NETN Forest Protocol
Prepared by Geri Tierney and Don Faber-Langendoen
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1.1 Introduction

This protocol has been developed for long-term monitoring of forest vegetation within the National Park Service’s (NPS) Northeastern Temperate Network (NETN) as part of the NPS Inventory and Monitoring Program. The protocol includes methods for assessing and reporting the ecological integrity of forested ecosystems.

1.1.1 Background
The ten parks of NETN have been grouped together as an NPS network due to their common temperate forest systems. Network forests range from the central oak-hardwood forests of southern New England to the northern hardwoods and spruce-fir forests of northern New England, and include the pine woodlands of Acadia National Park as well as the plantations and successional habitats found in several of the national historic parks. These forested systems are described in detail within Chapter 2 of the NETN Vital Signs Monitoring Plan (http://www1.nature.nps.gov/im/units/netn/reports/reports.cfm).

An extensive scoping process that included network and park staff, academic researchers and other stakeholders has identified key stressors to NETN systems. Within forested systems, key stressors include land use change and habitat fragmentation surrounding the parks (particularly fragmentation by roads), invasive exotic species, atmospheric deposition and ozone pollution, climate change, increased browsing pressure by white-tailed deer, land management within the parks, and visitor impacts. Both the scoping process and these stressors are described within Chapters 1 and 2 of the NETN Vital Signs Monitoring Plan.

1.1.2 Justification
In May 2004, NETN convened a workshop of park staff and managers, academic and government scientists, and other stakeholders to identify key “Vital Signs” or indicators of ecological condition for long-term monitoring in NETN parks. The terrestrial breakout group at this workshop identified Forest Vegetation as one of 23 high-priority Vital Signs for NETN. The group recognized that forest vegetation is a primary component of most NETN parks, and that the structure, composition and condition of forest vegetation determines habitat for a wide variety of organisms. This workshop is summarized in Chapter 3 of the NETN Vital Signs Monitoring Plan.

1.1.3 Goals and objectives
Our overall goal is to monitor status and trends in the structure, function and condition of NETN forested ecosystems in order to inform management decisions affecting those systems. To do so, NETN will use monitoring data to interpret and report the ecological integrity of NETN forested systems. The “ecological integrity” of an ecosystem is a measure of the structure, composition, and function of an ecosystem as compared to pristine or benchmark ecosystems operating within the bounds of natural or historic disturbance regimes (Lindenmayer and Franklin 2002).

Ecological integrity can be assessed by comparing key elements of the structure, composition and function of an ecosystem to a reference area or to historical measurements or modeling efforts. In this way, NETN hopes to provide reliable data to inform management decisions relevant to NETN forested systems, including NPS land management and forest harvest plans,
exotic species control, deer population management, NPS internal development, and national pollution control legislation.

Specific, measurable objectives for each component of the NETN forest protocol are listed in Table 1.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Objectives</th>
<th>Vital Sign(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand structural class</td>
<td>Determine the distribution of structural classes and determine change over time. Compare the distribution of structural classes to that expected under natural disturbance regimes.</td>
<td>Forest vegetation</td>
</tr>
<tr>
<td>Canopy closure</td>
<td>Determine if canopy closure is decreasing over time. Examine relationships between canopy closure and climatic stress, storms, pest and pathogen outbreaks and other disturbances.</td>
<td>Forest vegetation</td>
</tr>
<tr>
<td>Snag abundance</td>
<td>Estimate snag abundance and determine change over time. Examine whether land management is reducing snag</td>
<td>Forest vegetation</td>
</tr>
<tr>
<td>Coarse woody debris (CWD)</td>
<td>Estimate coarse woody debris biomass or volume. Determine if CWD is increasing or stable. Examine whether land management and silviculture are reducing CWD.</td>
<td>Forest vegetation</td>
</tr>
<tr>
<td>Photopoint</td>
<td>Provide visual reference of plots for long-term qualitative comparison.</td>
<td>Forest vegetation</td>
</tr>
<tr>
<td>Tree condition</td>
<td>Qualitatively assess tree condition and determine if condition of any tree species is declining over time.</td>
<td>Forest vegetation, Exotic animals - early detection</td>
</tr>
<tr>
<td>Tree growth and mortality rates</td>
<td>Estimate growth and mortality rates by tree species. Determine if growth rates are declining or if mortality rates are increasing over time. Examine correlation between vital rates and air pollution, pest or pathogen outbreaks, climatic stress or other known stressors.</td>
<td>Forest vegetation</td>
</tr>
<tr>
<td>Tree regeneration</td>
<td>Quantify canopy tree seedlings and saplings by species and size class. Determine if tree regeneration is increasing or decreasing over time. Determine species composition of tree regeneration.</td>
<td>Forest vegetation, White-tailed deer herbivory</td>
</tr>
<tr>
<td>Indicator plants</td>
<td>Determine the spatial extent of high priority invasive exotic plant species and track changes over time. Determine population trends of species most palatable to deer, most sensitive to ozone and acid deposition, or at the southern or lower edge of their range.</td>
<td>Forest vegetation, Exotic plants - early detection, White-tailed deer herbivory, Acidic deposition &amp; stress, Ozone</td>
</tr>
<tr>
<td>Understory diversity</td>
<td>Estimate native understory plant species richness and determine if richness is declining over time. Determine if exotic plant species are increasing in abundance.</td>
<td>Forest vegetation, Exotic plants - early detection</td>
</tr>
<tr>
<td>Forest floor condition</td>
<td>Qualitatively assess forest floor condition. Determine the spatial extent of invasive exotic earthworms, a well-developed humus layer, and trampling impacts. Determine change over time.</td>
<td>Forest vegetation, Visitor usage, Exotic animals - early detection</td>
</tr>
<tr>
<td>Soil chemistry</td>
<td>Determine soil Ca:Al and C:N ratios to assess the extent to which base cation depletion, increased aluminum availability and/or nitrogen saturation are impacting NETN forest soils. Determine whether the impact is increasing over time.</td>
<td>Forest vegetation, Acridic deposition &amp; stress</td>
</tr>
<tr>
<td>Canopy stress index</td>
<td>Determine the extent and magnitude of canopy stress within NETN forested systems from remotely sensed red reflectance data. Examine correlation between stress and covariates including air pollution exposure, pest and pathogen outbreaks, climatic stress and other known stressors.</td>
<td>Forest vegetation, Acridic deposition &amp; stress, Ozone</td>
</tr>
<tr>
<td>Landscape context</td>
<td>Assess landscape context impacting plot. Determine interior patch size. Determine distance from plot to roads, trails, and other anthropogenic edges. Determine proportion of surrounding area in natural cover and in anthropogenic landuse. Determine change over time.</td>
<td>Forest Vegetation, Landcover, Landuse</td>
</tr>
</tbody>
</table>

This Forest Protocol primarily addresses the NETN forest vegetation vital sign. However, some measures also address related vital signs selected by NETN as high priority. These include
atmospheric deposition & stress, ozone, white-tailed deer herbivory, invasive/exotic plants - early detection, invasive/exotic animals - early detection, landcover/ecosystem cover and land use. Relationships between NETN vital signs and specific components of this Forest Condition Protocol are shown in Table 1.

1.1.4 Existing monitoring programs
The USFS Forest Inventory and Analysis Program (FIA) has been monitoring forest resources on a regional basis across the US since the 1930s. Beginning in the 1990s, a Forest Health Monitoring (FHM) component was developed by several federal agencies, and later incorporated into the FIA program. FIA/FHM protocols have undergone extensive development by the USFS with academic and other government agency partners, and have been used to develop a substantial and ongoing database revealing regional trends in forest resource capacity and health across the region and the country. For these reasons, NETN has chosen to use FIA/FHM protocols as a starting point for the NETN forest monitoring protocol; however, NETN has tailored FIA/FHM protocols to fit NETN parks and objectives and to be cost-effective in this context.

At least two states in the region have undertaken monitoring programs for state-owned forests. In New York, permanent plots were established and monitored in forests on state lands during 2000 to 2002 (Manion et al. 2003). In Maine, a long term monitoring program is being established in state ecological reserves, including those near Acadia (Cutko 2005). Both of these programs use modified versions of FIA protocols.

Smaller-scale forest monitoring programs exist within two NETN parks. A forest monitoring program was established at Marsh-Billings-Rockefeller NHP (MABI) in 2001 (Keeton 2004). These plots were revisited in both 2002 and 2003 to establish initial conditions, and will likely be revisited on a multi-year interval in the future. Likewise, a forest health monitoring program was established at Saint-Gaudens NHS (SAGA) by USFS scientists in 1995. These plots were reassessed in 1999 and 2003.

Specific threats to forested systems are currently monitored in several NETN parks. Air quality data is currently collected at Acadia NP (ACAD) and is collected regionally throughout the northeast. White-tailed deer population size is currently monitored at two NETN parks - Morristown NHP (MORR) and Saratoga NHP (SARA) - where impacts of increased deer-browsing pressure on forest composition and regeneration have been documented. Monitoring of certain invasive exotic plant species and of visitor impacts on ecological resources are both ongoing at ACAD.

NETN’s forest monitoring program will complement these ongoing programs by monitoring park Vital Signs on a regular basis within a subset of these existing plots or by adding additional plots in under-represented areas. Ongoing monitoring efforts by individual parks can continue to provide more detailed information as desired.

1.2 Sampling design

1.2.1 Rationale
The NETN Forest Protocol is designed to monitor forest ecosystem integrity in a standardized and cost-efficient manner across NETN parks. This protocol must allow statistical inference of condition and trends within and across parks with sufficient statistical power. The use of permanent plots will increase power to detect trends over time by eliminating spatial variation. The protocol must also facilitate comparison of NETN data with other NPS networks and regional data such as that from the USFS Forest Inventory and Analysis and Forest Health Monitoring (FIA/FHM) programs. Thus, NETN has used the well-developed and widely-used FIA/FHM protocols as a starting point, and has modified these protocols to meet NETN objectives. In order to balance competing needs for broad spatial coverage and for intensive quantitative sampling, we have developed a hierarchical monitoring approach. We anticipate that this approach will be a cost-effective strategy which will allow comparison of NETN data to larger regional datasets, and to data collected by other NPS networks using FIA/FHM-style protocols.

1.2.2 Hierarchical approach

In order to balance competing needs for broad spatial coverage and intensive quantitative sampling, NETN has developed a hierarchical approach to forest monitoring that relies on three tiers of information (Table 2). At the broadest level, remote sensing imagery will provide landscape-level data on landuse and fragmentation in and around NETN parks. On the ground, a broad spatial network of plots will provide data describing forest stand structure and condition, while a subset of these plots will be more intensively monitored to quantify key aspects of forest stand composition and function.

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Remote Sensing</th>
<th>Tier Extensive plots</th>
<th>Intensive plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand structural class</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Canopy closure</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Snag abundance</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Coarse woody debris</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Photopoint</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tree condition</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tree growth and mortality rates</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Tree regeneration</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Indicator plants</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Understory diversity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest floor condition</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Soil chemistry</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Canopy stress index</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Landscape context</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The extensive tier is designed to assess stand structure and canopy closure, tree condition and regeneration, snag abundance, indicator plant presence, and forest floor condition at an extensive network of sites within all NETN forested parks. Data describing stand structure will allow comparison of the current distribution of stand structural classes in NETN forested stands with expected distributions under natural disturbance regimes. Canopy closure is a useful indicator of
stand level disturbance, and can be used to determine if forested stands are becoming more disturbed over time. Tree condition will be qualitatively assessed to provide an early warning of tree health problems. Tree regeneration data provides an early warning indicator of overstory composition change, and is also indicative of browsing pressure. Snags are key structural features for wildlife habitat, and are sensitive to park hazard tree removal and silvicultural policies. Presence and cover data for select groups of indicator plants can be used as a rapid measure to detect impacts of a variety of stressors, including exotic plant invasions, browsing pressure, climate change, and air pollution. Forest floor condition will be monitored for trampling impacts, as well as for the spread of invasive exotic earthworms and consequent humus reduction. Finally, photographs will document the appearance of the plot to provide long-term visual reference.

One quarter of these plots will be monitored using a more intensive protocol that will quantify tree growth and mortality rates, understory plant diversity, coarse woody debris, and soil chemistry. Tree growth and mortality rates will be calculated by species, and serve as indicators of health problems within a tree species. Like snags, coarse woody debris is a key structural feature of forest systems providing habitat for wildlife and fungi, and is sensitive to park management policies. Understory plant diversity will be quantified at intensive plots to allow monitoring of species richness and invasive exotic plants. Soil chemistry will be monitored to determine Ca:Al and C:N ratios, which are indicative of atmospheric deposition stress and nitrogen saturation. All extensive-tier measures will be assessed in full at intensive sites to allow correlation between related measures across tiers (such as relationships between indicator plant presence and total understory diversity).

In the remote sensing tier, digital orthophoto quarter quads (DOQQs) will be used to monitor change in the landscape context of forested plots over time. We will calculate the interior forested patch size within which plots lie, and the distance from plots to roads and trails; both of these statistics are useful measures of fragmentation. Likewise, calculation of the proportion of forest cover, natural non-forest cover and anthropogenic landuse within the immediate area surrounding plots provides an alternative measure of fragmentation and anthropogenic stress.

In the future, NETN would like to incorporate an additional remote sensing measure to this protocol - using hyperspectral remote sensing to assess canopy condition within the entire area of NETN parks. New hyperspectral sensors show promise for assessing the degree and spatial extent of stress experienced by canopy vegetation. Current research seeks to develop relationships between remotely sensed spectral signatures (e.g., red reflectance indices) and canopy vegetation stress for a variety of vegetation cover types. NETN hopes to incorporate this measure in the future, as reliable relationships for NETN vegetation cover types are developed and the cost of newer hyperspectral imagery such as Hyperion becomes more affordable.

In addition, NETN will monitor two related measures - terrestrial salamander abundance and ozone damage to vegetation - as part of other vital signs.

### 1.2.3 Sampling frame

NETN plans to monitor forest resources within eight NETN parks (Table 3), which vary in size, forested ecosystem cover, and management. Several NETN parks are comprised of more than
one unit. ACAD is comprised of two non-contiguous mainland units (Mt. Desert Island and the Schoodic peninsula) and numerous islands, the largest of which is Isle-au-Haut. NETN’s forest sampling frame will include both mainland units at Acadia as well as Isle-au-Haut, but will exclude the many smaller islands due to the logistical difficulty and cost of access by boat. Roosevelt-Vanderbilt NHS (ROVA) consists of three separate park units - Home of Franklin D. Roosevelt NHS (HOFR), Eleanor Roosevelt NHS (ELRO), and Vanderbilt Mansion NHS (VAMA) - which will be sampled as separate units. Minuteman NHP (MIMA) and Morristown NHP (MORR) each consist of two discontinuous but nearby units; at these parks both units will be sampled.

<table>
<thead>
<tr>
<th>Ecological system group</th>
<th>ACAD</th>
<th>SARA</th>
<th>MORR</th>
<th>MIMA</th>
<th>MABI</th>
<th>ROVA</th>
<th>SAGA</th>
<th>WEFA</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spruce-fir forest</td>
<td>7,952</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7,952</td>
</tr>
<tr>
<td>Northern hardwoods forest</td>
<td>1,234</td>
<td>705</td>
<td>44</td>
<td>20</td>
<td>130</td>
<td>160</td>
<td>32</td>
<td>1</td>
<td>2,327</td>
</tr>
<tr>
<td>Central hardwoods forest</td>
<td></td>
<td>229</td>
<td>112</td>
<td>1</td>
<td>3</td>
<td>20</td>
<td></td>
<td></td>
<td>364</td>
</tr>
<tr>
<td>Pine forest</td>
<td>731</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>731</td>
</tr>
<tr>
<td>Conifer woodland</td>
<td>2,959</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,959</td>
</tr>
<tr>
<td>Plantation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>92</td>
</tr>
<tr>
<td>Old-field successional</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>435</td>
</tr>
<tr>
<td>Total forested area (ha)</td>
<td>12,876</td>
<td>871</td>
<td>465</td>
<td>194</td>
<td>197</td>
<td>192</td>
<td>43</td>
<td>21</td>
<td>14,860</td>
</tr>
</tbody>
</table>

Table 3: Hectares of Forested Ecological Systems within NETN Parks

Two NETN parks will not participate in this forest monitoring. Saugus Iron Works NHS (SAIR) does not contain significant forested resources. Boston Harbor Islands NRA (BOHA) was not selected for forest monitoring because BOHA vegetation is largely exotic, and because the logistical difficulties in transport to the many islands that comprise BOHA preclude cost-efficient sampling.

NETN also coordinates monitoring activities with the Appalachian NST (APPA), which has extensive forest resources. A monitoring plan for this complex park is under development and will not be addressed herein.

1.2.4 Spatial allocation
In order to achieve balanced spatial coverage across NETN forested ecosystems, spatial allocation of plots will be based on random point placement within tessellated grid cells encompassing NETN parks. Clumping of plots will be prevented by imposing a buffer around each plot in which additional plots cannot be placed. This design employs random plot selection to allow statistical inference while also providing balanced spatial coverage and flexibility for post-stratification of plots based on ecological system, association, or other criteria as needed over the long-term. To accomplish this, NETN will overlay a tessellated hexagonal grid over each NETN park and select a random sampling location within each grid cell, as shown in Figure 1. Grid size will vary by park, in order to ensure a minimum sample size for statistical inference in the smallest NETN park, while allocating sufficient resources to ACAD. Proposed sampling intensity (plots per ha) will vary accordingly. An example of sample size allocation based on park area is shown in Table 4; however, appropriate sample size will be determined during protocol evaluation.
In addition, NETN may intensify the sampling grid within areas of special concern. One such area is the globally rare Pitch pine/Broom crowberry woodland at ACAD.

<table>
<thead>
<tr>
<th>Proposed total forest plots</th>
<th>ACAD</th>
<th>SARA</th>
<th>MORR</th>
<th>MIMA</th>
<th>MABI</th>
<th>elro</th>
<th>ROVA</th>
<th>hofr</th>
<th>vama</th>
<th>SAGA</th>
<th>WEFA</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed intensive plots (25% of total)</td>
<td>32</td>
<td>8</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>16</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Proposed sampling intensity (ha. forest/plot)</td>
<td>101</td>
<td>27</td>
<td>19</td>
<td>10</td>
<td>10</td>
<td>13</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>
sampled annually at ACAD, while 50% of the plots will be sampled biennially at the other forested parks (Table 5). Annual sampling at Acadia will ensure annual events (such as a drought or a pest outbreak) are not missed, while alternate-year sampling at the historical parks will optimize allocation of sampling effort by reducing travel costs compared to annual sampling. Within each panel, 25% of plots will be intensively monitored sites, while the remainder will belong to the extensive tier of measurements. Plots will be assigned to panels and tiers in a systematic fashion.

**Table 5: Proposed NETN Forest Monitoring Panel Design**

<table>
<thead>
<tr>
<th>Panel</th>
<th>Pilot</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td></td>
<td>X</td>
<td>X</td>
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<td></td>
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<td>X</td>
<td></td>
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<tr>
<td>2</td>
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<td>X</td>
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<td>X</td>
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<tr>
<td>3</td>
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<td></td>
<td></td>
<td>X</td>
<td>X</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Intensive plots comprise 25% of plots in each panel.
At ACAD plots will be equally distributed between panels, except plots on Isle au Haut, which will only occur in panels 2 & 4.
Other parks will be monitored in alternate years as follows: SARA, MABI, MIMA and SAGA will occur only in panels 1 and 3, MORR, ROVA and WEIR will only occur in panels 2 and 4.

Alternatively, if funding permits, NETN could increase the power to detect trends in the short-term by resampling intensive plots the year following establishment, before reverting to a four-year interval (Table 6). This would increase power to detect trends in the initial years of the program, but would incur increased cost.

**Table 6: Alternate NETN Forest Monitoring Panel Design**

<table>
<thead>
<tr>
<th>Panel</th>
<th>Pilot</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
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<td></td>
<td>X</td>
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<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

X=All plots in panel measured, IA=Only intensive plots at Acadia measured.
Intensive plots comprise 25% of plots in each panel.
At ACAD plots will be equally distributed between panels, except plots on Isle au Haut, which will only occur in panels 2 & 4.
Other parks will be monitored in alternate years as follows: SARA, MABI, MIMA and SAGA will occur only in panels 1 and 3, MORR, ROVA and WEIR will only occur in panels 2 and 4.

**1.2.6 Sample size determination**
Determination of appropriate sample size to allow trend detection is currently underway, and will be included herein when it is completed.

**1.3 Field methods**

Forests are highly valued ecosystems for the many economic, ecological and recreational benefits they provide. For this reason, methods for sampling forest vegetation are numerous and well developed. Wherever practicable, NETN has chosen to adopt or adapt existing protocols into this Forest Protocol rather than “reinvent the wheel” by creating new protocols that duplicate existing efforts. A primary source of forest vegetation data and methodology is the USFS Forest Inventory and Analysis (FIA) Program, which has been monitoring forest resources on a regional basis across the US since the 1930s. With the addition of Forest Health Monitoring (FHM) in
the 1990s, this program provides well researched and documented protocols for monitoring forest resources and health as well as many years of regional data for comparison (USFS 2004, http://fia.fs.fed.us/library/field-guides-methods-proc/). Adaptation of FIA/FHM conventions and protocols will allow NETN to compare conditions at the relatively small NETN parks to larger regional trends using FIA/FHM data.

Herein, we summarize field methods; the SOPs which follow this narrative provide detailed, step-by-step protocols to allow field personnel to exactly reproduce field methods on successive visits.

1.3.1 Field season preparation
Forest vegetation sampling should occur in the summer during peak foliage (June to August). Several preparations should be made before June 1.

NETN should ensure that all field personnel are familiar with these protocols prior to commencement of the field season. Field crew preparation should involve careful review of all protocols, in addition to in-field training sessions. The crew leader may benefit from participation in USFS FHM training sessions within the Northeast region, which are offered each year. However, NETN protocols have been adapted from FIA/FHM protocols to fit NETN objectives, so specific NETN field crew training should be performed annually by designated personnel.

Prior to each field season, maps showing sampling locations, topography and park features should be prepared. Plot locations should be printed and downloaded directly into the GPS.

NETN personnel should schedule park visits, and reserve or obtain lodging at sampled parks and a field vehicle. Natural resource managers at each park to be sampled should be supplied with an up-to-date version of the NETN Forest Protocol including all SOPs, as well as an up-to-date map of sampling locations. A map clearly showing the location of each intensive plot should be provided to each park’s cultural resource specialist at least one month prior to any soil sampling, to provide time for determination of the presence of cultural artifacts that might be compromised by soil sampling. Arrangements should be made with a suitable soil chemistry laboratory so that soil samples can be promptly shipped for analysis after collection.

Equipment and supplies listed in SOP #1 should be obtained and in working condition. Field data collection forms should be copied onto field Rite-in-the-Rain paper.

1.3.2 Sampling methods
As shown in Table 2 above, NETN will monitor an extensive network of permanent plots for a suite of stand, tree and regeneration measures, while a subset of these plots will be monitored more intensively for tree growth and mortality rates, CWD, understory diversity and soil chemistry. NETN forest monitoring plots are similar in size and layout to FIA subplots. Tree and stand measurements will be made within a 7.5-m radius circular plot, while regeneration will be measured within a 2-m radius circular microplot embedded within each plot. CWD will be assessed using line intersect sampling along three 7.5-m transects originating at plot center.

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1 The contact person is David J. Alerich - dalerich@fs.fed.us.
Understory diversity will be monitored within three 1-m² quadrats, one adjacent to each CWD transect. Soil samples will be obtained from a transect outside of the plot. This plot layout is depicted in Figure 2.

Figure 2: NETN forest plot layout

Within each plot, the field crew will collect basic information describing the site (e.g., slope, aspect, terrain position, and elevation) to allow proper interpretation of other data collected. Stand structure will be measured. Stand disturbance will be qualitatively assessed from visual inspection and will be quantified using digital canopy photography. The forest floor condition will be assessed by visual inspection for microtopography,² trampling and evidence of invasive exotic earthworm presence. Each tree >= 10 cm dbh will be measured for status (live/dead), size (dbh) and condition. These data will yield information on tree condition, as well as stand structure, composition, and biomass. Tree regeneration will be quantified by species and size class within the microplot in order to assess regeneration success, future cover and the effects of deer browsing. A time-constrained search will be conducted for indicator species within the plot; these species indicate specific stressors impacting forested systems such as invasive exotic species and deer browsing. Finally, photographs will be taken of the plot and microplot to document change in appearance of plots over time.

Additional measurements will be made on intensive plots. At these plots, tree growth and mortality rates will be calculated from careful size (dbh) remeasurement data on tagged trees. Coarse woody debris provides important habitat for wildlife and fungi, and will be quantified using line intersect sampling within intensive plots. Understory diversity within 1-m² quadrats will be recorded to yield information describing species diversity and rates of community change, including abundance and spread of invasive exotic species. A soil sample will be collected adjacent to the plot, and depth of the litter layer and forest floor will be recorded. Samples will be analyzed to characterize forest soil chemistry, and will provide information on the effects of atmospheric deposition and the ability of these soils to support forested ecosystems.

² Microtopography indicates site history. Lack of microtopography indicates the site has been plowed prior to establishment of second-growth forest.
Wherever possible, these protocols follow FIA/FHM conventions (USFS 2004), including overall plot design, definitions and size thresholds of items to be measured (e.g., trees and coarse woody debris), condition classes (e.g., disturbance classes). However, NETN protocols are adapted to specifically fit NETN objectives, and thus are not identical to FIA/FHM protocols. Significant departures are itemized here.

NETN plots (7.5 m radius) are equivalent in size and layout to a single FIA/FHM subplot (7.3 m radius). FIA/FHM clusters 4 subplots and samples 1 plot cluster for forest health measures within each 96,000 acres of land. Alternatively, NETN has chosen a simpler, single plot layout and a higher density of plots across the landscape. This strategy is more appropriate to the small parks NETN must monitor; FIA’s strategy is designed for sampling a much larger land area.

NETN uses metric rather than English units, so sizes have been adjusted accordingly. NETN will include all trees >=10 cm dbh as tally trees to be measured on these plots, rather than the 12.7 cm dbh cutoff used by FIA, to better calculate ecological stand structure indices (e.g., Tyrrell et al. 1998, Peet et al. 1998). However, NETN can analyze these tree data using the same cutoff as FIA for comparison. NETN will use simpler rules for measuring dbh of forked trees than FIA; FIA rules are more stringent and at times difficult to use because they seek to measure economic value of trees in addition to ecological characteristics.

Some components of FIA/FHM have not been adopted by NETN. FIA/FHM protocols are extensive and include several components not relevant to NETN objectives. NETN will not monitor lichen communities as an indicator of atmospheric deposition. NETN will instead monitor atmospheric deposition and stress directly using existing monitoring stations and foliar ozone-damage plots (see the Ozone protocol and the Wet and Dry Deposition Monitoring protocol), and indirectly as it impacts forest ecological integrity. NETN will not monitor fine woody debris. This is a time consuming protocol used as an indicator of fuel loading and fire occurrence, which is not an objective of NETN. Finally, the FIA methods that have been adapted into NETN protocols have been streamlined to fit NETN’s approach.

In addition, NETN will record some data not collected by FIA. Some measures of forest floor condition - microtopography and invasive earthworm presence - are not monitored by FIA but will provide NETN with useful information on the integrity of this critical soil layer. NETN hopes to use canopy photography to characterize canopy level disturbance over time in response to multiple stressors including global change. Finally, the use of indicator species to identify impacts due to specific stressors is not an approach used by FIA, but is an attempt by NETN to create a simple metric to characterize impacts in an extensive network of plots.

1.3.3 Sample processing
Soil samples from intensive plots should be air dried and then shipped to a designated soil laboratory for analysis. Total carbon and nitrogen should be assessed using dry (Dumas)

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3 NETN can choose among several soil laboratories with sufficient capabilities, including the Research Analytical Service of the Cornell Nutrient Analysis Lab in Ithaca NY (http://www.css.cornell.edu/soiltest/soil_testing/test_types/soil_research.asp) and the USDA Forest Service Lab at
combustion followed by measurement of evolved gases by infrared gas absorption or gas chromatography (Sollins et al. 1999). Ca^{2+} should be extracted using NH_{4}OAc or a similar solvent, and Al^{3+} should be extracted using KCl (Robertson et al. 1999).

1.3.4 Field QA/QC
NETN will use a carefully prepared standardized datasheet (Appendix A) or database for field data collection. Use of this datasheet or database will minimize data omission and recording of erroneous data values. NETN will encourage accurate data collection by employing specific QA techniques in the field including repetition of all data recorded and careful measuring techniques. Finally, NETN will resample approximately 5% of sampled plots annually to determine reliability of field data collection.

1.4 Data management - TBD
Revisions to this protocol (including the narrative and SOPs) will be handled according to the NETN revisions SOP. NETN uses version tracking software to record changes to the protocol, and the protocol database will reflect the protocol and SOP versions in effect at the time of data collection.

Datasheets should be copied within one week of collection, and the originals stored in a safe place. A second copy of the datasheets should be made on archival paper and delivered to the NETN data manager within two weeks of data collection. If data is recorded directly into a database in the field, that database should be backed up on a daily basis. Hard copies of the data should be printed and stored on a periodic basis.

If datasheets are used for field data collection, measures must be employed to ensure accurate data entry into the database. After data entry is complete, all database records should be compared for accuracy against the field datasheets. Ideally this review should be done by personnel other than the technician who entered the data. The database should reflect which records have been verified for accurate transcription.

Summary statistics should be used to verify that the correct number of sampling sites and dates are present in the database, and outliers should be inspected. The database should reflect which records have been examined using summary statistics.

1.5 Data analysis
1.5.1 Landscape context
NETN will calculate several landscape context metrics indicative of fragmentation and the influence of adjacent landuse and stressors on the ecological condition of the plot. These metrics will include interior patch size, distance to roads and major trails, and neighborhood forest cover, non-forest natural cover and anthropogenic landuse. Change over time will be monitored using Digital Orthophoto Quarter-Quadrangles (DOQQs).

the North Central Research Station in Grand Rapids MN (contact Randy Kolka, rkolka@fs.fed.us). The latter is where FIA/FHM soil samples from the northeast region are analyzed.
1.5.2 Calculations

Forest metrics will be calculated from field data as shown in Table 7. The tree regeneration index has been adopted from the USFS FIA Pennsylvania regeneration study (Will McWilliams, personal communication). Calculation of coarse woody debris biomass from line intersect sampling data follows conventions used by the USFS FIA/FHM program (Woodall and Williams 2005).

<table>
<thead>
<tr>
<th>Metric</th>
<th>Variable type</th>
<th>Units</th>
<th>Calculation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canopy closure</td>
<td>Percent</td>
<td>%</td>
<td>Calculated from canopy photograph</td>
<td>NA</td>
</tr>
<tr>
<td>Snag abundance</td>
<td>Quant</td>
<td>m² / ha</td>
<td>Sum basal area of snags in plot, converted to per hectare.</td>
<td>(Σ snagdbh_cm) / (PlotDiam_m)²</td>
</tr>
<tr>
<td>CWD volume</td>
<td>Quant</td>
<td>m³ / ha</td>
<td>Volume per ha. calculated from line-intersect data, slope corrected. Can be converted to biomass using woody specific gravity and decay class</td>
<td>(π² * (sqrt (1 + slope% / 100)) / (8 * TransLength_m)) Σ diam_cm²</td>
</tr>
<tr>
<td>Tree condition</td>
<td>Index</td>
<td>NA</td>
<td>Sum of points for tree health problems</td>
<td></td>
</tr>
<tr>
<td>Tree growth rate by species</td>
<td>Rate</td>
<td>% BA / yr</td>
<td>Annual percent tree basal area increase, calculated by species</td>
<td>(Σ (BAt2 - BAt1) / (BAt1 * revisitInterval)) / n</td>
</tr>
<tr>
<td>Tree mortality rate by species</td>
<td>Rate</td>
<td>% stems / yr</td>
<td>Annual percent tree stem mortality, calculated by species</td>
<td>#StemsDiedt1-t2 / (#LiveStems_t1 + revisitInterval)</td>
</tr>
<tr>
<td>Tree regeneration</td>
<td>Index</td>
<td>NA</td>
<td>Sum of points per seeding of high canopy species in each size class</td>
<td>1 * (#sdigs&lt;30 cm) + 2 * (#sdigs&lt;30-100 cm) + 20 * (#sdigs&lt;1-1.5 m) + 50 * (#sdigs&gt;1.5 m) + 50 * (#saplings)</td>
</tr>
<tr>
<td>Understory plants</td>
<td>Index</td>
<td>NA</td>
<td>Sum number of indicator species found in plot</td>
<td></td>
</tr>
<tr>
<td>Understory richness</td>
<td>Index</td>
<td>NA</td>
<td>Sum of native understory species found on plot</td>
<td></td>
</tr>
<tr>
<td>Native species ratio</td>
<td>Percent</td>
<td>% native species</td>
<td>Ratio of native to total species in plot</td>
<td></td>
</tr>
<tr>
<td>Soil chemistry - Ca:Al ratio</td>
<td>Ratio</td>
<td>NA</td>
<td>Molar calcium:aluminum ratio</td>
<td></td>
</tr>
<tr>
<td>Soil chemistry - C:N ratio</td>
<td>Ratio</td>
<td>NA</td>
<td>Molar ratio of total carbon:total nitrogen</td>
<td></td>
</tr>
</tbody>
</table>

1.5.3 Statistical analysis

NETN plans to estimate both status and trends over time of specific measures within forested systems in each sampled park, and also within specific ecological system groups in Acadia NP. Analyses will be based on a general linear model which partitions spatial and temporal variability to allow assessment of change over time, as is done by the USFS FIA/FHM program (Woodall and Williams 2005). This model is:

\[ y_{ij} = b_0 + b_1 (t_j - t_0) + \eta_i + \epsilon_{ij} \]  
Equation 1

where
- \( y_{ij} \) = the value of a measure on plot \( i \) at time \( j \)
- \( b_0 \) = the estimated mean value of all plots at year 0
- \( b_1 \) = estimated change in \( y \) over time
- \( t_j \) = time of measurement \( j \)
- \( t_0 \) = time of initial measurement
- \( \eta_i \) = spatial (between-plot) variability
- \( \epsilon_{ij} \) = temporal (within-plot) variability
and measurement error is assumed to be normally distributed with mean 0 and variance $\sigma^2$.

NETN also plans to collect and analyze covariate data (such as climate variables and air pollution concentration and deposition rates) in order to better account for the relationship between certain response variables (such as tree growth or mortality rate) and key ecosystem drivers and stressors. When a covariate is related to a response variable, incorporating the covariate into Equation 1 will allow more precise estimation of change and an estimate of the strength of the relationship as shown in Equation 2:

$$Y(i + n),j = b_0 + b_1 (t(i + n),j - tij) + b_2 (x(i + n),j - xij) + b_3 (t(i + n),j - tij)(x(i + n),j - xij) + \eta_{ij} + \epsilon_{ij}$$

where

- $n =$ the interval between measurements
- $Y(i + n),j =$ the value of $Y$ at measurement $i+n$ for plot $j$
- $b_0 =$ the initial value of $Y$
- $b_1 =$ the change in $Y$ over time
- $b_2 =$ the change in $Y$ per change in unit $x$
- $b_3 =$ the interaction between change in $x$ and $Y$
- $t(i + n),j =$ the time of measurement $i+n$ on plot $j$
- $tij =$ the time of measurement $i$ on plot $j$
- $x(i + n),j =$ the value of a covariate at measurement $i+n$ on plot $j$
- $xij =$ the value of a covariate at measurement $i$ on plot $j$
- $\eta_{ij} =$ spatial (between-plot) variability
- $\epsilon_{ij} =$ temporal (within-plot) variability

This covariate model is also used by the USFS FIA/FHM program (Woodall and Williams 2005).

1.6 Reporting

Assessing and reporting the ecological integrity of park resources is a major goal of both NETN and the larger IM program. Ultimately, a vital sign is useful only if it provides information which guides management decisions or quantifies the success of past decisions. Ecological integrity must be assessed from field data and presented in a format that can be clearly understood by managers, scientists, policy makers, and the public. Powerful communication tools will be needed to accomplish this goal - NETN will use an Ecological Integrity Scorecard as a primary communication tool.

1.6.1 Assessing ecological integrity

Assessment of ecological integrity is a challenging undertaking. “Ecological integrity” is not a static concept; rather it assesses the current condition of ecosystem structure, composition and function against baseline or benchmark conditions operating under natural disturbance regimes. These baseline conditions help define the “normal” or “acceptable range of variation” for ecosystem attributes (Lindenmayer and Franklin 2002). Ecological integrity can be assessed by comparing key attributes of the structure, composition and function of an ecosystem to a reference area or to historical measurements or modeling efforts. Useful attributes for
assessment of ecological integrity are those that change predictably in response to stressors, those that discriminate between anthropogenic and natural variability, and those are easy to measure and interpret (Karr and Chu 1999).

In order to identify key aspects of forest composition, structure and function most relevant to the assessment of ecological integrity, NETN developed a conceptual ecological model for terrestrial systems within NETN parks. This model highlights linkages between NETN terrestrial ecosystems, known stressors and agents of change acting within NETN parks, and key attributes and ecological processes of these systems. This model is presented within Chapter 2 of the NETN Monitoring plan. This conceptual model identifies a suite of metrics with which we can assess the ecological integrity of NETN forests (Table 1).

To assess ecological integrity using these metrics, we have tried to identify threshold values from the scientific literature and expert opinion which separate levels of ecological integrity. We will assess three levels of ecological integrity: Good, Caution and Significant Concern. For some metrics, such as soil Ca:Al ratio, clear physiological thresholds exist; for others metrics, threshold values are less clear but seem to exist, and for some metrics, current knowledge is insufficient to determine thresholds. For those, we will assess and report ecological integrity based on the statistical distribution of available data rather than on pre-determined thresholds. In some cases, we improve the calibration of a metric by distinguishing different thresholds for different forest types (e.g., the range of variability for coarse woody debris differs between pine-oak forests and hemlock-hardwood forests).

Full documentation of metric and rating development is presented in SOP #16.

As an example of this rating process, consider tree regeneration. This metric assesses the success of tree seedling establishment in the forest understory, and is indicative of the ability of the forest canopy to replace itself. Currently, a key stressor on tree regeneration is over-browsing by white-tailed deer. Our ratings for tree regeneration rely on an index developed by FIA in which points are assigned for canopy tree seedlings within height classes. Larger seedlings have survived longer and are more likely to outgrow browsing pressure, thus larger seedlings are worth more points. Index ratings range from ≥ 100 points in the “Good” condition category to < 25 points in the “Significant Concern” category.

1.6.2 Scorecard reporting
NETN will use a scorecard format to convey ecological integrity. An ecosystem integrity report card must fulfill several criteria to be successful. The scorecard must: 1) be understandable to multiple audiences, 2) address differences in ecosystem responses across time, 3) show the status or current condition of the ecosystem, 4) should characterize ecosystem condition thresholds, and 5) provide justification and transparency for those thresholds (Harwell et al. 1999). Following these criteria, we have developed a scorecard reporting framework to provide a clear communication tool for park managers, the public and other stakeholders. This scorecard will interpret relative ecological integrity in a transparent fashion such that integrity thresholds and actual data values measured are readily apparent.
The NETN forest scorecard framework employs a hierarchical design to allow reporting at multiple levels. This scorecard framework can be used to convey the ecological integrity as measured by a specific metric, such as soil chemistry, or aggregated to convey the overall integrity of forested systems within a park, or the integrity of specific forested ecosystems, such as the northern hardwood forest. For reporting on aggregate metrics, we will use three indices – landscape context, vegetation condition, and soil condition to assess forest integrity (EPA 2003). An example Forest Integrity Scorecard based on data collected in 2005 is shown in Appendix C. The data can be further aggregated into higher levels of the NPS Vital Signs Framework for reporting at the national level as described in Chapter 7 of the NETN Vital Signs Monitoring Plan.

The Forest Integrity scorecard will develop over time. Initially, the metrics will be aggregated using a simple point-scoring method (NatureServe 2002, Parrish et al. 2003), assigning 5 points for “Good”, 3 points for “Caution”, and 1 point for “Significant Concern.” These value ratings follow the approach proposed by Karr (1981) for aquatic systems, and used by others for developing terrestrial indices (Keddy and Drummond 1996, DeKeyser et al. 2003, Mack 2004). Over time, as the relative importance of individual metrics is better understood, a more quantitative forest index may be developed, as in the well-developed aquatic Index of Biological Integrity (Karr 1981) or the Vegetation Index of Biotic Integrity (Mack 2004).

The Forest Integrity scorecard will employ maps to indicate spatial patterns of ecological integrity. A park map showing the distribution of sample plots color coded by condition category will clearly indicate spatial patterns of integrity.

1.6.3 Reporting requirements and schedule

Results of NETN Forest Monitoring will be reported in three types of reports (Table 9). An annual implementation report will report methods and summarize data from each field season. This report will include summary statistics for each forest metric. The Forest Integrity Scorecard, as described above, will complement these annual implementation reports. An annual scorecard will be prepared for Acadia to match the annual sampling schedule at that park; biennial scorecards will be prepared for other NETN parks to match the biennial sampling schedules at those parks. Finally, NETN Forest Monitoring data will be synthesized and integrated with other vital signs and regional data every 4 or 5 years within Integration and Synthesis Reports prepared by Network staff and relevant collaborators.

<table>
<thead>
<tr>
<th>Report</th>
<th>Purpose</th>
<th>Audience</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation Report</td>
<td>Summarize information from annual implementation of Forest Protocol.</td>
<td>Parks, Network</td>
<td>Annual</td>
</tr>
<tr>
<td>Forest Integrity Scorecard</td>
<td>Report Forest Ecological Integrity.</td>
<td>Parks, Network, Public</td>
<td>Annual for ACAD, Biennial for other parks.</td>
</tr>
<tr>
<td>Integration and Synthesis Report</td>
<td>Report trends in forest vegetation. Integrate NETN forest data with other Vital Signs and regional data.</td>
<td>Parks, Network, Cooperators, External scientists</td>
<td>Every 4 or 5 years.</td>
</tr>
</tbody>
</table>

1.7 Operational requirements
1.7.1 Personnel requirements and training
NETN’s forest monitoring protocol will require a forest crew leader, a field crew of one to three, and a vegetation specialist, as well as support by NETN staff including the data manager. The vegetation specialist should be well trained in local flora, and is needed for intensive plots only. This specialist could be a member of the crew with sufficient botanical knowledge, or a contract botanist.

NETN should ensure that all field personnel are familiar with these protocols prior to commencement of the field season by conducting in-field training sessions. The crew leader may benefit from participation in USFS FHM training sessions within the Northeast region, which are offered each year. However, NETN protocols have been adapted from FIA/FHM protocols to fit NETN objectives, so specific NETN field crew training should be performed annually by designated personnel. Training should include familiarization with NETN forested and woodland ecosystems, identification of indicator plant species, identification of specific tree condition problems, familiarization with stand disturbance codes, visual inspection of forest floor for humus and earthworm casts and burrows, practice in estimating percent cover classes, and proper use of network GPS and digital camera equipment.

1.7.2 Facility and equipment needs
Necessary equipment is listed in SOP#1. NETN will need to contract soil samples analysis out to a regional soil chemistry lab, as described in the sample processing section of this narrative.

1.8 Literature Cited


Keddy, P.A. and C.G. Dummond. 1996. Ecological properties for the evaluation, management, and restoration of temperate deciduous forest ecosystems. Ecological Applications 6: 748-762.


Overview: This SOP delineates preparations for the summer field season and includes a list of necessary field equipment. These preparations should be complete by the start of the summer field season in early June.

Staff
This forest monitoring protocol will require a forest crew leader (at least GS-7), a field crew of one to three (at least one GS-5, up to two SCA volunteers), and a contract botanist, as well as support by NETN personnel. The forest crew leader and field crew should all be familiar with northeastern tree species identification and have some exposure to forest sampling methods. The contract botanist(s) should be well trained in local flora at each park sampled, and will accompany the crew to intensive plots only.

This protocol will also require some GIS analysis in ArcGIS or a similar program. This staff requirement for GIS skills could be met by NETN personnel, by some member of the field crew, or alternatively by a GIS technician.

Prior to each field season, NETN should examine network staffing scenarios and hire or acquire the necessary staff and expertise to accomplish the field season.

Training
Prior to commencement of each field season, NETN should ensure that all field personnel are familiar with these protocols. Field crew preparation should involve careful review of all protocols, in addition to in-field training sessions. The crew leader may benefit from participation in USFS Forest Inventory and Analysis/Forest Health Monitoring (FIA/FHM) training sessions within the Northeast region, which are offered each year. However, NETN protocols have been adapted from FIA/FHM protocols to fit NETN objectives, so specific NETN field crew training should be performed annually by designated personnel. Training should include familiarization with NETN forested and woodland ecosystems, identification of indicator plant species, identification of specific tree condition problems, familiarization with stand disturbance codes, visual inspection of forest floor for humus and earthworm casts and burrows, practice in estimating percent cover classes, and proper use of network GPS and digital camera equipment.

1 The contact person for USFS FIA/FHM training is David J. Alerich - dalerich@fs.fed.us.
General preparations
Prior to each field season, NETN personnel should prepare GIS maps showing sampling locations at each park in the annual panel. Maps should clearly show location of all plots in relation to topography, roads, trails and park features, and maps should distinguish extensive from intensive plots. Coordinates of each plot should be exported, printed and downloaded directly into the crew GPS unit.

NETN personnel or the field crew leader should contact the natural research manager at each park represented in the annual panel to schedule a visit and reserve park lodging if available. If no park lodging is available, motel reservations should be made.

NETN personnel or the field crew leader should reserve or acquire a field vehicle for transport to and within parks.

NETN personnel or the field crew leader should ensure that each park natural resource manager has an up-to-date version of the NETN Forest Protocol including all SOPs, as well as an up-to-date map of sampling locations. A map clearly showing the location of each intensive plot should be provided to each park’s cultural resource specialist at least one month prior to any soil sampling, to provide time for determination of the presence of cultural artifacts that might be compromised by soil sampling.

NETN should select a suitable soil chemistry laboratory and have a purchase order or other contract in place for analysis of soil samples collected each field season. It may be cost-efficient to join together with other eastern NPS networks to contract a soil chemistry lab to obtain better pricing. Several soil laboratories have sufficient capabilities, including the Research Analytical Service of the Cornell Nutrient Analysis Lab in Ithaca NY (http://www.css.cornell.edu/soiltest/soil_testing/test_types/soil_research.asp), the Research Soil Testing Lab at Kansas State University (http://www.oznet.ksu.edu/agronomy/SoilTesting/research.htm), and the USDA Forest Service Lab at the North Central Research Station in Grand Rapids MN (contact Randy Kolka, rkolka@fs.fed.us). The latter is where FIA/FHM soil samples from the northeast region are analyzed. Other academic and government labs within the northeast region may also have sufficient capabilities.

Equipment
Equipment and supplies listed in SOP #1 should be obtained and in working condition. If field data collection forms will be used, they should be copied onto Rite-in-the-Rain paper.
NETN Forest Monitoring Field Equipment & Gear

General:
- GPS unit
- Compass
- 25- or 50-m tape
- Protocols
- Slope conversion table
- Park topo map showing plot locations
- Data sheets
- Clip board
- Sharpened pencils
- Daypack
- First aid kit
- Sun screen
- Insect repellant
- Water

Plot establishment:
- 1-m rebar - 1 per plot²
- 1-m white PVC pipe - up to 1 per plot
- Rebar caps - up to 1 per plot
- Plot tags and wire
- Bright orange forestry spray paint³
- 40-cm flat-top steel stakes - 1 to 4 per plot
- Mallet

Intensive plots: all above plus
- Quadrat frame - 1x1 m²
- Hand lens
- Watch with timer
- Sealable plastic bags - 1 gal., 1 quart
- Wet paper towels
- Permanent markers
- Park plant species list
- Herb identification guide
- PVC soil corer
- Mallet
- Duct tape
- Cloth
- Pocket knife
- Trowel
- Small paint brush
- Forestry paint (unobtrusive color)

Back in field office:
- Flora - Gleason & Cronquist
- Plant press with cardboard inserts and newspaper

Extensive plots:
- Clinometer
- DBH tape
- PVC pole cut to breast height (1.37 m)
- Ruler
- Digital camera, batteries
- Tree book - Petrides
- Compact binoculars
- Metal detector⁴
- Pre-numbered tree tags or PIT tags⁵
- Tree nails (about 2 1/2” long)⁵

² Not to be used at MABI.
³ Check with park natural resource manager before using. Not to be used at MABI or ACAD. OK at MORR and SARA.
⁴ May be needed at ACAD to find plot centers near trails and visitor areas.
⁵ Check with park natural resource manager before using.
Overview: This SOP provides instruction for establishing plots and collecting site information. Plot locations will be selected using GIS prior to commencement of the field season. Spatial allocation of plots will be based on based on random point placement within tessellated grid cells encompassing NETN parks. Within each grid cell, a series of five random locations will be sequentially selected. Clumping of plots will be prevented by imposing a buffer around each plot in which additional plots cannot be placed. Locations which present a safety hazard or do not fall within forested, woodland or plantation systems will be discarded. Within each hexagon, selection will proceed sequentially through the series until a suitable plot location is established.

NETN must ensure that plot marking procedures have been approved by the natural resource manager and cultural resource specialist at each park prior to plot establishment. Plot marking procedures will vary slightly between parks in order to comply with different park management policies.

Procedure:
Examine park topographic maps to determine the best route to preselected plot locations. Using GPS and a compass, travel to a proposed plot location. Do not take safety risks when traveling to plots - if off-trail topography becomes too steep or difficult find an easier route to the plot location. If a safe route does not exist, discard the location and record the reason for doing so.

Upon arrival at the pre-selected plot location, visually examine the location to ensure it is primarily forested, succeeding to forest, a plantation or a woodland, and that exposed rock does not cover more than 50% of the plot. If the plot does not meet these criteria, or if the plot presents a safety hazard, discard the plot and record the reason for doing so. Safety hazards include the presence of extremely steep slopes or cliffs. Proceed to add the next backup location within the same hexagon to the list of plot locations for establishment, and travel to the next nearest location.

If the plot meets all criteria listed above, mark plot center with the approved plot center marker for that park. It is important to establish each plot center as exactly as possible to avoid bias in plot selection.
Approved plot center markers may be 1) a 1-m length of rebar embedded within a white PVC pipe and sunk half-way into the ground, or 2) a 1-m length of rebar pre-marked at the top with bright orange forestry paint, capped and sunk half-way into the ground. Use wire to affix a metal tag to the marker; the tag should read “NETN x” where x is the plot number. Do not apply spray paint to stakes in the forest; paint stakes prior to visit. In many cases, it will be possible to install rebar into forest soil using simple hand pressure. When more force is required, a mallet may be used. Ensure that rebar stakes do not create safety hazards for park visitors by ensuring that sharp tops are covered either by emergent PVC pipe or by caps. If the plot location is visible from a major trail or visitor location at ACAD, sink rebar flush with ground and cap with a large metal “mushroom” cap. The cap should be inscribed to read “NETN x” where x is the plot number. If shallow soils or exposed bedrock prevent installation of plot center markers, select up to three “witness trees” near or within the plot. Tag each witness tree using a metal tree tag or PIT tag, and record in plot notes the tag code, and the tree species and diameter at breast height. If the witness trees lie within the plot, the tag code should be the tree number as described in SOP #5; if the witness tree lies outside the plot, the tag code should be a non-numeric code.

The plot layout is shown below (Figure 1). Using a compass with no declination (i.e., using magnetic north), find the microplot center located 4 m slope distance from plot center at an azimuth of 90°. Insert a flat-topped 0.4-m stainless-steel stake half-way into the ground at this location. At parks where natural resource managers have approved the use of bright markings, use a stake pre-marked with fluorescent orange paint at the top, or impale a small piece of bright orange flagging with the stake at ground level. At parks where orange paint is not acceptable, use an unpainted metal stake.

At intensive plots only, lay out three 7.5-m transects (slope distance) starting at plot center; one each at 30, 150, and 270 degrees (+/- 2°), using a compass with no declination (i.e., using magnetic north). It is important to lay out transects along a straight line to avoid biasing line intersect transect sampling. Transects are marked at the far end with a 0.5-m stainless-steel stake inserted half-way into the ground. At parks where natural resource managers have approved the use of bright markings, use a stake pre-marked with fluorescent orange paint at the top, or impale a small piece of bright orange flagging with the stake at ground level. At parks where orange paint is not acceptable, use an unpainted metal stake.

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1 Orange paint is not acceptable at ACAD and MABI. Check with all parks before using.
2 Sighting using magnetic north simplifies this process of locating plot components by eliminating the need to reset exact declination as the crew travels across the network.
**Data collection:**

CURRENT DATE. Record the month, day, and year of the current visit as mm/dd/yyyy.

CURRENT TIME. Record the time plot was begun and finished as hh:mm-hh:mm using 24-hr clock.

CREW. Record the initials of field crew members.

PARK. Record 4-letter park code (ACAD, MABI, MIMA, MORR, ELRO, HOFR, VAMA, SAGA, SARA, or WEIR).

PLOT NUMBER. Record the plot identification number, unique within each park.

UTMN. Record the North Universal Transverse Mercator value.

UTME. Record the East Universal Transverse Mercator value.

ELEVATION. Record the elevation above mean sea level of the plot center, in meters, as determined by GPS.

SLOPE ANGLE. Record slope angle across plot to the nearest 1%. Slope is determined with a clinometer by sighting parallel to the average incline or decline of the plot. This angle is measured along the shortest pathway downslope before the direction of drainage changes. To measure slope, Observer 1 stands at the uphill edge of the plot and sights Observer 2 standing at the downhill edge of the plot. Observer 1 must sight Observer 2 at a height equivalent to the eye-level of Observer 1. Read slope directly as percent (not degrees!) from the clinometer, following rules below.

SLOPE ASPECT. Record aspect across plot to the nearest 5°. Aspect is determined along the direction of slope for land surfaces with at least 5% slope in a generally uniform direction. If slope is less than 5%, record NA to signify no aspect. Aspect is measured in degrees with a hand compass in the same direction used to determine slope.

For both SLOPE ANGLE and ASPECT:
- If slope or aspect changes gradually across the plot, record an average value.
- If slope or aspect changes across the plot but is predominately of one direction, code the predominant value rather than the average.
- If the plot falls on a canyon bottom or narrow ridge top, but most plot area lies on one side, code the slope and aspect of the side where most area lies.

TERRAIN POSITION. Record terrain position of the plot along slope profile, using codes below. Codes 2, 3, and 5 all have slope >= 5%. Codes 1, 4, 6 and 7 have slope < 5%.

1. Top-of-slope - convex region
2. Upper-slope - convex region near top of slope
3. Mid-slope - uniform, fairly straight region
4 Bench - level land with slopes above and below
5 Lower-slope - concave region near bottom of slope
6 Bottomland - flat and low-lying; may be associated with drainage and flooding
7 Flatland - unrelated to slopes or drainage; may have minimal elevation change (< 5%)

TRANSECT SLOPE. In intensive plots only, record to the nearest 5% the average slope along each CWD transect.

DIRECTIONS. Record directions for driving and walking to the plot, including landmarks and parking recommendations where applicable.

PLOT NOTES. Record any unusual plot features or problems encountered during plot setup.
Overview: This SOP collects stand-level measurements and site information on plots. These data will allow proper interpretation of other measures, and will be used to assess stand and canopy disturbance. This SOP is designed to be used only during the leaf-on period of the summer months (about June 1 to August 31).

Data collection:
CURRENT DATE. Record the month, day, and year of the current visit as mm/dd/yyyy.

CURRENT TIME. Record the time plot was begun and finished as hh:mm-hh:mm using 24-hr clock.

CREW. Record the initials of field crew members.

PARK. Record 4-letter park code (ACAD, MABI, MIMA, MORR, ELRO, HOFR, VAMA, SAGA, SARA, or WEIR).

PLOT NUMBER. Record the plot identification number, unique within each park.

ECOSYSTEM. Select NatureServe ecological system group represented by vegetation on this plot. This data will be recorded during the first visit, and verified or updated on subsequent visits. Forested and woodland ecological system groups present within NETN parks are:

Acadian Lowland Spruce-Fir-Hardwood Forest  
Boreal Aspen-Birch Forest  
Laurentian-Acadian Northern Hardwoods Forest  
Laurentian-Acadian Pine-Hemlock-Hardwood Forest  
Appalachian Hemlock-Hardwood Forest  
Central and Southern Appalachian Northern Hardwood Forest  
Central Appalachian Oak and Pine Forest  
Northeastern Interior Dry Oak Forest  
Laurentian-Acadian White Pine-Red Pine Forest  
Laurentian-Acadian Acidic Rocky Outcrop  
Native Plantation
Exotic Plantation
Old-field Successional

STAND STRUCTURE. Record the basic stand structure in the plot using these codes:

1 Single-storied: stand characterized by even canopy of uniform height with close competition between trees. Smaller trees are typically stressed or overtopped and have fallen behind their associates. Regeneration and/or tall relics from a previous stand may be present. Most trees are within the height class of the average stand height.

2 Two-storied: stands composed of two relatively even but distinct canopy layers, such as a mature overstory with an understory sapling layer, possibly from seed tree and shelterwood operations, or an overstory of tall conifers with an understory of low hardwoods. Neither canopy is necessarily continuous or closed, but both canopy levels tend to be uniformly distributed across the stand. Each canopy level must cover at least 25% of the stand.

3 Multi-storied: stands generally containing trees from every size group on a continuum from seedlings to mature trees and characterized by a broken or uneven canopy. Usually the largest number of trees is in the smaller diameter classes. Consider any stand with three or more structural layers as multi-storied if each layer covers at least 25% of the stand.

4 Mosaic: stands contain at least two distinct size classes each covering at least 25% of the stand. These classes are not uniformly distributed, but are grouped in small repeating aggregations throughout the stand. Each size class aggregation is too small to be recognized and mapped as an individual stand.

5 Early successional: early successional stand without closed canopy, but not distinctly single- or two-storied.

CROWN CLOSURE. Estimate % of plot area covered by live tree crowns directly overhead and record appropriate code. If foliage is not present due to seasonal variation or temporary defoliation, visualize the amount of live crown that would normally be present. Codes:

1 < 10 %
2 10 to 25 %
3 25 to 50 %
4 50 to 75 %
5 > 75 %

% COVER BY LAYER. Estimate the total cover of vascular plant foliage by layer within the plot. A rapid cover estimate is made, ignoring overlap among species. It may help to visualize cover by collapsing each layer into a 2-dimension space and ignoring any normal spaces occurring between the leaves of plants. Estimate total cover for each layer: Low, equivalent to < 0.5 m above ground; Mid, equivalent to 0.5 - 5 m above ground; and High, equivalent to > 5 m above ground. Use the following canopy cover classes: <1, 1-5, 6-25, 26-50, 51-75, 76-95, 96-100%.

DEER BROWSE LINE. Visually inspect the plot and record the presence (1) or absence (0) of an evident deer browse line. A deer browse line is a notable lack of leaves and understory below the level a deer can easily reach (about 2 meters).
DISTURBANCE CODE. Record up to 3 disturbance codes from most to least important based on visual inspection of the plot. To be recorded, a disturbance must cause "significant threshold" damage equivalent to either 1) 25% of trees in a plot, 2) 50% of an individual tree species’ count, or 3) disturbance to at least 25% of the soil surface or understory vegetation. For initial plot measurement, only record disturbances which appear to have occurred or be ongoing within the last 5 years. For remeasured plots, record only those disturbances occurring or ongoing since the previous inventory.

- **00** None - no observable disturbance
- **10** Insect damage
  - **11** insect damage to understory vegetation
  - **12** insect damage to trees, including seedlings and saplings
- **20** Disease damage
  - **21** disease damage to understory vegetation
  - **22** disease damage to trees, including seedlings and saplings
- **30** Fire - prescribed or natural
- **40** Animal damage
  - **41** beaver damage to vegetation
  - **42** porcupine
  - **43** deer/ungulate
  - **44** bear
  - **46** domestic animal/livestock including grazing
  - **47** flooding caused by beaver
- **50** Weather damage
  - **51** ice/snow
  - **52** wind including hurricane, tornado
  - **53** flooding caused by weather
  - **54** drought
  - **55** earth movement/avalanches
- **60** Vegetation - suppression, competition, or vines
- **70** Unknown/not sure/other. Describe in Notes.
- **80** Human-caused damage – any human-caused damage not described in these codes. Describe in Notes.
- **90** Silvicultural treatment
  - **91** Cutting - removal of one or more trees from a stand.
  - **92** Site preparation - clearing, slash burning, chopping, diskng, bedding, or other practice to prepare site for regeneration.
  - **93** Artificial regeneration
  - **95** Other silvicultural treatment - use of fertilizers, herbicides, girdling, pruning, or other activities designed to improve the commercial value of the stand. Describe in Notes.

DISTURBANCE THRESHOLD. For each disturbance recorded above, record which threshold was triggered: 1) damage to 25% of trees in a plot, 2) damage to 50% of an individual tree species’ count, or 3) disturbance to at least 25% of the soil surface or understory vegetation.
DISTURBANCE % CLASS. For each disturbance recorded above, record an approximate disturbance percentage to the nearest 10%. If the recorded disturbance was triggered by threshold 1, record the approximate % of trees in the plot damaged by that disturbance. If triggered by threshold 2, record the approximate % of an individual tree species’ count damaged by that disturbance. If triggered by threshold 3, record the % of the soil surface or understory affected by that disturbance.

WATER ON PLOT. Record the water source having the greatest impact on the plot using codes below. This data will be recorded during the first visit, and verified or updated on subsequent visits. It will be necessary to re-examine the plot for temporary water sources during each visit.

0  None – no water sources on plot
1  Permanent streams or ponds
2  Permanent water in the form of deep swamps, bogs, marshes
3  Ditch/canal – human-made channels such as for irrigation or drainage
4  Temporary streams
5  Flood zones – evidence of flooding when bodies of water exceed their natural banks
6  Vernal pool
9  Other temporary water – specify in plot notes

STAND HEIGHT: Record measurements to allow triangulation of stand height. Within plot, select a codominant tree of typical height and with a canopy visible from the ground. Move to a position as far from the base of the tree as possible while still allowing sufficient view of the tree canopy; if possible, take the angle from a position at least one-tree-height from the base of the tree along minimal slope. Do not select a position downslope from the tree. Using a clinometer, sight the top of the canopy of the selected tree and record the slope in degrees. Measure the distance from the center of the tree base to the point of measurement and record the distance in tenths of meters. If the point of measurement is upslope from the tree, use the clinometer to measure the angle from the point of measurement to the tree base by sighting on a crew member standing at the tree base and record this angle in degrees.

CANOPY PHOTOGRAPH. To be added.
Overview: This SOP measures species, diameter and condition of all standing live and dead trees >= 10 cm diameter-at-breast-height (DBH) within each 7.5-m radius tree plot. These data will yield information on tree growth, mortality and condition, and stand structure, composition, and biomass.

Caution: Dead trees can be a safety hazard. Crews must exercise caution - trees that are deemed unsafe to measure should be estimated.

Definitions:
All live or standing dead trees >= 10 cm DBH in a plot are measured by this protocol.

Diameter-at-breast-height (DBH) is measured at 1.37 m above the ground line on the uphill side of the tree.

Live trees are trees with any living parts (leaves, buds, cambium) present at or above DBH, including trees that have been temporarily defoliated.

Dead standing trees are dead trees that lean < 45 degrees from vertical. They need not be self-supported. Once included, dead trees are tracked until they no longer qualify as standing dead.

Horizontal distance is the straight line distance between two objects. This contrasts with slope distance which is measured parallel to the ground. Slope distance and horizontal distance are equivalent on flat land. On sloped land, the horizontal distance between two objects is less than the slope distance.

Data collection: Begin tallying trees at azimuth 001° and continue clockwise through plot, working outwards from plot center to perimeter. Include a tree in the plot if the horizontal distance from plot center to tree center is <= 7.5 m. Horizontal distance can be measured on minor slopes by holding the tape level. If slope is too steep to measure horizontal distance this way, measure slope distance and convert distance using a slope conversion table.

TREE NUMBER. Record a number to uniquely and permanently identify each tree on the plot. On remeasured plots, use the previously assigned tree number. Missed trees are assigned the
next available number; numbers assigned to trees that are subsequently withdrawn will be dropped and not reused.

At parks in which the use of tree tags have been approved, attach either a PIT tag or a pre-printed stainless steel tag to each tree as directed by the crew leader. If using tree tags, attach as follows: insert a small, stainless steel screw at a slight downward angle, just far enough so that it penetrates the bark and is secure but leaving as much space as possible for the tree to grow without “eating” the tag. Tag at 1.60 m above the ground, and consistently on the side of the tree facing plot center.

TREE LOCATION. This measurement is only made on intensive plots in parks which prohibit tree tags. In order to uniquely identify untagged trees, record the AZIMUTH from the plot center to each tree, sighting the center of the tree base. Use a compass with no declination (i.e., using magnetic north)\(^1\) and record AZIMUTH to the nearest degree. Measure and record the HORIZONTAL DISTANCE, to the nearest 0.1 m, from the plot center to the center of the tree base. For multi-stemmed trees, measure and sight to the geographic center - the point of equal distance between all tallied stems for a given tree. Horizontal distance can be measured on minor slopes by holding the tape level. If slope is too steep to measure horizontal distance this way, measure slope distance and convert distance using a slope conversion table.

SPECIES CODE. Record species code using the first three letters each of the genus and species. If species cannot be determined in the field, tally the tree and bring branch samples, foliage, cones, flowers, bark, photos, etc. to your supervisor for identification. If possible, collect samples outside the plot from similar specimens and make a note to correct the species code later. Use “Unk Con” for unknown conifer, “Unk Har” for unknown hardwood or “Unk” for unknown tree if genus or species cannot be determined; this is often the case with standing dead trees on newly established plots.

DBH. Measure tree diameter at breast height (1.37 m) above ground line on uphill side of tree. Use a PVC pole cut to 1.37 m to find breast height. Round measurement down to the last 0.1 cm.

**Within intensive plots only**, use paint as described here to accurately remeasure DBH at the same point during successive visits. On the side of the tree facing plot center, paint a thin line just at dbh using a small paintbrush and unobtrusive forestry paint. Upon remeasurement, line-up dbh tape with this line, and reapply paint if necessary to last until next remeasurement.

Special DBH situations:
**Irregularities at DBH:** On trees with swellings, bumps, depressions, and branches at DBH, measure diameter immediately above or below the irregularity at the place it ceases to affect normal stem form. Record location in tree notes.

**Missing wood or bark.** Do not reconstruct the DBH of a tree that is missing wood or bark at that point. Record diameter of the wood and bark that is still attached to the tree.

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\(^1\) Sighting using magnetic north simplifies this process of relocating trees by eliminating the need to reset exact declination as the crew travels across the network.
**Curved bole:** Find the point equivalent to breast-height (1.37 m) by measuring along the curvature of the bole on the upper surface (i.e., the short side) of the tree as shown in picture.

![Curved bole diagram](image)

**Leaning tree:** Find the point equivalent to breast-height (1.37 m) by measuring along the underside (i.e., the short side) of the tree; measure diameter perpendicular to the bole as shown in picture.

![Leaning tree diagram](image)

**Live windthrown tree:** Find the point equivalent to breast height (1.37 m) by measuring from the top of the root collar along the bole, as shown in picture.

![Live windthrown tree diagram](image)

**Forked tree:** Trees which fork at or above breast-height are tallied and measured as one tree. Diameter should be measured below the point at which forking affects dbh. This point should be recorded within tree notes.

Trees which fork below breast height are tallied and measured as two trees. The diameter of each fork >=10 cm DBH should be measured at breast-height unless forking influences DBH. If forking does influence DBH, the diameter of each stem >= 10 cm at the point of measurement should be measured at a position 50 cm above the fork. This point should be recorded within tree notes. Multiple stems should be recorded in clockwise order, or from front to back when one stem lies directly in front of another.
Independent trees that grow together: If two or more independent stems have grown together at or above the point of DBH, continue to treat them as separate trees. Estimate the diameter of each, and explain the situation in tree notes.

TREE STATUS. Record a status code for each tree to track status over time.

0 No status – for remeasured plots only. Previously tallied tree is no longer in sample because a) tree was incorrectly tallied in previous inventory; b) a change in definition or procedure since last inventory now excludes this tree; or c) tree can not be measured due to natural causes or inaccessibility. Record the reason in tree notes.

1 Live tree. New live trees in remeasured plots are assumed to be ingrowth. If a new tree is tallied that was missed during a previous inventory, note this in tree notes.

2 Standing dead tree

3 Removed - for remeasured plots only. Tree has been cut and removed by humans during harvest, silviculture or land clearing.

CROWN CLASS. Assign crown class code describing tree crown position in canopy and amount of sunlight received as described and shown below.

1 Open-grown – crown has received full sunlight from above and all sides through most of its life, particularly during early development.

2 Dominant – crown extends above canopy, receiving full light from above and some light from sides. Taller than the average tree in stand and has well-developed crown.

3 Co-dominant – crown at the general level of the canopy, receiving full light from above but little direct light from sides. Typically, co-dominant trees have medium-sized crowns and are crowded on the sides; in dense stands, co-dominant trees have small crowns.

4 Intermediate – tree is shorter than co-dominant trees but with a crown that extends into the general canopy. Crown receives little direct light from above and none from the side; tree has small crown and is very crowded from the sides.

5 Overtopped – crown is entirely below the general level of the canopy and receives no direct sunlight.
TREE CONDITION. Record the presence of any of the following: hemlock wooly adelgid, gypsy moth, spruce budworm, other insect damage (if insect is known, record in notes), beech bark disease (record degree of severity in notes), butternut canker, advanced decay, open wound(s), large dead branches, vine(s) in the crown, or other visible damage (record in notes).

FOLIAGE CONDITION. Visually assess foliage and record any problems as C - chlorosis, N - necrosis, H - holes, S - small leaves, W - wilting, or O - other. Estimate amount of crown affected using the following classes: <1%, 1-5%, 5-25%, 26-50%, 51-75%, 75-100%. If problem is recorded as “other” describe problem in tree notes.

DECAY CLASS. For each standing dead tree, record the code indicating the tree’s stage of decay.

<table>
<thead>
<tr>
<th>Decay class stage (code)</th>
<th>Limbs and branches</th>
<th>Top</th>
<th>% Bark Remaining</th>
<th>Sapwood presence and condition *</th>
<th>Heartwood condition *</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All present</td>
<td>Pointed</td>
<td>100</td>
<td>Intact; sound, incipient decay, hard, original color</td>
<td>Sound, hard, original color</td>
</tr>
<tr>
<td>2</td>
<td>Few limbs, no fine branches</td>
<td>May be broken</td>
<td>Variable</td>
<td>Sloughing; advanced decay, fibrous, firm to soft, light brown</td>
<td>Sound at base, incipient decay in outer edge of upper bole, hard, light to reddish brown</td>
</tr>
<tr>
<td>3</td>
<td>Limb stubs only</td>
<td>Broken</td>
<td>Variable</td>
<td>Sloughing; fibrous, soft, light to reddish brown</td>
<td>Incipient decay at base, advanced decay throughout upper bole, fibrous, hard to firm, reddish brown</td>
</tr>
<tr>
<td>4</td>
<td>Few or no stubs</td>
<td>Broken</td>
<td>Variable</td>
<td>Sloughing; cubical, soft, reddish to dark brown</td>
<td>Advanced decay at base, sloughing from upper bole, fibrous to cubical, soft, dark reddish brown</td>
</tr>
<tr>
<td>5</td>
<td>None</td>
<td>Broken</td>
<td>Less than 20</td>
<td>Gone</td>
<td>Sloughing, cubical, soft, dark brown, OR fibrous, very soft, dark reddish brown, encased in hardened shell</td>
</tr>
</tbody>
</table>

Characteristics are for Douglas-fir. Dead trees of other species may vary somewhat. Use this only as a guide.

TREE NOTES: Record any unusual tree features or notes required above.
Overview: This SOP quantifies live saplings, seedlings, and shrubs by species on a 2-m radius microplot. Seedlings are quantified by size class. These data yield information on tree regeneration, future cover, and the effects of deer browsing.

Definitions:
Saplings are defined as juvenile trees with diameter-at-breast-height (DBH) at least 2.0 cm but less than 10 cm.

Seedlings are defined as live, established juvenile trees that are at least 15 cm tall and less than 2.0 cm DBH, with at least two true leaves and no cotyledons present.

Shrubs are woody, sub-canopy species. To qualify for counting in this protocol, shrubs must be at least 30 cm long.

Horizontal distance is the straight line distance between two objects. This contrasts with slope distance which is measured parallel to the ground. Slope distance and horizontal distance are equivalent on flat land. On sloped land, the horizontal distance between two objects is less than the slope distance.

Height of seedlings or shrubs is defined as the distance from the ground to the top of the terminal bud, or to the top of the tallest fork. Do not include leaves or needles in this measurement. To measure height, gently align seedling or shrub along a ruler.

Data collection:
The 2-m radius microplot is located at azimuth 90° and 4 m from the plot center. Include a sapling, seedling or shrub within the microplot if the horizontal distance from plot center to the center of the stem is <= 2.0 m.

SAPLING SPECIES CODE. Record species code using the first three letters each of the genus and species. If species cannot be determined in the field, tally the tree and bring branch samples, foliage, cones, flowers, bark, photos, etc. to your supervisor for identification. If possible, collect samples outside the entire tree plot from similar specimens and make a note to correct the species code later. Record in sapling notes if sapling is sprouting from a stump.
SAPLING DIAMETER. Measure DBH at 1.37 m above ground line on the uphill side of sapling. Round measurement down to the last 0.1 cm. See instructions for measuring DBH in unusual situation in SOP #5.

SEEDLING COUNT. On each microplot, record the number of live, established tree seedlings by species within each height class: 15-30 cm, 30-100 cm, 1-1.5 m, > 1.5 m. Do not recount saplings. Count up to five individuals per species and height class; estimate the total count if there are more than five individuals of any given species in any given class.

Multiple “suckers” that originate from the same location, and stump sprouts are considered one seedling. Do not tally or count “layers” - undetached branches partially or completely covered by soil, usually at the base - as seedlings.

SEEDLING SPECIES CODE. Record species code using the first three letters each of the genus and species. If species cannot be determined in the field, tally the seedling and bring branch samples, foliage, bark, photos, etc. to your supervisor for identification. If possible, collect samples outside the entire tree plot from similar specimens and make a note to correct the species code later.

SHRUB SPECIES CODE. For each shrub species encountered on the microplot, record species code using the first three letters each of the genus and species. If species cannot be determined in the field, tally the shrub and bring branch samples, foliage, cones, flowers, bark, photos, etc. to your supervisor for identification. If possible, collect samples outside the subplots from similar specimens and make a note to correct the species code later.

SHRUB COUNT. Record the number of live shrubs >= 30 cm length on the microplot by species. Count up to 5 individuals per species; if more than 5 individuals are present, estimate the total count up to 50. Shrubs must be at least 30 cm length to qualify for counting. Multiple stems originating from a common base are counted as a single shrub.
Overview: This SOP provides a rapid measure for detection of specific indicator plant species within an extensive network of plots. Indicator plants will include understory species indicative of several stressors, including invasive exotic species, deer browsing, and perhaps air pollution and climate change. This SOP is designed to be used only during the summer months (about June 1 to August 31).

Data collection: Using a time constrained search, record species and percent cover class of any indicator plant species found within the entire tree plot. Indicator plant species are listed within Appendix B of the protocol narrative. Search for 15 minutes and record all species found. After search is completed, estimate % cover of each found species across the entire tree plot using the following cover classes: <1, 1-5, 6-15, 16-25, 26-50, 51-75, 76-95, 96-100%.
Overview: This SOP provides a rapid measure of forest floor condition. These data will be used to characterize the spatial extent of soil trampling and compaction, erosion, and the spread of invasive exotic earthworms.

Definitions:
Earthworm burrows are temporary or permanent soil channels made by earthworms for living space and during travel. Burrows can be observed as circular openings in the soil surface. Sometimes burrows are covered by, or surrounded by, casts, litter or organic matter.

Earthworm casts are excreted by earthworms after feeding, and are composed of soil mixed with digested plant residues. Casts appear as distinctive, moist aggregates of rich soil. Cast production is highest during moist spring and fall seasons, but should be visible throughout the summer in areas with established earthworm populations.

Forest floor is the top layer of organic matter overlying the mineral soil, consisting of intact and partially decomposed litter and humus.

Litter is undecomposed or partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs, etc.).

Humus or duff is a soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer is distinguished from litter by its degree of decomposition - within humus the origin of the organic matter can no longer be identified (e.g., as leaves, twigs, etc.).

Mineral soil is a soil consisting predominantly of products derived from the weathering of rocks (e.g., sands, silts, and clays).

Trampling is disturbance to ground vegetation or forest floor by humans, livestock, or wildlife.
Data collection:

% COVER ROCK. Record the percentage of the plot covered by exposed bedrock or large rocks (>10 cm) as: <1, 1-5, 6-25, 26-50, 51-75, 76-95 or 96-100 %. Rock may be covered by moss or lichens and still included in this estimate.

% COVER BARE SOIL. Record the percentage of the plot covered by bare soil (mineral or organic) as: <1, 1-5, 6-25, 26-50, 51-75, 76-95 or 96-100 %.

% TRAMPLED. Record the percentage of the plot showing evidence of trampling by humans, wildlife or livestock. Trampling is assessed relative to the conditions of adjacent undisturbed soil. Estimate the percentage as: <1, 1-5, 6-25, 26-50, 51-75, 76-95 or 96-100 %.

MICROTOPOGRAPHY. Record presence (1) or absence (0) of pit and mound microtopography on plot. If pit and mound topography is suggested but not clear, record 9.

HUMUS. Visually assess and record presence (1) or absence (0) of a well-developed humus layer within the plot. To do so, move to the edge of the plot and gently brush aside litter from the current year to assess humus underneath. If humus is present but minimal, record 2. If examination is inconclusive, record 9 and record a brief note explaining why.

EARTHWORMS. Visually assess and record the presence (1) or absence (0) of earthworm casts and burrows within the plot. To do so, move to the edge of the plot and gently brush aside litter from the current year to view casts and burrows at the soil surface. If examination is inconclusive, record 9, and record a brief note explaining why.
Overview: This SOP documents the procedure for photographing plots. These photographs will be archived and used as visual reference for change in appearance of plots over time. This photograph should be the first measure taken after plot setup in order to visually record the plot before field crew impacts occur.

Data collection:
Two digital photographs are taken at each plot, one of the plot overall and a second of the microplot. The first photograph is taken from the center of the microplot, facing towards the plot center. This photo should be taken lengthwise to get maximum coverage of all vegetation layers. The second photograph is a close-up of the microplot, taken from a position standing over the microplot.

An identification card must be visible in each photograph. This card should clearly show the park, plot, and date in large black letters. In remeasured plots, field crew should examine photographs from previous visits and attempt to recreate the position and angle used.

Photos should be 24-bit color photographs, taken at the highest resolution available on the network camera (at least 1024 x 768 pixels). Photos should be compressed using the high-quality JPEG compression setting on the camera.

CAMERA. Use a designated network digital camera for all pictures. Record the brand and model number of this camera, as it will change over time.

TIME. Record the time of day at which the photograph is taken.

WEATHER. Record the presence of clouds or fog.
Overview: This SOP describes procedures for calculating landscape context metrics for extensive plots as part of the Forest Vegetation Vital Sign. These landscape metrics are indicative of the influence of adjacent land use and stressors on the ecological condition of the plot. Change over time will be monitored using Digital Orthophoto Quarter-Quadrangles (DOQQs).

This SOP is specific to the landscape condition of forested plots; NETN will develop metrics for overall Landscape Dynamics as a separate protocol. However, it may be most efficient to bundle this analysis together with the large Landscape Dynamics analysis.

Sources of spatial data:
Vegetation maps of NETN parks are being developed as one of the IM base inventories by the USGS/NPS Vegetation Mapping Program (http://biology.usgs.gov/npsveg/) and distributed in digital and paper format. These maps will show National Vegetation Classification (NVC) vegetation communities within and surrounding each park using a minimum mapping unit of 0.5 ha. The NVC polygons can be grouped to show NatureServe Ecological Systems. These maps also designate human land use and cultural vegetation areas to standard land use/land cover (LUC) classification Level II.

While these USGS/NPS Vegetation maps provide a useful starting point for analysis, new spatial data will be needed for reassessment of landscape metrics. NETN should monitor change over time by periodically acquiring and analyzing high-resolution Digital Orthophoto Quarter-Quadrangles (DOQQs). DOQQs are digital images of aerial photographs that have been rectified to remove distortion from terrain and filming. A standard DOQQ is a grayscale or color-infrared image with 1-meter ground resolution, covering an area 3.75° longitude by 3.75° latitude – an area equivalent to one-quarter of a USGS quadrangle – plus 50 to 300 meters additional edge to facilitate mosaicking of adjacent images. DOQQs should be referenced to the North American Datum of 1983 (NAD83) and cast on the Universal Transverse Mercator (UTM) projection. For this analysis, we recommend color infrared images be used, and that imagery be photographed during the growing season when leaves are on trees.

Every 5 or 10 years, NETN should acquire recent (< 5 years old) DOQQs from the US Geologic Survey (USGS) and/or the National Digital Orthophoto Program (NDOP) for NETN park...
regions. These organizations create and distribute high-resolution DOQQS. If updated DOQQs photographed during the growing season are not available from these sources every 10 years, NETN may need to contract to have DOQQs created. Acquisition of DOQQs should be done in conjunction with NETNs Landscape Dynamics protocol.

In addition, periodically updated digital spatial data showing the location of roads, carriage roads and trails will be needed. This data can be acquired directly from the parks in some cases. For parks that do not maintain GIS data, road data should be available from state GIS clearinghouses.

**Spatial analysis:**
The following analyses should be performed separately for each extensive plot. Use locations of established plots, not the pre-selected plot locations. Spatial analysis should be performed using ArcView 3.x, ArcGIS or a program with similar capabilities.

It may not be possible to identify woodland patches and neighborhood cover for woodland plots using DOQQs; however, woodland plots only occur at ACAD and are a small percentage of total plots there.

**INTERIOR PATCH SIZE.** Calculate interior size in hectares of the forested patch within which each plot resides as described below.

1) For this analysis, a patch is considered to be an area of continuous high-canopy forest vegetation or plantation. Examine recent DOQQs and establish polygons representing continuous patches of high-canopy forest vegetation including plantations.
2) Paved roads present a barrier to many organisms living within a forested patch. Overlay road data upon polygons created in step 1, and at the point where a paved road intersects a polygon representing a forest patch, divide that polygon into separate polygons along the road centerline.
3) Within each polygon representing a forest patch, reduce the area of each polygon by creating a 150-m buffer directly interior to the polygon boundary and retaining only the interior area.
4) Record the size to the nearest 1/10 hectare of the buffered polygon within which each plot resides. If a plot resides within the buffer or outside of a forested patch, record 0.

**NEIGHBORHOOD FOREST COVER.** Calculate the percentage of forest cover found in a 1 km radius circle/square surrounding each plot. Examine recent DOQQs to determine presence or absence of high-canopy forest vegetation including plantations on a pixel-by-pixel or delineated polygon basis. Do not include early-successional area lacking a closed canopy.

**NEIGHBORHOOD NATURAL NON-FOREST COVER.** Calculate the percentage of natural non-forest vegetation cover found in a 1 km radius circle/square surrounding each plot. Examine the recent DOQQs to determine presence of natural vegetation cover on a pixel-by-pixel or delineated polygon basis. Exclude natural water cover (lakes, rivers, and streams).

**NEIGHBORHOOD ANTHROPOGENIC LANDUSE.** Calculate the percentage of anthropogenic landuse found in a 1 km radius circle/square surrounding each plot center. Examine recent DOQQs to determine presence of recognizable anthropogenic landuse on a pixel-by-pixel basis or delineated polygon basis.
DISTANCE TO PAVED ROAD. Calculate shortest distance in meters from plot center to the nearest paved road.

DISTANCE TO CARRIAGE ROAD OR MAJOR TRAIL. Calculate shortest distance in meters from plot center to the nearest carriage road or major trail.
Overview: This SOP describes and quantifies coarse woody debris using line intercept transect sampling along three transects laid out in each intensive plot. These data yield information on forest structural diversity and the availability and quality of habitat for wildlife and fungi.

Definitions: Coarse woody debris (CWD) includes down, dead tree and shrub boles, large limbs, and other woody pieces at least 7.5 cm diameter and 1 m long that are on the ground. CWD also includes dead trees that are leaning > 45 degrees from vertical.

Data collection: Three CWD transects were laid out during plot setup. Each transect begins at plot center and extends 7.5 m slope distance to the plot edge at azimuths of 30, 150, and 270 degrees (+/- 2°). Transects must be laid out along a straight line to avoid biasing the selection of pieces. Transects are marked at one end by the plot center marker and at the other end with a small steel pin.

Tally Rules for CWD Most CWD will be laying on the ground. To be tallied by this protocol, the point of intersection between the transect and the central longitudinal axis of the piece must occur above the ground, and the piece must meet the minimum diameter criteria (>= 7.5 cm) at the point of intersection.

---

**Central longitudinal axis**

**Transect line**

**Point of intersection**

---

December 13, 2005 DRAFT
There is no upper height limit for leaning snags in this protocol. All snags leaning >45° should be tallied regardless of height off the ground. If snag is too high to reach, record this fact and estimated diameter.

If a piece intersects a transect line more than once or intersects two transect lines, tally the piece each time it intersects. This is uncommon. However, if the subplot center falls directly on the central longitudinal axis of the piece, tally that piece only once, on the 30° transect.

To qualify as CWD, a piece must retain some structural integrity. Very decomposed logs that are slightly elevated ‘humps’ on the ground are not tallied as CWD.

For each piece of CWD to be tallied, record the following:
TRANSECT. Record the number indicating the azimuth of the transect on which the piece is sampled (30, 150 or 270).

DECAY CLASS
Record code indicating the predominant decay class of the piece.

<table>
<thead>
<tr>
<th>Class</th>
<th>Structural Integrity</th>
<th>Texture of Rotten Portions</th>
<th>Color of Wood</th>
<th>Invading Roots</th>
<th>Branches and Twigs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sound, freshly fallen, intact logs</td>
<td>Intact, no rot; conks of stem decay absent</td>
<td>Original color</td>
<td>Absent</td>
<td>If branches are present, fine twigs are still attached and have tight bark</td>
</tr>
<tr>
<td>2</td>
<td>Sound</td>
<td>Mostly intact; sapwood partly soft (starting to decay) but can’t be pulled apart by hand</td>
<td>Original color</td>
<td>Absent</td>
<td>If branches are present, many fine twigs are gone and remaining fine twigs have peeling bark</td>
</tr>
<tr>
<td>3</td>
<td>Heartwood sound; piece supports its own weight</td>
<td>Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent</td>
<td>Reddish-brown or original color</td>
<td>Sapwood only</td>
<td>Branch stubs will not pull out</td>
</tr>
<tr>
<td>4</td>
<td>Heartwood rotten; piece does not support its own weight, but maintains its shape</td>
<td>Soft, small blocky pieces; a metal pin can be pushed into heartwood</td>
<td>Reddish or light brown</td>
<td>Throughout</td>
<td>Branch stubs pull out</td>
</tr>
<tr>
<td>5</td>
<td>None, piece no longer maintains its shape, it spreads out on ground</td>
<td>Soft; powdery when dry</td>
<td>Red-brown to dark brown</td>
<td>Throughout</td>
<td>Branch stubs and pitch pockets have usually rotted down</td>
</tr>
</tbody>
</table>
This chart was developed primarily for Douglas-fir in the Pacific Northwest, but should be useful for other areas as well. Concentrate on the structural integrity and texture when estimating a decay class for CWD logs.

SPECIES CODE. Record species of the piece using the first three letters each of the genus and species. Species identification may be uncertain. On remeasurement plots, look for a tag, and/or see what tree species were tallied in past inventories. One way to distinguish hardwoods from softwoods is by the type of decay - hardwoods often have a white or grayish stringy rot, while softwoods have a reddish-brown blocky rot. If it is not possible to identify the species, record the genus if known, or “UNK CON” for unknown conifer or “UNK HAR” for unknown hardwood. If all else fails, enter “UNK” for unknown.

DIAMETER AT INTERSECTION. Record the piece's diameter, to the nearest cm, at the point where the transect intersects the longitudinal center of the piece. Take care to measure diameter perpendicular to the piece’s length (not along the line of the transect). Diameter of CWD is typically measured by holding a steel tape or ruler above the log. To avoid error, position your eyes directly over each end of the tape in sequence. Other methods include wrapping a tape around the bole (if possible) or using calipers.

For pieces that are not round in cross-section because of missing chunks or "settling" due to decay, measure the diameter in two directions and average. Estimate the longest and shortest axis of the cross-section (as shown in picture) and record the average value.

HOLLOW. Record the code indicating whether piece is hollow (Y) or not (N). A piece is considered hollow if a cavity extends at least 0.5 m along the central longitudinal axis of the piece, and the cavity entrance is at least 1/4 the diameter of the piece.
Overview: This SOP measures the type and relative abundance of all trees, shrubs, herbs, grasses, ferns and fern allies in intensive plots. Species richness and percent cover data is collected within each plot using nested quadrats. These data will yield information describing species richness, diversity and rates of community change, including abundance and spread of invasive exotic species. This SOP is designed to be conducted by a vegetation specialist or crew member familiar with vegetation at the sampled park, and should be used only during the summer months (approximately June 1 to August 31).

Data collection:

QUADRAT DATA. Species presence is noted within three 1 m² quadrats. From plot center, the quadrats are located on the right sides of transects laid out at azimuths of 30°, 150°, and 270°. Place the quadrat frame to the right side of the transect line extending from 5 to 6 m from the plot center. Level the quadrat, if necessary, by propping up the quadrat corners. In areas of thick vegetation, quadrat sides should be slid through the vegetation. A useful quadrat frame can be made from PVC pipe and pipe joints - the joints are detachable to improve maneuverability.

QUADRAT SAMPLING STATUS. Record whether each quadrat was sampled. If a quadrat was not sampled, record the reason in plot notes. This might occur if no vascular plants are rooted in or overhanging the plot within 2 m of ground surface, or if a safety hazard exists.

QUADRAT TRAMPLING. Note if more than 10% of the ground surface of any quadrat appears trampled. Trampling is defined as damage to plants or disturbance of the ground layer by humans, livestock, or wildlife. Examine each quadrat prior to sampling, and do not note trampling caused by the field crew.

QUADRAT CODE. Record the code(s) corresponding to each quadrat within which the species was found: 30, 150 or 270°.

QUADRAT SPECIES. Record each vascular plant species found rooted in or overhanging within 2 m above the quadrat. If a plant cannot be identified to species quickly and confidently, assign the species a number, record genus or family, if possible, and give a short descriptive name. If the unknown plant is not locally sparse, collect a specimen away from the quadrat as
described below. Do not collect any plants that are represented by 5 or fewer individuals (i.e., locally sparse) in the general vicinity of the plot. Anytime it is not possible to collect a specimen, collect a photograph. Do not collect if plant occupies less than 1% canopy cover on subplot AND no mature foliage or reproductive parts are present; these plants would be too difficult to identify.

**PLOT DATA.** After quadrat data has been collected, a time-constrained search is conducted for additional species on the entire intensive plot. Then, for each species occurring in the quadrats and on the plot, % cover is rapidly estimated as described below. For species found on the plot but not within a quad, record quad code 0.

**PLOT SPECIES.** Record all additional species rooted within or overhanging the plot, searching for no more than 15 minutes. If portions of the plot are wet, only emergent plants are recorded. Epiphytes and vines are recorded as best as possible as seen from the ground level. Record each species using guidelines above for quad species.

**% COVER BY SPECIES.** For each species occurring in the quadrats or on the plot, including overstory tree species and shrubs recorded in SOPs #6 and #7, estimate total cover over the entire plot. Cover is based on a vertically-projected polygon described by the outline of the foliage, ignoring any normal spaces occurring between the leaves of plants. For species of moderate cover, it may be easiest to divide the subplots into quarters, estimate canopy cover of each quarter separately, and then add them together. Use the following cover classes: <1, 1-5, 6-25, 26-50, 51-75, 76-95, 96-100%.

**PLANT COLLECTION:** Do not collect any plant that is locally sparse as described above. Use a digging tool to extract the entire plant, including any underground portions, flowers, fruits, and leaves. Collected unknown specimens should be transported from the field in zip-lock bags with a moist paper towel. Bag should be labeled with day of collection, plot, and collector and specimen number. Promptly identify collected plants promptly or press specimens for later identification.
Overview: This SOP documents the procedure for measuring forest floor thickness and collecting soil samples near each intensive plot. Soil samples will be collected and shipped to designated facilities for soil chemistry analysis, including total carbon, total nitrogen, and exchangeable cations. These data will characterize forest soil chemistry and provide information on the effects of atmospheric deposition upon the ability of these soils to support forested ecosystems.

Regulations Governing Sample Collection. The National Historic Preservation Act of 1966 (as amended) provides for the protection of historical and cultural artifacts. Due to the random placement of plots, a soil sampling site may be located on a site of prehistoric or historical significance.

Park archeologists or cultural resource specialists will be contacted prior to field visits in order to obtain permission to sample. However, if cultural artifacts are encountered at a plot, do not take soil samples. Code the site as not sampled and record a plot note explaining why soil samples were not taken.

Definitions:
Forest floor is the top layer of organic matter overlying the mineral soil, consisting of intact and partially decomposed litter and humus.

Litter is undecomposed or partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs, etc.).

Humus or duff is a soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer is distinguished from litter by its degree of decomposition - within humus the origin of the organic matter can no longer be identified (e.g., as leaves, twigs, etc.).

Mineral soil is a soil consisting predominantly of products derived from the weathering of rocks (e.g., sands, silts, and clays).
Data collection: Soil measurement and sampling is conducted along a transect adjacent to each intensive plot. The first time a plot is sampled, the soil measurement location is 10 meters slope distance at azimuth 180° from the plot center. During subsequent visits, soil measurement locations will be at 3-m intervals along an east-west transect alternating on opposite sides of soil measurement site #1 (the transect center point) as shown in the diagram below. For example, during the second visit, the soil measurement location will be 3 m east of soil measurement site #1; during the third visit, the soil measurement location will be 3 m west of soil measurement site #1; during the fourth visit, the soil measurement location will be 6 m east of soil measurement site #1, and so forth. If the soil cannot be measured or sampled at the designated sampling point due to trampling or an obstruction (e.g., boulder, tree, standing water), the sampling point may be relocated to any location within a radius of 3 m.

SOIL SAMPLE. Using a network soil corer, a single soil core is collected from the soil measurement location. At this location, gently remove any unconsolidated litter from the soil surface, and drive the core into the ground to a depth of 20 cm. If the core strikes a rock or obstruction before reaching this depth, remove the core and select another location with a radius of 3 m of the original sampling location. If three attempts fail to yield a 20 cm soil core, take whatever depth core is available.

Once the core is exposed, use a ruler to measure the depth collected and record this value. Then, use a knife to separate the core by depth. First, slice off any part that exceeds 20 cm depth. Second, slice the core at 10 cm depth and bag the lower section (10-20 cm depth). Finally, bag the upper section (0-10 cm). Label each sample bag with date collected, park, plot #, and depth.

Upon return from the field, leave soil sample bags open to air-dry in a safe location until soil no longer appears moist. Seal bags and ship to the designated soil chemistry lab for analysis.

FOREST FLOOR THICKNESS. Forest floor thickness is measured at three locations: the designated soil measurement location, a point 25 cm due north of this location, and a point 25 cm due south of this location. Carefully expose a shallow profile of the forest floor by digging out an area at the sample point using a knife or other tool. Using a ruler, measure and record the thickness of the entire forest floor (to the nearest cm) from the top of the litter layer to the boundary between the forest floor and mineral soil. Measure to a maximum depth of 50 cm. For locations where bare soil or bedrock material is exposed, record 0 cm depth.

LITTER LAYER THICKNESS. At the same locations used to measure forest floor thickness, measure and record the thickness of the litter layer (to the nearest cm). The bottom of the litter layer can be distinguished as the boundary where plant parts (such as leaves or needles) are no longer recognizable as such because of decomposition. Another criterion is that the organic layer may contain plant roots, but the litter layer will probably not. At some locations, the depth of the forest floor and the litter layer may be the same. For locations where bare soil or bedrock material is exposed, enter 0 cm depth.
Revision History Log:

<table>
<thead>
<tr>
<th>Previous Version No.</th>
<th>Revision Date</th>
<th>Revised By</th>
<th>Changes</th>
<th>Reason</th>
<th>Revised Version No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Overview: This SOP delineates calculation of forest variables and metrics from raw data, and provides a statistical model for analysis of status and long-term trends.

Calculations

For each plot, forest variables and metrics will be calculated from raw data as shown in Table 1. Calculation of landscape variables using GIS is not shown here, but is described within SOP #11.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Variable type</th>
<th>Units</th>
<th>Calculation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canopy closure</td>
<td>Percent</td>
<td>%</td>
<td>Calculated from canopy photograph</td>
<td>NA</td>
</tr>
<tr>
<td>Snag abundance</td>
<td>Quant</td>
<td>m² / ha</td>
<td>Sum basal area of snags in plot, converted to per hectare.</td>
<td>(Σ snagdbh_cm) / (PlotDiam_m)²</td>
</tr>
<tr>
<td>CWD volume</td>
<td>Quant</td>
<td>m³ / ha</td>
<td>Volume per ha. calculated from line-intersect data, slope corrected.</td>
<td>(π² * (sqrt (1 + slope% / 100)) / (8 * TransLength_m)) Σ diam_cm²</td>
</tr>
<tr>
<td>Tree condition</td>
<td>Index</td>
<td>NA</td>
<td>Sum of points for tree health problems</td>
<td></td>
</tr>
<tr>
<td>Tree growth rate by species</td>
<td>Rate</td>
<td>% BA / yr</td>
<td>Annual percent tree basal area increase, calculated by species</td>
<td>(Σ (BA_{t2} - BA_{t1}) / (BA_{t1} * revisitInterval)) / n</td>
</tr>
<tr>
<td>Tree mortality rate by species</td>
<td>Rate</td>
<td>% stems / yr</td>
<td>Annual percent tree stem mortality, calculated by species</td>
<td>#StemsDied_{t1-t2} / (#LiveStems_{t1} * revisitInterval)</td>
</tr>
<tr>
<td>Tree regeneration</td>
<td>Index</td>
<td>NA</td>
<td>Sum of points per seedling of high canopy species in each size class</td>
<td>(1 * (#sdgls&lt;30 cm) + 2 * (#sdgls30-100cm) + 20 * (#sdgls1-1.5 m) + 50 * (sdgls&gt;1.5 m) + 50 * (saplings) / (sdgls in plot))</td>
</tr>
<tr>
<td>Understory plants</td>
<td>Index</td>
<td>NA</td>
<td>Sum number of indicator species found in plot</td>
<td>NA</td>
</tr>
<tr>
<td>Understory richness</td>
<td>Index</td>
<td>NA</td>
<td>Sum of native understory species found on plot</td>
<td>NA</td>
</tr>
<tr>
<td>Native species ratio</td>
<td>Percent</td>
<td>% native species</td>
<td>Ratio of native to total species in plot</td>
<td>NA</td>
</tr>
<tr>
<td>Soil chemistry - Ca:Al ratio</td>
<td>Ratio</td>
<td>NA</td>
<td>Molar calcium:aluminum ratio</td>
<td>NA</td>
</tr>
<tr>
<td>Soil chemistry - C:N ratio</td>
<td>Ratio</td>
<td>NA</td>
<td>Molar ratio of total carbon:total nitrogen</td>
<td>NA</td>
</tr>
</tbody>
</table>

Descriptive statistics

Forest plot metrics will be summarized for each park using graphs to show means and standard deviation of each metric. Maps will be created to show spatial trends in specific metrics.
Statistical analysis

We will estimate status and trends over time of specific measures within forested systems in each sampled park, and also within specific ecological system groups in Acadia NP. Analyses will be based on a general linear model which partitions spatial and temporal variability to allow assessment of change over time, as is done by the USFS FIA/FHM program. This model is:

\[
y_{ij} = b_0 + b_1 (t_j - t_0) + \eta_i + \varepsilon_{ij}\]  

Equation 1

where

\(y_{ij}\) = the value of a measure on plot \(i\) at time \(j\)

\(b_0\) = the estimated mean value of all plots at year 0

\(b_1\) = estimated change in \(y\) over time

\(t_j\) = time of measurement \(j\)

\(t_0\) = time of initial measurement

\(\eta_i\) = spatial (between-plot) variability

\(\varepsilon_{ij}\) = temporal (within-plot) variability

and measurement error is assumed to be normally distributed with mean 0 and variance \(\sigma^2\).

We will also collect and analyze covariate data (such as climate variables and air pollution concentration and deposition rates) in order to better account for the relationship between certain response variables (such as tree growth or mortality rate) and key ecosystem drivers and stressors. When a covariate is related to a response variable, incorporating the covariate into Equation 1 will allow more precise estimation of change and an estimate of the strength of the relationship, as shown in Equation 2. This covariate model is also used by the USFS FIA/FHM program.

\[
Y(i + n),j = b_0 + b_1 (t(i + n),j - tij) + b_2 (x(i + n),j - xij) + b_3 (t(i + n),j - tij)(x(i + n),j - xij) + \eta_{ij} + \varepsilon_{ij}
\]  

Equ. 2

where

\(n\) = the interval between measurements

\(Y(i + n),j\) = the value of \(Y\) at measurement \(i+n\) for plot \(j\)

\(b_0\) = the initial value of \(Y\)

\(b_1\) = the change in \(Y\) over time

\(b_2\) = the change in \(Y\) per change in unit \(x\)

\(b_3\) = the interaction between change in \(x\) and \(Y\)

\(t(i + n),j\) = the time of measurement \(i+n\) on plot \(j\)

\(tij\) = the time of measurement \(i\) on plot \(j\)

\(x(i + n),j\) = the value of a covariate at measurement \(i+n\) on plot \(j\)

\(xij\) = the value of a covariate at measurement \(i\) on plot \(j\)

\(\eta_{ij}\) = spatial (between-plot) variability

\(\varepsilon_{ij}\) = temporal (within-plot) variability
INTRODUCTION

Overview:
The Northeast Temperate Network (NETN) will use a scorecard format to report on the status and trends in ecological integrity of forest vegetation. An ecosystem integrity report card or scorecard must fulfill several criteria to be successful. The scorecard must: 1) be understandable to multiple audiences, 2) address differences in ecosystem responses across time, 3) show the status or current condition of the ecosystem, 4) characterize ecosystem condition thresholds, and 5) provide justification and transparency for those thresholds (Harwell et al. 1999). Following these criteria, we have developed a scorecard reporting framework to provide a clear communication tool for park managers, the public and other stakeholders. This scorecard will interpret relative ecological integrity in a transparent fashion such that integrity thresholds and actual data values measured are readily apparent.

This SOP describes how metrics derived from field measurements are assessed and reported to determine the overall ecological condition or integrity of the Forest Vegetation Vital Sign. Where possible, a rating or grade scale is established for each metric, with thresholds for each rating. The thresholds indicate whether a metric qualifies as Good, Caution, or of Significant Concern. In some cases, there is not enough information to establish rating thresholds, and metrics in need of further research and development are indicated. Metrics will be improved over time as statistical analyses are completed. The scorecard ratings will provide guidance to managers and decision makers on the specific status of individual metrics (e.g., coarse woody debris). In addition, we provide three aggregate indices – Vegetation Condition Index, Landscape Context Index, and Soil Condition Index – based on combinations of the metrics. These indices provide managers with a tool for interpreting the interactions among the individual metrics, and a means of assessing the overall status of forest systems and the forest vegetation in general.

Forest vegetation is the predominant natural vegetation cover of all NETN parks. A variety of terrestrial (non-wetland) forest systems are found across the parks. The SOPs developed for forest vegetation are applicable to all forest types, but, where needed, ratings for each measure and metric will be tailored to the specific ecological characteristics of each system.
FOREST VEGETATION SCORECARD

A synopsis of the ecological metrics and ratings is presented in Tables 1 and 2. The three tiers (Table 2) refer to levels of sampling intensity. Tier 1 metrics can be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 metrics are measured at extensive sampling plots, while tier 3 metrics are measured at intensive plots. Most metrics can only be measured as Tier 2 or Tier 3 metrics (i.e., they require data collection on the ground). Our decisions as to which metrics to sample across all plots (as opposed to the intensive subset of plots) is determined by the cost of data collection and the importance assigned to the metrics. For example, tree growth and mortality metrics require tracking individual stems over time, and these metrics are measured across all plots because they are extremely important for assessing forest integrity. Table 1 identifies whether metrics are measured on all plots or only on intensive plots. Our method for aggregating metrics into ecological integrity indices accounts for the fact that intensive metrics provide better data for a subset of plots.

The summary of the metrics used in the scorecard (see Tables 1 & 2) includes metrics that have been completed and those that are still under development. The completed metrics are ready to be used to interpret data collected by the monitoring program. The metrics under development are shaded gray. They will be added as we gain more knowledge about appropriate thresholds.

RATING SCHEME

Metric value ratings were structured around a point-based scale of Good (5 points), Caution (3 points), and Significant Concern (1 point). These value ratings follow the multimetric approach proposed by Karr (1981) for aquatic systems, and that has been used by others for developing terrestrial indices (Keddy and Drummond 1996, DeKeyser et al. 2003, Mack 2004). In the future, it may be desirable to “lengthen” the scale (i.e., add more intervals) in order to make the metric more sensitive, as done by other users of scorecards. For example, NatureServe (2002) and The Nature Conservancy (Parrish et al. 2003) typically use four intervals (Excellent, Good, Fair, and Poor); others use five or more, depending on the metric (Wasniak et al. 2004). The NETN “Good” category can be thought of as a combination of the NatureServe “Excellent” and “Good” categories. The background, methods, and rationale for each metric rating are provided in section B.

Each core metric is combined into one of three indices: Vegetation Condition, Soil Condition, and Landscape Context. As we gain experience in working with the metrics and understanding their relative contribution to overall ecological integrity, we may want to adjust the metric weight to account for current knowledge. For example, within an index, one measure may be judged to be more important than the other(s), and could be weighted more strongly. Measures taken at intensive plots are considered more accurate than measures from extensive plots, and metrics based on these measures will be weighted more heavily than extensive metrics (by a factor of two). This will help prevent the more accurate (but sparser) data from being swamped by less accurate data collected at more plots. In all other
situations, metrics are currently weighted equally. Points for the various metrics are then added up. The resulting scores are used to assign Good, Caution, or Significant Concern ratings for the metrics and indices. The three indices can then be averaged to arrive at an overall ecological integrity score. However, based on the current needs of the NETN program, we only include a scorecard for the individual metrics and indices. Table 1 shows which metrics are collected on all plots and which ones are collected on intensive plots.

Table 1. Overall set of metrics for the forest vegetation vital sign. Shaded cells are completed metrics. Unshaded cells are in development, and will be added over time. The Plot column indicates those metrics that are collected on all plots and those collected only on intensive plots.

<table>
<thead>
<tr>
<th>VITAL SIGN</th>
<th>METRIC</th>
<th>Plot</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VEGETATION CONDITION INDEX</strong></td>
<td>Tree regeneration</td>
<td>All</td>
</tr>
<tr>
<td>Tree growth rate</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Tree mortality rate</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Tree condition</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Snag basal area</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Coarse woody debris</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Understory native plant species richness</td>
<td>Intensive</td>
<td></td>
</tr>
<tr>
<td>Understory native plant species cover</td>
<td>Intensive</td>
<td></td>
</tr>
<tr>
<td>Understory indicator plants - deer browse</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Stand canopy closure</td>
<td>Intensive</td>
<td></td>
</tr>
<tr>
<td>Tree basal area by species group</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Understory indicator plants – forest interior herbs</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Understory indicator plants – invasive exotics</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td><strong>SOIL CONDITION INDEX</strong></td>
<td>Forest floor condition – earthworms + trampling</td>
<td>All</td>
</tr>
<tr>
<td>Soil chemistry – Ca:Al ratio</td>
<td>Intensive</td>
<td></td>
</tr>
<tr>
<td>Soil chemistry – C:N ratio</td>
<td>Intensive</td>
<td></td>
</tr>
<tr>
<td><strong>LANDSCAPE CONTEXT INDEX</strong></td>
<td>Distance to road or major trail</td>
<td>All</td>
</tr>
<tr>
<td>Fragmentation</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Interior patch size</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Structural stage distribution</td>
<td>All</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Summary of the relevant measures and vital signs for the forest vegetation vital sign. Measures and metrics are rated as to whether they can be assessed using remote sensing (1), extensive (2), or intensive (3) methods. Ratings with threshold values are provided where possible, sometimes with separate sub-ratings by Ecological System. Shaded cells are completed metrics. Unshaded cells are in development, and will be added over time.

<table>
<thead>
<tr>
<th>AGGREGATE INDEX FOR VITAL SIGN</th>
<th>METRIC</th>
<th>TIER</th>
<th>Variable Type</th>
<th>Units</th>
<th>Metric Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Tree regeneration</td>
<td>2,3</td>
<td>Index</td>
<td>N/A</td>
<td>≥ 100 points</td>
</tr>
<tr>
<td></td>
<td>Tree growth rate</td>
<td>3</td>
<td>Continuous</td>
<td>Mn/yr</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Tree mortality rate</td>
<td>3</td>
<td>Proportion</td>
<td>stems/yr</td>
<td>&lt;2%</td>
</tr>
<tr>
<td></td>
<td>Tree condition</td>
<td>2</td>
<td>Index</td>
<td>N/A</td>
<td>&lt;5% of trees have canopy foliage problems &gt;25% AND stem/crown points &lt;3 points, AND no trees have Asian long-horned beetle.</td>
</tr>
<tr>
<td></td>
<td>Snag (basal area + density)</td>
<td>2,3</td>
<td>Continuous</td>
<td>Meter²/ hectare</td>
<td>Either basal area 0.5-12.0 m²/ha OR density 10-200 stems / ha</td>
</tr>
<tr>
<td></td>
<td>Coarse woody debris (volume)</td>
<td>3</td>
<td>Continuous</td>
<td>Meters³/ hectare</td>
<td>1. &gt;100 2. &gt;80 3. &gt;25</td>
</tr>
<tr>
<td></td>
<td>Understory native plant species richness</td>
<td>2,3</td>
<td>Continuous</td>
<td>N/A</td>
<td>1. &gt;14 2. &gt;20</td>
</tr>
<tr>
<td></td>
<td>Understory native plant cover</td>
<td>2,3</td>
<td>Proportion</td>
<td>Percent</td>
<td>&gt; 98%</td>
</tr>
</tbody>
</table>
## AGGREGATE INDEX FOR VITAL SIGN

<table>
<thead>
<tr>
<th>METRIC</th>
<th>TIER</th>
<th>Variable Type</th>
<th>Units</th>
<th>Good</th>
<th>Caution</th>
<th>Concern</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understory indicator plants - deer browse</td>
<td>2,3</td>
<td>Index, Proportion</td>
<td>N/A, Percent</td>
<td>Preferred &amp; browsed species present in expected abundance based on Deer Browse Index [TBD]. Hay-scented fern and New York fern &lt;25%.</td>
<td>Preferred &amp; browsed species lower than expected abundance based on Deer Browse Index. [TBD]. Hay-scented fern and New York fern 25-50%.</td>
<td>Preferred &amp; browsed species much lower than expected abundance based on Deer Browse Index. [TBD]. Hay-scented fern and New York fern &gt;50%.</td>
<td>List of indicators for Deer Browse Index is partially complete.</td>
</tr>
<tr>
<td>Stand canopy closure</td>
<td>3</td>
<td>Proportion</td>
<td>% visible sky</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>Metric not yet developed</td>
</tr>
<tr>
<td>Tree basal area by species group</td>
<td>2</td>
<td>Index</td>
<td>N/A</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>Metric not yet developed.</td>
</tr>
<tr>
<td>Understory indicator plants - forest interior herbs</td>
<td>2,3</td>
<td>Index</td>
<td>N/A</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>Protocol and metric not yet developed.</td>
</tr>
<tr>
<td>Forest floor condition – earthworms + trampling</td>
<td>2,3</td>
<td>Boolean</td>
<td>N/A</td>
<td>No evidence of invasive exotic earthworm AND presence of humus layer AND trampled area &lt; 5%.</td>
<td>Evidence of invasive exotic earthworm OR humus layer not well developed, OR trampled area 5-15%.</td>
<td>Evidence of invasive exotic earthworm AND humus layer not well developed, OR trampled area &gt;15%.</td>
<td>Forest floor is assessed for direct evidence of invasive exotic earthworms, or impacts on the humus layer, or trampling.</td>
</tr>
<tr>
<td>Soil chemistry - Ca:Al ratio</td>
<td>3</td>
<td>Ratio</td>
<td>N/A</td>
<td>Ratio &gt; 1.0 in top 10 cm</td>
<td>Ratio 0.51-1.00 in top 10 cm</td>
<td>Ratio &lt; 0.51 in either top 10 or in 10-20 cm.</td>
<td>Soil samples gathered at two depths (0-10 cm, 10-20 cm).</td>
</tr>
<tr>
<td>Soil chemistry – C:N ratio</td>
<td>3</td>
<td>Ratio</td>
<td>N/A</td>
<td>C: Ratio &gt;30 in top 10 cm H: Ratio &gt; 25 in top 10 cm</td>
<td>C: Ratio 25-30 in top 10 cm H: Ratio 20-25 in top 10 cm</td>
<td>C: Ratio &lt;25 in either top 10 or 10-20 cm H: Ratio &lt;20 in either top 10 or 10-20 cm.</td>
<td>C=Conifer-dominated, H=Hardwood-dominated Soil samples gathered at two depths (0-10 cm, 10-20 cm).</td>
</tr>
<tr>
<td>AGGREGATE INDEX FOR VITAL SIGN</td>
<td>METRIC</td>
<td>TIER</td>
<td>Variable Type</td>
<td>Units</td>
<td>Good</td>
<td>Caution</td>
<td>Concern</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------</td>
<td>------</td>
<td>---------------</td>
<td>-------</td>
<td>------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>LANDSCAPE CONTEXT INDEX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to road or major trail</td>
<td>1,2</td>
<td>Continuous</td>
<td>Meters (distance)</td>
<td>&gt;150m</td>
<td>50 - 150 m</td>
<td>&lt; 50m</td>
<td>Distance to nearest road in meters.</td>
</tr>
<tr>
<td>Fragmentation (neighborhood cover)</td>
<td>1,2</td>
<td>Proportion</td>
<td>Percent</td>
<td>&lt;10%</td>
<td>10-40%</td>
<td>&gt;40%</td>
<td>Percent of non-forest non-natural cover found in a local neighborhood (65 ha) around a forest plot.</td>
</tr>
<tr>
<td>Interior patch size</td>
<td>1</td>
<td>Continuous</td>
<td>Area (in hectares)</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>Calculate forest patch size. Metric not developed.</td>
</tr>
<tr>
<td>Structural stage distribution</td>
<td>1</td>
<td>Proportion</td>
<td>Percent</td>
<td>1. &gt;50</td>
<td>1. 20-50</td>
<td>1. &lt;20</td>
<td>1= Spruce-Fir, 2=Northern and Hemlock Hardwoods, 3 =Pine-Oak Systems.</td>
</tr>
</tbody>
</table>
RATING VEGETATION CONDITION

Rate the Vegetation Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 3) to combine the metrics into an overall Vegetation Condition rating. This rating can be calculated for a specific plot or for a group of plots (e.g., all plots in a park, or all plots in a community type). When calculating the index for an extensive plot, intensive metrics are ignored, so the rating is the sum of the scores divided by the sum of the weights for metrics that were actually collected.

Rationale for Scoring: At this time, all intensive metrics are given twice the weight of extensive metrics. Different weightings may be assigned, as more is learned about the relative strength and interaction among the various metrics.

Table 3. Vegetation Condition Rating Calculation. Developed metrics are listed. The overall vegetation condition rating is the sum of the scores divided by the sum of the weights. Good = 3.5 to 5.0, Caution = 2.0 to 3.5, and Significant Concern = 1.0 to 2.0.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Plot</th>
<th>Good</th>
<th>Caution</th>
<th>Significant Concern</th>
<th>Weight</th>
<th>Score (weight x rating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree regeneration</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Tree growth rate</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Tree mortality rate</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Tree condition</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Snag basal area</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Coarse woody debris</td>
<td>Intensive</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Understory native plant</td>
<td>Intensive</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>species richness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understory native plant</td>
<td>Intensive</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>species cover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understory indicator plants</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>- deer browse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RATING SOIL CONDITION

Rate the Soil Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 4) to combine the metrics into an overall Soil Condition rating. This rating can be calculated for a specific plot or for a group of plots (e.g., all plots in a park, or all plots in a community type). When calculating the index for an extensive plot, intensive metrics are ignored, so the rating is the sum of the scores divided by the sum of the weights for metrics that were actually collected.

Rationale for Scoring: At this time, all intensive metrics are given twice the weight of extensive metrics. Different weightings may be assigned, as more is learned about the relative strength and interaction among the various metrics.
Table 4. Soil Condition Rating Calculation. Completed metrics are listed. The overall soil condition rating is the sum of the scores divided by the sum of the weights. Good = 3.5 to 5.0, Caution = 2.0 to 3.5, and Significant Concern = 1.0 to 2.0.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Plot</th>
<th>Good</th>
<th>Caution</th>
<th>Significant Concern</th>
<th>Weight</th>
<th>Score (weight x rating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest floor condition (earthworms + trampling)</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Soil chemistry (Ca:Al ratio)</td>
<td>Intensive</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Soil chemistry (C:N ratio)</td>
<td>Intensive</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

RATING LANDSCAPE CONTEXT

Rate the Landscape Context metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 5) to combine the metrics into an overall Landscape Context rating. This rating can be calculated for a specific plot or for a group of plots (e.g., all plots in a park, or all plots in a community type). When calculating the index for an extensive plot, intensive metrics are ignored, so the rating is the sum of the scores divided by the sum of the weights for metrics that were actually collected.

Rationale for Scoring: At this time, all intensive metrics are given twice the weight of extensive metrics. Different weightings may be assigned, as more is learned about the relative strength and interaction among the various metrics.

Table 5. Landscape Context Rating Calculation. Completed metrics are listed. The overall soil condition rating is the sum of the scores divided by the sum of the weights. Good = 3.5 to 5.0, Caution = 2.0 to 3.5, and Significant Concern = 1.0 to 2.0.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Plot</th>
<th>Good</th>
<th>Caution</th>
<th>Significant Concern</th>
<th>Weight</th>
<th>Score (weight x rating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to road or major trail</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Fragmentation</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Interior patch size</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Structural stage distribution</td>
<td>All</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>
METRIC DOCUMENTATION & THRESHOLD JUSTIFICATION

This section documents the reporting thresholds we have chosen for our forest vegetation scorecard. The thresholds are listed in Table 2 and the field methods, threshold rationale, and threshold certainty are detailed in the following discussion.

TREE REGENERATION

**Definition:** This metric assesses the degree to which tree seedlings are successfully establishing in the regeneration layer.

**Measurement Protocol:** Seedlings are counted on a 2-m radius microplot (= 12.56 m² area). Seedlings are defined as live, established seedlings of tree species that are at least 15 cm tall and less than 2.5 cm DBH, with at least two true leaves and no cotyledons present. Sum of points per seedling of **high canopy tree species** in each size class; points awarded for each seedling based on seedling height as follows:
- <=30 cm seedling = 1 point;
- 30 cm – 100 cm seedling = 2 points;
- 100 – 150 cm seedling = 20 points;
- >150 cm seedling = 50 points;

**Metrics Rating:** See Table 2.

**Data:** See FIA study in Pennsylvania (McWilliams et al. 2005).

**Scaling Rationale:** FIA suggested thresholds at 25 points and 100 points.

**Confidence that reasonable logic and/or data support the rating:** Low/Medium. This metric may benefit from some fine-tuning, e.g., 1) define “high canopy tree species,” 2) exclude exotic tree seedlings, and 3) fine-tune points based on forest ecosystem type.

TREE GROWTH RATE

**Definition:** Monitoring growth rate serves as an early-warning indicator of decline in canopy tree species.

**Measurement Protocol:** Annual growth rate is calculated for each canopy tree species as % increase in basal area.

**Metrics Rating:** To be developed
**Data:** Data on variability in growth rate patterns for NETN forest systems is still being gathered. Woods (2000) reports mean annual growth rates (mm/yr) of dominant tree species in hemlock-hardwood stands of the upper peninsula of Michigan. Growth rates varied by species and by site type, but had mean values ranging from 0.62 to 4.2 mm/yr.

The FIA program reports net growth rates as percent basal area change, but this metric is apparently not used in the ecological literature. Steinman (2004) reports net growth rates for forests in the northeastern United States, using 5 categories of change: > 2%, 1.6-2.0, 1.1-1.5, 0.6-1.0, and <0.6. The basis for the thresholds is not specified, but growth rates of < 0.6 are indicated as cause for concern. Thus a metric for growth rate could be constructed as > 1.5% = Good, 0.6-1.5% = Caution, and <0.6% = Significant Concern.

**Scaling Rationale:** To be determined.

**Confidence that reasonable logic and/or data support the index:** Low

### TREE MORTALITY RATE

**Definition:** This metric assesses the percentage loss of stems as a measure of the mortality rate of overstory trees on the plot.

**Measurement Protocol:** All standing live and dead trees that are at least 10 cm (5 inches) diameter-at-breast-height (DBH) within each plot are measured for species, dbh, and location. The overall proportion of stems dieing on an annual basis is then calculated.

**Metrics Rating:** See Table 2.

**Data:** Tree mortality rates will depend on local tree species and conditions. A cursory review of various stand data by Guggenmoos (2002) suggests annual stem mortality rates ranging from 0.5% to 2% will be quite common (Plonski 1981, Campbell and Liegel 1996, Crookston 1997, Harmon 1999, Curtis et al 2000, Forest Service 2001, all cited in Guggenmoos 2002). Busing (2005) reports that in southern Appalachian old growth cove forests, the annual mortality of trees > 10 cm dbh was between 0.5-1.4% among stands (mean 0.7%). Runkle (2000) summarizes canopy tree turnover rates in old growth mesic forests of eastern North America and found that for old growth sites the average mortality was about 1% per year. Woods, in a study of hemlock-hardwood forests in the upper peninsula of Michigan found that in old growth forests, mortality rates varied from 0.3% per year (hemlock) to 1.6% (yellow birch).

The FIA program reports net mortality rates as percent basal area change, but this metric is apparently not used in the ecological literature. Steinman (2004) reports net mortality rates for forests in the northeastern United States, using 5 categories of change: > 2%, 1.6-2.0, 1.1-1.5, 0.6-1.0, and <0.6. The basis for the thresholds is not specified, but mortality rates of > 2% are indicated as cause for concern. Thus a metric for mortality rate could be constructed as <1.0% = Good, 1.0-2.0% = Caution, and >2% = Significant Concern.

**Scaling Rationale:** A cursory review of various stand data by Guggenmoos (2002) suggests annual mortality rates of tree stems ranges from 0.5% to 3% will be quite common, thus >4% mortality rate is treated as of concern. The threshold of 2% is based on studies from old growth stands that have mortality rates of < 2%.
Confidence that reasonable logic and/or data support the index: Medium

TREE CONDITION

Definition: This metric assesses the proportion of trees in the stand that have some kind of canopy foliage or stem problems as a measure of the tree health of a stand.

Measurement Protocol: All standing live and dead trees that are at least 10.0 cm (4 inches) diameter-at-breast-height (DBH) within each plot are measured for species, dbh, location, and condition.

Foliage: Estimate the amount of crown that is affected with some type of foliage problem, using the following classes: <1%, 1-5%, 5-25%, 26-50%, 51-75%, 75-100%. Score the foliage condition based on these points.

Specific stem/crown health problems. Record the presence of any of the following: insect damage, beech bark disease, butternut canker, dogwood anthracnose, advanced decay, large open wound(s), vine(s) in the crown. Score points as: presence/absence of Asian long-horned beetle, 3 points for hemlock wooly adelgid; 2 points for beech bark disease, dogwood anthracnose, butternut canker; 1 point for European gypsy moth, white pine blister rust, spruce budworm, tent caterpillar, advanced decay, large open wound(s); and 0.5 points for vine(s) in the crown. Total the points.

Metrics Rating: See Table 2.

Data: Not currently available. Data from FIA may be available.

Scaling Rationale: The scaling rationale reflects the potential for scope and severity of the pest or structural damage. Points are based on whether pest kills all trees of a species outright (3 points), infects and weakens them, but may or may not kill them (2 points), eats leafs & kills stems without killing the tree, or the stem shows signs of structural failures (1 point), or has the potential to weaken overall crown vigor (0.5 points), such as for vines in the crown. Asian long-horned beetle is treated separately because it is not host-specific, and presence in a stand could lead to wide-spread mortality of many tree species.

Confidence that reasonable logic and/or data support the index: Medium. We may need to assess native vs. exotic pests/pathogens differently. For example, natives such as spruce budworm and forest tent caterpillar may have less impact than exotics.

SNAGS (BASAL AREA + DENSITY)

Definition: This measure assesses the overall density and basal area of snags (standing dead trees).

Measurement Protocol: All dead standing trees greater than or equal to 10.0 cm (4 inches) DBH in a plot qualify as “tally trees” measured by this protocol.

Metrics Rating: See Table 2.
Data: Data on old growth stands from Tyrrell et al. (1998) suggest that both snag basal area and density may be too variable (at least at the typical plot sizes used to sample vegetation) to use as an indicator. Sampling design should be carefully considered for this metric. Concern conditions include both excessive and insufficient snag density and basal area.

Table 6. Data on density (# stems/ha) from old growth stands as reported by Tyrrell et al. (1998). Numbers in parentheses are the single extreme outlier value on either side of the range. “None” indicates there were no outliers because at least two stands had the lowest or highest value.

<table>
<thead>
<tr>
<th>Type (as defined by Tyrrell)</th>
<th>Basal Area Range (m²/ha) [outlier]</th>
<th>Density Range (# stems / ha) [outlier]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montane and Allied Spruce-Fir Forests (red spruce-fir) (&gt; 10 cm dbh)</td>
<td>3.7 – 13.9 [23.0]</td>
<td>44 – 280 [none, 592]</td>
</tr>
<tr>
<td>Conifer-Northern Hardwoods (hemlock-hardwood) (&gt; 10 cm dbh)</td>
<td>0.9 - 11.4 [none, 13.6]</td>
<td>20 - 180 [15,238]</td>
</tr>
<tr>
<td>Northern Hardwood Forests (&gt; 10 cm dbh)</td>
<td>0.3 - 11.4 [0, 12.5]</td>
<td>10-60 [0, none]</td>
</tr>
<tr>
<td>Northern Pine Forests (&gt;10 cm dbh)</td>
<td>0.89 – 7.0 [0.5, 10.4]</td>
<td>10-200 [none, none]</td>
</tr>
</tbody>
</table>

Scaling Rationale: Plots typically used by ecologists to assess forest structure tend to be small, introducing a great deal of variability in these measures. Here we take a conservative approach and use the range in values to separate the Good category from the Significant category, but we need more information to define a fuller set of ratings. Keddy and Drummond (1996) suggest evaluating number of snags greater than 50 cm dbh, but over a 10 ha area.

Confidence that reasonable logic and/or data support the index: Low

COARSE WOODY DEBRIS (VOLUME)

Definition: This measure assesses the overall coarse woody debris based on volume of downed stems (fallen logs and large branches). Coarse woody debris can also be measured using biomass, but the method is more time intensive and less data are available.

Measurement Protocol: All dead, fallen trees that are at least 7.5 cm diameter (dbh) and 1 m in length on each transect are measured for species, dbh and decay class. Standing dead snags are excluded. Estimate the volume and convert to m³ per hectare. For biomass, use specific gravity of each species to convert to Mg per hectare.

Metrics Rating: Sufficient variation exists among ecological system types to justify separate volume rating schemes for groups of systems. Not enough is known about biomass variation, so a single rating scheme is used.


Data:
Volume: Tyrrell et al. (1998) reported fallen dead tree volume, based on trees either ≥ 10 cm dbh or ≥ 7.5 cm dbh for a range of forest types (see Table 7), and those values correspond reasonably well to those of Keddy and Drummond (1996). The very high values reported by Tyrell (1998) for spruce-fir are based on one study in New Hampshire. Given the weak data from that source, Schuler et al. (2002), in a study of a red spruce stand in West Virginia, recommended using CWD volume values from the Conifer-Northern Hardwoods, which we follow here. They report coarse woody debris values of 86 m³/ha for a second growth stand, and projected maximum values in an old growth stand of 180 m³/ha. Fraver and White (2005) report a mean CWD value of 112 m³/ha in a red spruce stand in northern Maine.

Table 7. CWD volume on old growth stands (based on various tree size cutoffs), from Tyrrell et al. (1998), unless otherwise indicated. Outliers are reported if only a single plot contained either the highest of lowest value.

<table>
<thead>
<tr>
<th>Type</th>
<th>Range (m³/ha)</th>
<th>Outlier (m³/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montane and Allied Spruce-Fir Forests (red spruce-fir) (≥ 10 cm dbh)</td>
<td>691-951</td>
<td></td>
</tr>
<tr>
<td>Central Appalachian Red Spruce stand (Schuler et al. 2002)</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Northern Maine Red Spruce stand (Fraver and White 2005)</td>
<td>66-170</td>
<td></td>
</tr>
<tr>
<td>Conifer-Northern Hardwoods (hemlock-hardwood) &gt; 7.5 cm</td>
<td>88.4-124.7</td>
<td></td>
</tr>
<tr>
<td>Northern Hardwood Forests (≥ 10 cm dbh)</td>
<td>99-213</td>
<td></td>
</tr>
<tr>
<td>Northern Pine Forests (≥ 15 cm dbh)</td>
<td>3.8-107.4</td>
<td>183</td>
</tr>
</tbody>
</table>

Biomass: Keddy and Drummond (1996) summarize coarse woody debris of primary forest stands in the northeast and central U.S., and suggest three preliminary categories: Control/normal (>20 Mg/ha), Intermediate (10-20 Mg/ha), and Low (<10 Mg/ha). The mean (based on 3 data points with 7.5 cm cutoff) = 25, SD = 4. Data from other studies are needed.

Scaling Rationale: Given the different size classes used to assess CWD, it is difficult to establish a scale with confidence, especially for the Northern Pine Forests, which had the most stringent size-class cutoff (≥ 15 cm) and the greatest range in variation. In addition, the different forest systems appear to require their own scales. Not all stands may be expected to be in an old growth condition (though many or most will, depending on the system – see the Structural Stage Distribution metric); therefore, even somewhat low values of volume are within the acceptable range of variation. The
northern pine-oak forests and rocky woodlands may be expected to have the lowest coarse woody debris because of fire (which consumes CWD) or because overall density and basal area are lower in these drier or more stressful sites.

Confidence that reasonable logic and/or data support the index: Medium

UNDERSTORY NATIVE PLANT SPECIES RICHNESS

**Definition:** This measure assesses the vascular species richness of the understory (plants < 5 m tall, i.e., saplings, shrubs, and herbs).

**Measurement Protocol:** Species presence/absence data are first collected on three 1 m² quadrats. Record each vascular plant species found rooted in or overhanging within 2 m above the quadrat. After quadrat data has been collected, a time-constrained search is conducted for additional species on the entire intensive plot. Species richness can be assessed at either the 1 m² scale or the full plot scale (177 m²).

**Metrics Rating:** See Table 2.

**Data:** Data are not yet available on species richness at the 1 m² or 200 m² level – the metric suggested above is extrapolated (downward) from Goodell (2004, Table 3.3), who summarizes the richness and diversity of the ground layer across all forest types in upstate New York, based on 600 m² plots (based on a total list from three 200 m² subplots). Native Richness and Native Diversity are most relevant to this measure. It may be helpful to return to the original New York forest health data to calculate richness and diversity at the 200 m² subplot level, since that is much closer to the plot size used by NETN. There may also be a need for System-specific metrics, e.g., spruce-fir systems may be more species-poor on average than northern or central hardwood systems.

**Table 8.** Mean and standard deviation for understory plant species diversity (Richness /600 m²) between structural stages for all upstate New York forest types combined (from Goodell 2004, Table 3.3). Letters indicate significant differences (alpha = 0.05) between structural stages. NRICH = Native species richness, NSHAN = Native Shannon diversity index values. ERICH = Exotic species richness, ESHAN = Exotic species diversity. Shannon Index was calculated as H’ = -Σ (pᵢ) (ln pᵢ).

<table>
<thead>
<tr>
<th>Structural Stage</th>
<th>NRICH Mean</th>
<th>NRICH Std Dev</th>
<th>ERICH Mean</th>
<th>ERICH Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapling/Pole</td>
<td>33.64a</td>
<td>12.77</td>
<td>1.59</td>
<td>1.74</td>
</tr>
<tr>
<td>Mature</td>
<td>35.02a</td>
<td>12.6</td>
<td>1.46</td>
<td>1.64</td>
</tr>
<tr>
<td>Old Growth</td>
<td>29.4b</td>
<td>11.56</td>
<td>1.33</td>
<td>1.28</td>
</tr>
<tr>
<td>NSHAN</td>
<td>2.31</td>
<td>0.52</td>
<td>0.32</td>
<td>0.52</td>
</tr>
<tr>
<td>Mature</td>
<td>2.44</td>
<td>0.54</td>
<td>0.29</td>
<td>0.47</td>
</tr>
<tr>
<td>Old Growth</td>
<td>2.35</td>
<td>0.57</td>
<td>0.22</td>
<td>0.43</td>
</tr>
</tbody>
</table>

**Scaling Rationale:** Further work is needed to determine the metrics rating scheme for species diversity. Data are needed on understory richness and diversity at an appropriate scale to the plot sampling scheme used here. Data are also needed on variation in richness among systems, e.g., northern conifer (spruce-fir) systems may be more species-poor on average than northern or central hardwood systems.
hardwood systems (see Goodell 2004). In addition, it may be that change in richness or diversity over time is a more helpful metric for monitoring forest vegetation.

Confidence that reasonable logic and/or data support the index: Medium

UNDERSTORY NATIVE PLANT SPECIES COVER

Definition: This measure assesses the percentage cover of total native understory plant species (plants less than 16 ft tall, i.e., saplings, shrubs, and herbs).

Measurement Protocol: Species presence/absence data are initially collected on three 1 m² quadrats. Record each vascular plant species found rooted in or overhanging within 6 feet above the quadrat. After quadrat data has been collected, a time-constrained search is conducted for additional species on the entire intensive plot (177 m²). Then, for each species occurring on the entire plot, % canopy cover is rapidly estimated, first as total canopy cover and then as canopy cover within each of three layers (plants < 2 m, plants 2 – 5 m, plants > 5 m). Sum the cover values of each native species for the plants < 16 ft tall (taking the maximum cover value in a given layer if the species occurs in both layers), then sum the rest of the species, and divide the sum of native species cover by the total cover of all species.

Metrics Rating: See Table 2.

Data: [To be summarized.]

Scaling Rationale: Native stands of forest vegetation are widely reported to have no exotic species, when in excellent condition. Composition is graded “Caution” when native composition reaches 80-95% because it can be difficult to reverse compositional changes caused by exotic species.

Confidence that reasonable logic and/or data support the index: Medium

UNDERSTORY INDICATOR PLANTS - DEER BROWSE

Definition: This measure assesses the abundance or population status of selected indicators preferentially eaten, browsed, or avoided by deer.

Measurement Protocol: The protocol depends on the measures used to assess the preferred and browsed indicator species in the field, which has yet to be determined. For species avoided by deer, sum the cover of Hay-scented fern (*Dennstaedtia punctilobula*) and New York fern (*Thelypteris noveboracensis*).

Metrics Rating: See Table 2.

Data: A variety of studies have looked at potential indicators of intensity of deer browse. We summarize those studies in the table below. Our list of indicators is preliminary, and will depend on further validation through repeated measures of NETN plots. A deer browse index may be constructed, as recommended by Augustine and DeCalesta (2003).
**Table 9.** List of species preferentially selected or often browsed by deer, or species that are avoided by deer.

<table>
<thead>
<tr>
<th>Latin name</th>
<th>Common name</th>
<th>Habitat</th>
<th>Deer preference</th>
<th>Citations</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Clintonia</em> borealis</td>
<td>Blue bead lily</td>
<td>North. hardwood/boreal</td>
<td>P</td>
<td>Balgooyen &amp; Waller 1995, Viera 2003</td>
</tr>
<tr>
<td><em>Smilacina racemosa</em></td>
<td>Solomon's plume</td>
<td>hardwood/boreal</td>
<td>B</td>
<td>Fletcher et al. 2001, Augustine and deCalesta 2003</td>
</tr>
<tr>
<td><em>Polygonatum biflorum</em></td>
<td>Smooth Solomon's seal</td>
<td>hardwood/boreal</td>
<td>B</td>
<td>Augustine and deCalesta 2003</td>
</tr>
<tr>
<td><em>Sanguinaria canadensis</em></td>
<td>Bloodroot</td>
<td>North. hardwood</td>
<td>B</td>
<td>Webster et al. 2005</td>
</tr>
<tr>
<td><em>Caulophyllum thalictroides</em></td>
<td>Blue cohosh</td>
<td>North. hardwood</td>
<td>B</td>
<td>Augustine and deCalesta 2003</td>
</tr>
<tr>
<td><em>Thalictrum dioicum</em></td>
<td>Early meadowrue</td>
<td>North. hardwood</td>
<td>B</td>
<td>Augustine and deCalesta 2003</td>
</tr>
<tr>
<td><em>Actaea pachypoda</em></td>
<td>White baneberry</td>
<td>North. hardwood</td>
<td>B</td>
<td>Webster et al. 2001</td>
</tr>
<tr>
<td><em>Linnaea borealis</em></td>
<td>Twinflower</td>
<td>North. hardwood/hemlock/boreal</td>
<td>B</td>
<td>Viera 2003</td>
</tr>
<tr>
<td><em>Erythronium americanum</em></td>
<td>Trout lily</td>
<td>hardwood/boreal</td>
<td>B</td>
<td>None, but lily family species often preferentially browsed by deer</td>
</tr>
<tr>
<td><em>Demnaeditia punctilobula</em></td>
<td>Hay-scented fern</td>
<td>hardwood/boreal</td>
<td>A</td>
<td>Horsley et al. 2003</td>
</tr>
<tr>
<td><em>Thelypteris noveboracensis</em></td>
<td>New York fern</td>
<td>hardwood/boreal</td>
<td>A</td>
<td>Horsley et al. 2003</td>
</tr>
</tbody>
</table>

1 P = preferred, B = browsed, A = avoided.

**Scaling Rationale:** Current thresholds are based on field experience with fern abundance in browsed forests. Criteria for preferential and browsed species are under development.

**Confidence that reasonable logic and/or data support the index:** Low

**ADDITIONAL FOREST VEGETATION CONDITION METRICS (to be developed)**

**STAND CANOPY CLOSURE**

**Definition:**

**Measurement Protocol:** Measurement protocol will be based on canopy closure.

**Metrics Rating:** To be developed.

**Data:** Data not available.

**Scaling Rationale:**
Confidence that reasonable logic and/or data support the index:

TREE BASAL AREA BY SPECIES GROUP

Definition:

Measurement Protocol: Shade tolerant index, based on hemlock, beech, birch and maple?

Metrics Rating: To be developed.

Data: Data not available

Scaling Rationale:

Confidence that reasonable logic and/or data support the index:

UNDERSTORY INDICATOR PLANT – FOREST INTERIOR HERBS

Definition:

Measurement Protocol:

Metrics Rating: To be developed.

Data: Data not available.

Scaling Rationale:

Confidence that reasonable logic and/or data support the index:

SOIL CONDITION METRICS

FOREST FLOOR CONDITION CLASS – EARTHWORMS + TRAMPLING

Definition: This measure assesses the spatial extent of soil trampling and compaction, erosion, and the presence of invasive exotic earthworms across the plot.

Measurement Protocol: The forest floor is the entire thickness of organic material overlying the mineral soil, consisting of the litter and the duff (humus). Assess the forest floor across the entire plot for the following:

Percent Cover Bare Soil. Estimate the percentage as: None or trace (00), 1-10% (1_), 11-25% (2_), 26-50% (2_), more than 50% (6_).

Percent Trampled Area. Estimate the percentage: None or trace (00), 1-10% (1_), 11-25% (2_), 26-50% (2_), more than 50% (6_).
Humus. Visually assess and record presence (1) or absence (0) of a well-developed humus (duff) layer within the plot.

Earthworms. Record the presence (1) or absence (0) of earthworm casts and burrows within the plot.

**Metrics Rating:** See Table 2.

**Data:** [to be summarized]

**Scaling Rationale:** 0 if evidence of invasive exotic earthworm presence, and well developed humus layer; 1 if otherwise. [What if absence of humus layer is unrelated to earthworms, e.g., on thin-soil sites?]

**Confidence that reasonable logic and/or data support the index:**

**SOIL CHEMISTRY – CALCIUM:ALUMINUM RATIO**

**Definition:** The molar calcium:aluminum ratio (Ca:Al) in soil provides a valuable ecological indicator for identification of thresholds beyond which the risk of forest damage from Al stress and nutrient imbalances increases. It also can be used as an indicator to assess forest ecosystem change over time in response to acid deposition, forest harvesting, or other processes contributing to acid soil infertility.

**Measurement Protocol:** Using a soil corer, a single soil core is collected from a point along a transect adjacent to the plot. This core is split by depth (0-10 and 10-20 cm depth) to yield two samples from a single core.

**Metrics Rating:** See Table 2.

**Data:** Based on a critical review of the literature, Cronan and Grigal (1995) report that there is a 50:50 risk of adverse impacts on tree growth or nutrition when the soil solution Ca:Al ratio is as low as 1.0, a 75% risk when the ratio is as low as 0.5, and nearly a 100% risk when the ratio is as low as 0.2. Some precautions and caveats are provided. Driscoll et al. (2001) summarize several studies showing that acid deposition has altered the mineral nutrition of red spruce (*Picea rubens*).

**Scaling Rationale:** The adverse impacts of a declining Ca:Al ratio on soil fertility and tree growth provides the basis for the rating system proposed here. Driscoll et al. (2003) also suggest that a Ca:Al ratio can improve over time. If acid deposition levels decrease over time, a ratio of > 1.0 could be used to judge ecosystem recovery. Soil chemistry is typically measured in the top 10 cm, but for NETN we are measuring it at two depths. As a precaution, we use values from either the top 10 cm or the 10 – 20 cm level when establishing the threshold for “Significant Concern.”

**Confidence that reasonable logic and/or data support the index:** High

**SOIL CHEMISTRY CARBON:NITROGEN RATIO**

**Definition:** Changes in the ratio of Carbon:Nitrogen (C:N) concentration in the soil are a primary indicator of forest Nitrogen status. The C:N ratio decreases with increasing nitrogen deposition.
Measurement Protocol: Using a soil corer, a single soil core is collected from a point along a transect adjacent to the plot. This core is split by depth (0-10 and 10-20 cm depth) to yield two samples from a single core.

Metrics Rating: See Table 2.

Data: Conifer systems tend to have a slower breakdown of litter and have a higher C:N ratio under natural conditions than hardwoods do. Aber et al. (2003) report that C:N ratios are affected by elevation and soils as well as by conifer vs hardwood characteristics. Across all sites in the northeastern U.S. (Maryland to Maine), soil C:N ratios varied from 10 to 39 in the mineral soil; they were generally higher in coniferous than in hardwood stands. C:N ratios showed a negative relationship with N deposition and nitrification, with net nitrification increasing sharply below a threshold C:N ratio of between 20 and 25. Aber et al. (2003) cite European studies that used a threshold of approximately 24. The decrease in C:N with increasing N deposition was affected by elevation and mean annual temperate (MAT), with increases in elevation and decreases in MAT leading to stronger effects of N deposition on the C:N ratio.

Scaling Rationale: Aber et al. (2003) show that hardwood versus conifer stands differ in the natural range of the C:N ratio and the response to N deposition. Hardwood stands have a lower ratio to begin with, and a lower endpoint driven by N deposition than hardwood stands do. Similarly, increases in nitrification for hardwoods occurs at lower level of the C:N ratio (approx. 20) as compared to conifers (approximately 25). But further evidence of a difference in threshold response between the two system types is needed.

Confidence that reasonable logic and/or data support the index: Moderate/High

LANDSCAPE CONTEXT METRICS

DISTANCE TO ROAD OR MAJOR TRAIL

Definition: This metric addresses the potential impacts to the forest plot of roads or major trails, which are a specific type of altered habitat effect.

Measurement Protocol: Calculate distance from plot center to road or major trail using GIS.

Metric Rating: See Table 2.

Data: Watkins et al. (2003) found that unpaved roads in managed forests caused a significant increase in exotic plant species, a decrease in native plant species diversity, and a change in light levels within 15 m of the road (though exotic species were detected as far as 150 m into the forest). Edge effects on birds and amphibians have often been reported to extend much further into the forest, between 100 to 300 m (Mladenoff et al. 1994).

Scaling Rationale: Scaling is approximately logarithmic, presuming that edge effects become increasingly pronounced as distance to road or major trail decreases. A minimum threshold of 50 m was established, based on the many edge effects demonstrated to occur within the 50 m range. (Harper et al. 2005). Edge effects seem to decline rapidly after 150m, and few edge effects are
reported at over 500 m (Harper et al. 2005). Kennedy et al. (2003) recommend a minimum distance of 300 m to the nearest road or trail. Thus a Very Good category could be added of > 500 m.

Confidence that reasonable logic and/or data support the index: MEDIUM/HIGH

FRAGMENTATION (NEIGHBORHOOD COVER)

Definition: This metric assesses the percent of the forest neighborhood within the local neighborhood (65 ha) that is non-forest cover, excluding non-forest cover based on natural processes (water bodies, rock outcrops etc.).

Background: This metric is one aspect of the landscape context of specific occurrences of terrestrial forest systems. Habitat fragmentation is defined as “the division of large areas of natural habitat into smaller sections through conversion of the natural habitat to other uses (e.g., roads, development), resulting in populations of plants and animals becoming isolated from each others and potentially threatening their survival” (EPA 2003). Habitat loss and habitat fragmentation are closely related. As habitat is lost, the remaining fragments have a new size and edge to them, represent a subset of the original habitat diversity, and may be isolated. This metric assesses the degree to which fragmentation effects are likely to be present based on the percent of what is called the “local neighborhood” (0.656 km²; Heinz Center 2002). The metric could be applied to a series of increasingly larger neighborhood areas (e.g., from 2.2 ha to 5310 ha). It assesses the percentage of the area that is in non-forest and non-natural habitat cover (Heinz Center 2002, Riitters et al. 2002). Excluding natural non-forest cover helps to focus the metric on the fragmenting features that are of most concern in the definition.

Rationale for Selection of the Variable: Large blocks of contiguous forest support interior forest species. Partial forest cover creates forest edge habitat, which supports birds and other animals that nest in forests but forage in nearby fields (Riitters et al. 2002, EPA 2003). Fragmentation also creates areas that concentrate airborne nutrients and pollutants by increasing the area of unprotected forest edge (Weathers et al. 2001). Because fragmentation is partly a natural feature, the metric used here measures fragmentation that is likely to be of most concern to managers, i.e., fragmenting features that are caused by anthropogenic processes.

Measurement Protocol: Calculate from imagery the percent of non-forest cover found in a 0.656 km² area (65.6 ha, 160 acres, 457 m radius) around each forest point. If data from remote sensing imagery is based on pixels, a square frame may be preferable (Heinz Center 2002). Within the non-forest cover, separate the natural from the non-natural cover, and add the natural cover back to the forest cover. For example, if non forest cover is open wetlands, open woodlands or rock outcrops, add that cover back to total forest cover. Summarize the total non-forest - non-natural cover remaining. Adding the natural non-forest cover back allows this metric to focus on fragmentation caused by human activity (e.g., development and agriculture) from that of natural patchworks of forest and non-forest cover (Heinz 2002, p. 121).

Metric Rating: See Table 2.

Data: The Heinz Center (2002) used < 10% nonforest as a measure of unfragmented (core = 100%, interior = 90-99%) forest, and between 10-40% as “connected” forest. The data on which these breakpoints were established needs to be investigated. The Heinz Center is also investigating the use
of a fragmentation index that takes into account roads that occur within the neighborhood area. (Cavender-Bares pers. comm. 2005).

**Scaling Rationale:** The Heinz center (2002) used 100% forest as a measure of “core” forest, and 90-99% as “Interior” forest. Those values could be used to separate a “Very Good” rating from a “Good” rating.

**Confidence that reasonable logic and/or data support the index:** Low/Medium.

### INTERIOR PATCH SIZE

**Definition:** This metric is still under development. Interior patch size is defined as the contiguous area of interior forest cover around a plot.

**Measurement Protocol:** The land cover map or vegetation map of each park can be used to assess the interior patch size where the plot is located. All contiguous, natural forest polygons are aggregated together into a single patch. Each patch is buffered towards the interior by 150 m. Interior Patch Size is based only on this interior area. NETN may use this approach to define “interior forest areas” within which forest bird surveys are done. Vegetation from these areas could also be compared against “non-interior” plots to see if a suite of understory plant indicator species can be identified.

**Metrics Rating:** To be developed

**Data:**

**Scaling Rationale:** Buffer width: increases in buffer width improve the effectiveness of the buffer in preventing edge effects. The buffer width of 150 m is based in part on data from Kennedy et al (2003), who reviewed edge effects for both plants and animals. They recommend a buffer up to 230 – 300 m as a precautionary threshold. 100 m is also a widely used minimum threshold; here we work with 150 m as a compromise between the plant species-based effects (which require a smaller buffer to avoid edge effects) and those of animals (which can require very large buffers to avoid edge effects). **Interior patch size:** Rationale to be developed.

**Confidence that reasonable logic and/or data support the scaling of the metric:**

### STRUCTURAL STAGE DISTRIBUTION

**Definition:** Structural stage distribution assesses the relative proportion of forest structural or developmental stages (from seedling/sapling stages to old growth) on the current landscape in relation to their expected distribution based on natural disturbance regimes. At the landscape level (tens to thousands of hectares), assessing stand structural stages is important for maintaining biological diversity (Bormann and Likens 1979, Oliver and Larson 1996). Different species may depend upon one or more stand structural stages (Lorimer & White 2003), and the preservation of a mosaic of stands in each stage may be necessary to protect biodiversity (Spies & Turner 1999). Stands are assigned to development stages based on a modified version of the structural features identified by Frellich and Lorimer (1991, 1998), which provides a rapid and reliable method for assessing forest development stages (Goodell 2004, Goodell et al. 2005).
Measurement Protocol:
Assignment of structural stage for each plot is determined by the developmental stage and the large to mature tree ratio (L:M) of the plot. See Appendix A for complete calculations.

Metric Rating:
Separate metrics are developed for groups of systems, because of differences in the acceptable range of variation of proportion of stands in each structural stage.


2. Northern Hardwood and Hemlock-Hardwood Systems
   (Laurentian-Acadian Northern Hardwoods Forest, Laurentian-Acadian Pine-Hemlock-Hardwood Forest, Appalachian Hemlock-Hardwood Forest, Central and Southern Appalachian Northern Hardwood Forest). See Table 2.


Data: Frelich and Lorimer (1991) and Lorimer and White (2003) provide extensive data on the distribution of old growth stands under natural disturbance regimes (combination of fire and wind) for both the upper Midwest and Northeast forest systems. Their papers provide details on the full range of structural stages (from seedling-sapling to old, uneven aged classes). See especially Lorimer and White (2003, Table 1). [Insert Table showing data]

Scaling Rationale: Lorimer and White (2003, Table 1) model the expected distribution of all structural stages under natural disturbance regimes. For the northern hardwood and hemlock-hardwood systems, their range of variability under various disturbance regime scenarios is 74-89% old growth (“transitional uneven aged 150-300 yrs” and “old uneven-aged 300+ yrs”). For the spruce-fir system in southern, coastal Maine, where F2 hurricanes occur on average every 380 years, the expected percentage of the landscape in old growth under a random pattern of disturbance was 52% old growth. Less data are available on the pine and oak-pine systems, but Lorimer and White (2003, p. 50) suggest that multi-cohort stands would occupy roughly 25-40% of the landscape. These data provide good thresholds for the excellent condition; lower thresholds are less well-defined. The authors note that site or local landscape studies should be used to improve these estimates. These estimates are also an average over time.

Confidence that reasonable logic and/or data support the scaling of the metric: High

REFERENCES


Fletcher J.D., W.J. McShea, L.A. Shipley et al. 2001. Use of common forest forbs to measure browsing pressure by white-tailed deer (Odocoileus virginianus Zimmerman) in Virginia, USA Natural Areas Journal 21 (2): 172-176


Keddy, P.A. and C.G. Drummond. 1996. Ecological properties for the evaluation, management, and restoration of temperate deciduous forest ecosystems. Ecological Applications 6: 748-762.


Viera, V. 2003. Effect of long-term browsing by white-tailed deer on plant communities of Anticosti Island. M.S. Thesis at University of Laval, Quebec, Canada.


APPENDIX A. Calculations for Structural Stage Distribution

1. Calculating the Developmental Stage:

First, use only canopy trees, as they better reflect structural stage development. Canopy trees are defined as having a crown position of any of the following crown classes: dominant, co-dominant, intermediate, or open-grown (i.e. all crown classes where some sunlight is received directly on the top of the crown). Overtopped trees are excluded (see CROWN CLASS definition below). Development stages are easier to interpret if canopy trees only are used.

CROWN CLASS. Rate tree crowns in relation to the sunlight received and proximity to neighboring trees. Base the assessment on the position of the crown at the time of observation. Example: a formerly overtopped tree which is now dominant due to tree removal is classified as dominant.

Codes:
1 Open Grown – trees with crowns that received full light from above and from all sides throughout most of its life, particularly during its early developmental period.
2 Dominant – trees with crown extending above the general level of the crown canopy and receiving full light from above and partly from the sides. These trees are taller than the average trees in the stand and their crowns are well developed, but they could be somewhat crowded on the sides. Also, trees whose crowns have received full light from above and from all sides during early development and most of their life. Their crown form or shape appears to be free of influence from neighboring trees.
3 Co-dominant – trees with crowns at the general level of the crown canopy. Crowns receive full light from above but little direct sunlight penetrates their sides. Usually they have medium-sized crowns and are somewhat crowded from the sides. In stagnated stands, co-dominant trees have small-sized crowns and are crowded on the sides.
4 Intermediate – trees that are shorter than dominants and co-dominant, but their crowns extend into the canopy of co-dominant and dominant trees. They receive little direct light from above and none from the sides. As a result, intermediate trees usually have small crowns and are very crowded from the sides.
5 Overtopped – trees with crowns entirely below the general level of the crown canopy that receive no direct sunlight either from above or the sides.

Second, assign each stem to one of the following size classes (the tree size classes are based on the tree diameter at breast height (dbh) in centimeters):
- sapling (0-10.9),
- pole (11-25.9),
- mature (26-45.9),
- large (≥ 46).

Third, calculate the basal area of each stem in each size classes, as follows:

Basal area of individual tree stem = \( \pi r^2 \) OR \( (\text{diameter}/2)^2 \pi \).

E.g. If stem diameter = 15 cm, then

\[ \text{Basal Area} = \pi (15/2)^2 \]
Fourth, sum the basal area of all stems in each size class, and calculate the % of the total canopy basal area represented by the size class.

E.g.:

\[
\% \text{ Sapling BA} = \frac{(\text{BA sapling stem 1} + \text{BA sapling stem 2} + \ldots \text{BA sapling stem x})}{(\text{total BA of all canopy stems})}
\]

**Development stages** are then assigned by the following set of rules:

- **Sapling Developmental Stage:** \[ \geq 67\% \text{ of BA in saplings plus poles, with more basal area in saplings than poles} \]
- **Pole Developmental Stage:** \[ \geq 67\% \text{ of BA in saplings plus poles, with more basal area in poles than in saplings; or } \geq 67\% \text{ in poles plus mature trees, with more basal area in poles than in mature trees} \]
- **Mature Developmental Stage:** \[ \geq 67\% \text{ of BA in poles plus mature trees, with more basal area in mature trees than in poles; or } \geq 67\% \text{ in mature plus large trees, with more basal area in mature than in large trees} \]
- **Old-growth Developmental Stage:** \[ \geq 67\% \text{ of BA in mature plus large trees, with more basal area in large than in mature trees} \]
- **Mature-sapling mosaic Developmental Stage:** any stand not meeting above criteria

2. Calculating the large to mature (L:M) ratio:

Calculate the ratio of large and mature trees basal area using the tree sizes listed above for large (> 46 cm dbh) and mature (26 - 45.9 cm dbh). [check whether all stems are used or just canopy]

Basal area of individual tree stem = \( \pi r^2 \) or \( \frac{\text{diameter}}{2}^2 \pi \).

E.g. If stem diameter = 15 cm, then

\[
\text{Basal Area} = \pi \left(\frac{15}{2}\right)^2 = 176.7 \text{ cm}^2 \text{ (or 0.0177 m}^2)\]

The large to mature ratio = \( \frac{\% \text{ BA of large trees}}{\% \text{ BA of mature trees}} \)

Calculate the large/mature (L:M) tree ratio for each plot.

3. Assigning Structural Stage:

Using the results from the developmental stage and L:M ratio, the structural stage is then calculated for each plot according to the following set of rules:

1) Old Growth Structural Stage
A plot is characterized as old growth if the L:M ≥ 1.5 and in the Old Growth developmental stage.

2) Transition to Old Growth Structural stage

A plot is characterized as “Transition to Old Growth” if
   a) 0.75 ≤ L:M < 1.5 and in the “Mature” or “Old Growth” developmental stage
   b).L:M ≥ 1.5 and in either the “Pole” stage or “Mosaic” stage

3) Mature Structural Stage

A plot is characterized as Mature if:
   a) L:M < 0.75 and in the “Mature” stage
   b) 0.75 ≤ L:M < 1.5 and in the “Pole” or “Mosaic” stage

4) Pole Structural stage

A plot is characterized as Pole if the L:M < 0.75 and the development stage is “Pole”

5) Sapling Structural Stage –

A plot is characterized as Sapling if the developmental stage is “Sapling”

For the purposes of assessing proportion of plots that are old growth, the “transition” and “old growth” classes can be combined.
APPENDIX B. LIST OF EXOTIC SPECIES IN NETN PARK PLOTS
[to be completed as plot data are collected.]
**Plot Info**

<table>
<thead>
<tr>
<th>Date:</th>
<th>/</th>
<th>/</th>
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</thead>
<tbody>
<tr>
<td>Time in:</td>
<td></td>
<td></td>
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<tr>
<td>Time out:</td>
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<td></td>
</tr>
<tr>
<td>Crew:</td>
<td></td>
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<tr>
<td>UTME:</td>
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<tr>
<td>UTMN:</td>
<td></td>
<td></td>
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<tr>
<td>GPS accuracy: +/- m</td>
<td>Elev: m asl</td>
<td></td>
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<tr>
<td>Slope %:</td>
<td>Aspect: °</td>
<td></td>
</tr>
<tr>
<td>Terrain Position: 1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tran slope%</td>
<td>30:</td>
<td>150:</td>
</tr>
<tr>
<td>Directions:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Plot notes:**

---

**Stand Info**

| Ecosystem: |     |     |
| Stand Structure: 1 2 3 4 5 |
| Crown Closure: 1 2 3 4 5 |
| %Cover Low: | %Cover Mid: |     |     |
| %Cover High: | Browseline: 0 1 |
| Disturbance Code | Threshold | % Class |
| Dist 1: | 1 2 3 |
| Dist 2: | 1 2 3 |
| Dist 3: | 1 2 3 |
| Water on Plot: 1 2 3 4 5 6 7 8 9 |
| St Height Dist: m | SH <1: | SH <2: |

**Forest Floor**

| % Rock: | % Trampled: |
| % Bare Soil: | Microtop: 0 1 9 |
| Humus: 0 1 2 9 | Earthworms: 0 1 9 |
| FF Notes: |     |

**Photopoint**

| Camera: |     |
| Time: | Weather: |

---

**Trees:** All stems >= 10 cm DBH

<table>
<thead>
<tr>
<th>Tr#</th>
<th>Species Code</th>
<th>DBH</th>
<th>Stat</th>
<th>Crwn</th>
<th>Tree Cond</th>
<th>Foliage</th>
<th>Dec</th>
<th>(Az)</th>
<th>(Dst)</th>
<th>Tr Notes</th>
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**December 13, 2005**
**Saplings:** Stems 2 - 10 cm DBH

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**Indicator Plant Cover**

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<th>Species</th>
<th>% Cover</th>
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<tbody>
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</table>

**Tree Seedling Tally**

<table>
<thead>
<tr>
<th>Species Code</th>
<th>15-30 cm</th>
<th>30-100 cm</th>
<th>1-1.5 m</th>
<th>&gt;1.5 m</th>
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</tbody>
</table>

**Shrub Tally:** >=30 cm tall

<table>
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<th>Species</th>
<th>Count</th>
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</table>

**CWD: >= 7.5 cm >= 1 m long - Intens. Plots Only**

<table>
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<tr>
<th>Transect</th>
<th>Dec</th>
<th>Species Code</th>
<th>Diam</th>
<th>Hollow</th>
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</tbody>
</table>

**Soil - Intensive Plots Only**

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<tr>
<th>Depths in cm</th>
<th>FF</th>
<th>Litter</th>
</tr>
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<tbody>
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<td></td>
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</tbody>
</table>

**Sample depth:**

**Species Diversity - Intensive Plots Only**

<table>
<thead>
<tr>
<th>Quad</th>
<th>Species</th>
<th>Cover</th>
<th>Samp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Quads sampled: 1 2 3</th>
<th>Quads trampled: 1 2 3</th>
</tr>
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<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
# NETN Forest Monitoring Appendix B
## Indicator Plants

Indicator Plants for Deer Herbivory

<table>
<thead>
<tr>
<th>Latin name</th>
<th>Common name</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trillium spp. (grandiflorum, etc.)</td>
<td>Trillium</td>
<td>North. hardwood/boreal</td>
</tr>
<tr>
<td>Uvularia spp. (grandiflora, perfoliata, sessifolia)</td>
<td>Bellwort</td>
<td>North. hardwood/boreal</td>
</tr>
<tr>
<td>Smilacina racemosa</td>
<td>Solomon's plume</td>
<td>North. hardwood/boreal</td>
</tr>
<tr>
<td>Polygonatum biflorum</td>
<td>Smooth Solomon's seal</td>
<td>North. hardwood/boreal</td>
</tr>
<tr>
<td>Sanguinaria canadensis</td>
<td>Bloodroot</td>
<td>North. hardwood</td>
</tr>
<tr>
<td>Caulophyllum thalictroides</td>
<td>Blue cohosh</td>
<td>North. hardwood</td>
</tr>
<tr>
<td>Thalictrum dioicum</td>
<td>Early meadowrue</td>
<td>North. hardwood</td>
</tr>
<tr>
<td>Clintonia borealis</td>
<td>Blue bead lily</td>
<td>North. hardwood/hemlock/boreal</td>
</tr>
<tr>
<td>Actaea pachypoda</td>
<td>White baneberry</td>
<td>North. hardwood</td>
</tr>
<tr>
<td>Linnaea borealis</td>
<td>Twinflower</td>
<td>North. hardwood/hemlock/boreal</td>
</tr>
<tr>
<td>Dennstaedtia punctilobula</td>
<td>Hay-scented fern</td>
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</tr>
<tr>
<td>Thelypteris noveboracensis</td>
<td>New York fern</td>
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</tr>
<tr>
<td>Erythronium americanum</td>
<td>Trout lily</td>
<td>North. hardwood/boreal</td>
</tr>
</tbody>
</table>
Appendix C: Example NETN Forest Integrity Scorecard for Acadia National Park

NETN has developed a scorecard to report the ecological integrity of forest and woodland ecosystems. This scorecard interprets and summarizes ecological integrity based on 17 metrics selected for their ecological relevance, management significance, feasibility of implementation and low response variability. Ecological integrity is determined by comparing monitoring data from permanent plots in NETN parks to threshold levels determined from the scientific literature. These threshold levels are intended to identify values which may trigger management action because they fall outside of an accepted range of variation based on our current knowledge of ecosystem condition.

This example scorecard for Acadia National Park is based on a preliminary dataset from NETN’s 2005 protocol evaluation study. In 2005, we established 17 permanent plots in forested and woodland ecosystems at Acadia; 6 of these plots were “intensive plots” upon which understory plant richness and exotic plant ratio, CWD, and soil chemistry were measured in addition to the other metrics. We created this example scorecard to illustrate our scorecard reporting format. This example should not be used to drive management actions at Acadia because the data is preliminary, the sample size is small, and some thresholds are still under development.

What did we find?

Our preliminary 2005 dataset indicates that forest and woodland plots at Acadia earned a good rating for half of the metrics measured, but the remaining metrics indicated problems which may, after further monitoring data collection, merit management action (Table 1). Overall, native plant diversity and regeneration are good, but some aspects of forest structure merit caution, and soil chemistry indicates a problem caused by air pollution.

Tree regeneration, understory native plant richness, and exotic plant cover all earned “good” ratings while coarse woody debris and snag abundance both merited “caution.” Tree regeneration is likely to be sufficient to replenish the canopy at more than two-thirds of plots measured, but may be insufficient in some locations (Figure 1). Mean understory native plant richness was “good” overall, but richness was slightly lower at half the plots measured (Table 2). Only one exotic understory plant species was found during the 2005 data collection, resulting in a clear “good” rating for exotic plant cover.

<table>
<thead>
<tr>
<th>Table 1: Preliminary ecological integrity rating for Acadia National Park based on 2005 protocol evaluation data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Vegetation Condition</td>
</tr>
<tr>
<td>Canopy closure</td>
</tr>
<tr>
<td>Tree growth rate</td>
</tr>
<tr>
<td>Tree mortality rate</td>
</tr>
<tr>
<td>Tree condition</td>
</tr>
<tr>
<td>Coarse woody debris</td>
</tr>
<tr>
<td>Snag abundance</td>
</tr>
<tr>
<td>Indicator plants</td>
</tr>
<tr>
<td>Understory native plant richness</td>
</tr>
<tr>
<td>Exotic plant cover</td>
</tr>
<tr>
<td>Soil Condition</td>
</tr>
<tr>
<td>Forest floor condition</td>
</tr>
<tr>
<td>Soil chemistry - nitrogen saturation</td>
</tr>
<tr>
<td>Soil chemistry - acidic deposition</td>
</tr>
<tr>
<td>Landscape Context</td>
</tr>
<tr>
<td>Stand structure</td>
</tr>
<tr>
<td>Road impacts</td>
</tr>
<tr>
<td>Interior patch size</td>
</tr>
</tbody>
</table>

**Appendix C: Example NETN Forest Integrity Scorecard for Acadia National Park**
Overall mean values for coarse woody debris (CWD) and snag abundance both rated “caution” (Table 1), though most plots rated “significant concern” for CWD and “good” for snags (Table 2). It was surprising that mean CWD rated low compared to the “good” threshold, while snags rated high; this discrepancy merits further investigation.

Within the soil, forest floor condition was “good” at almost all plots, but soil chemistry measures of nitrogen and acidic deposition impacts fell in the “significant concern” category (Table 1). While the sample size is too small to warrant management action, further monitoring is required to better define this potential problem.

At the landscape level, the lack of old-growth structure at measured plots merited “significant concern” for stand structure (Table 1). Acadia is recovering from a devastating fire in 1947, and from a complex history of harvest and development. It remains to be seen what full recovery will look like for structural stage distribution now that Acadia is protected from harvest and clearing, and our thresholds for this metric may need to be adjusted accordingly. Acadia rated “good” for the road impact metric (Table 1), with 3/4 of measured plots falling beyond the distance of most impacts from paved roads (Table 2).

The canopy closure, tree condition, indicator plant, interior patch size and anthropogenic cover metrics are still under development and are not reported in this example, while the tree growth and mortality rate metrics can not be calculated until plots are remeasured.

Table 2: Preliminary plot distribution by condition category

<table>
<thead>
<tr>
<th>Metric</th>
<th>Proportion of plots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>Canopy closure</td>
<td>0.94</td>
</tr>
<tr>
<td>Tree growth rate</td>
<td>0.89</td>
</tr>
<tr>
<td>Tree mortality rate</td>
<td>0.89</td>
</tr>
<tr>
<td>Tree condition</td>
<td>0.89</td>
</tr>
<tr>
<td>Tree regeneration</td>
<td>0.71</td>
</tr>
<tr>
<td>Coarse woody debris</td>
<td>0.33</td>
</tr>
<tr>
<td>Snag abundance</td>
<td>0.53</td>
</tr>
<tr>
<td>Indicator plants</td>
<td>0.50</td>
</tr>
<tr>
<td>Understory native plant richness</td>
<td>0.63</td>
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<tr>
<td>Exotic plant cover</td>
<td>0.63</td>
</tr>
<tr>
<td>Soil chemistry - nitrogen saturation</td>
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<tr>
<td>Soil chemistry - acidic deposition</td>
<td>0.00</td>
</tr>
<tr>
<td>Forest floor condition</td>
<td>0.94</td>
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<tr>
<td>Road impacts</td>
<td>0.76</td>
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<tr>
<td>Interior patch size</td>
<td>NA</td>
</tr>
<tr>
<td>Anthropogenic cover</td>
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</tbody>
</table>

**What do the ratings mean?**

For each metric, plots were rated “good,” “caution” or “significant concern” based upon comparison of measured values with established threshold values (Table 3). A “good” rating indicates that values fall within an expected range of variation indicative of a healthy ecosystem. A “caution” rating indicates that measured values fall slightly outside of the expected range, and suggests corrective management action.
should be considered. A “significant concern” rating indicates that measured values fall far from an expected range, or fall within a range associated with negative ecosystem consequences, and suggests that corrective management action is needed. Where needed, thresholds apply to specific ecosystems. We also present a relative estimate of our confidence in each metric’s rating (Table 1). Our confidence in these preliminary ratings is low, but our confidence will increase after full implementation of the monitoring protocol.

What was measured?

Ten of the metrics directly relate to the condition of forest vegetation. Canopy closure is an important indicator used to determine if stands are becoming more disturbed over time. Tree growth and mortality rates indicate health problems within specific tree species. Tree condition qualitatively assesses tree health to identify specific health problems. Tree regeneration assesses the success of tree seedling and sapling establishment and is an early-warning indicator of changes in canopy vegetation. Coarse woody debris (CWD) refers to large dead branches and whole downed trees, while snags are standing dead trees. Measuring the abundance of these features provides an indicator of wildlife habitat

| Table 3: Ecological integrity thresholds and ratings for NETN forest and woodland ecosystems. |
|--------------------------------------------------|-------------------|-------------------|-------------------|
| Metric                                           | Units             | Rating            | Ecosystem         |
| Canopy closure                                   | %                | To be developed   |                   |
| Tree growth rate                                 | % BA / yr        | To be developed   |                   |
| Tree mortality rate                              | % stems / yr     | <2%               | 2-4%              | >4%               | All               |
| Tree condition                                   | Index points     | <3                | 3-5               | >5                | All               |
| Tree regeneration                                | Index points     | >= 100            | 25-99             | < 25              | Forested          |
| Coarse woody debris                              | m²/ha            | >80               | 50-80             | <50               | Northern hardwood |
| Snag abundance                                   | m²/ha            | >25               | 10-25             | <10               | Pine-oak          |
| Understory native plant richness                 | # species / plot | >14               | 5-14              | <5                | Spruce-fir        |
| Exotic plant cover                               | %                | <2%               | 2-20%             | >20%              | All               |
| Forest floor condition                           | NA               | <5% trampled AND  | 15% trampled OR   | >15% trampled OR  | Forested          |
| Soil chemistry - nitrogen saturation             | NA; ratio        | >30               | 25-30             | <25               | Conifer           |
| Soil chemistry - acidic deposition               | NA; ratio        | >25               | 20-25             | <20               | Hardwood          |
| Stand structure                                  | % stands old     | >50               | 20-50             | <20               | Spruce-fir        |
| Road impacts                                     | meters            | >60               | 25-60             | <25               | Northern hardwood |
| Anthropogenic cover                              | %                | <10%              | 10-40%            | >40%              | All               |

| Vegetation condition                             | Index points     | To be developed   |                   |
| Indicator plants                                 | Index points     | To be developed   |                   |
| Soil condition                                   | NA               | Worms absent      | Worms present     | Worms present     |                        |
| Soil chemistry - nitrogen saturation             | NA; ratio        | >30               | 25-30             | <25               |                        |
| Soil chemistry - acidic deposition               | NA; ratio        | >25               | 20-25             | <20               |                        |
| Landscape context                                | % stands old     | >50               | 20-50             | <20               | Spruce-fir           |
| Road impacts                                     | meters            | >150 m            | 50-150 m          | <50 m             | All                 |
| Interior patch size                              | ha               | To be developed   |                   |

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availability. The presence of indicator plants that are sensitive to specific stressors acting upon NETN forests is indicative of the impacts of these stressors. Understory native plant richness measures the number of understory native plant species on a plot, while exotic plant cover measures the relative importance of exotic plant species in the understory; both of these metrics are indicative of the integrity of the forest understory.

The scorecard also includes metrics of soil condition and landscape context, both of which can strongly influence forest integrity. Three metrics directly relate to soil condition. Forest floor condition is a qualitative assessment of both trampling impacts and exotic earthworm invasion upon the forest floor. Two useful indicators of soil chemistry are measured in both surface and deeper soil layers. The carbon to nitrogen ratio of the soil is an important indicator of nitrogen saturation, a problem caused by anthropogenic atmospheric deposition which can lead to watershed pollution and forest decline. Likewise, the calcium to aluminum ratio of the soil is a critical indicator of acidic deposition impacts. The final four metrics relate to landscape context. Stand structure assesses the percentage of plots in mature and old-growth structural stages and is indicative of the habitat value of the landscape. The distance from each plot to the nearest paved road is used as an indicator of road impacts. Interior patch size measures the size of intact forest patches relatively unimpacted by edge effects, and is an important indicator of forest integrity and nearby landuse impacts. Finally, the relative impact of fragmentation and nearby landuse is assessed by calculating the percentage of anthropogenic cover in the close vicinity of each plot.