



Forest Vegetation Monitoring Protocol

Terrestrial Long-term Fixed Plot Monitoring Program

Regional Watershed Monitoring and Reporting

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Toronto and Region Conservation for The Living City®

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1.0 INTRODUCTION

Long-term monitoring of forest vegetation in permanently marked forest plots can provide valuable information on the structure, composition and function of a forest ecosystem. Monitoring enables potentially unknown information on species condition, growth rates and longevity to be obtained. It also allows changes in species composition, population size; and the effects of environmental change at the different layers (i.e. canopy, shrub, herbaceous etc) to be detected over time. Long-term monitoring measures are therefore crucial for the development of informed land management practices for forest vegetation (Roberts-Pichette and Gillespie 1999).

The methodology for monitoring forest ecosystems used by the TRCA is based upon the EMAN (Ecological Monitoring and Assessment Network) endorsed terrestrial vegetation biodiversity monitoring protocols identified by Robert-Pichette and Gillespie. Some small adjustments were made to allow plots that are placed in an urban area to be discreet and not attract unwanted attention. Some additional changes were made following Credit Valley Conservation (CVC) monitoring protocols.

2.0 STUDY DESIGN

Program objective(s):

- To determine the health of forests in the TRCA jurisdiction.
- To determine regeneration rates in the understorey of saplings.
- To determine if the population and abundance of flora species, including those of conservation concern, are changing over time.
- To determine the floristic quality of the site.
- To determine the rate of spread of selected invasive species.
- To determine if non-native invasive species are replacing native species.

An *a priori* power analysis was conducted in 2008 (Zorn 2008) to determine the appropriate number of monitoring plots needed to achieve sufficient power. In 2015, a further power analysis (retrospective) was conducted to ensure the appropriate number of plots are monitored for assessing spatial and temporal trends in multiple forest indicators (outlined in TRCA 2015a). The sample sizes used in this power analysis were based on sample sizes used in TRCA (2015a).

Power was sufficient (>86%) for all analyses comparing the rural and urban zones (sample size is specific to each forest indicator). Power was sufficient (>78%) for analyzing temporal trends regionally for the main forest indicators: tree mortality, crown vigour, % cover of non-native flora and density of woody stems. Temporal trends for floristic quality index (FQI), the number of L1-L3 species and the % native flora species were not analyzed due to suspected artificial increases in these parameters since plot set-up. This is a common situation when starting monitoring programs and in scientific studies and it is expected that these values will plateau at a point when all species have been identified (Grandin 2011).

Temporal trends specific to the urban and rural zones were only analyzed for % cover of non-native flora and density of woody stems. Power was low for analyzing temporal trends in the rural zone for % cover of non-native flora and density of woody stems. In order to improve power to an acceptable level (>90%) for % cover of non-native flora, it is recommended to increase the effect size from a warning threshold cover of 1% at the end of 5 years to 4% at the end of 5 years. In order to improve power to an acceptable level (>91%) for the density of woody stems, it is recommended to increase the effect size from 16% over 5 years to 30% over 5 years. Full details of the 2015 power analysis can be found in TRCA (2015b).

Also in 2015, an additional review of plot location was completed to ensure that various forest types are appropriately represented in the monitoring program. This analysis concluded that one mixed forest (FOM) plot should be added in the rural zone and two lowland forest plots should be added in each of the urban and rural zones. Forest types considered lowland include: FOD7-1, FOD7-3, FOD7-4, FOD7-5, FOD7-a, FOD7-b, FOD7-c, FOD7-E and FOD7-F.

3.0 EQUIPMENT & MATERIALS

Different materials and equipment are needed depending on whether the plot is being set-up for the very first time or if visited for seasonal monitoring (Table 1).

Table 1. List of required equipment and materials for plot/subplot set-up and data collection. * *Items only needed for 5 year visits.* [1]*Items needed for plot maintenance.*

Equipment	Set-up	Forest Health Plot	Regeneration Subplot	Herbaceous Vegetation Subplot
Map showing location		x		
Compass	x	x		
Handheld GPS Unit	x	x		
Camera	x	x	x	x
Clipboard, data sheets, pencils	x	x	x	x
Previous years' data		x	x	x
61-cm pieces of rebar, (24 needed for set-up),	x	x[1]	x[1]	x[1]
2 heavy mallets	x	x[1]	x[1]	x[1]
Tree paint (for tree tagging)	x	x*		
Diameter tape (dbh)	x	x*		
Paint brush (if necessary)	x	x[1]		
Laser range finder (i.e. vertex)	x	x*		
Measuring tape (30m)	x	x	x[1]	
Grid square (1 m^2)			x	x
Metre stick (minimum of 2 m)			x	

Twine (minimum of 10m)			x	
Field guides (i.e. Peterson's)	x	x	x	x
Marking stakes (6-24)	x		x	x
Flagging tape	x	x[1]	x[1]	x[1]
Lead-free spray paint (red and blue)	x	x[1]	x[1]	x[1]
Tree borer	x			
Drinking straws (for transporting tree cores)	x			
Soil auger	x			
Muriatic acid solution	x			

4.0 PLOT SET-UP METHODOLOGY

Each forest plot is comprised of one 20 x 20 m (400 m^2) tree health plot, five 2 x 2 m (4 m^2) shrub and sapling regeneration sub-plots and five 1 x 1 m (1 m^2) ground cover vegetation sub-plots (nested within the larger regeneration sub-plots) (Figure 1). Crews consist of approximately four people, with one person recording, and two or three people assessing and measuring as needed. Depending on the number of trees, it should take approximately 1.5 - 3 hours to set up each forest plot.

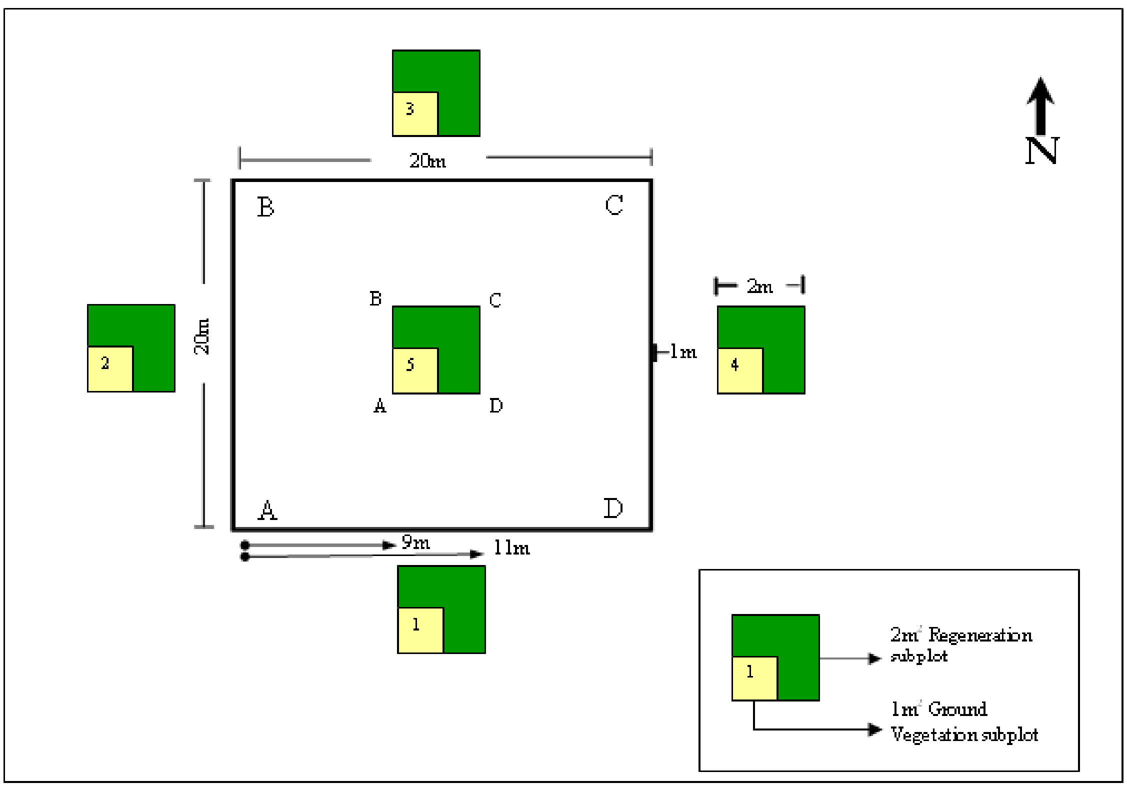


Figure 1. Forest plot design

4.1 TREE HEALTH PLOT SET-UP

To begin, teams establish the location of the south-west corner of the plot, always referred to as "Corner A". The placement of this corner is based on site conditions and varies accordingly (i.e. slope, distance to watercourse or trail). From corner "A", using a compass set to 90 degrees, teams measure out 20 m to the next corner post, "B", the process is repeated for the remaining two posts. After all four plot corners and measurements have been verified, the pieces of rebar are firmly hammered into the ground. Usually, only 3-6 cm is allowed to remain above ground (especially where there is pedestrian traffic in the vicinity). To assist in their identification, corner bars are colour coded. Corner "A" is spray painted red and all other corners are painted blue. The "A" post is also geo-referenced using a Trimble unit in order to record plot location for future visits. Appendix A shows a sample data sheet. Appendix K provides detailed set-up instructions.

4.1.1 Tree Mapping and Tagging

As part of the initial set-up, all standing living and dead trees within the 20 x 20 m tree health plot with a diameter at breast height (dbh) ≥10 cm are identified, measured, and tagged. Each tree tag has a unique number which can be related to the site, tree species and corresponding tree data (Figure 2). In order to relocate each tree in future visits trees are mapped in the field, using the A/B distance method of collecting positional tree data. Using a range finder (comprised of a transponder and a receiver) two distance measurements, known as the "A" and "B" distances are taken for each individual tree within the plot. This data is used to produce a tree map showing the location of all numbered trees within the plot. New recruits are mapped in the year that they are found. Appendix L provides detailed instructions on this procedure.

Figure 2: Painted tree tag

4.1.2 Stand Age

Stand age provides a general timeframe for when stands first established. Stand age, collected at set-up, is determined from five off-plot trees in the vicinity that are representative of both the size (dbh) and species present within the plot. An increment borer is used to collect the tree cores. Each increment core is taken at breast height (1.3 m) so that the borer does not bend from excess downward pressure. To give accurate ring widths, cores are taken in the field on the north-facing side of the tree. Trees that are prone to infectious fungal diseases such as butternut (*Juglans cinerea*) and American beech (*Fagus grandifolia*) are not cored. Trees that have visible branch stubs near breast height (i.e. evidence of knots), compression wood or rotten/hollow centers' are avoided as these can cause either the increment borer to break or become stuck. The rings of each core are counted in the field but if the age cannot be determined then the individual core(s) are placed in a straw to protect them damage, and taken back to the office for further analysis. Information on how to properly bore a tree is provided in Appendix C. Data sheets used for recording stand age are provided in Appendix A.

4.2 SHRUB AND SAPLING REGENERATION SUBPLOT SET-UP

Five 2 x 2 m forest regeneration subplots are set-up in and around the larger 20 x 20 m tree health plot. Four subplots are positioned 1 m outside the 20 x 20 m plot with the fifth located directly in the centre (Figure 1). For all subplots, corner points are marked by rebar and labelled following the same procedure used for the tree health plot. The subplot corner “A” (the southwest corner) is spray-painted red and the remaining corners are spray-painted blue. Subplots are not tagged; instead, the subplot number is determined on the basis of its position relative to corner “A” of the 20 x 20 m plot (see Figure 1). Appendix M provides detailed instructions on this procedure.

4.3 GROUND VEGETATION SUBPLOT SET-UP

Nested within each of the five forest regeneration sub-plots are a 1 x 1 m ground vegetation subplots. To reduce the amount of trampling within the plot, the ground vegetation subplot is placed in the south-west corner of the 2 x 2 m regeneration subplot. For this reason, Corner “A” is shared by both the forest regeneration (2 x 2 m) and ground vegetation sub-plots (1 x 1 m) (see Figure 1). The remaining corner points have no permanent markers, although marking stakes may be used. A 1 m^2 grid square is positioned over corner A and defines the subplot boundaries at the time of survey.

4.4 GENERAL PRECAUTIONARY MEASURES

The monitoring process can in and of itself have a negative influence on the subject being monitored. Trampling and the introduction of invasive species are a few of the risks associated with monitoring. To limit these impacts certain precautions are taken.

1. Careful footing in and around the main plot and subplots is needed during set-up and monitoring. When possible, plots are set-up in the late fall to reduce the amount of trampling. At this time of year, many flora species have gone or are going dormant so the ground floor is less densely covered with sensitive flora. Where ground flora is thick and dense, equipment and backpacks are placed in flora-free patches or on logs or rocks outside the plot.

2. To make the plots less noticeable rebar corner markers are hammered very low to the ground, usually less than 6 cm above the surface. This also reduces the potential tripping hazard that these plots pose.

3. In between sites, crew members remove seeds from clothing and excess dirt from shoes to limit the risk of introducing invasive/exotic species into a site.

4. Clean boots well after being at sites with garlic mustard or other aggressive invasive flora species. This is to prevent you from carrying seeds to rural regional plots and creating plant communities that are not reflective of what would be there in your absence.

5.0 MONITORING FREQUENCY AND VARIABLES COLLECTED

This section provides detailed information on the variables collected for each component of the long-term monitoring plots including the frequency with which they are collected. Variables such as age of stand and soils are collected only once to establish baseline conditions while all other variables within each indicator category are collected on an annual or five year basis. For certain variables repeated visits to the monitoring plots are warranted in order to properly collect the required data.

5.1 TREE HEALTH PLOT (20 x 20 m) VARIABLES

The condition of each tree within a given plot is examined once per year. This visit typically coincides with the second visit made to assess ground vegetation, as the trees are in full leaf-out, enabling a proper crown assessment to be conducted. Sites are visited around the same time each year to allow a better comparison from year to year.

Table 2. Tree health monitoring variables and frequency

Variable	Details	Frequency
Age of Stand	Determines the general year that the trees were established, based on five trees outside, but representative of the plot.	Once; at plot set-up
Stand Disturbance	Establishes the current stand conditions within the plot and in the immediate vicinity. Documents any evidence of: • Logging • Wind/storm damage • Tapping Trails and trampling • Defoliation/insect damage • Browsing/grazing • Trash/dumping	Plot set-up, every 5 years
Tree Height	Provides a height measurement of each tree within the plot.	Plot set-up, every 5 years
Tree Diameter	Provides a measurement of the outside bark diameter at breast height, typically measured at 1.3 m for each tree within the plot. Measurements are taken to nearest 0.1cm. Appendix D provides detailed rules.	Plot set-up, every 5 years; and as new recruits appear
Tree Status	Establishes the living status of the tree. Four categories • **Living:** has green foliage attached • **Recently dead (natural):** no green foliage, fine branches and bark attached • **Old dead (natural):** no green foliage, no fine branches, bark falling off • **Cut down:** cut down/girdled, human caused	Annually
Crown Class	Represents the amount of sunlight received by the crown of each tree.	Annually

	Crown class does not necessarily coincide with tree height. • **Dominant:** Top of crown receives full sunlight and sides receive partial sunlight. Approximately 80% of the crown is fully exposed to sunlight • **Co-dominant:** Top of crown received full sun and sides receive minimal sunlight. Approximately 50-80% of the crown is fully exposed to sunlight. • **Intermediate:** Top of crown receives a little direct sunlight. Sides blocked. Approximately 20- 40% of crown is fully exposed to sunlight • **Suppressed:** Direct sunlight not received on any side. Crown covered. • **Open grown:** Exposed to full sunlight from directly above and on all sides	

Table 2. Tree health monitoring variables and frequency (cont.)

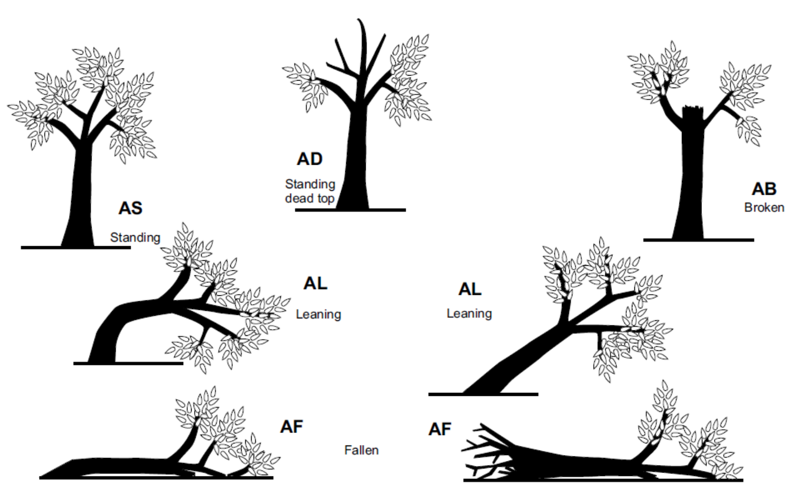
Variable	Details	Frequency
Crown Vigour	Assesses the degree of crown dieback. Six categories. • **Healthy** (<10% crown mortality) • **Light to Moderate decline** (≤ 50% crown mortality) • **Severe Decline** (>50% crown mortality) • **Dead** (specify natural or human caused)	Annually
Tree Condition	Determines the physical status of each tree (Fig.5). Nine categories.  	Annually

	Figure 5: Illustration of tree conditions (Roberts-Pichette & Gillespie 1999) • **AS** – Alive standing • **AB** – Alive broken (part/entire crown broken) • **AL** – Alive leaning • **AF** – Alive fallen/prone (tree has fallen but root system still alive • **AD** – Alive standing dead top (main stem alive but crown dead) • **DS** – Dead standing (i.e. snag) • **DB** – Dead broken (i.e. snag with broken crown) • **DL** - Dead leaning • **DF** - Dead fallen/prone	

Table 2. Tree health monitoring variables and frequency (cont.)

Variable	**Details**		**Frequency**
Stem Defects	Identifies presence, type and location of biotic and/or abiotic stem defects along the entire stem (from base to crown). See glossary in Appendix E for working definitions of defect types and locations.		Annually
	Defect Type(s): • Decay/Fungus* • Seam, frost crack (wet) • Open wound • Closed wound or scar • Insect damage* • Prune • Animal Damage • Canker* • No Type	**Defect Location(s):** • Lower stem • Upper stem • Entire stem • Stump, root collar • No defect	
Pest & Disease	Presence and abundance of 14 pest and diseases in jurisdiction. (See (Table 3)		Annually

Note(s)*: For the categories of "Insect damage", "Decay/fungus" and "Canker" under stem defect types; as well as for agents that damage the crown and foliage the TRCA has created a list of harmful pest and diseases to be monitored for in the jurisdiction (Table 3). A guide on how to identify these pests and diseases is provided in Appendix F.

Table 3. List of the top 14 tree diseases or pests in the TRCA jurisdiction.

Top 14 Tree Diseases or Pests of the TRCA Jurisdiction	
Beech bark disease	Asian long-horned beetle
Butternut canker	Emerald ash borer
Dutch elm disease	Gypsy moth
Eutypella canker of maple	Armillaria root rot
Ash yellows	White pine blister rust
Spring cankerworm	Fall cankerworm
Two-lined chestnut borer	Forest tent caterpillar

5.2 SHRUB AND SAPLING REGENERATION SUBPLOT (2m x 2m) VARIABLES

Subplot monitoring is conducted once during the growing season (July-August). Sites are visited around the same time each year. This visit coincides with the second ground vegetation visit. Table 4 provides detailed information on the data collected.

Table 4. Tree regeneration monitoring subplot variables and frequency

Variable	Details	Frequency
Species Diversity	Establishes the richness and abundance/evenness of regenerating young trees and other woody species within the understory. **Note(s):** *Seedlings are considered to be young woody plants less than 2 m tall with a dbh of less than 10 cm. Saplings are considered to be woody plants greater than 2 m tall with a dbh of less than 10cm. Data collected:* **Stem Count:** Number of tree seedlings, tree saplings, shrubs and woody vines by species occurring within each height class (16-35, 36-55, 56-75, 76-95, 96-200, >200 (cm) and originating within the plot **Percent Cover:** Estimate of cover for each species originating within the plot that is over 16 cm tall	Annually

5.3 GROUND VEGETATION SUBPLOT (1m x 1m) VARIABLES

These variables pertain to the herbaceous layer. Subplot monitoring is conducted twice during the growing season to capture early and late growing species. The first visit is in May and the second occurs at the peak of summer growth (late June to late July). Sites are visited around the same time each year. Table 5 provides detailed information on the variables collected.

Table 5. Ground vegetation monitoring subplot variables and frequency

Variable	Details	Frequency
Species Diversity	Establishes the richness and abundance/evenness of herbaceous and woody species within the herbaceous layer. Data collected includes: **Percent Cover:** Estimate of cover for each species within the plot. Only woody species under 16 cm in height are recorded. All herbaceous species regardless of height are recorded. Covers include vegetation that is overhanging but not originating from within the plot	Twice annually (spring & summer)

5.4 SPECIES RICHNESS

A full species inventory is completed once annually to ensure that the full diversity of woody and herbaceous species occurring within all parts of forest plot is captured. Species that overhang into these plots are also included.

6.0 DATA COLLECTION METHODOLOGY

Navigational aids such as GPS units, site maps, and compasses are used (as needed) to locate and access all sites. A written description of all access routes to the including photos are noted. When approaching a site, special care is taken to avoid trampling within plots and/or subplots. To maintain consistency and limit the amount of data collection errors, the collection of plot and subplot data always begins from the southwest corner. Additionally, subplots are monitored in ascending numerical order from one to five with the position of each subplot relative to orientation of the main plot verified prior to collection of data. After each plot and subplot is completed all data sheets are verified to ensure data is complete and accurate. Field sheets are kept together in a secure and easily accessible location. When revisiting a site, a copy of the previous years' data is taken for reference purposes. Working in teams of two, on average, it takes 1½ to 2 ½ hours to collect the necessary data.

6.1 TREE HEALTH PLOT (20 x 20 m) DATA COLLECTION METHODOLOGY

The boundaries of the 20 x 20 m tree health plot, as marked by colour-coded rebar, are located and identified before data collection begins. Any damaged or missing posts are replaced while intact posts are repainted (if required). In plots where ground flora is dense, or terrain is undulating, the visibility of the corner posts may be obscured. To assist with this, marking stakes with flagging tape attached are inserted into the ground next to corner posts. Flagging may also be attached to vegetation directly above or in the immediate vicinity of these posts to further maintain site lines. For each plot, photos are taken to provide a record of change over time.

With boundary delineation completed, tree health assessment commences. Starting at the southwest corner surveyors locate the lowest numbered tree. Each tree is carefully circled while observations on the crown as well as on the overall status and condition are made. To properly comment on the crown vigour and crown class, surveyor(s) must be able to view the crown in its entirety. This can be difficult, especially in dense stands where trees are growing closely together, in such instances; surveyors are required to navigate the plot until the crown of the desired tree becomes visible.

All dead fallen (DF) trees should be given a crown class of 0 and a crown vigour of 4. Only trees (dead or live) with an intact crown should be assigned a crown class and subsequent crown vigour. If a surveyor does not know if a tree is alive or dead and they have exhausted all means of determining this, complete the survey as if the tree is alive and flag that the surveyor needs to re-assess next year. For alive broken (AB) trees, assign a crown class and appropriate vigour only if there is a branch (leading stem) or leaves present. If there are no leading stems or living leaves on the alive broken (AB) tree and the tree is still alive, assign a crown class of 4 and appropriate crown vigour.

Use the data from the previous year when assessing tree health for each tree. Only make changes to data, especially crown class, if absolutely necessary. If you suspect a tree's crown class has changed from a 1 or 2 to a 3 or 4, or a 3 or 4 to a 1 or 2, take extra time to verify this. Discussion with fellow surveyors in the field could be helpful.

To assess stem defects, the surveyor(s) circle the tree to examine the bark along the entire stem thoroughly for any defect or evidence of damage, pest or disease. All observations pertaining to tree health along with any associated comments are recorded on the tree health data sheet. This process is completed until all trees have been recorded and confirmed.

Tree heights are measured with the use of a range finder (i.e. vertex), an electronic device that measures vertical and horizontal distances through ultrasonic technology (Figure 4). To begin, the receiver is placed on the tree to be measured at or near dbh level. Once the receiver is in the position, the transponder is moved away from the tree until the crown is observed (*the instrument does not require that the transponder be a set distance away from the tree*). With the crown visible, the cross-hairs in the view of the transponder is aimed at the receiver and fired, and then it is aimed at the highest living portion of the tree and fired again. The final height measurement that appears is recorded. The receiver is then moved to the next tree in the plot and the process is repeated until all trees within the plot have been measured. Observations are recorded on the tree health data sheet with any associated comments. Appendix G provides a sample data sheet.

Any unmarked trees within the plot that are close to 10 cm dbh are checked during the spring visit to see if they qualify for health assessment (after having been too small in previous years). If they do qualify, they are tagged with tree paint and mapped with dbh also recorded. The heights for these new trees are not taken until the next scheduled height monitoring year for the plot. At each site visit, the condition of each painted tree tag is examined and touched-up as necessary. Photos are taken along the plot diagonal; they point from the southwest corner towards the northeast corner of the plot (i.e. from the “A” post to the “C” post) (taken at spring and summer visits).

6.2 SHRUB & SAPLING REGENERATION SUBPLOT (2x2 m) DATA COLLECTION METHODOLOGY

All shrubs and seedlings that are <10 cm dbh and ≥16 cm in height are considered in regeneration subplots. Only live plants should be recorded in regeneration sub-plots.

The boundaries of the 2 x 2 m subplots are identified and delineated with the use of twine. Next, all qualifying plant species originating within the subplot are indentified. Individuals within each species’ are then measured with a metre stick and recorded into the appropriate height class located on the data sheet. Height measurements are taken from the ground to the upper most living portion of the plant. For plants that lean, the vertical distance from the ground to the highest part of the plant is recorded as the height.

The total number of individuals in each height class is then tallied, by species, to establish the total stem count. The percent cover that each species provide is estimated. A check is done to ensure that species have not been missed, misidentified or duplicated in the recording and that all information is accurate and complete. This procedure is repeated for all subplots (see Appendix H for sample data sheet).

6.3 GROUND VEGETATION SUBPLOT (1x1m) DATA COLLECTION METHODOLOGY

All herbaceous plants, regardless of size, as well as shrub, tree and woody vines <16 cm in height are considered in ground vegetation subplots. To begin, the south-west corner of the subplot is identified. Next, the other corner points of the subplot are measured out with the use of a measuring tape and temporarily marked with stakes. Then, every plant species originating within or hanging over into the 1 x 1 m subplot is identified. A 1 x 1 m grid square comprised of smaller 10 x 10 cm grids is positioned over corner “A” of the subplot and shifted to the other three corners. The number of 10 x 10 cm squares that each species occupies is summed to determine their total percentage of cover within the subplot. It is also noted if a species is solitary. Appendix I shows a sample data collection sheet.

6.4 SPECIES RICHNESS DATA COLLECTION

Once all the data has been collected, the entire 20 x 20 m plot and the smaller regeneration and ground vegetation subplots are surveyed. All species found within this area are identified and added to a species checklist for the plot. Appendix J provides a sample to checklist used.

7.0 DATA MANAGEMENT AND ANALYSIS

Data Management

At the end of each field season all data collected are entered into a corporate TRCA access database and all field collection forms are stored in a corporate filing system.

Data Analysis for the 2015 Terrestrial Long-term Monitoring Program Report (TRCA 2015a)

The TRCA Natural Heritage Monitoring database was queried using the ‘Species List - Complete’ button and selecting regional forest plots in all years. ‘Species List – Complete’ provides an automatic summary of all the species found at the site. In step 1 of selecting species in the database query, bare soil, algae, Chara, dead/live wood grasses, mosses, liverworts, lichens, N/A, open water/area submerged, seedling, unknown sp., wood and species identified as non-vascular were excluded. Hybrids and sub-species were included as new species.

Coefficient of conservatism values and L-ranks are automatically exported from the database for each species. If a species could only be identified to the genus level it is labelled with the genus name and “.sp” follows the genus name. If a species with the same genus name as the “.sp” was already found in the species list for that site in that year, the “.sp” was excluded to be conservative (likely not a new species). If a “.sp” was a new genus for that list it was assigned an L-rank and cc value matching the species in the same genus with the lowest L-rank and cc value found in the jurisdiction (conservative). If a “.sp” had genera that were a mix of native and non-native species it was excluded from the analysis because native/exotic status could not be determined. Species only assigned to genus level accounted for 53 of 6102 species records.

Data were then arranged into sheets by site and sorted by year. Variables (floristic quality index (FQI), # L1-L3 species and % native species) were calculated for each site in each year between 2008 and 2014. Non-native species were considered to be those ranked L+ and L+?. Data were then transferred to excel tables with the site name shown in each row and year running across the top as columns.

For both temporal and spatial analysis, summary tables with site as row and year as column were used. For temporal analysis, data analysis attempted to maximize the number of years with the same list of sites consistently surveyed each year. This often resulted in limiting the number of sites included because new sites were added in more recent years. Keeping the same group of sites studied in each year allows for valid comparisons among years. The current baseline year for the temporal data is 2008 but in future years a later baseline year may be used in order to increase the number of sites included in the analysis. When analyzing the temporal data for forest vegetation there was a significant increase in species richness over time. This result is likely spurious and is a common problem when starting monitoring programs and could be caused by either increased observer ability or increased observer knowledge of species already found at the site as time progresses. It is assumed that eventually there will be a plateau and tracking temporal trends can begin at that point.

Temporal trends can be statistically analyzed using Mann-Kendall tests in an established Microsoft Excel^{TM} spreadsheet provided by the Ministry of Natural Resources and Forestry. The Mann-Kendall test is a non-parametric test for identifying monotonic trends in time series data. This test is favourable over traditional regression analyses because the data do not meet the assumption of independent samples required for regression analyses. When analyzing time-series data, data collected at the same site from one year to the next are not independent. This makes the Mann-Kendall test the best option. The Mann-Kendall test uses the S statistic to determine an associated p-value. If the value of S is zero, there is no trend in the data. If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by one. On the other hand, if a data value from a later time period is lower than a data value sampled earlier, S is decremented by one. The net result of all such increments and decrements yields the final value of S (TRCA 2011). For example, a very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend (TRCA 2011). A p-value of less than 0.05 denotes a significant trend (increasing or decreasing) and a p-value of greater than 0.05 indicates that there is no increase or decrease over time and that the variable of interest is stable.

For spatial analysis, data analysis attempted to maximize the number of sites. This often resulted in using more recent years of data because new sites were added in more recent years. Often the most recent 2-4 years of data were used because they contained a consistent set of sites in each year. An average value across the selected years was calculated for each site and this single value per site was used for analysis. The list of sites and years included for the spatial analysis can be found in the appendix of TRCA (2015a).

Spatial trend analysis was conducted using SAS JMP statistical software (SAS Institute Inc. 2008). Differences between urban and rural land use zones were analyzed using independent t-tests. An independent t-test is a parametric test that compares the mean value between two groups (e.g. urban and rural land use zones). This test is reported using the test statistic, t, and an associated p-value where a p-value of less than 0.05 indicates a difference between groups. A p-value of greater than 0.05 indicates that there is no difference between groups. Before performing t-tests, all data were checked for normality and homoscedasticity because these are two assumptions of using parametric statistics. If these assumptions were not met, data transformations were attempted to improve normality or heteroscedasticity. If data transformations were not effective, a Wilcoxon test was conducted (Z-statistic). This is the non-parametric version of an independent t-test and is the appropriate test to proceed with if the data do not meet assumptions. For TRCA (2015a), an independent t-test was used but this may not be the appropriate test to use in the future if the data violate the assumptions of using parametric statistics listed previously.

Other Variables Examined in TRCA (2015a)

Density of Woody Regeneration (temporal and spatial)

The TRCA Natural Heritage Monitoring database was queried using the ‘Regeneration’ button and selecting regional forest plots in all years. Density of woody stems was calculated for all woody species combined and choke cherry alone in the regeneration layer. The column labelled ‘Total Num’ was used as a measure of density/abundance. The total number of stems was used for the analysis of density of all woody stems combined. Choke cherry was examined individually for relative abundance and percent cover. Relative abundance was calculated using the ‘Total Num’ column and by adding the number of choke cherry stems in all sub-plots then dividing by the total number of stems of all species in all sub-plots in a specific site in a specific year. Relative cover was calculated using the column labelled ‘Cover’. Average relative percent cover was calculated by taking the sum of all the choke cherry covers then dividing by the total cover of all species at a given site in a given year. Both the ‘Total Num’ and the ‘Cover’ columns are automatically exported from the TRCA Natural Heritage Monitoring database. Summary tables were then created and spatial and temporal trends were analyzed as previously mentioned (Wilcoxon tests and Mann-Kendall).

Spread of Invasive Species (temporal and spatial)

Cover of exotic species in the ground vegetation layer was also examined. The TRCA Natural Heritage Monitoring database was queried using the ‘Ground Vegetation’ button and selecting regional forest plots in all years. Cover was calculated for all exotics combined and garlic mustard alone. A list of all exotics included in the analysis can be found in the appendix of TRCA (2015a). Only garlic mustard was examined alone because it occurred in a high enough cover and frequency for analysis. Other species were only qualitatively summarized in TRCA (2015a) although in the future these may increase in cover and frequency and analysis could potentially be conducted. For calculations, the maximum cover between the two visits (spring and summer) was used and relative % cover was calculated as per regeneration (above).

Relative cover and abundance of common buckthorn as an exotic species was also analyzed alone and data were retrieved and analyzed similar as above for the density of woody regeneration. Summary tables were then created and spatial and temporal trends were analyzed as previously mentioned.

Tree Health

Crown Vigour

Tree health data were retrieved from the TRCA Natural Heritage Monitoring database by selecting the 'Tree Health' button. Crown class affects crown vigour because trees with crowns that are dominant and co-dominant in the forest canopy are naturally less stressed because they receive more sunlight than crowns that are intermediate or suppressed. For this reason crown vigour was analyzed using only trees with crown classes of dominant and co-dominant (classes 1 and 2). Infrequently trees switched from a crown class of 3 to 2 or from 2 to 3. This caused trees to move in and out of the data set over the years and therefore only trees with crown classes that remained in the same category (1/2 or 3/4) among years were included. Due to methodological inconsistencies, crown vigour category 4 (dead) could not be included in the analysis. Instead, crown vigour of only live trees was analyzed. All trees with conditions dead broken (DB), dead leaning (DL), dead fallen (DF) and dead standing (DS) were removed. Trees with a missing crown class or a crown class of zero were excluded from analysis. Only trees that consistently had a crown vigour recorded each year were included in the analysis to avoid spurious results caused by different trees being included in different years.

The percentage of trees in each crown vigour class was determined at each site in each year by dividing the number of trees in each class by the total number of trees in the plot. Summary tables were then created in excel for each crown vigour separately. Temporal trends were analyzed as previously mentioned using Mann-Kendall tests. Spatial trends used either an independent t-test (crown vigour 2) or the Wilcoxon test (crown vigour 1 and 3) based on the distribution of the data.

Tree Mortality

Annual tree mortality was measured by determining the number of trees that changed in status from living to dead between two consecutive years. Only trees with dominant and co-dominant crown classes and those that were surveyed annually between 2008 and 2014 were included in this analysis (n=185 trees). Summary tables were then created and temporal trends were analyzed using Mann-Kendall tests. No statistical spatial trends were conducted for TRCA (2015a) because of the generally low mortality rates (only one or two trees dying each year and often none in one of the land use zones).

Alive Trees vs. Snags

Tree conditions included as snags were dead broken (DB), dead standing (DS) and dead leaning (DL) and all live trees were included in the alive category. The category DF – dead fallen was removed from analysis. The percent live trees and percent snags were then calculated for each site in each year. Summary tables were then created and spatial and temporal trends were analyzed as previously mentioned (independent t-test and Mann-Kendall).

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APPENDICES

APPENDIX A: STAND AGE AND GPS LOCATION DATA SHEET

Site Name:____Plot #________
Date(d/m/y):____________
Observers:____

Tree *(not in plot)*	Species Code	Age (measured by increment borer)	Year of establishment (i.e. current year – age)	Comments
1				
2				
3				
4				
5				

GPS reading (off 'A' post): ______________________________

Type of GPS unit: ____________________________________

APPENDIX B: TREE MAPPING DATA SHEET

Site Name:____Plot #________
Date(d/m/y):____________
Observers:____

Tree tag #	Species Code	'A' distance, m (measured to right from tree)	Corner post used for measurement (A, B, C, D)	'B' distance, m (measured to left from tree)	Corner post used for measurement (A, B, C, D)

APPENDIX C: PROTOCOL FOR DETERMINING TREE AGE

INTRODUCTION:

This protocol discusses how to properly age forest stands. It also provides instructions on the proper maintenance and care of the increment borer. Stand age is an integral part of the baseline data collected at the time of forest plot set-up. The structure and composition of a forest is, in part, of a factor of time. The collection of age data provides a frame of reference around which tree health findings can be properly interpreted.

EQUIPMENT & MATERIALS:

- Increment borer
- Marker
- Stain (i.e. tea/coffee)
- Metric dbh tape
- Isopropyl (disinfectant)
- Light oil (lubricant)
- Field notebook and pencils
- Drinking straws
- Masking tape
- Light rag

TREE SELECTION

Examine the composition of the forest to identify the species of trees that together represent the largest and most common canopy trees. From the stand surrounding the plot (do not core trees from within the plot), select five specimens for coring that are representative of the plot, making sure that they mirror the range of sizes on the plot. Record their dbh. If re-sampling is to occur, consider marking/tagging trees in some way for future reference. **Note:** *Trees that are prone to infectious fungal diseases such as butternut (Juglans cinerea) and American beech (Fagus grandifolia) should not be cored. Trees that have compression wood or are rotten should also be avoided as these can cause either the increment borer to break or cause it to become stuck in the tree.*

CORING LOCATION

According to the EMAN protocol cores can be taken at either the 130 cm breast height or the 30 cm stump height (just above swelling where the roots originate). Although it is preferable to core the tree at breast height so that excess downward force does not bend the auger, cores taken from the stem base will give a minimum age closer to the real age.

Cores are taken at right angles to the stem axis on the north-facing side of the tree to ensure that accurate ring widths are obtained. If the tree has a definite lean, core from the upper side. Also avoid areas of the stem that are deformed, core outside of these regions. Record the stem position of each core.

CORING PROCEDURE

1.) To begin, place the bit of the auger firmly into the tree making sure it is slightly off of a 90 degree angle so the increment borer is pointed towards the ground. This will slow or stop water from entering the open wound, which will help in preventing fungal rot. Turn the handle clockwise, gently, until the borer has gone slightly past the centre of the tree (Figure 4). ***Tip:*** *Place some lubricant or bees wax on the bit of the auger, this will decrease the friction and also enable smoother operation of the instrument.*

2.) Once the auger has gone slightly past the centre of the tree insert the extractor into the auger chamber, lift it slightly to ensure that it goes under the core (Figure 5).

3.) Turn the increment borer ¼ to ½ counter clockwise keeping the extractor handle firmly in place. This will break contact between the core and the tree tissue. This is important so the core is not damaged (Figure 6). The notch on the extractor should be up so that if the core breaks, it will still rest in the extractor.

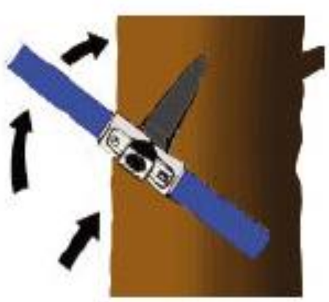

Figure 4. Place the increment borer into the tree and turn clockwise until the centre of the tree has been reached. Photo courtesy of Haglof of Sweden

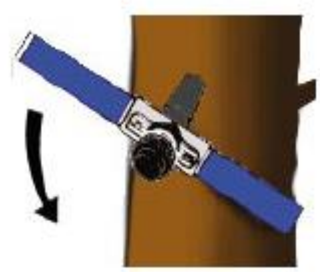

Figure 5. Once the auger has gone slightly past the centre of the tree, insert the extractor into the auger chamber. Photo courtesy of Haglof of Sweden (2009).

Figure 6. Turn the increment borer ¼ to ½ counter clockwise keeping the handle firmly in place. Photo courtesy of Haglof of Sweden (2009).

4.) Then pull the handle of the extractor removing it and the core from the auger (Figure 7). If the core does not come out put the extractor back in the auger chamber making sure it is all the way in. Then turn the increment borer ¼ to ½ clockwise and ¼ to ½ counter clockwise. Then remove the core.

5.) Place the core and extractor somewhere safe (Figure 8). Then remove the increment borer by turning it counter clockwise. It is important to remove the borer before counting the tree rings as the wood swells quickly making it difficult and sometimes impossible to remove the auger from the tree.

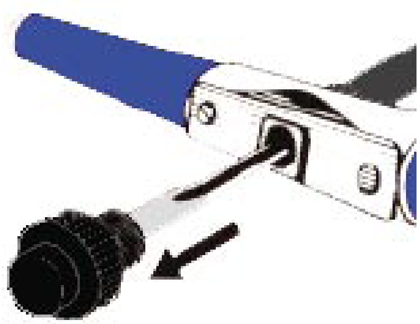

Figure 7. Remove the extractor and the core. Photo courtesy of Haglof of Sweden (2009).

Figure 8. Extractor and core. Photo courtesy of Haglof of Sweden (2009).

6.) Once the increment borer has been removed from the tree, the rings are ready to be counted (Figure 9).

Figure 9. Tree core (Anonymous, A. 2009).

7.) If there is not enough time to count the rings in the field the core can be stored in a large plastic straw. Both ends of the straw should be taped so the core does not fall out. In addition there should be a piece of masking tape that has been labelled with the following information; the tree species, plot number, dbh, date and any other relevant information. Store the core(s) in a safe place, preferably in a refrigerator if the cores are wet or full of sap (or freezer if ring widths are also to be measured), until the counting can be done. If a refrigerator is not available for wet cores, mount (see below) as soon as possible to avoid fungal attack. It is much easier to count the rings in the field and this is preferred over the storage method.

8.) After counting, store the cores for future reference, they are part of the voucher specimens and may be used for further study.

COUNTING TREE RINGS

The late wood appears dark and each of these rings represents one year of growth (Figure 10). Count these rings making sure that once the centre of the tree is reached that these subsequent rings are omitted from the count. If the early and late woods are hard to distinguish as in the case of some sugar maples (*Acer saccharum* ssp. *saccharum*) there are a few methods of distinguishing these rings. A knife can be used to cut a flat side on the core, which usually makes counting easier. Liquid such as water, coffee or wood stain can be applied to the core helping to distinguish the rings.

Coniferous trees are generally easier than deciduous trees to bore and their rings easier to count - often with the naked eye or a 10 x hand lens. Cores from diffuse-porous deciduous species must be mounted (glued) into wooden grooves (core trays), and sanded successively with finer and finer grades of wet-or-dry sandpaper backed with a pencil eraser. Count the rings using a dissecting microscope. For accurate counting, all species should be mounted, sanded and counted under a microscope.

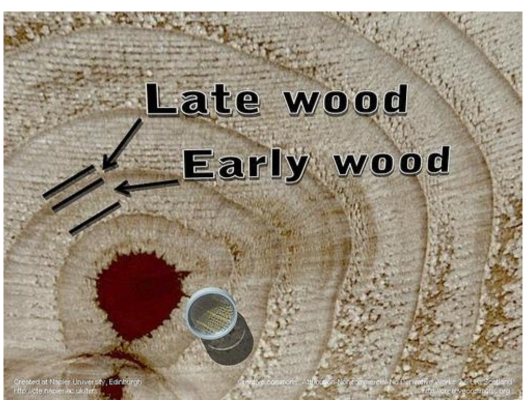

Figure 10. Late and early wood (Anonymous, B. 2009).

INCREMENT BORER MAINTENANCE

After each use the increment borer should be cleaned with a cotton rag. In addition isopropyl can be used to disinfect the borer to prevent the spread of disease. At this time light oil can be applied to the tip and the shaft of the borer (auger). Cleaning after each use and adding oil will greatly extend the life of the instrument.

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APPENDIX D: GENERAL RULES FOR MEASURING DBH

Straight tree(s): Tree diameter measured at 1.3 m above ground (Figure 1a)

Tree growing vertically on a slope: Measure dbh of the trunk on the upper side of the slope (Figure 1b and 1c)

Leaning tree(s): Measure dbh on the side of the trunk that the tree leans towards (Figure 1d and 1i).

Tree(s) with irregular stem at 1.3m: trees with bulges, wounds, hollows and branches, etc. at breast height, are to be measured just above the irregular point, where the irregular shape does not affect the stem (Figure 1e).

Tree(s) with aerial roots: Diameter measurement is done at 1.3m from the limit between the stem and roots (see Figure 1f)

Fork tree(s): If the fork begins (the point where the core is divided) below 1.3 m height, each stem with diameter required (≥10 cm) will be considered as a separate tree and will be measured. Diameter measurement of each stem will be taken at 1.3 m height (Figure 1h).

Fork tree(s) II: If the fork begins at 1.3 m or a little higher, the tree will be counted as a single tree. The diameter measurement is thus carried out below the fork intersection point, just below the bulge that could influence the dbh (Figure 1g).

Trees with an enlarged stem base or buttressed tree(s): Diameter measurement is made at 30 cm above the enlargement or main width of buttress, if the buttress /enlargement attain more than 90 cm height above the ground (Figure 1j)

Fallen tree(s): Diameter measurement is made at 1.3 m from the transition point between the stem and the root

Coppice: Coppice shoots originate between ground level and 1.3m on the stem of a dead or cut tree. Coppice shoots originating below 30 cm are measured at 1.3 m above the ground; those originating between 30 cm and 1.3 m are measured at 1 meter above point.

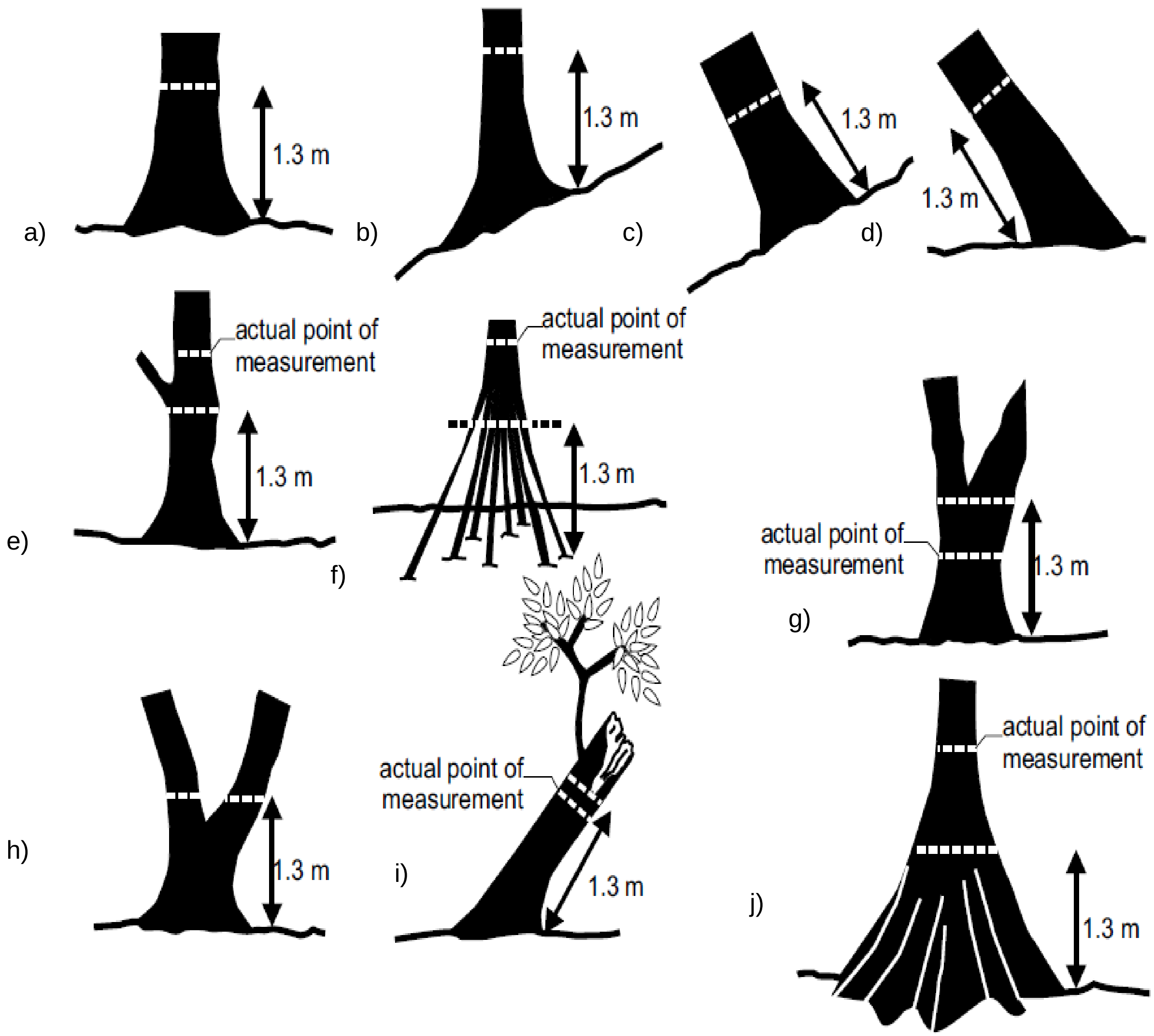

Figure 1. DBH measurement locations (Roberts-Pichette & Gillespie, 1999)

APPENDIX E: GLOSSARY OF TERMS

CROWN VIGOR/CLASS DEFINITIONS

Crown: is defined at the upper portion of the tree including the branches and leaves.

STEM LOCATION DEFINITIONS

Main stem: is defined at the area between the upper boundary of the root collar and the base of the crown.

Lower stem: is defined as the area between the middle of the main stem and the upper boundary of the root collar.

Upper stem: is defined as the area between the middle of the main stem and the base of the crown.

Stump root collar: is defined as the area where the main stem begins to flare.

STEM DEFECT DEFINITIONS

Evidence of Decay/Fungus: Decaying wood is usually soft, spongy, or crumbly and is often marked by the presence of fungal fruiting bodies on the root flares, stems, or branches. Examples include: mushrooms, conks, and brackets. Cavities within wood can also develop.

Seam/Crack: A deep split through the bark, extending into the wood of the tree.

Open wound: A wound that has not completely sealed leaving inner tissues exposed.

Closed wound: A wound that has been sealed. Thick callus tissue often forms.

Canker: A localized area on the stem or branch of a tree, where the bark is sunken or missing. Cankers are caused by wounding or disease.

APPENDIX F: IDENTIFICATION GUIDE TO THE TOP 14 TREE DISEASES OR PESTS IN THE TRCA JURISDICTION

Top 14 Tree Diseases or Pests of the TRCA Jurisdiction	
Ash yellows	Eutypella canker
Armillaria root rot	White pine blister rust
Beech bark disease	Asian long-horned beetle
Butternut canker	Emerald ash borer
Dutch elm disease	Gypsy moth
Fall cankerworm	Spring cankerworm
Two-lined chestnut borer	Forest tent caterpillar

1. Ash Yellows

Ash yellows disease is caused by wall-less microbes which invade the tree's phloem sieve tubes. It is believed that they are transmitted by leaf hoppers and other related insects. The most commonly infected trees are white ash (*Fraxinus americana*) and green ash (*F. pennsylvanica*)

Figure 1: Ash tree infected with ash yellows. Note the Witches broom (Cornell University, 2009).

Identification
Leaves become stunted and chlorotic exhibiting a yellowish appearance. The branches die back and witches broom occurs near the base of the trunk.

Symptoms and Damage
The tree becomes less dominant and eventually it dies. Open trees are more susceptible than ones growing within the forest.

2. Armillaria Root Rot

Armillaria root (*Armillaria* spp.) rot is cited as one of the most damaging forest diseases in Ontario. It attacks both deciduous and coniferous trees as well as shrubs. It is caused by a number of soil borne fungi.

Figure 2: Fruiting bodies of armillaria root rot (Natural resources Canada, 2009).

Identification
The first symptoms of infection are yellowing and dwarfing of foliage, followed by the death of branches in the upper crown. Fruiting bodies are found around the stump of the tree (Figure 2).

Symptoms and Damage
The fungal hyphae travel through the roots to about a meter above the soil killing the cambium and the tree eventually dies. The fungus is spread by root grafts and spores.

3. Beech Bark Disease

The disease is the result of an interaction between a scale insect (beech scale, *Cryptococcus fagisuga*) and one or two species of fungus. One fungus, *Nectria galligena*, is native to North America while the other fungus *Nectria coccinea* var. *faginata* is an introduced species. The disease does not occur if either pest is absent. The scale feeds on the sap and inadvertently transports spores from the two fungal species.

Identification
Beech scale insects are yellow, soft-bodied and are 0.5 to 1.0 mm long as adults, but have a whitish appearance due to the white waxy coat they secrete. They look like small patches of white wool. After the tree is infected with beech scale insects; soon fungal lesions are present on non-resistant trees. The fungus causes a "target canker" which kills the active cambium layer leaving dead tissue which often has a sunken appearance. Infected trees often have rough scaly bark (Figure 3).


Figure 3: Beech tree heavily infected with beech scale disease. Note the many cankers (Anonymous A, 2009)

Symptoms and Damage
If the cankers correlate and enough cambial tissue is killed, the tree will die. Some infected trees will break off in heavy winds.

4. Butternut Canker

Butternut canker (*Sirococcus clavigignenti-juglandacearum)* is caused by an introduced fungal pathogen that invades the cambium of butternut trees.


Figure 4: Butternut heavily infected with Butternut canker (FGCA, 2009)

Identification
Cankers are elongated, sunken and black, that form under the bark of infected trees, which in the early stages of the disease makes them difficult to detect. Cracks or open wounds in these cankers may exude a black fluid (spores) in early spring and summer (Figure 4). Sometimes in the early stages of the disease the distinctive black cankers may only be present in the branches in the crown. This can be detected by branch die-off, although other factors might cause these issues.

Symptoms and Damage

Butternut canker usually develops in the crown of the tree. Rain washes the spores to lower sections of the tree. As the branches and the stem develop multiple cankers they can eventually join together killing the branch or the tree.

5. Dutch Elm Disease

Dutch elm disease (*Ceratocystis ulmi)* is caused by a wilt fungus that invades the vascular system of elm trees. The spores of this fungus are transported from the European elm bark beetle (*Scolytus multistriatus)* and native elm bark beetle *(Hylurgopinus rufipes).* The beetles feed on the bark and emerge from their nuptial chambers after the tree dies. They then search out healthy trees and infect them. The introduced beetle is far more aggressive than the native beetle. Younger elms are less susceptible to the disease as the beetles prefer to feed on the thicker bark of older trees.

Figure 5. Branch flagging caused by Dutch elm disease (Desrochers P, 2009).

Identification

The first signs of infection are yellowing leaves and flagging of the branches (Figure 5).

Symptoms and Damage

The fungus interferes with the translocation of fluids in the tree, resulting in a reduction of water to the leaves and subsequent wilting. Eventually the trees vascular system becomes clogged with the fungal hyphae and dies. Dead elms that have been attacked by Dutch elm disease will have nuptial chambers between the bark and sapwood. The fugal hyphae can travel to neighbouring trees from root grafts.

6. Eutypella Canker

Eutypella canker (*Eutypella parasitica)* is caused by a parasitic fungus that attacks the cambial tissue of maple species. Sugar maple is the most susceptible and the disease is usually only found on 2 to 4% of these trees.

Figure 6: Eutypella canker of maple (Anonymous C, 2009).

Identification

The disease is characterized by a large roughened area of bark (Figure 6). The disease attacks branches and the main stem but it is usually not found more than 4 to 5 m above the soil. The canker usually has a branch stub in the middle as this could have been the entry point of the fungus. The area is sunken with heavy callous tissue around the margin. Older cankers produce black fungal fruiting bodies near the centre of the canker.

Symptoms and Damage

Trees are rarely killed by this disease although it is fairly common and can weaken the tree. Trees with huge cankers are more likely to snap than ones unaffected. It more of an aesthetic and forestry issue.

7. White Pine Blister Rust

White pine blister rust *(Cronartium ribicola)* is a rust fungus with a complex lifecycle. It is an exotic pathogen from Asia. It attacks and kills the cambium of five needle pines and is the most serious disease of white pine (*Pinus strobus*) in North America. The alternate hosts are members of the gooseberry (*Ribes*) family.

Figure 7: White pine blister rust (Anonymous D, 2009)

Identification

The first signs of blister rust are yellow and red spots on the needles. This stage is usually difficult to detect and the disease is most noticeable when the infected branches begin to swell. The swollen area eventually develops into a spindle-shaped canker. When cankers appear on the main stem they usually have an orange sunken appearance (Figure 7).

Symptoms and Damage

Eventually the canker can completely girdle the bole; killing the tree.

8. Asian long-horned beetle

Asian long-horned beetles (*Anoplophora glabripennis*) (ALB) are an introduced wood boring insect that attacks deciduous trees of any age or size and have a preference for maples. Thus far it has only been observed in the west end of Toronto.

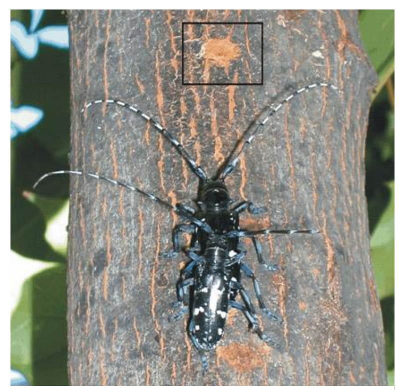

Figure 8: Asian long-horned beetle and nuptial chamber (Anonymous E, 2009).

Identification

Adult Asian long-horned beetles are large measuring 20 to 35 mm in length and are 7 to 12 mm wide. They are black with up to 20 white dots on the wing covers (elytra) that are usually arranged in parallel lines (Figure 8). Eggs are relatively easy to find as they resemble small grain of rice. The female chews a round pit into the infected tree and deposits her eggs (Figure 8: note the square box).

Symptoms and Damage

During the larval stage Asian long - horned beetles eat the cambium and bore into the heartwood where they transform into pupae. Once the pupae are adults they bore through the tree leaving a 20 mm hole with sawdust and leaking sap. Also the egg laying holes are also visible and are associated with leaking sap and sawdust. The trees foliage can become yellow, have premature leaf drop and

the crown may start to die-off. Infested trees are also prone to secondary attack from insects and disease.
The tree must have a thorough investigation to determine if the symptoms are from the Asian long-horned beetle or other diseases or insects.

9. Emerald Ash Borer

Emerald ash borer (*Agrilus planipennis*) is an introduced wood boring insect from China that attacks ash (*Fraxinus*) species. Adult emerald ash borers emerge in May and live for three -six weeks. Emerald ash borer eats leaves for 5-14 days. The female then oviposits her eggs individually on or just under the bark. Larvae feed on the cambium from July to October leaving s-shaped galleries.

Figure 9: Emerald ash borer adult and larvae photo courtesy of the MNR (2009).

Identification

Emerald ash borer are 8.5 to 13.5 mm long, have a flattened head with big compound eyes, shortened antennae and are a metallic green colour (Figure 9). Eggs are very difficult to detect on the trees. Larvae are cream coloured with a brown head and when mature are 26-32 mm in length. Pupae are cream-colour and 10-14 mm in length.

Symptoms and Damage

The first signs of emerald ash borer are crown die-back, witches broom, and yellowing leaves. Then the bark starts to crack, fall off, s-shaped tunnels and exit holes can be observed on the bole. Trees can succumb in as little as 2 years. This insect has been observed in many places in the TRCA jurisdiction.

10. Gypsy moth

The gypsy moth (*Lymantria dispar)* was accidentally introduced from Eurasia and defoliates deciduous trees.

Identification

Male and female moths are different in appearance with the male moths being tan to brown with a wingspan of 37 to 50 mm. Females are often larger (37 to 62 mm), white with faint dark wavy bands across the forewings (Figure 10). The larvae are very hairy with six pairs of distinctive red spots and five pairs of blue dots across the back (Figure 11). They are usually found grazing on the leaves in deciduous trees. In early instars they can often be found in shady places such as fissures in the trees bark.

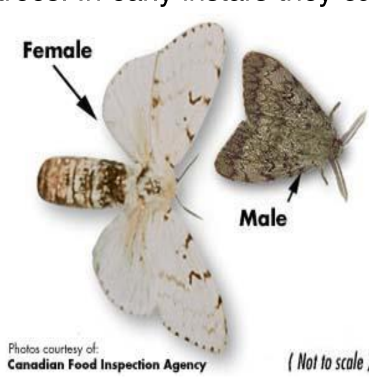

Figure 10: Female and male gypsy moths (Canadian Food Inspection Agency, 2009)

Figure 11: Gypsy moth larvae (Gypsy Moth Alert, 2009).

Symptoms and Damage

Gypsy moth larvae are aggressive feeders and a large infestation can greatly reduce the amount of leaves in the crown. Usually the tree is able to produce new leaves as the larvae are finished feeding by late June early July. If this continues for a number of consecutive years the tree can die. With heavy infestations large quantities of scat and cast skins can collect at the base of the host tree.

11. Spring Cankerworm (*Paleacrita vernata*)

The spring cankerworm is native to North America. This pest is a defoliator of many deciduous trees and shrubs. The spring cankerworm tends to prefer Siberian elm *(Ulmus pumila)* but other hosts include ash, basswood, bur oak, white birch, trembling aspen, and various fruit trees (NRCAN, 2009). This pest has a one year life cycle. Young larvae emerge from overwintering eggs in the spring. They feed on the leaves of their host tree from May to June. At maturity, larvae will enter the soil to overwinter and then pupate in the very early spring. Mating occurs shortly after adult emerge. After mating the females climb up to the lower stems and branches of the host trees and shrubs to lay a cluster of eggs (NRCAN, 2009).

Identification

The larvae are slender and move with a looping motion. Mature spring cankerworm larvae are about 20–30 mm long, and vary in colour from yellowish green to black, with a mottled appearance (Figure 12). Adult males (Figure 13) have wings while females are wingless (Figure 14) (NRCAN, 2009).

Figure 12: Spring cankerworm larvae (Arcand, 2009)

Figure 13 & 14: Adult Spring cankerworm (*Paleacrita vernata)* male (left) and female (right)) (Arcand, 2009).

Symptoms and Damage

Defoliation typically starts in May when the young larvae emerge from their overwintering eggs and begin to the chew into the developing leaves. As feeding continues, these holes gradually enlarge until only the larger leaf veins and midribs remain. Heavy defoliation can cause growth loss, branch die-back, mast reduction, and, if coupled with other stresses, tree mortality (USDA, 2005).

12. Fall Cankerworm (*Alsophila pometaria* [Harris]).

The fall cankerworm is native to North America. It is a defoliator of hardwood species. It's preferred host species are Manitoba maple *(Acer negundo)* and American elm *(Ulmus americana)* but in their absence they will attack other deciduous species including ash, basswood, bur oak, Siberian elm, aspen, white birch and a variety of fruit trees (NRCAN, 2009).

This pest has a one year life cycle. Larvae emerge in the spring (late May) around the same time as bud break/leaf-out, after which they feed on the leaves of the host plant. They will continue to feed on the host tree/shrub until the end of June. At this time, the mature larvae will enter the ground to pupate. Adults emerge in the late fall, usually by end of October, and mate. After mating, females will crawl up the trunk and lay their eggs (~ 100 eggs) on the upper twigs and branches of the tree. Here the eggs will overwinter until the following spring.

Identification

Just like the spring cankerworm larvae are slender in form and move with a characteristic "looping" motion. Mature larvae, are approximately 25 mm in length and have longitudinal stripes running down the length of their bodies (Figure 15). Their colour can vary from light green to a brownish green. Adult females are wingless, grayish brown, and about 12 mm long, while the grayish brown, adult male moths have wings with a span of about 30 mm (Figure 13 & 14)(NRCAN, 2009).

Figure 15: Mature larvae (Arcand, 2009)

Figure 16: Adult female (Arcand, 2009).

Figure 17. Adult male (Arcand, 2009).

Symptoms and Damage

Small holes in the leaves often provide early evidence of young larvae feeding on foliage. Older larvae consume the entire leaf, except the midribs and major veins. Most trees are able to withstand a light infestation, often re-foliating after the cankerworm have stopped feeding and gone into the ground to pupate. However, their resilience or ability to recovery is weakened if the intensity of the defoliation is severe. Heavy defoliation can cause growth loss, upper branch die-back, mast reduction, and, if coupled with other stresses, may result in mortality (USDA, 2005).

13. Two-lined Chestnut Borer (*Agrilus bilineatus* [Weber]*)*

Two-lined chestnut borer is a secondary invader meaning that it only attacks trees that are already in a stressed condition due to other environmental factor (i.e. disease). This pest attacks oak, beech, birch and chestnut tree species.

In late May and throughout June/July the adult borers emerge through D-shaped holes in the bark and feed on the foliage of the host tree.
If populations are large, borers will fly over to neighboring trees to feed. After mating, the females will lay their eggs in crevices in the bark. When the young worm-like larvae hatch 2 weeks later, they bore through the bark into the cambium and phloem, where they construct meandering tunnels. (NRCAN, 2009).

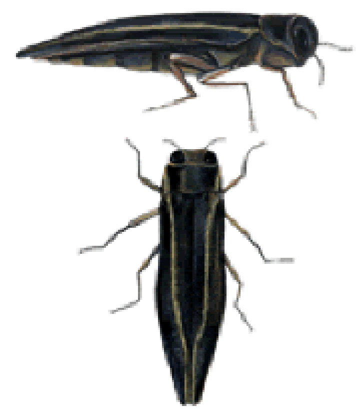

Figure 18: Two-lined chestnut borer (Mikel, 2009)

Identification

The adult borer is a slender, dark-coloured winged beetle, approximately 8–12 mm long, with a pair of yellow stripes that run along its thorax and wing (Figure 18). The body is cylindrical, bluish-black and approximately 1/2 inch long. Larvae have a cream-colored, flattened, slender, grub-like body, which is approximately one inch long when fully grown. Mature larvae grow to a length of 25–30 mm (Figure 19) (NRCAN, 2009).

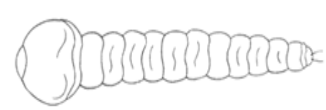

Figure 19: Two-lined chestnut borer larvae (Mikel, 2009)

Symptoms and Damage

The impact of the two-lined chestnut borer can range from minor branch dieback to complete tree mortality. The larvae of this insect feed by creating meandering tunnels, known as galleries, throughout the inner bark of branches and the main trunk. These tunnels impede the flow of water and nutrients from the roots to the leaves, resulting in the eventual girdling and death of the infested portion of the tree. Crown die-back, usually in the late summer to early fall (August and September), marks the first visible signs of an infestation. Typically foliage in the upper crown begins to wilt and turn brown and as the die-back continues downward towards the main trunk, the leaves do not drop but instead remain on the tree for about 1 year. Heavy infestations will kill the tree (NRCAN, 2009).

14.0 Forest tent caterpillar (*Malacosoma disstria*)

Trembling aspen (*Populus tremuloides*) is the tent caterpillars preferred host, although the caterpillars will attack a wide variety of deciduous trees and shrubs. This species has been known to feed on certain conifers when the preferred hosts are not present.

Figure 20: Forest tent caterpillars (NRCAN, 2007)

The forest tent caterpillar (Figure 20) has one generation per year. The larvae hatch in early spring and feed on the foliage of the host tree until June. The caterpillars will then migrate in search of food or cocooning sites. The larvae reach maturity by mid July and pupate between leaves (Figure 18). The adult moths emerge 10 days later to mate. Females will lay a band-like structure of about 150 -200 gray-coloured eggs around small twigs of host trees in the mid-summer (Figure 21). The eggs will overwinter until the following spring.

Figure 21: Egg band (NRCAN, 2007)

Identification

Mature larvae are about 45mm in length and are covered in fine, light coloured, silky hairs. The appearance of a forest tent caterpillar can vary but they typically have blue sides; a black back with a thin white strip running down the centre and orange markings. The adult moths are a light yellow to light brown in colour with 2 slanted dark bands on their forewings and a wingspan of 35-45 m (Figure 22 & 23).

Figure 22: Adult male moth (NRCAN, 2007)

Figure 23: Adult female moth (NRCAN, 2007)

Symptoms and Damage

The damage caused by the forest tent caterpillar can range from minor to extensive depending on the intensity and duration of the infestation. Short-term infestations can lead to thinning of the crown which most trees can recover from while heavy, long-term infestations can result in complete defoliation, branch die-back and/or tree mortality (AAFC, 2007).

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APPENDIX G: FOREST TREE HEALTH DATA SHEET *(page 1)*

SITE NAME:______________________________ PLOT #________ DATE (D/M/Y):__________ WATERSHED:_______________

OBSERVERS:____

Tree Status
1 = Living (green foliage)
2 = Recently dead (no green foliage, fine branches and bark attached)
3 = Old dead (no green foliage, no fine branches, bark falling off)
4 = Cut down, girdled (human caused)

Tree Condition
AS = alive standing
AB = alive broken
AL = alive leaning
AF = alive fallen or prone
AD = alive standing but dead top
DS = dead standing
DB = dead broken
DL = dead leaning
DF = dead fallen or prone

Crown Class
1 = Dominant
2 = Co-dominant
3 = Intermediate
4 = Suppressed
5 = Open Grown (exposed to full sunlight)

Crown Vigor Rating
1 = Healthy (10% or less crown mortality)
2 = Light to Moderate Decline (less than 50% of crown)
3 = Severe decline (more than 50% crown mortality)
4 = Dead, Natural
5 = Dead, Human Caused

Defect Type
1 = Decay fungus, fruiting body
2 = Seam, frost crack (dry)
3 = Seam, frost crack (bleeding/wet)
4 = Open wound
5 = Closed wound or scar
6 = Canker
7 = Insect damage
8 = Pruned
9 = Animal Damage
10 = No type

Defect Location
1 = Lower Stem
2 = Upper Stem
3 = Entire Stem
4 = Stump, Root collar
5 = No Defect

Tree #	Species Code	Tree Stat & Cond	DBH (cm) if req'd	Height (m) if req'd	Crown Class	Crown Vigour	Stem Defect #1		Stem Defect #2		Comments (include whether new recruit - see also Pests & Diseases page)
							Type	Location	Type	Location	

APPENDIX G: FOREST TREE HEALTH MONITORING DATA SHEET (*page 2*)

STAND DISTURBANCE (mark all applicable)

LOGGING DAMAGE	Comments:			
1. Current	2. Recent, less than 5 years, but not current	3. Recent, greater than 5 years (firm stumps)	4. Old (no firm stumps)	5. None
DEFOLIATION/INSECT DAMAGE:	Comments:			
1. Current	2. Recent in the last 5 years	3. Greater than 5 years	4. None	
WIND/STORM DAMAGE	Comments:			
1. Current (obvious damage, trees blown over or large branches	2. Recent, in the last 5 years	3. Greater than 5 years	4. None	
BROWSING/GRAZING	Comments(slight, moderate,severe):			
1. Current, light damage, (no obvious	2. Current, heavy damage (obvious tree damage and soil compaction)	3. Old damage	4. None	
TAPPING	Comments:			
1. Current/active (tap holes are present)	2. In the last five years, but not current (tap holes have closed)	3. Greater than 5 years	4. No history of tapping	
TRAILS/TRAMPLING	Comments(slight, moderate,severe):			
1. trails being used currently	2. In the last five years, but not current (trails closed)	3. Greater than 5 years	4. No history	
TRASH/DUMPING	Comments(slight, moderate,severe):			
1. recent trash/dumping (same year)	2. In the last five years, but not current	3. Greater than 5 years	4. No history	

APPENDIX G: FOREST TREE HEALTH FIELD DATA SHEET *(page 3)*

TREE PEST AND DISEASE DETAILS

TREE #	NAME OF PEST/DISEASE	Photo Taken Y/N	COUNT ON TREE 1-10,11-20,21-50,51-100,>100	Evidence Observed e.g. egg masses, bore hole...	COMMENTS

APPENDIX H: SHRUB AND SAPLING REGENERATION FIELD DATA SHEET

SITE NAME:______________________ PLOT #:_______

DATE (D/M/Y):___________ OBSERVERS:____

Subplot #	Tree and Shrub Species (full species name)	Tree Regen and Shrub Height Classes (cm)						% Cover	Total #	Comments
		16-35	36-55	56-75	76-95	96-200	>200			

APPENDIX I: GROUND VEGETATION FIELD DATA SHEET

Site Name:___________________________ Plot #________ VISIT (*CIRCLE ONE*) SPRING SUMMER

Date (d/m/y):____________ OBServers:____

Subplot #	Species (full species name)	Solitary (check only when applicable)	% Cover	Comments (e.g. collected, photo, etc.)

APPENDIX J: FLORA SPECIES CHECK LIST *(page 1)*

ACERACEAE
__A negundo
__A platanoides
__A rubrum◄
__A saccharinum◄
__A saccharum
__A saccharum nigrum◄
__Acer spicatum◄
__*Acer x freemanii*◄
__A …
ALISMATACEAE
__Alisma plantago-aquati
__Sagittaria latifolia◄
__S …
ANACARDIACEAE
__Rhus radicans (vine)
__Rhus rydbergii (shrub)
__Rhus typhina
APIACEAE
__Aegopodium podagrari
__*Angelica atropurpure*◄
__*Cicuta bulbifera*◄
__C maculata
__Cryptotaenia canadensi
__Daucus carota
__Heracleum ...
__*Hydrocotyle america*◄
__Osmorhiza claytonii◄
__Pastinaca sativa
__Sanicula marilandica◄
__Sium suave◄
__Torilis japonica
APOCYNACEAE
__Apocynum androsae◄
__A cannabinum
__A ……..
__Vinca minor
AQUIFOLIACEAE
__*Ilex verticillata*◄
__*Nemopanthus mucro*◄
ARACEAE
__Arisaema triphyllum
__*Calla palustris*◄
__Symplocarpus foetid◄
ARALIACEAE
__Aralia nudicaulis
__*Aralia racemosa*◄
ARISTOLOCHIACEAE
__Asarum canadense◄
ASCLEPIADACEAE
__Asclepias incarnata◄
__A syriaca
__Cynanchum rossicum
ASTERACEAE

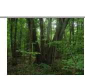
__
Achillea millefolium ...
__Ambrosia artemisiifolia
__Ambrosia trifida
__*Anaphalis margarit*◄
__*Antennaria …………*
__Anthemis cotula
__Arctium lappa
__Arctium minus
__Artemisia biennis
__*A campestris caudat*◄
__A vulgaris
__*A ciliolatus*◄
__A cordifolius
__A ericoides ericoides
__*A laevis*◄
__A lanceolatus
__A lateriflorus
__A macrophyllus◄
__A novae-angliae
__*A ontarionis*◄
__A puniceus
__*A umbellatus*◄
__*A urophyllus*◄
__A x amethystinus◄
__Bidens cernuus
__*Bidens discoideus*◄
__Bidens frondosus
__Bidens tripartitus◄
__Bidens vulgatus◄
__Carduus ...
__Centaurea maculosa
__C ...
__Chrysanthemum leuca
__Cichorium intybus
__Cirsium arvense
__Cirsium vulgare
__Conyza canadensis
__Erigeron annuus
__Erigeron philadelphicus
__E strigosus
__Eupatorium maculatum
__E perfoliatum◄
__E rugosum
__Euthamia graminifolia
__Galinsoga ...
__Gnaphalium ...
__Grindelia squarrosa
__Helianthus annuus
__*H decapetalus*◄
__*H divaricatus*◄
__H strumosus◄
__H tuberosus
__Hieracium aurantiacum
__H caespitosum (praten
__H lachenalii
__H piloselloides
__H ...
__Inula helenium
__Lactuca biennis◄
__L canadensis◄
__L serriola
__Lapsana communis
__Matricaria matricarioide
__M ...
__*Prenanthes alba*◄
__P altissima
__Rudbeckia hirta◄
__R triloba
__Senecio vulgaris
__Solidago altissima
__Solidago caesia
__Solidago canadensis
__Solidago flexicaulis
__Solidago gigantea
__Solidago juncea◄
__Solidago nemoralis
__*Solidago patula*◄
__Solidago rugosa◄
__S ...
__Sonchus arvensis ...
__S asper
__S oleraceus
__Tanacetum vulgare
__Taraxacum officinale
__Tragopogon...
__Tussilago farfara
__Xanthium spinosum
__Xanthium strumarium
BALSAMINACEAE
__Impatiens capensis
__I glandulifera
__I pallida◄
BERBERIDACEAE
__Berberis …
__Caulophyllum gigant◄
__*C thalictroides*◄
__Podophyllum peltatum
BETULACEAE
__Alnus glutinosa
__*A incana rugosa*◄
__Betula allegheniensis◄
__B papyrifera◄
__B pendula
__Carpinus caroliniana◄
__Corylus cornuta◄
__Ostrya virginiana
BORAGINACEAE
__Cynoglossum officinale
__Echium vulgare
__*Hackelia deflexa*◄
__H virginiana
__Lappula squarrosa
__Lithospermum officinal
__Myosotis laxa◄
__M scorpioides
__Symphytum ...
BRASSICACEAE
__Alliaria petiolata
__Arabis ...
__Barbarea vulgaris
__Brassica….
__*Cakile edentula*◄
__Capsella bursa-pastoris
__*Cardamine concaten*◄
__C diphylla◄
__*C douglasii*◄
__C pensylvanica◄
__C x maxima◄
__C ...
__Diplotaxis ...
__Erysimum cheiranthoid
__Hesperis matronalis
__Lepidium ...
__L ...
__Nasturtium microphyllu
__Rorippa palustris ...◄
__Sinapis arvensis (charl
CAMPANULACEAE
__Campanula rapunculoi
__*Lobelia inflata*◄
__*L siphilitica*◄

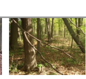
ADDITIONAL SPECIES ACERACEAE TO CAMPANULACEAE

____

____

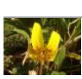




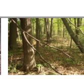


APPENDIX J: FLORA SPECIES CHECK LIST *(page 2)*

CAPRIFOLIACEAE
__Diervilla lonicera◀
__*Lonicera canadensis*◀
__*Lonicera dioica*◀
__Lonicera morrowii
__Lonicera tatarica
__Lonicera xylosteum
__Lonicera x bella
__Sambucus canadensis
__S racemosa pubens
__Symphoricarpos ...
__*Viburnum acerifolium*◀
__V lantana
__V lentago
__V opulus (European)
__V ...
CARYOPHYLLACEAE
__Arenaria serpyllifolia
__Cerastium fontanum
__C arvense ssp. arvense
__Dianthus armeria
__Myosoton aquaticum
__Saponaria officinalis
__*Silene antirrhina*◀
__S pratensis (alba)
__S vulgaris (cucuba
__Stellaria graminea
__S …
CELASTRACEAE
__Celastrus orbiculatus
__*C scandens*◀
__C orbiculatus x scande
__Euonymus europaea
__Euonymus fortunei
__*Euonymus obovata*◀
CERATOPHYLLACEAE
__*Ceratophyllum deme*◀
CHENOPODIACEAE
__Chenopodium album
__C …
__Kochia scoparia
__Salsola ...
CLUSIACEAE
__Amaranthus…..
__*Hypericum ascyron*◀
__H perforatum
__*H punctatum*◀
__*Triadenum fraseri*◀
CONVOLVULACEAE
__Calystegia sepium
__Convolvulus arvensis
CORNACEAE
__Cornus alternifolia
__C foemina racemosa
__C rugosa◀
__C stolonifera
__*C …*
CUCURBITACEAE
__Echinocystis lobata
__*Sicyos angulatus*◀
CUPRESSACEAE
__Juniperus virginiana
__J…
__Thuja occidentalis◀
CUSCUTACEAE
__Cuscuta gronovii◀
__C campestris
CYPERACEAE
__*Carex albursina*◀
__Carex alopecoidea◀
__Carex aquatilis◀
__Carex arctata◀
__Carex aurea◀
__Carex bebbii
__Carex blanda
__*Carex cephaloidea*◀
__*Carex cephalophora*◀
__Carex communis◀
__*Carex comosa*◀
__*Carex crinita*◀
__Carex cristatella
__Carex deweyana◀
__*Carex disperma*◀
__*Carex eburnea*◀
__Carex gracillima◀
__Carex granularis
__Carex hirtifolia◀
__Carex hystericina◀
__*Carex interior*◀
__Carex intumescens◀
__Carex lacustris◀
__*Carex laevivaginata*◀
__*Carex laxiculmis*◀
__Carex laxiflora◀
__*Carex leptalea*◀
__*Carex leptonervia*◀
__*Carex lupulina*◀
__Carex pedunculata◀
__Carex pensylvanica◀
__*Carex plantaginea*◀
__Carex projecta◀
__Carex pseudo-cyper◀
__Carex radiata
__Carex retrorsa◀
__Carex rosea
__Carex scabrata◀
__Carex sparganioides◀
__Carex sprengelii◀
__Carex spicata
__Carex stipata
__Carex stricta◀
__Carex tenera◀
__*Carex utriculata*◀
__Carex vulpinoidea
__C ...
__C ...
__C ...
__C ...
__Cyperus ...
__*Dulichium arundinac*◀
__Eleocharis erythropoda
__E ...
__Eriophorum ...
__Scirpus atrovirens
__*S cyperinus*◀
__*S hattorianus*◀
__S microcarpus◀
__S validus◀
__S ...
DIPSACACEAE
__Dipsacus fullonum sylv
DRYOPTERIDACEAE
__Athyrium filix-femina
__Cystopteris bulbifera◀
__*Deparia acrostichoid*◀
__Dryopteris carthusiana
__*Dryopteris clintonian*◀
__*Dryopteris cristata*◀
__Dryopteris intermedia◀
__Dryopteris marginalis◀
__*Gymnocarpium dryo*◀
__Matteucia struthiopteris
__Onoclea sensibilis
__*Polystichum acrostic*◀
ELEAGNACEAE
__Elaeagnus angustifolia
__E umbellata
__*Shepherdia canaden*◀
EQUISETACEAE
__Equisetum arvense
__E hyemale
__*E scirpoides*◀
__E variegatum◀
__E ...
ERICACEAE
__*Chamaedaphne caly*◀
__Gaultheria ...
__Vaccinium ...
EUPHORBIACEAE
__Acalypha virginica
__Chamaesyce ...
__Euphorbia cyparissias
FABACEAE
__Amphicarpaea bracteat
__Apios americana◀
__Coronilla varia
__Desmodium canadens
__*D glutinosum*◀
__Lathyrus ...
__Lotus corniculatus
__Medicago lupulina
__M sativa ...
__Melilotus alba
__M officinalis
__Robinia pseudo-acacia
__Trifolium pratense
__Vicia cracca
FAGACEAE
__Fagus grandifolia◀
__Quercus macrocarpa◀
__Quercus rubra◀
FUMARIACEAE
__*Dicentra canadensis*◀
__*D cucullaria*◀
GENTIANACEAE
__*Gentiana andrewsii*◀
__*Gentianella quinquef*◀
__*Gentianopsis crinita*◀
GERANIACEAE
__Geranium maculatu◀
__Geranium robertianum
GROSSULARIACEAE
__Ribes americanum
__R cynosbati
__R rubrum
HALORAGACEAE
__Myriophyllum ...
HAMAMELIDACEAE
__*Hamamelis virginiana*◀
HYDROCHARITACEAE
__Elodea…
__*Vallisneria americana*◀
HYDROPHYLLACEAE
__*Hydrophyllum canad*◀
__H virginianum







APPENDIX J: FLORA SPECIES CHECK LIST *(page 3)*

IRIDACEAE
__Iris pseudoacorus
__*I versicolor*◀
__*Sisyrinchium montan*◀
JUGLANDACEAE
__Carya cordiformes◀
__*Juglans cinerea*◀
__J nigra
JUNCACEAE
__Juncus articulatus
__Juncus dudleyi
__Juncus effusus◀
__Juncus tenuis
__J ...
__J ...
__Luzula ...
LAMIACEAE
__Clinopodium vulgare
__Galeopsis tetrahit
__Glechoma hederacea
__Lamium ...
__Leonurus cardiaca
__Lycopus americanus◀
__L europaeus
__L uniflorus◀
__L america x europaeus
__Mentha arvensis
__*Monarda didyma*◀
__M fistulosa◀
__Nepeta cataria
__Prunella vulgaris lan◀
__Scutellaria galiculata
__S lateriflorus
__Stachys ...
LEMNACEAE
__Lemna minor
__*Lemna trisulca*◀
__*Spirodela polyrhiza*◀
__Wolffia ...
LILIACEAE
__Allium tricoccum◀
__Asparagus officinalis
__*Clintonia borealis*◀
__Convallaria majalis
__Erythronium americ
__Hemerocallis…
__*Lilium michiganense*◀
__Maianthemum canad◀
__M racemosum (Smilaci
__M stellatum (Smilacina)
__*Medeola virginiana*◀
__Polygonatum pubesc◀
__Scilla siberica
__*Streptopus roseus*◀
__*Trillium cernuum*◀
__Trillium erectum◀
__Trillium grandiflorum◀
__*Uvularia grandiflora*◀
LYCOPODIACEAE
__*Diphasiastrum digitat*◀
__*D tristachyum*◀
__*Huperzia lucidula*◀
__*Lycopodium annotin*◀
__*L clavatum*◀
__*L dendroideum*◀
__*L hickeyi*◀
__*L obscurum*◀
LYTHRACEAE
__*Decodon verticillatus*◀
__Lythrum salicaria
MALVACEAE
__Malva ...
MENISPERMACEAE
__*Menispermum canad*◀
MONOTROPACEAE
__*Monotropa uniflora*◀
__*Monotropa hypopithy*◀
NYMPHAEACEAE
__*Nuphar variegata*◀
__*Nymphaea odorat…*◀
OLEACEAE
__Fraxinus americana
__F excelsior
__F nigra◀
__F pennsylvanica penns
__F pennsylvanica subint
__Ligustrum vulgare
__Syringa vulgaris
ONAGRACEAE
__*Circaea alpina*◀
__C lutetiana canadensis
__*Epilobium angustifoli*◀
__E ciliatum
__E coloratum◀
__E parviflorum
__E ...
__Oenothera biennis
OPHIOGLOSSACEAE
__*Botrychium virginian*◀
__B ...
ORCHIDACEAE
__*Cypripedium cal. par*◀
__*Ccalceolus pubesce*◀
__Epipactis helleborine
__*Liparis loeselii*◀
__*Platanthera* ...
__*Spiranthes* ...
OROBANCHACEAE
__Epifagus virginiana◀
OSMUNDACEAE
__*Osmunda cinnamom*◀
__*Osmunda claytonian*◀
__*Osmunda regalis*◀
OXALIDACEAE
__Oxalis stricta (europaea
__O …
PAPAVERACEAE
__Chelidonium majus
__Sanguinaria canadens
PINACEAE
__*Abies balsamea*◀
__Larix decidua
__*Larix laricina*◀
__Picea abies
__*P glauca*◀
__P…
__*Pinus resinosa*◀
__P sylvestris
__P strobus◀
__P…..
__Tsuga canadensis◀
PLANTAGINACEAE
__Plantago lanceolata
__P major
__P rugelii
POACEAE
__Agrostis gigantea
__A stolonifera
__A ...
__Alopecurus…..
__*Ammophila breviligul*◀
__*Andropogon gerardii*◀
__*Brachyelytrum erectu*◀
__*Bromus ciliatus*◀
__B inermis
__B latiglumis◀
__*B pubescens*◀
__B …
__Calamagrostis canad◀
__*Cinna* ...
__Dactylis glomerata
__Danthonia spicata◀
__Digitaria ...
__Echinochloa ...
__Elymus canadensis◀
__E hystrix (H patula)◀
__E riparius◀
__E virgininicus
__E ...
__Eragrostis ...
__Festuca arundinacea
__F pratensis
__F subverticillata (obtu◀
__F trachyphylla (longifo
__F ...
__Glyceria grandis◀
__*G septentrionalis*◀
__G striata
__G ...
__Hordeum jubatum
__Leersia oryzoides
__L virginica◀
__*Milium effusum*◀
__Muhlenbergia mex….
__M ...
__Oryzopsis ...
__Panicum acumin….
__P capillare
__*P latifolium*◀
__*P linearifolium*◀
__Phalaris arundinacea
__Phleum pratense
__Phragmites australis
__Poa compressa
__P nemoralis
__P palustris
__P pratensis
__P ...
__Schizachne purpuras◀
__*Schizachyrium scopa*◀
__Setaria ...
__*Sphenopholis interm*◀
__*Sporobolus cryptand*◀
POLYGALACEAE
__Polygala ...

ADDITIONAL SPECIES IRIDACEAE TO POLYGALACEAE

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APPENDIX J: FLORA SPECIES CHECK LIST *(page 4)*

__Polygonum achoreum
__P amphibium◀
__P aviculare
__*P cilinode*◀
__P convolvulus
__P cuspidatum
__P hydropiper
__*P hydropiperoides*◀
__P lapathifolium
__P pensylvanicum◀
__P persicaria
__*P scandens*◀
__Rumex acetosella
__R crispus
__R obtusifolius
__*R orbiculatus*◀
PORTULACACEAE
__*Claytonia caroliniana*◀
__*Claytonia virginica*◀
POTAMOGETONACEAE
__Potamogeton crispus
__*Potamogeton natans*◀
__P pectinatus◀
__P ...
PRIMULACEAE
__Anagallis arvensis
__Lysimachia ciliata
__L nummularia
__*L thyrsiflora*◀
__L ...
__*Trientalis borealis*◀
PTERIDACEAE
__*Adiantum pedatum*◀
__Pteridium aquilinum◀
PYROLACEAE
__*Moneses uniflora*◀
__*Orthilia secunda*◀
__*Pyrola elliptica*◀
__*P …*
RANUNCULACEAE
__Actaea pachypoda◀
__A rubra
__*Anemone acutiloba*◀
__*A americana*◀
__A canadensis
__*A cylindrica*◀
__*A quinquefolia*◀
__A virginiana
__*Aquilegia canadensis*◀
__Caltha palustris◀
__Clematis virginiana
__*Coptis trifolia*◀
__Ranunculus abortivus
__R acris
__*R hispidus caricetoru*◀
__*R pensylvanicus*◀
__R recurvatus
__R repens
__R sceleratus
__Thalictrum dioicum
__T pubescens (polygam
RHAMNACEAE
__*Ceanothus americas*◀
__*Rhamnus alnifolia*◀
__Rhamnus cathartica
__Rhamnus frangula
ROSACEAE
__Agrimonia gryposepala
__*Amelanchier spicata*◀
__A ...
__A.…
__Crataegus macracan◀
__C monogyna
__C pedicillata◀
__C punctata
__C ...
__C ...
__Fragaria vesca
__F virginiana
__Geum aleppicum
__Geum canadense
__Geum urbanum
__Malus pumila
__Potentilla anserina
__P argentea
__P norvegica
__P recta
__P ...
__Prunus pensylvanica◀
__P serotina
__P virginiana
__P ...
__Pyrus communis
__Rosa blanda◀
__R canina
__R multiflora
__R ...
__Rubus allegheniensis
__R ideaus melanolasius
__R occidentalis
__R odoratus
__R pubescens◀
__Spiraea alba◀
__Sorbus aucuparia
__Waldsteinia fragarioi◀
RUBIACEAE
__Galium aparine◀
__G asprellum◀
__*G lanceolatum*◀
__G mollugo
__*G obtusum*◀
__G palustre
__G triflorum
__G verum
__G ...
__*Mitchella repens*◀
SALICACEAE
__Populus balsamifera
__P deltoides
__P grandidentata◀
__P tremuloides
__P …
__Salix alba
__Salix amygdaloides◀
__Salix bebbiana◀
__Salix discolor◀
__Salix eriocephala
__Salix exigua
__Salix fragilis
__*Salix lucida*◀
__Salix petiolaris◀
__Salix x rubens
__Salix x sepulcralis
__S ...
SANTALACEAE
__*Comandra umbellata*◀
SAXIFRAGACEAE
__*Chrysosplenium ame*◀
__*Mitella diphylla*◀
__*Mitella nuda*◀
__Tiarella cordifolia◀
SCROPHULARIACEAE
__Agalinis ...
__*Chelone glabra*◀
__Linaria vulgaris
__Mimulus ringens◀
__*Penstemon …………*◀
__Scrophularia ...
__Verbascum thapsus
__Veronica americana◀
__V anagallis-aquatica
__V officinalis
__V ...
SIMAROUBACEAE
__Ailanthus altissima
SMILACACEAE
__Smilax herbacea
__S hispida◀
SOLANACEAE
__Physalis heterophylla◀
__Solanum dulcamara
__S nigrum
__S ptychanthum
SPARGANACEAE
__*Sparganium eurycar*◀
__*S emersum (chlorcar*◀
STAPHYLEACEAE
__*Staphylea trifoliata*◀
TAXACEAE
__*Taxus canadensis*◀
__T cuspidata
THELYPTERIDACEAE
__*Thelypteris novabora*◀
__T palustris◀
__*Phegopteris connecti*◀
THYMELAEACEAE
__*Dirca palustris*◀
TILIACEAE
__Tilia americana
__Tilia cordata
TYPHACEAE
__Typha angustifolia
__T latifolia◀
__T x glauca
ULMACEAE
__Ulmus americana
__U ...
URTICACEAE
__Boehmeria cylindrica◀
__Laportea canadensis
__*Pilea fontana*◀
__P pumila
__Urtica dioica dioica
__U dioica gracilis
VERBENACEAE
__Phryma leptostachya
__Verbena hastata
__V urticifolia
VIOLACEAE
__*Viola affinis*◀
__*V blanda (incognita)*◀
__*V canadensis*◀
__V conspersa

__V pubescens
__*V selkirkii*◄
__V sororia
__V ...
VITACEAE
__Parthenocissus inserta
__Vitis riparia

APPENDIX K: TREE HEALTH PLOT SET-UP INSTRUCTIONS

1. Locate and mark the south-west corner (referred to as corner "A") of the 20 x 20m plot with 61cm rebar. (**Note:** The placement of this corner is based on site conditions and varies accordingly (i.e. slope, distance to watercourse or trail).

2. From corner "A", set compass to North, obtain a clear sight line and walk a measured distance of 20 m to corner "B". (**Note:** Performed by one crew member. If the sight-line is not clear, marking stakes and flagging tape are used as line markers).

3. Mark corner "B" with rebar (loosely placed into the ground). Verify the position of corner "B" by back-checking the A-B line angle (i.e. corner A should be due south from B).

4. From corner B, adjust the bearing to 90 degrees (east), and obtain the sight line to corner C.

5. Before walking the B-C line, perform a small check is to ensure that the alignment is correct.

   a. Working with crew members, create a small right angle. The following is the trigonometric rule for a right angle:

   $$a^2 + b^2 = c^2$$ *If a = 3 m and b = 4 m, then the hypotenuse, c =5 m.*

   b. Place marking stakes at the 17m location along the A-B and at the 4m location along the B-C line.

   c. Measure the diagonal distance between the two marking stakes (the hypotenuse) with tape. If the hypotenuse is not equal to 5, then the appropriate adjustments are made, until a perfect right triangle is achieved.

   d. After confirming the sight line is accurate, crew members proceed 20m to corner C.

6. Repeat step 5 for both C and D corners. Teams move in a clockwise direction, adjusting the bearing by 90 degrees at each corner point (i.e. compass set to south for the C-D line and west for the D-A line).

7. After all four plot corners and measurements have been verified, firmly hammer the pieces of rebar into the ground. Allow only 3-6 cm to remain above ground (especially where there is pedestrian traffic in the vicinity).

8. To assist in their identification, corner bars are colour coded. Spray paint the southwest corner (corner "A") red and all other corners blue.

9. Geo-reference the "A" post using a Trimble unit in order to record plot location for future visits on data sheet. Appendix A shows a sample data sheet.

APPENDIX L: TREE MAPPING AND TAGGING INSTRUCTIONS

Tree tagging:


Figure 1: Painted tree tag

1. Tree tag numbers begin at the number "one" and increase in sequential order. Each unique tag number for a site is related to a tree species and the corresponding tree data (Figure 1).

2. Move to the south-west quadrant of the plot and identify the tree closest to the corner post "A". This will be the first tree in the sequence (i.e. "1"). Crews work from the perimeter and spiral inwards towards the centre of the plot in a clockwise direction.

3. Using the approved tree paint, mark the appropriate tree number onto the north-facing side of the tree stem at dbh. If preferred, crews may use a paint brush to mark trees rather than the tube nozzle.

4. Flag the tagged tree with some kind of marker or tape in order to keep track of what trees have been done (This is especially helpful for dense forest plots). Remove tape/marker once all trees tagged.

5. Move to the next tree closest to the perimeter and repeat tagging process until all trees within the plot are marked.

6. Walk around plot to ensure that no trees were missed.

7. Return data sheets to file folder and store safely.

8. In office, enter data onto database.

General rule(s):

1. When a tree is multi-stemmed and the branches separate below 1.3 m, each stem that is ≥10 cm dbh is considered to be an individual tree and for that reason is tagged and measured.

2. If the tree is on the boundary line of the plot, it is only tagged and measured if at least half the stump or root collar is inside the quadrat, otherwise it is ignored.

Tree mapping:

In order to relocate each tree in future visits, the A/B distance method of collecting positional tree data is employed in the field. In this method, the length from one corner post to the next is assigned a number and becomes what is known as a reference line. The base reference line is always "Line 1" and originates between posts "A" and "D". From here, line numbers ascend clockwise from corner to corner. For example, the distance between corners A-B is "Line 2" while corners B-C and C-D becomes "Line 3 and 4" respectively (Figure 2). Assigning each side of the quadrat a line-number allows the quadrat corners to act as a reference post from which the exact location of every tree within the plot to be triangulated. To collect distance data a minimum of **two** people are required.

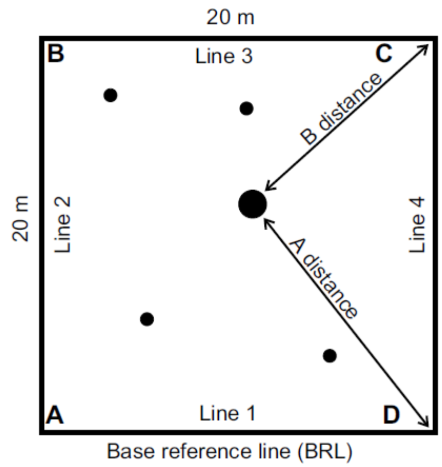

Figure 2. A/B distance method (Roberts-Pichette & Gillespie, 1999)

Using a range finder (comprised of a transponder and a receiver) (Figure 3), two distance measurements, known as the "A" and "B" distances are taken for each individual tree within the plot. The "A" distances are always those taken to the **right** of the tree, while "B" distances are always those taken to the **left** of the tree. Each distance measurement (A or B) value will reference a separate but adjacent corner post from the other. For example, if the **A distance** from tree #100 references the "D" post then the **B distance** will reference the "C" post. Not all trees will use the same reference posts; it is entirely dependent upon the orientation of the tree within the plot. For any given tree, surveyors will use their best judgment to determine the most suitable corner post from which to record a set of distance values. ***Tip:*** *Marking the palm of your right hand with an "A" and that of your left with a "B" can be helpful reminder. For this to work, surveyors must have their back to the tree looking outside the plot.*

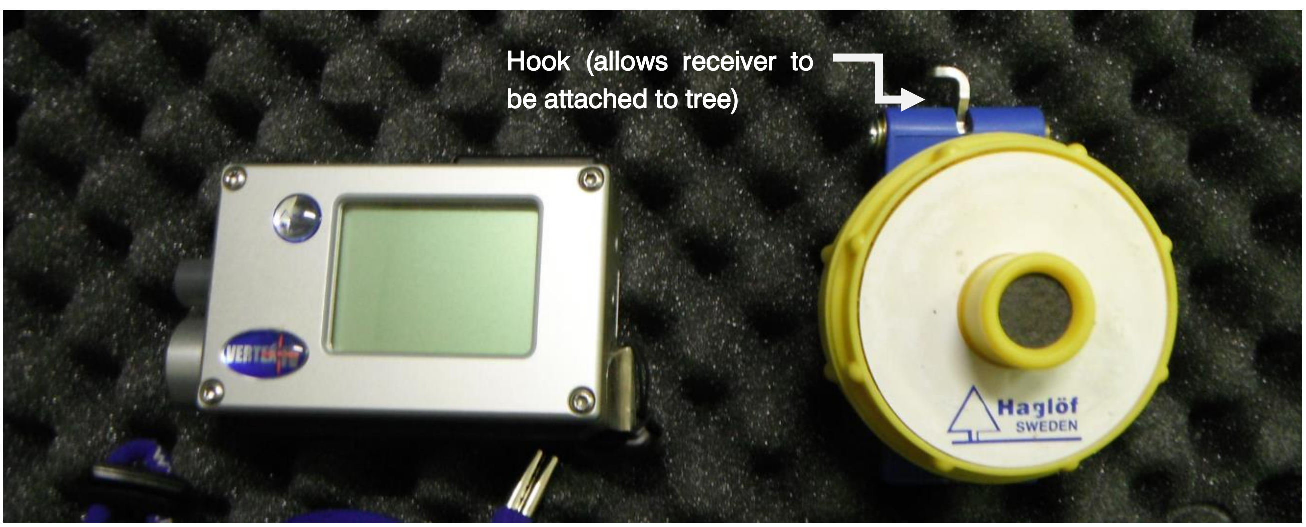

Figure 3: Components of laser range finder; transponder (left) and receiver (right)

1. Start at the lowest numbered tree and advance in numerical order to the last. ***Option:*** *depending on the plot, surveyors may find it quicker to complete a set of "A" distances for a group of trees that use the same reference post before proceeding to next reference post to complete the corresponding set of "B" distances.*

2. Assign one crew member to position the transponder and one crew member to position the receiver. Assign a third crew member as the record keeper is available, otherwise the crew member with the receiver can record.

3. To take the first distance measurement, attach the receiver to a tagged tree and position the transponder over a chosen reference post.

4. Aim the two devices (transponder and receiver) at each other. To ensure accurate reading position the devices such that they are along the same horizontal plane (i.e. level).

5. When ready, press the "shoot' button on the transponder (see user manual for detailed device information). The transponder will measure the distance to the receiver and show the reading on its side.

6. Record this first reading (identify if it is the A or B distance) on the data sheet along with the reference post that it was taken from (i.e. A, B, C or D) and reference line used (i.e. 1, 2, 3, or 4).

7. To get the second distance measurement, move the transponder to an adjacent reference post (i.e. A, B, C, or D).

8. Keep the receiver on the same tree but shift it so that it remains in alignment with the transponder. **Note(s):** *The receiver does not have to be visible (e.g. line of sight is obscured or blocked by another tree) for an accurate reading to be taken*.

9. When ready, press the "shoot" button on the transponder. Record this second reading (identify if it is the A or B distance) on the data sheet along with the reference post that it was taken from (i.e. A, B, C or D) and reference line used (i.e. 1, 2, 3, or 4).

10. To prevent mapping errors, verify each measurement value along with their associated reference post and line number before it is recorded on the data sheet (Appendix B).

11. Repeat this process until the A/B distances for all tagged trees within a plot are obtained.

12. Once complete double check raw data sheets to ensure all data was collected.

13. Return data sheets to file folder and store safely. At office, enter data into the computer using BIOMON software to produce a tree map showing the location of all numbered trees within the plot.

APPENDIX M: SHRUB AND SAPLING REGENERATION SUBPLOT SET-UP INSTRUCTIONS

1. Start at corner "A" of the tree health plot.
2. Walk along one line of the 20 x 20m plot (e.g. Line 1, 2, 3, or 4 in Fig. 2) with a measuring tape.
3. Place a marking stake at the 9 m and 11 m distances respectively.
4. At the 9m marking stake and on a 90 degree angle (i.e. perpendicular to 20 x 20m plot), measure out 1m and 3m respectively. Mark these locations with marking stakes (these will be the first two corners of the subplot.
5. Repeat step 4 for the 11m marking stake (these will be the last two corners of the subplot).
6. Check the angle and orientation of each subplot by running a measuring tape around the subplot. Make adjustments as necessary so that a distance of 2m should be maintained on all sides.
7. Once all adjustments have been made replace the marking stakes with rebar. Hammer the rebar firmly into the ground until only 3-6 cm remains above a ground (especially where there is pedestrian traffic in the vicinity).
8. Spray-paint the subplot corner "A" (the southwest corner) red and the remaining three corners blue. Subplots are not tagged; instead, the subplot number is determined on the basis of its position relative to corner "A" of the 20 x 20 m plot (see Figure 1).
9. Proceed to the next line along the 20 x 20m plot and repeat steps 3-9 until all of the subplots located outside of the forest plots are set-up.
10. The centre plot is set up in a slightly different manner. To begin, have one crew member stand at the 9 m marking stake along any side of the tree health plot boundary (the same ones used in the set-up of the outside subplots).
11. From this point measure across the plot towards the 9 m mark directly opposite them (e.g. from the 9m mark on line 1 to the 9 m mark on line 3).
12. Once complete, ensure the measuring tape bisecting the plot is straight and free of tangles or bends.
13. Next, measure to the 9 m and 11 m points along this bisecting line.
14. Mark these points with marking stakes to define one side of the centre plot.

15. Repeat steps 11-15 at 11m mark (along the plot boundary line) to set up the remainder of the centre plot.

16. Once all four corners of the centre plot are in position repeat steps 7-9 to complete set-up.

17. Remove all marking stakes that exist along the 9m and 11m lines of the forest health plot (20 x 20m).