Invasive Plant Species Inventory and Assessment of the Beaverkill and Panther Mountain Forest Matrix Blocks in the Catskill Mountains in Southeast New York

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A report prepared by the Eastern New York Chapter of The Nature Conservancy

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Executive Summary

The threat of invasive plant species to forest and aquatic ecosystems of the Catskill Mountains in eastern New York has not been well documented. In this study we assessed the distribution and threat of 12 invasive plant species to forest and aquatic ecosystems in the 55,037 hectare (136,000 acre) Beaverkill and 49,378 hectare (122,016 acres) Panther Mountain forest matrix blocks in the Catskill Mountains and identified factors that best predict their distribution. Species considered during the study were chosen because they are known to be invasive in New York State and have the potential to occur in the Catskill Mountains. They included: Norway maple (*Acer platanoides*), garlic mustard (*Alliaria petiolata*), Japanese barberry (*Berberis thunbergii*), Asiatic bittersweet (*Celastrus orbiculatus*), autumn olive (*Elaeagnus umbellata*), Japanese knotweed (*Polygonum cuspidatum*), bush honeysuckle (*Lonicera* spp.), purple loosestrife (*Lythrum salicaria*), common reed *(Phragmites australis)*, buckthorn (*Rhamnus spp.*), multiflora rose (*Rosa multiflora*), and black swallow-wort (*Vincetoxicum nigrum*).

To determine the threat of the 12 invasive species, their frequency was measured by recording each species presence/absence in 20 50 m x 10 m sub-plots located along each of 356 0.5 km belt transects. Transects were randomly located along roads and trails within or adjacent to the Beaverkill forest matrix block. Roads and trails in and surrounding the block were stratified into nine road/trail types based on road class, adjacent land use, and block location using National Land Cover Data and Tiger road data in ArcView GIS 3.3.

The frequency and density of invasive species varied, as did their distribution patterns across the Beaverkill and Panther Mountain forest matrix blocks (FMB). In the Beaverkill FMB Asiatic bittersweet was the only focal species not detected in any of the 176 transects. All 12 focal species were found in the Panther Mountain FMB. The Panther Mountain FMB had a higher frequency of transects containing at least one invasive plant species at 82.8%, compared to the Beaverkill FMB at 68.2%. Garlic mustard and honeysuckle were the most abundant species, found in approximately three quarters to half of the transects sampled in the FMBs. State Route 28 and exterior county/town roads supported a greater richness and higher density of invasive species than interior roads and trails. In addition, roads that supported a higher forest cover had a lower richness and density of focal invasive species. The distribution of focal invasive species was best predicted by the proximity to developed areas, the percent of road side forest cover, road class, and, agricultural fields > 10 acres. The south central portion of the Beaverkill FMB was relatively free of invasive plant species.

The relative threat for each invasive species was determined based on the extent of the invasive plant species, its ecological impact, and the difficulty to control the species. Garlic mustard, Norway maple, and Japanese barberry were found to pose the greatest threat to the Northern Hardwood forest ecosystem and purple loosestrife, common reed, and Japanese knotweed were found to pose the greatest threat to aquatic ecosystems.

Control efforts in the Beaverkill and Panther Mountain FMBs should focus on the six high threat species as well as maintaining the “weed free areas” on the trails and road system in the south central portion of the Beaverkill FMB. The limited extent of Norway maple, purple loosestrife, common reed, and Japanese knotweed, coupled with their potential high ecological impact, indicate that these species should be prevented from expanding their distribution. Garlic mustard

and Japanese barberry are widespread throughout the road system; therefore control efforts should focus on preventing their expansion onto the trails and the weed free area in the southern portion of the Beaverkill FMB.

An invasive species inventory is an important first step in developing a comprehensive invasive plant species management program. By determining the frequency, distribution, and threat of invasive plant species, prevention, early detection and rapid response, and control strategies can be developed to target high threat species and maintain “weed free” and other priority management areas. With adequate funding, a comprehensive invasive species management program can abate the negative impact of invasive plant species on the forest and aquatic ecosystems in the Beaverkill and Panther Mountain forest matrix block.

I - Introduction

Invasive species are considered one of the greatest threats to biodiversity worldwide (Meffe Carrol 1997, Wilcove et al. 1998, Mack et al. 2000). The National Invasive Plant Species Council (2001) defines an invasive species as "a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health." Non-native or exotic species are those that directly or indirectly have been introduced to a region, which were not present in the region prior to European settlement and which would not have spread into the area without human interference (Randal 2003). Invasive species can influence ecosystem structure and function in the following ways: 1) alter composition, 2) displace native species, 3) change soil processes and nutrient cycling, 4) alter the disturbance regime, and 5) alter hydrology (Morse et al. 2004). The most harmful invasive species include those that change ecosystem function by altering processes that influence structure and function (Randal 2003).

Invasive plant species are not randomly distributed in most landscapes. Roads facilitate the distribution of invasive plant species throughout the landscape by acting as corridors for dispersal (Parendes and Jones 2000, Gelbard and Belnap 2003). Vehicle traffic and road side maintenance act as dispersal agents, spreading invasive plant seed across landscapes. In addition, the disturbance from roadside work such as mowing and drainage ditches provides suitable conditions for exotic species establishment. Roads constructed through forested landscapes create edge habitat, which alters species composition, structure and function (Chen et al. 1992, Parendes and Jones 2000, Watkins et al. 2003). In a forested landscape in Wisconsin, exotic species were most prevalent 5m from roads, but were detected up to 60m into the forest interior (Watkins et al. 2003). The distribution of exotic species in these forest stands were similar to changes in forest site variables induced by road construction and maintenance. Forest canopy cover was significantly lower 15 m from the roads edge than in the forest interior, and litter cover and depth also decreased. These road-induced changes in forest site characteristics aid in the establishment of exotic species. The presence of exotic species along roads can also be thought of as a gradient that corresponds to the amount of road traffic, road improvement level, and maintenance frequency. For example, paved improved roads that are frequently traveled and are maintained more often have a greater frequency of exotic species than unimproved, closed canopy, four-wheel drive roads (Jones and Parendes 2000, Gelbard and Belnap 2003, Sadighi and Lowenstein in press).

In The Nature Conservancy's conservation planning process for the Catskills Mountains, invasive plant species were identified as one of the top threats to forest and aquatic ecosystems. To conserve forest and aquatic ecosystems in the Catskills, The Nature Conservancy's ecoregional plan for the High Allegheny Plateau identifies seven high-quality forest matrix blocks in the Catskill Mountain Region based on the percent of forest cover and lack of fragmenting features such a roads and developed lands (Figure 1) (The Nature Conservancy 2003). Matrix forest blocks represent landscapes identified as having the size and condition to maintain functional forest systems over the long term, including the ability to recover from natural and human caused disturbances (Poiani et al. 2000). The objective of these conservation planning areas is to maintain and restore the long-term viability of forest systems and the conservation targets embedded within them (Anderson 1999). The forest matrix blocks in the Catskill Mountains contain significant amounts of interior forest land protected as Wilderness

Forest Preserve. The health of these forests also plays a major role in the protection of the New York City water supply.

Currently, little is known about the distribution of invasive plant species in the Catskill Mountain Region. Qualitative observations in the Catskills indicated that invasive plant species occur in the landscape, but are not wide spread. To maintain the high quality of the forest matrix blocks, The Nature Conservancy's Catskill Mountain Program is working with partners to develop a comprehensive invasive species control program. An invasive plant inventory is a necessary first step in developing this control program to ensure a rapid response to high priority infestations.

Objectives

This study assessed distribution of 12 invasive species along roads, trails, and stream corridors in the Beaverkill and Panther Mountain forest matrix blocks in the Catskills Mountain Region to:

1) Identify the current frequency of invasive plant species.
2) Determine the most important variables for predicting the distribution of invasive plant species using Geographical Information System (GIS) derived data layers and field data.
3) Identify the current relative threat of individual invasive plant species to the forest and aquatic systems in the Beaverkill and Panther Mountain forest matrix blocks.

Study Area

The New York state-designated Catskills Park encompasses approximately 283,280 hectares (700,000 acres) and is located in the High Alleghany Plateau Ecoregion in eastern New York. The Beaverkill FMB consists of 55,130 hectares (136,173 acres), is 98% forested and the interior of the block contains 390 kilometers (242 miles) of roads (The Nature Conservancy 2003). The Panther Mountain FMB is 49,378 hectares in size (122,016 acres), is 98.5% forested, and contains 314 kilometers (195.2 miles) or roads in its interior. The Beaverkill and Panther Mountain FMBs are located in the southern portion of the Catskills in Ulster, Sullivan, and Delaware Counties (Figure 1).

In the Catskill Mountain region the matrix forming vegetation type is the Northern Hardwoods forest ecosystem (Comer et al. 2003). The dominant tree species are sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), yellow birch (*Betula lutea*), red maple (*Acer rubrum*), and eastern hemlock (*Tsuga canadensis*).

The soils in the Catskills are largely comprised of sandy loams consisting of 60% sand, 30% silt and 10% clay with a medium soil texture (Kudish 2000). Soil depth to bedrock averages approximately 30 inches. The bedrock consists of primarily 60% sandstone and 40% shale. Glacial till covers a majority of the bedrock, ranging in depth from several inches to 100 feet thick, with the deepest depths in the valley bottoms. Soil pH is acidic, due to the lack of limestone.

The land use history in the Catskills has influenced the current forest composition and structure. European settlement began in the early 1800s and portions of the Catskills were cleared for settlements (McIntosh 1972). By the beginning of the 1900s, the tanning industry was in full swing and was having a major impact on the hemlock forest. Hemlocks were cleared for the tannins in their bark and declined in the Catskills from 20% of the total stem density in presettlement times to 9.5% currently (McIntosh 1972). Additionally, extensive timber was harvested at lower elevations for glass factory kilns. With the exception of the higher slopes, a majority of the Catskills forest is at least second growth (Kudish 2000). Over the last 100 years, American beech has declined precipitously, primarily due to beech bark disease. Since 1885, much of the forest above 1000 m elevation has been protected in the Catskill Forest Preserve.

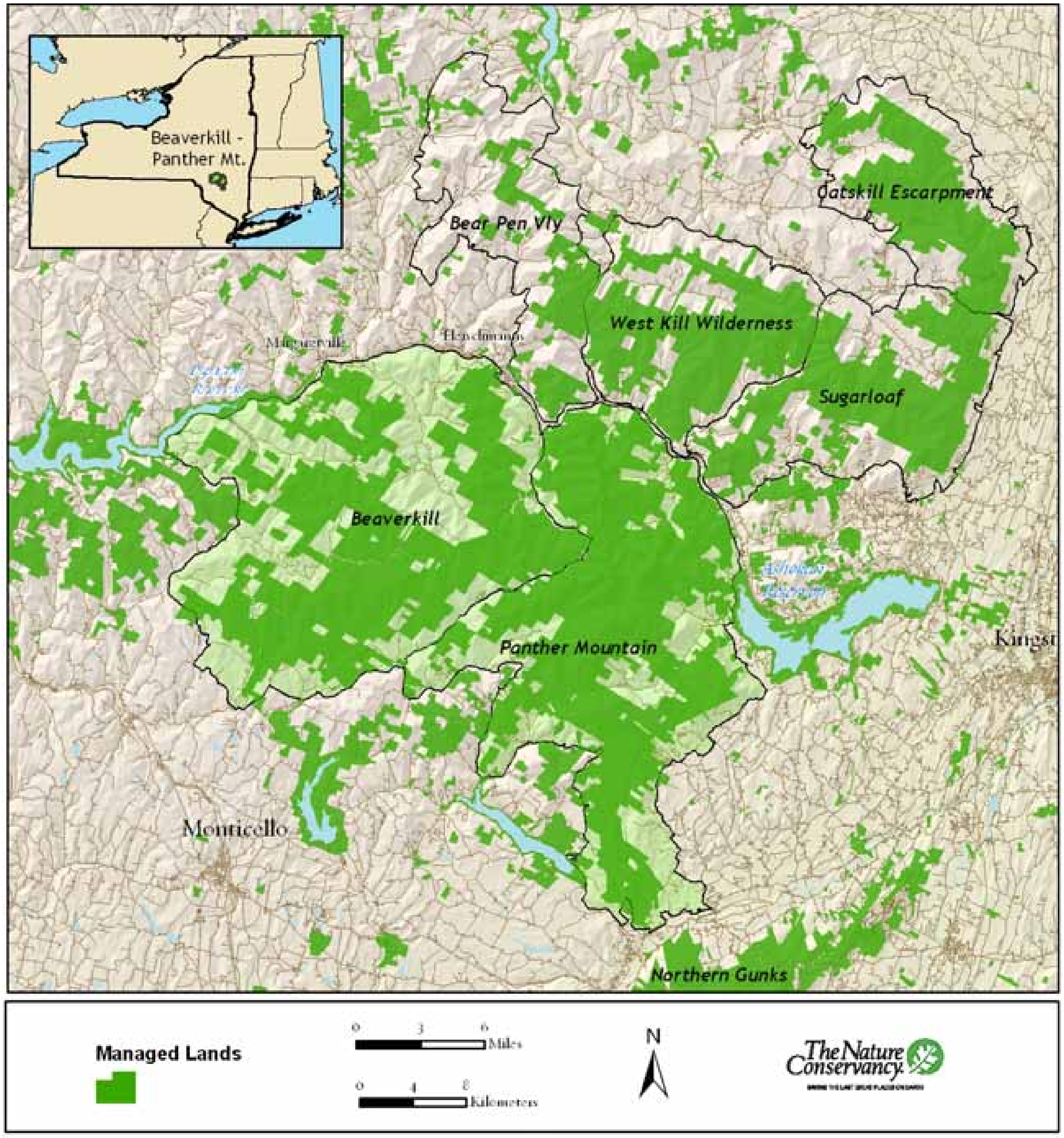

Figure 1. Location of the Beaverkill and Panther Mountain FMBs in the Catskills Mountains in New York State.

II – Sample Design and Field Methods

Focal Species

We recorded the presence/absence of twelve invasive plants: Norway maple (*Acer platanoides*), garlic mustard (*Alliaria petiolata*), Japanese barberry (*Berberis thunbergii*), Asiatic bittersweet (*Celastrus orbiculatus*), autumn olive (*Elaeagnus umbellata*), Japanese knotweed (*Polygonum cuspidatum*), bush honeysuckle (*Lonicera* spp.), purple loosestrife (*Lythrum salicaria*), common reed *(Phragmites australis)*, buckthorn (*Rhamnus spp.*), multiflora rose (*Rosa multiflora*), and black swallow-wort (*Vincetoxicum nigrum*). These species are known to be invasive in New York and have the potential to occur in the Catskill Mountains. All of the focal species are primarily found in terrestrial upland habitats with the exception of common reed and purple loosestrife.

Sample Design

Sample locations along roads and trails were stratified into nine road/trail types based on road classes, adjacent land use, and block location using 1992 National Land Cover Data and 2000 Tiger road data in ArcView GIS 3.3 (Table 1) (ESRI 1999). The road/trail types are as follows: 1) state highways adjacent to forest, 2) state highways adjacent to agriculture, 3) boundary county and town roads adjacent to forest, 4) boundary roads adjacent to agriculture, 5) connecting interior roads adjacent to forest, 6) connecting interior roads adjacent to agriculture, 7) interior dead end roads adjacent to forest, 8) interior dead end roads adjacent to agriculture, and 9) interior trails and abandoned roads adjacent to forest. The dead end road class was defined as the last two kilometers of any interior road. To stratify the road sections as forest or agriculture, a forest – agriculture data layer was created in ArcView using the National Land Cover Data (NLCD). A majority filter in ArcView using the default settings was then used to replace isolated cells. Areas classified as agriculture were a combination of the agriculture and pasture/hay NLCD land cover classes and forest areas within a 50 m buffer of agriculture areas. Road sections were then classified as forest or agriculture and sections < 0.5 km long were deleted. Only public roads and trails in the Tiger road dataset were sampled.

Initial observations in the Catskills indicate that invasive species are not currently widespread. Therefore, a large sample size was used to assess the frequency of the focal species in the forest block. Approximately 25% of the total distance of each of the nine road/trail types was sampled. The center points for the transects were randomly located using ArcView within each of the nine road/trail types. Each point was at least 0.5 km apart to avoid overlapping of any transects.

Table 1. Sample locations and geographic class variables in the Catskills Mountain Beaverkill and Panther Mountain FMBs.

	Block Location	Road Class	Land Cover	Sample Size	
				Beaverkill	Panther Mt.
1	Boundary	State highway	Forest > 50 m from Ag.	4	10
2	Boundary	State highway	Agriculture	5	6
3	Boundary	County/Town roads	Forest > 50 m from Ag.	29	48
4	Boundary	County/Town roads	Agriculture	11	26
5	Interior	County/Town roads	Forest > 50 m from Ag.	34	31
6	Interior	County/Town roads	Agriculture	21	8
7	Interior	Dead ends	Forest > 50 m from Ag.	31	31
8	Interior	Dead ends	Agriculture	9	2
9	Interior	Trail/abandoned road	Forest > 50 m from Ag.	32	18
	Total			176	180

Data Collection

In the field, the center points for the 0.5 km belt transect were located using Magellan Meridian Gold and Sportrak global positioning systems. Each 0.5 km belt transect contained twenty 50 m x 10 m subplots, with ten located on each side of the road, trail, or stream and the presence/absence of each focal species was recorded for each subplot (Figure 2). The ten meter distance was chosen based on research in Wisconsin that demonstrated that exotic species frequency and abundance were greatest within the first five meters from the forest edge (Watkins et al. 2003). An additional five meters was added to this distance because many of the roads in the Catskills have a one to two meter periodically mowed strips adjacent to the road. The edge of a road was defined as the surface which is traveled upon, whether it is paved, gravel or bare ground. Not included were pull off areas or drainage ditches.

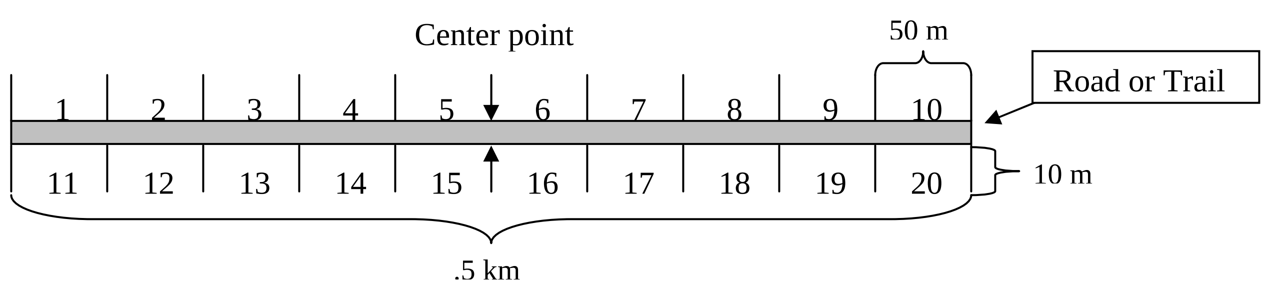

Figure 2. Diagram of sample belt transect.

Additionally, for each 50 m x 10 m subplot the percent cover of forest, disturbed, unvegetated, and lawn/agriculture areas were estimated in the field using the following five cover classes: 0, 1.0 - 24.9, 25.0 - 49.9, 50.0 – 74.9, and 75 – 100. The definition of each of these categories is as follows:

> Forest: Overstory trees exceed 5 m in height and tree canopy cover is 75% or greater. Forested area is greater than 10 m sq., (including adjacent forest outside of the surveyed area) with the boundary of forest cover generally defined by the edge of the base of the trees.
> Disturbed: Regularly disturbed areas. Due to difficulty in assessing frequency of disturbance this category includes all vegetated area that is not forest or lawn/ agriculture.
> Unvegetated: Impermeable surfaces, open water, and other unvegetated, maintained open ground (such as dirt and gravel trails or roads)
> Lawn/Agriculture: Planted, seasonally maintained monoculture.

Geographical Information System Derived Variables

In addition to road class, block location, and land cover class, four additional GIS variables were developed using NLCD and transect point centers. From the NLCD, all residential/commercial land cover classes were combined and converted into a developed land cover data layer. From the residential/commercial polygons two variables were developed: 1) the distance from the transect point center to the closest residential/commercial land cover polygon, and 2) the distance from the transect point center to the closest residential/commercial land cover polygon > 0.4 ha (1 acre). From the forest - agriculture land cover data layer (as described above), two additional variables were developed: 1) the distance from the transect point center to the closest agriculture land cover polygon, and 2) the distance from the transect point center to the closest agriculture land cover polygon > 4.0 ha (10 acres).

Data Analysis

The frequency of transects, mean transect invasive species richness, and mean percent of subplots containing the focal species was calculated for the FMB, by road class, by block location, and by land cover class. The mean percent of subplots containing the focal species was used to measure the density of focal species in a transect. Data were analyzed using non-parametric tests due to the categorical nature of the data and non-normal distribution. Kruskal-Wallis ANOVA on Ranks followed by Dunn's multiple comparison procedure were used to test for differences between road classes (Sigma Stat 2004). Mann-Whitney rank sum test was used to test the difference in block location and land cover class. .

An invasive species index was derived for each transect by averaging the percent species richness with the mean percent of subplots containing a focal species. The equation was adapted from Lundgren et al. (2004).

((# of species focal present along a transect / 12 = *% of focal invasive plant species*) +
(# of 50m x 10m subplots occupied by any focal species/ 20 =
% of subplots containing a focal species) / 2) = Invasive Species Index

Forward stepwise regressions were run to determine the most important variables predicting the distribution of: 1) invasive species richness, 2) percent of sub-plots containing an invasive species, 3) invasive species index, and 4) the most abundant invasive species (Sigma Stat 2000). The following 11 independent variables were loaded into the stepwise regression: road class, block location, land cover class, distance to all residential/commercial areas, distance to residential/commercial areas > .4 ha, distance to all agricultural areas, distance to agricultural areas > 4.0 ha, mean transect forest cover, mean transect disturbed cover, mean transect unvegetated cover, and mean transect agricultural/lawn cover.

In ArcGIS 9.0, Inverse Distance Weighting (IDW) and the invasive plant index (IPI) sample point data were used to create an IPI grid for the block. IDW is an operation that assigns values to locations based on the surrounding known values and on mathematical formulas that determine the smoothness of the resulting surface (ESRI 2004). Interpolation was used to extrapolate the point data to the surrounding road and trail system to depict the level of invasion within the block. A 0.5 km road/trail buffer was used to clip the IPI grid, due to the lack of data points in interior forest areas.

Invasive Species Threat Assessment

A framework developed by The Nature Conservancy's Invasive Species Initiative was used to assess the threat of individual invasive species (Tu and Myers-Rice 2001). As indicated below, invasive species were assigned a rank for each criterion and then a total rank was calculated. Species with a lower rank represent a higher priority than species with a higher rank. The focal species distribution data and the existing literature were used to assign the ranks for each species.

I. **Current and potential impacts of the species:** For this criterion, invasive species that pose the greatest potential adverse impact to conservation targets received higher priority than invasives that pose little ecological impact.
   1. Species that alter ecosystem processes such as sedimentation, nutrient cycling, or other ecosystem processes. These are species that often alter conditions so radically that few native plants and animals can persist (Rank = Very High).
   2. Species that out compete natives and dominate otherwise undisturbed native communities (Rank = High).
   3. Species that do not out compete dominant natives but (Rank = Moderate):
      a. prevent or depress recruitment or regeneration of native species; OR
      b. reduce or eliminate resources (e.g., food, cover, nesting sites) 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 disturbances such as fires, floods, or hurricanes, thereby altering succession, or that hinder restoration of natural communities (Rank = Low).

II. Current extent of the species: Under this criterion, higher priority was given to species in order to: first prevent the establishment of new weed species, second to eliminate small, rapidly-growing infestations, third to prevent large infestations from expanding, and fourth to reduce or eliminate large infestations.

Priorities were assigned in the following sequence.

1. Species not yet on the site but which are present nearby. Pay special attention to species known to be pests elsewhere in the region (Rank = Very High).
2. Species present as new populations or outliers of larger infestations, especially if they are expanding rapidly (Rank = High).
3. Species present in large infestations that continue to expand (Rank = Moderate).
4. Species present in large infestations that are not expanding (Rank = Low).

III. Difficulty of control and establishing replacement species: Priorities were assigned in the following order:

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

III – Beaverkill Forest Matrix Block Inventory Results

On the roads and trails in and surrounding the Beaverkill FMB, 176 belt transects were sampled. With the exception of Japanese bittersweet, each of the twelve focal species were found in at least one transect (Table 2). Sixty-eight percent of the belt transects contained at least one of the twelve focal invasive species (Table 3). The mean percent frequency of subplots containing one of the focal invasive species was 28.72%. The mean number of invasive species detected in a transect was 1.77 species.

Garlic mustard and bush honeysuckle were the most abundant species in the Beaverkill block, found in approximately half of the belt transects (Table 2). Multiflora rose and Japanese barberry were found at frequencies of 31.3% and 25.0% respectively, with the remaining eight focal species occurring at frequencies <10%.

Table 2. The percent frequency of focal invasive species in the Beaverkill FMB.

Focal Species	Belt Transect % Frequency	Focal Species	Belt Transect % Frequency
Garlic mustard	49.4	Autumn olive	5.1
Bush honeysuckle	45.5	Norway maple	4.5
Multiflora rose	31.3	Common reed	1.7
Japanese barberry	25.0	Black swallowwort	0.6
Purple loosestrife	6.3	Buckthorn spp.	0.6
Japanese knotweed	5.7	Bittersweet	0.0

<u>Influence of Road Class</u>

The frequency, density, and richness of invasive species varied among the road classes in the Beaverkill block (Table 3 and Fig. 3). One hundred percent of the belt transects along State Route 28 (the only state highway surrounding the matrix block) had a least one the focal invasive species. Along county/town and dead end roads, approximately 80% of the transects had one focal species. However, the focal invasive species were only encountered in nine percent of the trail transects. The percent of subplots containing focal invasive species and the invasive species richness were significantly different between the four road classes, with the exception of the county/town roads and dead end roads. State Route 28 had a significantly greater number of invasive species and significantly greater percentage of subplots containing focal species than the county/town roads, dead end roads, and trails. County/town roads and dead end roads had a similar number of focal species and a similar percentage of subplots occupied. The trails were found to have the lowest number of focal species and the lowest percentage of subplots that contain focal species. Of the 32 trail transects, only three contained two focal invasive species.

For the four most abundant species there were only a few significant differences between the road classes. Garlic mustard, multiflora rose, and Japanese barberry occupied a significantly less number of subplots on the trail transects (Table 4). Bush honeysuckle had significantly greater density on State Route 28 compared to the other three road classes. Additionally, for each of the four most abundant species, the belt transect frequency on State Route 28 was at least 15% higher than county/town roads and dead end roads. Multiflora rose had a higher frequency and occupied a higher mean number of subplots on dead end roads than on county and town roads.

Table 3. Percent frequency of focal species along transects, mean percent of subplots occupied by focal species + S.E. and mean invasive species richness for transects by road class, block location, and land cover.

	N	Percent Frequency	Percent of Subplots	S.E.	Invasive Richness	S.E.
Total	176	68.2	28.72	2.25	1.77	0.13
Road Class						
State Route 28	9	100.00	58.89[a]	7.90	4.33[a]	0.33
County/Town Roads	95	81.05	33.94[b]	2.87	2.06[b]	0.17
Dead End Roads	40	77.50	32.20[b]	5.07	1.85[b]	0.23
Trails	32	9.38	0.47[c]	0.26	0.09[c]	0.05
Block Location						
Boundary Road*	49	85.71	42.65**	4.22	2.59**	0.25
Interior Roads*	95	78.95	31.053**	2.96	1.92**	0.16
Land Cover Type						
Agriculture Roads*	46	89.13	43.91**	3.87	2.59**	0.23
Forest Roads*	98	77.55	30.82**	3.04	1.9**	0.17

Letters indicate a significant difference ($P \leq 0.05$)
* Frequency, means, and Mann-Whitney rank sum test for block location and land cover calculated without trail data.
** Significantly different ($P \leq 0.05$)

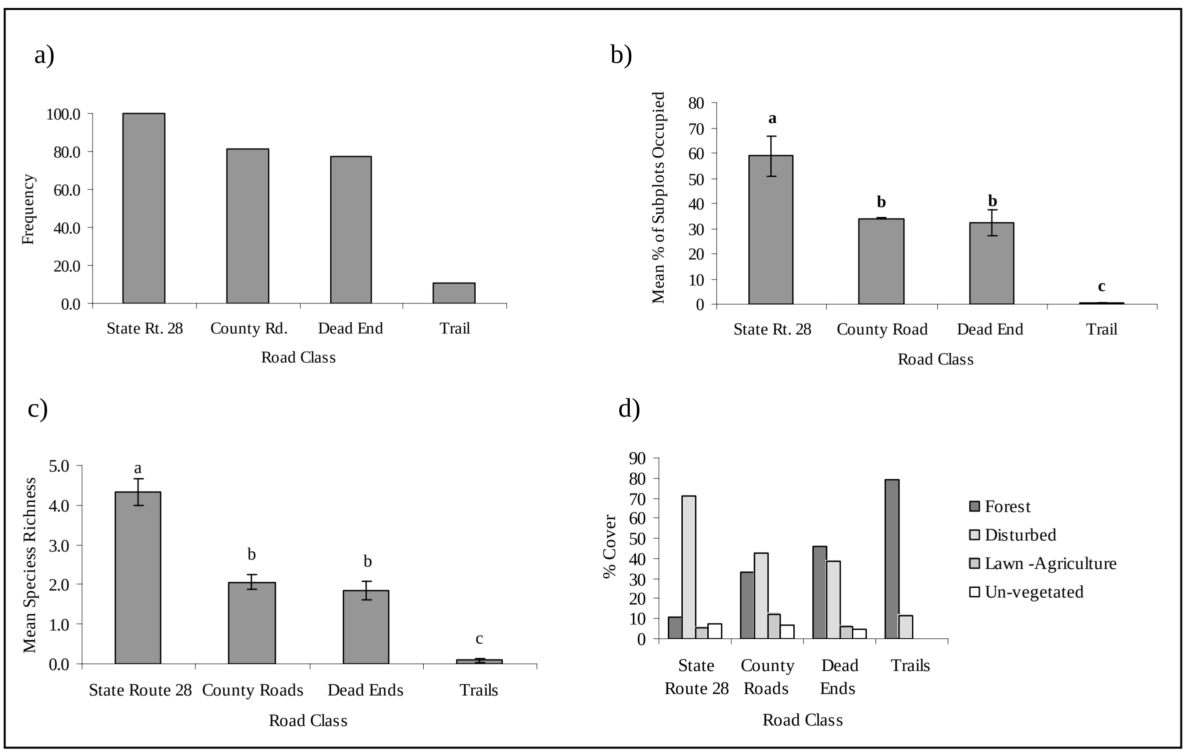

Figure 3. Distribution of : (a) focal species frequency, (b) mean percent of subplots occupied by focal species + S.E., (c) species richness + S.E. , and (d) transect cover estimates by road class. Letters indicate significant differences ($P \leq 0.05$).

Influence of Block Location

Boundary transects had significantly greater mean invasive species richness and a significantly greater percentage of subplots occupied by a focal species compared to the interior transects (Table 3). Of the four most abundant species, bush honeysuckle was the only species that occupied a significantly higher percentage of subplots in the boundary roads versus the interior roads (Table 4). However, all four of the most abundant species had at least a 20% higher frequency in the boundary transects compared to the interior transects.

Influence of Land Cover

Agriculture transects had a significantly higher invasive species richness and a significantly greater percentage of subplots occupied by a focal species than forested transects (Table 3). Multiflora rose was the only species that occupied a significantly higher percentage of subplots in agricultural transects than the forested ones (Table 4).

Table 4. Transect percent frequency (FRQ) and mean percent of subplots occupied ± S.E of garlic mustard, honey suckle, multiflora rose, and Japanese barberry by road class, block location and land cover.

	Garlic Mustard			Honey Suckle			Multiflora Rose			Japanese Barberry		
	FRQ	% SP	S.E.	FRQ	% SP	S.E.	FRQ	% SP	S.E.	FRQ	% SP	S.E.
Total	49.4	12.50	1.50	45.5	10.31	1.32	31.3	6.05	1.03	25.0	3.27	0.64
Road Class												
State Route 28	77.78	15.00 [a]	4.17	88.89	37.22 [a]	10.48	66.67	10.56 [a]	5.03	66.67	5.00 [a]	1.44
County Roads	60.00	14.84 [a]	1.97	54.74	12.16 [b]	1.78	33.68	6.9 [a]	1.53	28.42	4.00 [ab]	1.11
Dead Ends	52.50	16.13 [a]	4.2	47.50	8.00 [b]	2.15	42.50	7.88 [a]	2.31	27.50	3.75 [ab]	1.43
Trails	6.25	0.31 [b]	0.22	3.13	0.16 [c]	0.16	0.00	0.00 [b]	0.00	0.00	0.00 [b]	0.00
Block Location												
Boundary Roads*	67.35	14.69	2.61	63.27	21.22**	3.54	42.86	8.27	2.40	42.86	6.63	2.02
Interior Roads*	40.94	11.65	1.82	37.80	6.10**	1.00	26.77	5.20	1.08	18.11	1.96	.53
Land Cover Type												
Agriculture Roads*	65.22	19.02	3.25	63.04	13.04	2.53	56.52	8.91**	1.70	32.61	6.20	2.1
Forest Roads*	56.12	13.41	2.07	51.02	12.35	1.95	29.59	6.68**	1.62	29.59	2.96	0.68

Letters indicate a significant difference (P ≤ 0.05

* Frequency, means, and Mann-Whitney rank sum test for block location and land cover calculated without trail data.

** Significantly different (P ≤ 0.05)

Distribution of Forest, Disturbed, Lawn/Agriculture, and Non-vegetated Cover

In the field, the estimated mean percent of forested, disturbed, lawn/agriculture, and non-vegetated cover for each transect was not evenly distributed across the block. State Route 28 transects had significantly less mean forest cover and significantly more disturbed and un-vegetated cover than dead end roads and trails (Table 5 and Fig. 3d). The trail transects had the greatest percentage of forest cover and the lowest percentage of disturbed cover. Additionally, the block boundary roads had significantly less forest cover and more disturbed cover than interior road transects. The forest land cover class transects identified using GIS were found to have significantly greater mean forest cover, and significantly less disturbed and unvegetated cover than the transects in the field. However, the agriculture transects did not have significantly more disturbed cover than the forested transects.

Table 5. Mean percent of forest, disturbed, lawn/agriculture, and unvegetated cover by road class, block location and land cover.

	Forest	Disturbed	Lawn-Agriculture	Unvegetated
Total	43.59	37.55	5.11	8.20
Road Class				
State Route 28	10.76[a]	71.39[a]	5.49[a]	7.36[a]
County Roads	33.37[ab]	42.69[b]	12.08[b]	6.84[b]
Dead Ends	46.31[b]	38.67[b]	6.19[ab]	4.54[b]
Trails	79.36[c]	11.50[c]	0.16[c]	0.14[b]
Block Location				
Boundary Road*	30.03**	50.41**	5.57	8.56
Interior Roads*	38.53**	39.69**	6.55	10.72
Land Cover Type				
Agriculture Roads*	19.03**	46.11	8.93**	22.36**
Forest Roads*	43.43**	42.03	4.95**	4.17**

Letters indicate a significant difference ($P \leq 0.05$)

* Frequency, means, and Mann-Whitney rank sum test for block location and land cover calculated without trail data.

** Significantly different ($P \leq 0.05$)

Focal Species Distribution

The invasive species index was used to integrate invasive species richness and the percent of subplots occupied by an invasive species within a transect, and to depict invasive species hot spots within and surrounding the block. The north and northeast portion of the block was found to have the highest richness and abundance of focal species, while the central and southern portion of the block was found to be relatively uninvaded (Figure 4). The distribution of agricultural fields and developed areas followed a similar pattern.

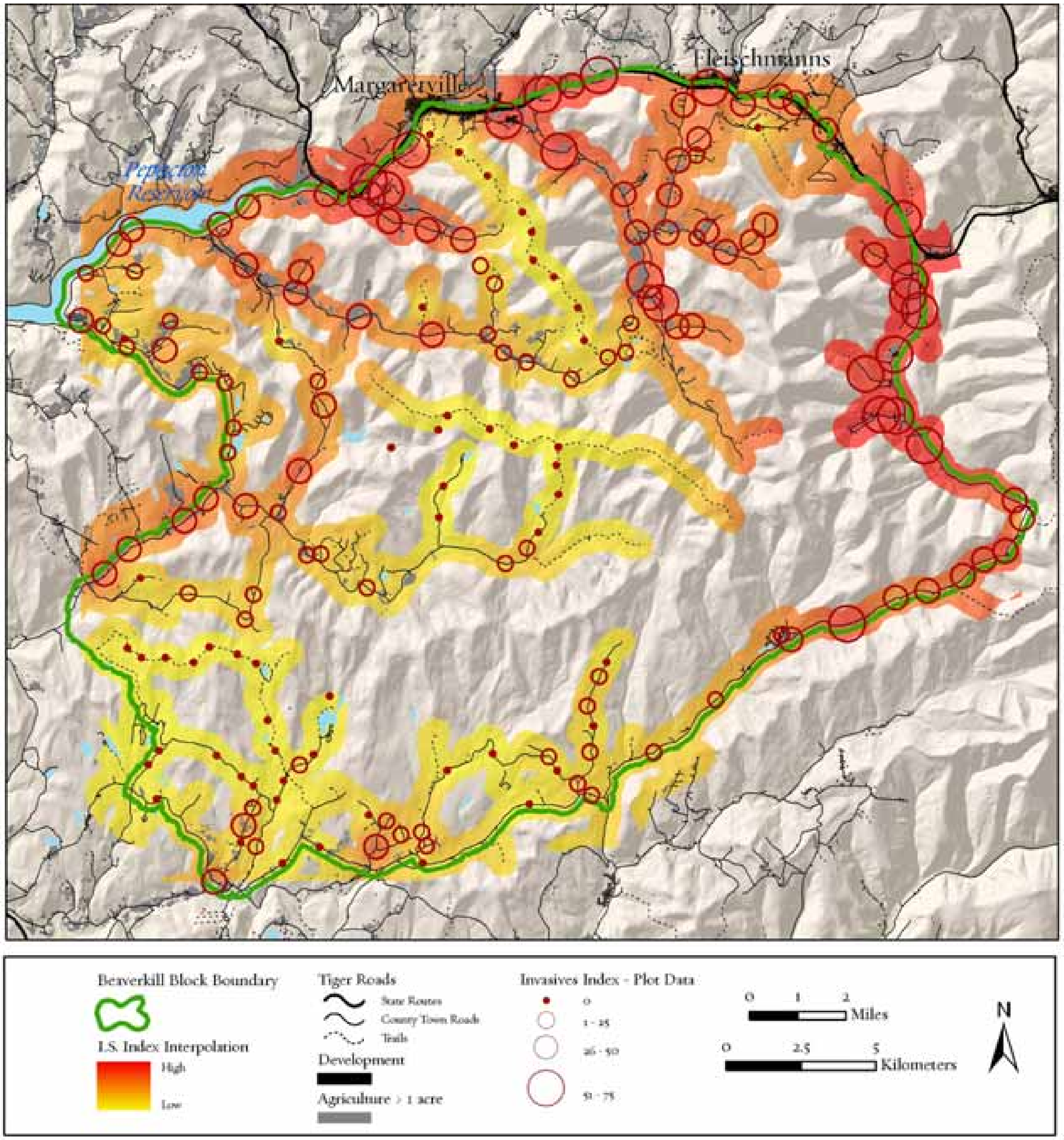

Figure 4. Distribution of invasive plant species in the Beaverkill FMB in relation to the road class, developed, and agricultural areas. Invasive species distribution is depicted by invasive species index at point locations and by point interpolation analysis. Invasive species index is the average of the relative percentage of the number of invasive species present in the .5km belt transect divided by 12 focal species, with the mean percent of subplots containing a focal species (See Methods section for further explanation).

Invasive Plant Species Predictive Model

The forward stepwise multiple regression determined that invasive species richness across the Beaverkill block was best explained by the distance to the closest developed area, followed by road class and distance to the closest agricultural field > 4 ha (Table 6). The three variables combined had a $R^2 = 0.442$ with a P = < 0.001. The same set of variables were the best predictors of the percent of subplots occupied by a focal species ($R^2 = 0.390$) and the invasive species index ($R^2 = 0.449$).

Table 6. Variables predicting invasive species richness, mean percent of subplots occupied by a focal species and invasive species index determined by forward stepwise multiple regressions.

Dependant Variable	Step	Independent Variables	R^2 cum.	F	P
Invasive Species Richness		Unchanged	0.000		
	1	Distance to all development	0.276	20.122	< 0.001
	2	Road class	0.397	29.982	< 0.001
	3	Distance to agricultural fields > 4 ha	0.442	15.810	< 0.001
		Model	0.442	56.861	< 0.001
Percent of Subplots		Unchanged	0.000		
	1	Distance to all development	0.253	15.077	< 0.001
	2	Dist. to agricultural fields > 4 ha	0.336	11.200	0.001
	3	Road class	0.390	25.240	< 0.001
		Model	0.390	36.643	< 0.001
Invasive Species Index		Unchanged	0.000		
	1	Distance to all development	0.288	19.268	< 0.001
	2	Road class	0.388	17.281	< 0.001
	3	Distance to agricultural fields > 4 ha	0.449	26.120	< 0.001
		Model	0.449	46.722	< 0.001

For the four most frequent focal invasive species, the amount of variation explained by the variables ranged substantially (Table 7). The percent of subplots occupied by bush honeysuckle had the greatest amount of variation explained ($R^2 = 0.303$), followed by garlic mustard ($R^2 = 0.153$), Japanese barberry ($R^2 = 0.148$), and multiflora rose ($R^2 = 0.133$). The distribution of bush honeysuckle was best explained by the distance to all developed areas, followed by block location, percent of forest cover, and percent of lawn/agriculture cover. Similarly, the percent of subplots occupied by garlic mustard was best predicted by the distance to all developed areas with the addition of the percent of unvegetated cover. The percent of subplots occupied by Japanese barberry was best explained by the distance to developed areas > 0.4 ha, followed by percent of lawn/agriculture cover, and block location. The distribution of multiflora rose was best explained by the percent of forest cover and the distance to developed areas > 0.4 ha.

Table 7. Variables predicting the percent of subplot occupied by garlic mustard, bush honeysuckle, Japanese barberry, and multiflora rose determined by forward stepwise multiple regressions.

Dependant Variable	Step	Independent Variables	R^2 cum.	F	P
Garlic Mustard		Unchanged	0.000		
	1	Distance to all development	0.123	16.642	<0.001
	2	Mean % of unvegetated cover along transect	0.153	6.125	0.014
		Model	0.153	15.586	<0.001
Honeysuckle		Unchanged	0.000		
	1	Distance to all development	0.179	11.283	<0.001
	2	Block location	0.244	6.774	0.010
	3	Mean % of forest cover along transect	0.271	11.978	<0.001
	4	Mean % of lawn/agriculture cover along transect	0.303	7.623	0.006
		Model	0.303	16.040	<0.001
Japanese Barberry		Unchanged	0.000		
	1	Distance to development >1 ac.	0.084	10.336	0.002
	2	Mean % of lawn/agriculture cover along transect	0.119	7.216	0.008
	3	Block location	0.148	5.813	0.017
		Model	0.148	9.965	<0.001
Multiflora Rose		Unchanged	0.000		
	1	Mean % of forest cover along transect	0.094	12.824	<0.001
	2	Distance to development >1 ac.	0.133	7.925	0.005
		Model	0.133	13.307	<0.001

Threat Assessment

Garlic mustard, Japanese barberry, and Norway maple were determined to be the highest priority to abate the threat to forest ecosystems in the Beaverkill block based on their current extent, impact to the system and the feasibility of control of the species (Table 8). See the Threats Assessment Discussion section (Chapter VIII) for an overview of justification for the rankings.

Table 8. An assessment of invasive plant species threat to North Hardwood forest ecosystem in the Beaverkill FMB. Lower values indicate a higher priority.

Species	Threat	Feasibility		Priority
	Impact	Extent	Control	Total
Norway maple	V. High/High?	4.5%	High	V. High / High
Barberry	V. High/High?	25.0%	High	High
Garlic mustard	V. High/High?	49.4%	High	Medium
Honeysuckle spp.	Medium	45.5%	High	Med. / Low
Bittersweet	Low ?	0.0%	Medium	Med. / Low
Swallowwort spp.	Low ?	0.6%	Medium	Med. / Low
Multiflora rose	Low	31.3%	High	Low
Autumn olive	Low	5.1%	High	Low / Med.
Buckthorn spp.	Low	0.6%	High	Low / Med.

Beaverkill Forest Matrix Block Conclusions

Garlic mustard was the only focal species found to be widespread throughout the road system, in and surrounding the Beaverkill FMB. The remaining focal species were not evenly distributed across the road and trail system in the block, indicating that portions of the block are relatively uninvaded. Focal invasive species were found in the highest frequencies in the developed and agricultural areas along State Route 28 in the northern portion of the block. For example, bush honeysuckle was found in approximately 50% of the transects sampled, but was significantly more abundant along State Route 28 and along the boundary of the FMB. The frequency of invasive plant species in the Beaverkill FMB and their distribution pattern is similar to the frequency and pattern of invasive plant species found in other matrix blocks in the Northeast (Lundgren et al. 2004, Sadighi and Lowenstein in press). Given the large number of invasive plant species found in the Beaverkill block it is critical to identify high priority management areas and assess the relative threat of individual species to ensure that future management actions have the greatest impact on maintaining the health of the forest and aquatic ecosystems in the Catskills.

IV – Panther Mt. Forest Matrix Block Inventory Results

On the roads and trails in and surrounding the Panther Mountain FMB, 180 belt transects were sampled. All twelve focal species were detected (Table 9) and 83% of the belt transects contained at least one of the twelve focal invasive species (Table 10). The mean percent of subplots containing one of the focal invasive species was 49.92%. Hence, an average of approximately half of the subplots (10 out 20) had an invasive plant species present. The mean number of invasive species detected in a transect was 2.94 species.

Garlic mustard was the most abundant species in the Panther Mountain FMB, found in approximately three quarters of the belt transects (Table 9). Japanese barberry, multiflora rose and bush honeysuckle were found in approximately half of the belt transects, with the remaining eight focal species occurring at frequencies <15%.

Table 9. The percent frequency of focal invasive species in the Panther Mountain forest matrix block.

Focal Species	Belt Transect % Frequency	Focal Species	Belt Transect % Frequency
Garlic mustard	75.0	Japanese knotweed	7.8
Japanese barberry	55.0	Common reed	7.8
Multiflora rose	53.9	Buckthorn spp.	6.7
Bush honeysuckle	50.0	Norway maple	6.1
Purple loosestrife	15.0	Autumn olive	3.9
Bittersweet	11.1	Black swallowwort	2.2

Influence of Road Class

The frequency, density, and richness of invasive species varied among the road classes in the Panther Mountain FMB (Table 10). One hundred percent of the belt transects along State Route 28 (the only state highway surrounding the matrix block) had a least one of the focal invasive species. Along county/town and dead end roads, approximately 94% and 82% of the transects respectively had at least one focal species present. However, none of the focal invasive species were detected in any of the trail transects. The percent of subplots containing focal invasive species and the invasive species richness were significantly different between county/town roads and dead end roads. State Route 28 had similar invasive species density and richness to county/town roads.

For the four most abundant species in the Panther Mountain FMB there were only a few significant differences between the road classes (Table 11). Multiflora rose and bush honeysuckle were significantly more abundant along State Route 28 when compared to the county/town roads and dead ends. Bush honeysuckle had the greatest range in frequency and density along the road transects. Along State Route 28 it was present in 87.5 % of the transects, while along dead end road it was only found in approximately four percent of the transects. Garlic mustard was found in relatively high frequencies in all of the road classes, ranging from 100% of the road transects along State Route 28 to approximately 81% of the transects in dead end roads; however, it was found in moderate to low densities. Garlic mustard was found in its highest abundance along county/town roads, occupying on an average 34% of the subplots (~ an average of 7 subplots). Japanese barberry and multiflora rose were moderately frequency and were found in moderately low densities.

Table 10. Percent frequency of focal species along transects, mean percent of subplots occupied by focal species ± S.E. and mean invasive species richness for transects by road class, block location, and land cover.

	N	Percent Frequency	Percent of Subplots	S.E.	Invasive Richness	S.E.
Total	180	82.78	48.92	2.67	2.94	0.15
Road Class						
State Route 28	16	100.00	68.43a	5.88	5.63a	0.46
County/Town Roads	113	93.81	56.86a	3.14	3.26b	0.16
Dead End Roads	33	81.82	38.94b	5.94	2.18c	0.27
Trails	18	0.00	0	0	0	0
Block Location						
Boundary Road*	90	95.56	56.89	3.31	3.70**	0.20
Interior Roads*	72	87.50	51.18	4.26	2.73**	0.20
Land Cover Type						
Agriculture Roads*	42	100.00	61.07	4.71	3.73**	0.21
Forest Roads*	120	89.17	52.00	3.15	3.11**	0.18

Letters indicate a significant difference ($P \leq 0.05$)
* Frequency, means, and Mann-Whitney rank sum test for block location and land cover calculated without trail data.
** Significantly different ($P \leq 0.05$)

Influence of Block Location

In the Panther Mountain FMB the boundary transects had significantly greater mean invasive species richness compared to the interior transects (Table 10). There was not a significant difference in the mean density of focal species when comparing the boundary transects to the interior transects. Of the four most abundant species, multiflora was the only species that occupied a significantly greater percentage of subplots in the boundary roads versus the interior roads (Table 11). The boundary road transects had a similar frequency and density of Garlic mustard, barberry, and honeysuckle to the interior road transects.

Influence of Land Cover

Agriculture transects had a significantly higher invasive species richness than forested transects (Table 10). The frequency and density of focal species in the two land cover types were similar. Multiflora rose was the only species that occupied a significantly higher percentage of subplots in agricultural transects than the forested ones (Table 11).

Table 11. Transect percent frequency (FRQ) and mean percent of subplots occupied ± S.E of garlic mustard, honey suckle, multiflora rose, and Japanese barberry by road class, block location and land cover.

	Garlic Mustard			Japanese Barberry			Multiflora Rose			Honey Suckle		
	FRQ	% SP	S.E.	FRQ	% SP	S.E.	FRQ	% SP	S.E.	FRQ	% SP	S.E.
Total	75.00	28.5	2.07	55.00	15.92	1.70	53.90	14.61	1.62	55.00	16.17	1.83
Road Class												
State Route 28	100.0	26.88a	4.07	56.25	6.88a	2.28	87.50	22.11a	5.53	87.50	40.31a	7.15
County Roads	85.84	34.20a	2.66	65.49	21.11a	2.40	61.95	15.80b	2.02	58.41	16.73b	2.24
Dead Ends	66.67	25.30a	5.07	48.48	11.21a	2.98	39.39	10.30b	3.89	3.30	11.36b	4.09
Trails	0	0	0	0	0	0	0	0	0	0	0	0
Block Location												
Boundary Roads*	88.89	30.05	2.65	61.11	16.50	2.30	66.67	18.89**	2.37	61.11	18.89	2.66
Interior Roads*	76.39	33.68	3.58	61.11	19.17	2.98	51.39	12.91**	2.57	48.61	16.80	3.00
Land Cover Type												
Agriculture Roads*	83.33	30.48	4.28	73.81	22.38	3.96	76.19	22.74**	3.76	64.29	16.67	2.85
Forest Roads*	72.46	32.08	2.53	49.28	16.04	2.04	47.10	13.95**	1.94	45.65	18.41	2.50

Letters indicate a significant difference ($P \leq 0.05$

* Frequency, means, and Mann-Whitney rank sum test for block location and land cover calculated without trail data.

** Significantly different ($P \leq 0.05$)

Distribution of Forest, Disturbed, Lawn/Agriculture, and Non-vegetated Cover

Adjacent to the road and trail transects in the field, the estimated mean percent of forested, disturbed, lawn/agriculture, and non-vegetated cover was not evenly distributed across the Panther Mountain FMB. State Route 28 transects had significantly less mean forest cover than county/town roads, dead end roads, and trails (Table 12). The trail transects had the greatest percentage of forest cover and no disturbed area cover. Additionally, the block boundary roads had significantly less forest cover and more disturbed cover than interior road transects. The forest land cover class transects identified using GIS were found to have significantly greater mean forest cover, and significantly less disturbed cover. However, the mean cover of disturbed area between the road and land cover type classes was not significantly different. The mean cover of unvegetated areas (primarily drive ways and parking areas) was significantly greater along State Route 28.

Table 12. Mean percent of forest, disturbed, lawn/agriculture, and unvegetated cover by road class, block location and land cover.

	Forest	S.E.	Disturbed	S.E.	Lawn - Agriculture	S.E.	Unvegetated	S.E.
Total	35.09	1.96	36.20	1.49	11.04	1.17	5.71	0.46
Road Class								
State Route 28	10.43a	4.46	43.85	5.41	26.00a	5.32	9.49a	2.08
County Roads	29.15b	1.63	40.50	1.41	11.92b	1.43	6.42ab	0.58
Dead Ends	38.52b	4.41	37.50	3.46	6.79b	2.11	4.57b	0.83
Trails	88.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Block Location								
Boundary Road*	23.07**	1.61	43.82**	1.66	15.31**	1.84	6.50	0.68
Interior Roads*	36.89**	2.76	35.73**	2.00	8.47**	1.56	6.14	0.71
Land Cover Type								
Agriculture Roads*	16.74**	2.18	40.07	2.79	26.65**	3.06	6.02	0.76
Forest Roads*	33.58**	1.88	40.27	1.49	7.24**	0.98	6.46	0.61

Letters indicate a significant difference ($P \leq 0.05$)

* Frequency, means, and Mann-Whitney rank sum test for block location and land cover calculated without trail data.

** Significantly different ($P \leq 0.05$)

Focal Invasive Plant Species Distribution

The invasive species index was used to integrate invasive species richness and the percent of subplots occupied by an invasive species present at a belt transect, and to depict invasive species hot spots within and surrounding the block. On the road system in the Panther Mountain FMB the focal invasive plant species were fairly evenly distributed as depicted by Figure 5 (See also Appendix B and C). Some notable exceptions are: 1) none of the focal invasive species were detected on the trails, 2) the southeast boundary of the FMB and dead end roads had lower invasive species index scores, and 3) the transects along Peakamoose Road, that bisects the FMB, had relatively moderate invasive species index scores compared to the block boundary transects.

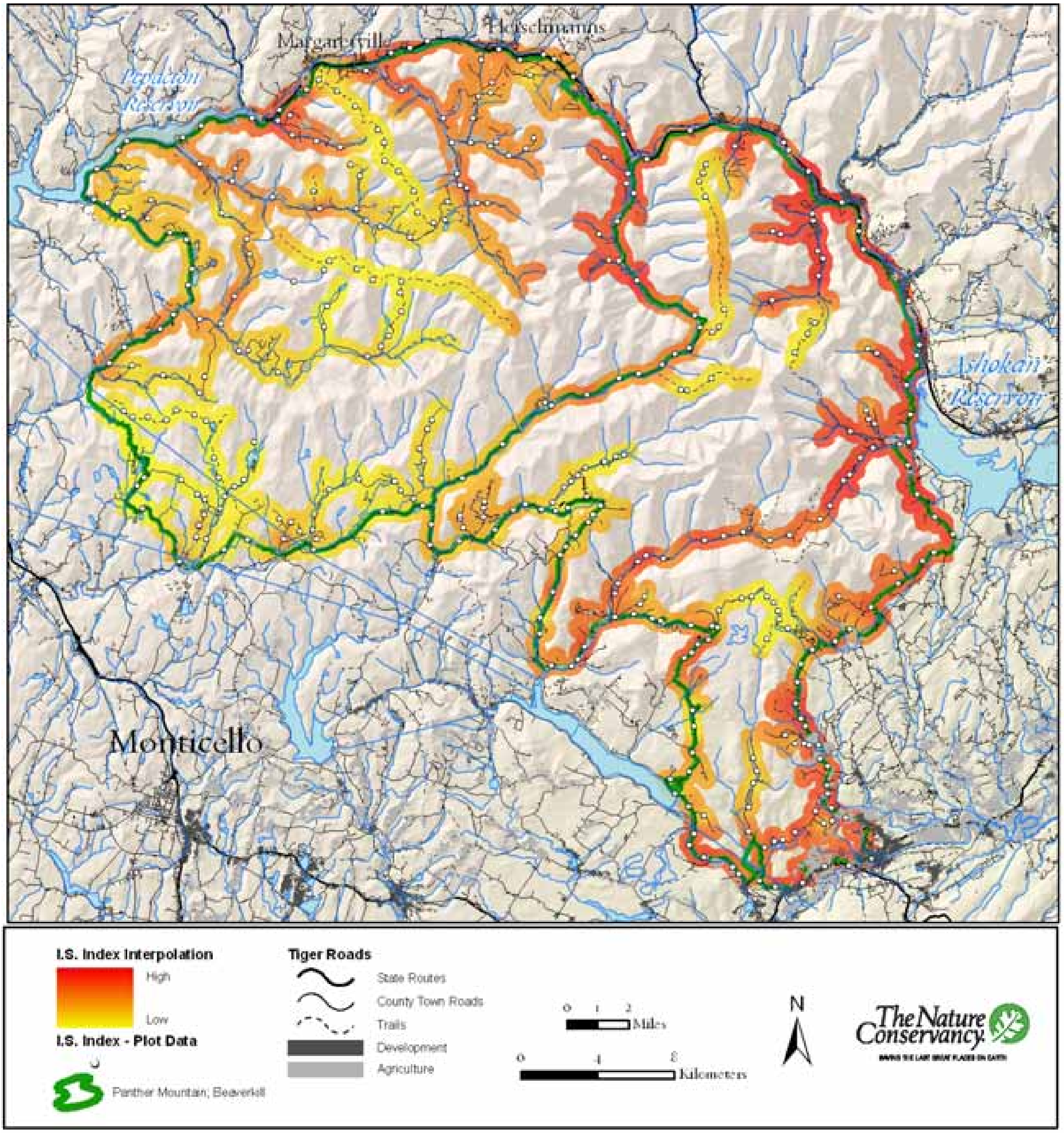

Figure 5. Distribution of invasive plant species in the Panther Mountain and Beaverkill forest matrix blocks in relation to the road class, developed, and agricultural areas. Invasive species distribution is depicted by invasive species index by point interpolation analysis. Invasive species index is the average of the relative percentage of the number of invasive species present in the .5km belt transect divided by 12 focal species, with the mean percent of subplots containing a focal species (See Methods section for further explanation).

Invasive Plant Species Predictive Model

The forward stepwise multiple regression determined that invasive species richness across the Panther Mountain FMB was best explained by road class, distance to all developed areas, the mean percent of forest cover along transects, and block location (Table 13). The three variables combined had a $R^2 = 0.527$ with a $P = < 0.001$. The best predictors of the percent of subplots occupied by a focal species ($R^2 = 0.402$) and the invasive species index ($R^2 = 0.481$) were the mean percent of forest cover along transects, distance to developed areas, road class, block location, and the mean % of lawn/agriculture cover along transects.

Table 13. Variables predicting invasive species richness, mean percent of subplots occupied by a focal species and invasive species index determined by forward stepwise multiple regressions.

Dependant Variable	Step	Independent Variables	R^2 cum.	P
Invasive Species Richness		Unchanged	0.000	
	1	Road class	0.378	< 0.001
	2	Distance to all development	0.480	< 0.001
	3	Mean % of forest cover along transect	0.511	< 0.001
	4	Block Location	0.527	0.015
		Model	0.527	< 0.001
Percent of Subplots		Unchanged	0.000	
	1	Mean % of forest cover along transect	0.279	< 0.001
	2	Distance to all development	0.323	< 0.001
	3	Road class	0.347	< 0.001
	4	Block Location	0.383	0.002
	5	Mean % of lawn/agriculture cover along transect	0.402	0.020
		Model	0.402	< 0.001
Invasive Species Index		Unchanged	0.000	
	1	Mean % of forest cover along transect	0.333	< 0.001
	2	Distance to all development	0.397	< 0.001
	3	Road class	0.436	< 0.001
	4	Block Location	0.468	0.001
	5	Mean % of lawn/agriculture cover along transect	0.481	0.043
		Model	0.481	< 0.001

For the four most frequent focal invasive species in the Panther Mountain FMB, the amount of variation explained by the variables ranged substantially (Table 14). The percent of subplots occupied by bush honeysuckle had the greatest amount of variation explained (R^2 = 0.273), followed by multiflora rose (R^2 = 0.222), garlic mustard (R^2 = 0.201), and Japanese barberry (R^2 = 0.061). The distribution of bush honeysuckle was best explained by the mean percent of forest cover along transects, the distance to developed areas > 1 acre, followed by distance to all agricultural areas, and the land cover type. Similarly, the distribution of multiflora rose was best explained by the percent of forest cover and the distance to developed areas > 1 acre. The percent of subplots occupied by garlic mustard was best predicted by the mean percent of forest cover along transects, followed by mean lawn/agriculture cover, and the number of houses along a transect. The percent of subplots occupied by Japanese barberry was best explained by the distance to all developed areas.

Table 14. Variables predicting the percent of subplot occupied by garlic mustard, bush honeysuckle, Japanese barberry, and multiflora rose determined by forward stepwise multiple regressions.

Dependant Variable	Step	Independent Variables	R^2 cum.	P
Garlic Mustard		Unchanged	0.000	
	1	Mean % of forest cover along transect	0.116	<0.001
	2	Mean % of lawn/agriculture cover along transect	0.158	<0.001
	3	Number of Houses along transect	0.201	0.002
		Model	0.201	<0.001
Japanese Barberry		Unchanged	0.000	
	1	Distance to all development	0.061	<0.001
		Model	0.061	<0.001
Multiflora Rose		Unchanged	0.000	
	1	Mean % of forest cover along transect	0.154	<0.001
	2	Distance to development >1 ac.	0.222	<0.001
		Model	0.222	<0.001
Honeysuckle		Unchanged	0.000	
	1	Mean % of forest cover along transect	0.156	<0.001
	2	Distance to development >1 ac.	0.207	<0.001
	3	Distance to all agriculture	0.252	0.003
	4	Landuse	0.273	0.026
		Model	0.273	<0.001

Threat Assessment
Garlic mustard, Japanese barberry, and Norway maple were determined to be the highest priority to abate the threat to forest ecosystems in the Panther Mountain FMB based on their current extent, impact to the system and the feasibility of control of the species (Table 8). See the Threats Assessment Discussion section (Chapter VIII) for an overview of justification for the rankings.

Table 15. An assessment of invasive plant species threat to North Hardwood forest ecosystem in the Panther Mountain forest matrix block. Lower values indicate a higher priority.

Species	Threat	Feasibility		Priority
	Impact	Extent	Control	Total
Norway maple	V. High/High?	6.1	High	V. High / High
Barberry	V. High/High?	55.0	High	High
Garlic mustard	V. High/High?	75.0	High	Medium
Honeysuckle spp.	Medium	50.0	High	Med. / Low
Bittersweet	Low ?	11.1	Medium	Med. / Low
Swallowwort spp.	Low ?	2.2	Medium	Med. / Low
Multiflora rose	Low	53.9	High	Low
Autumn olive	Low	3.9	High	Low / Med.
Buckthorn spp.	Low	6.7	High	Low / Med.

Panther Mountain Forest Matrix Block Conclusions
Garlic mustard, Japanese barberry, and bush honeysuckle were the only focal species found to be widespread throughout the road system, in and surrounding the Panther FMB. The remaining focal species were not evenly distributed across the road system in the block. Focal invasive species were found in the highest frequencies in the developed and agricultural areas along State Highways in the northern and southern boundaries of the FMB. For example Asiatic bittersweet was only found on the north, south and eastern boundary on the FMB and Norway maple was only detected along the state highways and along Woodland Valley Road in the northern portion of the block.

V – Beaverkill Forest Matrix Block Riparian Zone Inventory Results

In the Dry Brook, Beaverkill, Mongaup and Willowemoc watersheds 59 belt transects were sampled along low, moderate, and high stream corridors and 33.8% of those transects had at least one of the focal invasive species present. Seven of the twelve focal species were detected in at least one transect in one of the watersheds (Table 16). Norway maple, autumn olive, common reed, Asiatic bittersweet, and black swallowwort were not found in any of the transects.

Garlic mustard was the most frequent species present in all of the watersheds, with an overall frequency of 33.8%. In transects where garlic mustard occurred it was found in low densities, occupying an average of 13.1% of the subplots. Multiflora rose, bush honeysuckle, and barberry were the next most frequent species, found in 10.2%, 8.5%, and 6.8% of the transects respectively. The remaining species were found at relatively low frequencies. Four out of the five transects at which bush honeysuckle occupied were located in the Dry Brook watershed in the low gradient stream corridor. It ranged substantially in its density, occupying two to sixteen subplots out of twenty.

The frequency, richness, and density of focal invasive species varied between the watersheds and stream gradient classes. The Beaverkill and Dry Brook watersheds had the highest focal species frequency with 44.4% and 43.8% of the transects occupied by at least one invasive plant species respectively. The Dry Brook watershed had a higher richness of focal invasive plant species and a higher number of subplots occupied by focal species when compared to the other watersheds (Figure 6 and 7). Low gradient stream transects in the Dry Brook and Willowemoc watersheds had a higher frequency of focal invasive species in comparison with moderate gradient stream transects. No focal species were detected along the three high gradient stream transects sampled.

Table 16. The percent frequency of focal invasive species in the Dry Brook, Beaverkill, Mongaup, and Willowemoc watersheds by gradient class.

	Dry Brook			Beaverkill	Mongaup		Willowemoc			Grand
Grandient	Low	Mod.	Total	Mod.	Mod.	Total	Low	Mod.	Total	Total
Sample Size	4	11	16	9	10	12	13	9	22	59
Total Frequency	100.0	27.3	43.8	44.4	20.0	16.7	38.5	22.2	31.8	33.8
Garlic mustard	100.0	27.3	43.8	22.2	20.0	16.7	15.4	0.0	9.1	22.0
Bush honeysuckle	100.0	0.0	25.0	11.1	0.0	0.0	0.0	0.0	0.0	8.5
Barberry	50.0	9.1	18.8	0.0	0.0	0.0	0.0	11.1	4.5	6.8
Knotweed	0.0	0.0	0.0	11.1	10.0	8.3	7.7	0.0	4.5	5.1
Multiflora rose	75.0	0.0	18.8	0.0	10.0	8.3	7.7	11.1	9.1	10.2
Purple loosestrife	0.0	0.0	0.0	0.0	10.0	8.3	15.4	0.0	9.1	5.1
Buckthorn	25.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0	0.0	1.7

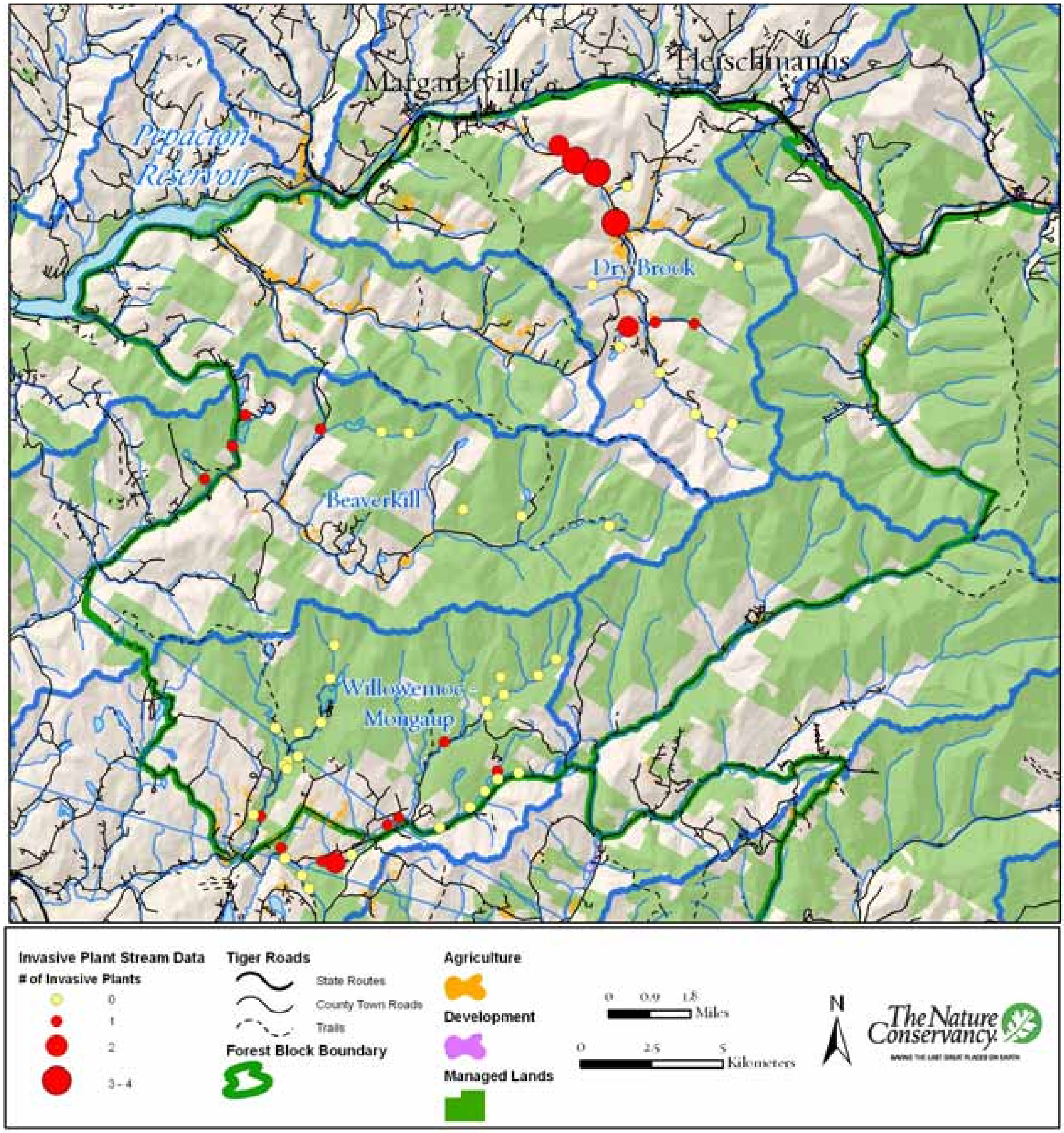

Figure 6. Focal invasive species richness in the Dry Brook, Beaverkill, Mongaup, and Willowemoc watersheds by gradient class.

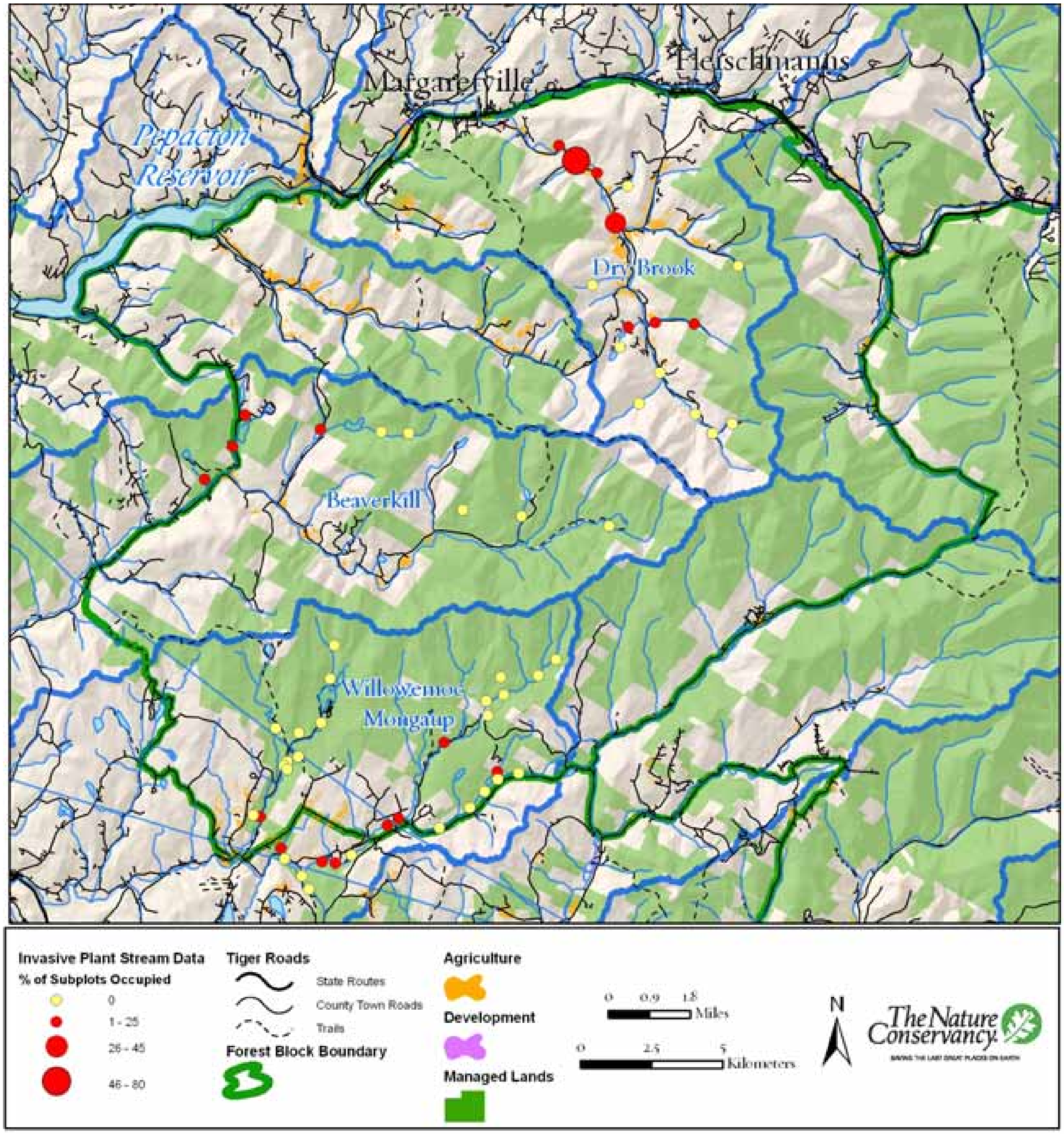

Figure 7. Percent of subplots occupied by focal invasive species in the Dry Brook, Beaverkill, Mongaup, and Willowemoc watersheds.

Riparian Ecosystem Threat Assessment
Japanese knotweed, garlic mustard, Norway maple, and bush honeysuckle were determined to be the highest priority to abate the threat to riparian ecosystems in the Beaverkill FMB based on their current extent, impact to the system and the feasibility of control of the species (Table 8). See the Threats Assessment Discussion section (Chapter VIII) for an overview of justification for the rankings.

Table 17. An assessment of invasive plant species threat to riparian ecosystems in the Beaverkill forest matrix block.

Species	Threat	Feasibility		Priority
	Impact	**Extent**	**Control**	**Total**
Knotweed	Very High / High?	5.1	Moderate	Mod. / High
Garlic mustard	Very High / High?	22.0	Moderate	Moderate
Norway maple	Very High / High?	0.0	Moderate	High
Bush honeysuckle	Very High / High?	8.5	Moderate	Moderate
Purple Loosestrife	Moderate?	5.1	Moderate	Moderate
Common Reed	Moderate?	0.0	Moderate	Moderate
Barberry	Moderate	6.8	Moderate	Moderate
Bittersweet	Moderate	0.0	Low	Moderate

VI – Invasive Species Distribution across the Forest Matrix Blocks

The focal invasive plant species were not evenly distributed across the two FMB.
The frequency, density, and richness of focal invasive plant species were great in the Panther Mountain FMB than in the Beaverkill FMB (Table 18). The mean percent of subplots occupied by a focal invasive plant species was 20% greater in the Panther Mountain FMB compared to the Beaverkill FMB.

All of the focal species were more frequent in the Panther Mountain FMB than in the Beaverkill FMB with the exception of buckthorn (Table 19). Asiatic bittersweet which was not detected in the Beaverkill FMB, was found in 11.1% of the belt transects in the Panther Mountain FMB. Garlic mustard, bush honeysuckle, Japanese barberry, and multiflora rose were the four most abundant species in both the Beaverkill and Panther Mountain FMBs. All four species occupied a greater mean number of subplots in the Panther Mountain FMB (Table 20). In the Panther Mountain FMB garlic mustard, Japanese barberry, and multiflora rose occupied greater than twice the mean number of subplots. These results indicate that the focal invasive plant species are more frequent and have a higher density in the Panther Mountain FMB than in the Beaverkill FMB.

Table 18. Percent frequency of focal species along transects, mean percent of subplots occupied by focal species ± S.E. and mean invasive species richness for transects for the Beaverkill and Panther Mountain forest matrix blocks.

	N	Percent Frequency	Percent of Subplots	S.E.	Invasive Richness	S.E.
Beaverkill	176	68.2	28.72	2.25	1.77	0.13
Panther Mountain	180	82.78	48.92	2.67	2.94	0.15

Table 19. The percent frequency of focal invasive species in the Beaverkill forest matrix block.

Focal Species	**Beaverkill % Frequency**	**Panther Mt. % Frequency**
Garlic mustard	49.4	75.0
Bush honeysuckle	45.5	50.0
Multiflora rose	31.3	53.9
Japanese barberry	25.0	55.0
Purple loosestrife	6.3	15.0
Common Reed	1.7	7.8
Japanese knotweed	5.7	7.8
Bittersweet	0.0	11.1
Swallowwort spp.	0.6	2.2
Norway maple	4.5	6.1
Autumn olive	5.1	3.9
Buckthorn spp.	0.6	6.7

Table 20. Transect percent frequency (FRQ) and mean percent of subplots occupied ± S.E of garlic mustard, honey suckle, multiflora rose, and Japanese barberry in the Beaverkill and Panther Mountain FMBs.

FMB	Garlic Mustard			Japanese Barberry			Multiflora Rose			Honey Suckle		
	FRQ	% SP	S.E.	FRQ	% SP	S.E.	FRQ	% SP	S.E.	FRQ	% SP	S.E.
Beaverkill	49.4	12.50	1.50	25.0	3.27	0.64	31.3	6.05	1.03	45.5	10.31	1.32
Panther	75.00	28.5	2.07	55.00	15.92	1.70	53.90	14.61	1.62	55.00	16.17	1.83

It is somewhat unclear what factors are responsible for producing a higher frequency and density of the focal invasive plant species in the Panther Mountain FMB. The forward stepwise regression analysis for the FMBs identified road class, distance to all developed areas, mean % of forest cover along the belt transects, and distance to agricultural areas > 10 acres as the factors that best predict the distribution of the focal species. A majority of these attributes are relatively similar in the Beaverkill and Panther Mountain FMBs. The FMBs are relatively the same size, consisting of 55,130 hectares (136,173 acres) and 49,378 hectares (122,016 acres) respectively. The Beaverkill FMB is 98% forested and the interior of the block contains 390 kilometers (242 miles) of roads and the Panther Mountain FMB has a forest cover of 98.5% and contains less interior roads at 314 kilometers (195.2 miles) (The Nature Conservancy 2003). The average forest cover along road transects in the Beaverkill FMB was approximately 36%, while the Panther Mountain FMB was found to have an average cover of 29%. The most notable difference between the two FMBs was distance to developed areas > 1 acre. The road and trail transects in the Panther Mountain FMB were on an average approximately 2000 meters closer to developed areas > 1 acre.

Table 21. The mean distance (meters) from transect point centers to the closest developed area, developed area > 1 acre, agricultural area, and agricultural area > 10 acres using National Land Cover Data in the Beaverkill and Panther Mountain FMBs. Mean distances were calculated using the entire data set and excluding the trail transects.

FMB		Dist. to all dev.	Dist. to dev. >1ac.	Dist. to all ag.	Dist. to ag. >10ac.
Panther Mt.	Trail	1418.3	2488.9	526.0	2127.1
Panther Mt.	No trail	1462.0	2618.6	487.0	1927.8
Beaverkill	Trail	1624.6	4764.9	566.1	1797.0
Beaverkill	No Trail	1442.8	4561.5	480.1	1592.9

The greater frequency, density, and richness of focal invasive plant species in the Panther Mountain Forest Matrix are potential due to its closer proximity to the large developed areas in the Hudson River Valley (See Figure 1). The transects on the eastern boundary of the Panther Mountain FMB (closest proximity to the Hudson Valley) have greater invasive species index scores (Figure 5). Asiatic bittersweet was only found on the eastern boundary of the Panther Mountain FMB (Appendix M). Additionally, Japanese barberry was found in greater a frequency and density along the eastern boundary of the Panther Mountain FMB (Appendix E).

VII - Predicting Invasive Plant Species Distribution

The forward stepwise regression analysis determined that road class and distance to all developed areas were the factors that best predicted the distribution of the focal species in both the Beaverkill and Panther Mountain FMBs. In the Panther Mountain FMB, the mean percent of forest cover along road and trail transects was the most important factor predicting focal invasive species density. Forest cover was not identified as a significant predictive factor in the Beaverkill FMB. Distance to agricultural areas > 10 acres was a significantly predictive factor in the Beaverkill FMB, but was not determined to be a significant factor in the Panther Mountain FMB, possibly due to the greater percentage of agricultural cover in the Beaverkill FMB. Based on National Land Cover Data the Beaverkill FMB has 2.0% agricultural cover as compared to 1.3% cover in the Panther Mountain FMB (The Nature Conservancy 2003).

The invasive plant species predictive factors identified for the Beaverkill and Panther Mountain FMBs are consistent with other studies in the region that found road class, forest cover, along with present and past land use to be the factors that most significantly influence the distribution of invasive plant species (Parendes and Jones 1999, Lundgren et al. 2004, Pauchard and Alaback 2004, Sadighi and Lowenstein in press). Additionally, the invasive species index map corroborates the results of the predictive models by depicting the central and south eastern portions of the FMBs with low index scores and relatively little developed and agricultural land cover.

Residential and commercially developed areas commonly serve as a source for invasive plant species distribution. In the Beaverkill FMB, proximity to a developed area was the most important variable explaining invasive plant species richness and density. In southern New England, areas with only one house per square kilometer had significantly greater invasive species cover and richness compared to areas with no houses (Lundgren et al. 2004). Developed areas often are an abundant source of invasive species, due to the influx of exotic species for landscaping (barberry, Norway maple, and purple loosestrife) and historical uses (garlic mustard). Additionally, the frequency and intensity of human disturbance within developed areas create ideal conditions for invasion. Developed areas in the Beaverkill block should be viewed as the primary locations for occurrences of new invasive plant species.

The significantly higher number and density of focal invasive species associated with the larger, well traveled roads in the Beaverkill and Panther Mountain FMBs can be partially explained by the human disturbance along roadsides. Human disturbance and vegetation management along roadsides often decrease forest cover and disturbs soil, altering the micro environmental factors such as light, moisture, and nutrient levels (Parendes and Jones 2000, Lundgren et al. 2004). In the FMBs, as the road size increased the percent of forest cover significantly decreased (Table 5 and 12). Additionally, the percent cover of disturbed habitat (i.e. power lines, road cuts, and successional fields) increased as the size of the road increased. Similarly, Parendes and Jones (2000) found that forest cover along U.S. Forest Service roads in the Pacific Northwest were significantly correlated with road size and exotic plant species richness. In the Panther Mountain FMB the average road side forest cover was the best predictor of the number of subplot occupied by an invasive plant species. Road side maintenance and vegetation management also often expose bare mineral soil, providing an opportunity for exotic plant invasion. Invasive plant species can often capitalize on these altered conditions and out-compete native species due to their high rate of reproduction and growth. Well traveled roads, with large maintained road sides, such as State Route 28, could be considered invasive plant species hot spots and may be facilitating the dispersal of invasive plant species into the interior of the FMBs.

The road system in and surrounding the FMBs may be acting as a corridor for invasive plant species distribution into uninvaded areas. How susceptible a location is to invasion is a combination of habitat condition (degree of disturbance) and its proximity to an abundant seed source (Hutchinson and Vankat 1997, With 2002). The road sides in the interior of FMBs are consistently disturbed by road maintenance and are connected to relatively large populations of numerous invasive species. Even dead end roads in the Beaverkill FMB were found to have a mean disturbed cover of 38% (Table 5). Invasive species seed can be dispersed throughout a road system by automobile tires, road maintenance equipment, and by edge dependant bird species (Parendes and Jones 2000). Due to these factors, invasive plant species will likely increase in their distribution along the road system. However, on the trails, the high percentage of forest cover and minimal disturbance may act as a barrier for particular invasive plant species and make establishment more difficult. In the FMBs, only three invasive species occurrences were detected along the trail transects (9%) and they all were found within close proximity to the trail head. Similar results were found along the Appalachian trail in the Berkshire-Taconic ridge, with 7% of plots sampled invaded by an invasive plant species (Sadighi, and Lowenstein in press). In the Quinebaug Highlands in southern New England, Japanese barberry was found in 30% of the sampled plots along trails (Lundgren et al. 2004). Invasive species seed may be distributed into interior forest areas through the soles of hiking boots, horses, ATVs, and the tires of logging equipment. While this study has shown that the trail system in the FMBs is relatively uninvaded, shade tolerant species such as garlic mustard, Japanese barberry, and Norway maple may be able to establish populations in forest interior areas through the road and trail system.

In the Beaverkill and Panther Mountain FMBs road transects within agricultural areas supported a significantly greater richness and density of invasive plant species (Table 3 and 10). Present and past land use has a considerable influence on the vegetation composition and structure of surrounding plant communities (Matlack 1994a, 1994b). Numerous studies have found that active and abandoned agricultural areas have greater richness and abundance of invasive species (Lundgren et al. 2004, Pauchard and Alaback 2004, Sadighi and Lowenstein in press). A consistent disturbance regime in fields, fence lines, and hedge rows, coupled with an abundant seed source, has led to the relatively high level of invasion within agricultural areas. Species such as multiflora rose and bush honeysuckle have been distributed by the U.S. Soil Conservation Service for soil erosion projects and as wildlife food sources (Eckardt 1987, Luken and Thierat 1995). Successional forests on past agricultural lands also have a higher frequency of invasive species when compared to similar forest types (Lundgren et al. 2004). The agricultural valleys that extend well into the interior of the Beaverkill FMB potentially are one of the primary vectors for invasive plant species distribution into uninvaded locations.

VIII - Threat Assessment Discussion

The threat of individual invasive plant species to forest and aquatic ecosystems in the Catskill Mountains is dependant on their abundance and distribution within a conservation planning area, the severity of their ecological impact, and the ease of control (Tu and Myers-Rice 2001, Morse et al. 2004). Japanese barberry, Norway maple, and garlic mustard were determined to be the highest threats to the forest ecosystem in the Beaverkill and Panther Mountain FMBs (Table 8 and 15). It was concluded that Japanese knotweed, purple loosestrife, and common reed present the greatest threat to riparian and wetland ecosystems respectively (Table 17).

The following discussion provides a partial summary of research conducted on the focal species that were determined to be a high threat to the forest and aquatic ecosystems in the Beaverkill and Panther Mountain FMBs. A wide range of research exists for many of these and other species, however for the purpose of this report we have primarily focused on discussing the ecological influence of the priority species.

Garlic Mustard

Garlic mustard was widespread on both road systems in and surrounding the FMBs. (See Appendix D for distribution map). It was the most frequently occurring focal species, found in approximately 60% of the road transects sampled in the Beaverkill FMB and approximately 83% of the road transects sampled in the Panther Mountain FMB. Additionally, it was the most frequency focal species in riparian areas in the Beaverkill FMB. However, the trails were relatively free of garlic mustard, found in only 2 of the 50 transects sampled. This indicates that garlic mustard currently occurs primarily on the road system and has not yet invaded the trail system. It distribution in interior forest areas adjacent to invaded road systems is currently unknown.

Garlic mustard possesses many properties that allow it to invade the forest understory and out-compete native vegetation. It is an herbaceous biennial that can tolerate a wide range of light and moisture levels (McCarthy 1997, Nuzzo 1999, Meekins and McCarthy 2002). Its growth and reproduction is greatest in areas with high soil moisture and high light levels (Meekins and McCarthy 2002). The rapid spread of garlic mustard is primarily associated with small scale disturbances that expose mineral soil. It has been found in high densities in floodplain ecosystems where disturbance from flooding is a frequent event (McCarthy 1997). Conversely in the Midwest, garlic mustard has been found to spread through mature high quality upland forest (Nuzzo 1999).

Garlic mustard out-competes some native plant species (McCarthy 1997, Meekins and McCarthy 1999). In a greenhouse experiment, garlic mustard suppressed the growth of box elder (*Acer negundo*) and chestnut oak (*Quercus prinus*) at densities comparable to a typical invasion (Meekins and McCarthy 1999). A three-year removal experiment in a floodplain forest in Maryland found that species richness was significantly higher in removal areas compared to paired control areas (McCarthy 1997). Annual species, tree seedlings and vines showed the greatest increase in the removal plots. The potential allelopathic properties of garlic mustard may further aid its competitive abilities (Roberts and Anderson 2001).

Given the widespread distribution of garlic mustard on the road system in the FMBs and its high potential impact on forest ecosystems, management strategies should prevent the spread of garlic mustard into the forest interior. Future inventory and control efforts should focus on areas in the forest interior that have frequent soil disturbance (i.e. trails, logging roads, and stream corridors).

Japanese Barberry

Japanese barberry was found in a greater frequency and density in the Panther Mountain FMB (See Appendix E for a distribution map). In the Beaverkill FMB it primarily occurring on exterior road transects and near developed areas. Sixty percent of transects along State Route 28 had barberry present, but only an average of 5% of the subplots were occupied by the species. Barberry was only present in 18% of transects along the interior road transects. However, in the Panther Mountain FMB barberry was twice as frequent and had a mean density that was five times greater than that found in the Beaverkill FMB. In the Berkshire-Taconic and Quinebaug Highlands invasive species inventories, Japanese barberry was the most frequently detected species (Sadighi and Lowenstein in press, Lungren et al. 2004).

Japanese barberry is a high threat to the forest ecosystems in the Catskills due to its ability to invade forest understories and out-compete native vegetation. Barberry is bird dispersed and can tolerate a wide range of light and moisture conditions (Silander and Klepeis 1999). Barberry populations primarily expand from a parent plant, however seedlings have been found at distances greater than 50 meters from the source population. Once established, barberry can maintain positive growth and seed production at low light levels (4% of daylight) (Ehrenfeld 1999, Silander and Klepeis 1999). Currently, there is limited information on the influence of barberry on forest system composition, structure, and function. A study in Connecticut found that high infestations of barberry suppress the growth of co-occurring species (Silander and Klepeis 1999). A study in New Jersey found that forest sites invaded by barberry were lacking the presence of a common understory shrub and had soil pH levels that were significantly higher than an adjacent uninvaded forest (Koutev et al. 1999). Additionally, an established population of Japanese barberry can have a negative impact on the microbial community in the soil (Kourtev et al. 2002).

The limited extent of barberry on the road system in the Beaverkill FMB, coupled with its potential high ecological impact indicated that control strategies should be developed. The present distribution of barberry in the FMBs precludes complete eradiation; however the species should be contained and prevented from spreading into forest interior areas.

Norway Maple

Norway maple occurred in 19 of the 356 belt transects sampled. The five largest populations were found on State Route 28 near Arkville, Margaretville, and Phoenicia and along Woodland Valley Road (See Appendix F for a distribution map). Norway maple is shade tolerant and has the ability to invade and reproduce in the low light levels characteristic of forest understories (Wyckoff and Webb 1996). In an 18-ha forest patch in New Jersey, Norway maple comprised 26% of the stem density and was present in all size classes (Wyckoff and Webb 1996). Understory species richness was significantly less under a Norway maple forest canopy. This study suggests that Norway maple influences the diversity, structure, and composition of small forest patches. The current frequency of Norway maple in the FMBs and its potential impact on forest diversity and structure suggest that a control strategy should be developed.

Bush Honeysuckle

Bush honeysuckle was found in approximately half of the road transects in the FMBs and was the second most frequency species in riparian areas in the Beaverkill FMB (See Appendix G for a distribution map). Bush honeysuckle is moderately shade tolerant and often occurs in forests with histories of fragmentation, woodcutting, and grazing and along stream corridors (Luken and Thierat 1995). Distance to developed areas and the mean percent of forest cover in the belt transect were significant predictors of bush honeysuckle. Likewise, a southwestern Ohio study also found that forest canopy cover and distance to the nearest town were the best predictors of the distribution of honeysuckle (Hutchins and Vankat 1997). Forest light levels and distance to a seed source appear to increase the susceptibly of a forest patch to honeysuckle invasion (Hutchins and Vankat 1997).

High densities of bush honeysuckle negatively influence tree seedlings and the herbaceous layer by reducing tree seedling density, tree species richness, and herbaceous cover (Hutchins and Vankat 1997). Similarly, on mesic nutrient rich sites in southern Vermont, total herbaceous cover and richness, and the density of tree seedlings were significantly lower in areas with high bush honeysuckle cover, while on nutrient poor dry sites no relationship was observed (Woods 2005).

The wide distribution of bush honeysuckle on the road system in the FMBs coupled with its ability to invade disturbed forest and its potential ecological impact suggest that future management strategies should minimize the spread of this species, particularly along low gradient stream corridors. Mesic forest and low gradient stream corridors that have experienced a reduction in the forest canopy and that are in or near infested areas are the most likely locations for invasion.

Multiflora Rose

Multiflora rose was found primarily in agricultural areas in the FMBs and the ecological impact on the forest system in the Catskills is believed to be moderate to low (See Appendix H for a distribution map). The percent of subplots occupied by multiflora rose was significantly greater in the agriculture transect when compared to forested transects. Forest cover was the best predictor of the presence of multiflora rose. It can be extremely prolific, creating dense thickets, and in some areas taking over entire pastures (Eckardt 1987). While it rarely invades forest understories, at high densities it is a threat to the reforestation of successional fields.

Swallowwort and Asiatic Bittersweet

Swallowwort occurred in only four of the 356 transects sampled in the FMBs. Asiatic bittersweet was only found in the Panther Mountain FMB, occurring in 20 of the 180 transects sampled. Both species are climbing vines that have rapid growth rates and can reduce plant diversity (See Appendix I for a distribution map) (Dreyer 2005). Upland meadows, road sides, disturbed forest, and potential floodplain forest are the most susceptible to invasions. In dense infestations, swallowwort and bittersweet can overtop entire plant communities with vegetative growth. Bittersweet has been a concern of forestry programs in the southeastern United States where road sides are covered by the species (McNab and Meeker 1987). In the FMBs, an effort should be made to detect any new infestations of these species and eradicating any present or new infestations.

Purple loosestrife and Common Reed
Purple loosestrife and common reed invade wetland ecosystems, altering ecosystem processes and negatively impacting native vegetation (See Appendix K, and L for distribution maps). Their current low frequency but high potential ecological impact resulted in a priority ranking.

Purple loosestrife is currently not widespread along road sides in the FMBs (see Appendix I for a distribution map); it was only detected in 38 of the 356 transects sampled and approximately half of these sites were located along State Route 28. Originally from Eurasia, purple loosestrife has spread extensively throughout the northeast U.S. and Canada. Since its establishment in the early 1800s, purple loosestrife has altered wetland hydrology and nutrient cycling, displaced native wetland species, and provided poor habitat for animals (Thompson et al. 1987). Control efforts should immediately address the current populations and high priority wetland areas should be survey for the presence of the species.

Common reed occurred 14 transect in the Beaverkill and Panther FMBs. Common reed can occur in undisturbed habitats, but is most common in roadside ditches, disturbed wetlands, and disturbed soil (Marks et al. 1993). It can reproduce vegetatively and from seed. Once a new population takes hold, it spreads vegetatively, forming dense monospecific stands, changing vegetation structure, composition, and altering wildlife habitat. Future management strategies should remove any common reed populations in and surrounding the block and focus on early detection of any new populations.

Japanese Knotweed
Japanese knotweed was found in 21 road transects the Beaverkill and Panther Mountain FMBs, with approximately half of them along State Route 28 (See appendix H for a distribution map). It was encountered in 3 of the 59 stream side transects sampled in four watershed in the Beaverkill FMB. Qualitative observations suggest that knotweed has a greater distribution than the road and stream side transects indicate. In the Beaverkill watershed a drive-by knotweed inventory was conducted of the stream corridor that was visible from the road side. Along Beaverkill and Alder road 22 distinct knotweed patches were identified. A majority of patches were small ($<10\ m^2$), but two patches were estimated to be $>300\ m^2$ (Appendix O).

Japanese knotweed can spread rapidly, due to its ability to vegetatively reproduce with as small as a ½-inch fragment establishing new colonies along road sides and streams (Seiger 1991). Studies suggest that knotweed is shade intolerant, is unable to invade forest understories, and is primarily found in open habitats (Seiger 1991). Heavy infestations of knotweed along river banks can result in the loss of wildlife habitat, decrease species diversity, and reduce water carrying capacity in rivers (Sieger and Merchant 1997).

Future control efforts should focus on eliminating up stream occurrences and preventing new infestations in high priority watersheds.

VIIII - Limitations of the Study

The distribution of purple loosestrife and common reed along roads and trails in the Beaverkill and Panther FMBs are likely limited by soil moisture. They are classified by the USDA Plants Database (2005) as having a facultative wetland indicator status. This may have influenced the results of the comparative analysis and forward stepwise regression in our study. However, purple loosestrife and common reed were included in the analysis of the distribution of the invasive plant species to depict the complete range and abundance of invasive plant species across the FMBs. A majority of the purple loosestrife and common reed occurrences were located in roadside drainage ditches (personal observation). These ditches were found along all road types within the FMBs (personal observation). Additionally, the 38 transects in which purple loosestrife occurred were evenly distributed between State Route 28 and the interior county/town roads. The presence of artificially created wetland habitat across the road system provides some indication that purple loosestrife and common reed have the potential to be distributed across the entire road system, and so may be included in the analysis.

Past land use was not included in the invasive plant species predictive modeling. In the Quinebaug Highlands, Lungren et al. (2004) used historical aerial photographs to determine that past land use was the most important factor predicting invasive species richness and cover. Past land use was not included in this study due to the time intensive nature of interpreting past land use from aerial photographs for a 130,000 acre area. However, a more focused analysis of the land use history of invaded areas could be included in future studies.

Additionally, environmental variables such as soil data and elevation were not included in the invasive plant species predictive modeling, because of the lack of data and their relationship with the distribution of the land use variables. Digital soil data was not available for the Catskills at the time of this project. Elevation was not included in the predictive modeling because of its relationship with the distribution of agricultural and developed areas. These land use types were clustered at the lower elevations, with approximately 80% of their area in the Beaverkill FMB falling bellow 600 m (1,800 ft.). The inclusion of both the land use variables and elevation was precluded due to the relationship in their distribution. It is believed that current land use and disturbance factors are more important in predicting the distribution of invasive plant species than environmental variables. However, the distribution of particular invasive plant species could be limited by environmental variables such as soil conditions and elevation.

X - Future Inventory and Research Recommendations

Future inventory efforts should focus on: 1) developing a comprehensive early detection program, 2) surveying for the focal invasive plant species in the high priority areas within the four additional FMBs, 3) surveying additional high priority stream corridors for high threat species, and 4) surveying wetland communities for purple loosestrife and common reed. Research efforts should focus on determining if high threat species (garlic mustard, Norway maple, Japanese barberry) to the Northern Hardwood Forest System are invading the forest interior. Potential research question are: 1) under what conditions are the high threat species invading the forest interior (site variables and disturbance history), 2) how far are the high threat species invading into the forest interior from the forest edge, and 3) is the density of the species along the road corridor a predictive factor in a successful invasion into a interior forest area?

XI - Management Recommendations

Control strategies in the Beaverkill and Panther block should focus on the three forest and three aquatic high threat species. The limited extent of Norway maple, purple loosestrife, common reed, and Japanese knotweed, coupled with their potential high ecological impact, indicate that these species should be prevented from expanding their distribution. Garlic mustard and Japanese barberry are widespread throughout the road system; therefore control efforts should focus on preventing their expansion into interior forest areas and into the southeast portion of the Beaverkill Block. The low frequency of Asiatic bittersweet and black swallowwort in the FMBs, in conjunction with their ability to spread rapidly indicated that strategies should be developed to prevent new population from establishing in the FMBs. To accomplish these objectives prevention, early detection and rapid response, and control strategies should be developed.

Prevention Strategies

The development a comprehensive education and outreach program is needed to prevent the spread of high threat species and the establishment of new invasive plant species not yet present in the Catskills. Education materials should be developed for specific target audiences that correspond to potential invasive plant species vectors. Some examples are: 1) New York State Department of Transportation (DOT), 2) county and town road maintenance crews, 3) forest and natural resource managers, and 4) plant nurseries within the Catskills. For example, Japanese knotweed is believed to be spread by fill material that is used for road and building construction. Working with NYS DOT and county/town road departments best management practices can be developed and implement to prevent of spread of knotweed. Another example would be to work with natural resources managers and foresters to prevent garlic mustard from spreading into interior forest areas via skid roads and log landings, for garlic mustard spreads rapidly in areas with soil disturbances. Lastly, working with local plant nurseries could prevent the establishment of new populations of Norway maple and Japanese barberry by discontinuing their sale in the Catskills.

Early Detection and Rapid Response

An early detection program to detect and eradicate new infestations of high threat species in the forest interior and new invasive plant species to the Catskills such as Japanese stiltgrass (*Microstegium vimineum*) and mile-a-minute vine (*Polygonuum perfoliatum*) should be established. Currently, a volunteer based survey for garlic mustard at 40 trail heads and associated trails in the six FMBs is underway. Within the FMBS Norway maple, purple loosestrife, common reed, Japanese knotweed, Asiatic bittersweet and black swallowwort should be considered early detection species.

Control Strategies

Based on the Beaverkill and Panther Mountain FMB inventory results the following control strategies have been developed:

1. Establish a "weed prevention area" (WPA) in the south-central portion of the Beaverkill Forest Matrix Block (See Figure 5). The "weed prevention area" concept has been developed and implemented with success by the Long Island Invasive Species Management Area. The WPAs are strategically located within high priority conservation areas, which have relatively few infestations that are fairly small and quite manageable. The southeast portion of the Beaverkill FMB had a low frequency and density of the high threat invasive plant species.

2. Eradiate Japanese knotweed in the upper portions of the Beaverkill and Willowemoc watersheds. The Beaverkill and Willowemoc stream systems flow into the Delaware River, which is the largest undammed river east of the Mississippi. Additionally, the Beaverkill contains a number of ecoregionally important fish species (The Nature Conservancy 2003). Given the high ecological importance of the Beaverkill river system coupled with the estimated high threat and low frequency of Japanese knotweed, a strategy to eradicate knotweed in the upper portions of these watershed is both ecologically significant and feasible.

XII - Conclusions

Six of the twelve focal invasive plant species were determined to present a high threat to the forest and aquatic systems in the Beaverkill and Panther Mountain FMBs. Garlic mustard was widespread throughout the road system, while the remaining five high threat species were generally found in moderate to low frequencies in the FMBs.

The frequency and density of focal invasive species varied, as did their distribution patterns across the FMBs. State Route 28 and exterior county/town roads supported a greater richness and higher density of invasive species than interior roads and trails. In addition, roads that supported a higher forest cover had lower densities and richness of focal invasive species. The distribution of focal invasive species was best predicted by the proximity to developed areas, percent of forest cover adjacent to the road/trail, large agricultural fields, and the size of the road. Developed areas, large agricultural fields, and larger paved state and county roads are potential invasive plant species vectors from which high threat species could spread into the non-invaded portions of the FMBs.

Current populations of the high threat invasive plant species should be completely eradicated when possible or prevented from spreading into uninvaded areas. With adequate funding an invasive species management program can abate the threat of invasive plant species on the forest and aquatic ecosystems in the Beaverkill and Panther FMBs.

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APPENDIX A. CATSKILLS INVASIVE SPECIES INVENTORY DATASHEET

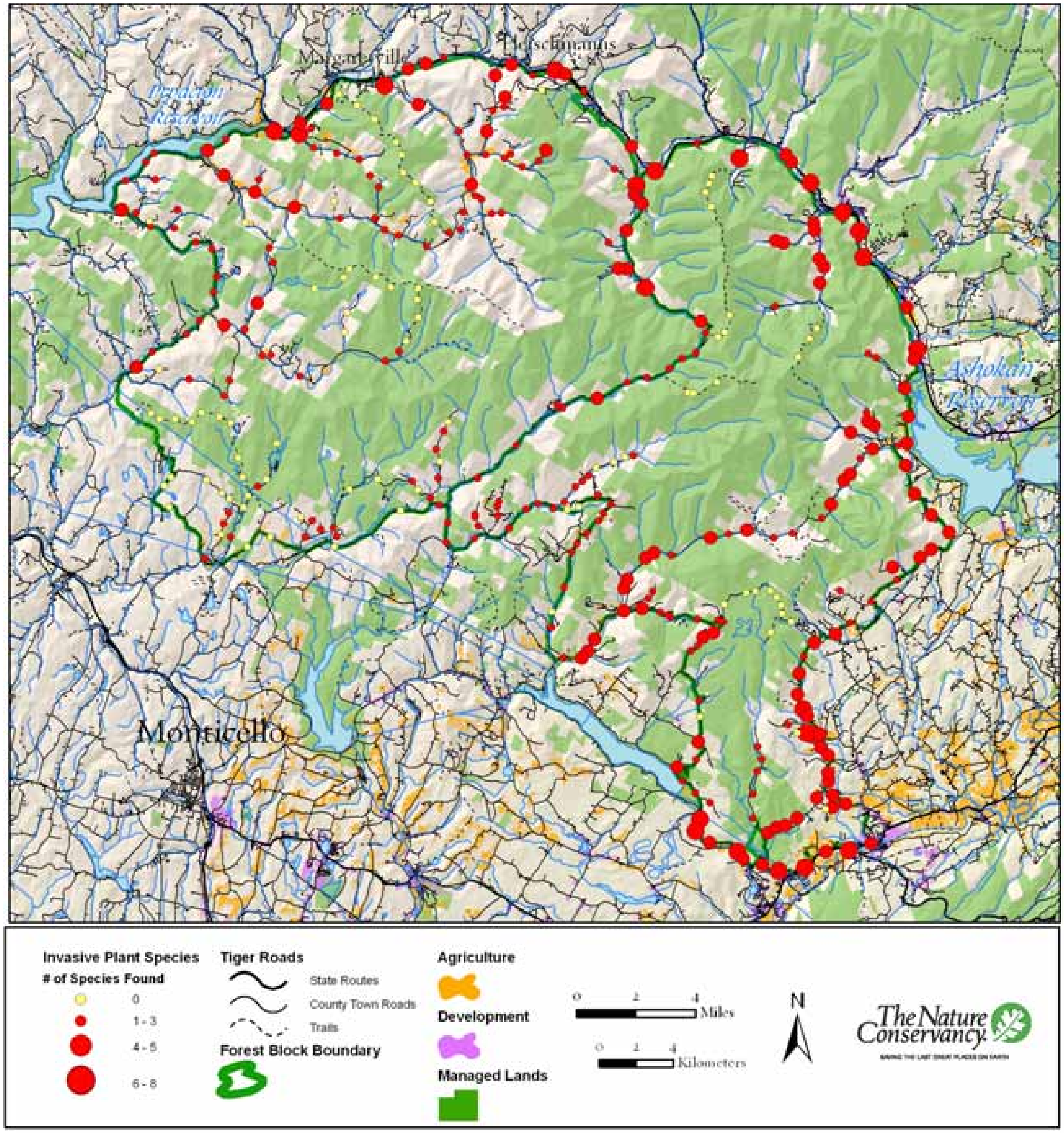
Group #: _____________ **Observer(s):**_______________________ _________
Date: ________________ **Coordinates:** _____________N _____________W
Transcect #: ___________ **Location:** ___________________________________

___________________ side of road _______________________										
Focal Species	**250m**	**200m**	**150m**	**100m**	**50m**	**50m**	**100m**	**150m**	**200m**	**250m**
Forested Area										
Disturbed Area										
Unvegetated Area										
Lawn/Agriculture										
autumn olive										
bittersweet										
black swallowwort										
bush honeysuckle										
garlic mustard										
Japanese barberry										
Japanese knotweed										
Norway maple										
multiflora rose										
phragmities										
purple loosestrife										
common buckthorn										
glossy buckthorn										

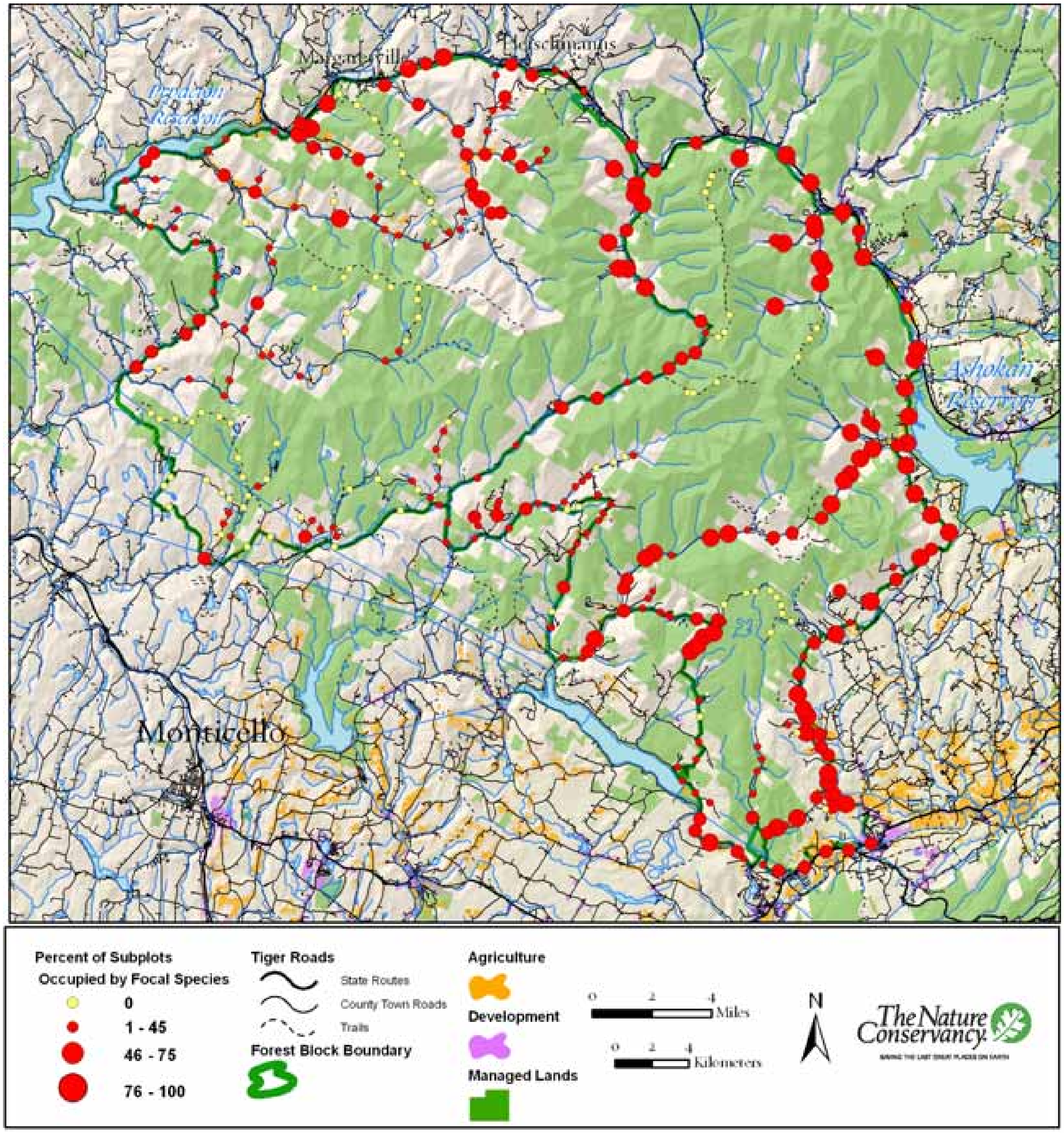
___________________ side of road _______________________										
Focal Species	**250m**	**200m**	**150m**	**100m**	**50m**	**50m**	**100m**	**150m**	**200m**	**250m**
Forested Area										
Disturbed Area										
Unvegetated Area										
Lawn/Agriculture										
autumn olive										
bittersweet										
black swallowwort										
bush honeysuckle										
garlic mustard										
Japanese barberry										
Japanese knotweed										
Norway maple										
multiflora rose										
phragmities										
purple loosestrife										
common buckthorn										
glossy buckthorn										

Cover classes: 0 = 0% 1 = .1% - 25% 2 = 26% - 50% 3 = 51% - 75% 4 = 76% - 100%
Presence of invasives: d = disturbed

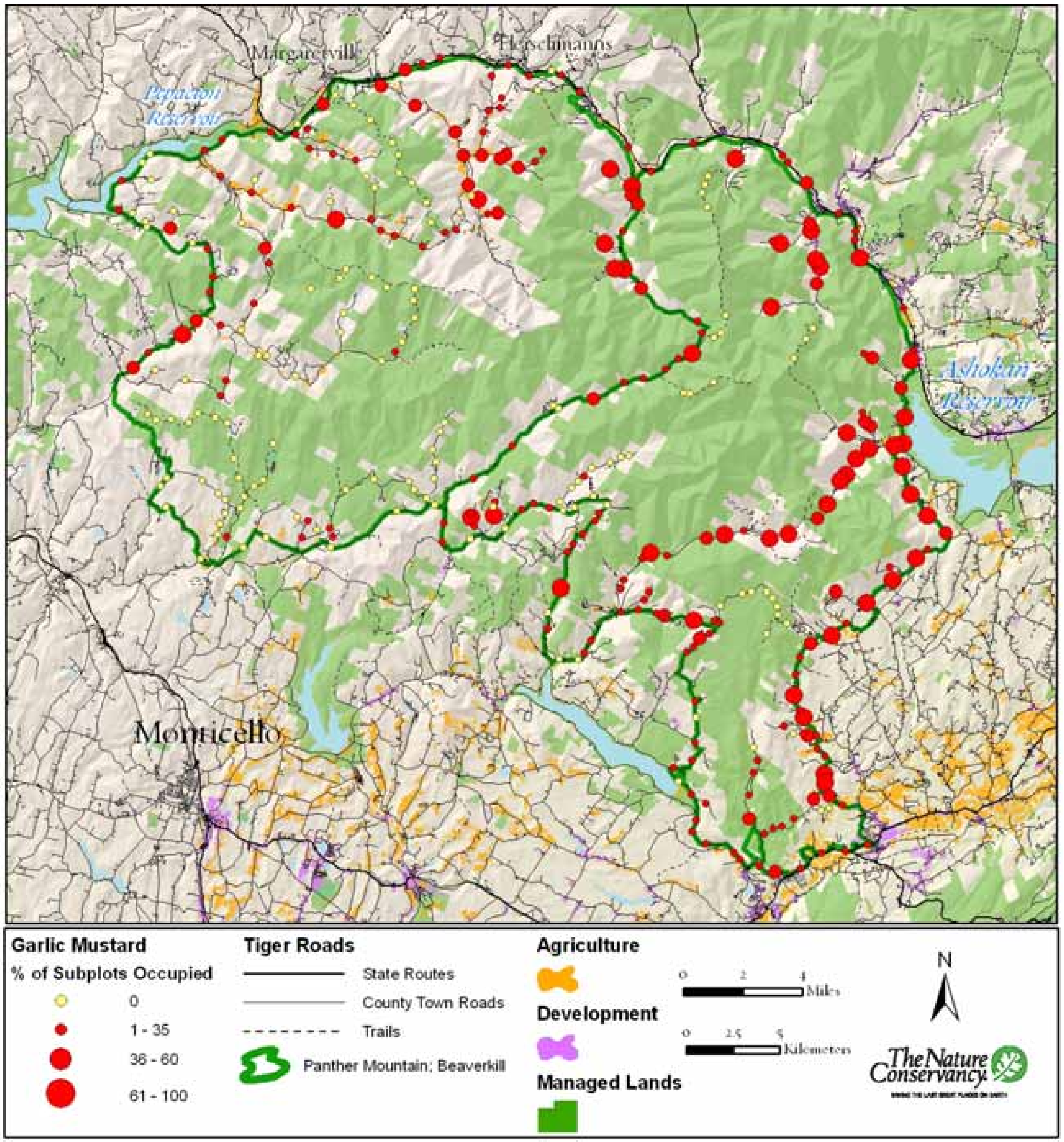
APPENDIX B. NUMBER OF INVASIVE SPECIES FOUND IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



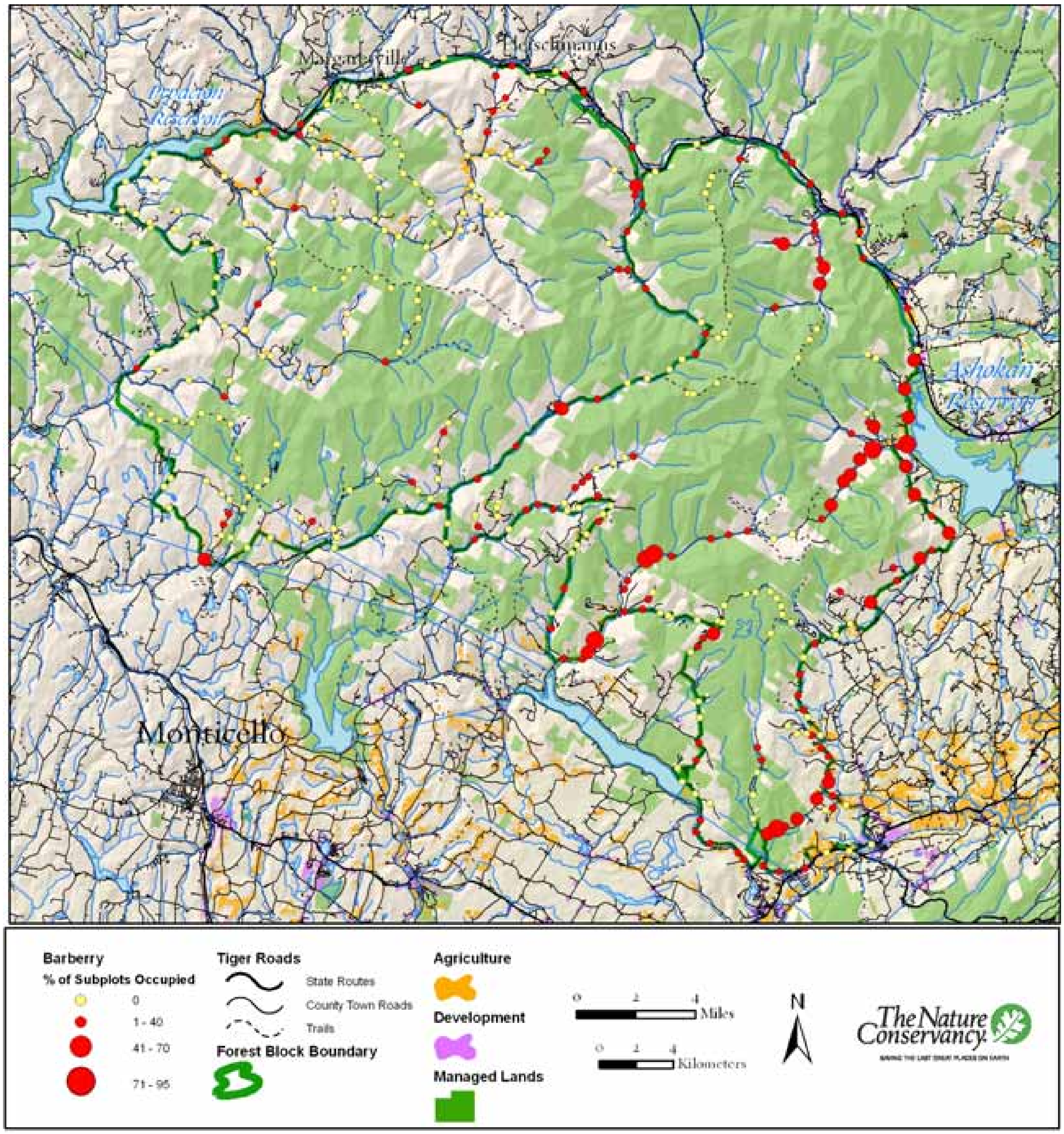
APPENDIX C. PERCENT OF SUBPLOTS OCCUPIED BY A FOCAL SPECIES IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



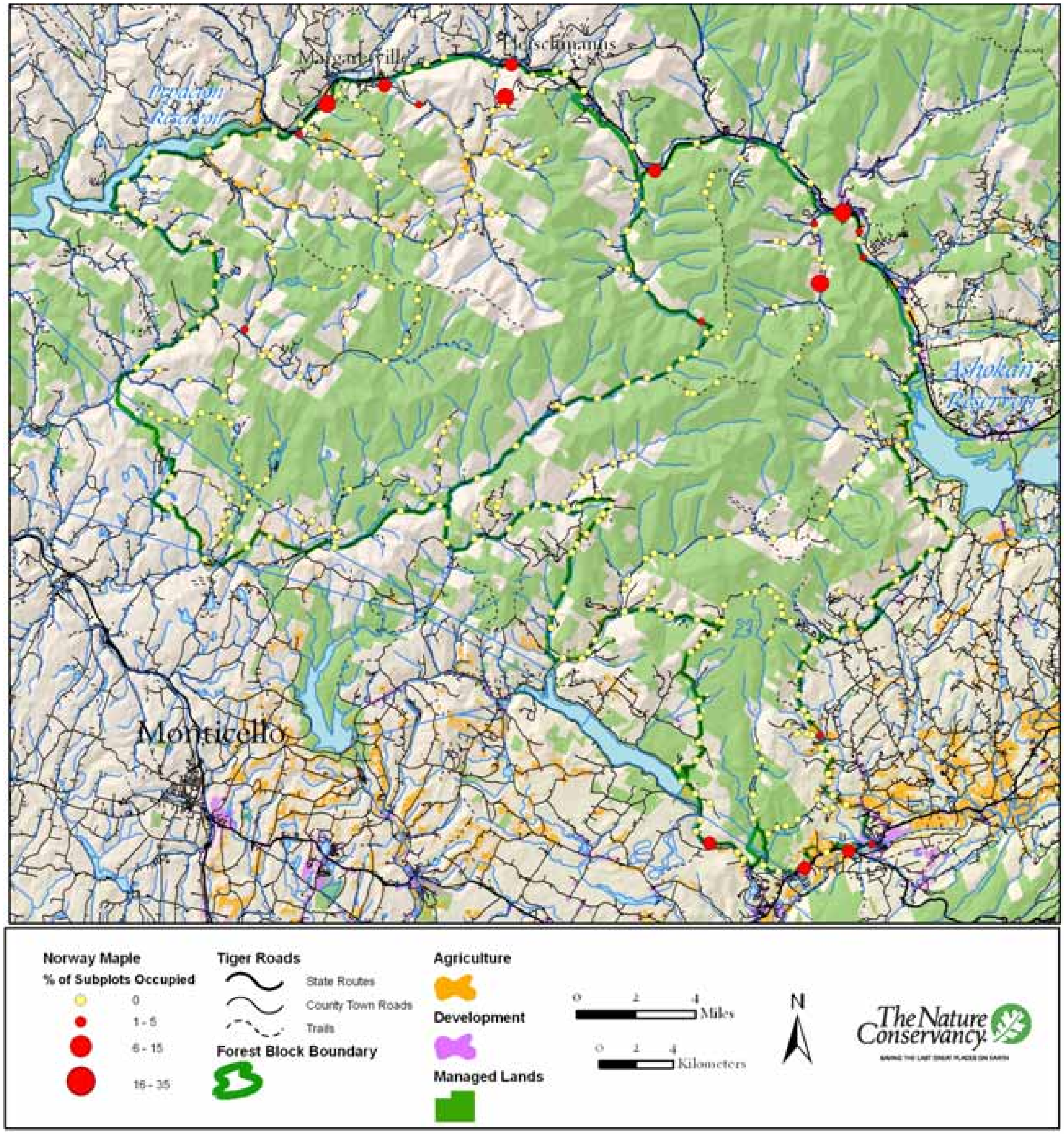
APPENDIX D. DISTRIBUTION OF GARLIC MUSTARD IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



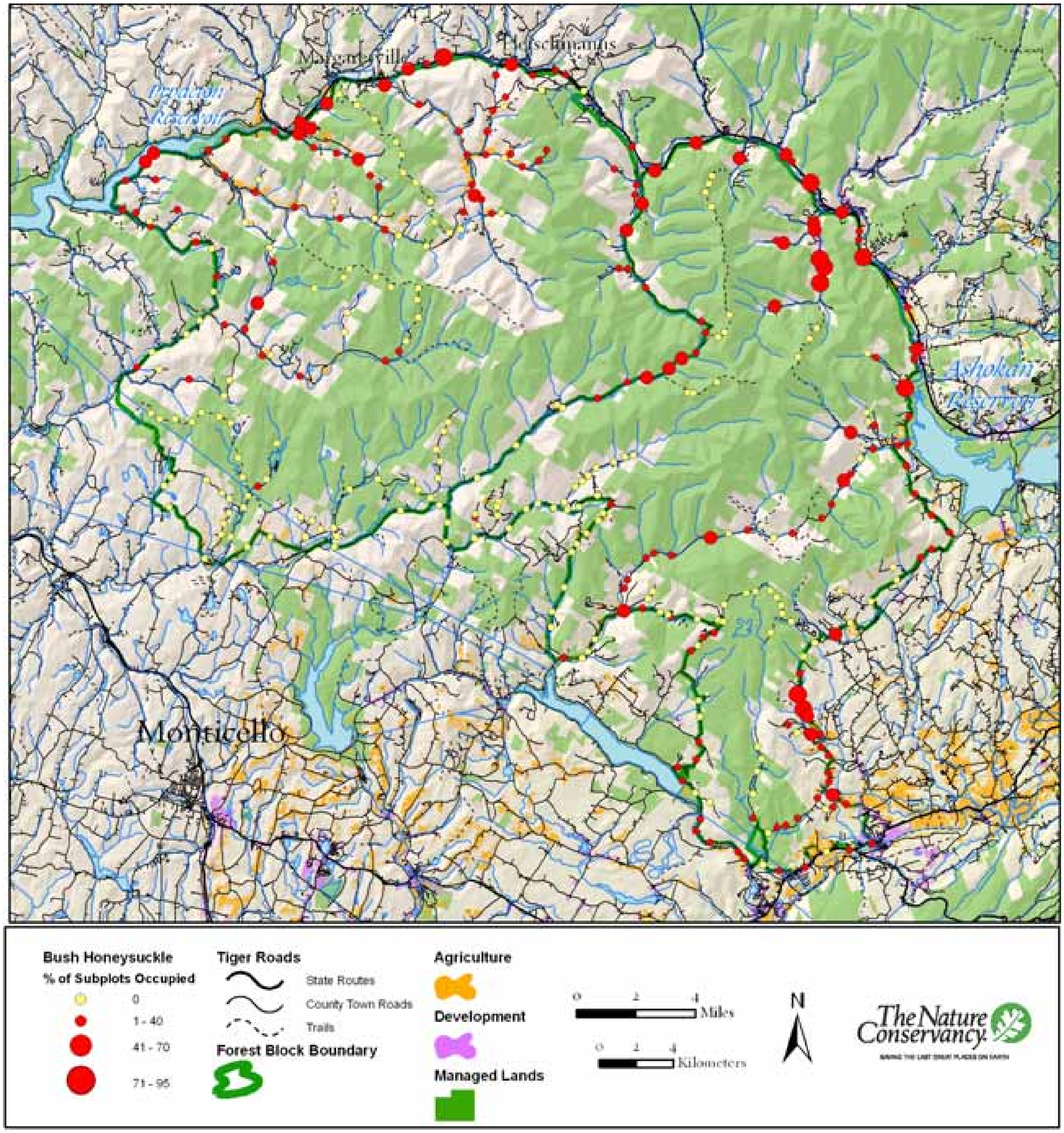
APPENDIX E. DISTRIBUTION OF JAPANESE BARBERRY IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



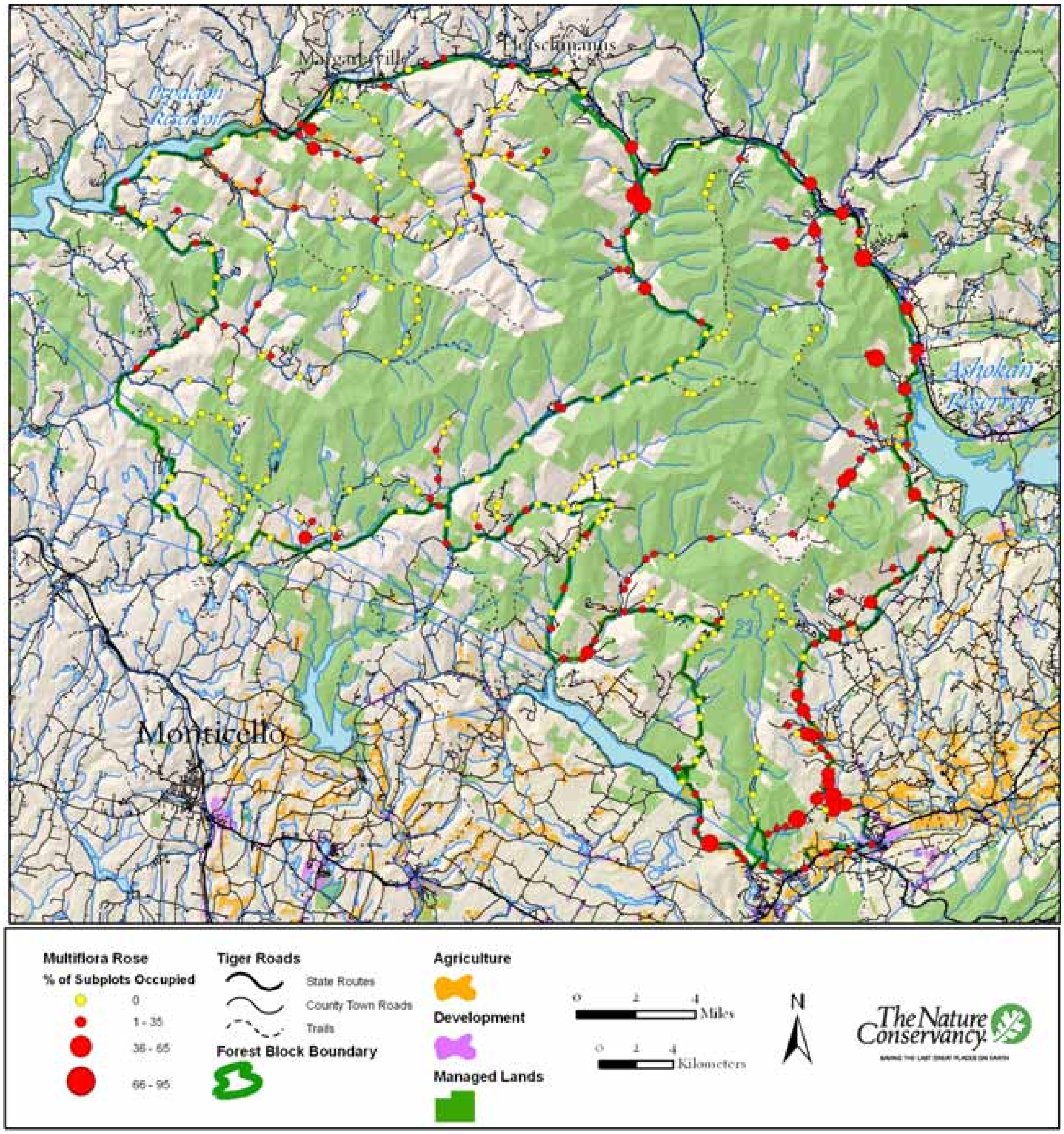
APPENDIX F. DISTRIBUTION OF NORWAY MAPLE IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



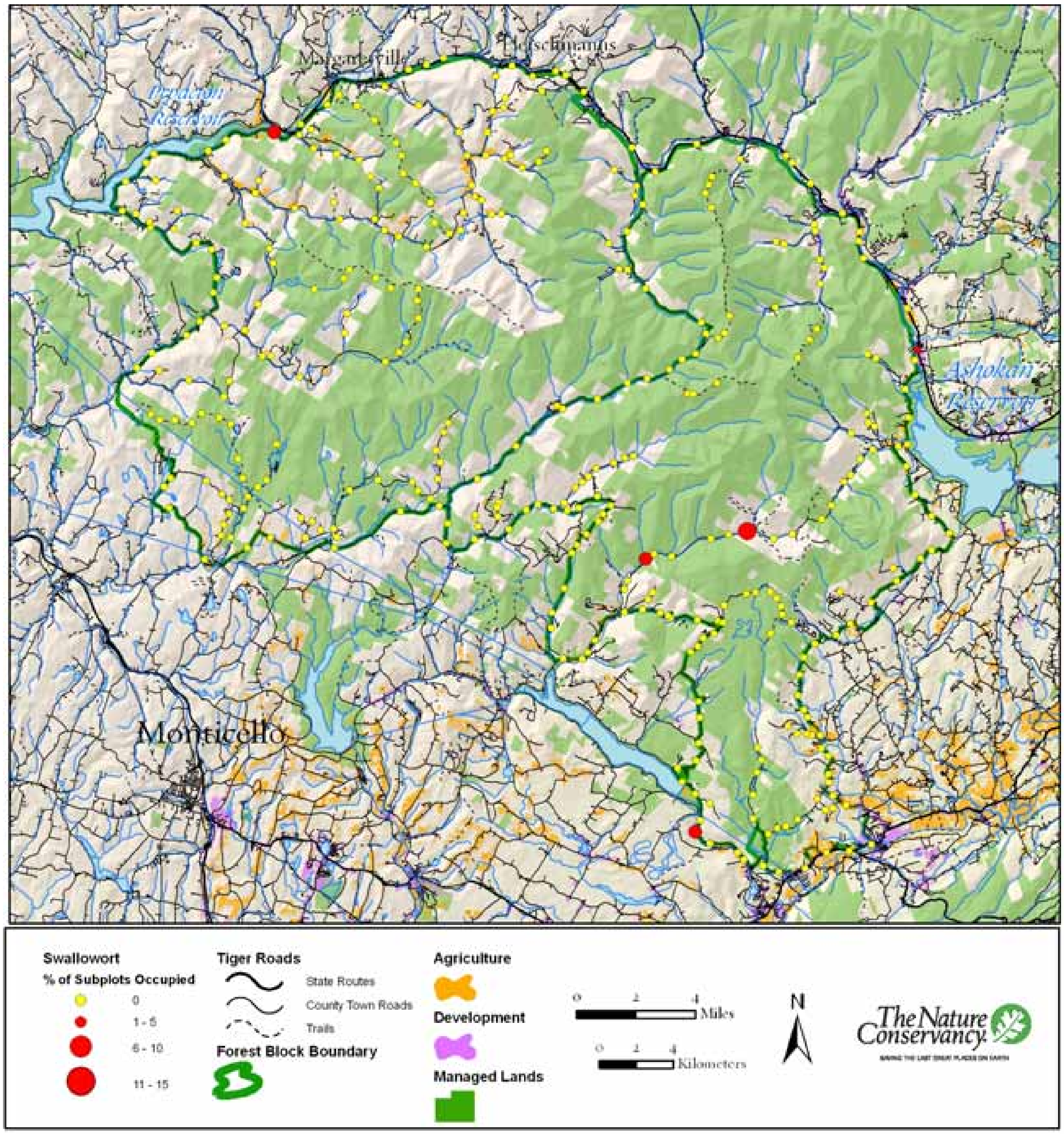
APPENDIX G. DISTRIBUTION OF BUSH HONEYSUCKLE IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



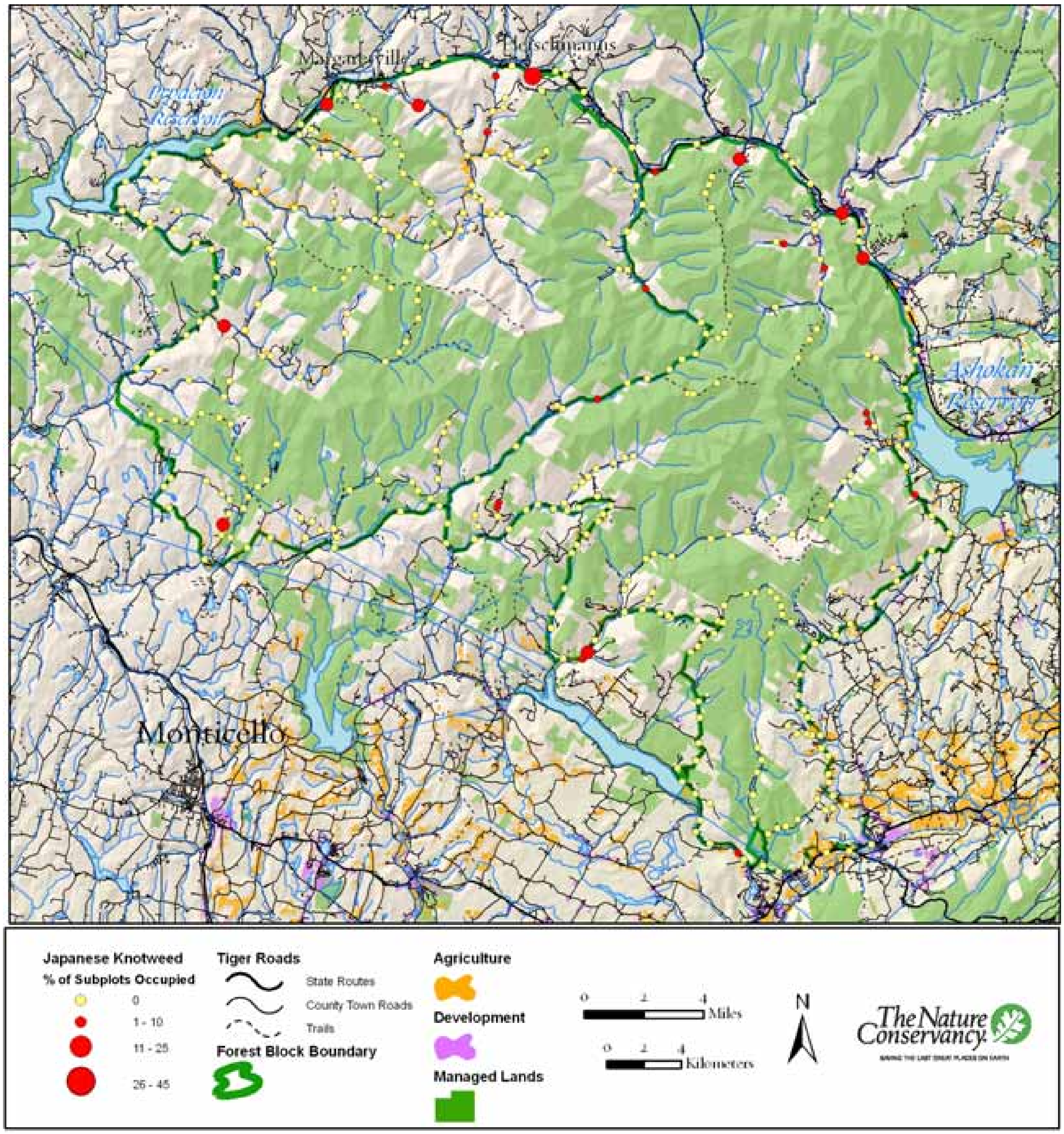
APPENDIX H. DISTRIBUTION OF MULTIFLORA ROSE IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



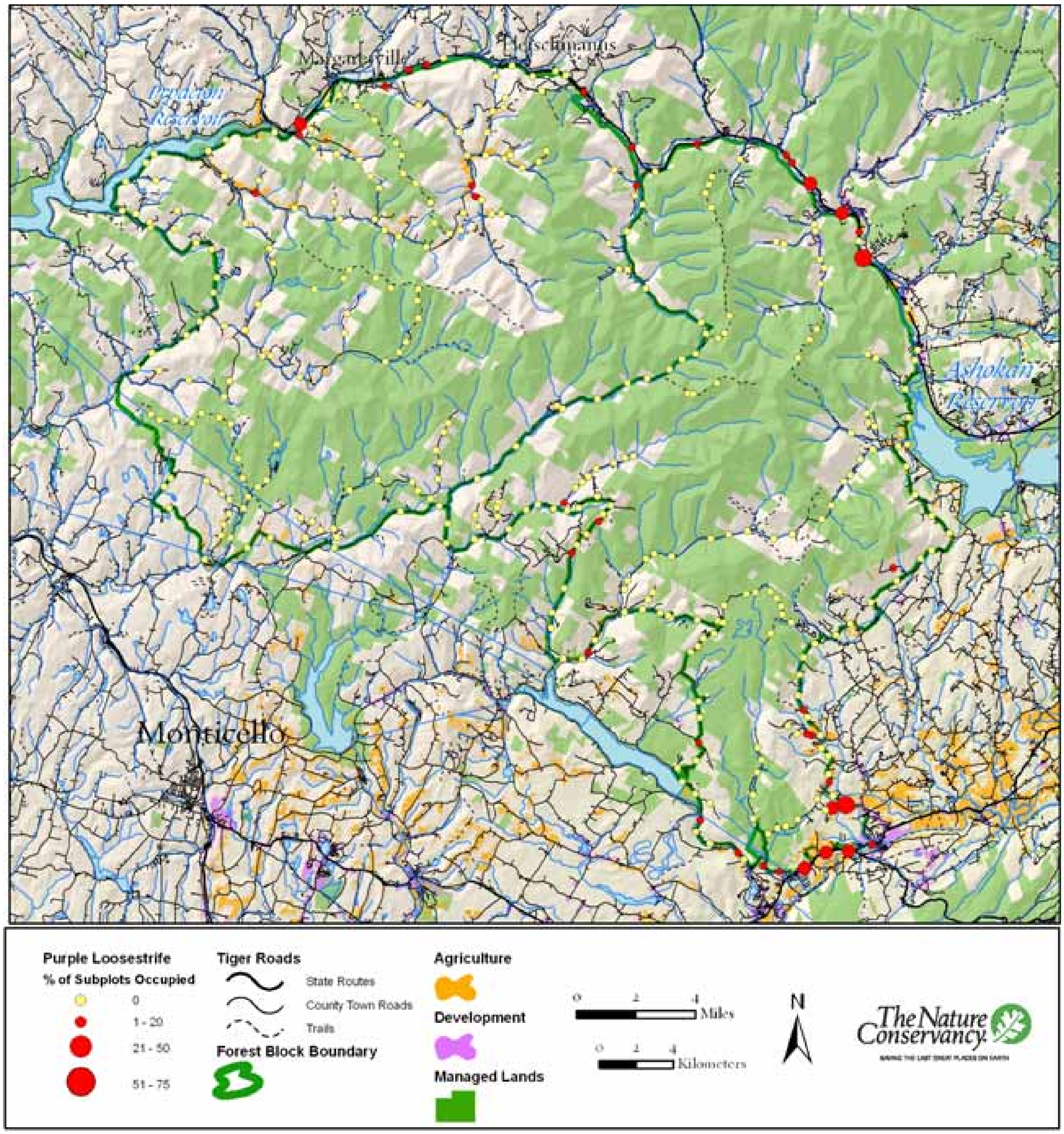
APPENDIX I. DISTRIBUTION OF BLACK SWALLOWWORT IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



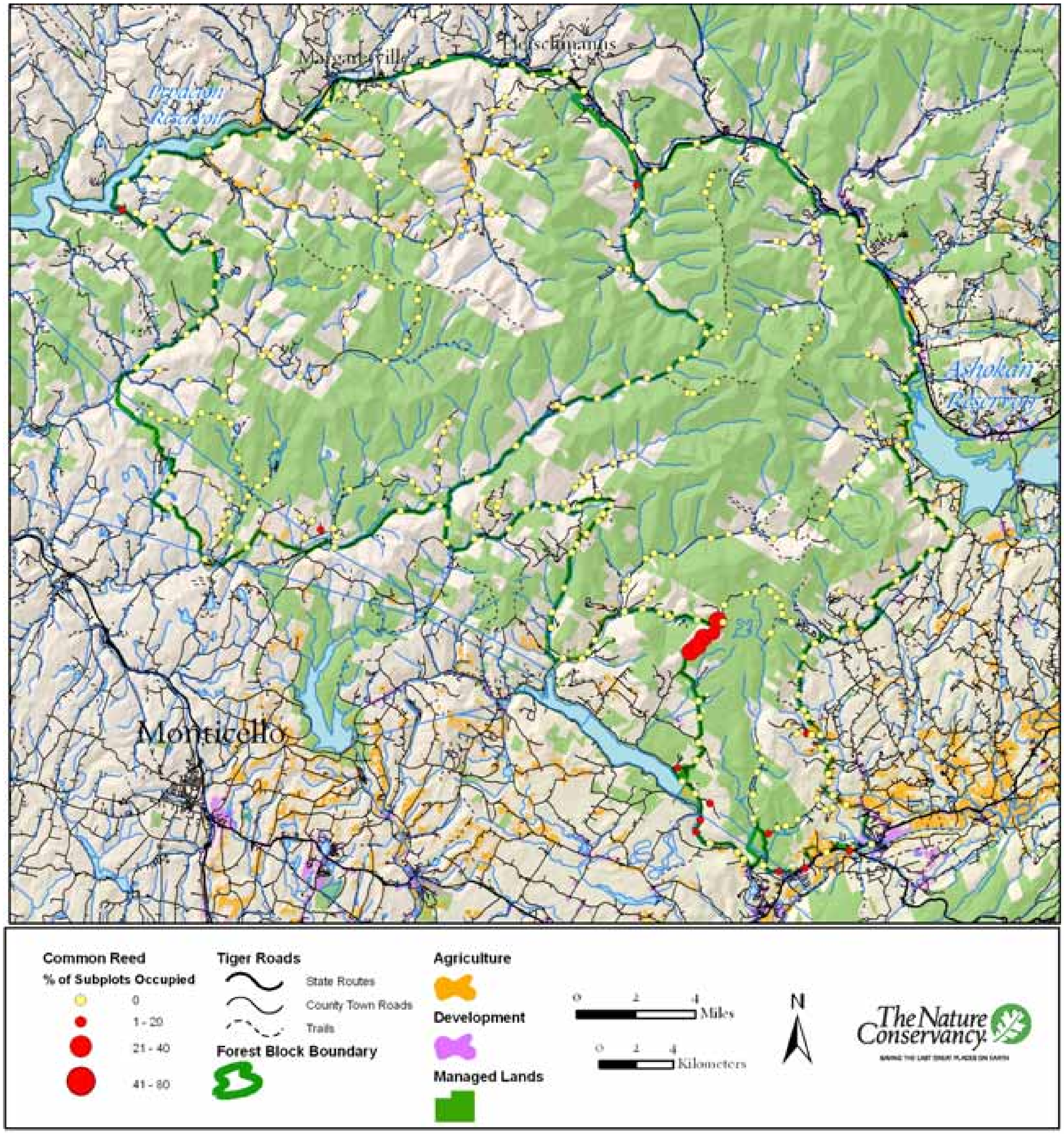
APPENDIX J. DISTRIBUTION OF JAPANESE KNOTWEED IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



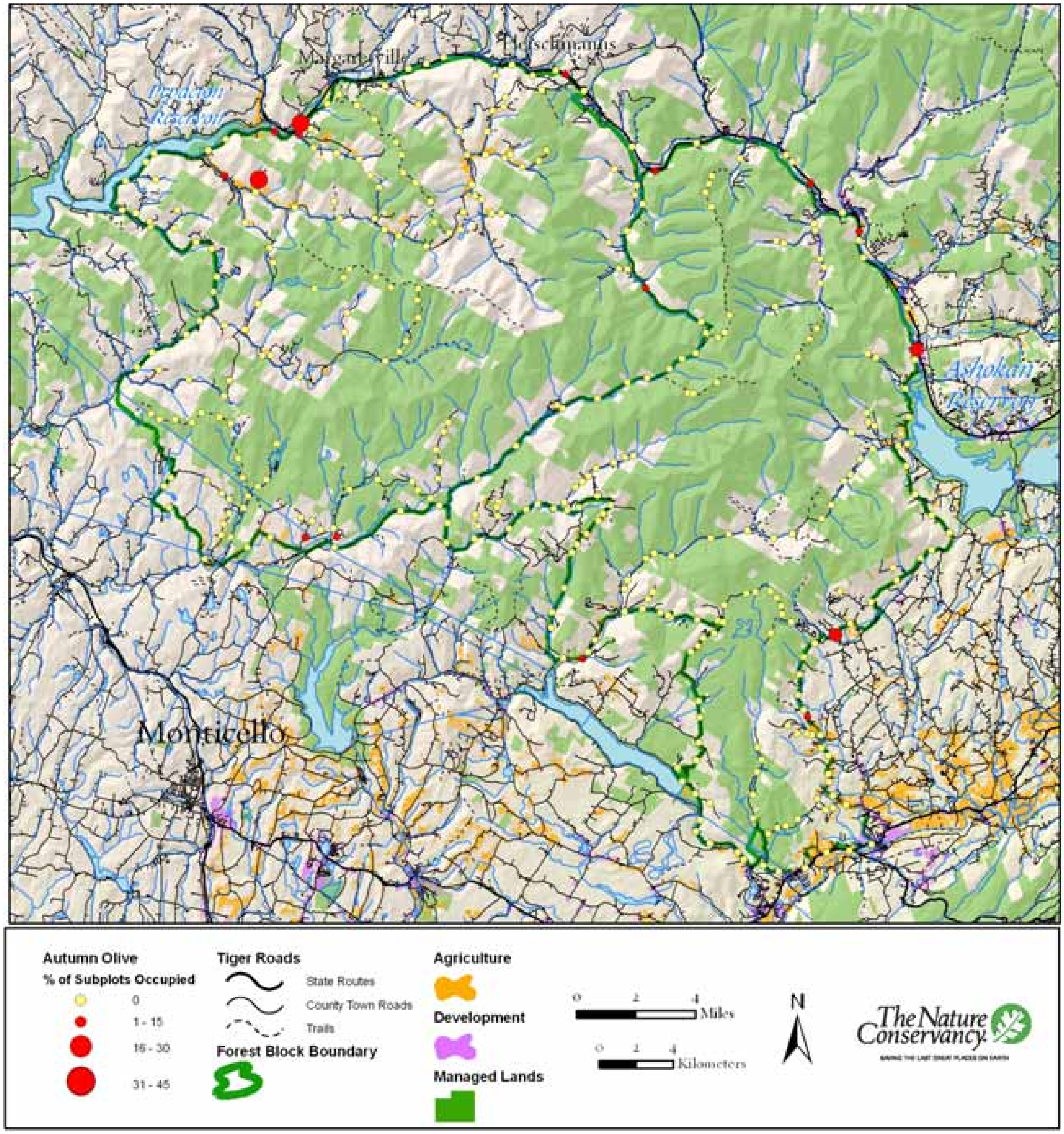
APPENDIX K. DISTRIBUTION OF PURPLE LOOSESTRIFE IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



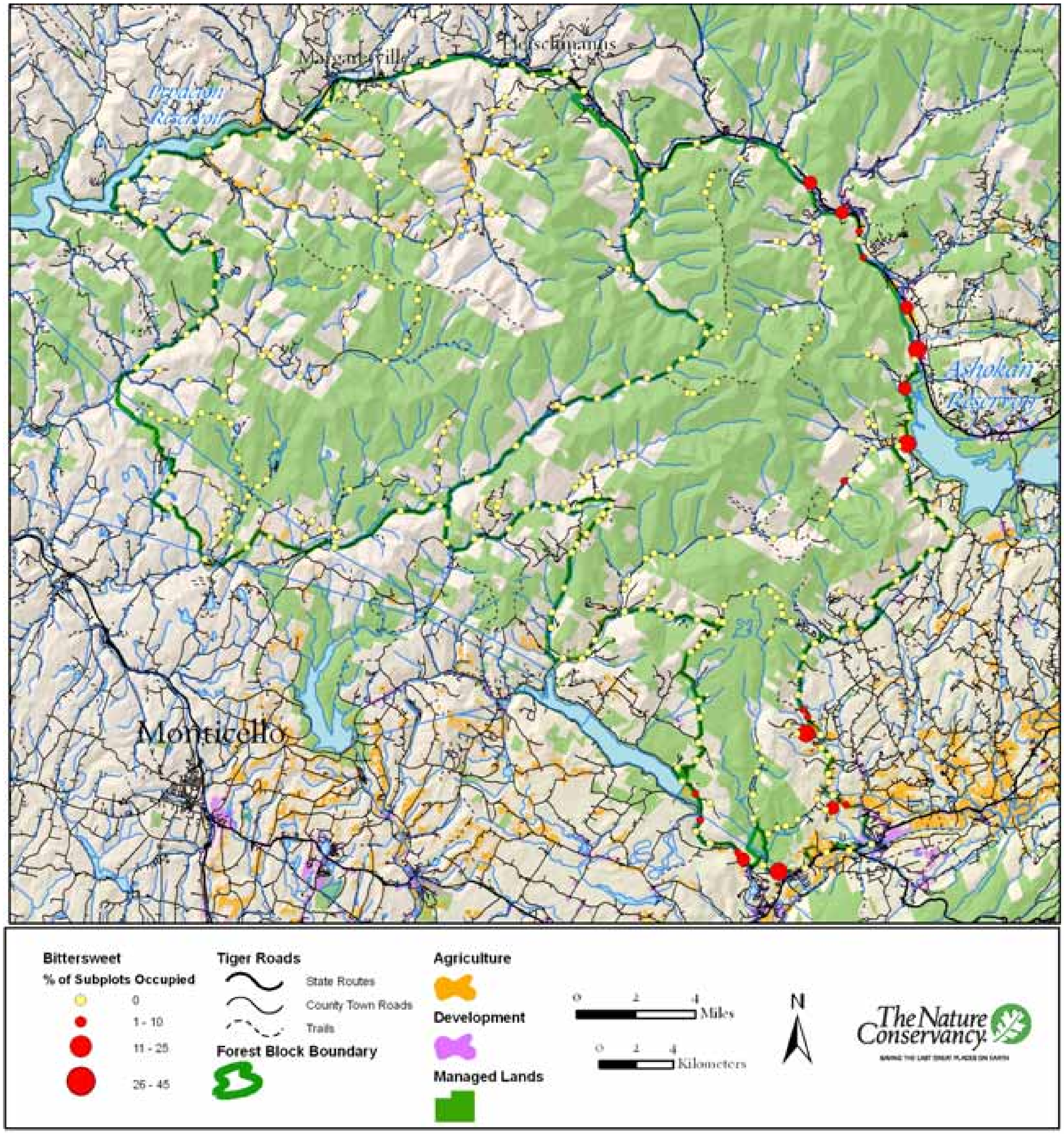
APPENDIX L. DISTRIBUTION OF COMMON REED IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



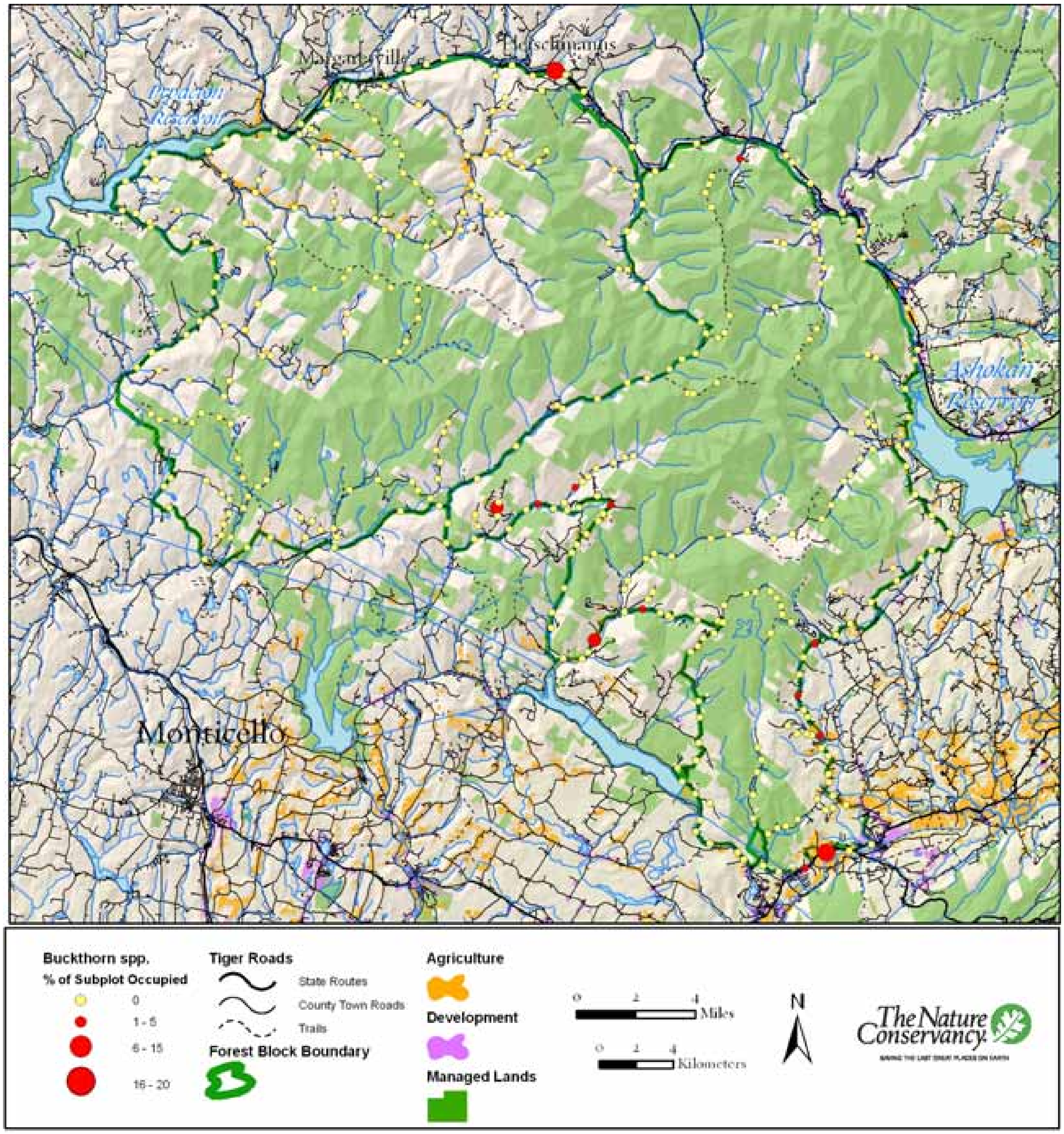
APPENDIX M. DISTRIBUTION OF AUTUMN OLIVE IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



APPENDIX N. DISTRIBUTION OF ASIATIC BITTERSWEET IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



APPENDIX O. DISTRIBUTION OF BUCKTHORN IN ROAD AND TRAIL TRANSECTS IN THE BEAVERKILL AND PANTHER MOUNTAIN FOREST MATRIX BLOCKS.



APPENDIX P. LOCATIONS OF JAPANESE KNOTWEED, PURPLE LOOSESTRIFE, AND COMMON REED IN THE BEAVERKILL WATERSHED FROM A DRIVE-BY SURVEY.