NATIONAL FOREST HEALTH MONITORING PROGRAM

Maryland and Massachusetts Street Tree Monitoring Pilot Projects

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Northeastern Area
State and Private Forestry
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EXECUTIVE SUMMARY

Urban forests have many components: park trees, small woodlands, riparian buffers, street trees, and others. While some communities conduct city-wide inventories of street tree populations, there has been no comprehensive, statewide sampling to characterize the structure, health, and function of street tree populations. A statewide Street Tree Monitoring pilot study was initiated by the USDA Forest Service, National Forest Health Monitoring Program to help fill data gaps in what is presently known (or unknown) about this segment of urban forests. The objective of the pilot was to demonstrate the feasibility and utility of statewide street tree assessment and monitoring. Results presented within this report document baseline street tree conditions in two comparative studies in Maryland and Massachusetts. Refinement of the methods used in these pilot studies will result in a statewide data collection protocol that can be used to assess and monitor street trees and detect changes in their condition, status, and health.

A protocol similar to National Forest Health Monitoring was followed to implement the pilots—establish a baseline sample, revisit plots on a rotating basis over time, and collect information related to both tree characteristics and tree condition. A concurrent set of pilot studies to enhance data collection on the Forest Inventory and Analysis grid system for non-forest plots in urban areas is also being conducted. These two data collection methods may be used in tandem or singly. State partners participating in the street tree monitoring study expressed the need and preference for a protocol to examine only the street tree population. Time, safety, and cost issues were considerations that favored a street tree study.

Pilot studies were established in Maryland (2001) and Massachusetts (2002) to test street tree sampling methods. Within urban areas, plots were located statewide along public rights-of-way. Street trees were defined as trees growing within that right-of-way. Data on 15 variables were collected to describe each tree's location and condition.

The following report discusses the findings of the pilot studies that were conducted in Maryland and Massachusetts. It summarizes many of the data results collected, while also identifying challenges and opportunities to refine and improve the methods of data collection and replication in other States. Several topics surfaced as issues to be addressed in future protocol refinement. These included:

- Survey design – Survey plots were allocated proportional to the amount of roadways within urban areas, resulting in a survey heavily weighted toward larger urban areas. Although an appropriate method of sampling was used, end users desired more regional information than the survey method allows.

- Definition of right-of-way – The survey was based upon trees within the public right-of-way. The criteria used to identify the right-of-way in the field were somewhat subjective. The right-of-way could be more formally identified through contact with each municipality.

- Tree identification – The pilot studies relied on the ability of survey crews to identify tree species. More formal training and training aids could be provided.

- Tree damage – Forest Health Monitoring damage rating protocols were used. While these protocols were comprehensive, it would be more useful to end users if the damage characteristics were modified to reflect tree care industry standards.

Street tree monitoring can provide valuable data about the most visible segment of the urban forest. Benefits from this monitoring include the following:

- Describing the baseline structure and condition of a State or region's street tree population and monitoring change over time enable State, regional, and national urban foresters to be more strategic in their planning of urban and community forestry programs.

- Exotic pest problems often appear first within urban areas. Inventory information about potential host species (for example, ash and the emerald ash borer, sugar maple and the Asian longhorned beetle) enables pest risk assessment, early detection, and targeting of mitigation strategies.

- Information about specific street tree conditions enables State and regional urban foresters to address issues through public outreach (e.g. 'topping,' species diversity, and damage).
- Establishment of baseline information about street tree conditions provides a mechanism to monitor change and health over time.

Data Highlights	**Maryland**	**Massachusetts**
Estimated number of street trees	643,958	1,184,776
Potential plantable spaces	35/mile	23/mile
Most common street tree	Callery pear	Norway maple
Percent of street trees with sidewalk conflict	18	28
Percent of street trees with wire conflict	18	25
Percent of street trees with dieback	4	7
Percent of street trees with damage	36	29
Most common damage	open wounds	conks and decay

INTRODUCTION

The urban forest can be described as the canopy of tree cover created by shade trees, small woodlots, parks and publicly managed wooded areas, and street or roadside trees within urban areas. Urban areas, using a U.S. Census Bureau definition from 1990, include areas with at least 1,000 people per square mile and those geographically recognized places with at least 2,500 people. Dwyer et al. (2000) estimated that urban areas include about 3.5 percent of the total land area of the coterminous United States, more than 75 percent of the population, and about 3.8 billion trees. Street trees, which were defined as those trees growing along streets and roadways and generally within the public right-of-way, were estimated to comprise 10 to 20 percent of the urban forest, which could translate into between 380 million and 780 million trees.

Forest assessments are a periodic function of the USDA Forest Service, Forest Inventory and Analysis Program. Specific information about the status and trends of urban forests, however, is lacking, and this pilot, together with a sister pilot known as Urban Forest Inventory and Analysis, fills an important information gap.

The Street Tree pilot was initiated by the USDA Forest Service, National Forest Health Monitoring Program, to help fill data gaps in what is presently known (or unknown) about one segment of urban forests. A protocol similar to National Forest Health Monitoring was followed to implement the pilots—establish a baseline sample, revisit plots on a rotating basis over time, and collect information related to both tree characteristics and tree condition.

The pilot demonstrates the acquisition of information about street tree populations and characteristics of that population. This information can be used for overall urban forestry program management and policy direction, particularly since street trees are often the centerpiece of those programs and normally fall under the management of local government jurisdictions. In highly urban areas, street trees are a major component of the urban forest. In Chicago, for example, street trees account for 1 in 10 trees, while in urban residential areas that increases to 1 in 4 (Nowak 1994). The underlying premise in the Street Tree pilot, then, is that the more we know about the nature of the street tree population and the trends and factors affecting it, the more effective we can be in managing this important, visible, and valuable resource.

The objective of the pilot was to demonstrate the feasibility and utility of statewide street tree assessment and monitoring. Results presented within this report document baseline street tree conditions. Refinement of the methods used in these pilot studies will result in a statewide data collection protocol that can be used to assess and monitor street trees and detect changes in their condition, status, and health.

This report discusses the findings of the pilot studies that were conducted in Maryland and Massachusetts. It summarizes many of the data results collected, while also identifying challenges and opportunities to refine and improve the methods of data collection and implementation in other States.

METHODS

Pilot studies were established in Maryland and Massachusetts to test urban street tree sampling methods. Roadside trees in both States were sampled to provide information on the health and structure of the forest resource. The pilot study included trees within the public right-of-way along roads in urban areas. The 1990 census was used to develop boundaries of urban areas (colored as pink in map 1). Urban areas were defined as the combination of urbanized areas (population of 50,000 or more and a minimum of 1,000 people per square mile) and urban places (incorporated or unincorporated places with at least 2,500 people).

Within the urban areas, plots were located statewide along public rights-of-way. Geographic Information System (GIS) software was used to link all roads and divide the roads into segments. Road segments were obtained from 1995 TIGER (Topologically Integrated Geographic Encoding and Referencing System) road files. Segments were then selected from the total population of urban road segments using a random sample with a systematic start. Over 14,000 miles of urban roads exist in Maryland, while in Massachusetts there are over 20,000 miles of urban roads. Private roads, interstate highways, and divided highway segments were removed from the population and were not sampled.

Street trees are defined as trees growing in public rights-of-way. Although these trees may only comprise a small percentage of the total urban forest, they are the most visible trees in a community, readily accessible, and are most often managed and cared for by public agencies.

Plots were installed without permanent markers or monuments. Notes were included for locating plot start locations with azimuths and distances to known objects. Four subplots were used, each measuring 10 feet by 181 feet. This 1/24-acre subplot configuration corresponds to the current National Forest Health Monitoring plot size, while accommodating the linear nature of rights-of-way. The first subplot was installed at a random distance from the plot start point (beginning of a road segment as defined in the TIGER files). Random distances were assigned prior to the crew arriving in the field. The first subplot was established on either the south or the west side of the road. The second subplot was started 72 feet from the end of the first plot, on the same side of the road. The third and fourth subplots were installed directly across the road. In cases where a median with vegetation was present, plots were installed on the median. Accommodations were made for cul-de-sacs and other special circumstances. A manual detailing the plot setup and variable collection was developed (Twardus et al. 2002). Crews were trained each spring on plot setup and data collection methods by USDA Forest Service and State personnel. Data were collected during the summer using either paper, personal data recorders (PDRs – specifically designed for field data collection), or personal data assistants (PDAs – generally available, hand-held computers).

Information was collected to describe the subplot. Basic location information, such as plot number, road name, county, and city, was recorded. In addition, one of three land uses was assigned to the plot (residential, industrial, or commercial); one of four road types was assigned (Federal, State, county, or municipal); and the posted road speed and plot accessibility were noted.

Information about right-of-way width; percent ground cover (pavement, vegetation, or pervious material-not vegetation); and the presence of trees in the subplot was also recorded. Since adjacent trees that are not in the right-of-way can significantly influence the roadside environment, thus functioning as street trees, the length of the subplot intersected by adjacent trees was recorded.

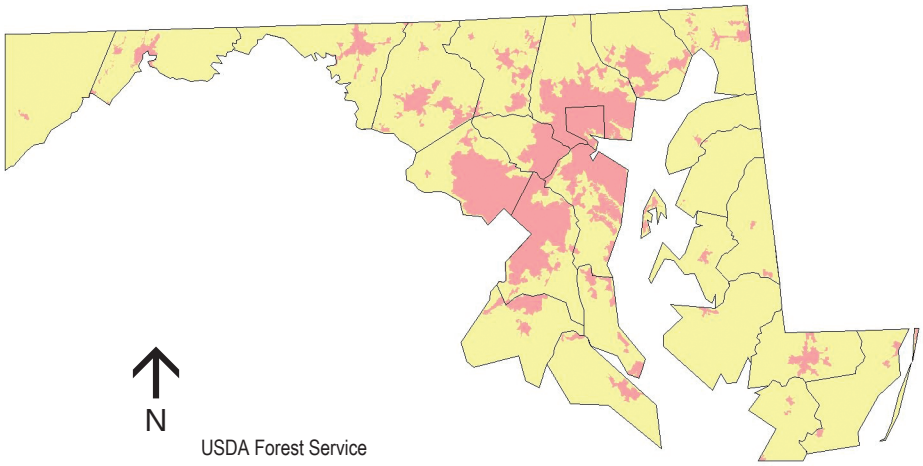
Within the subplot, data on 15 variables were collected to describe each tree's location and condition. These data included physical descriptions of the trees (species, diameter, height, and crown dimensions); and specific descriptions of the crown condition, damage types, and damage locations. Conflicts between tree roots and sidewalks and tree crowns in overhead wires were noted.

In both Maryland and Massachusetts, a subsample of plots is being remeasured each year to demonstrate the value of the pilot in terms of monitoring change. Some measurements (crown condition and damage, for example) are particularly useful when viewed

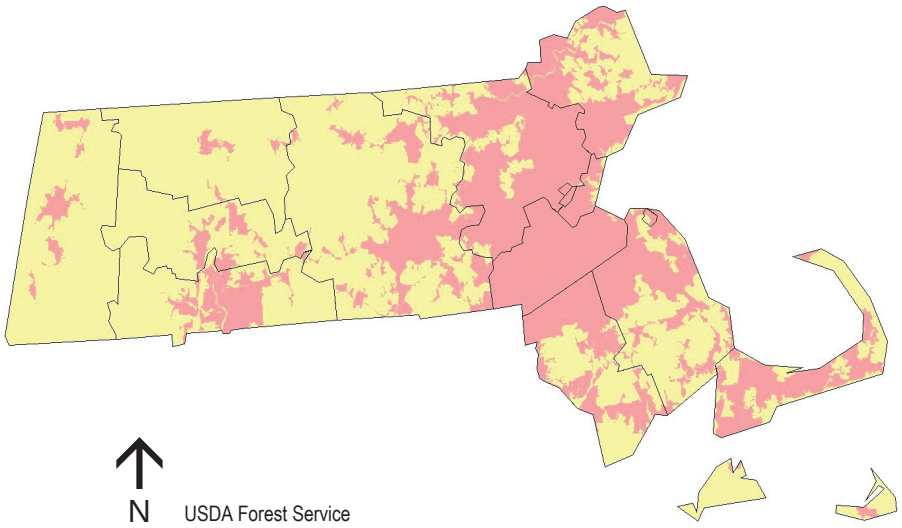
over time to detect changes that may be occurring within the street tree population. A rotating panel with overlap design was used to establish plot revisits. This aspect of the pilot will be complete in Maryland in 2005 and in 2006 in Massachusetts. At that point, all plots will have been revisited once.

Map 1. Maryland and Massachusetts urban areas.

Maryland Urban Areas



Massachusetts Urban Areas



Methods: Considerations for Replication

Returning to plot locations not permanently marked does necessitate that procedures to carefully record plot starting and center points be followed. Occasional problems were encountered in exactly relocating plots, indicating that more effort needs to be made in providing location information. In addition, data collection procedures were modified after the first year of the pilot to consider the addition of new street trees that might be planted between first and subsequent visits.

The pilot defined street trees as trees growing within the right-of-way. This definition made it necessary for field crews to delineate the right-of-way prior to establishing a plot. In the pilot, a set of rules was used to delineate right-of-way. These rules were: a tree lawn (that area between the curb and sidewalk), the area between expansion joints of a driveway and the curb, the area between utility boxes or utility poles and the curb, the area between and including drainage conveyances and the curb, the area between fire hydrants and the curb, and the area between a private fence line and the curb or road edge.

The right-of-way has a legal definition that varies by community and sometimes by roadway or even within portions of roadways. Figures 1 and 2 illustrate that right-of-way width, as delineated in the field, could range from zero to more than 10 feet. While the lack of right-of-way may be suspicious, figure 1 illustrates that, in some cases, when the field crews used the rules they were provided, an apparent right-of-way of minimal or non-existent width could result. Whether or not this is the actual legally defined right-of-way was identified as a concern. Resolving this concern would require considerably more time and effort on the part of the field crew. The decision was made to continue using the field rules for identifying right-of-way, recognizing that in some cases an error may occur, but that generally the rules were a legitimate method of establishing a consistent street tree population.

Figure 1. Width of right-of-way, Maryland 2001

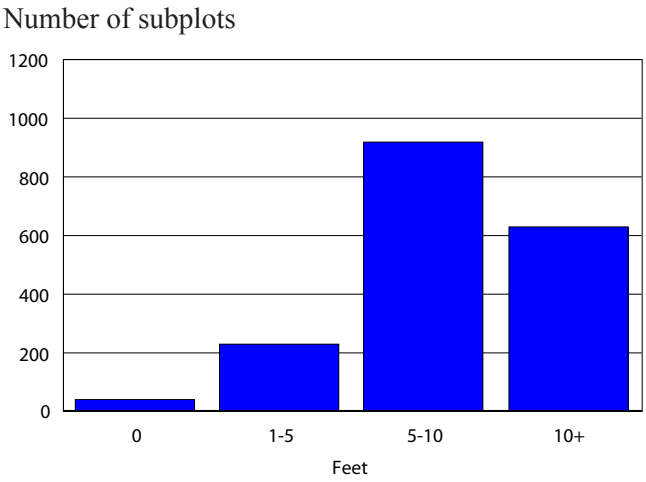
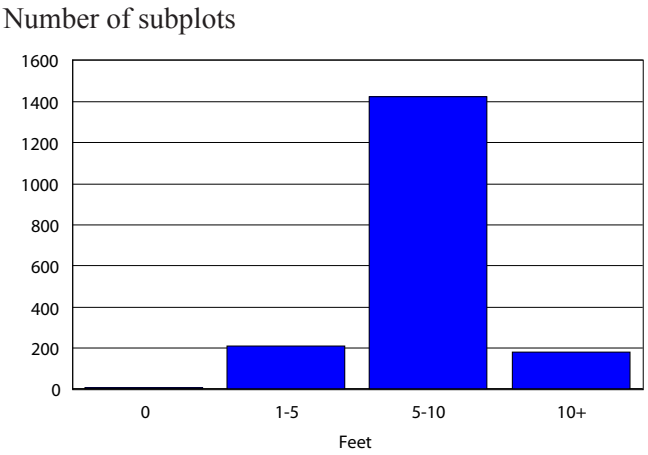


Figure 2. Width of right-of-way, Massachusetts 2002



One addition to the right-of-way rules can be recommended. When no apparent right-of-way is discernible using the provided rules, the right-of-way should be established as 10 feet from the curb or curb-like structure. This simple addition to the rule set includes trees that, while possibly not within a legally defined right-of-way, still function as street trees. This may result in some privately owned trees being included in the sample.

Plot Establishment

Maryland plots were established statewide in 2001. Massachusetts plots were installed during the 2002 field season. Each State established and visited a full set of plots (300) during the first field season. If a plot was inaccessible due to permission issues (private road not previously identified), safety concerns (high traffic or crime area), or other reasons (water), the plot was dropped or replaced with a new plot in a different location. Due to plot access issues and other safety concerns, Maryland established 286 plots (table 1), and 296 plots were created in Massachusetts (table 1). Since urban roadways were used as the population from which sample plots were drawn, plot locations were selected at random, but with a probability proportional to the amount of urban roadway within urban areas. This resulted in regions of the State that had fewer or smaller urban areas having fewer plots. Eighty percent of the plots in Maryland fell within the heavily urbanized Baltimore/Washington DC corridor and 34 percent of the Massachusetts plots occurred in the North Shore/Boston area. Map 2 on page 8 illustrates the regions listed for each State in tables 2a and 2b.

Table 1. Number of plots and total number of trees sampled, by State

State	Number of plots	Total number of trees sampled
MD	286	883
MA	296	1,124

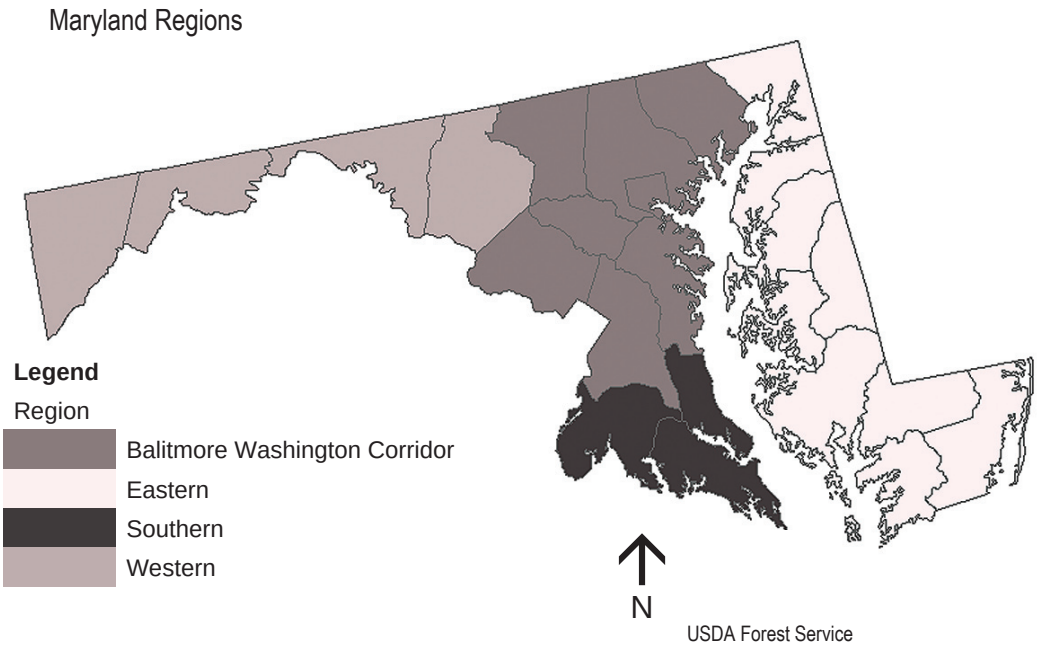
Table 2a. Maryland plot distribution and trees per plot

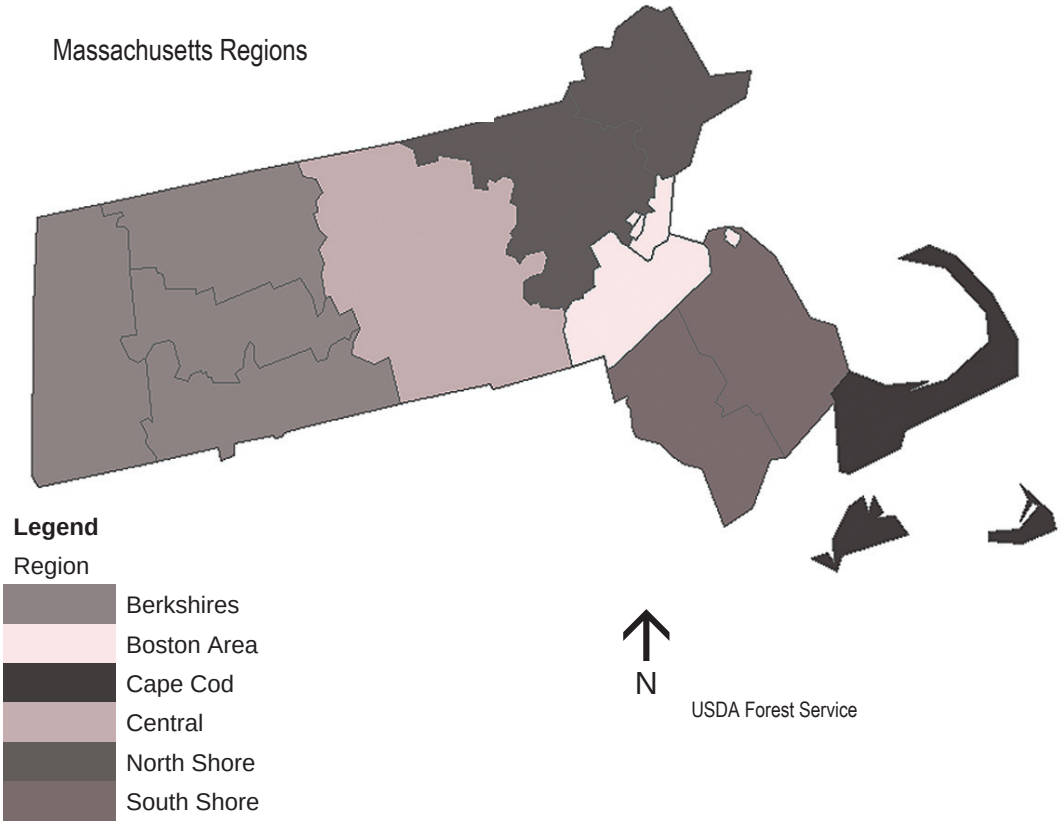
Region	Number of plots	Average number of trees per plot	Std error of mean	Lower 67% CL for mean	Upper 67% CL for mean
Baltimore/Washington Corridor	242	3.47	0.33	3.14	3.79
Eastern	14	1.64	1.26	0.37	2.91
Southern	8	0.25	0.16	0.08	0.42
Western	22	0.89	0.59	0.30	1.48
Total	286	3.07	0.29	2.79	3.36

Table 2b. Massachusetts plot distribution and trees per plot

Region	Number of plots	Average number of trees per plot	Std error of mean	Lower 67% CL for mean	Upper 67% CL for mean
Berkshires	44	3.18	0.70	2.49	3.87
Boston Area	46	2.61	0.72	1.90	3.31
CapCod	21	4.90	1.77	3.14	6.67
Central	46	4.67	0.85	3.84	5.51
Northshore	102	4.15	0.71	3.45	4.85
Southshore	37	3.32	1.00	2.34	4.31
Total	296	3.89	0.38	3.53	4.26

Map 2. Sampling regions in Maryland and Massachusetts. The number of plots per region is listed in tables 2a and 2b.





RESULTS AND DISCUSSION

Statewide Street Tree Population Estimates

Trees occurred on fewer than half of all plots in both Maryland (127 plots) and Massachusetts (146 plots). In Maryland, 883 trees were measured. In Massachusetts, 1,124 trees were sampled (table 1). An estimate of the total miles of urban roadways within each State and the occurrence of trees within our sample plots were used to estimate the number of trees per mile and to calculate an overall estimate of the total street tree population. It was calculated that along Maryland's 14,139 miles of urban roadway, there are an estimated 643,958 trees, or 46 trees per mile. In Massachusetts, the 20,384 miles of urban roads are lined with an estimated 1,184,776 trees or about 58 trees per mile (table 3).

Sometimes the crowns of trees growing adjacent to the right-of-way extend over it, shading and essentially functioning as a street tree. In order to accurately assess the available planting space within the right-of-way, adjacent trees with crowns overlapping the right-of-way were taken into account. Results indicate that 38 percent of Maryland's rights-of-way and 49 percent of Massachusetts' are shaded by trees within the right-of-way or adjacent trees large enough to shade the right-of-way (table 4). Trees growing directly within the right-of-way accounted for about one-third to one-fourth of the canopy. Trees growing on adjacent private property contribute significantly to the structure and function of the roadside tree canopy.

Since plot establishment was not dependent on the presence of trees, the pilot study was able to determine potentially available planting spaces. Available planting space was determined by factoring an accepted planting space between trees (50 feet), knowing what proportion of the roadways does not currently have street trees, and taking into consideration trees adjacent to the public right-of-way with crowns that overlap the right-of-way and essentially function as street trees.

Table 3. Statewide estimates for total number of street trees

State	Estimate of total number of urban street trees, statewide
MD	643,958
MA	1,184,776

Table 4. Percent of right-of-way (ROW) with tree cover, by State

State	Percent tree cover in ROW	Percent ROW tree cover of adjacent trees	Total percent ROW tree cover, including adjacent trees
MD	11	27	38
MA	13	36	49

In Maryland, the potential for planting would almost double the number of street trees present, while in Massachusetts, available planting space would increase the number of street trees by roughly 30 percent (table 5). This potential planting space is, however, contingent upon conditions within the right-of-way, for example, the amount of hardscape, including driveways, sidewalks, and other impervious surfaces (table 6).

Hardscape in the right-of-way can be a driveway apron or sidewalk. The amount of hardscape within the right-of-way can affect plantable space depending upon the location. The presence of a sidewalk, occupying a portion of the right-of-way, may not limit plantable space if a tree lawn exists within the right-of-way. Data were not collected in a manner sufficient to refine potential plantable space with respect to hardscape area within the right-of-way.

Table 5. Trees per mile and plantable spaces per mile, by State

State	Miles of urban roadway	Trees per mile	SE of the mean-trees per mile	Plantable spaces per mile
MD	14,139	46	4.4	35
MA	20,384	58	5.7	23

Table 6. Average right-of-way width and ground cover, by State

State	Average width of ROW	Hardscape	Veg. Cover	Bare Soil
MD	9.3 ft	44%	54%	2%
MA	7.8 ft	41%	51%	8%

Composition of the Street Tree Population

Diversity is a crucial characteristic of any ecosystem. A forest population that is genetically diverse and forest communities that are diverse in structure have high species richness and species evenness (members of each species are distributed spatially) and tend to be more resilient to changes in conditions and, therefore, more stable over time (Kimmins 1997). Santamour (1990) states that while the 10-20-30 rule (no more than 10 percent of one species, 20 percent of one genus, and 30 percent of any one family be planted within a city's landscape) may seem reasonable, it does not address the realities of host-pest relationships. Raupp (2003) further explains that many plant-feeding insects specialize at the level of genus or family, thereby making the "10 percent of one species" rule ineffective. Both Raupp and Santamour encourage urban foresters to consider species diversity at classification levels higher than genus.

With the devastating effects of Dutch elm disease, chestnut blight, and gypsy moth still evident, managers need to look to the future. Diversity in street trees is especially critical in light of recent exotic pest infestations confronting urban forests, namely the Asian longhorned beetle and the emerald ash borer.

While diverse urban tree populations help buffer losses from disease and pest infestations, they also increase the value of the resource in terms of structure and function. Many types and sizes of trees are needed to maximize the multiple functions of the urban forest. Larger trees are able to absorb and sequester more carbon than smaller trees, and likewise, remove larger quantities of pollutants (Nowak et al. 2002). Smaller trees coexist well with infrastructure like sidewalks and overhead wires, but still offer cooling, beauty, and pollution absorption and removal benefits. To gain the greatest benefit from urban trees, the urban forest, including street trees, must have a full assortment of healthy species, genera, and families to maintain pest and disease resilience as well as provide the many beneficial functions of an urban forest.

Maryland

The 2001 pilot study found that Maryland's street tree population contained 67 different species, none comprising more than 13 percent of the total population (table 7). Species diversity at the genus level showed 32 different genera, with over 70 percent of the trees falling into only 5 genera (table 8). Finally, Maryland's roadside trees are made up of 23 unique families with 60 percent of the trees being members of only two plant families—the "maple" and "rose" families (table 9). While diversity at the species level in Maryland seems to conform to the recommended "10 percent" rule, further examination of the genus and family diversity shows that the trees on Maryland's roadsides are not as diverse as first appears. To minimize potential risks from insect and disease, diversity at these higher classifications should be increased.

Table 8. Ten most frequent genera found on Maryland's urban roadways

Genus	Percent of Total
Acer	38
Pyrus	13
Quercus	8
Prunus	7
Platanus	5
Fraxinus	3
Gleditsia	3
Malus	3
Tilia	2
Rhus	2

Table 7. Ten most frequent species found on Maryland's urban roadways

Species	Percent of total	Mean DBH (inches)
Callery pear	13	9
Red maple	11	13
Maple species*	10	10
Norway maple	6	11
Silver maple	5	13
Cherry plum	3	6
Oak species*	3	16
Crabapple	3	10
Honey locust	3	12
Sweetgum	2	8
* Crews unable to determine species.		

Table 9. Ten most frequent families found on Maryland's urban roadways

Family	Percent of Total
Aceraceae	38
Rosaceae	22
Fagaceae	8
Platanaceae	5
Oleaceae	3
Fabaceae	3
Tiliaceae	2
Anacardiaceae	2
Hamamelidaceae	2
Ulmaceae	2

Massachusetts

Lack of diversity in Massachusetts' street tree population is striking at the species level. With a total of 66 different species, Norway maple clearly dominates the population, making up 34 percent of all species (table 10). The size of these trees (average diameter of 15 inches) indicates that the trees were planted some time ago and possibly in response to a large-scale street tree planting effort resulting from the effects of Dutch elm disease.

Following the line of diversity up to the genus level, Massachusetts' street trees represented 29 different genera, with over 50 percent of all trees falling into only two: maple and oak (table 11). At the family classification level, Massachusetts' roadside trees came from 17 distinct families, with 65 percent of trees occurring in two families (table 12).

Overall, the street tree population in both States is dominated by the genus *Acer* with nearly 50 percent of the trees in Massachusetts and 40 percent of the trees in Maryland being Norway, sugar, red, silver, or other maple species. This pattern has implications for insect or disease problems that could cause significant losses in street tree populations. For example, the recently introduced Asian longhorned beetle, which is known to attack and kill at least six species of *Acer*, could have a devastating effect on the street tree population. Other examples of pests include the gypsy moth that affects species within *Quercus*, the emerald ash borer that affects species of *Fraxinus*, and Dutch elm disease affecting species of *Ulmus*. This latter example is one of the more striking examples of an introduced pathogen dramatically affecting the urban street tree landscape simply because the genus *Ulmus* had been heavily favored as a street tree. From a pest standpoint, diversity at the family level is preferable to minimize widespread impacts from either native or exotic pests.

Table 10. Ten most frequent species found on Massachusetts' urban roadways

Species	Percent of total	Mean DBH (inches)
Norway maple	34	15
Red maple	9	12
Northern red oak	8	16
Callery pear	4	6
Pitch pine	4	8
White ash	3	19
Black oak	3	9
White oak	3	15
Sugar maple	3	18
Silver maple	3	25

Table 11. Ten most frequent genera found on Massachusetts' urban roadways

Genus	Percent of Total
Acer	49
Quercus	15
Pinus	7
Fraxinus	5
Pyrus	4
Prunus	3
Betula	3
Tilia	2
Robinia	1
Gleditsia	1

Table 12. Ten most frequent families found on Massachusetts' urban roadways

Family	Percent of total
Aceraceae	49
Fagaceae	16
Pinaceae	9
Rosaceae	7
Oleaceae	5
Fabaceae	3
Betulaceae	3
Tiliaceae	2
Ulmaceae	1
Platanaceae	1

Forests vs. Street Trees

Forest Inventory and Analysis data for Maryland and Massachusetts were used to compare street tree populations with forested areas of both States. Street trees are not included within FIA estimates of forest land conditions, so to calculate the total number of trees for the State as a whole, the estimates of street tree numbers obtained from this pilot would be additive (table 13).

Of the most common species found within the street tree population, five (red maple, northern red oak, white oak, black oak, and sugar maple) are among the most common species found within forests of Massachusetts, and three (red maple, oak species, and sweetgum) are found in forests of Maryland (table 14 and table 15).

Red maple is a predominant species found in forests and along roadways in both States. Norway maple, a potentially invasive species that is dominant as a street tree in Massachusetts, has not yet appeared to have invaded the forest environment (table 14).

Species Identification: Considerations for Replication

The identification of tree species encountered by field crews was an important aspect of the successful implementation of the pilot. Although personnel experienced in tree identification collected the data, the occurrence of horticultural varieties and exotic species sometimes confused field crews to the extent that only a genus categorization could be made.

During the first year of the pilot, field crews were instructed to use FIA tree codes for data entry. Due to the horticultural varieties and exotic species encountered, the tree identification coding system was switched to one based upon the Plants Database (USDA NRCS 2004). It is thus recommended that replication include training for field crews in varietal and exotic tree identification and that a standard tree list be used for coding.

Table13. Estimated number of street trees and forest trees by State

State	Estimate of number of Street Trees (greater than 1")	Estimate of number of forest land trees (1" and greater)
MD	643,958 +/- 9%	1,519,503,000 +/- 3%
MA	1,184,776 +/- 9%	1,754,722,000 +/- 3%

Table 14. Comparison of street tree and forest tree species in Maryland

Species	% of total street tree population	% of total forest population
Callery pear	13	Not Available
Red maple	11	17
Other Maple species	10	13
Norway maple	6	<1
Silver	5	<1
Ornamental cherry	3	Not Available
Oak species	3	11
Crabapple	3	Not Available
Honey locust	3	<1
Sweetgum	2	10

Table 15. Comparison of street tree and forest tree species in Massachusetts

Species	% of total street tree population	% of total forest population
Norway maple	34	<1%
Red maple	9	22
Northern Red Oak	8	5
Callery pear	4	Not Available
Pitch pine	4	2
White ash	3	3
Black oak	3	3
White oak	3	2
Sugar maple	3	5
Silver maple	3	<1

Native, Exotic, and Invasive Street Trees

Describing and tracking numbers of invasive, exotic, and native trees within an ecosystem gives natural resource managers vital information and guidance for management and maintenance. Invasive species, by definition, cause harm or damage to an ecosystem. Exotic versus native species of trees will provide habitat, food, and nesting sites for sometimes vastly different fauna and/or insect groups.

In both Maryland and Massachusetts, there are considerably more native than exotic species occurring throughout the street tree landscape (figures 3 and 4). In terms of numbers of trees, however, the exotic Norway maple dominates the street tree landscape in Massachusetts, and Callery pear is the most common street tree in Maryland. Both of these trees are considered to be invasive and pose potentially detrimental consequences for adjacent forested environments. For purposes of this study, invasive species included both native and introduced trees.

Figure 3

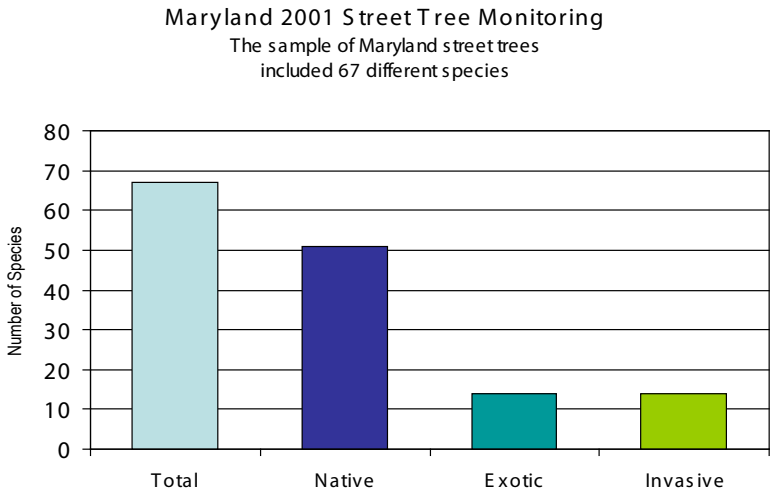
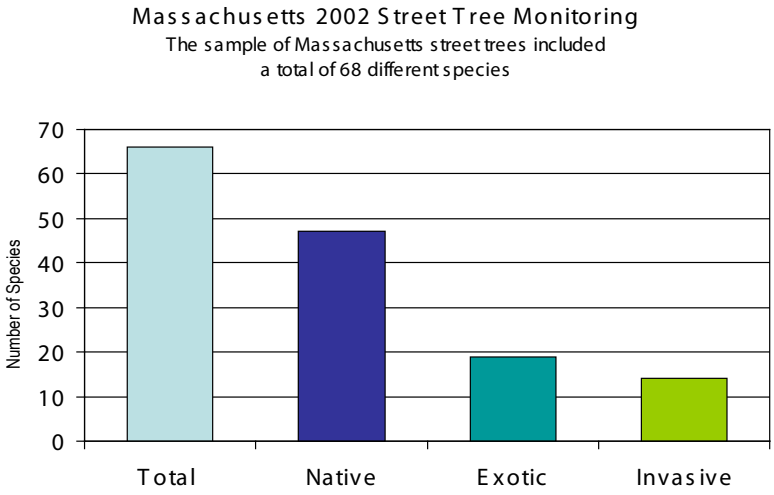


Figure 4



Tree Diameter

Tree diameter is a measure that is easily collected by field crews without causing injury to the tree. Diameter measurements can be used to estimate tree age. Since each species has a finite life expectancy, diameter measurements can be helpful to gauge approximate life stage of street trees (young, mature, old) and prescribe the appropriate management regime. Knowing the age of the street tree population allows managers to estimate costs of maintenance, eventual removal, and replanting.

Tree size distribution as reflected by diameter class distribution indicates that street tree populations in Maryland are relatively well distributed with the largest proportion of trees falling within the 5- to 15-inch diameter classes (figure 5). In Massachusetts, larger trees (15 inches and greater in diameter) constitute about 50 percent of the total, indicating a somewhat older or maturing street tree population (figure 6).

In both States, some of the more common street trees are trees with large growth habits – maples, oaks, ash, and sweetgum. While the larger trees are aesthetically pleasing, offer shade, and positive effects in terms of temperature moderation and air filtration, trees with large growth habits planted as street trees also pose greater potential risks as hazard trees as they age and can conflict with overhead utility wires.

Figure 5

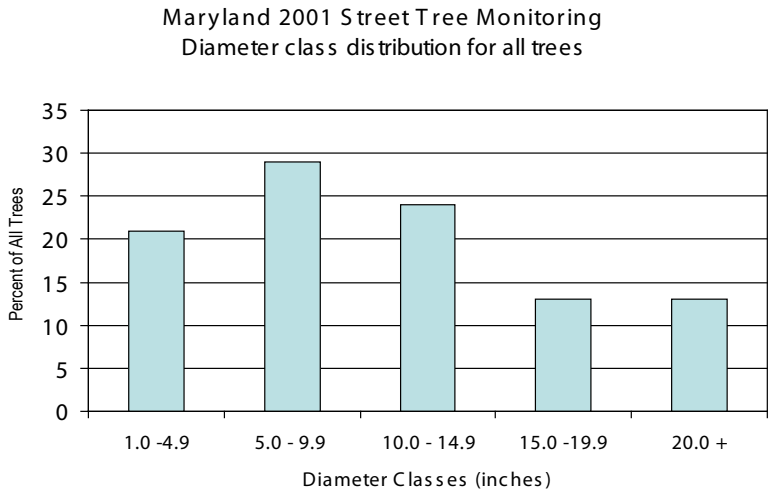
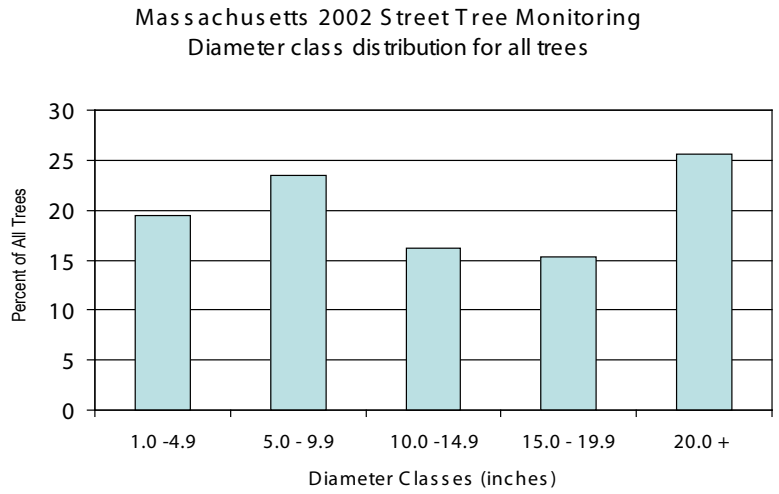


Figure 6



The Largest Street Trees

Figures 7 and 8 show the most frequently occurring species in each State. For all trees of a species, the bars indicate the proportion of trees within each diameter class. If tree diameter is taken as a surrogate indicator for age, an ideal age structure for an urban forest has a high proportion of small (or young) trees that will offset establishment-related mortality (Richards 1982). Nowak et al. (2004) found that the overall mortality rate for the city of Baltimore, MD, of 6.6 percent was dependent on four factors, including tree size. Smaller trees had significantly higher mortality. Size structure of the urban forest influences both present and future maintenance costs as well as benefits derived from tree canopies. Urban forests composed of a variety of size (age) classes allow costs for maintenance to be uniformly spent over time and provide continuity in tree canopy and forest function (Peper et al. 2004). Species selection should be a factor in planning. Larger maturing trees should be considered, maintained, and replanted.

Of the 10 most common species in Maryland, 6 have the potential to be large, tall trees at maturity (maples, locust, and oaks). Four of these six have size classes containing nearly 40 percent of the individuals of that species. Although the size classes are not the same for the four species, significant canopy losses will occur as these trees age and decline (table 7 and figure 7).

The common trees in Massachusetts are comprised of older trees (figure 8). Over 60 percent of the silver maples and nearly 60 percent of the white ash have diameters 20 inches or greater. One would likely expect significant loss of these species in the near future. Large trees provide the maximum benefits and ecosystem function. A replacement and planting regime should include trees appropriate for use under utilities (small at maturity) as well as large maturing trees in appropriate locations.

Figure 7

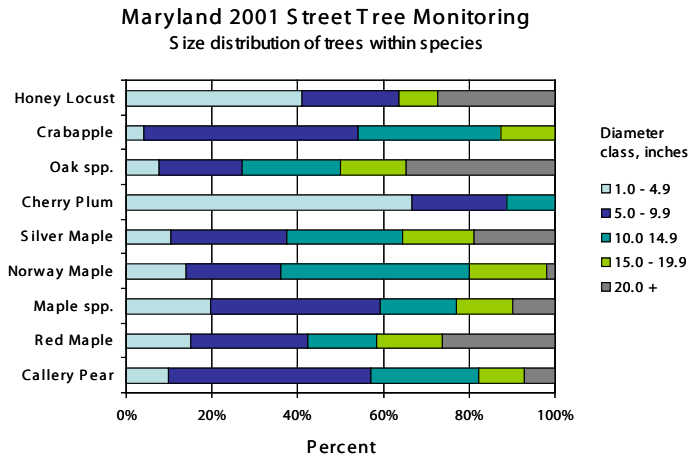
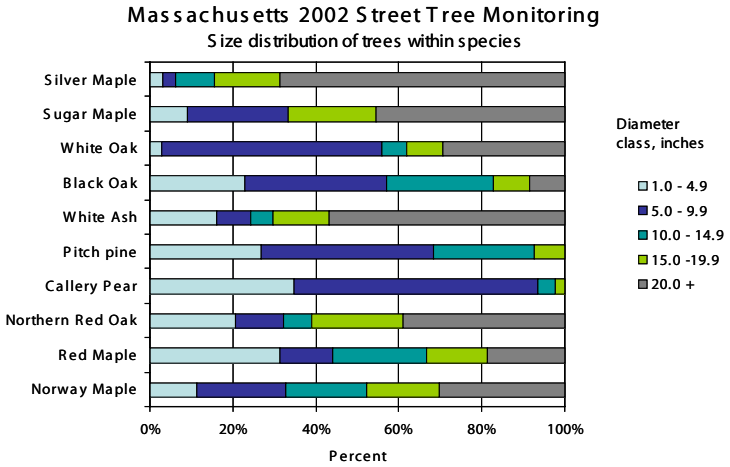


Figure 8



Sidewalk and Wire Conflicts

As previously noted, trees growing along roads provide many benefits. However, trees in this public space are of special concern with respect to conflicts with overhead wires (electric, telephone, etc.) and ground-level hardscape (sidewalks, parking lots, etc.). Trees are perceived to be a major threat to electrical utility reliability. Utility companies spend more than $1.5 billion annually to prune and trim trees around electrical wires (Goodfellow 1995). Likewise, repairs to sidewalks, curbs, and other paved surfaces due to tree damage are estimated at more than $135 million annually in the U.S. (McPherson and Peper 1995). Data collected from the pilot study will help State and regional programs to manage and better integrate trees along the roadside with much-needed utility and hardscape infrastructure.

While large street trees are aesthetically pleasing in terms of how they shade the roadway and sidewalk, they often can present additional management concerns such as pruning or interference with sidewalks and overhead wires. For the purposes of this study, sidewalk conflicts were identified when there was visible heaving or breaking of the sidewalk adjacent to the tree. Likewise, overhead wire conflicts were noted when tree branches were directly adjacent to the wires. The Massachusetts street tree population, with a generally larger (and probably older) proportion of trees than in Maryland, also demonstrated a higher incidence of sidewalk conflicts: 28 percent and 18 percent, respectively. Similarly, 25 percent of Massachusetts street trees were described as conflicting with overhead wires, compared to only 18 percent in Maryland (table 16).

Large street trees can be aesthetically pleasing, but require special planning and maintenance when overhead wires are present.

Table 16. Incidence of sidewalk and overhead wire conflicts

State	Sidewalk Conflict	Wire Conflict
MD	18%	18%
MA	28%	25%

Crown Conditions

The tree crown is an important component of tree health. Large, dense crowns are associated with vigorous growth. Crowns with twig and branch dieback suggest unfavorable conditions, such as competition from other trees, moisture stress, chemical damage, insects, or disease.

Crown dieback is measured as dead branches and branchtips on the outer and upper portions of the tree crown. Crown dieback in the 0 to 5 percent class reflects a healthy tree, while crown dieback above 30 percent in hardwoods and 20 percent in conifers suggests these trees will most likely die within 1 year (Steinman 1998).

In Maryland, 4 percent of trees sampled showed signs of crown dieback in excess of 30 percent, and in Massachusetts, 7 percent of sampled trees exceeded the warning signs for dieback (table 17). Some species, as a group, showed signs of this moderate to severe dieback (>30 percent). In Maryland, these species were American holly, sycamore, maple (non-specific), and Norway maple. In Massachusetts, species showing serious dieback (>30 percent) included eastern hemlock, eastern white pine, Norway maple, sugar maple, and white ash.

Crown density is a measurement of the fullness of the tree crown. For both hardwoods and conifers, trees with less than 30 percent crown density are indicative of stress, which may result in tree death (Steinman 1998). In Maryland, 11 percent of trees were found to be in this category, while 14 percent were found in this category in Massachusetts (table 18). In Maryland, trees most commonly found with poor crown densities (<30 percent) included crabapple and maple species, including red and silver maples. In Massachusetts, trees most commonly found with poor crown densities included yellow birch, hawthorn, pitch pine, eastern white pine, eastern hemlock, sugar maple, and American elm.

Table 17. Percent of trees sampled by crown dieback class

State	0-5%	6-15%	16-30%	31-60%	61-99%	dead
MD	83	7	7	2	1	1
MA	66	23	8	2	1	.4

Table 18. Percent of trees sampled by crown density class

State	0-15%	15-30%	31-50%	50+%
MD	10	1	8	81
MA	3	11	33	53

Damage

Tree damage was assessed using predefined classifications (table 19). Each damage must exceed a set threshold before it is measured. Damage was recorded as type of damage, location on the tree, and severity. Up to three separate damages were recorded for each tree (table 20).

Damage caused by a variety of natural and human-caused sources affects growth and development of trees and may increase hazard risk potential. Street trees are vulnerable to a variety of damages and damage-causing agents primarily because of their exposure to injury and due to the often less-than-desirable growing conditions. Nowak et al. (2004) found relatively high mortality rates among Baltimore trees in transportation and commercial/industrial land uses compared to six other land use types.

In Maryland, 36 percent of the trees had observable damage (table 20). For the first damage recorded (Damage 1), which would be on the lower portion of the tree, 16 percent of the damage recorded in Maryland was open wounds (table 19). Open wounds were predominantly observed on red maples, callery pear, sugar maple, and other maple species. When additional damage was observed on the same tree in Maryland, it was most commonly conks and signs of advanced decay.

Table 19. Damage classifications. Percent of all trees

Damage Classifications	MD	MA
No damage	64%	71%
Open wounds	16%	3%
Conks, advanced decay	8%	17%
Broken or dead branches	4%	2%
Vines in crown	2%	1%
Cankers	1%	1%
Discolored foliage	1%	1%

Table 20. Percent of trees with damage

State	% of trees with 1 damage	% of trees with 2 damages	% of trees with 3 damages
MD	36%	13%	5%
MA	29%	6%	1%

Table 21. Damage occurrence on ten most frequent species

MD	% of trees with damage	MA	% of trees with damage
Honey locust	46%	Silver maple	45%
Other maple species	25%	White ash	35%
Norway maple	22%	Sugar maple	33%
Red maple	21%	Red maple	31%
Crabapple	19%	Norway maple	28%
Oak species	17%	Northern Red Oak	20%
Silver maple	10%	Pitch pine	20%
Callery pear	6%	White oak	15%
Cherry plum	0	Black oak	11%
Sweetgum	0	Callery pear	0

Twenty-nine percent of the street trees in Massachusetts had observable damage (table 20). Seventeen percent of the trees had conks and signs of advanced decay recorded as Damage 1 (table 19). These damages were predominantly observed on Norway maple and red maple. When additional damage was observed on the same tree in Massachusetts, it was most often conks and signs of advanced decay and open wounds. Considering their exposure to injury, open wounds are an expected damage for urban street trees. Fungal fruiting bodies (conks) and signs of advanced decay can result from previous wounding. This latter damage category can be an indication of serious internal decay, resulting in tree failure.

Information on these damage agents is collected on rural forest trees by the Forest Inventory and Analysis Program. Data pulled from those sources offer a comparison between rural and urban trees. The incidence of damage on trees within the forest averages 31 percent in Maryland and 21 percent in Massachusetts (Alerich 2000, Frieswyk 2001).

Maples, commonly planted in both States, had many damaged individuals. Of the top 10 most frequently damaged species, both States had four species of maple. Damage to maples in Maryland ranged from 10 to 25 percent, while maples in Massachusetts had 28 to 45 percent of individual trees within a species showing damage symptoms (table 21). Green ash in Massachusetts sustained the highest incidence of damage at 70 percent.

Damage Agents: Considerations for Replication

National Forest Health Monitoring (FHM) damage rating protocols were used for the pilot. While the FHM damage protocol may be useful in forested situations, it was determined that adding some damage ratings for street tree monitoring would enhance the assessment. These additions include:

- Roots – Stem Girdling; Sidewalk/Structural Conflict; Excessive Mulch; Improper Planting

- Trunk – Wound or Crack; Canker or Decay; Borer Holes; Severe Topping

- Branches – Bark Inclusion with Codominant Leaders; Dead or Dying Crown; Poor Pruning; Vines in Crown; Borer Holes; Dead Top

Definitions for each of these urban damage ratings have been added to the Urban FHM Street Tree Field Manual.

Costs

Costs incurred for the pilot study included crew salaries, travel, equipment, and analysis costs. Cost per plot visit was estimated to be between $250 and $350 (2004 dollars). This is consistent with the cost estimates that Riemann determined in a pilot inventory of Forest Inventory and Analysis plots traditionally called ‘nonforest’ (Riemann 2003). The USDA Forest Service conducts continuous inventories of forest lands through the Forest Inventory and Analysis (FIA) Program. Typical costs for visiting forested plots in that program, including analysis costs, are estimated at $1,300 (2003 dollars) per plot. Sampling of street tree populations requires less field time by the crews, since plots are easily accessible by car. In addition, preparation time is reduced when compared to typical FIA sampling, because plots are located in public rights-of-way and do not require permission of land owners, a time-consuming step for samples that span multiple land uses and owners (Riemann 2003).

CONCLUSION

The pilot studies to inventory and assess street trees in Maryland and Massachusetts have successfully demonstrated that large-scale evaluation of urban street tree resources can be done in a cost-effective manner and yield useful data. The pilot study has shown that data could be collected and used to estimate the total statewide street tree population, extent of potential planting sites, overall health and size of street trees, and extent of exotic/invasive trees on the roadside. This information, in turn, can help urban foresters better plan for and manage the statewide street tree resource in several ways. Specifically:

- Describing the baseline structure and condition of a State or region's street tree population and monitoring change over time enable State, regional, and national urban foresters to be more strategic in their planning of urban and community forestry programs.

- Inventory information about potential host species (for example, ash and the emerald ash borer, sugar maple and the Asian longhorned beetle) enables pest risk assessment, early detection, and targeting of mitigation strategies.

- Information about specific street tree conditions enables State and regional urban foresters to address issues through public outreach (e.g. 'topping,' species diversity, and damage).

- Establishment of baseline information about street tree conditions provides a mechanism to monitor change and health over time.

The pilot provided clarification on several aspects of data collection and training, notably the need for:

- More accurate plot location descriptions;
- Detailed description of a right-of-way;
- Better tree species identification in the field; and
- Recording damage agents that are common in non-forest areas.

Overall, these data provide specifics about the urban street tree population that have been missing at state and regional scales. This comprehensive package of information can be used alone or in conjunction with a state-level urban forest assessment for policy and management decisions at the State, regional, and national level.

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