  - Cut climbing vines as close to root collar as possible
  - Repeat cutting throughout growing season
  - Remove cut vines from trees and shrubs to prevent girdling
- Manual
  - Hand pull entire plant, including roots and runners
  - Bag and dispose in a trash dumpster to prevent reestablishment
- Chemical
  - Cut stump

- 25% solution of glyphosate or triclopyr and water to cut surface of stem
- Retreatment with foliar spray may be necessary for resprouts

▪ Foliar
- Tordon 101 as a 3 % solution in water with a surfactant
- Tordon K as a 2% solution in water with a surfactant
- Triclopyr as a 4% solution in water with a surfactant
- Clopyralid as a 0.5% solution in water when safety to surrounding vegetation is desired (may leach into water)
- A glyphosate herbicide as a 2-4% solution in water with a surfactant, repeatedly
- July to October for successive years

RECOMMENDED ACTIONS

The current populations of *W. sinensis* are generally small and are not in highly valued areas of the Duke Forest. Therefore it is recommended that *W. sinensis* be monitored for rate of spread. Active control of *W. sinensis* is only recommended for those populations that exist in Natural Heritage areas.

In the Natural Heritage areas, cut stem treatments are recommended as these are applied directly to the plants, minimizing negative impacts on surrounding vegetation.

Note: Since *W. sinensis* tends to be associated with old homestead sites, an inventory of this species could assist in documenting sites of historical significance throughout the Duke Forest.

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B. Descriptions of Species to Watch

Acer platanoides – Norway maple
Updated: 2007

DESCRIPTION

Life History

- Copious wind dispersed seeds
- Seeds in late summer, but frequently remain on tree into winter
- Shallow root system

Habitat and Range

- Deciduous forests, urban and suburban natural areas, urban woodlots
- Cold tolerant
- Tolerant of poor soils and air pollution

History and Use

- Native to Scandinavia to Northern Iran
- Introduced in 1776
- Used for ornamental shade and musical instruments

DAMAGE & THREATS

- Casts heavy shade
- Shallow dense root system makes it difficult for other plants to establish
- Reduces plant diversity
- Subject to blowdowns

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Akebia quinata – Chocolate vine
Updated: 2007

DESCRIPTION

Life History

- Evergreen in the South
- Produces seedpods in fall
- Requires cross-pollination for fruits to set
- Ground crawling or tree climbing vine
- Reproduces vegetatively
- Lives 3 to 10 years
- Perennial
- Can grow 20-40 feet in a year
- Bird dispersed seeds

Habitat and Range

- Shade tolerant
- Drought tolerant
- Well-drained soils
- Sunny to partially sunny

History and Use

- Introduced from Asia in 1845
- In Asia, used for food and medicine
- Used primarily as an ornamental

DAMAGE & THREATS

- Ground coverage outcompetes native plants and prevents seed germination
- Climbs over understory trees and shrubs
- Blocks light to vegetation below

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Alliaria petiolata – Garlic Mustard
Updated: 2007

DESCRIPTION

Life History

- Human, animal, and water dispersed seeds
- Dormant 2 to 6 years before germinating
- Allelopathic
- Cool season biennial forb
- Flowers April to May
- Fruit and seeds May to June
- Does not reproduce vegetatively
- Self or cross-pollinating
- A single plant can produce thousands of seeds

Habitat and Range

- Occurs on floodplains, under forest canopies, and at forest margins and openings, savannas, woodlots, roadsides
- Shade tolerant
- Grows in soils with limestone or sandstone substrates
- Grows in soils neutral to basic pH
- Can establish in undisturbed sites

History and Use

- Introduced from Europe in 1800s
- First sighted as escaped in 1868 on Long Island, NY
- Originally cultivated for medicinal use and food

DAMAGE & THREATS

- Dense stands shade and compete with native understory flora
- Lowers native species diversity
- Emerges early in growing season competing with native spring ephemerals
- May interfere with larval development of two rare butterflies
- May inhibit growth of mycorrhizal fungi needed by native plants to obtain nutrients
- Reduces food sources for native wildlife
- Replaces toothworts which are essential to the development of the West Virginia white butterfly

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Arundo donax – Giant reed
Updated: 2007

DESCRIPTION

Life History

- Dense clumps
- Colonizes by branching tuberous rhizome growth
- Does not produce viable seed
- Flowers August to September
- Seeds October to March

Habitat and Range

- Occurs mainly on upland sites
- Along roadsides, forest margins, and old home sites
- Riverbanks, streams, ditches
- Moist to wet soils

History and Use

- Introduced from Mediterranean in early 1800s
- Native of Asia
- Cultivated in Asia, southern Europe, the Middle East, Latin America, and Africa
- Used as an ornamental and erosion control
- Cultivated for use in paper, fishing poles, mats and weaving, and woodwind instrument reeds

DAMAGE & THREATS

- Destroys stands of native vegetation
- Increases fire dangers
- Decreases native wildlife habitat
- Fixes channels of rivers that have naturally wandered and watered a broad floodplain
- Change areas from flood dependent to fire dependent habitat
- Contains chemicals toxic to insects and vertebrates

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Berberis thunbergii – Japanese barberry
Updated: 2007

DESCRIPTION

Life History

- Leafs out early in spring
- Flowers in spring (mid-April to May)
- Fruits in late summer and hang on into winter
- Animal dispersed seeds
- Root sprout
- Branch rooting

Habitat and Range

- Woodlands and young forests
- Partial sunlight to shade
- Forest edges, oak forests, and savannas
- Canopy forests, wetland, pastures, and meadows
- Shade tolerant
- Drought resistant

History and Use

- Introduced from Russia in 1875
- Used as an ornamental

DAMAGE & THREATS

- Forms thickets from a single bush
- Lowers plant diversity
- Leaf litter causes changes in soil chemistry
- Changes soil pH, nitrogen levels, and biological activity
- Displaces native plants
- Reduces wildlife habitat and forage

REFERENCES

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Broussonetia papyrifera – Paper mulberry
Updated: 2007

DESCRIPTION

Life History

- Fruits early to midsummer
- Root sprouts
- Spreads by sending up suckers from spreading roots

Habitat and Range

- Floodplains, meadows, field edges, thickets

History and Use

- Introduced from Asia in mid-1800s
- Used for ornamental shade
- In Asia used for making paper and medicine

DAMAGE & THREATS

- Forms dense shallowly rooted thickets
- Excludes other plants
- Blow over easily

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Celastrus orbiculatus – Oriental Bittersweet
Updated: 2007

DESCRIPTION

Life History

- Prolific vine growth
- Bird and animal dispersed seeds
- Flowers in May
- Fruit and seeds August to January
- Damage and cutting encourage re-sprouting
- Reproduces via runners and root sprouts

Habitat and Range

- Found in forest edges, open and young forests, meadows, glades, savannas, roadsides, fencerows, old home sites, and disturbed areas
- Old fields
- Coastal areas
- Prefers sun to part shade
- Generally found in hardwood forests
- Shade tolerant

History and Use

- Introduced from Asia in 1736
- Berries collected for home decorations

DAMAGE & THREATS

- Encircles and girdles trees
- Completely covers other vegetation
- Shades and restrict growth of native understory species
- Kills trees
- Increases susceptibility of trees to ice storms and wind damage
- Hybridizes with American bittersweet, decreasing genetic identity
- Can establish in dense shade and be released after disturbance creates gaps

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Coronilla varia – Purple crown vetch
Updated: 2007

DESCRIPTION

Life History

- Flowers through summer
- Seedpods mature in lat summer
- Aboveground stems die back in winter
- Perennial
- Stems trail along ground
- Fixes nitrogen
- Spreads by underground roots and seeds
- Seeds viable in soil for many years
- Animal dispersed seed

Habitat and Range

- Roadsides, prairies, pastures, woodland edges, and stream banks
- Prefers full sun
- Most soil types

History and Use

- Native to Europe, Asia, and northern Africa
- Introduce in 1950s
- Used for ground cover, erosion control, and a green fertilizer crop on fields

DAMAGE & THREATS

- Stems grow over native vegetation, shading it out
- Increases soil nitrogen
- Changes community composition
- Threatens rare and endangered plants
- Toxic to horses

REFERENCES

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Dioscorea oppositifolia – Chinese yam, Cinnamon vine
Updated: 2007

DESCRIPTION

Life History

- Rapid growing
- Die back during winter
- Spread by underground tubers
- Can spread by water
- Flowers May to August
- Fruit and seeds June to September
- Dead vines serve as trellis for reestablishment

Habitat and Range

- Open to semi-shady sites
- Able to cover small trees
- Rich soils
- Stream banks and floodplain forests
- Fencerows and roadsides

History and Use

- Introduced from Asia in 1800s
- Used for ornamentals, food and medicinal use
- Noticed in the wild in 1980's

DAMAGE & THREATS

- Quickly overgrows shrubs and small trees
- Blocks light to the ground
- Decreases plant diversity
- Branches can break under weight of vines

REFERENCES

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Elaeagnus angustifolia – Russian olive
Updated: 2007

DESCRIPTION

Life History

- Bird and animal dispersed seeds
- Nitrogen fixer
- Flowers April to July
- Fruit and seeds August to October
- Can reproduce vegetatively, though primarily by seed

Habitat and Range

- Found as scattered plants
- Forest openings, open forests, and forest edges
- Steams, fields, open areas
- Prefers sandy floodplains
- Shade intolerant

History and Use

- Introduced from Europe and western Asia in early 1900s
- Used for ornamental, windbreaks, surface mine reclamation, and wildlife habitat

DAMAGE & THREATS

- Increase soil nitrogen
- Alters plant community
- Outcompete other plants
- Reduces diversity of cover types for wildlife
- Interferes with natural plant succession and nutrient cycling
- Taxes water reserves

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Euonymus alata – Burning bush, Winged euonymus
Updated: 2007

DESCRIPTION

Life History

- Colonizes by root suckers
- Animal-dispersed seeds
- Flowers April to May
- Fruit and seeds August to January

Habitat and Range

- Shade tolerant
- Open woods
- Disturbed lands
- Young forests
- Floodplains
- Range of soil types

History and Use

- Introduced from Asia in 1860s
- Used as ornamental and highway beautification

DAMAGE & THREATS

- Out-compete native plants for light and space

REFERENCES

IUCN Species Survival Commission, Invasive Species Specialist Group. 2005. *Euonymus alata*. Global invasive species database. http://www.issg.org/database/species/ecology.asp?si=574&fr=1&sts=sss

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Euonymus fortunei – Climbing euonymus
Updated: 2007

DESCRIPTION

Life History

- Colonizes by rooting at nodes
- Bird, animal and water dispersed seeds
- Flowers May to July
- Fruit and seeds September to November
- Evergreen woody vine

Habitat and Range

- Forms dense ground cover and can climb trees
- Shade tolerant
- Avoids wet areas
- Forest and forest gaps
- Prefers drier soils
- Thrives in poor or rich, acidic or basic soils
- Drought tolerant

History and Use

- Introduced from China in 1907
- Used for ornamental ground cover

DAMAGE & THREATS

- Forms dense ground cover
- Excludes native plants
- Climbing vines can kill trees and shrubs

REFERENCES

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Frangula alnus, Rhamnus frangula – Glossy buckthorn
Updated: 2007

DESCRIPTION

Life History

- Flowers in spring
- Male and female flowers on separate plants
- Bird dispersed seeds

Habitat and Range

- Wetland communities, marshes, fens, bogs, fields, roadsides

History and Use

- Introduced in early 1800s
- Used as ornamentals, fencerows, and wildlife habitat

DAMAGE & THREATS

- Forms dense thickets
- Excludes other plants
- Reduces or eliminates fires
- The high nitrogen content in leaf litter stimulates soil organisms to break down all leaf letter
- Changes quantity of leaf litter
- Increases soil nitrogen
- Changes community composition

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Kaufman, S. R., and W. Kaufman. 2007. Invasive Plants: A Guide to Identification and the Impacts and Control of Common North American Species. Stackpole Books, Mechanicsburg, PA.

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Glecoma hederacea – Ground ivy, Gill-over-the-ground
Updated: 2007

DESCRIPTION

Life History

- Flowers March-June
- Fruit and seeds May to July
- Evergreen
- Stems root at nodes
- Spread from stem fragments

Habitat and Range

- Found in lawns, gardens, and disturbed areas
- Prefers moist ground
- Shaded floodplains
- Lowland woods
- Shade tolerant

History and Use

- Introduced from Eurasia as early as the 1800s
- Originally used as an ornamental or medicinal plant

DAMAGE & THREATS

- Deters establishment and growth of other species
- Forms dense ground cover

REFERENCES

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Hedera helix – English ivy
Updated: 2007

DESCRIPTION

Life History

- Bird-dispersed seeds
- Colonizes by trailing and climbing vines
- Flowers June to October
- Fruit and seeds October to May
- New plants can grow from broken pieces of stems that are able to root in the soil

Habitat and Range

- Prefers moist open forests
- Adaptable to range of moisture and soil conditions
- Shade tolerant
- Avoids wet areas
- Woodlands, forest edges, fields, hedgerows, coastal areas, salt marsh edges, and old home sites
- Tolerates a variety of pH levels, but prefers slightly acidic soils

History and Use

- Introduced from Europe in colonial times, as early as 1727
- Used as an ornamental and source for varnish resin, dye, and tanning substances

DAMAGE & THREATS

- Grows on any plant of object in its path
- Forms dense blankets that exclude native vegetation
- Blocks light and germination of other plants beneath it
- Reduces biodiversity
- Will grow into canopy, adding weight to trees
- Can loosen bark and hold moisture against tree trunk, making trees more susceptible to fungus and decay
- Berries are mildly toxic, reducing food availability for birds
- Serves as a reservoir for Bacterial Leaf Scorch (*Xylella fastidiosa*), a pathogen that is harmful to elms, oaks, maples, and other native plants

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Imperata cylindrica – Cogon grass
Updated: 2007

DESCRIPTION

Life History

- Branching rhizomes form dense mats
- Wind dispersed seeds
- Promoted by burning
- Flower February to May
- Seeds May to June
- Re-grows after being cut
- Perennial grass

Habitat and Range

- Full sunlight to partial shade
- Right-of-ways, new forest plantations, open forests, old fields, pastures, road sides, ditches, sand dunes, waste areas, pine savannahs, along streams
- Absent in areas with frequent tillage
- Drought tolerant
- Saline tolerant
- Cold intolerant

History and Use

- Introduced from Southeast Asia in 1912
- Used for soil stabilization and forage

DAMAGE & THREATS

- Forms dense mats
- Excludes all other understory vegetation
- Desirable species displaced
- New species prevented from establishing
- Restrict tree and shrub establishment
- Creates fire hazards in winter
- Loss of wildlife habitat
- Reduces nesting by ground nesting birds and other animals

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Lespedeza bicolor – Bicolor lespedeza, Shrub bushclover
Updated: 2007

PRIORITY
Low

DESCRIPTION
Life History
- Nitrogen fixer
- Reproduces and spreads under medium to dense overstory
- Flowers June to July
- Fruit and seeds August to January
- Animal dispersed seeds
- Stump sprouts
- Root sprouts
- Seeds remain viable in soil for decades

Habitat and Range
- Drought tolerant
- Prefers open woods/grasslands
- Forests, old fields, roadsides

History and Use
- Introduced from Japan in late 1800's
- Used for wildlife food, soil stabilization, soil improvement, beekeeping, and landscaping

DAMAGE & THREATS
- Dense thickets form
- Displaces native vegetation
- Alters species diversity
- Alters wildlife suitability
- Alters fire regimes
- Tannins and allelopathic chemicals inhibit growth of other plant species
- Increases soil nitrogen

REFERENCES
Evans, C. W., D. J. Moorhead, C. T. Bargeron, and G. K. Douce. 2006. Invasive plant responses to silvicultural practices in the South. The Bugwood Network, University of Georgia, BW-2006-03.

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Ligustrum japonica – Japanese privet
Updated: 2007

DESCRIPTION

Life History

- Root sprouts
- Bird and animal dispersed seeds
- Single plant or thicket forming
- Flowers April to June
- Fruit and seeds July to February

Habitat and Range

- Invade both lowland and upland habitats
- More prevalent in lowlands
- Shade tolerant
- Present along fencerows, forest edges, fields, and rights of way
- Floodplains, riparian forests, upland forests
- Tolerant of occasional drought
- Invades wide variety of soil types, nutrient availability, moisture, and pH

History and Use

- Introduced from Japan in 1845
- Used as ornamentals and hedgerows

DAMAGE & THREATS

- Forms dense impenetrable thickets
- Shade and displace native understory and shrub species
- Mid-canopy trees and developing seedlings and saplings can be replaced or restricted from establishing

REFERENCES

Evans, C. W., D. J. Moorhead, C. T. Bargeron, and G. K. Douce. 2006. Invasive plant responses to silvicultural practices in the South. The Bugwood Network, University of Georgia, BW-2006-03.

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The Nature Conservancy. 2006. *Ligustrum spp.* Global Invasive Species Initiative. http://tncweeds.ucdavis.edu/esadocs/ligu_spp.html (accessed August 16, 2007).

Petrides, G. A. 1998. A field guide to eastern trees: eastern United States and Canada. Houghton Mifflin, New York, NY. 424 p.

Ligustrum lucidum – Shiny privet
Updated: 2007

DESCRIPTION

Life History

- Root sprouts
- Bird and animal dispersed seeds
- Single plant or thicket forming
- Flowers April to June
- Fruit and seeds July to February
- Evergreen

Habitat and Range

- Invade both lowland and upland habitats
- More prevalent in lowlands
- Shade tolerant
- Present along fencerows, forest edges, fields, and rights of way
- Floodplains, riparian forests, upland forests
- Tolerant of occasional drought
- Invades wide variety of soil types, nutrient availability, moisture, and pH

History and Use

- Introduced from Korea in 1794
- Used as ornamental and hedgerows

DAMAGE & THREATS

- Forms dense impenetrable thickets
- Shade and displace native understory and shrub species
- Mid-canopy trees and developing seedlings and saplings can be replaced or restricted from establishing

REFERENCES

Evans, C. W., D. J. Moorhead, C. T. Bargeron, and G. K. Douce. 2006. Invasive plant responses to silvicultural practices in the South. The Bugwood Network, University of Georgia, BW-2006-03.

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Miller, J. H. 2006. Nonnative invasive plants of southern forests: a field guide for identification and control. General Technical Report SRS-62. Asheville, NC: United States Department of Agriculture Forest Service, Southern Research Station. 93 p.

The Nature Conservancy. 2006. *Ligustrum spp.* Global Invasive Species Initiative. http://tncweeds.ucdavis.edu/esadocs/ligu_spp.html (accessed August 16, 2007).

Lygodium japonicum – Japanese climbing fern
Updated: 2007

DESCRIPTION

Life History

- Wind disperse spores
- Perennial viney fern
- Colonizes by rhizomes
- Dies back in late winter
- Dead vines serve as trellis for reestablishment
- Promoted by fire
- Re-grows after being cut
- Evergreen, semi-evergreen

Habitat and Range

- Highway right-of-ways, under and around bridges, open forests, forest road edges, stream, lake and swamp margins, open timber stands and plantations, coastal hammocks, ditches, savannas
- Can form mats and smother shrubs and trees
- Can invade undisturbed areas
- Flood tolerant
- Shade tolerant
- Drought intolerant

History and Use

- Native to Asia and tropical Australia
- Introduced from Japan in 1932
- Used as ornamental

DAMAGE & THREATS

- Can form dense tangled mats
- Covers ground and shrubs
- Shades and kills understory vegetation and tree seedlings
- Reduces biodiversity
- May form “walls” which block any available sunlight
- Increase fuel load and can carry fires into tree crowns
- Dense root mats can impede the flow of water in creeks and wetlands

REFERENCES

Evans, C. W., D. J. Moorhead, C. T. Bargeron, and G. K. Douce. 2006. Invasive plant responses to silvicultural practices in the South. The Bugwood Network, University of Georgia, BW-2006-03.

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Miller, J. H. 2006. Nonnative invasive plants of southern forests: a field guide for identification and control. General Technical Report SRS-62. Asheville, NC: United States Department of Agriculture Forest Service, Southern Research Station. 93 p.

Melia azedarach – Chinaberry Tree
Updated: 2007

DESCRIPTION

Life History

- Root sprouts
- Bird dispersed seeds
- Flowers March to May
- Fruit and seeds July to January

Habitat and Range

- Found on road sides, forest margins, old home sites, fencerows, old pastures
- Can invade relatively undisturbed areas
- Tolerant of high temperatures, poor soils, and periods of drought
- Rare at high elevations
- Semi-shade tolerant

History and Use

- Introduced from Asia in 1830s
- Used for ornamental shade
- Native to Asia and northern Australia
- Extracts potentially useful for natural pesticides

DAMAGE & THREATS

- Forms thickets
- Reduces plant diversity
- Bark, leaves, and seeds poisonous to most domestic animals and humans
- Decaying leaves increase soil nitrogen and pH

REFERENCES

IUCN Species Survival Commission, Invasive Species Specialist Group. 2006. *Melia azedarach*. Global invasive species database. http://www.issg.org/database/species/ecology.asp?si=636&fr=1&sts=sss (accessed August 16, 2007).

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Petrides, G. A. 1998. A field guide to eastern trees: eastern United States and Canada. Houghton Mifflin, New York, NY. 424 p.

Morus alba – White mulberry
Updated: 2007

DESCRIPTION

Life History

- Fruit early to midsummer

Habitat and Range

- Prefers warm, moist, well-drained loamy soil
- Prefers sunny positions
- Drought tolerant
- Salt tolerant
- Wind-resistant
- Floodplains, meadows, field edges, and thickets

History and Use

- Used for food, tea, wood for sporting goods, medicine, wildlife, windbreaks, silkworm industry
- Introduced from Britain in 1700's
- Originated in China
- Now spread through Japan, Europe, North America, and Africa

DAMAGE & THREATS

- Pollen overwhelms red mulberry, creating hybrids
- Reducing genetic identity of red mulberry

REFERENCES

Kaufman, S. R., and W. Kaufman. 2007. Invasive Plants: A Guide to Identification and the Impacts and Control of Common North American Species. Stackpole Books, Mechanicsburg, PA.

Moore, L. M. 2003. Plant fact sheet: white mulberry. United States Department of Agriculture, Natural Resources Conservation Science, National Plant Materials Center. Available online: plants.usda.gov/plantguide/doc/pg_moal.doc (accessed June 11, 2007).

Petrides, G. A. 1998. A field guide to eastern trees: eastern United States and Canada. Houghton Mifflin, New York, NY. 424 p.

Nandina domestica – Sacred bamboo
Updated: 2007

DESCRIPTION

Life History

- Colonizes by root sprouts
- Animal dispersed seeds
- Flowers May to July
- Fruit and seeds September to April
- Evergreen erect shrub

Habitat and Range

- Under forest canopies and near forest edges
- Sun to full shade tolerant
- Prefers moist soils
- Drought tolerant
- Floodplains

History and Use

- Introduced from China in 1804
- Discovered in natural areas in 1960s
- Native to eastern Asia and India
- Used as ornamental

DAMAGE & THREATS

- Can form dense stands
- Can displace rare plants

REFERENCES

Evans, C. W., D. J. Moorhead, C. T. Bargeron, and G. K. Douce. 2006. Invasive plant responses to silvicultural practices in the South. The Bugwood Network, University of Georgia, BW-2006-03.

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Phyllostachys aurea – Golden bamboo
Updated: 2007

DESCRIPTION

Life History

- Colonize by rhizomes
- Perennial
- Flowers once every 7 to 12 years

Habitat and Range

- Prefers open sunlight and warm climates
- Cold tolerant – to 0 degrees F
- Partially wooded areas
- Light moist soils or southeastern clay

History and Use

- Introduced from Asia in 1882
- Used as ornamentals and fishing poles
- Common around old home sites

DAMAGE & THREATS

- Suppress growth of native plants
- Retain ground moisture

REFERENCES

Kaufman, S. R., and W. Kaufman. 2007. Invasive Plants: A Guide to Identification and the Impacts and Control of Common North American Species. Stackpole Books, Mechanicsburg, PA.

Miller, J. H. 2006. Nonnative invasive plants of southern forests: a field guide for identification and control. General Technical Report SRS-62. Asheville, NC: United States Department of Agriculture Forest Service, Southern Research Station. 93 p.

Polygonum cuspidatum – Japanese knotweed
Updated: 2007

DESCRIPTION

Life History

- Semi-woody shrub
- Reproduces from vegetative cuttings
- Spreads through underground rhizomes
- Wind dispersed seeds
- Flowers in summer

Habitat and Range

- Shade intolerant
- Prefers road sides, ditches, wetlands, right-of-way, open hillsides, wet meadows, yards, sandbars, islands, waterways, waste places, old home sites, and stream banks
- Soil types, salinity levels, pH, and nutrient availabilities can vary
- Tolerates high temperatures, high salinity, and drought
- Prefers full sun
- Does not invade undisturbed sites
- Flood tolerant

History and Use

- Introduced from Asia in 1800's
- Used for fodder, erosion control, and ornamentals
- Young stems are edible with a flavor similar to rhubarb

DAMAGE & THREATS

- Creates dense patches
- Shade and displace other plant life
- Mulches out competitors
- Re-colonizes quickly after severe floods – usurping role of native species
- Alter fish and wildlife habitat
- Sprout through asphalt and foundations
- Reduce wildlife habitat
- Can increase susceptibility to erosion along stream banks

REFERENCES

Evans, C. W., D. J. Moorhead, C. T. Bargeron, and G. K. Douce. 2006. Invasive plant responses to silvicultural practices in the South. The Bugwood Network, University of Georgia, BW-2006-03.

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Remaley, T. 2005. Fact sheet: Japanese knotweed. Plant Conservation Alliance, Alien Plant Working Group. Available online: http://www.nps.gov/plants/alien/fact/pocu1.htm (accessed June 22, 2007).

University of Connecticut. 2004. *Polygonum cuspidatum*. Invasive Plant Atlas of New England. http://www.lib.uconn.edu/webapps/ipane/browsing.cfm?descriptionid=86 (accessed August 16, 2007).

Populus alba – White poplar
Updated: 2007

DESCRIPTION

Life History

- Catkins form in early spring before leaf-out
- Male and female flowers (catkins) on separate trees
- Wind dispersed seeds
- Few viable seeds
- Stump sprout
- Spread vegetatively

Habitat and Range

- Prefers open sunlight
- Acidic and alkaline soils
- Saline soils
- Grasslands and forest edges

History and Use

- Introduced in 1784
- Native to Europe and Russia
- Used as a landscape tree, windbreak, and hedgerow tree

DAMAGE & THREATS

- Forms large colonies
- Overwhelms native species

REFERENCES

IUCN Species Survival Commission, Invasive Species Specialist Group. 2005. *Populus alba*. Global invasive species database. http://www.issg.org/database/species/ecology.asp?si=261&fr=1&sts=sss (accessed August 16, 2007).

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Remaley, T. and J. M. Swearingen. 2005. Fact sheet: white poplar. Plant Conservation Alliance, Alien Plant Working Group. Available online: http://www.nps.gov/plants/alien/fact/poal1.htm (accessed June 22, 2007).

University of Connecticut. 2004. *Populus alba.* Invasive Plant Atlas of New England. http://www.lib.uconn.edu/webapps/ipane/browsing.cfm?descriptionid=87 (accessed August 16, 2007).

Pyrus calleryana – Callery pear, Bradford pear
Updated: 2007

DESCRIPTION

Life History

- Flowers in spring
- Seeds require cold to germinate
- Can produce fruits after 3 years of growth
- Live 25-30 years
- Bird and mammal dispersed seeds

Habitat and Range

- Disturbed woodlands, roadsides, old fields
- Range of soil types

History and Use

- Introduced in 1908
- Used for ornamental trees and to improve stock of commercial pears

DAMAGE & THREATS

- Forms dense thorny thickets
- Prevents colonization by native species
- Vulnerable to storm and ice damage

REFERENCES

Kaufman, S. R., and W. Kaufman. 2007. Invasive Plants: A Guide to Identification and the Impacts and Control of Common North American Species. Stackpole Books, Mechanicsburg, PA.

Sorghum halepense – Johnsongrass
Updated: 2007

DESCRIPTION

Life History

- Reproduces by rhizomes
- Copious seed producer – over 80,000 seeds in one season
- Seeds viable for over 20 years
- Stressed plants produce cyanide

Habitat and Range

- Old fields, croplands, pastures, forest edges, power line clearing, fertile bottomlands, and stream banks

History and Use

- Native to Mediterranean
- Introduced by mid-1800s

DAMAGE & THREATS

- Spreads rapidly
- Forms pure stands
- Outcompetes native grasses for space, water and nutrients
- Reduces animal and plant diversity
- Increases fire hazards in drought years
- Toxic if wilted, frost damaged, trampled, or otherwise injured
- Pollen causes human allergies

REFERENCES

Evans, C. W., D. J. Moorhead, C. T. Bargeron, and G. K. Douce. 2006. Invasive plant responses to silvicultural practices in the South. The Bugwood Network, University of Georgia, BW-2006-03.

Howard, Janet L. 2004. Sorghum halepense. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available online: *http://www.fs.fed.us/database/feis/plants/graminoid/sorhal/all.html* (accessed August 16, 2007).

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Spiraea japonica – Japanese spiraea, Japanese meadowsweet
Updated: 2007

DESCRIPTION

Life History

- Flowers in early summer
- Water and soil dispersed seeds
- Seeds persistent for several years in soil
- A single plant can produce hundreds of seeds

Habitat and Range

- Stream and river banks, canopy gaps, old fields
- Disturbed ground
- Sun to part shade
- Meadows, forest openings, forest edges, roadsides, and power line right-of-ways

History and Use

- Introduced from Asia around 1870
- Ornamental

DAMAGE & THREATS

- Forms dense thickets
- Shades out existing plants
- Prevents establishment of new plants

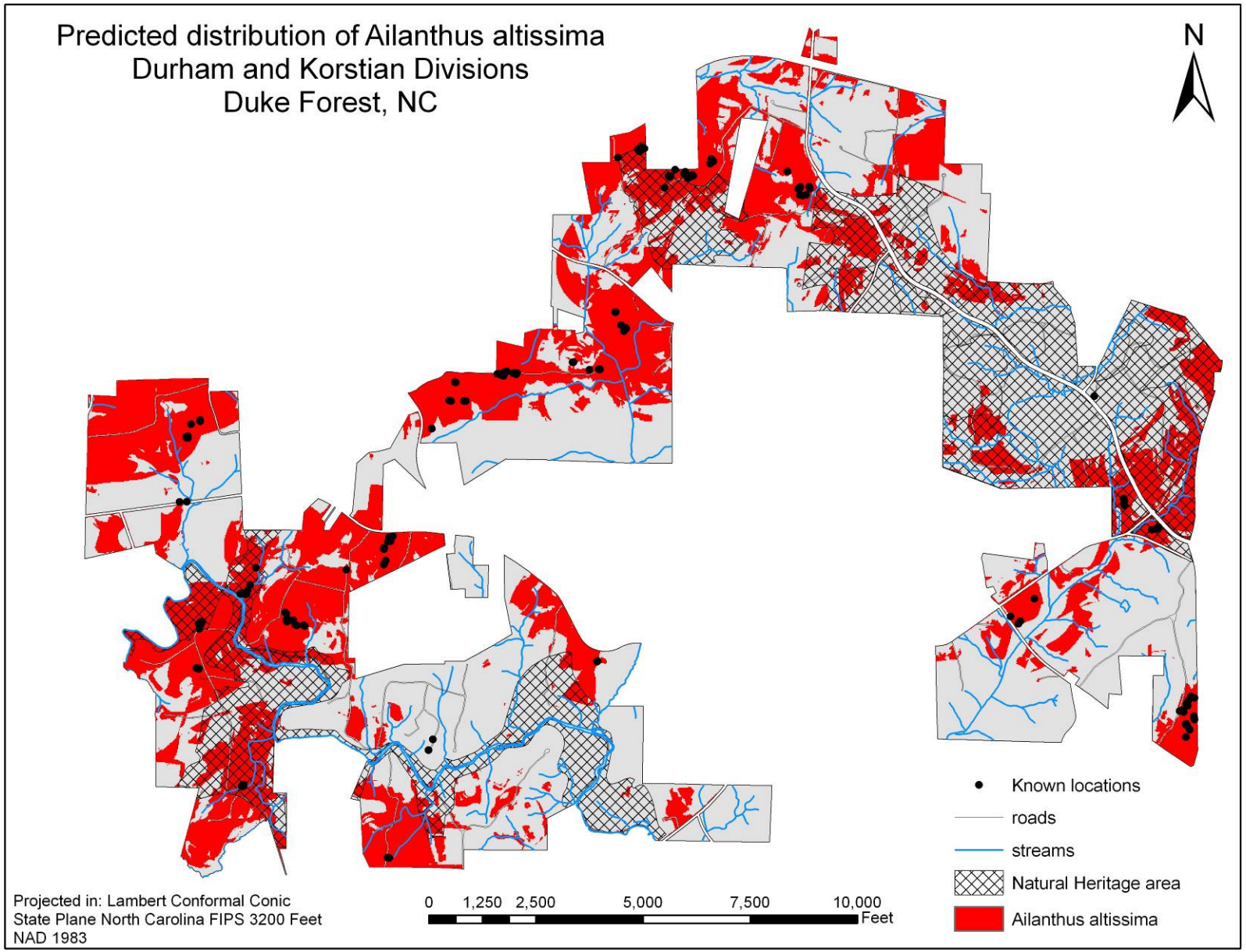
REFERENCES

IUCN Species Survival Commission, Invasive Species Specialist Group. 2005. *Spiraea japonica*. Global invasive species database. http://www.issg.org/database/species/ecology.asp?si=622&fr=1&sts=sss (accessed August 16, 2007).

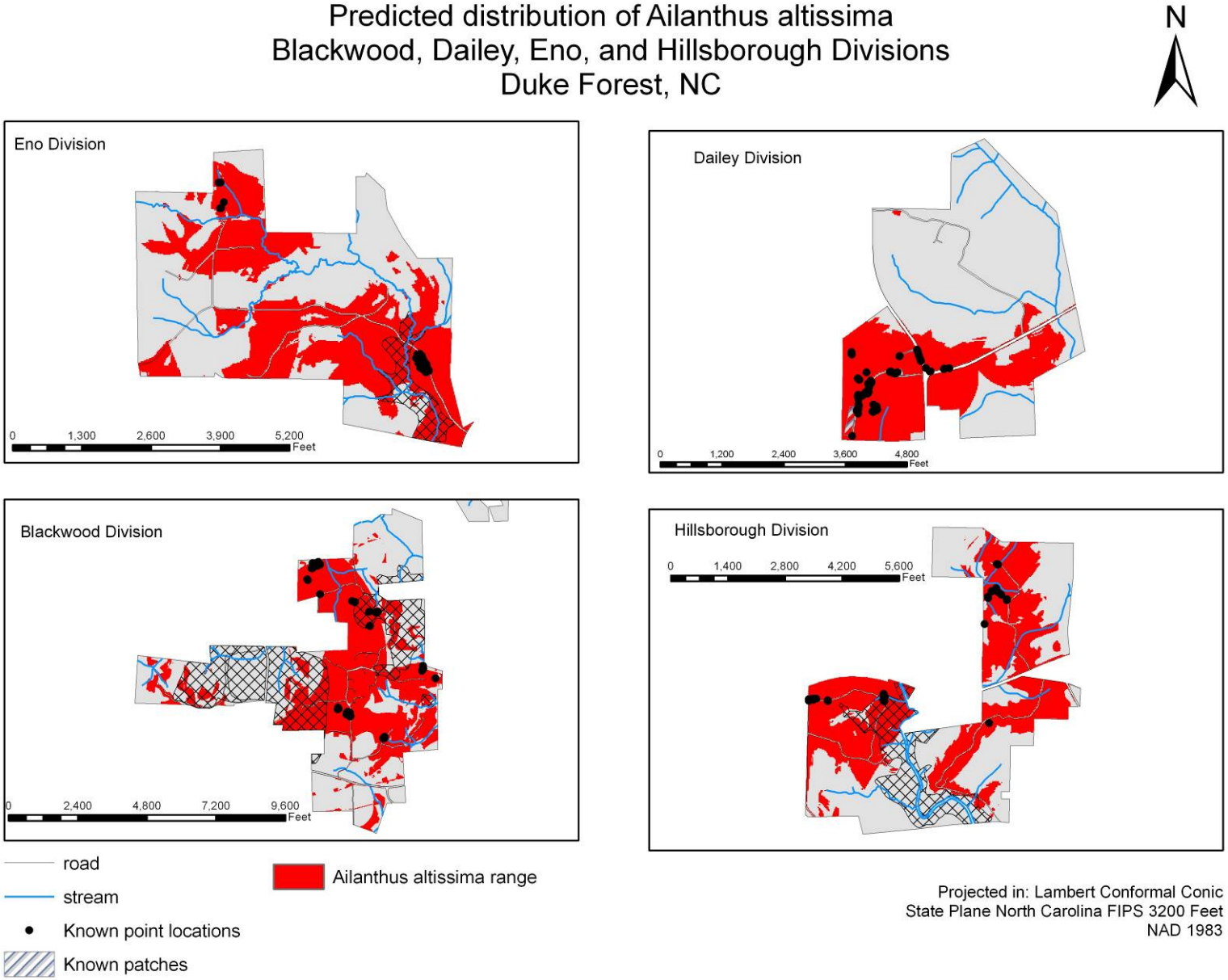
Kaufman, S. R., and W. Kaufman. 2007. Invasive Plants: A Guide to Identification and the Impacts and Control of Common North American Species. Stackpole Books, Mechanicsburg, PA.

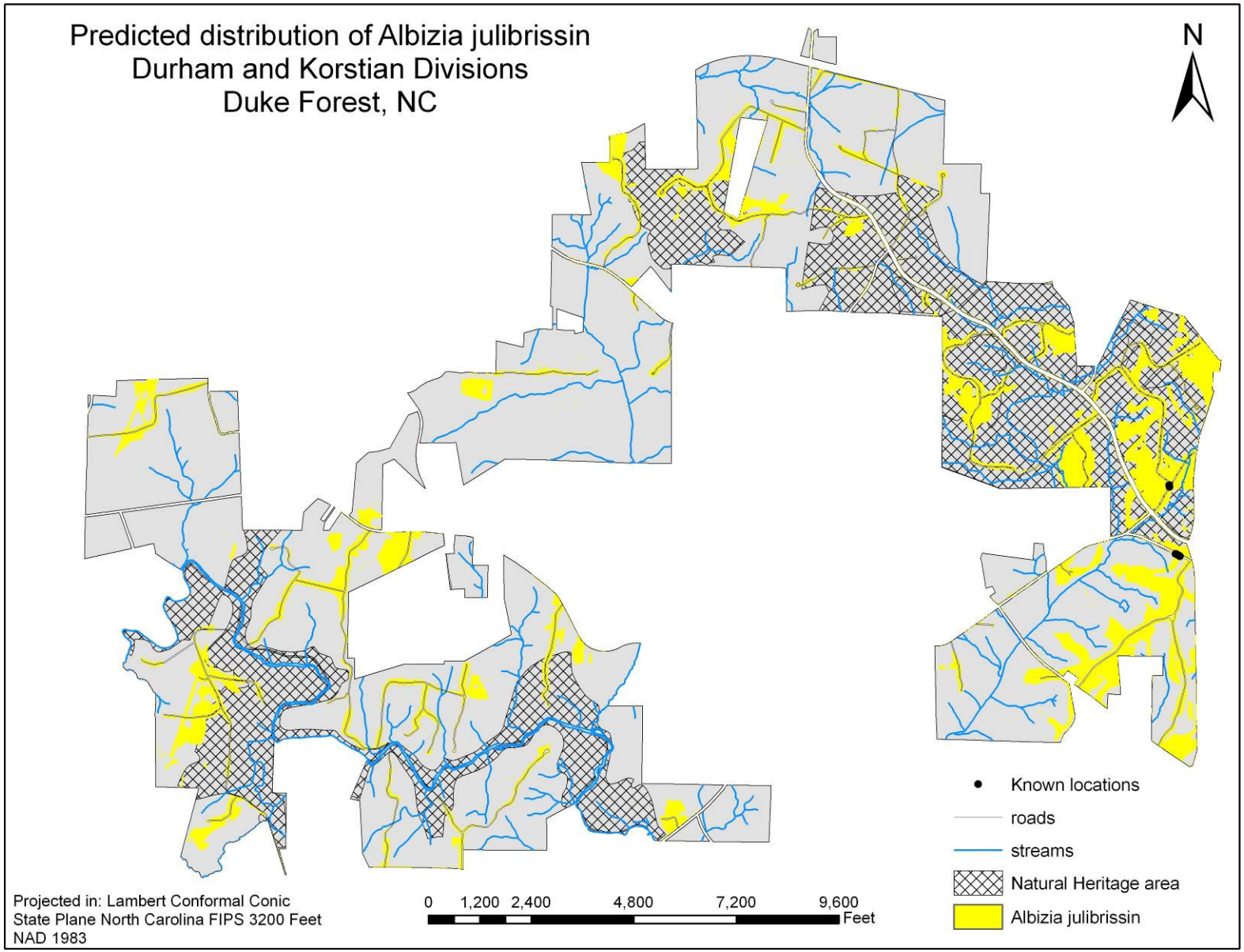
Remaley, T. 2005. Fact sheet: Japanese spiraea. Plant Conservation Alliance, Alien Plant Working Group. Available online: www.nps.gov/plants/alien/fact/spja1.htm (accessed June 22, 2007).

C. Maps of Predicted Distributions

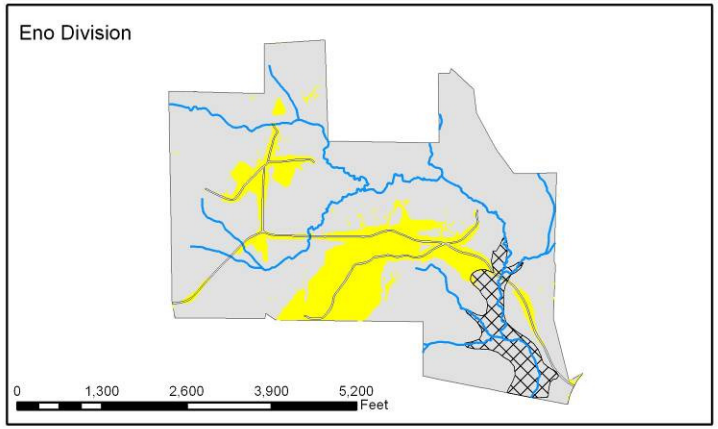

Predicted distribution of Ailanthus altissima
Durham and Korstian Divisions
Duke Forest, NC
N
Known locations
roads
streams
Natural Heritage area
Ailanthus altissima
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,250 2,500 5,000 7,500 10,000
Feet

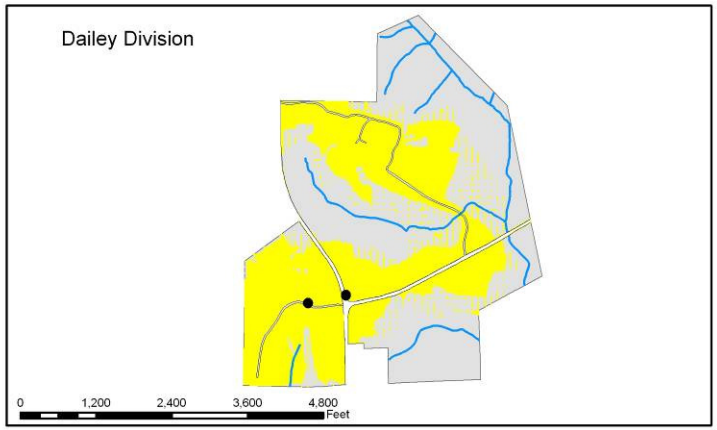
Predicted distribution of Ailanthus altissima
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC

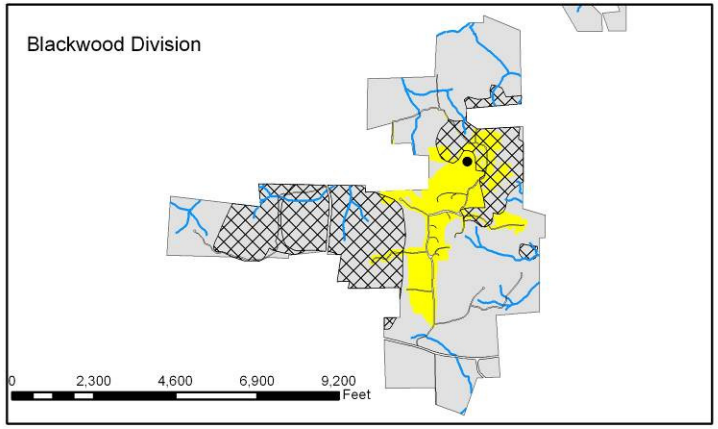


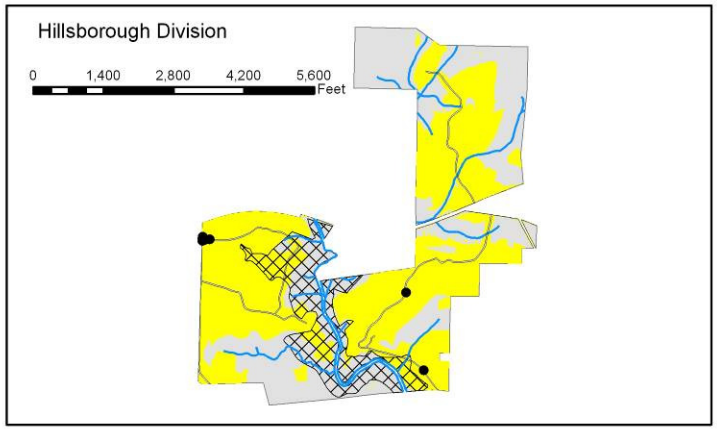

Predicted distribution of Albizia julibrissin
Durham and Korstian Divisions
Duke Forest, NC
N
Known locations
roads
streams
Natural Heritage area
Albizia julibrissin
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

Predicted distribution of Albizia julibrissin
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC



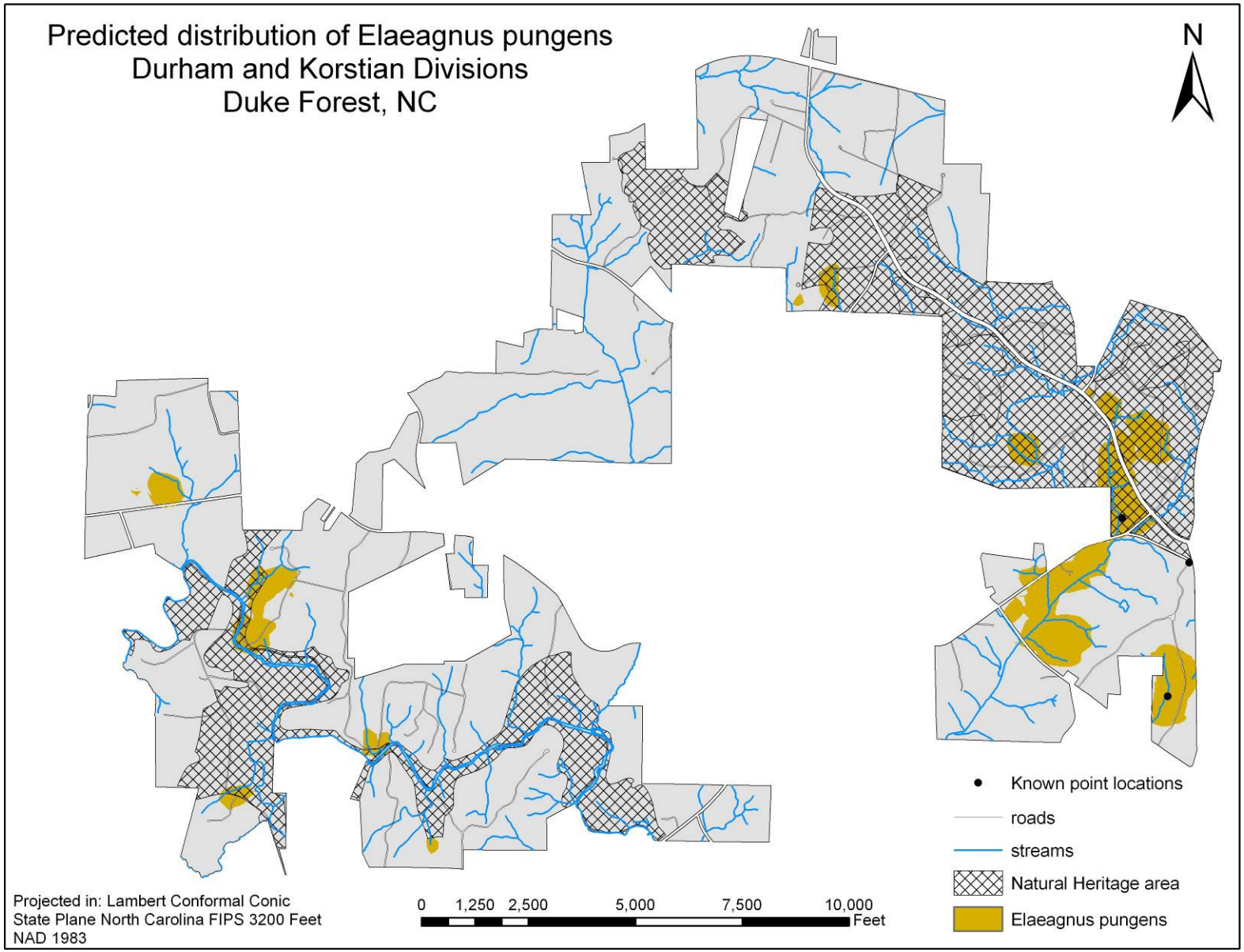




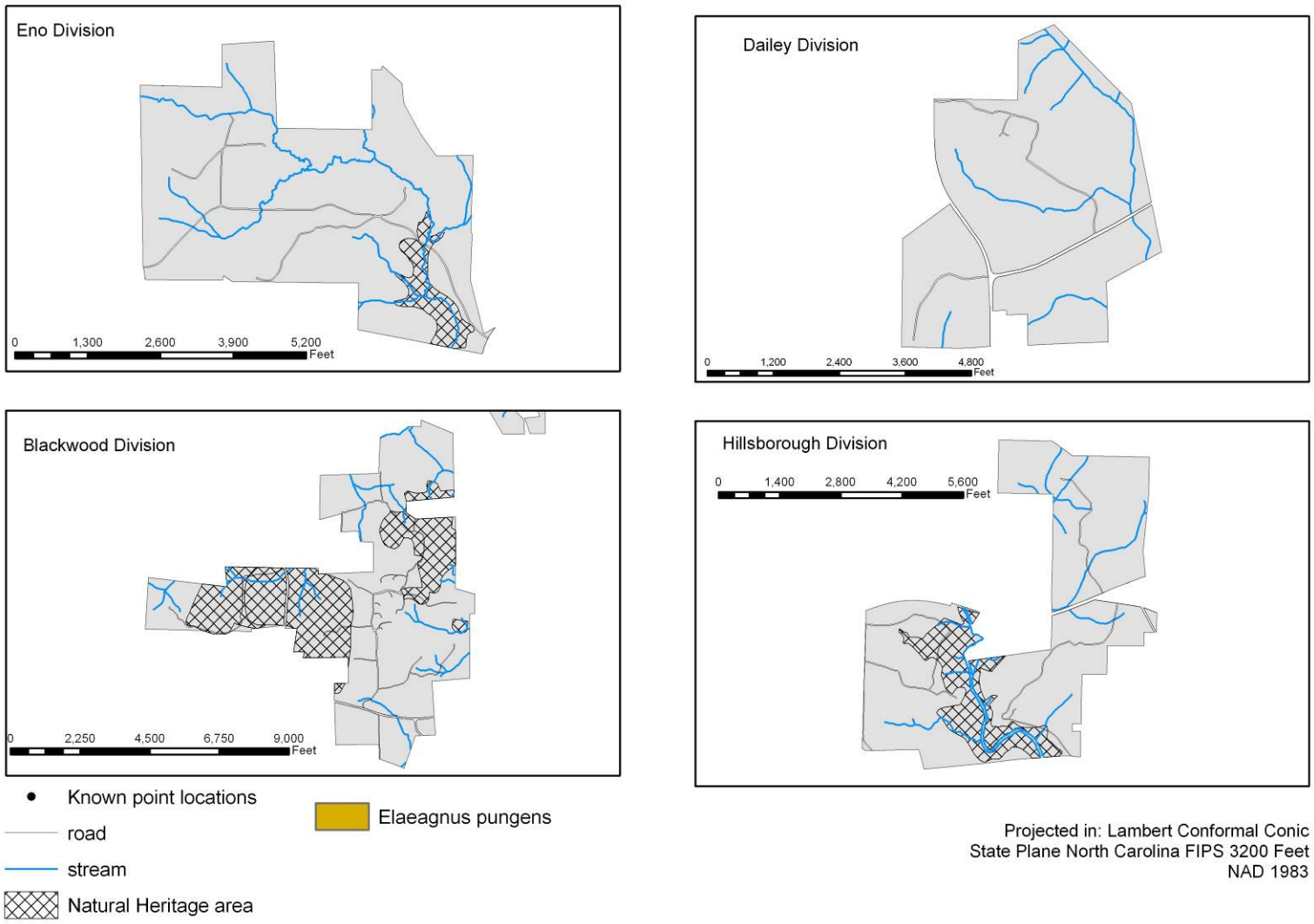


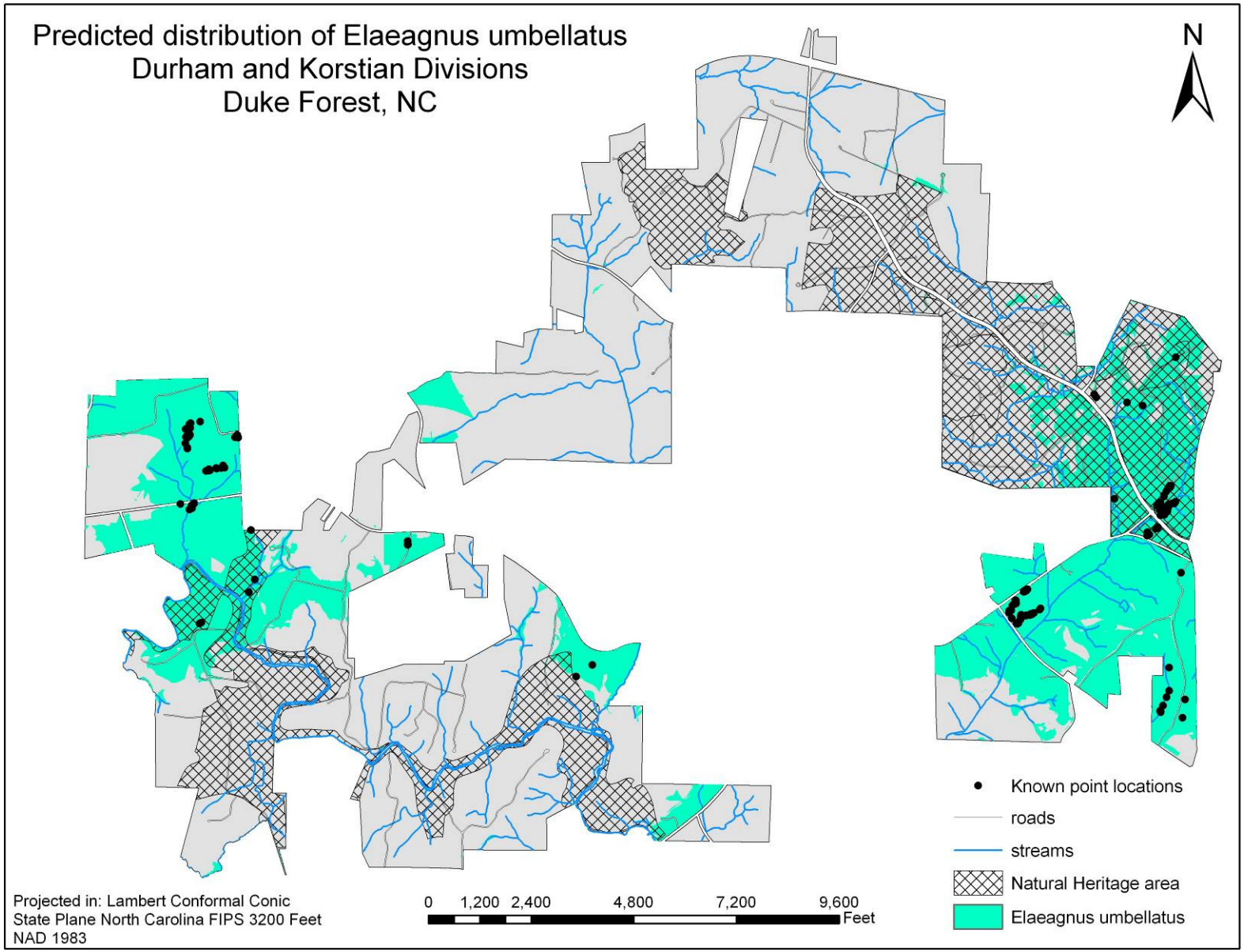
- Known point locations
- road
- stream
- Natural Heritage area
- Albizia julibrissin range

Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983

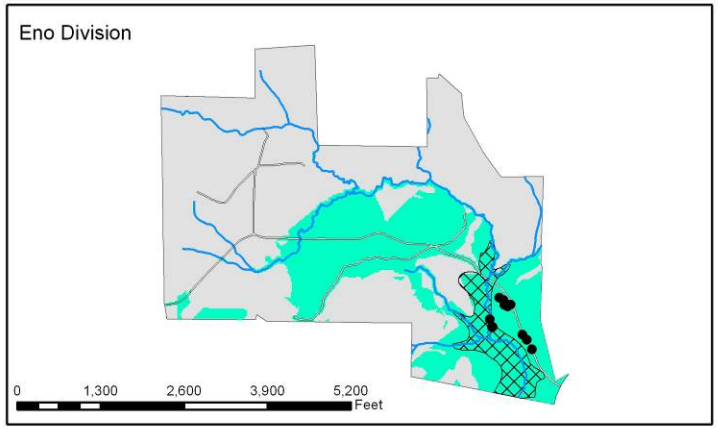

Predicted distribution of Elaeagnus pungens
Durham and Korstian Divisions
Duke Forest, NC
N
Known point locations
roads
streams
Natural Heritage area
Elaeagnus pungens
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,250 2,500 5,000 7,500 10,000
Feet

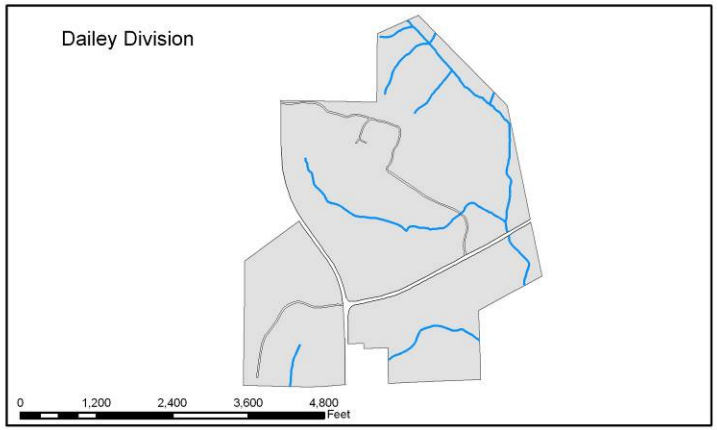
Predicted distribution of Elaeagnus pungens
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC

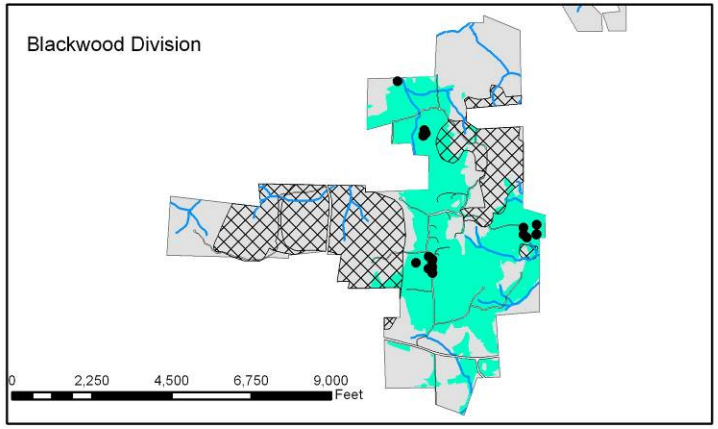


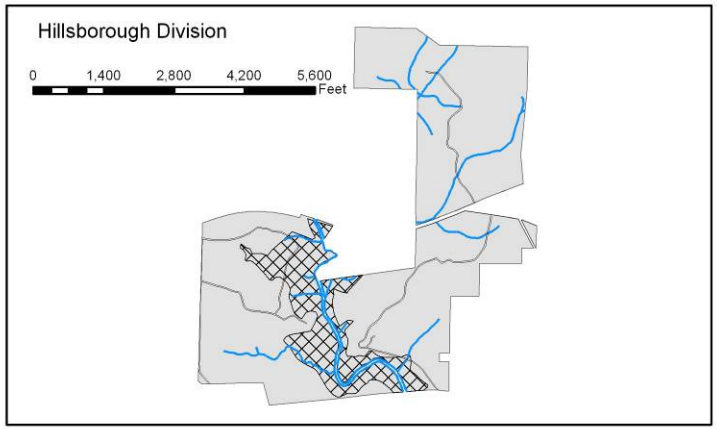

Predicted distribution of Elaeagnus umbellatus
Durham and Korstian Divisions
Duke Forest, NC
N
Known point locations
roads
streams
Natural Heritage area
Elaeagnus umbellatus
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

Predicted distribution of Elaeagnus umbellatus
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC









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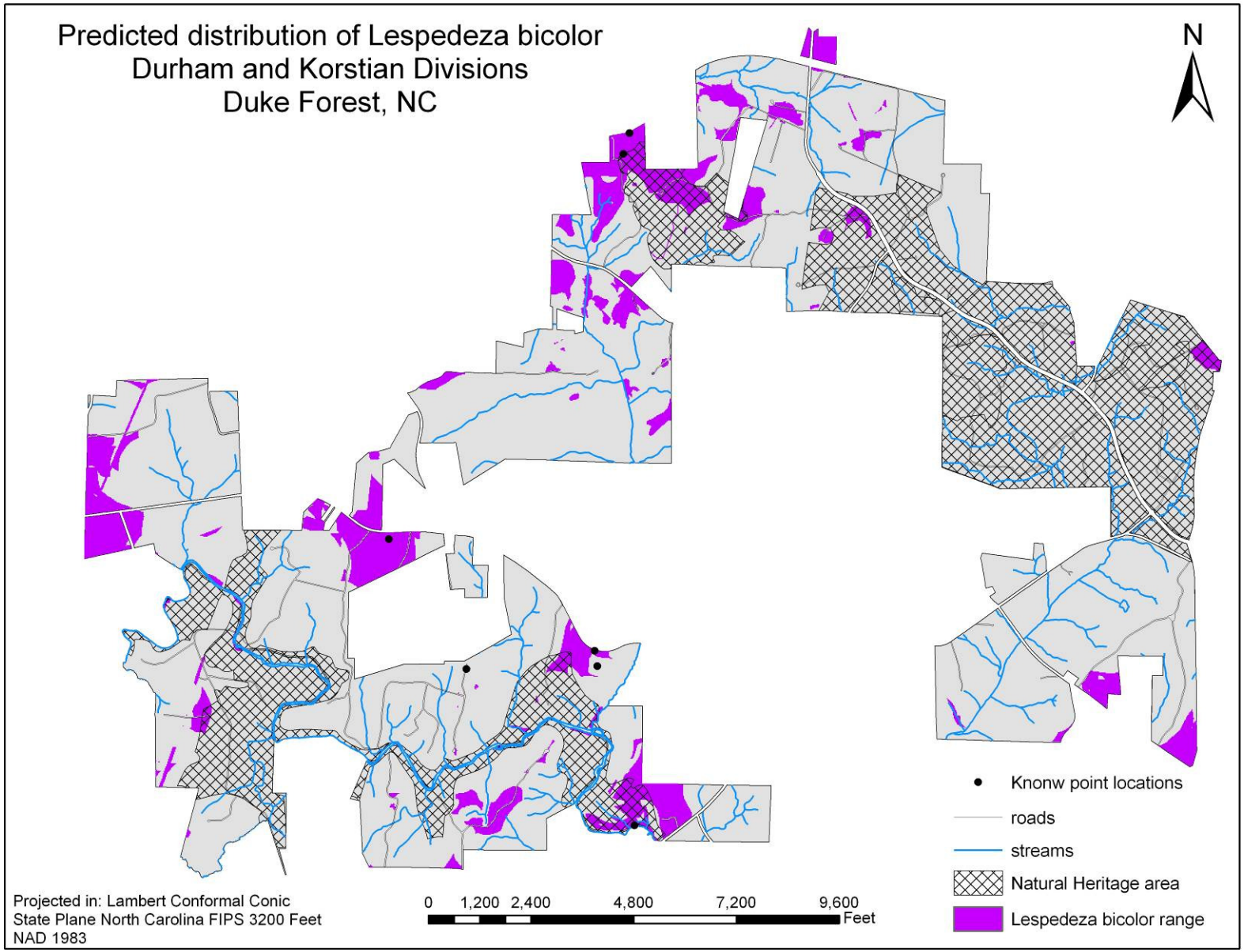
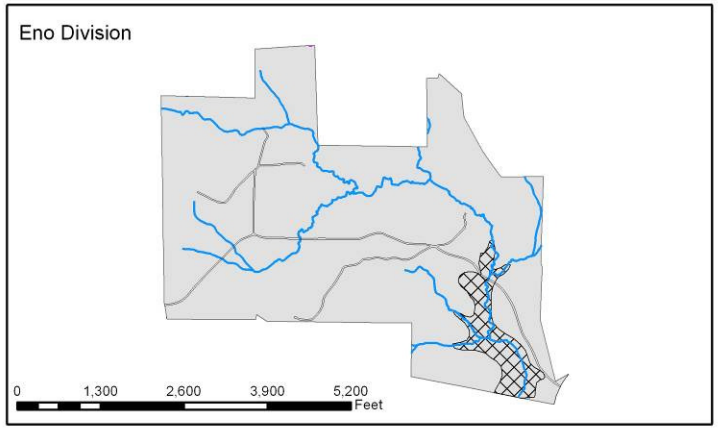
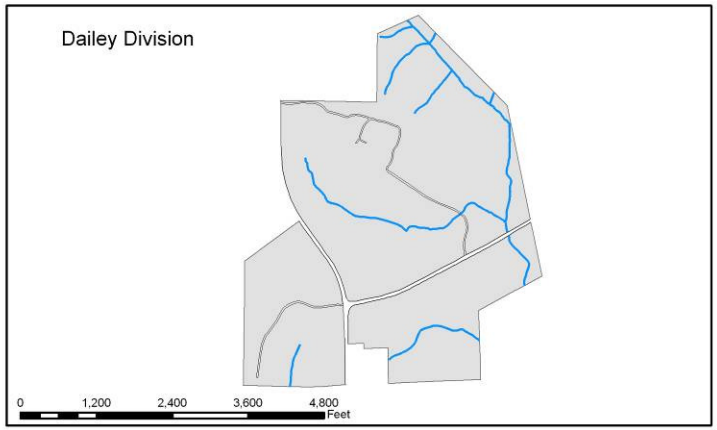
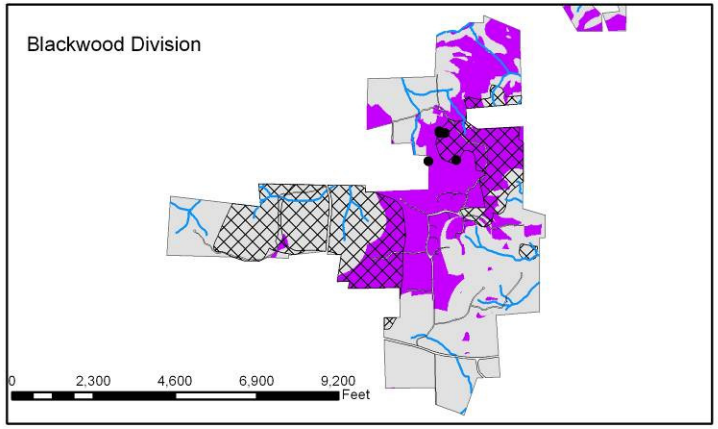
State Plane North Carolina FIPS 3200 Feet
NAD 1983

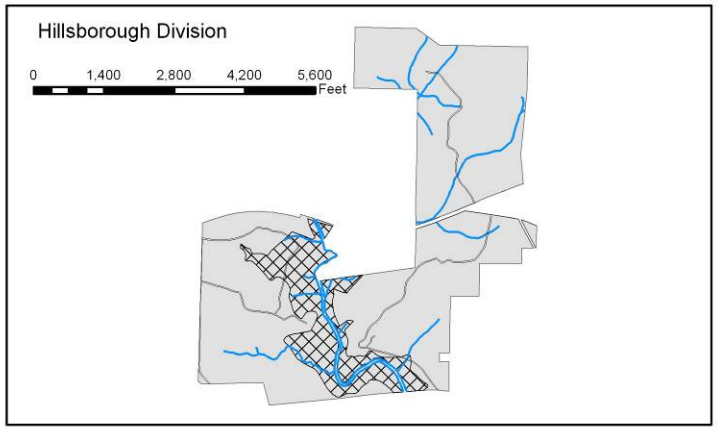

Predicted distribution of Lespedeza bicolor
Durham and Korstian Divisions
Duke Forest, NC
N
Knonw point locations
roads
streams
Natural Heritage area
Lespedeza bicolor range
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

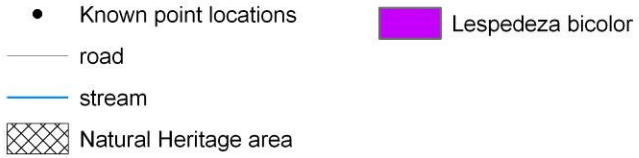
Predicted distribution of Lespedeza bicolor
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC



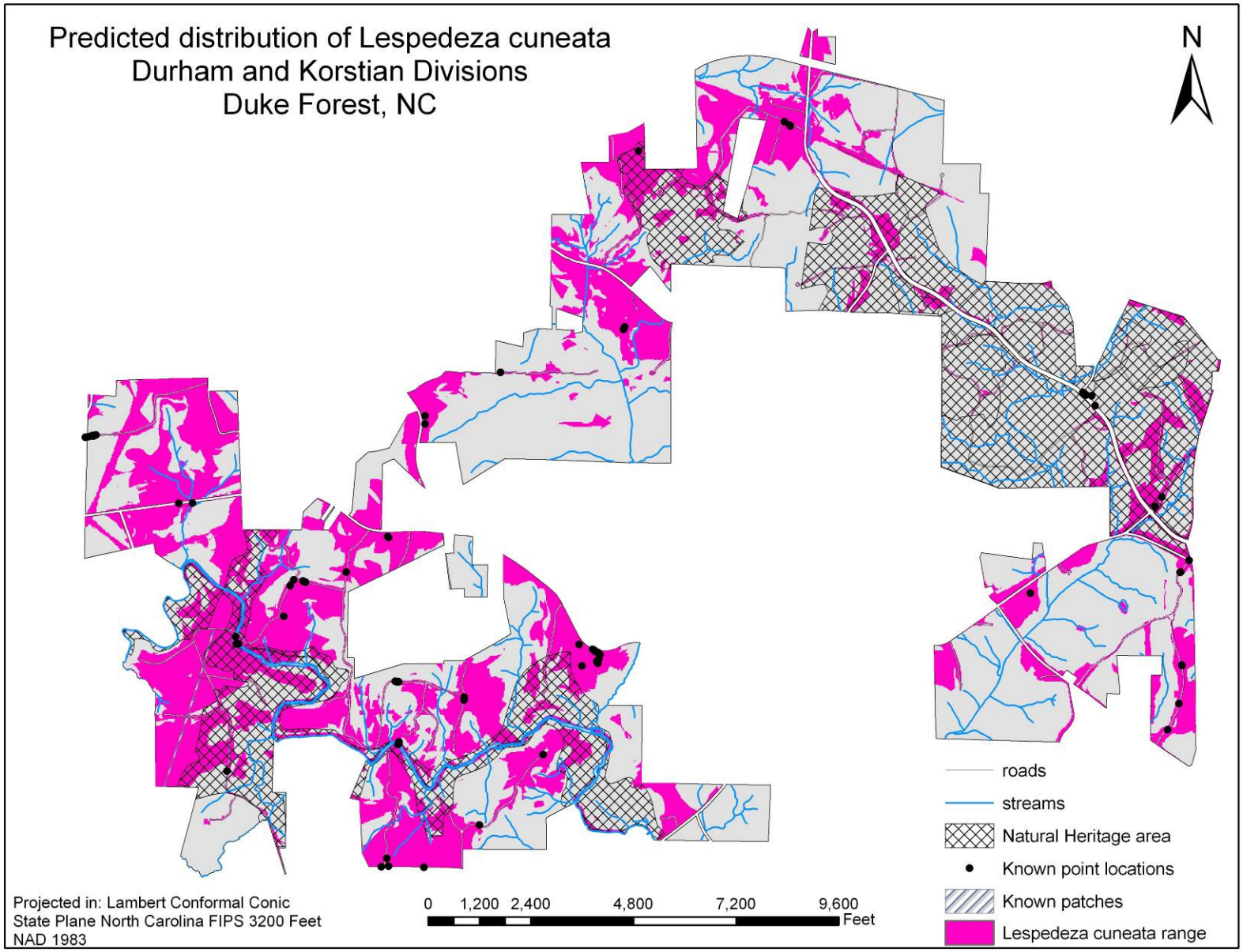




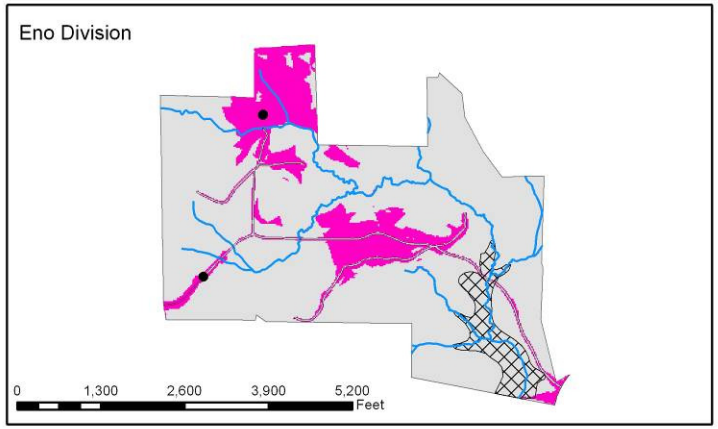


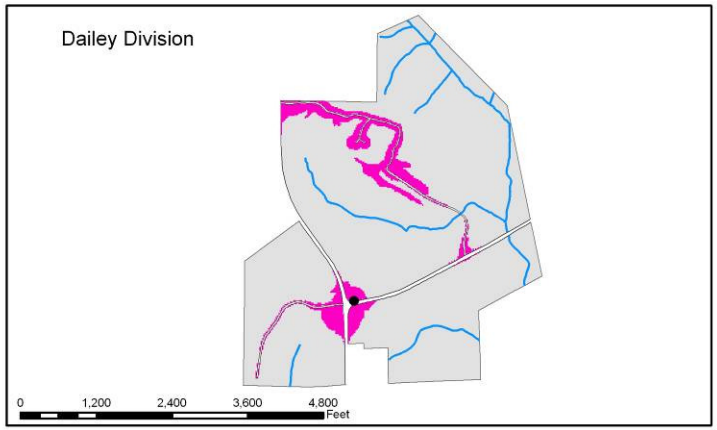


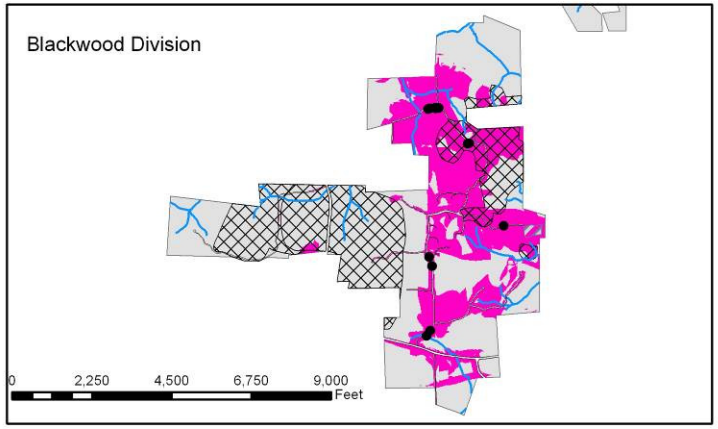
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983

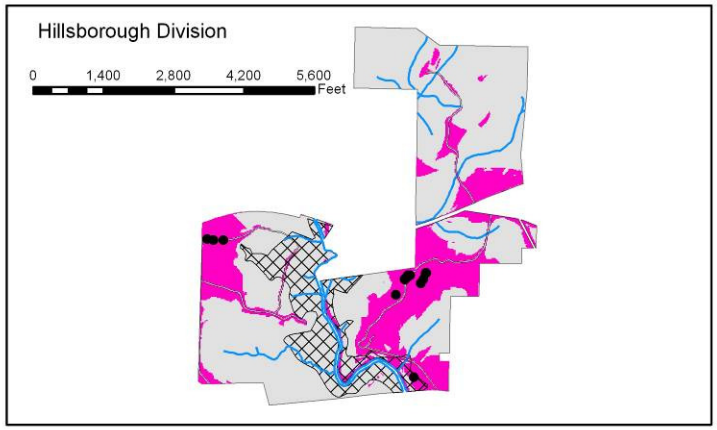

Predicted distribution of Lespedeza cuneata
Durham and Korstian Divisions
Duke Forest, NC
N
roads
streams
Natural Heritage area
Known point locations
Known patches
Lespedeza cuneata range
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

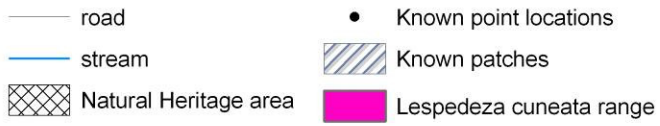
Predicted distribution of Lespedeza cuneata
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC



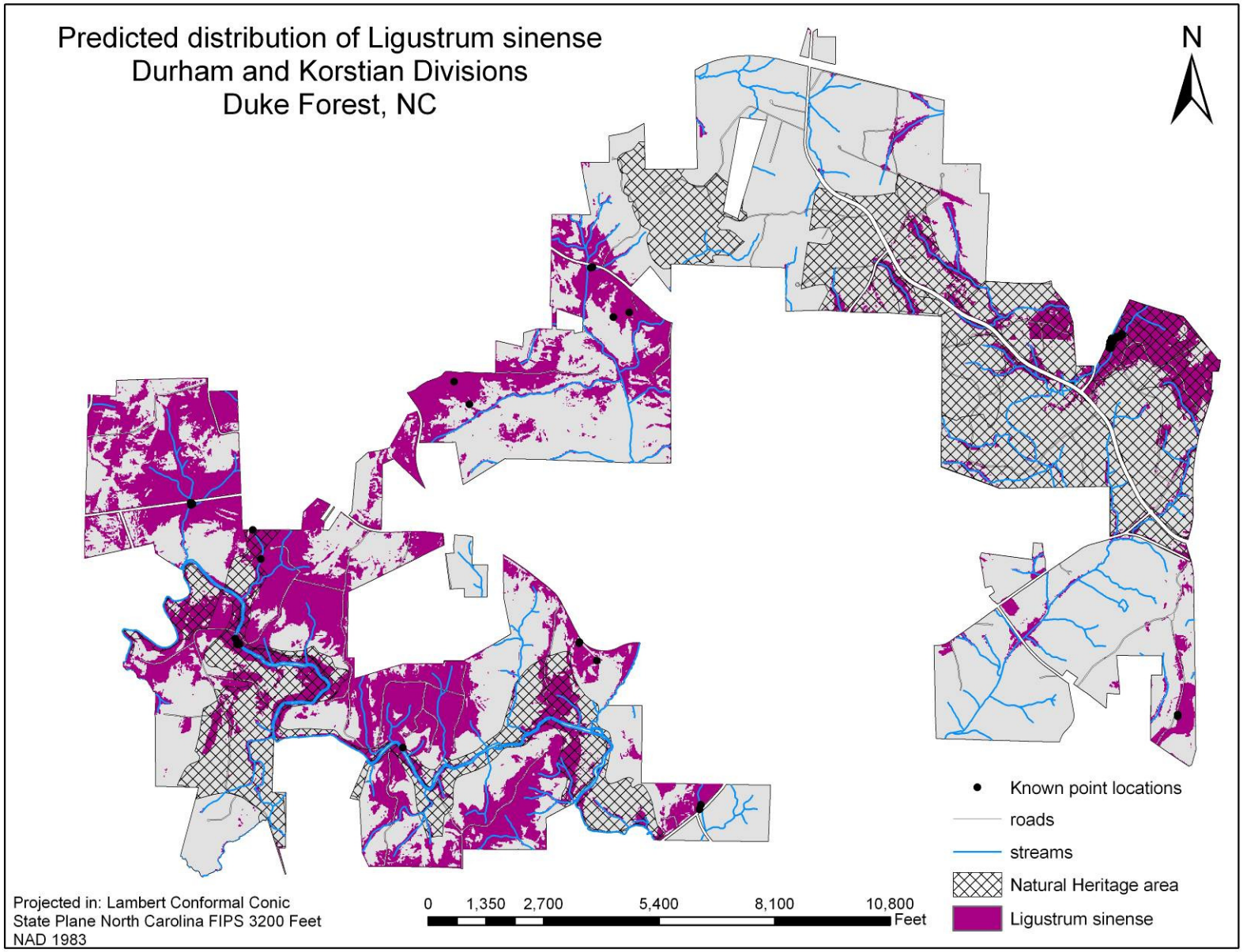




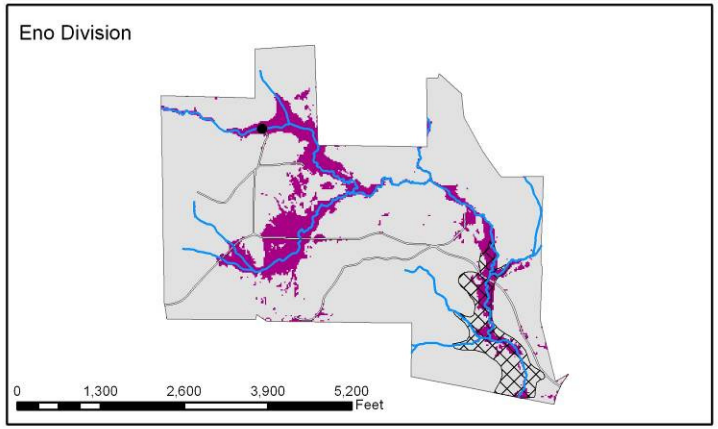


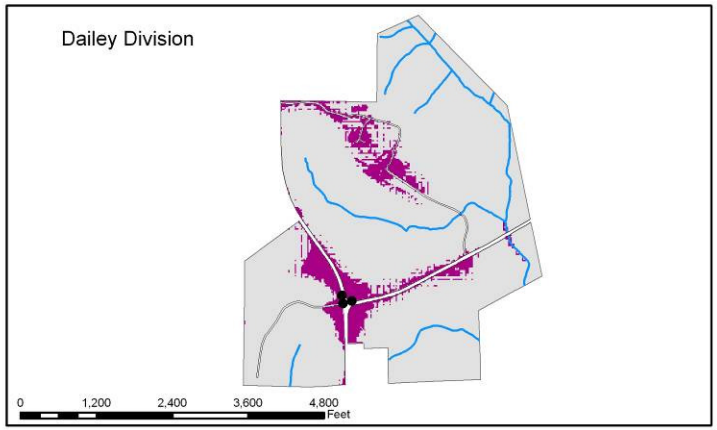


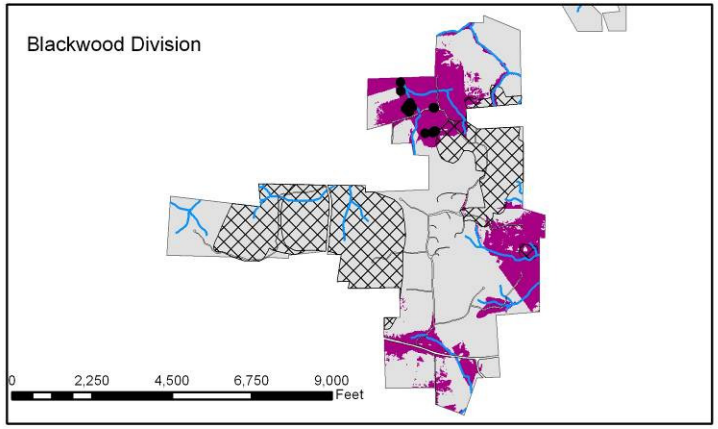
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983

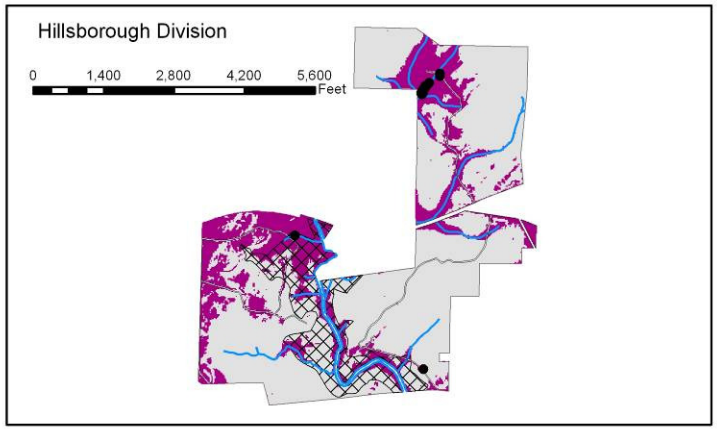

Predicted distribution of Ligustrum sinense
Durham and Korstian Divisions
Duke Forest, NC
N
Known point locations
roads
streams
Natural Heritage area
Ligustrum sinense
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,350 2,700 5,400 8,100 10,800
Feet

Predicted distribution of Ligustrum sinense
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC



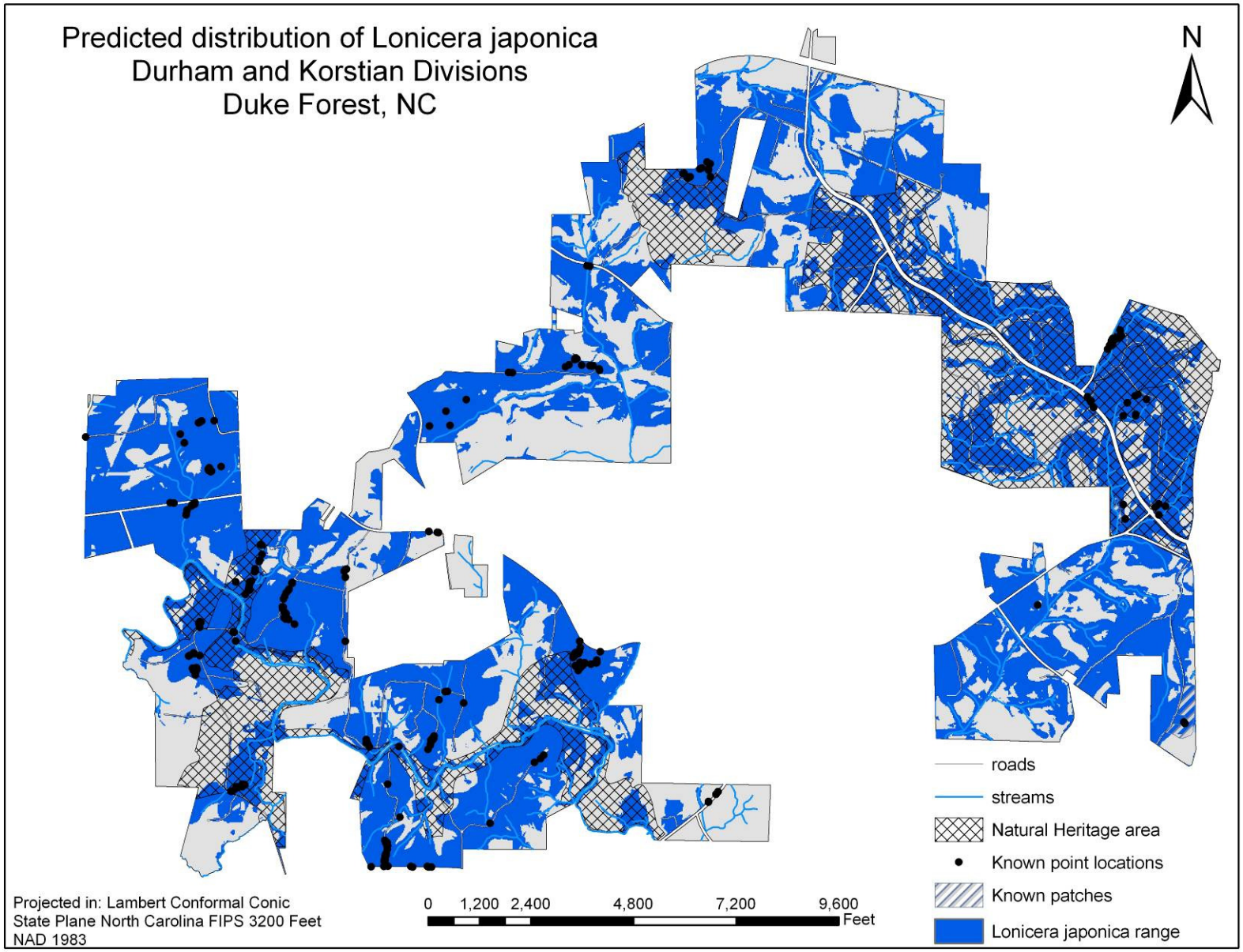




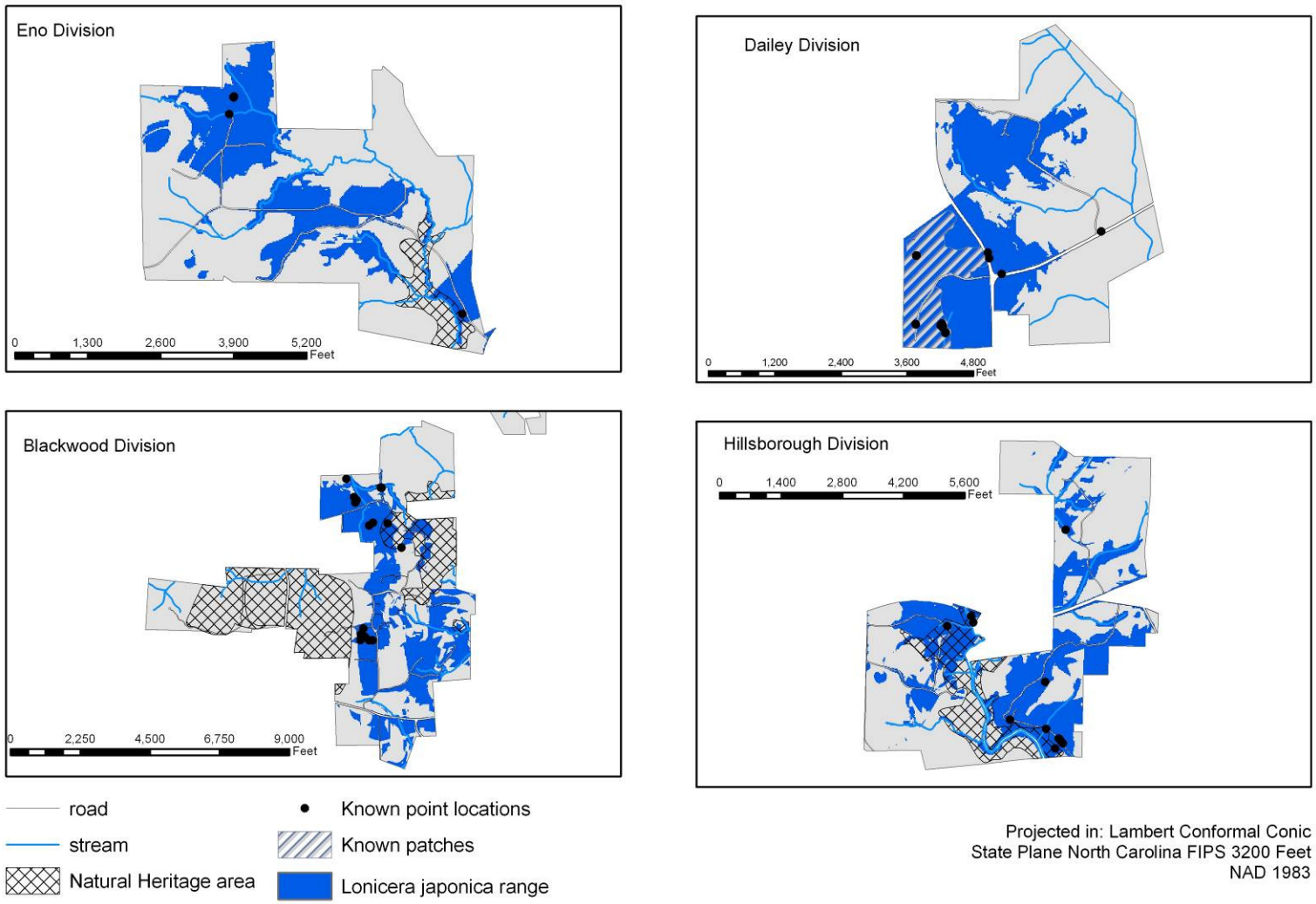


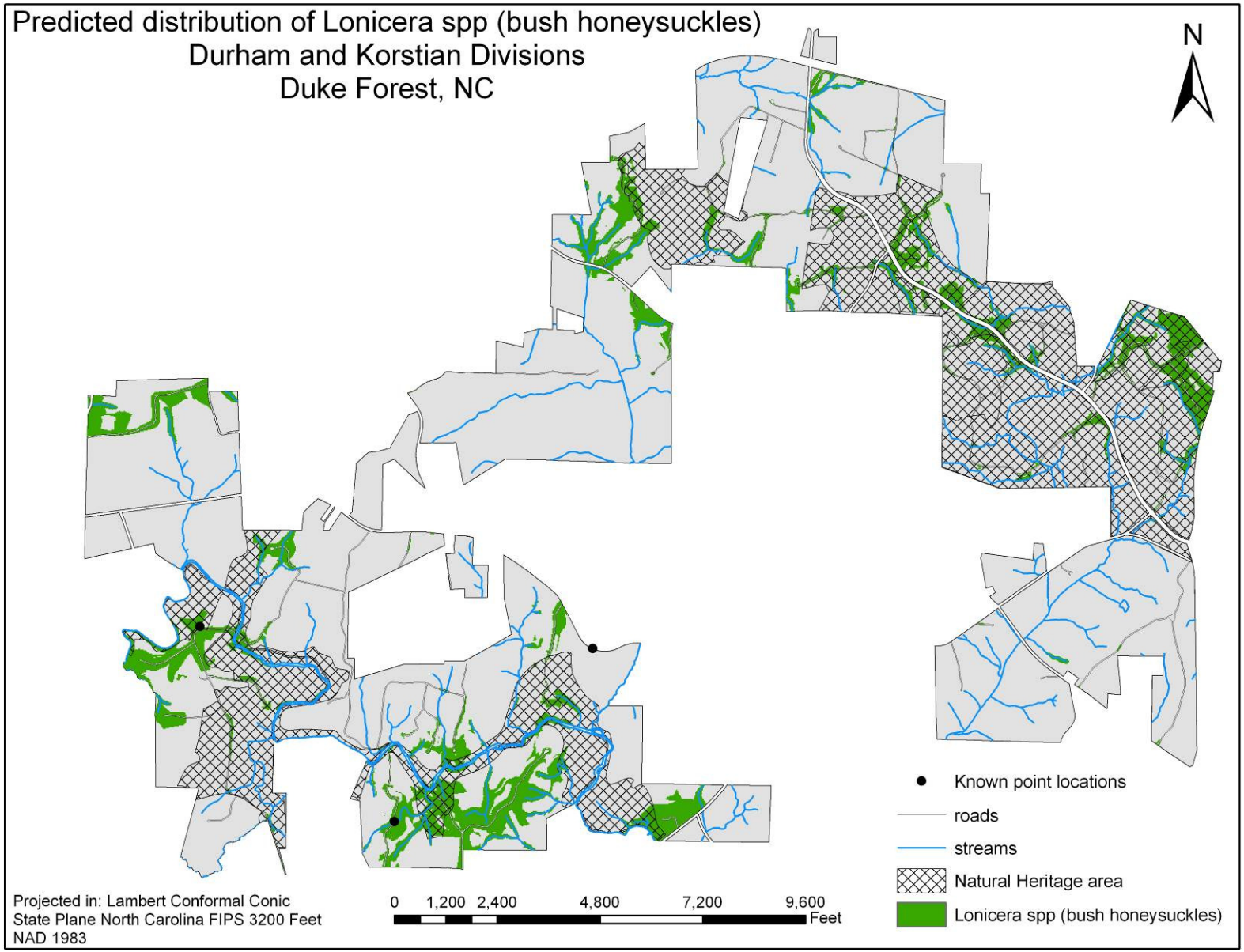
- Known point locations
- road
- stream
- Natural Heritage area
- Ligustrum sinense

Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983

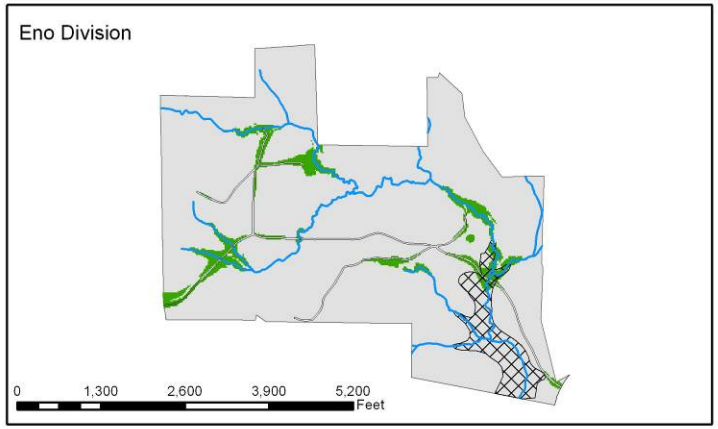

Predicted distribution of Lonicera japonica
Durham and Korstian Divisions
Duke Forest, NC
N
roads
streams
Natural Heritage area
Known point locations
Known patches
Lonicera japonica range
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

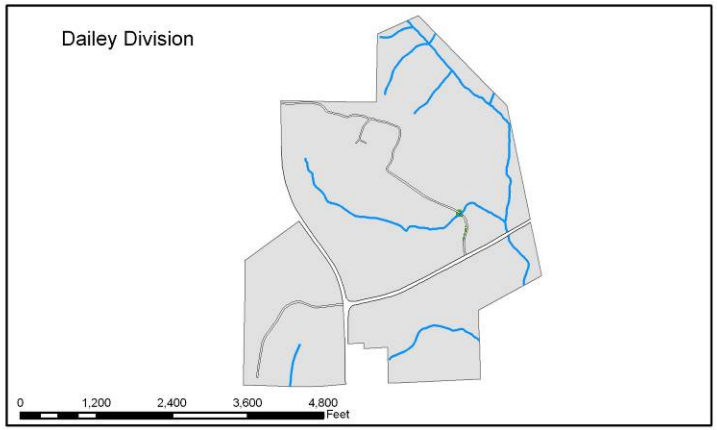
Predicted distribution of Lonicera japonica
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC

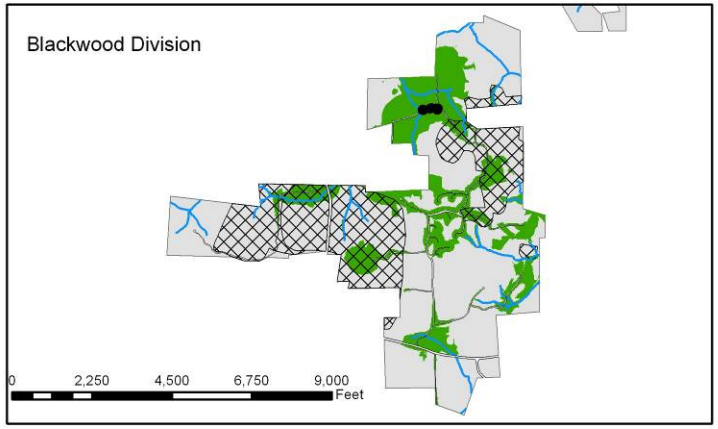


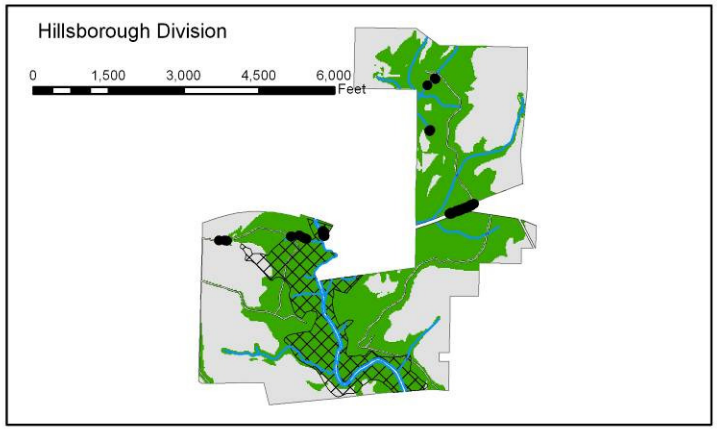

Predicted distribution of Lonicera spp (bush honeysuckles)
Durham and Korstian Divisions
Duke Forest, NC
N
Known point locations
roads
streams
Natural Heritage area
Lonicera spp (bush honeysuckles)
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

Predicted distribution of Lonicera spp. (bush honeysuckles)
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC

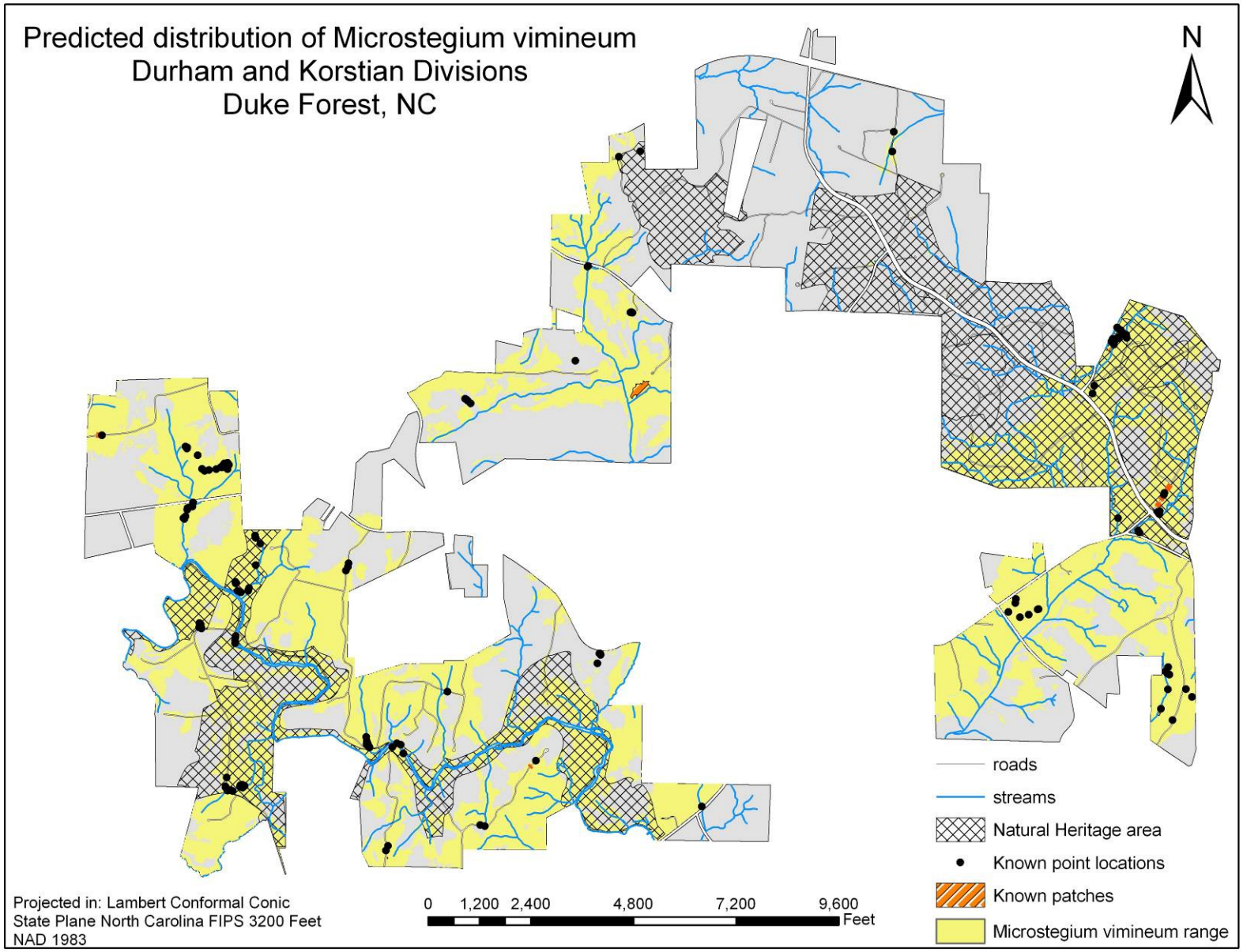




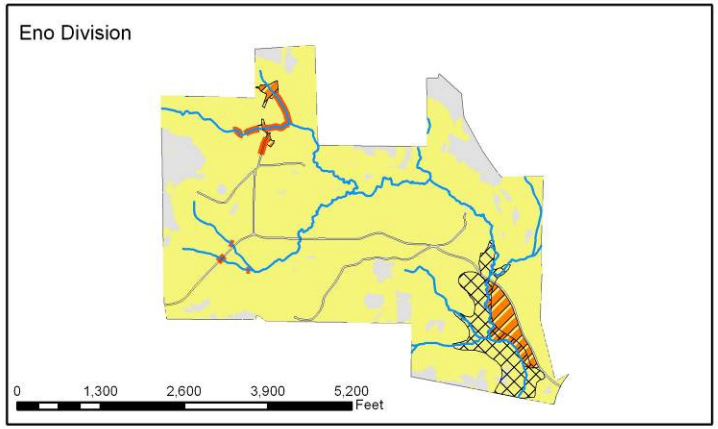


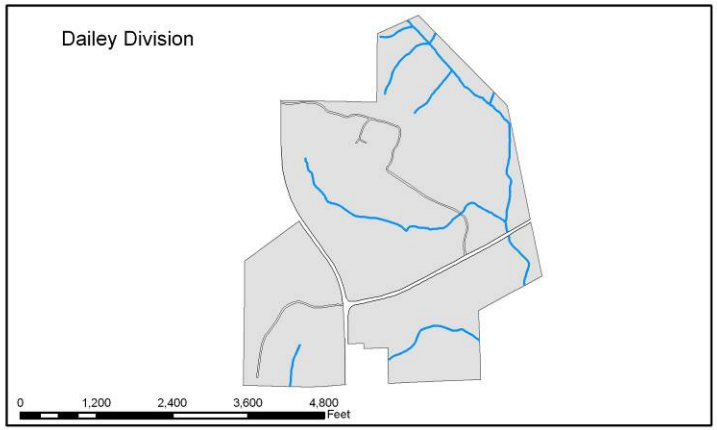


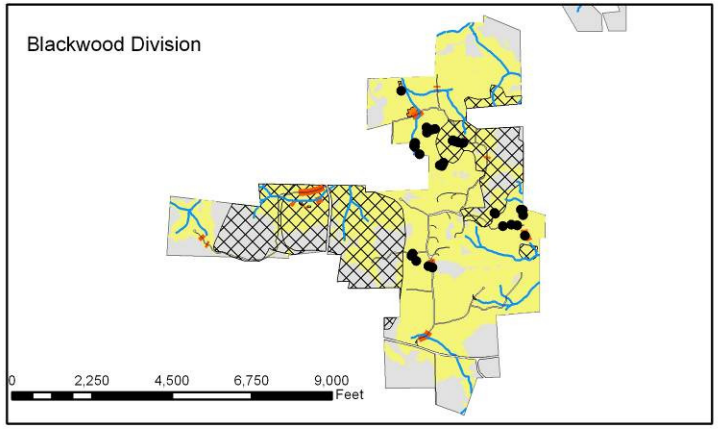
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983

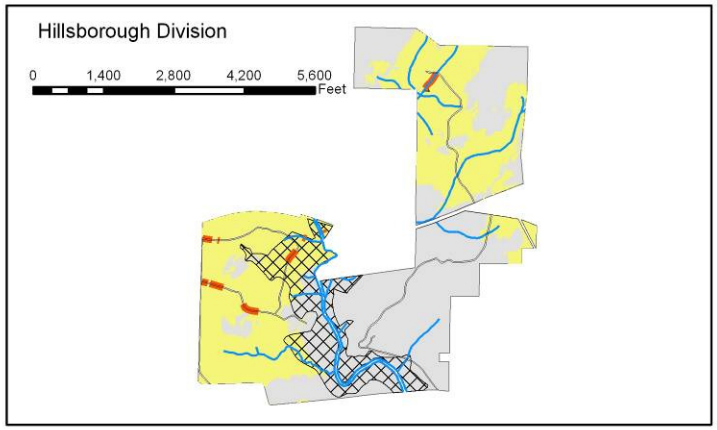

Predicted distribution of Microstegium vimineum
Durham and Korstian Divisions
Duke Forest, NC
N
roads
streams
Natural Heritage area
Known point locations
Known patches
Microstegium vimineum range
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

Predicted distribution of Microstegium vimineum
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC



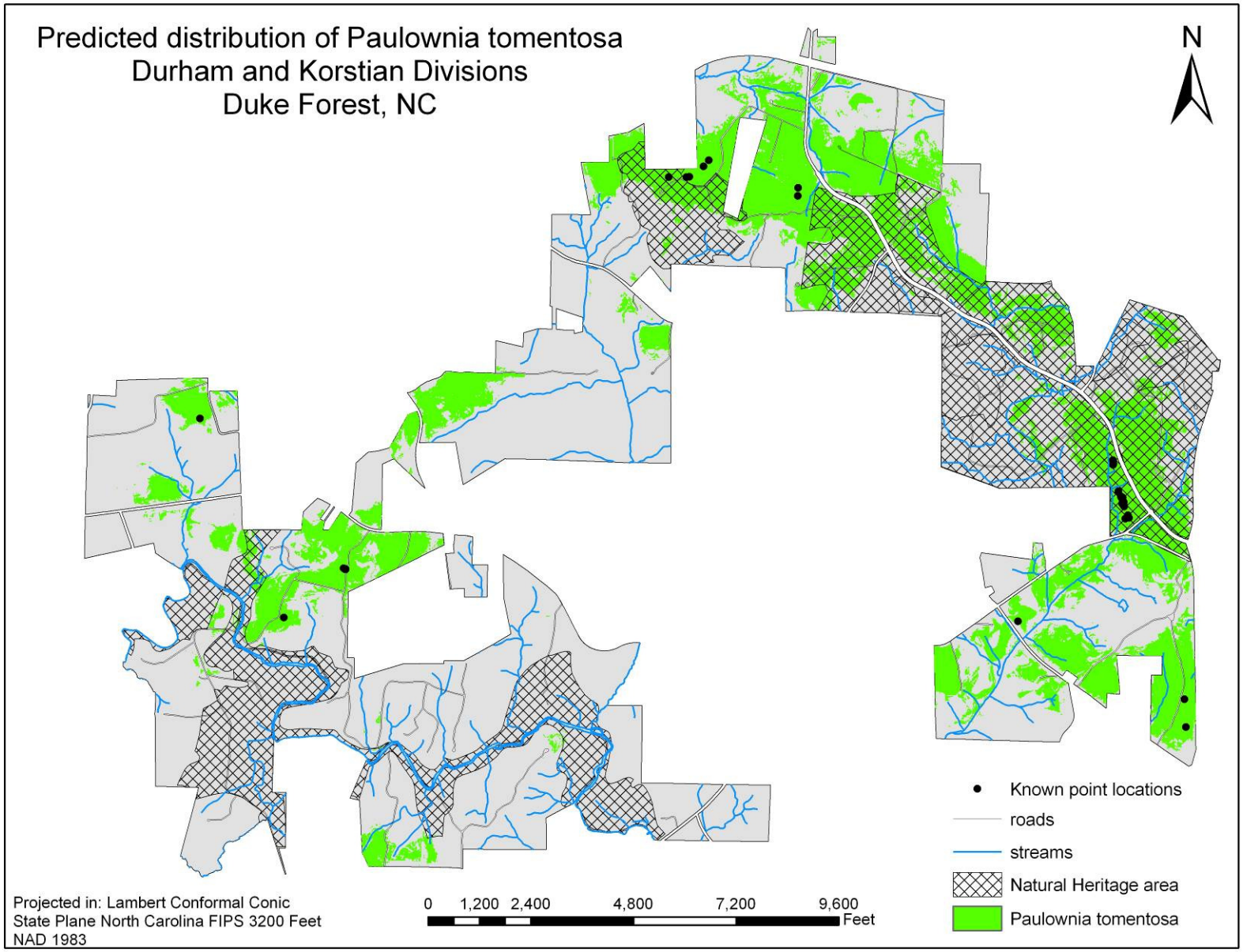




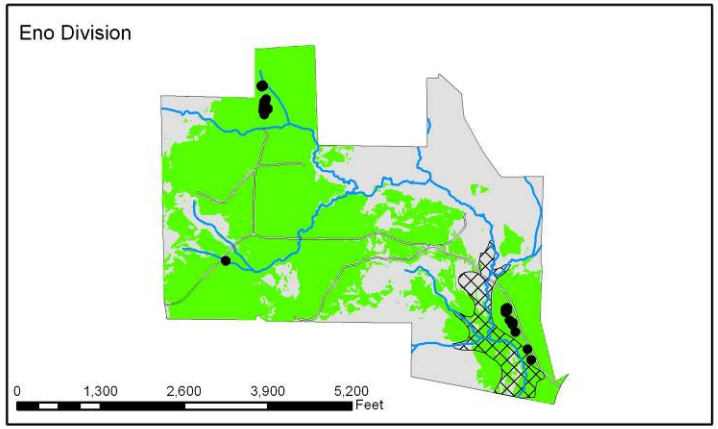


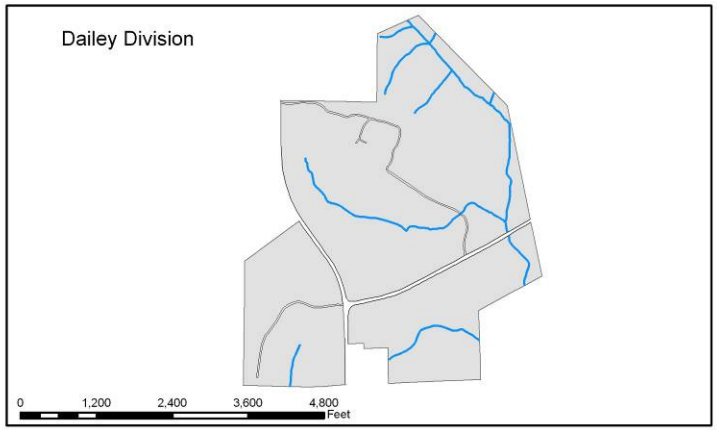
road
stream
Natural Heritage area
Known point locations
Known patches
Microstegium vimineum range

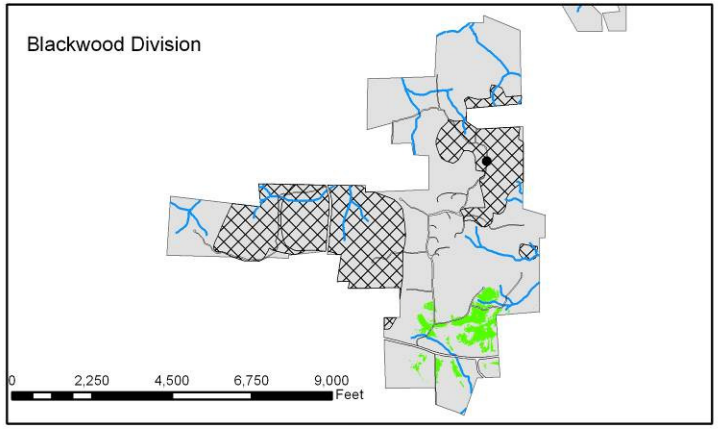
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983

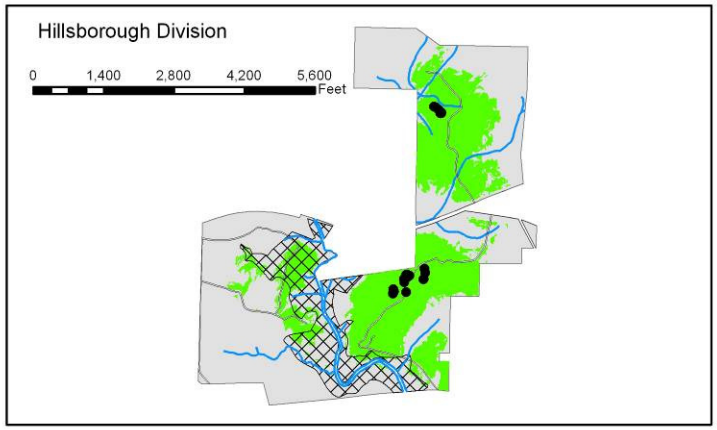

Predicted distribution of Paulownia tomentosa
Durham and Korstian Divisions
Duke Forest, NC
N
Known point locations
roads
streams
Natural Heritage area
Paulownia tomentosa
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

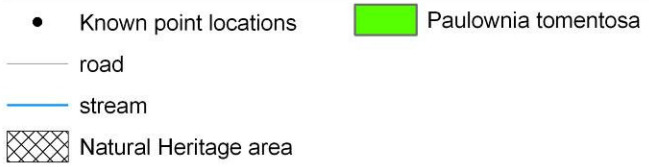
Predicted distribution of Paulownia tomentosa
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC



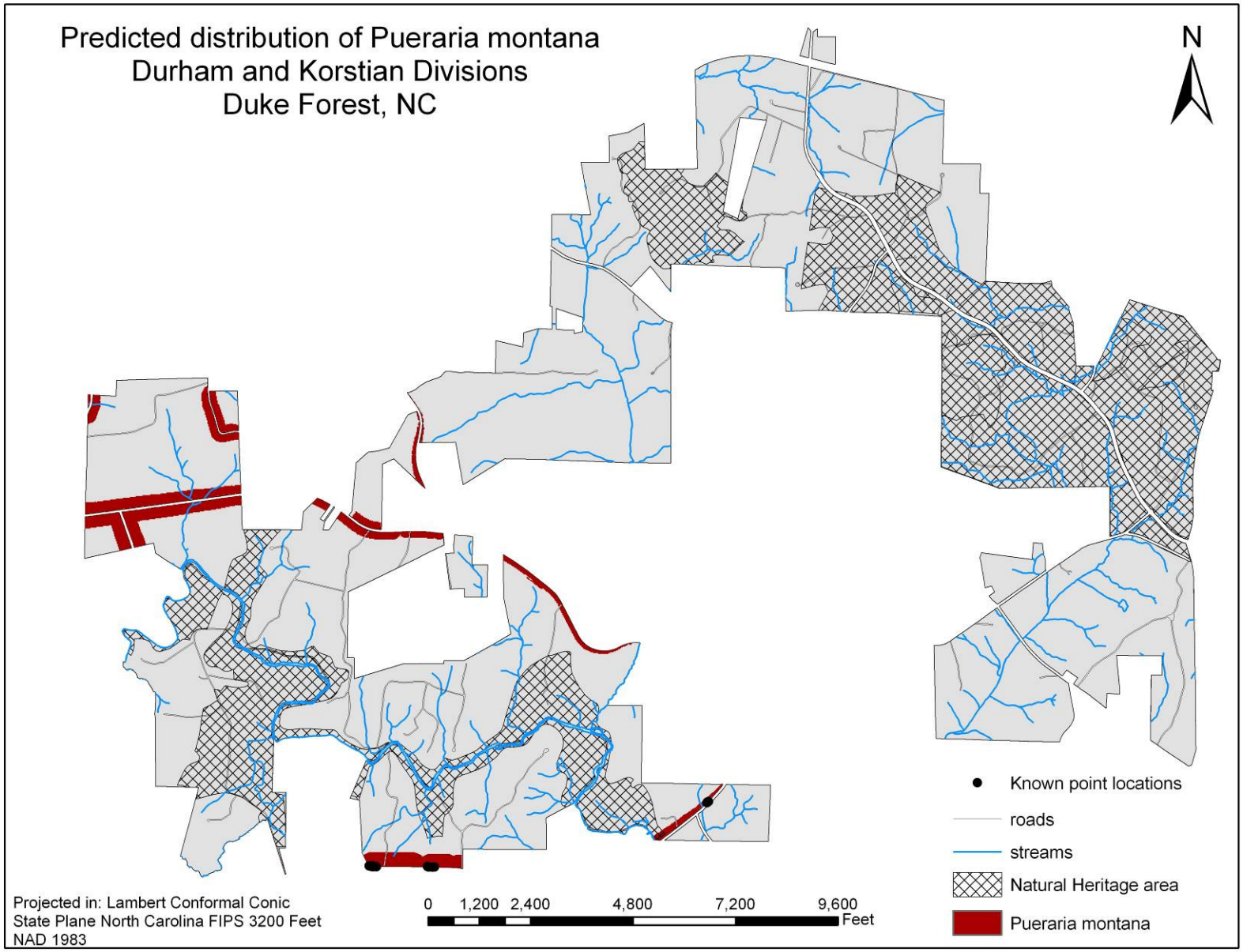




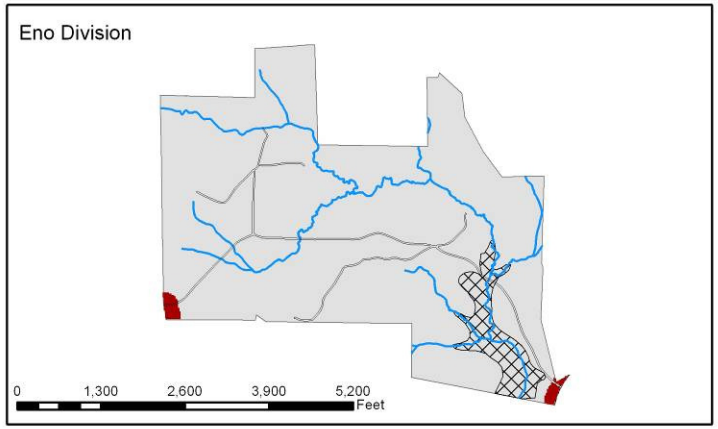


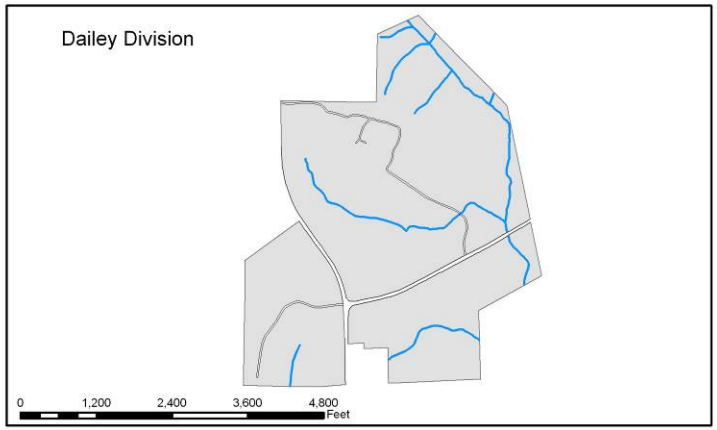


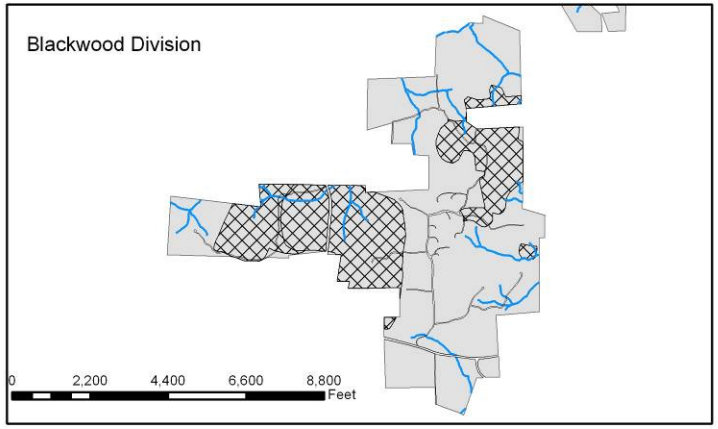
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983

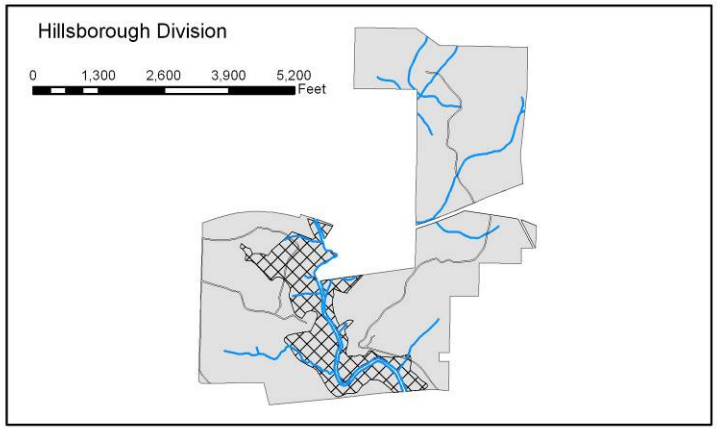

Predicted distribution of Pueraria montana
Durham and Korstian Divisions
Duke Forest, NC
N
Known point locations
roads
streams
Natural Heritage area
Pueraria montana
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

Predicted distribution of Pueraria montana
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC









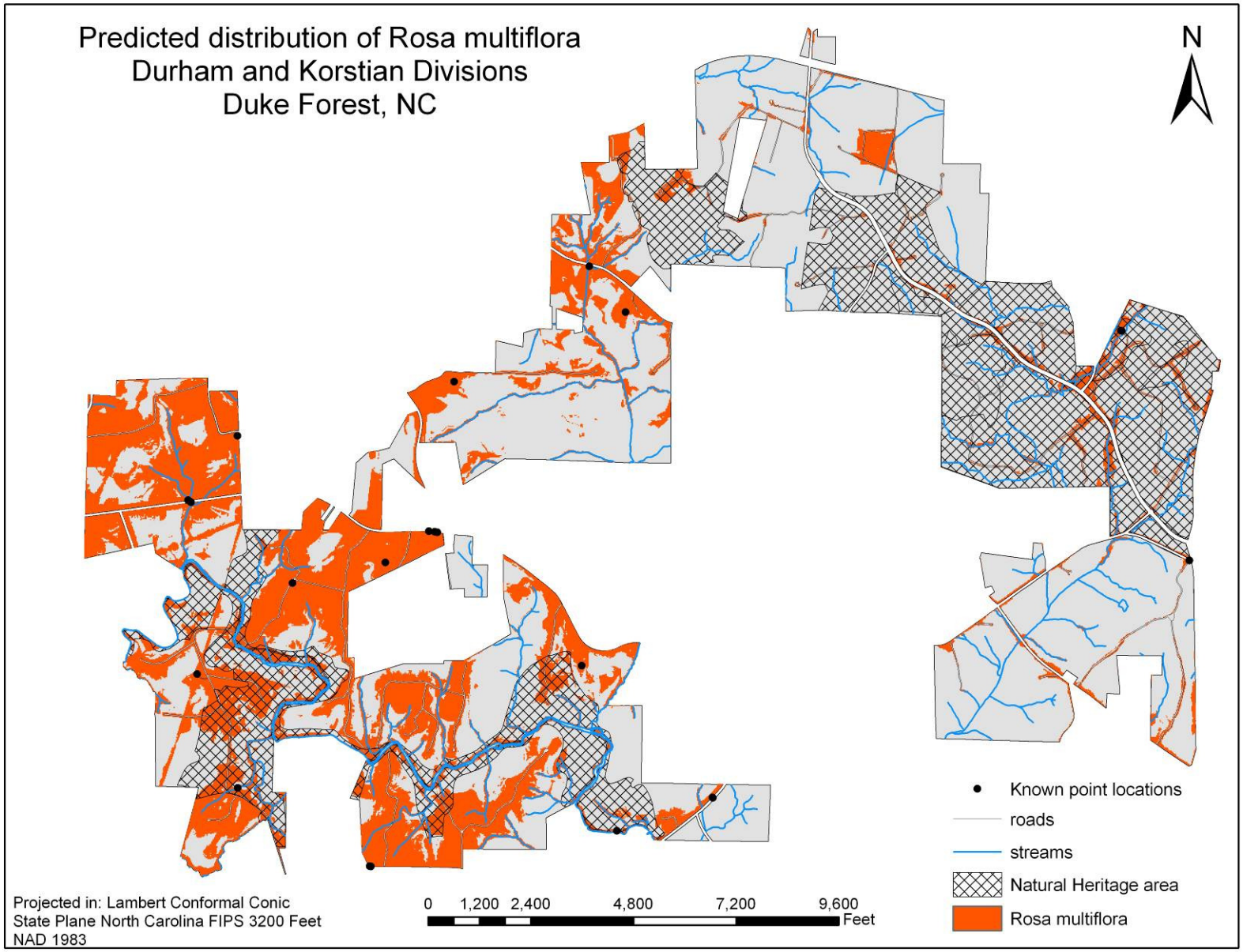
road

stream

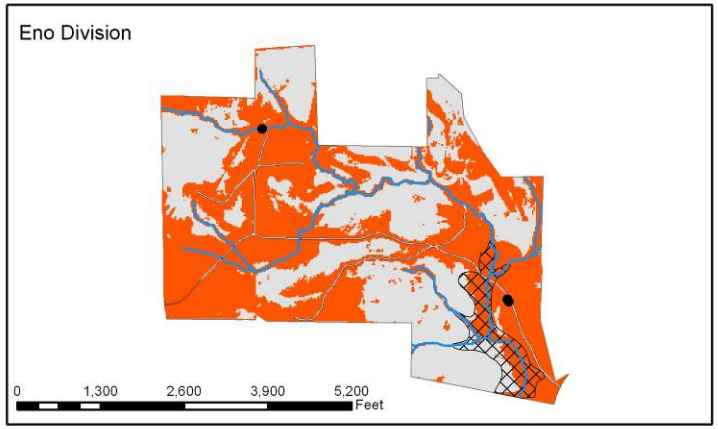
Natural Heritage area

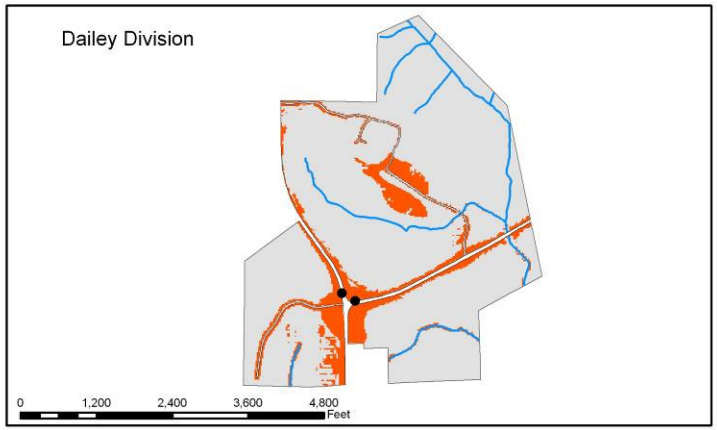
Pueraria montana

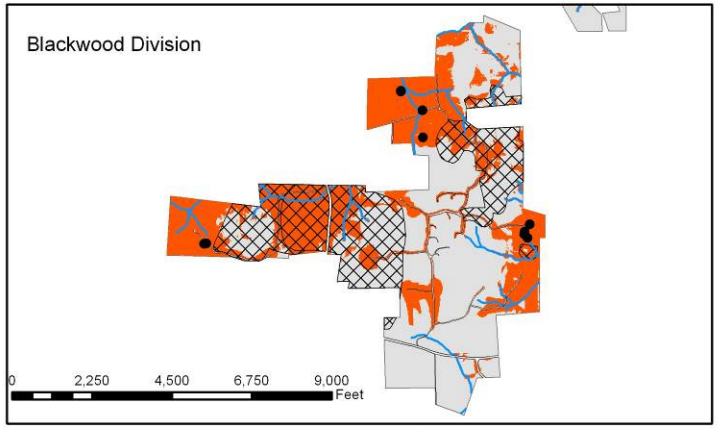
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983

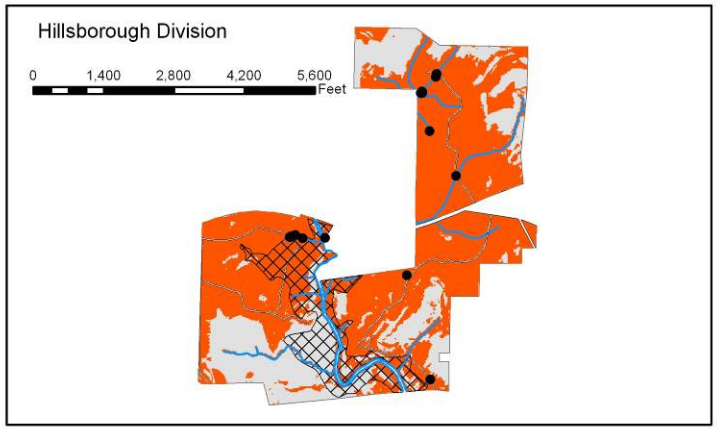

Predicted distribution of Rosa multiflora
Durham and Korstian Divisions
Duke Forest, NC
N
Known point locations
roads
streams
Natural Heritage area
Rosa multiflora
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

Predicted distribution of Rosa multiflora
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC

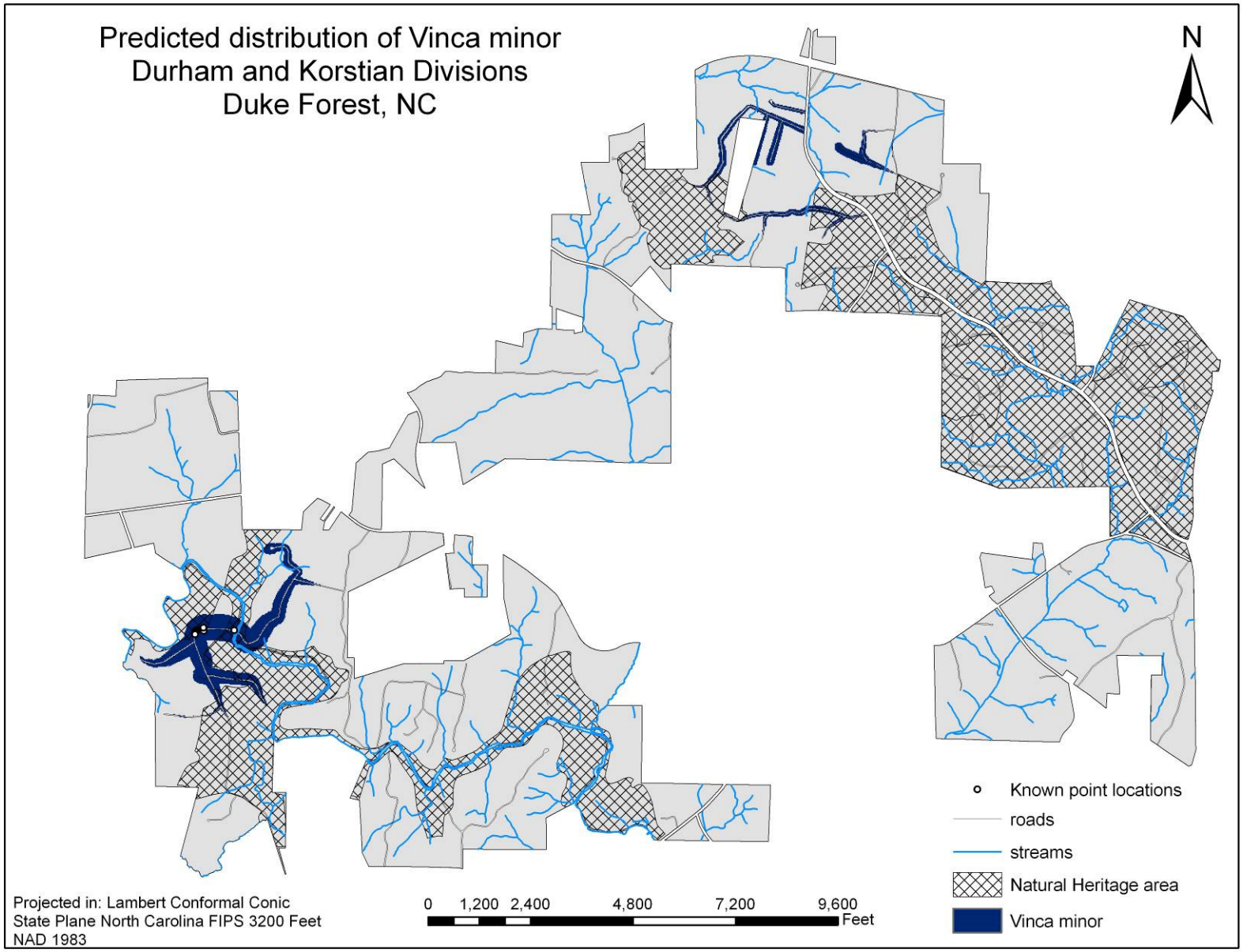




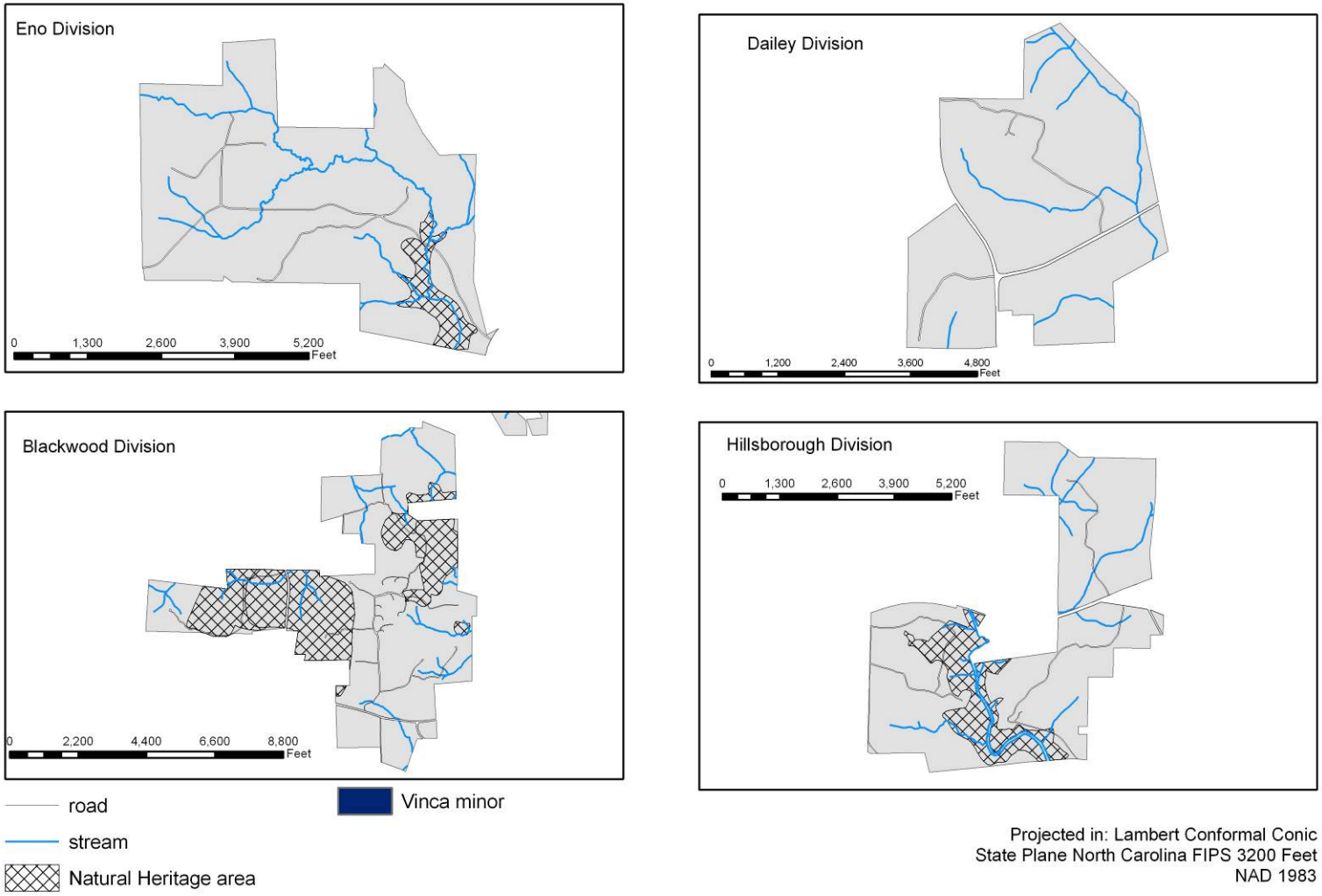


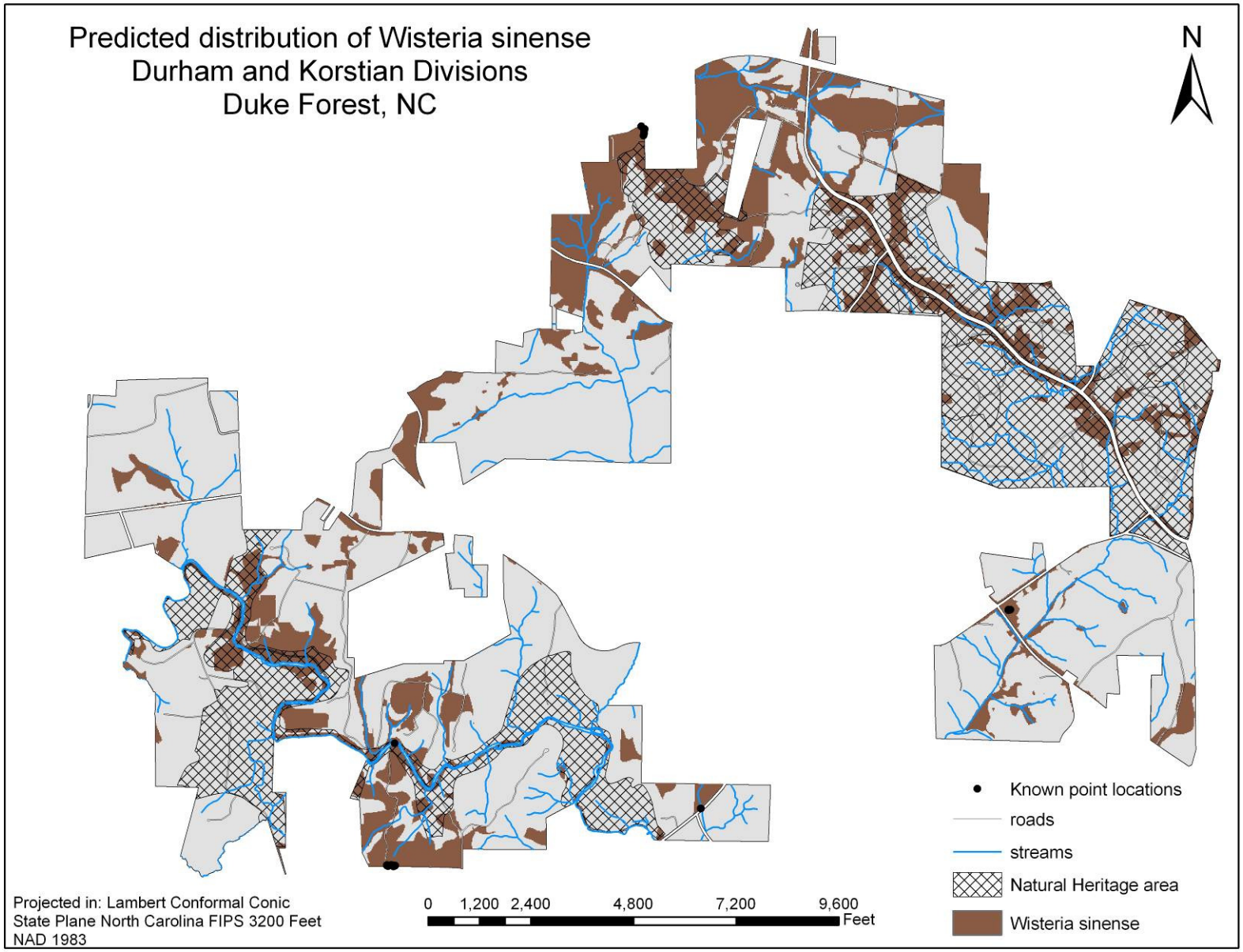


Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983

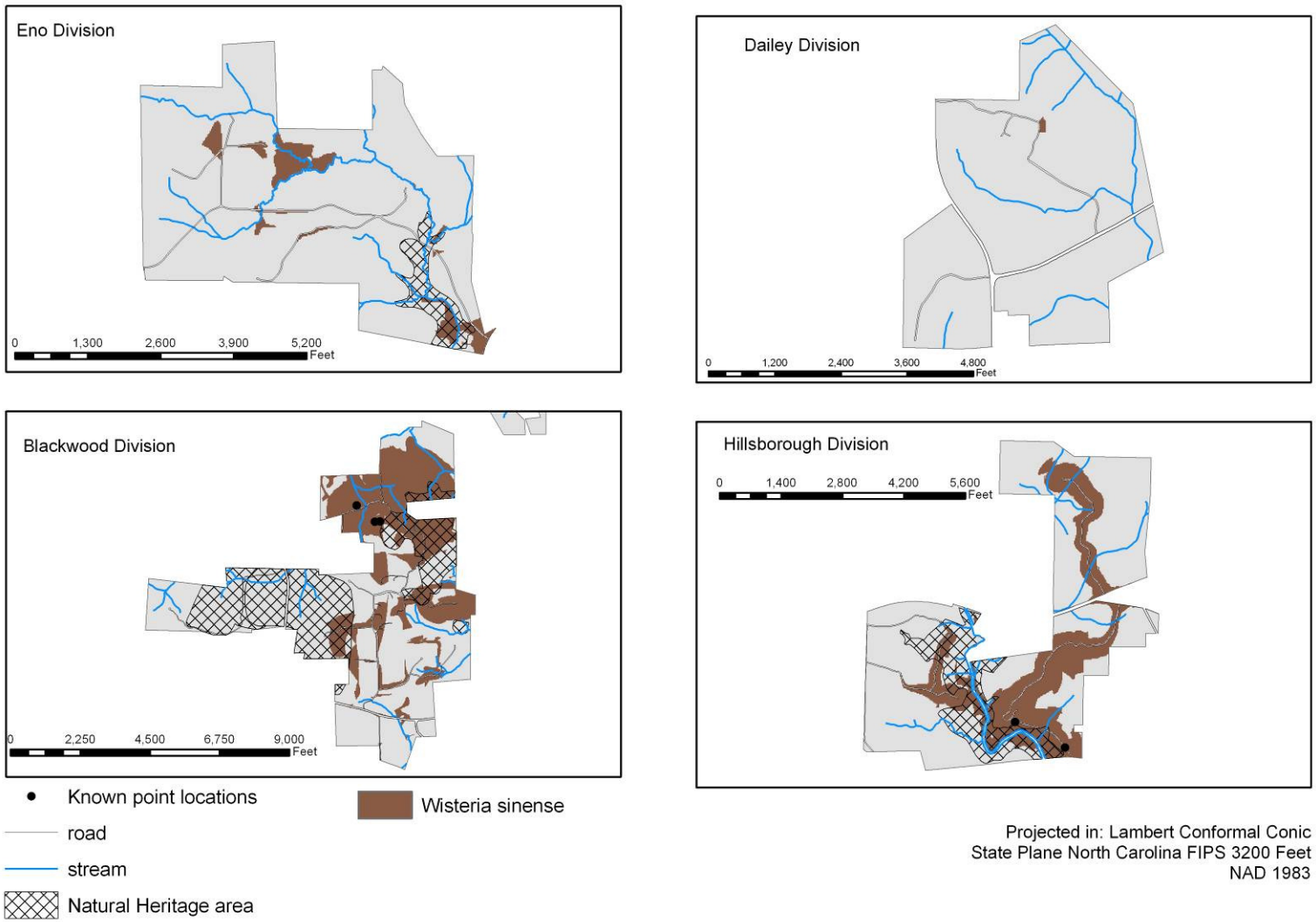

Predicted distribution of Vinca minor
Durham and Korstian Divisions
Duke Forest, NC
N
Known point locations
roads
streams
Natural Heritage area
Vinca minor
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

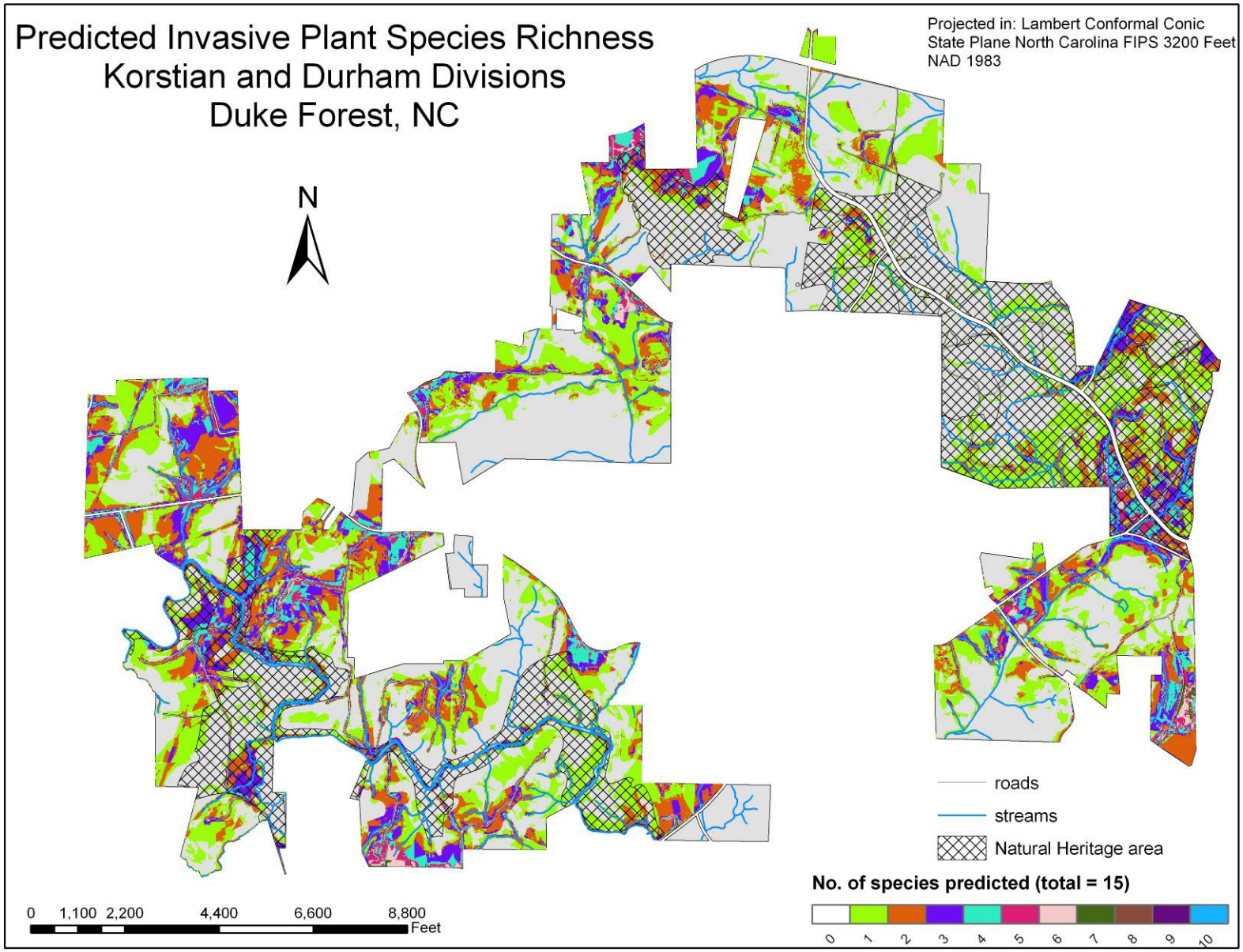
Predicted distribution of Vinca minor
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC




Predicted distribution of Wisteria sinense
Durham and Korstian Divisions
Duke Forest, NC
N
Known point locations
roads
streams
Natural Heritage area
Wisteria sinense
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
0 1,200 2,400 4,800 7,200 9,600
Feet

Predicted distribution of Wisteria sinense
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC




Predicted Invasive Plant Species Richness
Korstian and Durham Divisions
Duke Forest, NC
Projected in: Lambert Conformal Conic
State Plane North Carolina FIPS 3200 Feet
NAD 1983
N
roads
streams
Natural Heritage area
No. of species predicted (total = 15)
0 1 2 3 4 5 6 7 8 9 10
0 1,100 2,200 4,400 6,600 8,800
Feet

Predicted Invasive Plant Species Richness
Blackwood, Dailey, Eno, and Hillsborough Divisions
Duke Forest, NC