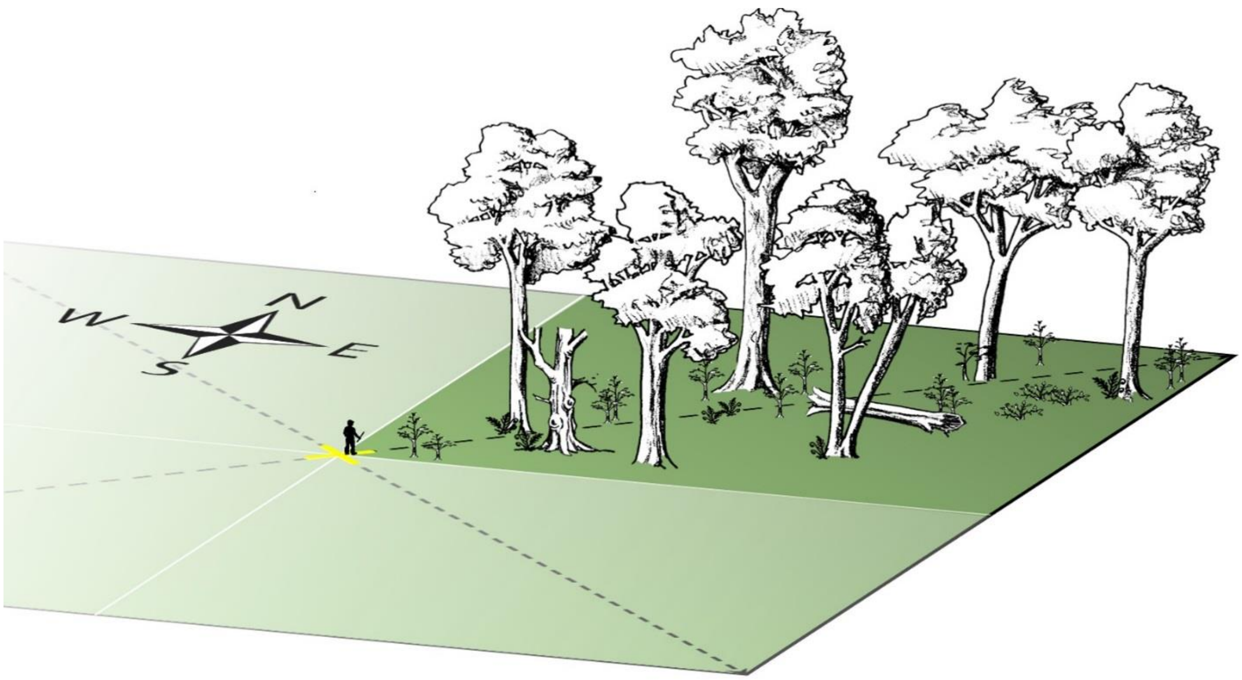
The Holden Arboretum's

Rapid Upland Forest Assessment (RUFA) Version 3.0

User Manual



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Overview

Purpose/Background

The Holden Arboretum (HA) has embarked on a project to develop a research and land management plan for its natural areas. However, how can Holden develop a land management plan for a large natural area without knowing what we have? The development of a meaningful management plan would be impossible without some means to measure forest quality across HA natural areas. Given the scope of the project only a rapid measurement tool could be utilized. Unfortunately such a rapid forest assessment tool did not exist. At the time Holden only had data relating to plant communities, deer exclosures and a long term research project in old growth beech-maple forests of Stebbins. Holden decided to create its own rapid assessment method to evaluate forest quality as none seemed to exist. All other assessment methods have been developed for aquatic and wetland systems and any upland forest assessments that do exist are geared toward the forest industry. HA conservation staff developed its own based on the Tierney paper[1]. The resulting evaluation tool is the Rapid Upland Forest Assessment (RUFA) V. 1.0. The RUFA V. 1.0 has been modified into a fifth iteration V. 3.0 after several shortcomings were identified during the initial versions implementation in the first field season. The RUFA is also designed to rank forest sites into Forest Integrity categories ranging from low to high with the main purpose of making landscape level comparisons. The RUFA is also designed to place forest sites into Forest Condition categories to determine forest management goals and actions. Ultimately the RUFA was developed to as a means to determine how to manage the forest to improve forest integrity.

Development and Rationale:

Five basic criteria were established from the onset to serve as a framework for the development of the rapid assessment:

1) First, the rapid assessment must be rapid (completed in approximately ¾ of an hour), repeatable, and be simple to implement, maximizing efficiency while maintaining high scientific integrity. To meet these criteria, a simple, streamlined timed 4-transect concept was developed.

[1] Tierney, G.L., et al. “Monitoring and evaluating the ecological integrity of forest ecosystems”. *Frontiers in Ecology*, 2009.

2) The area assessed with the RUFA must represent a sizable area—for Holden this meant a minimum of 1 hectare, 100 meters by 100 meters.
3) The assessment must capture information related to the unique characteristics of a mature to old growth forest that has not been impacted by prior human activity and forestry/logging practice.
4) Address ecologically oriented forest management goals and concerns. Manage Holden's forests towards high ecological integrity old growth forests.
5) Provide quantitative data on the age and health of the forest from which management actions can be derived.

Definition of Upland Forest

The RUFA tool has been designed and calibrated to work in an upland forest. Upland forests are primarily defined by upland deciduous vegetation communities. Wet woods, or wetlands of any sort, should not be assessed with the RUFA. The other areas that are currently under question are hemlock hardwood forests and floodplain forests; additional testing is required to determine whether the RUFA methodology can accurately depict forest integrity in these areas because of significant differences in features from other upland ecosystems.

Timing

The RUFA V. 3.0 should be performed from late May/early June to the end of September to avoid skewing the data due to fall senescence and spring ephemerals (a separate assessment—the Spring Ephemeral Rapid Assessment [SERA]—was developed and applied in 2016 to account for spring ephemerals and the way they can inform a land-manager's understanding of forest integrity).

Transects and Hectare Cells

GIS was used to drape a 1 hectare cell sized grid over the entire Holden Arboretum. Cells were named in a similar fashion to a projected coordinate system such as the state plane system. The cell in the southwestern extreme was labeled 1-E1-N. The cell number changes by a value of 1 for every cell east and/or north from the starting cell.

As described above, a timed transect approach was chosen for the rapid assessment. Starting in the center of the hectare cell, one assessor walks northeast or a 45 degree bearing, a second does a southeast transect at 135 degrees, a third walks southwest at 225 degrees, and the fourth northwest at 315 degrees. Starting at the cell center one assessor indicates which metric is being assessed and initiates the start of the transect walk, each assessor is responsible for keeping their own time. Each assessor begins making observations according to the specific metric as they walk along that bearing for one minute. After one minute has passed each assessor then turns around and walks one minute back to the cell center. Meeting back at the cell center a designated staff member would tally the data collected. Metrics are paired up to help accommodate the two one-minute transects a person would walk thereby maximizing efficiency. In addition, the total number of metrics is kept to an even number, thereby maximizing efficiency by eliminating a single one minute transect.

Holden chose to utilize the 1 hectare sized grid to assess its natural areas in order to meet multiple goals—among these, the grid allows for the assessment of a large area of continuous forest. This is not to suggest that the end user cannot choose random locations in which to locate a center of a hectare cell within their subject area, provided that the center location reasonably represents the forest the user assesses, and there are no other significant constraints (such as different habitat types, aquatic systems, or topographic limitations). It is useful to place individual cells instead of a grid on small or discontinuous areas of forested natural area targeted for assessment. It is, however, advised to keep the orientation of the cell to a north/south and east/west orientation to simplify data entry.

Process

The Rapid Upland Forest Assessment (RUFA) V. 3.0 takes a team of 4 between 40 and 45 min. to complete depending on sight conditions. The RUFA has been designed to assess a 1 hectare (100m x 100m) area oriented north to south, east to west. The RUFA can be completed with a minimum of 2 assessors in 1 ¼ hour.

1) A selected site should be homogenous with minimal inclusions of other habitat types. Four assessors begin at the hectare center and each is assigned a direction starting with NW, each assessor traverses the hectare cell towards the corner along the predetermined transect.
2) Paired metrics 1 through 6 involve a timed walk along transects, observing and tracking feature counts for each metric. The A metric is counted on the way out toward the corner for one minute and then all assessors stop, turn and assess the B metric on the one minute walk back to the center. Each time assessors re-gather in the center, data is recorded on the data sheet.

3) Metrics 7-11 are discussed by all assessors at the center. If any are observed, the metric is scored accordingly. If not, additional, untimed investigations are made.
4) Metric 12 involves ~30m/30 pace-walk along the 4 transects from the center. After ~30m/30 paces, assessors do a simplified IERAT assessment of leaf fragment cover under the past year's leaf litter. One more sample is assessed at the center so that there are 5 leaf fragmentation scores in all.
5) Then, all data is totaled and the sheet is handed off to at least one other assessor for quality control and subsequently entered into the GPS data-unit.

Metrics

Description and Rationale

Eastern deciduous old growth forest was held as the highest standard for the development of the metrics. It should be noted that the RUFA takes a different approach to forest value from classic forest management where trees are removed or harvested before they die naturally. RUFA is designed to be useful in managing forests towards increased ecological integrity, and thus holds a mature, healthy, unharvested forest as its highest standard; unmanaged, old-growth forests receive the highest scores with RUFA as forests that have had enough time to reach full biological potential in structure, function and integrity. Therefore, scores are not intended to apply value judgment on forests; it is possible to have a forest that scores somewhat low in integrity and yet has potential and health (see **Forest Management Implications** section on page 31—with each score, and the distribution of points therein, there are a variety of possible forest conditions and therefore forest management strategies). The scoring system is simply meant to give an assessment of how intact the ecological integrity of the forest is. Despite the different approach of the RUFA, a number of adopted forestry practices have proven useful in the development/implementation of the latest RUFA version, and are explained in detail.

The rapid assessment captures and measures the following features of an old growth forest:

1) Old growth forests are—in our present time and location—a rare forest habitat where **evidence of past human interference is minimal to nonexistent**.
2) A key component of old growth forests is the simple fact that they were allowed to mature to the point where trees could live and die before they were harvested. As a result large **mature trees** are present, **very large "legacy trees"** (have lived about half or more of their possible lifespan) are present, **light gaps** form, there are **standing dead trees or snags**, and **fallen trees** are present in various stages of decay.
3) Old growth forests also feature **micro-topography such as pits and mounds** formed from trees falling, root/soil exposure and the original tree rotting away.
4) Old growth forests will also possess a **rich, deep organic soil (humus) layer** which is not present in young forests or forests with a significant invasive earthworm presence.
5) Other features such as **seedling presence** were identified through cover assessment during early field trials but analysis suggested that it was not a statistically significant

metric and this characteristic is now considered under Metric 8, wherein light-gaps are assessed as regenerative features.

6) Old growth forests are also **well balanced and resilient enough to prohibit the invasion and establishment of non-native plant species**, provided there are minimal vectors for their introduction.
7) The richness (composition/diversity and density) characteristics of the **shrub, tree seedling and herbaceous layers** are also important in old growth forest.

The thresholds set for each of the metrics were established by averaging the counts of various forest features across a broad range of apparent forest quality. Approximately 100 sites were visited ranging from old growth beech maple forests and old growth oak maple forests at the high end of forest integrity to monoculture young red maple stands at the low end. Data was collected at these sites for the following metrics to determine the thresholds. Once the thresholds were established the data were analyzed to determine if the RUFA was sensitive enough to distinguish between forest qualities.

Furthermore, the RUFA was tested against other more vigorous assessment methods with partner organizations and HA's Research Department. Comparisons were made against soil chemistry data (soil ph, C, and N), plant community composition and structure (including herbaceous plant inventory, pit/mound, tree composition, course woody debris volumes, soil profile, standing dead tree basal area), spring ephemeral diversity and richness study, land use history analysis, and intensive vegetation survey methods (protocol based on the Carolina Vegetation Survey method). The RUFA V. 3.0 ranked favorably against these other methods, ranking forest integrity similarly.[2]

The following table (**Table 1**) is useful in introducing the individual metrics and showing how each represents multiple functions. The Mature Tree set of paired metrics, for example, represents the canopy and is often the most prominent feature of the forest while serving as a forest layer element in the same way shrubs/saplings are. The Mature Tree metric is also useful in determining the forest condition by being a Forest Age metric (explained in greater detail in the **Forest Management Implication** section). Finally, the Mature Tree metric is a measured type of metric in that mature trees are actually counted and compared to minimum threshold rather than a simple observation of its presence or absence.

[2] Burke, D.J., Knisely, C., Watson, M.L., Carrino-Kyker, S.R., Mauk, R.L. "The effects of agricultural history on forest ecological integrity as determined by a rapid forest assessment method". *Forest Ecology and Management*, 2016. 378: 1–13.

Table 1: RUFA Metrics

Number	Metric	Feature	Element	Type	Condition
1A	Herbaceous Plant Species	Forest Floor	Forest Layer	Measured	Health Metric
1B	Tree Seedling Groups	Forest Floor	Forest Layer	Measured	Health Metric
2A	Shrub/Saplings	Understory	Forest Layer	Measured	Health Metric
2B	Shrub/Sapling Species	Understory	Forest Layer	Measured	Health Metric
3A	Mature Trees	Canopy	Forest Layer	Measured	Age Metric
3B	Mature Tree Species	Canopy	Forest Layer	Measured	Age Metric
4A	Legacy Trees	Canopy	Forest Layer	Measured	Age Metric
4B	Legacy Tree Species	Canopy	Forest Layer	Measured	Age Metric
5A	Snags	Stand Age	Structure	Measured	Age Metric
5B	Woody Tree Debris Units	Stand Age	Structure	Measured	Age Metric
6A	Invasive Shrubs/Vines	Invasive Impact	Threat	Measured	Health Metric
6B	Herbaceous Invasive Plants	Invasive Impact	Threat	Measured	Health Metric
7	Absence of Invasive Plants	Resistance to Invasion	Threat	Observed	Health Metric
8	Healthy Light Gaps	Natural Disturbance	Regeneration	Measured	Health Metric
9	Pit/Mound Microtopography	Stand Age	Structure	Observed	Health Metric
10	Absence of Human Activity	Human Impact	Threat	Observed	Health Metric
11	Absence of Deer Browse Line	Browse Pressure	Threat	Observed	Health Metric
12	Leaf Fragment Cover	Earthworm Impact	Threat	Measured	Health Metric

TIMED METRICS

1. Seedlings and Herbaceous Plants

A healthy forest shows signs of supporting both canopy tree species regeneration and a flourishing, diverse herbaceous community, this pair of metrics is a Forest Floor Feature and a Forest Layer Element.

A. 16 Tree Seedling Groups <12”

- Only seedlings meeting the height requirements are counted. Additionally, because seedlings can be difficult to rapidly identify in their early stages of growth, we have grouped them, by forestry standards, into categories that are listed on the Tree Species Code list (see **Table 2**, at the end of **4. Legacy Trees**) (i.e. instead of telling the difference between a black and red oak seedling, these are both classified in a broader category as red oaks and would be counted as one species).
- Only canopy tree species are counted (i.e. a *Carpinus*—Musclewood—seedling, as an understory tree, does not count).
- The threshold of 16 represents the combination of species counts rather than the total number of species (see notes on 3.B)

B. 20 Herbaceous Species

- If there is a conspicuous light gap or different inclusion of plant community (i.e. small wetland), the assessor should essentially skip over it because it is not representative and may skew counts. The assessor should take note of how long it takes to get through the inclusion and walk for a similar amount of time at the transect's end. If the inclusion is large, it may be better to alter the direction of the transect to avoid the inclusion of a non-representative plant-community all together.
- Only native plants are counted.
- Native vines that can get woody (i.e. Virginia creeper, poison ivy) are not counted in the herbaceous plants category.
- Grasses and mosses are not counted.
- Ferns are counted.
- Sedges are counted but only differentiated on a species level when obviously different characteristics can be rapidly observed. See **Figure 1**.

Figure 1: In the rapid method, only sedges showing obvious difference count

2. Shrubs and Saplings

A significant number and diversity of shrubs and sapling trees is an indicator of regeneration in a healthy forest. For the purposes of the RUFA, a shrub or sapling is defined as a native woody plant ranging in height from 12" to 6.5'. The Shrub and Sapling paired metric is considered an Understory Feature and a Forest Layer Element.

A. 120 Ind. Shrubs/Saplings 12" to 6.5'

- A shrub or sapling has been designated at 12" to 6.5'. Other research protocol at the Holden Arboretum has used <12" as a designation for the herbaceous layer. The 6.5' limit was set in order to reflect the typical upper height of the deer browse line. The idea is that a healthy forest—with a healthy deer population—would have a significant population of woody plants in this height zone. Anything taller has survived through the size it is most vulnerable to herbivory.
- The threshold of 120 reflects the approximate average of the set of 35 sites ranging from highest to low quality with a higher representation of high or mid-high quality sites (all the highest scoring sites to date were included in the set).

B. 16 Shrub/Sapling Species

- The 16 species threshold represents the sum of the transects. This number does not represent the total sum of species found in the hectare; this number represents the combination of counts from each transect, acknowledging that each assessor will likely be counting some of the same species. Ultimately, it represents that there are an average of 4 shrub/sapling species found in each transect.
- This is an important metric to be calibrated between assessors. The rule is to count as quickly *and* accurately as possible. When coming across a shrub clump, the assessor should attempt to observe how many stems are included in the clump without painstakingly seeking out each individual.
- "Shrub/Sapling" includes all native woody species between the height designations. The species can be a young tree or woody plant typically designated as a shrub.
- Root-sprouts from the bottom of trees are not counted. Since beech root-sprouts are difficult to quickly discern from saplings and are often located further from the parent tree than other trees' root-sprouts, these are counted as shrubs.
- In the case of a shrub/sapling that has dead material, only the observed living material is counted so the living material must exist between the 12" and 6.5' height.

3. Mature Trees

This metric considers the presence of large mature trees, which indicate a healthy forest system. This metric seeks to capture the impacts of canopy size, ecosystem services by mature trees (habitat, food resources etc), and tree/community age among others by looking at DBH which correlates with these factors. Mature trees need to be at least 20" DBH, as assessed with a Biltmore stick. For Biltmore stick measurement rules, refer to **Figures 2**, **3**, and **4**. The Mature Tree paired metric is considered a Canopy Feature and a Forest Layer Element.

A. 24 Mature Trees >20" DBH

- One defining characteristic of what turned out to be the higher quality forest sites was the presence of numerous larger sized trees, greater than or equal to 20" in DBH.
- At least a total of 24 trees must be found to earn a point. The designated 20" DBH was set because of forestry standards of mature, harvestable trees and because this is the approximate diameter most LEAP[3]-native trees achieve when they have reached maturity.

Figure 2: Using a Biltmore stick. Holding stick horizontal and ~2' from body at ~4.5' above the ground close one eye and visually line up the end of the stick with the left side of the trunk. This tree pictured just makes the cutoff for mature tree size.

[3] LEAP refers to the Lake Erie Allegheny Plateau bioregion, in which RUFA was designed to assess upland forests.

- The threshold was set at 24 after statistical analysis on 35 sites ranging from highest to low quality with a higher representation of high or mid-high quality sites (all the highest scoring sites to date were included in the set). The mean number of total mature trees in the set was 25, so the threshold was set just below this average.
- Measuring trees with split trunks: RUFA goes with the forestry standard of measuring however many trunks are present at breast-height. If the trunk is split below breast height, each trunk must be considered and scored as separate individuals (if one trunk is below 20" DBH and one above, then it is scored as 1 mature tree). If the split is above breast height, the tree is measured as one individual. See **Figure 4** below for reference on other special cases.

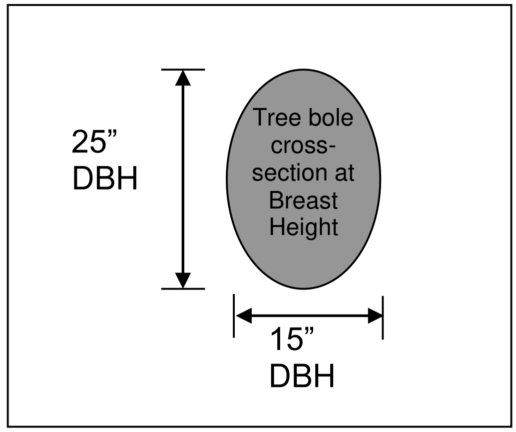


Figure 3: Example to illustrate measuring unevenly shaped boles of trees from multiple sides to obtain an accurate DBH reading.

- Occasionally the bole of a tree may be misshapen such that one side measured with the Biltmore stick is less than 20" but another side is more (see **Figure 3**). In these cases, the assessor should measure from multiple sides of the tree and average the measurements.

B. 3 Mature Tree Species >20" DBH

- Mature tree species diversity is also an indicator of quality. According to RUFA standard, old growth forests have multiple species (which differ according to plant community type) of tree reaching maturity in a given area. This indicates a resilient, reproductive-aged, and diverse canopy-tree community.
- 3 species of mature trees was chosen as the threshold because in mature to old-growth LEAP forests, there is typically a diversity (more than 2 species) of trees of mature age.
- Only native trees can be counted.
- Species are recorded according to common name codes (see **Table 2: Tree Species List and Abbreviation Codes** at the end of the next section [**4**]).These were generated because we anticipate that using common names will widen the pool of possible RUFA assessors.
- In most situations, species-level ID is possible and using the groupings should be avoided. However, if species identification is in doubt, or there is some other constraint, this is a general protocol:
    - *Ash:* Often difficult to ID when there is a high canopy. If it is an obvious well-drained, dry/upland soil, assume white ash (WHAS). Otherwise, without enough other quick evidence (samaras on ground, accessible twigs w/leaf scars), use the abbreviation ASH.

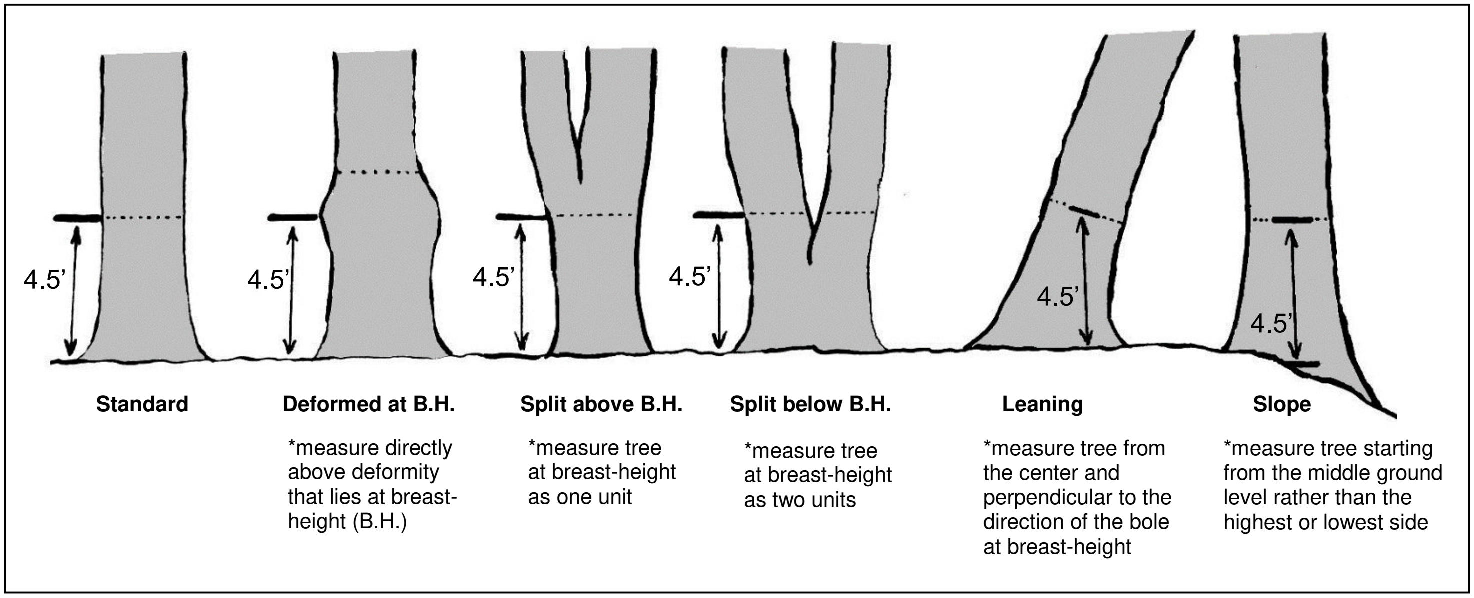


Figure 4: Pictorial summary of DBH measurement rules.

4. Legacy Trees

This metric is meant to capture characteristics of old-growth, unmanaged forest. Legacy trees, or large old trees, around half or more as old as their potential lifespan, are a salient feature of old-growth forest. These large trees are individuals that have grown up, their entire lives, in forest conditions. Furthermore, they are old enough to be, by forestry standards, “overmature”, meaning that their canopy is not growing substantially or is in decline and they are past peak reproduction. The Legacy Tree paired metric is considered a Canopy Feature and a Forest Layer Element.

A. 7 Legacy Trees >32” DBH

- Legacy Trees have basic criteria of being above 32” DBH but also need to be large, straight-bole trees without major trunk splits (no “double-leaders”, or double trunks) and usually with a large root flare. “Wolf Trees” (see **Figure 5** and **7**) or trees with “wolfish” characteristics—evidence of having spent a good portion of its growing life without forest conditions (low main branches, large branch scars on the main trunk etc.)—are not technically Legacy Trees and should not be counted in this metric.

Figure 5: Wolf Tree with younger trees surrounding, low branches, branch scars and wide

- The designated 32” DBH was set because of conversations with forest managers and experience of encountering a break when measuring large trees wherein communities of large trees were often around 30” or below or above 32”. Only occasionally do trees seem to be right at 31 or 32” DBH. In the case that a tree is on the borderline, measure from multiple sides of the tree and consider the approximate average of measurements.

- The threshold was set at 7 after statistical analysis on 35 sites ranging from highest to low quality with a higher representation of high or mid-high quality sites (all the highest scoring sites to date were included in the set). 7 was around one standard deviation above the average and this amount or more of Legacy Trees coincided with other old-growth and high-integrity features (most other categories had points).

Figure 6: A qualifying legacy tree DBH

B. 2 Legacy Tree Species >32" DBH

- 2 species of Legacy Trees was chosen as the threshold because of the trend in LEAP region forest types wherein 2 or more species typically characterize a mature tree community.
  - Only native trees can be counted.
  - In using the Biltmore stick, the tree must *at least* reach the 32" mark when the stick is held at arm's length. We have found that most times true Legacy Trees are clearly above the 32" mark (see **Figure 6**)

Legacy Tree

- Larger than 32" DBH
- Root flare
- Straight, tall bole
- Small crown
- *Characteristics suggest the tree has grown up in forested conditions*

Borderline Conditions

- Larger than 32" DBH
- Trunk not very straight
- A main branch or double leader coming off main bole at 25' to 75'
- *In these conditions, consider the context: Does the area show evidence of farming or logging? What characteristics do other trees of this size class show?*

Wolf Tree

- Larger than 32" DBH
- Low branch scars from self-pruning
- Low branches (live or dead)
- Trunk splits or main branches at 50' or lower
- Wide crown growth pattern

Figure 7: Pictorial summary of characteristics qualifying Legacy Trees versus wolf trees.

Table 2: Native Tree Species List* and Abbreviation Codes**

Common Name	***Scientific name***	**Species Code†**	**Seedling Grouping Code††**
Ash, Green	*Fraxinus pennsylvanica*	GRAS	ASH
Ash, White	*Fraxinus americana*	WHAS	ASH
Aspen, Bigtooth	*Populus grandidentata*	BIAS	ASP
Aspen, Quaking	*Populus tremuloides*	QUAS	ASP
Baldcypress	*Taxodium distichum*	BALD	
Basswood, American	*Tilia americana*	BASS	
Beech, American	*Fagus grandif*	AMBE	
Birch, Black	*Betula lenta*	BLBI	BIR
Birch, River	*Betula occidentalis*	RIBI	BIR
Birch, Yellow	*Betula allegheniensis*	YEBI	BIR
Boxelder	*Acer negundo*	BOXE	SMA
Buckeye	*Aesculus glabra*	BUCK	
Butternut	*Juglans cinerea*	BUTT	WAL
Catalpa, Northern	*Catalpa speciosa*	CATA	
Cherry, Black	*Prunus serotina*	BLCH	
Chestnut, American	*Castanea dentata*	AMCH	
Cottonwood, Eastern	*Populus deltoides*	COTT	
Cucumbertree	*Magnolia acuminata*	CUCU	
Eastern Hemlock	*Tsuga canadensis*	EAHE	
Elm, American/white	*Ulmus americana*	AMEL	ELM
Elm, Slippery/Red	*Ulmus rubra*	REEL	ELM
Hickory, Bitternut	*Carya cordiformis*	BIHI	HIC
Hickory, Pignut	*Carya glabra*	PIHI	HIC
Hickory, Shagbark	*Carya ovata*	SHHI	HIC
Hickory, Shellbark	*Carya laciniosa*	*SLHI*	HIC
Locust, Black	*Robinia pseudoacacia*	BLLO	
Locust, Honey	*Gleditsia triacanthos*	HOLO	
Maple, Black	*Acer nigrum*	BLMA	HMA
Maple, Sugar	*Acer saccharum*	SUMA	HMA
Maple, Red	*Acer rubrum*	REMA	SMA
Maple, Silver	*Acer saccharinum*	SIMA	SMA
Oak, Black	*Quercus velutina*	BLOA	RED
Oak, Bur	*Quercus macrocarpa*	BUOA	WHI
Oak, Chestnut	*Quercus montana*	*CSOA*	WHI
Oak, Chinquapin	*Quercus muehlenbergii*	CHOA	WHI
Oak, Pin	*Quercus palustris*	PIOA	RED
Oak, Red	*Quercus rubra*	REOA	RED
Oak, Scarlet	*Quercus coccinea*	SCOA	RED
Oak, Swamp White	*Quercus bicolor*	SWOA	WHI
Oak, White	*Quercus alba*	WHOA	WHI
Osage-Orange	*Maclura pomifera*	OSOR	
Pawpaw	*Asimina triloba*	PAWP	
Pine, White	*Pinus strobus*	WHPI	
Redcedar, Eastern	*Juniperus virginiana*	REDC	

Sassafras	*Sassafras albidum*	SASS	
Sweetgum	*Liquidambar styracifula*	SWGU	
Sycamore	*Platanus occidentalis*	SYCA	
Tamarack/Larch, Eastern	*Larix laricina*	TAMA	
Tulip Poplar	*Liriodendron tulipfera*	TUPO	
Tupelo/ Black Gum	*Nyssa sylvatica*	TUPE	
Walnut, Black	*Juglans nigra*	BLWA	WAL
Willow (all)	*Salix spp.*	WILL	WIL

*List is based off ODNR Division of Forestry "Common Ohio Trees". It includes only natives and represents trees expected to reach at least 20" DBH at maturity.

*4-letter abbreviations based on systems such as IBP's standardized species codes for birds. Other systems (i.e. USDA PLANTS database) usually use standardized codes from scientific names. These (like IBP's) are organized by English, or common, name.

†† Species groupings based on standard US forestry practices

†Species codes are essentially the first two letters of each word in the plant name. If the commonly used name is one word, the code is the first four letters of that name. Codes in italics don't follow those rules because the abbreviation was already taken by another species

5. Snags and Woody Debris Tree Units

A healthy forest has these elements representing the forest age and that trees have been allowed to grow to a significant size and die before being harvested. These standing dead trees (snags) indicate health. The Snags and Woody Debris paired metric is considered a Stand Age Feature and a forest Structure Element.

A. 6 Snags >12" DBH

- Snags need to match the basic size criteria because this metric is meant to represent trees that have had the chance to grow to a significant size and die before being harvested.
- It is important to distinguish between a tree recently dead because of invasive insects or disease (i.e. Emerald Ash Borer, Dutch Elm Disease). The snag must in some way represent habitat—have holes, peeling bark, hollow etc.—that indicate its being used in its current condition. It will no longer have any fine twigs and any branches remaining are tertiary main branches or some secondary branches.

Figure 8: Exemplary snags (lack of bark/peeling bark, holes, hollows, meeting size requirements)

- If a tree that meets these criteria is leaning on another/not self-supporting anymore, that is still scored because its structure is still functioning as a snag until it hits the ground and becomes woody debris.
- In a forest with non-native trees (most likely planted evergreens in LEAP forests), non-native snags are *not* counted. Obviously, it may be difficult to observe the species type, but evergreens tend to have persistent knots or knobs of branches even after some decay.
- In the case of a tree broken off at 6.5' or higher and the part above resting next to it, this unit counts as both a snag and as woody debris. See **Figure 9**.

Figure 9: Snag and woody debris unit from same tree

- An upper limit of 12 has also been established for the number of snags. A score of zero is assigned if more than 12 snags are identified. There does appear to be a point in which too many snags might indicate a problem, EAB for example, and an unhealthy forest where numerous canopy trees are dead. This situation was observed at one hectare cell, where numerous canopy ash and sassafras were dead and fairly evenly distributed. If the upper 12 snag limit is reached the assessing team should consider the distribution of the snags before assigning a 0.

B. 12 Woody Debris Tree Units >12" DBH (Tree-Unit Logs)

- Only course woody debris representing a main trunk/stem—"tree unit"—is counted (see **Figure 10**). Therefore, upon finding large pieces of woody debris, assessors should identify the presence or absence of the root flare/bole/pit and mound. This is because this metric is not only to measure structural aspects of debris but also the history of the forest—trees that have grown above 12" diameter, died/tipped and have become woody debris logs indicate that they have had enough time to grow to that size (and also die and sometimes to begin decomposing and contributing to the soil and habitat).

Figure 10: Large tree limbs are not to be counted as woody debris tree units.

- The native deadwood rule is also true for woody debris—only native woody debris is counted (i.e. pine plantation debris not counted).
- Woody debris must meet the size category (12" diameter) at "breast height", or approximately 4.5 feet (1.4m) above the area of the root flare (or what's left of it). See **Figure 11**.

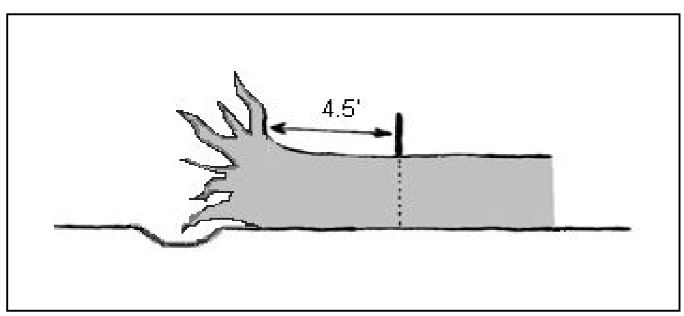


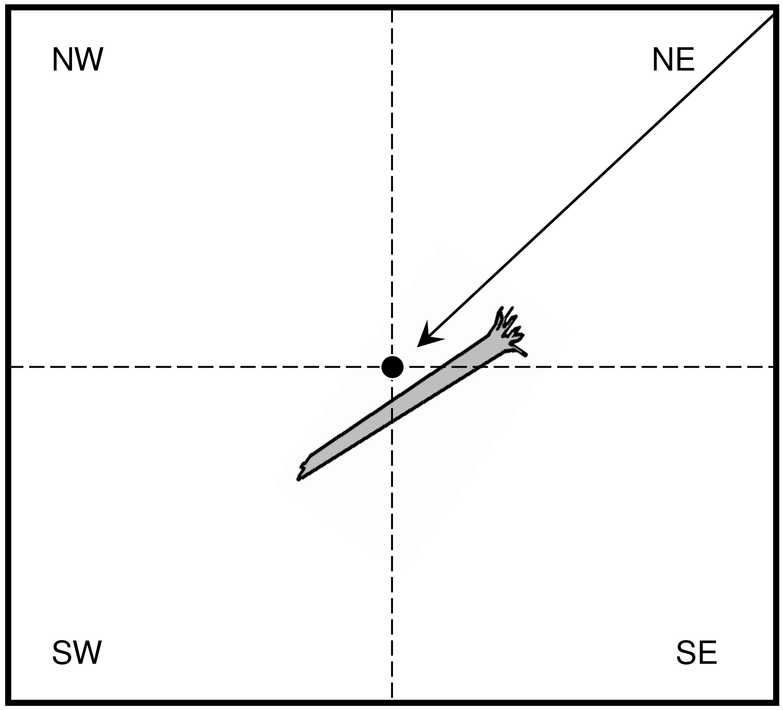
Figure 11: DBH Measurement on a log (woody debris tree unit).

- Since the length of a piece of debris may be encountered in two transects, it is only counted in the transect where the bole/stump/tip-up lies and "breast height" measurement is taken. See **Figure 12.** To avoid double-counts, dialogue between assessors is also helpful.

Figure 12: Counting woody debris units that cross multiple transect areas.

In many cases, the woody debris units observed and counted on the assessors' walk back to the center for metric 5.B. lie across multiple transects. In order to avoid double or even triple counts on the same unit of woody debris, this rule, as illustrated in the example, applies:

The assessors in the SE, SW and NE transects walking back to center and counting woody debris will all encounter this one large tree unit pictured. Only the one on the NE transect (with the arrow) should count this unit, however. This is because the base/origin of the unit falls in her/his transect.



6. Invasive Plants

Old growth forests are also well balanced and resilient enough to prohibit the invasion and establishment of non-native plant species, provided there are minimal vectors for their introduction. The thresholds for each invasive plant species metric were set at a level below which the plants will have a minimal "presence" in the forest. The Invasive Plant paired metric is an Impact Feature and a forest Threat Element.

A. >80 Invasive Shrubs and/or Vines

- Invasive shrubs and vines are visually targeted and counted, stem-by-stem. The threshold for this metric is based on the number of individual plants it would reasonably take a small crew (~3 individuals) to manage in 15 minutes or less and represents a minor impact on the site. The management method for woody plants is typically cutting and stamping/painting, so after experience managing invasions of multiple woody species, and considering the average counts at invaded sites, the threshold of 80 was set.
- Woody invasives are counted much as the woody stems of shrubs/saplings are counted, and the same "shrub clump" rules apply for the woody species. It is important, as always, to simply count as much or as many as possible in the given minute for each category. This may mean high numbers for hectares with heavy invasions.

- We comply with ODNR's designation of Ohio-listed invasive plants and are attentive to the ongoing dialogue of natural area managers about potential new invaders.

B. >200 Invasive Herbaceous Plants

- Invasive herbaceous plants are visually targeted and counted, stem-by-stem. The threshold for this metric is based on the number of individual plants it would reasonably take a small crew (~3 individuals) to manage in 15 minutes or less and represents a minor impact on the site. The management method for invasive herbs is typically spraying or hand-pulling, so the threshold of 200 was set.
- In the case that there are so many woody invasives that only a portion of the transect has been covered within the first minute, the assessor should walk out at least more than 30 paces and then back toward the center to allow for an opportunity to see invasive herbaceous plants.
- We comply with ODNR's designation of Ohio-listed invasive plants and are attentive to the ongoing dialogue of natural area managers about potential new invaders.

OBSERVATION-BASED METRICS

7. Observed Invasive Plants

If there aren't any invasive plants observed in transect walks, this should be a separate meander assigned to one or more assessors during leaf fragment assessment/data entry. This metric is intended to benefit a site that is absent of invasive plants. It is possible to identify invasive plants within a hectare cell without observing them on the transects. Observed Invasives Metric is considered a forest Resilience Feature and a Threat Element.

Figure 13: Exemplary light gap with regeneration of native samplings, seedlings and shrubs and canopy opening.

8. Light Gap

Only healthy light gaps count—healthy gaps are created by a natural disturbance such as windfall or a fallen limb (>12" in diameter in either case), have a visual break in the canopy, and are dominated by the new growth of native shrubs, seedlings, young trees etc. See **Figure 13**. Light Gaps are considered a Natural Disturbance Feature and a forest Regeneration Element

9. Pit-Mound Microtopography

Old growth forests also feature micro-topography such as pit and mound formed from the action of trees falling and rotting completely away. Pit-Mound indicates that trees have had long enough to grow, be blown over/fall and decompose/contribute to the humus and structural function (see **Figure 15**) Therefore any observed will need to be because of a tip-up, not human activity or other geological features. This should be kept in mind when a trail runs through a cell and portions might have been excavated and the soil relocated, forming an artificial mound. See **Figure 14**. The Pit/Mound metric is considered a Stand Age Feature and a forest Structure Element.

Figure 14: Example of human made "pit mound" next to an improved trail.

Figure 15: Stages of the creation of pit-mound topography. From the left, only stages 3, 4 and 5 are counted as pit-mound.

10. Absence of Human Activity

The Absence of Human Activity Metric is considered a human Impact Feature and a Threat Element. Significant human activity affecting forest ecosystem integrity, whether in the past or present, is noted here. This includes but isn't limited to cut stumps, furrows, planted pines, dump sites and fieldstone piles. In the case of footpaths, footpaths meeting these criteria do not count as "human activity" because of their low impact:

Figure 16: Improved trail surface

1. Must not act as a light gap/no interruption in canopy
2. Must not be wider than 3 ft. across/single track trail
3. Footpath must have an unimproved surface (see **Figure 16**)

11. Absence of Deer Browse Line

Deer browse lines are visually assessed by kneeling and must be definitive. This "line" tends to be around 5-6ft. and is characterized by a low shrub layer or missing/browsed leaves and twigs on lower branches of saplings and shrubs. See **Figure 17**. There have been occurrences where a low browse line has been observed on plants at the forest floor level, also counting as a browse line. Absence of Deer Browse Line feature is considered a Browse Pressure Feature and a Threat Forest Element.

Figure 17: Deer Browse Line

12. Leaf Fragment Assessment

Old growth forests possess a very rich, deep organic soil layer. Metric 12 attempts to capture this feature. When the assessors are scoring leaf fragment cover, they must gently pull back the top (this past autumn's) layer of leaves to reveal the next layer. It is this layer that is assessed. Stem or midveins of leaves do not count as leaf fragments (this is indicative of worm activity). If there is any parent soil visible, the assessor should be cautious of assigning a 1 (greater or equal to 50% cover). See **Figure 18** and **Figure 19**. The Leaf Fragment Metric is an Earthworm Impact Feature and a Threat Element.

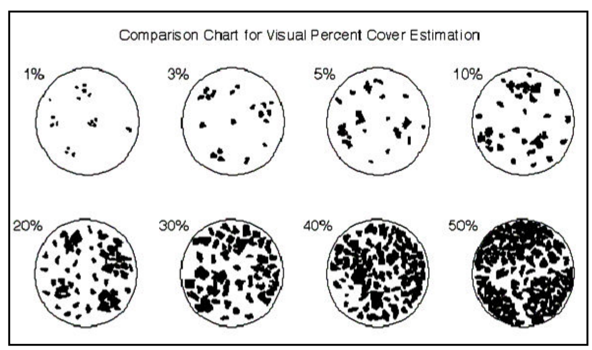


Figure 18: Comparison Chart for visual percent-cover estimation

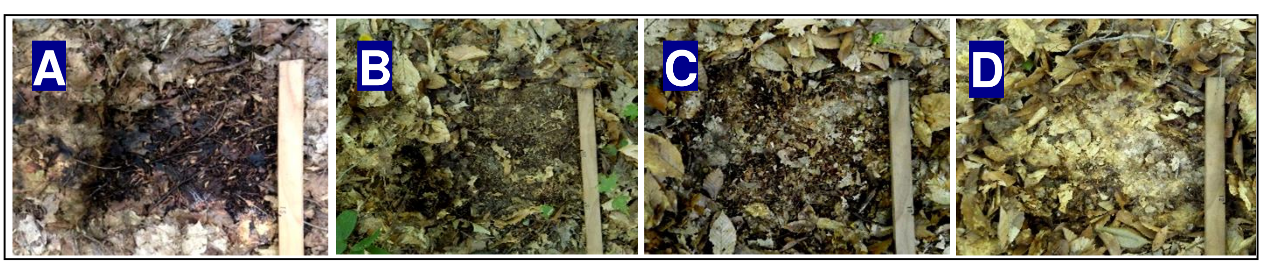


Figure 19: Different examples of leaf fragmentation and scores. A: less than 10% fragments (score 0) B: 10-25% fragment cover (score 0) C: 50-60% fragment cover (score 1) D. 100% leaf fragment cover (score 1).

Problematic Site Conditions

Occasionally we encounter hectare centers that present a problem for sampling. In these cases, the center cannot be adjusted within the cell because of the existing grid. However, there are other ways to adjust transects to avoid these inclusions and still record accurate data representing the majority of the cell.

Assessors should always aim to sample whenever possible, but when these issues are too numerous or extreme to avoid skewing data, the site is “abandoned” and that is recorded on the data sheet with the cell number, date and an X in the data column—notes as to why the cell was abandoned should be recorded on the back of the data sheet.
Examples of problem areas encountered along transects include:

1) Scrub-shrub successional forest
2) Grapevine tangles
3) Large light gaps
4) Steep topography
5) Stream beds, seeps, and expansive wetlands

Notes: It is possible for a hectare center to fall in a scrub-shrub community. These areas should not be sampled because they represent a successional stage and do not yet represent a true, functional forest where trees with a high, dense canopy largely determine the character of the biotic community. Scrub-shrub or young successional stands are dominated by early succession trees <20” DBH (i.e. red maple) and significant shrub/herbaceous layers from an open canopy.

Always consider if altering the design of the transect sample will significantly influence the data.

Normally assessors will walk about 50m to 60m of the total ~71m along a transect in a minute. Thus transect bearing alterations are acceptable if the change is within 10 to 20 degrees. Alterations to the sample design should never cause assessors to walk outside the cell.

Always record any changes to the sampling model in the Notes section of the data sheet. Direction changes should include bearings and the altered transects should always be identified.

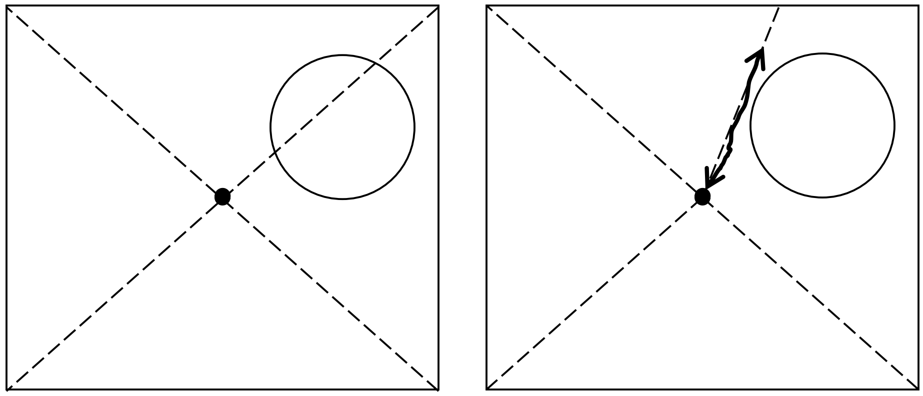
Examples of viable solutions to the other issues are illustrated in **Figure 20** below:

Figure 20:

Problem Condition	Example	Solution Example

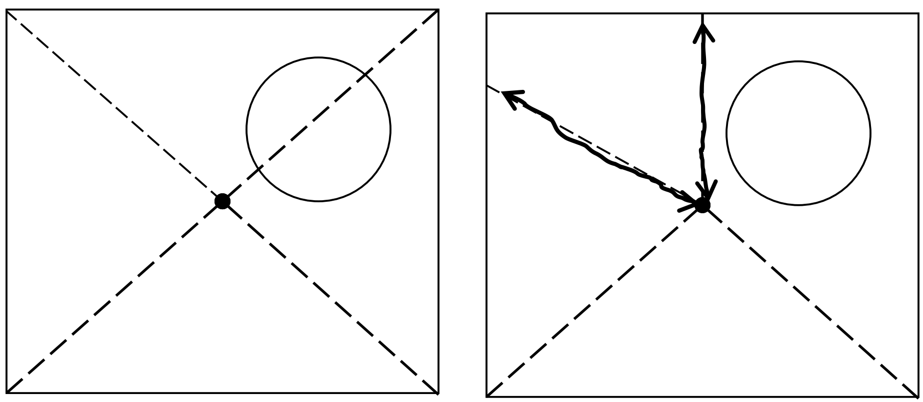
1. Transect cuts through large inclusion (requiring a ~5 to 30° adjustment)

Solution: When an inclusion is large, consider a slight direction change on the affected transect. If the direction change is more than 30°, consider the solution illustrated in the next figure.



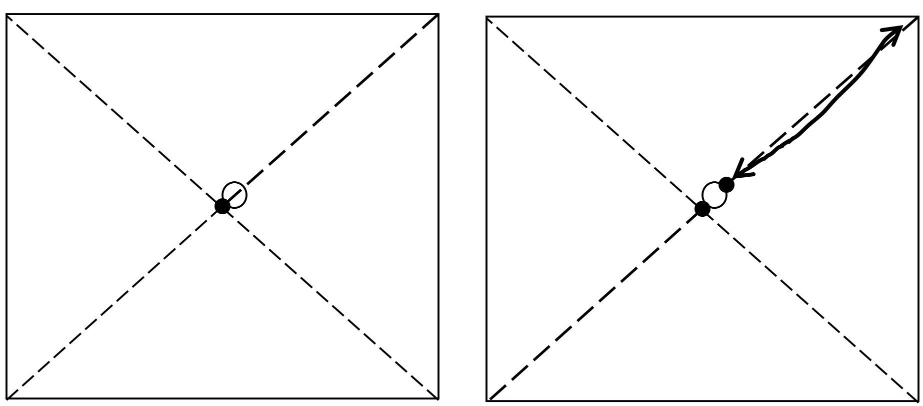
2. Transect cuts through large inclusion (requiring a ~30 to 45° adjustment and adjacent transect adjustment)

Solution: If the direction change to avoid a large inclusion is more than 30°, consider also altering the nearby transect slightly in the same direction. A 45° shift is the absolute limit of transect alteration.



3. Transect starts at small inclusion

Solution: When a small inclusion or difficult topographical feature is close to the center (within 10-20m), start the transect on the other side. The assessor will get further along the transect as a result but should remain inside the cell.



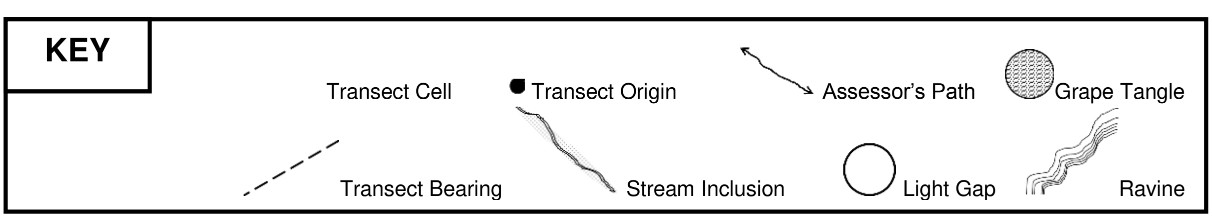
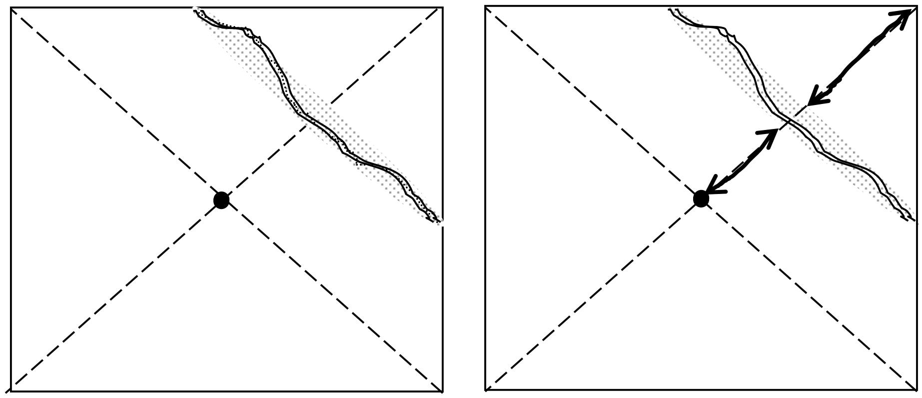


Figure 20: *continued*

Problem Condition **Example** **Solution Example**

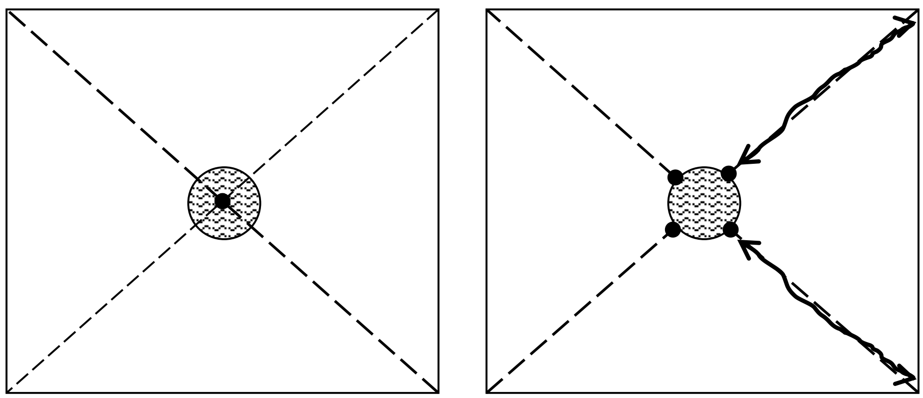
4. Transect cuts through small inclusion

Solution: When inclusion is small enough, you can skip over it, count how long it takes to cross, and add on that time to the end of your minute walk along the transect. The assessor will get further along the transect as a result but should remain inside the cell.



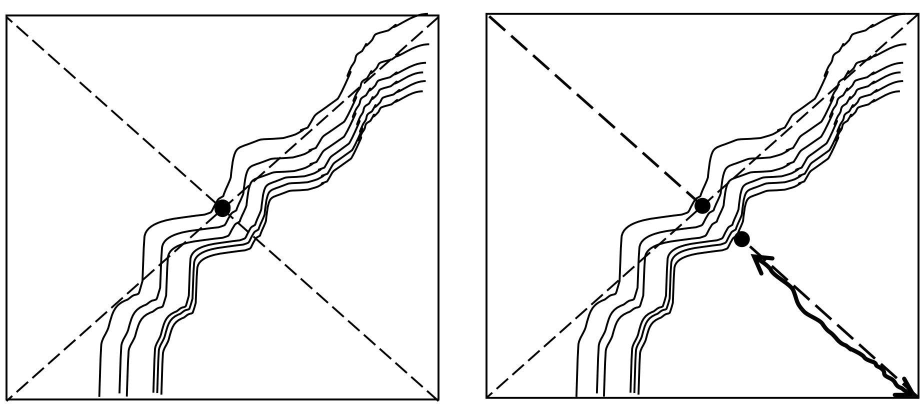
5. Inclusion at plot center

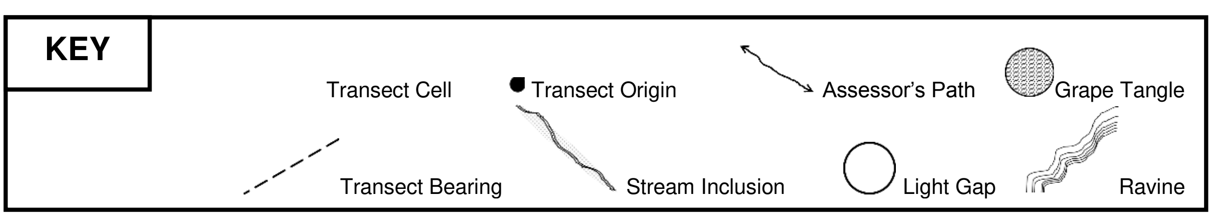
Solution: When a small-to-medium-sized inclusion lies right at the center of a hectare, begin each transect outside of it. Assessors will get further along the transects as a result but should remain inside the cell.



6. Difficult Topography

Solution: Topographical conditions can be addressed sometimes by altering transect bearings but when the center lies right next to a difficult feature (i.e. ravine), it can be treated much as a small inclusion at the center (situation 3) wherein the assessor begins at the other side (as long as they are ≤20m from the center) and walks farther along the transect—though still within the cell—as a result.





Testing and Statistical Analysis

In order to test the legitimacy and accuracy of RUFA to assess forest integrity, we identified 15 sites in North Chagrin Reservation (Cleveland Metroparks) and 3 at the Holden Arboretum to test our protocol. These sites were assessed with VIBI protocols in 2010 or 2013. Additionally, five sites in old growth and near old-growth stands in Ashtabula were assessed. This was in order to allow some of the highest quality forests inform the data set and inform our protocol.

Comparing RUFA data and results to the VIBI site data and results would, we hoped, give us an idea of how accurate this method is. The VIBI protocol—intensive, research-oriented, detailed, and including floristic quality (FQAI)—is significantly different from the RUFA—rapid, management-directed, broad-perspective, and without FQAI. This provides the opportunity to see if different methodologies can arrive at similar conclusions about forest integrity.

Figure 21: VIBI and RUFA 2.5 ranks for all 15 plots sampled.

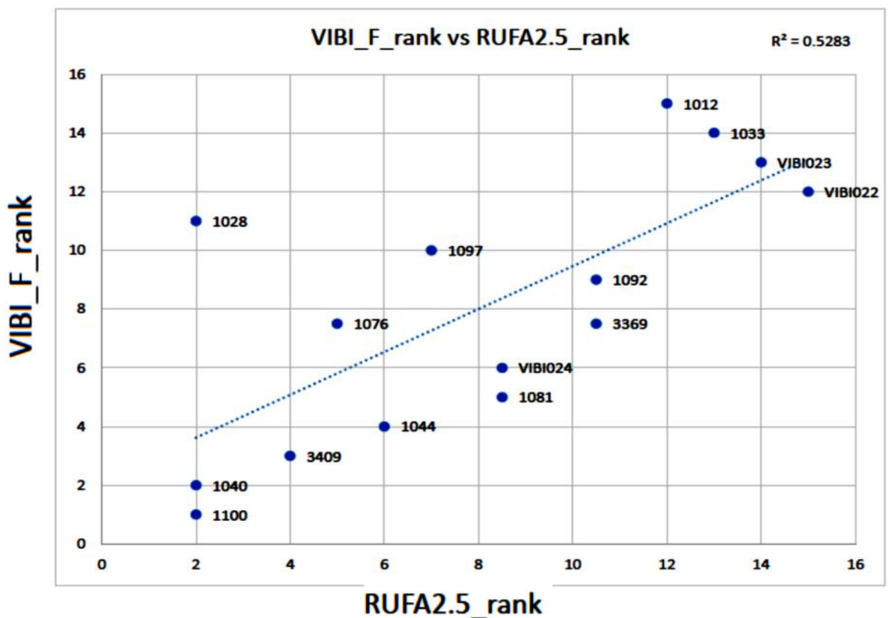
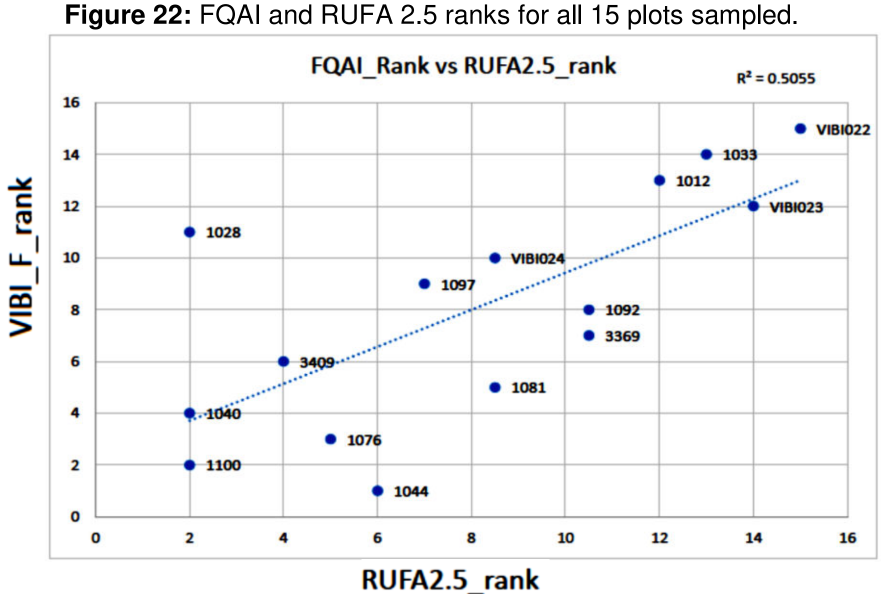


Figure 22: FQAI and RUFA 2.5 ranks for all 15 plots sampled.



Upon encountering the 18 selected sites, two at North Chagrin were not sampled due to unnavigable terrain and 15 were sampled with the 2.5 protocol. After RUFAs were performed at the total of 15 VIBI-assessed plots, we performed a rank correlation analysis of the RUFA scores v. VIBI-F scores and RUFA scres v. FQAI scores. The results are featured in **Table 2** and **Figures 21 and 22**.

Although some correlation was suggested, we identified at least one potential outlier. Because of the very different scoring results of one plot in particular—1028—we decided to go back to this plot and assess it for potential difference. Our team revisited that site at NC to better understand why it got such high VIBI-F and FQAI scores. After observing the site closely, our team arrived at consensus as to why the scores were so different. 1028 was set up under PCAP (Plant Community Assessment Protocol) as a 20x50m plot. The plot includes a conspicuous area of uncharacteristically lush herbaceous and shrub plants (see **Figure 23**). This area appears to be influenced by a thin canopy and sheet flow running through it (see **Figure 24**). This small feature seems to have influenced the score of VIBI-F more than it has the RUFA score because RUFA looks at the entire hectare that contains the 20x50 plot. In that wider area, there was also a change in the age and character of the forest running just next to the plot. One side of the hectare was much younger and edgy (showing more herbaceous and shrub and younger pioneer trees) than the other. We think that the RUFA and VIBI-F were so different because of the conspicuous inclusion and the apparent presence of two different forests in the hectare.

Figure 23: Site 1028 looking west from the origin (pink flag). Herbaceous inclusion circled.

Figure 24: Canopy thinning (*left*) and surface flow (*right*) at site 1028

As a result of these closer observations, we concluded that this site would not have been sampled with RUFA protocol since it represented two different community types. Thus, 1028 was eliminated from the data set. The resulting rank correlations are shown **Figures 25** and **26**.

With the resulting R scores of 0.72 and 0.74, a significant, strong correlation is suggested for RUFA , VIBI and FQAI. In turn this suggests that the RUFA methodology obtains comparable results to other methods of forest assessment and is an accurate measure of forest quality and integrity.

Table 3: Scores and ranks of RUFA, VIBI-F and FQAI for 15 sites. **1028 is eliminated from the data set as an outlier.*

Site Name	RUFA2.5	RUFA2.5 Rank	VIBI-F	VIBI-F Rank	FQAI	FQAI Rank
1012	12	11	67	14	28.4345	12
1033	13	12	66	13	30.66793	13
1040	3	1.5	22	2	16.0859	4
1044	6	5	41	4	12.79204	1
1076	5	4	50	7.5	15.94763	3
1081	10	7.5	43	5	18.54846	5
1092	11	9.5	52	9	20.79788	8
1097	8	6	54	10	21.0634	9
1100	3	1.5	16	1	13.85805	2
3369	11	9.5	50	7.5	20.5	7
3409	4	3	40	3	18.89822	6
VIBI 023	18	14	59	11	30.74261	14
VIBI 022	17	13	60	12	27.55203	11
VIBI 024	10	7.5	47	6	21.82821	10
1028*	3	n/a	55	n/a	23.19253	n/a

Figure 25: RUFA 2.5 and VIBI-F score rank comparison without 1028. R=0.7431.

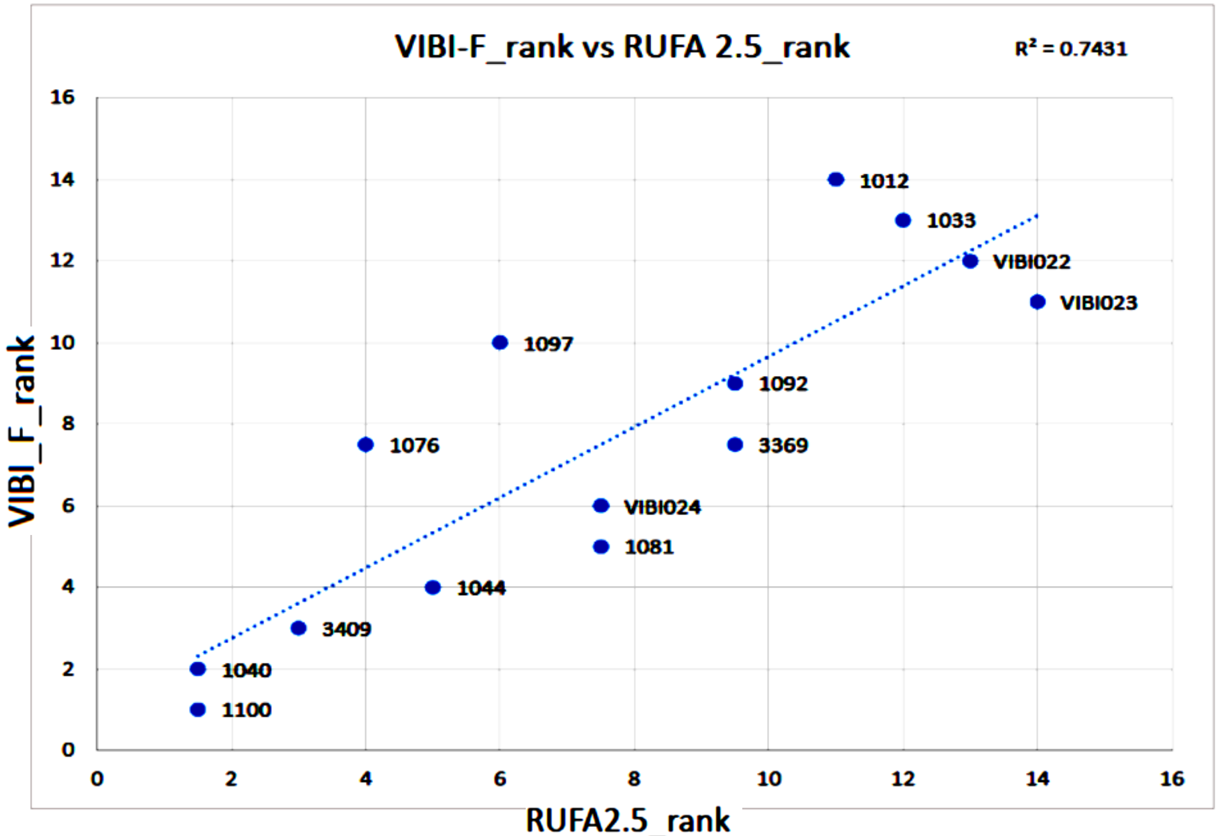
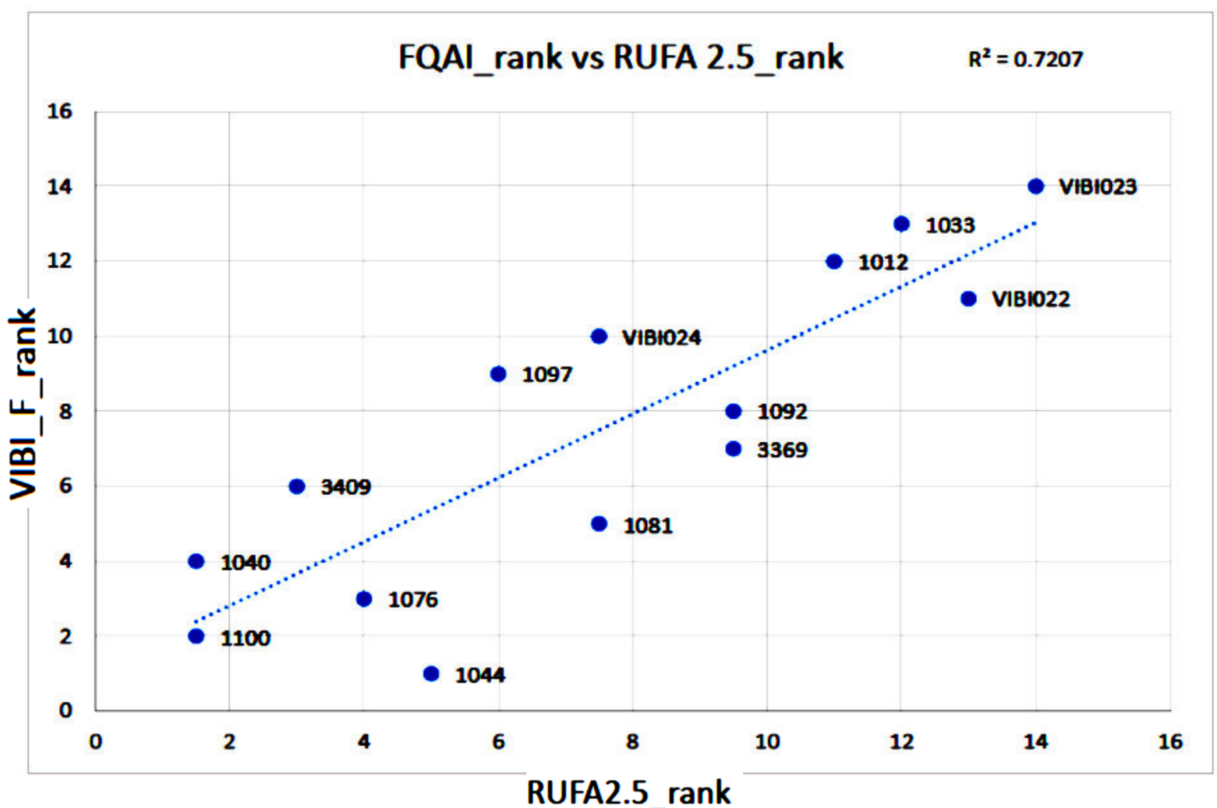


Figure 26: RUFA 2.5 and FQAI score rank comparison without 1028. R=0.7207.



Rationale for the Omission of Features

In the development of version 3.0, we were questioned repeatedly on a few subjects, one of which was the apparent omission of a few features of forests from the RUFA. Many of these features are implicitly considered in existing metrics. The rationale for apparent omissions is discussed here.

Information regarding the features below is not included as a RUFA metric, however, information is still recorded on the back of the field sheet or with a different assessment tool all together. The information collected is not factored into the overall score or rank, but may provide useful information about the site.

Seedling Cover/Abundance: Unlike the tree and shrub metric, there is no abundance measure for seedlings—they are counted much as the herbaceous plants are, by species diversity only. This is because:

1) The influence of mast years on seedling abundance causes high variability in cover year to year.
2) The high mortality rate of seedlings in the first few years after germination and variable mortalities according to species suggests that measuring the abundance wouldn't give an accurate picture of regeneration.
3) Version 1.0 used a metric for seedling abundance by estimating cover, which a cluster analysis suggested was insignificant whereas all other metrics showed statistical significance. This metric was therefore abandoned. However, the seedling cover is still recorded as an estimated percentage.

Tree Age Classes <20" DBH and above 6.5': There is a span of tree age for which the RUFA does not have a metric: The Shrub/Sapling metric stops at 6.5 feet and the Mature Tree category begins at 20" DBH. This is because:

1) Although young/immature trees are not measured, they are ultimately considered because it is assumed that any tree that is able to survive above browse level height has a reasonable chance of becoming a mature canopy tree under the proper conditions.

2) This age class of trees is not as structurally important as mature trees and tells us less about the overall age of the forest.
3) However, there is some use in knowing what age classes are present, therefore a series of checkboxes has been added to the back of the field form where the presence or absence of various age classes can be documented. While this information is not used in the total score calculation it is useful in understanding why a particular site scores as it does.

Forest Pests/Pathogens: The RUFA does not consider forest pests or pathogens

1) Observation of forest pest/pathogens is difficult to accomplish in a rapid manner and with the amount of training required.
2) Forest pathogens/pest are reflected in the snags metric as an upper limit.
3) Readily observable conditions such as the unknown beech leaf disease (beech blight) are documented as well as spicebush dieback or EAB.

Spring Ephemerals: The RUFA does not consider indicator species, such as spring ephemerals.

1) Many of these plants are identifiable only in a small window of time and forest assessments realistically require a longer field season.
2) Instead of including spring ephemerals in the RUFA, a separate protocol—the Spring Ephemeral Rapid Assessment (SERA)—has been developed and tested on sites where the RUFA has been completed and provides many opportunities for comparison with categorical data from RUFA.

Heterotrophic Plants: These are not assessed because they have various times of flowering and appearance (i.e. *Epifagus virginiana*—beechdrops—typically don't appear until early autumn).

Forest Management Implications

The integrity category ranks as determined by the final RUFA scores are useful in evaluating the forest at the landscape level and making comparisons to other aspects of the landscape, such as land use history. **Figure 27** depicts the RUFA Forest Integrity Ranks from 132 sites assessed in 2016 and current boundary of HA's Stebbins Gulch Natural Area against the historic aerial photographs taken of the area in 1937. In general the RUFA is sensitive enough to identify the land use history signal, as suggested by this map. **Figure 28** depicts the Forest Integrity Rankings of the 2016 RUFA sites in Stebbins showing the overall integrity ranking pattern across the forested landscape.

However, forest sites may achieve the same or similar final scores but be quite different in character—two sites with identical final scores may have very different point distributions in their metrics (i.e. one may lose points for lack of mature trees, another for invasive species presence). Therefore, making management decisions is difficult with the final score or integrity category alone. To distinguish between similar ranked sites the RUFA metrics are divided into 2 groups, metrics pertaining most to Forest Health and those that pertain to Forest Age.

Forest Health Metrics

- 1.A Herbaceous Species
- 1.B Seedling Species
- 2.A Shrub Individuals
- 2.B Shrub Species
- 6.A Invasive Herbs
- 6.B Invasive Shrubs/Vines
- 7. Absence of Observed Invasive Plants
- 8. Light Gap
- 10. Absence of Human Activity
- 11. Absence of Deer Browse Line
- 12. Leaf Fragment Cover

Forest Age Metrics

- 3.A Mature Tree Individuals
- 3.B Mature Tree Species
- 4.A Legacy Tree Individuals
- 4.B Legacy Tree Species
- 5.B Woody Debris
- 9. Pit/Mound Micro-Topography

Natural areas managers can gain a better understanding of how to manage a specific site by plotting the Forest Health metric scores against the Forest Age metric scores, as has been done below in **Figure 30.** This graph was developed with the 2016 RUFA assessments in Stebbins and at an additional 8 locations on privately held and partner organization-owned land in Ashtabula County or NE Ohio. Here, based on the distribution of Health vs Age points, the forest sites are grouped into four Forest Condition Categories. **Figure 29** depicts the Forest Condition Categories of 2016 sites in Stebbins. The management implications suggested by this figure are described and illustrated with an example (**Figure 31**).

Figure 27: Stebbins Land Use History

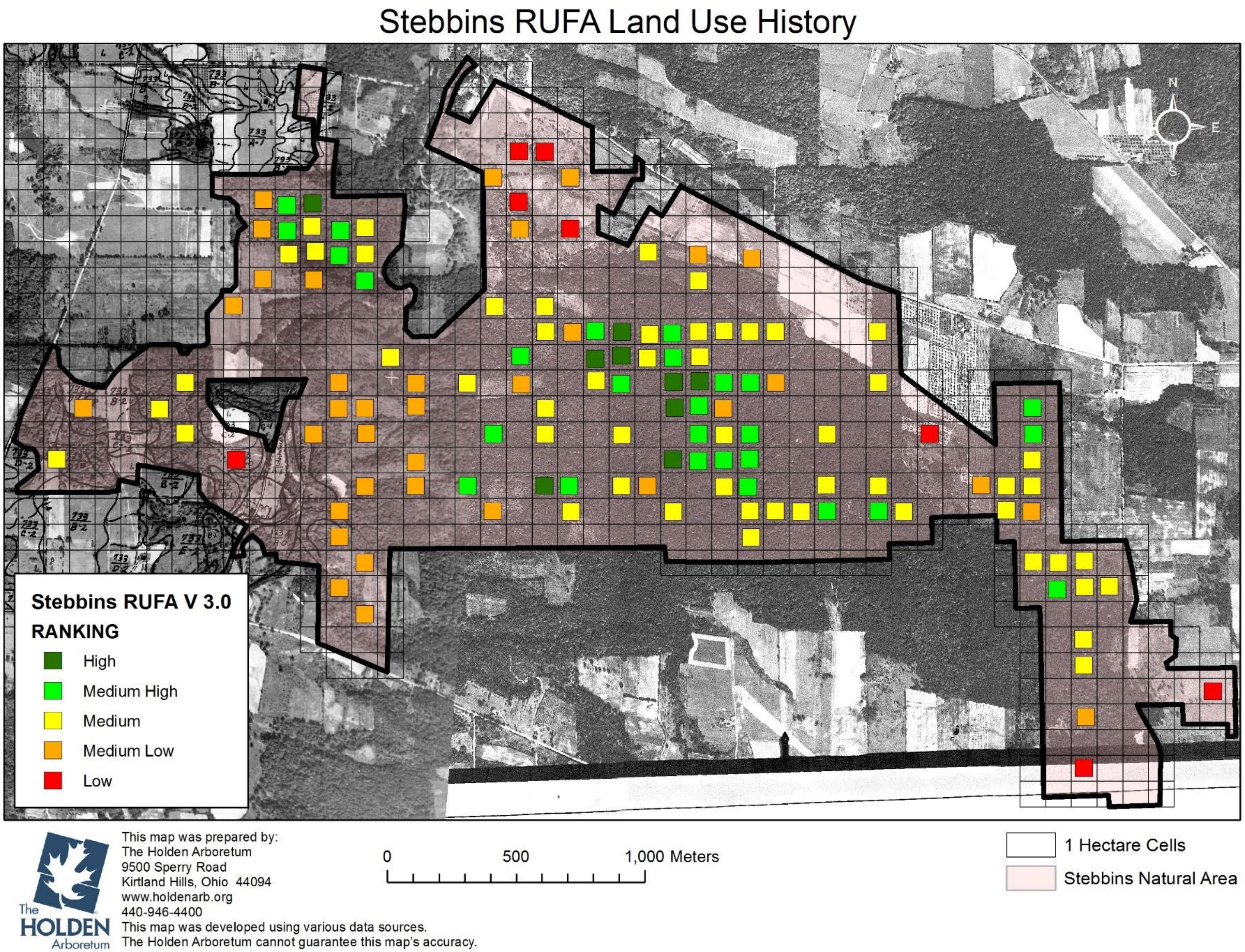


Figure 28: Stebbins RUFA Integrity Rankings

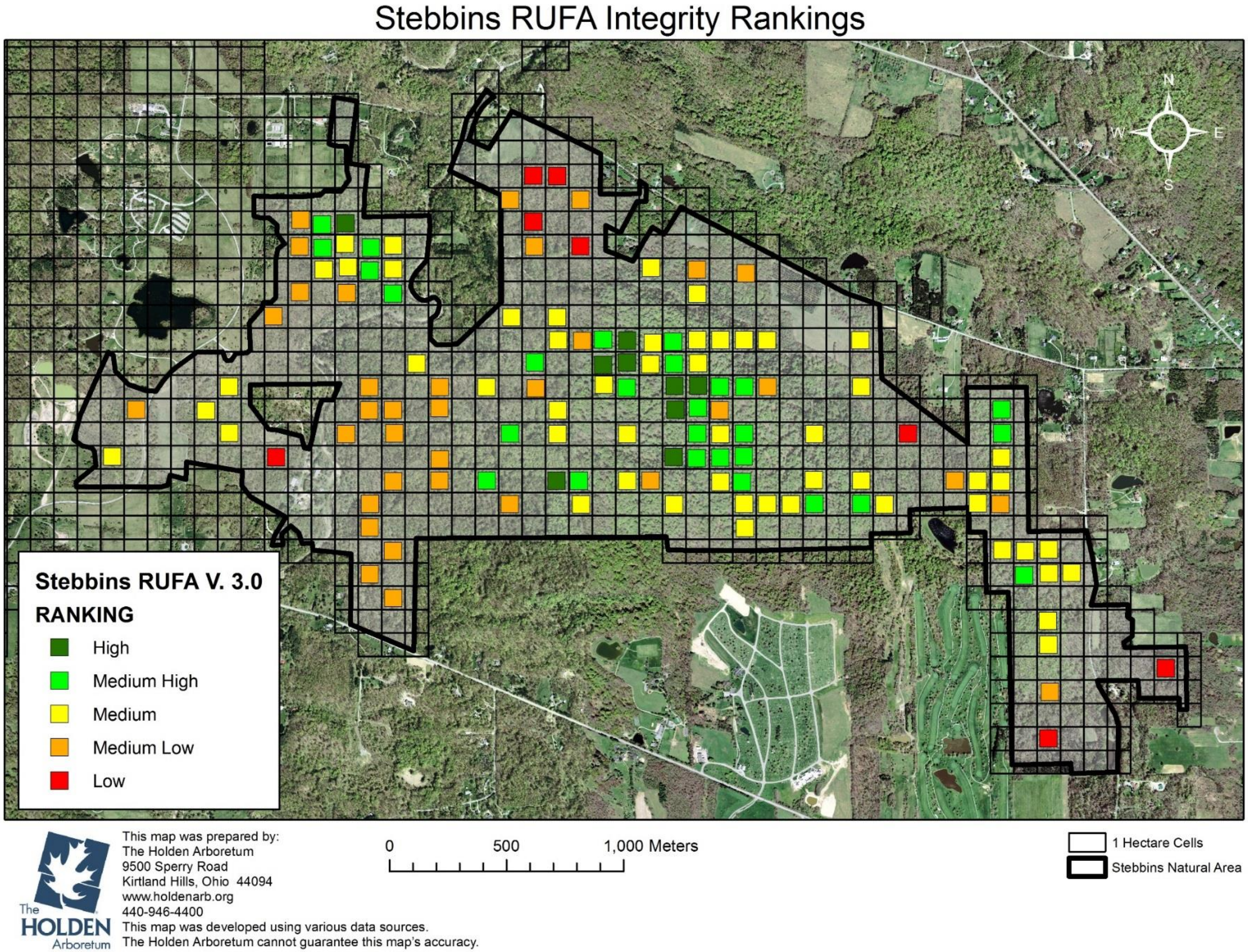


Figure 29: Stebbins RUFA Forest Condition

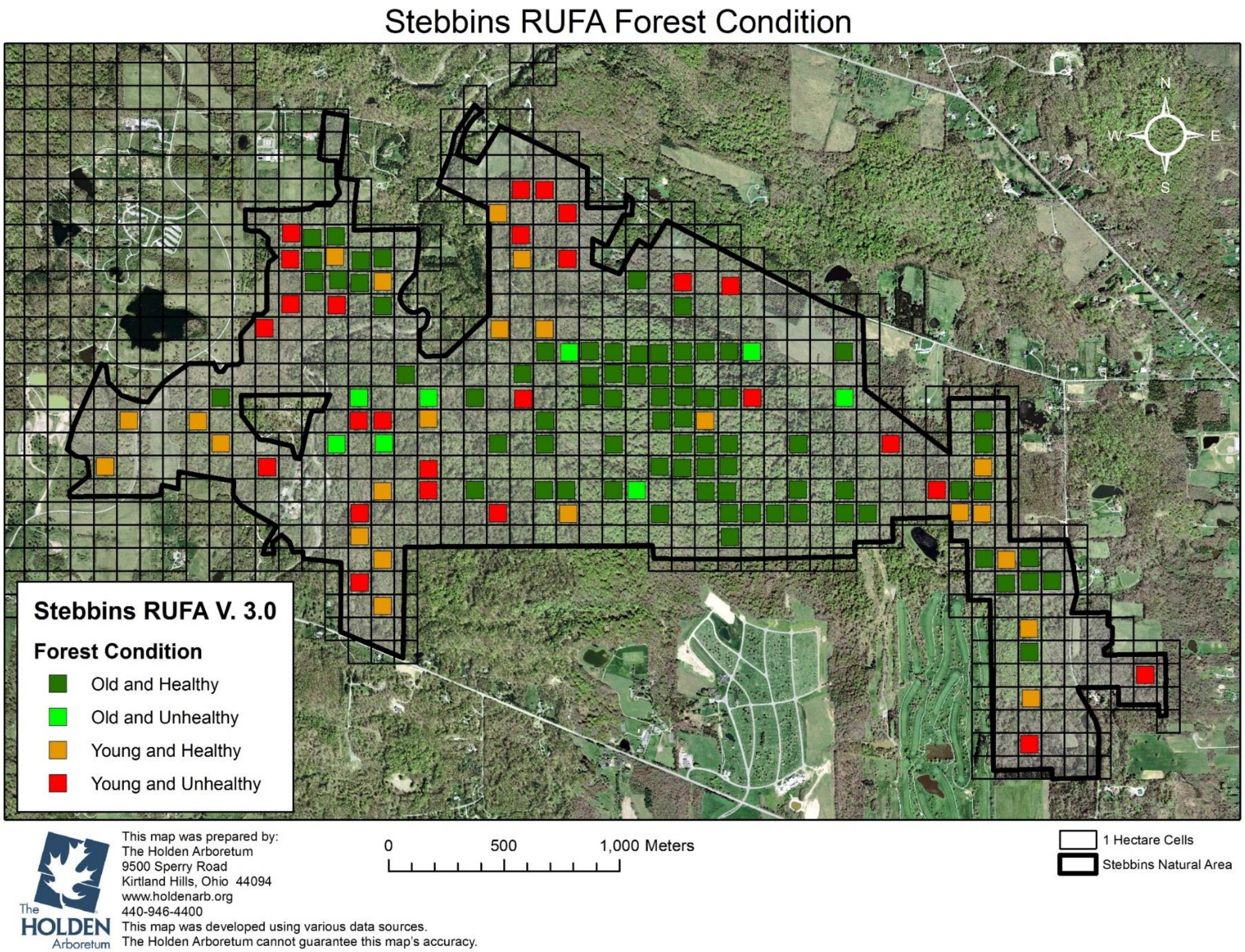


Figure 30: Age and Health of Stebbins Natural Area Forest Sites (n=132)

Sites are plotted according to the distribution of their Health and Age points. Forest Condition categories are Young and Unhealthy (Age [A]<4, Health [H]<6), Young and Healthy ([A]<4, [H]≥6), Old and Healthy ([A]≥4, [H]≥6), Old and Unhealthy ([A]≥4, [H]<6), Blue circles indicate sites: center numbers are scores and circle size indicates how many sites achieve that particular score and point distribution.

Forest Condition Categories:

Reference Figure 30

1) ***Old and Healthy Forests*** have Forest Age metric scores of 4 and above and Forest Health metric scores of 6 and above. Preservation is recommended for High Forest Integrity sites meeting these Forest Condition criteria. Conservation and small scale management is recommended for those Medium-High Forest integrity sites falling into the Old and Healthy Forest Condition.

2) ***Old and Unhealthy Forests*** have Forest Age metric scores of 4 and above and Forest Health metric scores less than 6. Few sites are likely to fall into this Forest Condition and those that do are generally in the Medium-Low Forest Integrity category. Conservation and aggressive management is recommended for these forest areas falling into the Old and Unhealthy Forest Condition.

3) ***Young and Healthy Forests*** have Forest Age metric scores of less than 4 and Forest Health metric scores of 6 or more and generally fall into the Medium Forest Integrity category. Conservation and aggressive management is recommended for those forest areas of Medium Forest integrity sites falling into the Old and Unhealthy Forest Condition.

4) ***Young and Unhealthy*** have Forest Age metric scores of less than 4 and Forest Health metric scores of less than 6 and having Forest Integrity categories of Low to Medium-Low. Restoration management is recommended for those forest areas of Low to Medium-Low Forest Integrity sites falling into the Old and Unhealthy Forest Condition.

Below is a sample of RUFA V. 3.0 data representing a Medium Forest Integrity site (**Figure 31**) that demonstrates simple forest management techniques that could be adopted to increase the site's Forest Integrity Score and ranking.

Figure 31: Forest Cell Example

Cell		32-E24-N		
Date		6/1/2016		
Scorers (with transect directions)		NW CK, NE MW	SE JM	SW CA
1A. 20 Herbaceous Plant Species in Combination *Herb_S and Herb_S_P*	combo	4	6	24
	point	6	8	1
1B. 16 Tree Seedling Groups in Comb. ≤ 12" (30cm) High *Seedl_S and Seedl_S_P*	combo	6	5	20
	point	5	4	1
2A. 120 Shrub/Saplings ≥ 12" (30 cm) and < 6.5' (2m) *Shrub_I and Shrub_I_P*	sum	41	36	159
	point	43	39	1
2B. 16 Shrub/Sapling Species in Combination *Shrub_S and Shrub_S_P*	combo	4	6	19
	point	4	5	1
3A. 24 Mature Trees ≥ 20" (50cm) DBH *M_Tree_S and M_Tree_S_P*	sum	12	9	34
	point	8	5	1
3B. 3 Mature Tree Species ≥ 20" (50cm) DBH *M_Tree_S and M_Tree_S_P*	sum	REOA REMA	TUPO BLCH	4
	point			1
4A. 7 Legacy Trees ≥ 32" (80cm) DBH *L_Tree_I and L_Tree_I_P*	sum	Ø	Ø	Ø
	point	Ø	Ø	Ø
4B. 2 Legacy Tree Species ≥ 32" (80cm) DBH *L_Tree_S and L_Tree_S_P*	sum	X	X	Ø
	point			Ø
5A. 5 - 12 Snags ≥ 12" (30cm) DBH and ≥ 6.5' (2m) High *Snags and Snags_P*	sum	Ø	2	3
	point	Ø	1	Ø
5B. 12 Woody Debris Tree Units ≥ 12" (30cm) Diam. *Woody_D and Woody_D_P*	sum	3	5	13
	point	4	1	1
6A. < 80 Invasive Shrubs/Vines *I_Shrub and I_Shrub_P*	sum	24	25	99
	point	19	31	Ø
6B. < 200 Invasive Herbaceous Plants *I_Herb and I_Herb_P*	sum	Ø	Ø	Ø
	point	Ø	Ø	1
7. No observed Invasive Plants				Ø
8. Presence of Healthy Light Gap				Ø
9. Microtopography: Pit/Mound				1
10. Absence of Human Activity				1
11. Absence of Deer Browse Line				1
12. 4 out of 5 Transects ≥ 50% Leaf Fragment Cover	total	1 1	1	4
	point	1	Ø	1
Total			12	

Missing Forest Features:
To encourage higher Forest Integrity scores management actions should target metrics where points are missing. It should be noted that one simple forestry practice of girdling trees may be used to boost the scores on multiple metrics.

Metrics 4. A and 4.B Legacy Trees:
In the example to the left, Legacy Trees are missing from this forest site. However, given enough time some of the mature trees maybe recruited into the Legacy Tree size class. One strategy could be a very small scale "crop" tree release performed by girdling competing, poorly formed trees. This process hastens the growth by slightly reducing competition for light around selected individual trees, provided that Mature Tree counts will not be effected.

Metric 5.A Snags:
The number of snags fell short of the threshold of 5 by 2. Poorly formed red maples in the Mature Tree metric could be girdled and over a span of 2-3 seasons these now dead trees could serve as functional snags thereby increasing the Forest Integrity score by 1.

Metric 6.A Invasive Species:
A minimal effort to control invasive woody and vine plants at this forest site would reduce the impact the invading plants may have thereby increasing the Forest Integrity Rank. While this management action is a once a year event it may take multiple years to have fully eradicated the invasive shrubs. Thereby increasing the overall score by a minimum of 1 and possibly 2 if the invasive pants can be fully eradicated.

Metric 8. Light Gap
Careful tree selection for girdling may also have the effect of creating a regenerating light gap in addition to creating snags. Thus being eligible to receive an additional point.

Conclusion:
With minimal effort, sufficient time this particular site could boosted to at minimum a Medium-High Forest Integrity rank.

Management Strategy Categories

1) ***Preservation:*** Management actions include monitoring for change and early detection of threats. Reducing threats is the highest priority in Healthy Old forests of high integrity. This includes limiting vectors for invasive species threats. One way to reduce threat vectors is to create and/or protect buffer areas around high Forest Integrity sites. Limiting access to only those activities necessary for research and management may also be necessary. Creating or maintaining deer-culling programs may also be warranted given the threat that overpopulation can present. Ultimately, multiple layers of protection are warranted in these rare forest habitats. Simple ownership by a conservation organization is not enough; organization missions, Board of Trustees, and financial status can all change. Thus conservation easements upheld by second party land trusts would protect these areas in theoretic perpetuity from risk associated with changing missions, boards etc…

2) ***Conservation, Small Scale Management:*** A majority of forests that would be subject to the following recommendations are Old and Healthy and of Medium-High Forest Integrity. Several small-scale and traditional forest management techniques can be utilized in these forests to improve their overall scores and Forest Integrity ranks. Some are one-time actions and others recurring. Girdling trees could be a useful technique to create snags and light gaps. Trees subject to this technique would be of poor form, a less-desirable species (such as red maple), and/or 12” to 16” DBH size class. Simple felling of trees with the same characteristics could also add woody debris to the site adding structural elements and organic material to feed the forest floor. Time is also of value; when mature trees may be allowed sufficient time to grow they will eventually be recruited into the Legacy Tree size class of greater than 32” DBH. Therefore, selecting the trees with the best form, largest diameters and releasing their crowns by girdling or felling lesser competing trees, otherwise treating them as “crop trees” may speed the process of recruitment while adding structure and nutrients to the forest floor.

3) ***Conservation, Aggressive Management:*** Forested areas subject to the following actions are generally categorized as Young and Healthy with Medium Forest Integrity scores and can have highly variable characteristics. Forest succession could be sped up by utilizing crop tree release to improve recruitment of trees into the Mature Tree class. Grapevine removal can also accomplish the same goal of improving growth rates. Aggressive invasive plant species management may also be required to improve scores in the Shrub, Herbaceous, and Seedling metrics. Recurring invasive species management to the point of near eradication would improve the scores in the Invasive Species metrics of the RUFA. Aggressive deer management via culling and hunting, if not implemented too late, has been shown to reduce their numbers to the point where the understory can be rejuvenated.

4) ***Restoration:*** Young and Unhealthy forests with Low to Medium-Low Forest Integrity scores are subject to intensive restoration work in order for positive change to occur. Restoration requires intensive amounts of staff time and energy with sometimes uncertain and/or mixed results. Small scale experimentation may be required to determine the outcome of specific actions before any are implemented on a larger scale. This may require on-going aggressive invasive species management in these forests that are often heavily invaded, followed by planting of native shrubs and trees. Crop tree release could add organic material to these often depleted and impacted soils.

Chronological Development

Many people were involved in the development of the RUFA. Holden intentionally involved as many area experts as possible with the end goal of producing a final product that accurately quantifies forest quality. This section of the manual briefly describes the development process, which occurred rapidly over the 2014 and 2015 field seasons.

RUFA V. 1.0

HA conservation staff developed a draft version of the RUFA based upon a protocol outlined in the Tierney paper (a vigorous method to establish forest quality standards) and upon our own working knowledge of local forests. The initial version of the RUFA 1.0 was based on a three 1 minute transect model from the center of the hectare cell. The transects were oriented at 0, 120, and 240 degree bearings from the center. All the thresholds were set based on the average calculation of the counts determined by the assessors on their 1 minute search. Like the latest version of the RUFA, V. 1.0 used the same binary system of scores. Many of the definitions of the metrics are similar and therefore are not described in detail. The RUFA V. 1.0 was implemented at 69 sites across the Stebbins Gulch Natural Area and was developed and tested at 6 locations within Stebbins Gulch Natural Area ranging in forest quality from low to high, based solely on anecdotal evidence. The RUFA V. 1.0 seemed to reasonably represent and distinguish between the forest qualities, it was decided to implement the first version at 69 sites in the Stebbins Gulch Natural Area.

Metrics 1 and 2, 6 and 7, and Metrics 9 and 10 are scored based on the same 1 minute search concept as the current RUFA version, but along the three transects. Metrics 1 and 2 were based on mature trees. Metric 1, a score of one was assigned if the threshold of an average of 10 or more mature trees with a DBH greater than 50cm were identified. Metric 2, a score of 1 is assigned if more than three species of mature trees with a 50cm DBH are identified. Metrics 6 and 7 are related to shrubs and saplings. Metric 6, a score of 1 is assigned if an average of 30 or more shrubs or tree saplings with a height greater than 30 cm and less than 2m were identified in the 1 minute searches. Metric 7, a score of 1 is assigned if an average of 3 or more shrub or tree saplings species were identified by the three assessors in the 1 minute search. A score of 1 is assigned to Metric 9, tree seedlings, if an average of 3 or more species of tree seedlings less than 30cm high are identified by the 3 assessors. Metric 10, herbaceous plant species, a score of 1 is assigned to the metric if an average of 3 or more species of herbaceous plants were identified.

Metrics 3, 4, 5, 8, 11, 12, 13, and 14 are scored based on casual observations while performing the other timed 1 minute searches. Metric 3, a score of one is assigned if there is at least one dead snag with a DBH >30 cm and a health greater than 2m. Metric 4, a score of 1 is assigned if at least one section of course woody debris of a diameter greater than 30cm was identified. Metric 5, referred to light gaps created by a fallen tree or limb, as with the other metrics if one was identified a score of one was assigned. Metric 8, seedling cover, a score of 1 is assigned to the metric of the seedling cover was greater than 50%. Metric 15, is related to the absence of past human activity such as dead furrows, piles of field stones, cut stumps, logging roads, improved trails etc. Metrics 11 and 13, are related to the apparent absence of invasive shrubs/vines and herbaceous plants. A score of is given if there is an apparent absence of invasive shrubs/vines and/or herbaceous plants. Metrics 12 and 14, were related to the low abundance of invasive shrubs/vines and herbaceous plants. If the invasive shrubs/vines and/or herbaceous plants are in low abundance, having little impact on the forest community a point is assigned.

The remaining transect Metric 16 used another rapid assessment technique to score the impact of invasive worms on the forest floor. Metric 16 involved the average IERAT score less than 2. The IERAT was performed at the each of the three transects and at the center. The scores were then averaged and if they were less than 2, a one is assigned for the metric.

After completing the assessments at the end of August 2014 at the original 69 sites in the Stebbins Gulch Natural Area we evaluated the initial version of the RUFA. Initially we were encouraged by the results and it appeared that 1.0 was good way to compare hectare cells. But Holden was not yet sure if the RUFA V. 1.0 reflected absolute forest quality. The resulting data seemed to coincide with simple analysis of the scores against prior land use maps. That is, sites that were forested nearly 77 years ago attained high RUFA scores and those that were is some of agriculture scored relatively low. Holden felt the information collected with 1.0 was suitable to use within Holden Arboretum to guide future management planning and activities. The results were encouraging enough that Holden felt if this was a tool other conservation organizations should be made aware of. If Holden was to take that course improvements and additional testing would be required. As with any draft version several issues were identified during 1.0 implementation in Stebbins and changes needed to be made.

A site evaluated with RUFA V. 1.0 could earn a potential of 16 points. Three different ranks of quality where identified. High quality sites had scores ranging from 10 to 16. Medium quality sites had scores ranging from 5 to 9, and low quality sites scores from 0 to 4.

RUFA V. 1.5

One of the characteristics of the old growth forest was missing from the RUFA V. 1.0 was pit and mound topography. To improve the RUFA a metric regarding pit and mound topography was added, for this metric only one substantial pit was required for a point to be assigned. Another identified for forests is deer browse impacts from an overabundant deer population. Another metric was added, deer browse line. A point is assigned if there is no clear deer browse line can be observed. In addition, the Metric regarding seedling cover was ultimately dropped after much discussion. It that seedling cover would be a highly variable component of the forest, and subject to changes in percent cover, due on and off mast years, weather, etc. A volunteer performed a cluster analysis and found that the seedling cover metric did not contribute in a meaningful way to the overall score, thus giving Holden the impetus to eliminate the metric all together. The order in which the data for the RUFA was collected was also revised. All together these revisions resulted in RUFA V. 1.5. No other changes were to any of the thresholds or definitions. A section on the back of the field sheet was added where notes could be taken for specific cells and bearing changes to the primary direction could be formally documented.

For the 2015 field season Holden staff returned to the original 69 sites in Stebbins from the previous season and collected information related to the new metrics of pit mound and deer browse. In addition, Holden staff identified 33 new sites in the Stebbins Gulch Natural

Area and assessed them as well with the new variation of the RUFA, V. 1.5. While Holden staff sought to make even further changes and conduct additional testing, it was decided that Stebbins would be evaluated with RUFA V. 1.5 early in the 2015 field season, with the complete understanding that additional testing would be conducted and additional changes made. This decision was made with the understanding that the information collected would still be relevant to the development of the research and management plan.

The metrics for RUFA V. 1.5: Metrics 1A and 1B were the pairing of the mature trees, with 1A being the individual tree counts and 1B the tree species. Metric pair 2A and 2B dealt with the shrubs and tree saplings, 2A with the individual counts and 2B the species of shrubs and tree saplings. Metric 3A captured data of the tree seedlings, and Metric 3B the herbaceous species. Metrics 4A and 4B related to forest structure, 4A dead snags and 4B woody debris. Metrics 5A through 6B are related to invasive plant species. Paired metrics 5A and 5B, involved invasive shrubs/vines, 5A the absence of invasive shrubs and vines and 5B the low abundance of invasive shrubs/vines. Paired metrics 6A and 6B, involved invasive herbaceous plants, 6A the absence of invasive herbaceous plants and 5B the low abundance of invasive herbaceous plants. Metric 7 the presence or absence of a healthy light gap, Metric 8 presence of pit and mound micro-topography, Metric 9 the presence or absence of human activity, and Metric 10 the absence of a deer browse line. Lastly, the average IERAT score for Metric 11.

A site evaluated with RUFA V. 1.5 could earn a potential of 16 points. Three different ranks of quality where identified. High quality sites had scores ranging from 14 to 17. Medium quality sites had scores ranging from 8 to 13, and low quality sites scores from 0 to 7.

RUFA V. 2.0

To add relevancy to the RUFA, we decided to test it against other rigorous assessment methods (VIBI, PCAP) and establish additional reference sites (at high-quality forests) outside of Holden and within the Stebbins Gulch Natural Area. This would be done before assessing sites in the Pierson Creek Valley Natural Area. Time would not allow for Holden staff to re-assess the Stebbins Gulch Natural Area with the resulting RUFA V. 2.0 so it was decided to simply implement RUFA V. 1.5 in Stebbins to save time. Permitting Holden staff to move forward with additional assessments at sites within other natural areas.

Holden Conservation staff had numerous discussions around the shortcomings identified by Holden staff and other professionals during its implementation in the prior year at the Stebbins Gulch Natural Area. The first major issue with the RUFA Vs. 1.0 and 1.5 was the orientation of the transects. It was found that in certain situations, such as where a thin understory may be present, it was possible to walk outside the boundary of the hectare cell along the north transect within a minute. A four transect model was adopted. There would be now be four transects, one to each of the corners of the hectare cell. By traversing to the corner of the cell an assessor has almost 70 meters to travel rather than the 50 meters of the north transect of the original 3 transect model. Holden staff found that while walking at a steady pace it was not possible to walk outside the hectare cell with in a minute if one walked to the corner. New transect bearings are 45, 135, 225, and 315 degrees. The thresholds also had to be adjusted with the addition of a fourth transect. While this additional transect would more accurately represent the hectare cell, it would require an additional staff member to run. The averaging calculation was dropped and the species counts combined to simplify the process in the field. A paired metric was added for legacy trees. It was generally accepted that the RUFA V. 1.5 was not sensitive enough to distinguish between a mature forest and a true old growth forest. A metric pair was established for legacy individual tree counts and species. In an effort o reduce subjectivity Holden staff decided that actual counts and thresholds would be necessary for woody debris, snags, and invasive species rather than a simple presence/absence scheme. In the same manner trees and snags were actually measured with a modified Biltmore stick to ensure accuracy. We eliminated the IERAT metric and replaced with a leaf fragmentation metric to address forest floor/soil integrity and thus avoiding the cumbersome “rapid method on top of rapid method” issue. At the end of the 2015 field season, the IERAT data was compared with the leaf fragmentation scores in Pierson Natural Area, and there was a strong negative correlation. This strong correlation between IERAT score and the Leaf Fragment metric in RUFA indicates that RUFA adequately captures leaf litter and soil conditions relative to earthworm impacts. For that reason, IERATs will not be conducted at RUFA sites in 2016 in SGNA.

The Cleveland Metroparks were testing an intensive methodology which would also be used to determine upland forest quality. Holden staff decided to address a number of additional shortcomings of the RUFA to create yet a third version, V. 2.0. At the beginning of the 2015 field season, Holden conservation staff established 6 new test sites in Stebbins Gulch Natural Area, now 12 in total that would be evaluated by the research department, 3 CMP VIBI sites in the Stebbins Gulch Natural Area, 11 VIBI sites at the Cleveland Metroparks (there were originally 14 sites however, 2 were eliminated because of unsuitable site conditions and another was eliminated as the site didn’t accurately reflect the hectare area for the RUFA), North Chagrin Reservation, Assessed 7 sites in Ashtabula Co. that ranged from mature to old-growth forest, and 1 old-growth site in Bole Woods of Holden. Holden conservation staff intended to assess these 34 sites with RUFA V. 2.0 with the intention of using the information to set threshold values as the basis for the binary system of points. These assessments were performed between late June and early July 2015. Once the thresholds were set the resulting RUFA V. 2.5 would then be implemented in the Pierson Creek Valley Natural Area. Because of this quality rankings were not established for V. 2.0 and it was never truly implemented in any natural area.

RUFA V. 2.5

Conservation staff analyzed the data from the 34 reference sites to establish thresholds for binary point system resulting in version 2.5. Compared VIBI data from the 14 sites against the data collected with RUFA 2.5 at the same sites with a simple rank correlation. Resulting comparison yielded a strong rank comparison. No changes were made to RUFA 2.5 and implemented it at 100 sites in the Pierson natural area. All the metrics from RUFA V. 2.0 were retained for V. 2.5, only the thresholds were different. For example the threshold for the number of legacy trees was increased from 4 to 7, likewise the mature tree metric adjusted from 14 to 24 individuals, the metrics for shrubs and tree saplings did not change, and the tree seedling counts adjusted from 12 to 16, and the herbaceous plant metric changed from 16 to 20 species in combination. RUFA V. 2.5 was then implemented at 92 sites within Pierson Creek Natural Area from early July to the middle of August.

Five natural breaks were identified in the overall scores, RUFA V. 2.5 places forest sites into 5 quality categories. Scores of 17 and 18 are high quality sites that are most likely old growth forests and are rather rare. Holden does not expect many sites to rank in this upper level quality rank. Scores of 14 to 16 represent the upper end of medium quality sites, these are considered medium high. Scores of 10 to 13 represent medium quality sites and scores of 5 to 9 being medium low. Lastly, scores of 0 to 4 are of the low quality.

RUFA V. 2.8

A number of limitations with the actual field form were identified with the RUFA V. 2.5 during implementation in the Pierson Creek Valley Natural Area. The order in which the metrics were assessed was changed. Primarily because conservation staff observed trampling of herbaceous and tree seedlings by the time the metrics for legacy tree, mature trees, and shrubs/tree saplings were completed. Staff felt this trampling could interfere with the counts for herbaceous plants and tree seedlings. The order in which the metrics are completed was reordered to avoid such an issue. The metrics regarding the herbaceous and tree seedlings is completed first, followed by the paired metric for shrubs/tree saplings, the mature trees, then the legacy tree paired metrics, followed by snags and woody debris, lastly by the invasive plant paired metrics. The woody debris metric was more clearly defined as well, qualifying woody debris is described as being a woody debris unit. In effect if a scorer could envision the presence of a whole tree or unit, it would count as woody debris. This is described in more detail earlier in this manual. This concept of the woody debris unit was suggested by other conservation staff while teaching them how to use the RUFA at The University of Akron's field station.

The blocks in which the data is entered was divided into quadrants to represent the actual NW, NE, SE, and SW transects. Also the Scorers column was modified so the transect each scorer was assigned to could be recorded. The last format change was to the leaf fragmentation metric. Here the scores could be recorded for each of the four transects and at the center. The quality of data collected and recorded increased with these changes to the field form. RUFA V. 2.8 was implemented at only a few sites, most notably Lake Metroparks Chapin Forest and at the Nature Center at Shaker Lakes. In both outreach efforts a couple of other changes were suggested, thus requiring yet another version of the RUFA V. 3.0. The range of scores is the same as for RUFA V 2.5.

RUFA V. 3.0

This entire manual describes the RUFA V. 3.0 in detail. In brief, upon encountering an EAB impacted forest site it was decided to establish an upper limit for snags resulting in version 3.0. Metric 5A Snags, if the total number of snags ranged from 5 to 12 a point is assigned and if there are less than 5 and more than 12 a 0 is assigned for the metric. Additional changes included the revision of the field sheet to allow for easier recording of the leaf fragmentation scores for each transect and center.

A series of checkboxes was added in order to improve the quality of the data collected and to document other conditions of the forest being assessed. It is felt that this documentation may help determine why a site may have scored the way it did. The checkboxes were added to the back side of the field sheets to capture information regarding age classes of trees, any pathogen/pest related damage, canopy closure, and plant communities. The first series is related to the plant community of the hectare cell being assessed. Is the forest plant community type determined ahead of time or on site by analyzing the dominant tree species. Like the previous versions there is also a section where any bearing changes can be noted. The next series of check boxes is where any past evidence of land use can be documented. There is also a section where the canopy condition can be documented, whether it is open or closed. This was added after having visited sites where the canopy was sparse and a dense herbaceous layer present. The last checkboxes were added to document any readily observable pathogens or threats to the stand, such as beech blight, emerald ash borer, dieback, or any other issue. Lastly, like in other versions there is a blank area where any notes can be made.

RUFA V. 3.0 was implemented across 132 sites of the Stebbins Gulch Natural Area during the 2016 field season. The categories of forest quality remain the same as in RUFA V. 2.5 and V. 2.8.