Surveying Urban Forest Management in the San Francisco Bay Area

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ABSTRACT

In 2007, Igor Lacan surveyed 50 arborists in 50 different cities in the San Francisco Bay Area with a goal to assess urban tree diversity and pest problems. These arborists were asked to list the best and worst tree species in their area, and what phenomena they believed had contributed to tree death in their area. I distributed this survey in 2017 to investigate how the best and worst performing tree species have changed with regards to the opinions stated forth by the arborists in 2007, and whether the most influential tree mortality factors have changed after three years of drought, from 2014-2017. This survey sought to capture changes in urban forester opinions, and interpret input on common problems and the best and worst performing trees in study areas to provide a more comprehensive understanding of the state of these urban trees. Notable findings included continuation of a trend observed in the 2007 survey, in which abiotic problems remained the largest problem affecting urban forests. There is one outlier city that claimed insects to be the most significant. These results may help city managers better maintain their urban forests, and aid them to better predict tree health problems in the Bay Area. Knowing possible problem-causing agents may save money and labor by minimizing future follow-up fixes.

KEYWORDS

city managers, city planning, perception survey, arborists, urban tree health

INTRODUCTION

Urban forests provide economic and health benefits for the city landscapes they reside in but require both labor and monetary investment to upkeep. The benefits of urban trees revolve around economics and health (Nowak et al. 2013, Widney et al. 2016). Shade trees remain one of the most effective ways to mitigate extreme heat, especially during summer months, and prevent death among children caused by over-heating (Solotaroff 1911). Urban forests also increase real estate and draw new people to live in that area (Solotaroff 1911). However, damaged trees often drop debris and leave behind a foul visual image, which require labor to repair or replace (Solotaroff 1911). Urban forests attract pests and tree diseases without active prevention and these urban trees then act as problem rather than a solution to city-wide economics and health.

Pests, disease, and abiotic issues, such as drought, represent major causes of tree mortality and damage in urban ecosystems that lead to excess spending and labor in order to replace urban trees. City planners and arborists initiate this spending labor and hold the decision-making power with regards to urban trees. In addition to insect or fungal pests and diseases, abiotic issues often cause traumatic injury to urban forests (Solotaroff 1911). This includes car accidents, vandalism, and California's recent four-year drought. It is necessary to determine the effects of these pests and problems in order to effectively combat them and prevent them from reoccurring. But only through good management can these issues be correctly identified and treated from a leadership standpoint that directly affects the status of these trees.

Predicting which pests and diseases affect urban forests is a necessary first step in preventing tree mortality; however, the perceptions of these ailments of city arborists, with regards to what the problems are and how severe they may be, are key to how effectively they can care for their trees. As the major decision maker in urban forest management, city tree managers play one of the most important roles in maintaining urban forests as they determine the pesticides used, treatments necessary, and more to ensure prolonged tree health (Langemeyer et al. 2016). For the purpose of this paper, there is no distinction between city planners, arborists, and tree managers as the survey reaches decision-makers for urban forests in the Bay Area regardless of title. Lacan's survey of city arborists, planners, and managers in 2007 determined abiotic factors as the most important issue plaguing urban forests (Lacan 2007). The survey also demonstrated that climate zones did not affect response patterns (Lacan 2007). The major issues

affecting tree health include the environment, pest or problem, and amount of time given to allow the problem to fester (Lacan 2007). It remains questionable what city planners are able to account for and control in order to prolong the life of their trees, but the more important question for urban foresters is what these planners are trying to control for with regards to tree health and possible problems and whether that is or is not the correct approach. Incorrect predictions and diagnoses can lead to incorrect treatment that cannot prevent tree mortality and can even hasten damage (Lacan 2007). While causes for tree mortality (pests, disease, abiotic factors) remain similar across the Bay Area, the perceived importance with regards to amount of management attention can vary widely between cities and can change every year; therefore, it remains unknown whether views on major urban forestry problems have changed in the past decade and how city planners are approaching them now. This decision-making directly affects urban forest health and the economic and health benefits available to cities

A continuation of the 2007 survey is necessary to update results, in order to assess changing perceptions, such as new important pests, diseases, or abiotic problems, that affect management practices and learn how city planners are currently approaching tree management in their areas in the aim to better urban forest health. This is necessary in order to improve tree health and prevent future problems to reap maximum health and economic benefits from our urban forests. The California drought acts as one of the biggest environmental problems in the Bay Area since 2007. Planners in cities in different climate zones in 2007 showed little difference in response patterns with regards to which problems affected their trees most severely but it is unknown if that remains true today after a four-year drought (Lacan 2007). It remains important to determine which issues are most important to city planners, such as mortality, diversity, and more. Only by knowing this can we hope to learn how arborists maintain their urban forests. The perspectives of these arborists are key to tree health as they remain in a leadership position that directly affects the health of their trees (Langemeyer et al. 2016). Little is known about current perspectives of these urban arborists as recent data is lacking. As perspectives change over time, so do management practices that influence urban forest health.

I seek to investigate how city planners' perspectives on urban forestry have changed in the past decade, in order to learn more about their management practices and approaches and to evaluate how the urban forest characteristics asked through the survey relate to environmental factors, such as climate zones, city size, and demographic characteristics of the cities of the San

Francisco Bay Area. I will identify what city planners think are the most common, the best-performing, and most troublesome tree species, in addition to the most problematic insects, diseases and abiotic factors that cause tree mortality has changed since 2007 in the cities of the San Francisco Bay Area . In addition, I seek to determine how causes of tree mortality have changed in the eyes of city planners especially with regards to drought, and see if there are any changes with results from different climate zones since the drought may have exacerbated environmental differences. Ultimately, the knowledge of perceived pests and issues with regards to urban forest health in relation to city demographics and environmental factors can educate city planners and allow them to improve their management practices and effectively care for their trees.

METHODS

Study system

I studied urban forests in 50 cities in the San Francisco Bay area. My study population included city managers or arborists (N = 11) that had control over the management of these forests. I surveyed one city manager per study city, and used the same candidate as the 2007 survey if they were available and still held their position among city offices (Lacan 2007). If the original candidate was no longer available, I surveyed a new candidate in the same office department. I did not report on any personal identifying information that might be linked to individual respondents. I contacted the candidates as described above with the help of my mentor, Igor Lacan, and asked for their agreement to participate through an initial email. Those that agreed then received the survey via email, and additional follow-ups as described in the next section. Those who did not agree to participate were removed from the list of potential participants, and I proceeded to contact another candidate in their department. I sent out a total of 50 surveys to participants who agreed to complete the survey and received 11.

Data collection methods

To compare study survey results to the original 2007 survey (Lacan 2007), I transcribed the exact 2007 survey questionnaire online and sent it to my study population via email. I uploaded the 2007 survey onto Igor Lacan's website, and distributed the link through email to the study subjects. After the initial contact email and the survey distribution email, I followed up after a 4-week period via email and then every 2 weeks post.

The survey questionnaire was divided into 7 sections: 1) General Questions, 2) Most Common Trees, 3) Best-performing Trees, 4) Most Troublesome Trees, 5) Insects, 6) Diseases, 7) Abiotic Problems. The first section asked respondents to report on their urban forest's pest situation, including pest management and tree diversity while the next section asked for the most numerous tree species in their area. These first two sections were used to collect information on the size and health of the respondent's urban forest. The third and fourth sections queried respondents on the "best" and "worst" performing trees in their forest, and requested their reasoning behind these judgments. The last 3 sections asked respondents to report on the most problematic pests in each category: insects, diseases, and abiotic problems. The final three survey sections discerned opinions and perspectives of these city planners regarding health issues (insects, disease, and abiotic problems) in their area that they determined to be damaging urban forests. The full survey questionnaire is included as Appendix A.

Data analysis methods

I looked at categorical questions and compared the raw data between the 11 responses. Categorical data in this survey included tree diversity, measured through a question asking whether these tree managers believe their diversity is excellent to poor. Severity levels for pest, disease, or abiotic problems were measured through a similar question asking the opinions of these arborists on their effect on trees such as tree death or expenses.

Next, I looked at differences among climate zones. Cities were sorted into 3 climate zones based on their average overall climate. There are no specific questions about climate zones on the survey questionnaire but I compared each categorical response between climate zone cities to determine if there is a trend in the data that could be separated by their climate zone. I

compared this climate zone data to that of the 2007 survey where no trends were found. This same method was used to determine differences among climate zones in reported tree conditions, reasons on why reported "worst trees" were undesirable (we did not ask why managers believed certain trees were "best trees" as we focused on what possible problems these trees could have instead), and the effects of insects, diseases, and abiotic issues on urban forests.

To compare and analyze the survey questions that required a ranked response, I provided a numerical value to each answer; for questions that required ranking, such as most common trees, insects, etc., each answer was given a numerical value that was weighted by its rank before analysis. The first ranked answer was given a weight of 5, the next, a 4, and so on. My final data ranked all tree species in a comprehensive list based on their overall weighted score. For example, if Eucalyptus was ranked as 1 by one surveyor and a 3 by another, its score for those two surveys will be an 8 (rank 1= score of 5, rank 3=score of 3). The assumptions necessary for these scores to be representative of the SF Bay Area in regards to their tree diversity and population are that we receive an ample sample size of 90% (45 responses) (Lacan 2007), and that the data is independent - meaning that each surveyor fills out their survey independently without the influence of others taking the survey as well.

RESULTS

Response Results

My online survey was sent through email to 50 recipients and I received 11 completed responses in return; this representing a 22% response rate. In comparison to the 2007 survey, this was a 73% decrease. In 2007, 55 arborists were contacted, 53 agreed to complete the questionnaire and 50 were returned (Lacan 2007).

Survey Comparison 2007/2017

The 2017 respondent population expressed (different) preferences for X tree species than did those respondents in 2007. When asked for the "best" and "worst" performing trees in their area, the first ranked answer was given a weight of 5, the next, a 4, and so on. The finalized

ranking of the top 5 most popular "good" trees are summarized in Figure 1 and "bad" trees in Figure 2. The "good" trees include Oaks, Crape Myrtle, Chinese Pistach, London planetree, and Sycamore. Oaks hold the highest overall score showing some consensus between city managers as the skew in scores is more apparent. "Bad" trees include Eucalyptus, Callery pear, Sweetgum, Raywood Ash, and Black Acacia. Common reasons behind undesirable trees include sidewalk damage, limb drop, high maintenance, and prone-ness to disease and insects. The numbers are much lower showing a lack of consensus overall.

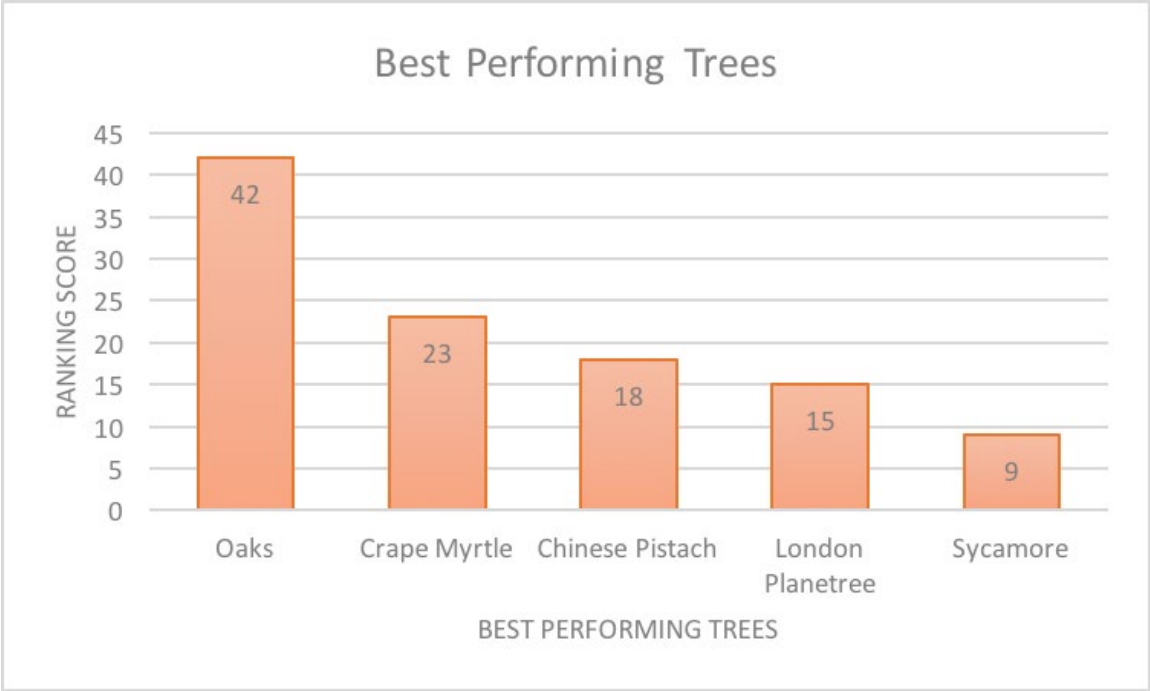

Figure 1. Best performing trees according to city managers in the SF Bay Area. The "good" trees include Oaks, Crape Myrtle, Chinese Pistach, London planetree, and Sycamore. Oaks hold the highest overall score showing some consensus between city managers as the skew in scores is more apparent.

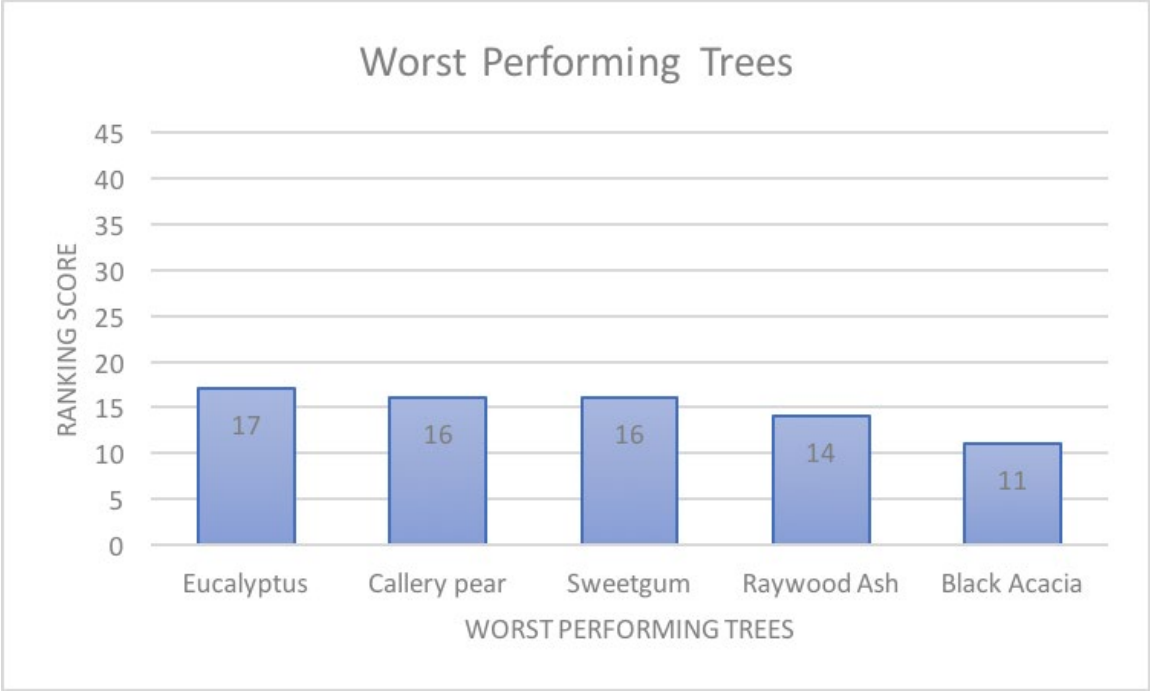

Figure 2. The most undesirable trees according to city managers. "Bad" trees include Eucalyptus, Callery pear, Sweetgum, Raywood Ash, and Black Acacia. Common reasons behind undesirable trees include sidewalk damage, limb drop, high maintenance, and prone-ness to disease and insects. The numbers are much lower showing a lack of consensus overall.

Insects, Diseases, and Abiotic Problems

Abiotic problems were considered the most severe problem in urban forests by respondents. Insect and diseases was deemed as a non-significant problem among surveyed cities with only one city reporting it at average to high severity. Percentage of responses that marked each problem as "Significant" can be seen in Figure 3. The most common response related to abiotic stress was stress due drought, especially through summer months but also include street trees being hit by cars, vandalism, and infrastructure conflicts. The most prominent response regarding insects were aphids and for diseases was fire blight.

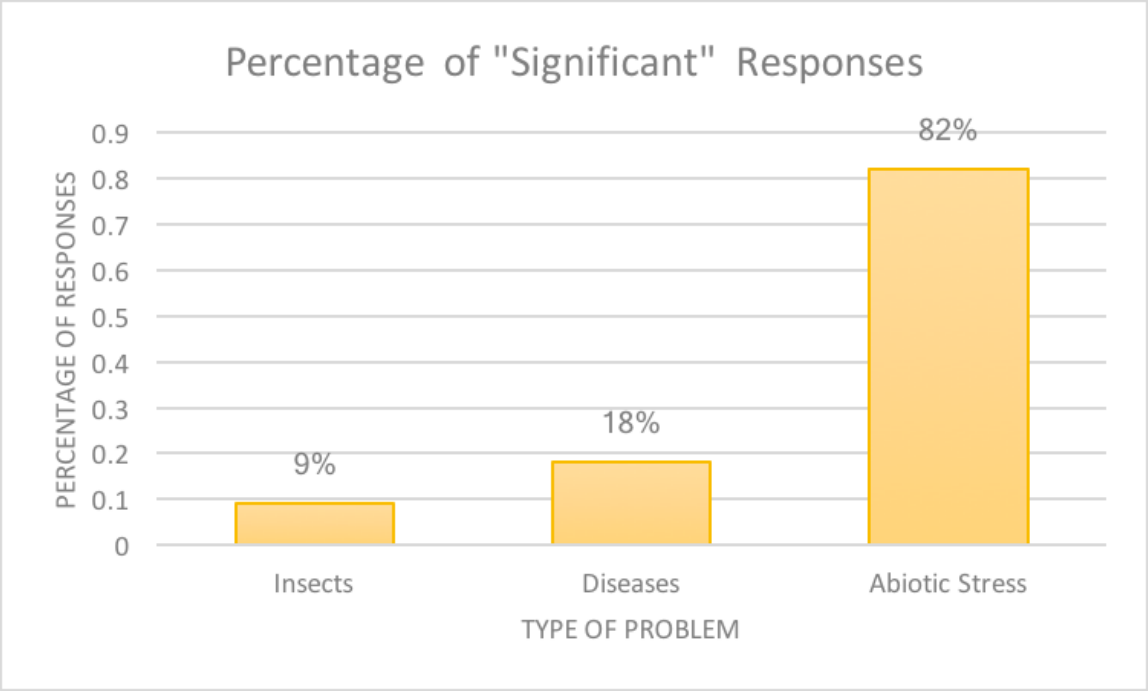

Figure 3. Percentage of "Significant" responses when asked about the impact of each problem. The most common response related to abiotic stress was stress due drought, especially through summer months but also include Causes of death from abiotic issues, include street trees being hit by cars, vandalism, and infrastructure conflicts. The most prominent response regarding insects were aphids and for diseases was fire blight.

Climate zones

I did not receive enough responses to claim correlations based off of climate zones as there was not a wide enough spread in spatial areas between the cities that responded. There is growing awareness concerning relationships between drought and pest and disease problems in urban forests, such as increased susceptibility due to tree stress. Further research will need to be done in order to claim relationships among climate zones in the San Francisco Bay Area.

DISCUSSION

This survey sought to capture changes in urban forester opinions, and interpret input on common problems and the best and worst performing trees in study areas to provide a more comprehensive understanding of said issues. City managers may use findings to make predictions and learn about current and, potentially, future problems facing their urban forests. In

this way, this group can make more informed decisions regarding the care and planting of their urban trees in relation to their city characteristics such as demographics and dynamics, and ultimately lower maintenance and replacement costs for urban trees. Being able to compare between climate zones allows for a more comprehensive view of better performing trees in different climate types.

Changes over time

Changes in responses from the 2007 survey may be interpreted as a shift in perception for city managers, as with this project alone we may not be able to determine any biological changes in the urban forest. Abiotic stress was deemed the most significant problem regarding tree health. Causes of death from abiotic issues, include street trees being hit by cars, drought, and infrastructure conflicts. This knowledge could help managers better prevent future tree replacements and death. There is a high importance of tree selection when planting urban trees as different plants react differently to their environmental factors and may be more resilient to these problems (Vogt et al. 2017). This follows the trends of the 2007 survey which found that insects and diseases were less of a problem in urban forest management in the San Francisco Bay Area than were abiotic factors (Lacan 2007). As this may be a lead-in cause for more pests and diseases, severe abiotic stress represents both an action item for city managers to focus on now, and also as a predictor for possible pest or disease outbreaks that may come. Much like the 2007 survey, insects were deemed more of a nuisance than the causal agent of tree damage, with very little of them reaching levels where city planners called for the use of pesticides. Diseases were deemed more severe than insects but less severe than abiotic issues when causing tree damage which remains the same as the 2007 survey.

Insects, Diseases, and Abiotic Problems

The most common response related to abiotic stress was stress due drought, especially through summer months which may be due to the recent 3-year drought from 2014-2017. Continued drought stress hastens tree mortality and can increase interactions with other climate-associated forest problems such as insect outbreaks and wildfire (Allen et al. 2010). The most

prominent response regarding insects were aphids which are sap-sucking insects often noticed feeding in clusters. Low infestations do not require pesticide control which may explain the minimal use of pesticides reported by city planners. The most common disease reported was fire blight. Fire blight is caused by the bacterium, *Erwinia amylovora*, and is a common disease affecting fruit trees and related plants (Vanneste 2000). The first sign is a watery pus that exudes from cankers on stems and branches. However, many cankers can be small and inconspicuous and so infections are difficult to notice until a more dramatic sign is shown like when the flowers, shoots, or leaves shrivel and blacken (Vanneste 2000).

Broader implications

These results may help city managers better care for and maintain their urban forests, and aid them to better predict common tree health problems in the Bay Area. Knowing possible problem-causing agents may help planners predict the likelihood of similar problems affecting their own cities, which may save money and labor as preventative knowledge rather than follow up fixes. In addition, this paper may better public opinions and attitudes towards their urban trees and parks. Citizens prioritized planting a larger number of trees and increasing species richness (Jennings et al. 2016). Knowledge of best and worst performing trees in the Bay Area can help these planners better choose which species of trees to plant and how to maintain them and prolong their lifespan. Although this project alone may not provide a complete view, it represents a first step toward bringing attention to problems that provide economic strain on urban forest management professionals.

Limitations and future directions

The low response rate may not be geographically representative of the San Francisco Bay Area as the location and spread of cities may affect the actual results regarding tree health problems. Further steps must be taken in future research to derive more representative results which may include redoing this survey in the future or over a longer time span in order to obtain more results. The 22% response rate was low compared to the 2007 survey and was limited to 11 cities, which may have skewed the results. Changes from the 2007 survey bring attention to the

need for timely updates in city manager opinions, in order to remain relevant for use in the future for easing economic strain with regards to urban forests. This survey focused on tree manager's opinions on their best and worst trees, in addition to problems they have seemingly faced; however, further steps to be taken in future research include comparing tree logs for lifespans, and pesticide and treatment logs for problems faced. This may provide a new view on what troubles urban forests, and when compared to this survey can provide useful insight on possible knowledge gaps faced by urban foresters.

ACKNOWLEDGEMENTS

Thank you to Professor Patina Mendez, Professor Kurt Spreyer, and Abby Cochran for helping me put together this project in ESPM 175, and to Igor Lacan for mentoring me through this process and allowing me to use his survey. Thank you to Professor John Battles for guiding me through the skills necessary to write this thesis. I greatly benefitted from the reviewing and feedback I received from my work group members: Vanessa Chi, Anthony Fortney, and Ashley Killmon. Lastly, thank you to my friends and family that have helped me mentally and emotionally throughout this process.

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APPENDIX A: Distributed Questionnaire

Please check the words that – in your opinion **– best describe the situation in your area**

A) Insect pests of trees are a _____ problem in my area	☐ Huge	☐ Significant
	☐ Minor	☐ Not at all
B) Tree diseases are a _____ problem in my area	☐ Huge	☐ Significant
	☐ Minor	☐ Not at all
C) Abiotic stresses* are a _____ problem in my area (*drought, compacted soil, construction damage, etc.)	☐ Huge	☐ Significant
	☐ Minor	☐ Not at all

D) Primary cause of the need for tree replacement in my area is	☐ Old age of trees	☐ Tree death from abiotic problems
	☐ Tree death from insects/diseases	☐ Other _____

E) In my opinion, urban tree species diversity in my area is	☐ Excellent	☐ Good
	☐ Fair	☐ Poor

F) In tree management we use the following **F** – frequently, **S** – sometimes, **R** – rarely *leave blank if the answer is "never"* (Biocontrol = parasitoids, predators, etc.; Mechanical = water jets to wash off aphids etc.)	Insecticides ☐**F** ☐**S** ☐**R**	Biocontrol ☐**F** ☐**S** ☐**R**	☐ Mechanical Control
	Fungicides ☐**F** ☐**S** ☐**R**	Tree fertilizers ☐**F** ☐**S** ☐**R**	☐ IPM

0) **Approximate number of street and park trees**: _____

(or, check one: ☐ < 1000 ☐ 1000–5000 ☐ 5000–10 000 ☐ 10 000–20 000 ☐ 20 000–30 000 ☐ 30 000–40 000 ☐ 40 000–50 000 ☐ 50 000–100 000 ☐ > 100 000

1) Please list the FIVE MOST COMMON TREE SPECIES in your area (i.e. species with most trees)

I) Five Most Common (i.e. most numerous) tree species

Rank	Tree Species (Common or Scientific name)	Condition	
1 (Most Common)		☐ Good	☐ Fair
		☐ Poor	☐Dying
2		☐ Good	☐ Fair
		☐ Poor	☐Dying
3		☐ Good	☐ Fair
		☐ Poor	☐Dying
4		☐ Good	☐ Fair
		☐ Poor	☐Dying
5		☐ Good	☐ Fair
		☐ Poor	☐Dying

2) Please list the FIVE TREE SPECIES YOU WOULD CONSIDER BEST FOR USE IN YOUR AREA, based on both the species' past performance, and on your own professional judgment about a tree species' future prospects.

II) Five "BEST" tree species

Rank	Tree Species (Common or Scientific name)
1 (Best)	
2	
3	
4	
5	

Any comments on "best tree species"? _____

_____

3) Please list the FIVE TREE SPECIES LEAST DESIRABLE IN YOUR AREA based on problems with theses tree species you have experienced in the past (i.e. base the answer on your own experiences).

III) Five LEAST DESIRABLE tree species (i.e. the 'most troublesome')

Rank	Tree Species (Common or Scientific name)	Why undesirable?
1 (Most trouble)		
2		
3		
4		
5		

Any comments on "least desirable tree species"? _____

4) Please list FIVE MOST CHRONIC AND / OR MOST DAMAGING INSECT PESTS (including mites), and for each pest note whether they are just a nuisance (N) or cause damage (D), which tree species is *most commonly* attacked, and whether you use pesticides to control the pest (Y/N)

IV) Five MOST CHRONIC AND/OR DAMAGING INSECT PESTS (& mites)

Rank	Pest Species (Common or Scientific name)	**N**uisance or **D**amage?	Tree species attacked	Pesticide Y/N?
1 (Most trouble)				
2				
3				
4				
5				

Any comments on "insect pests"? _____

5) Please list FIVE MOST CHRONIC AND/OR MOST DAMAGING DISEASES (either name of pathogen or name of disease: *Erwinia* or Fireblight), and for each disease note which tree species are *most commonly* attacked, and what is the main effect(s) of the disease

V) MOST CHRONIC &/OR DAMAGING DISEASES (fungal, bacterial, viral, etc.)

Rank	Pathogen or Disease Name **and** Tree host Species		Effect on Tree	
1 (Most trouble)			☐ Tree death ☐ Ugliness*	☐ Failure Other_____
2			☐ Tree death ☐ Ugliness	☐ Failure Other_____
3			☐ Tree death ☐ Ugliness	☐ Failure Other_____
4			☐ Tree death ☐ Ugliness	☐ Failure Other_____
5			☐ Tree death ☐ Ugliness	☐ Failure Other_____

* "Ugliness" is shorthand for aesthetic concerns – e.g. defoliated trees.

Any comments on "pathogens/diseases"? _____

6) Please list FIVE MOST CHRONIC AND/OR MOST DAMAGING ABIOTIC PROBLEMS (e.g. "summer drought", "overwatering", "small planting space", "compacted soils", "vandalism", "construction damage"), and for each problem note the main effect(s).

6) MOST CHRONIC &/OR DAMAGING ENVIRONMENTAL PROBLEMS (abiotic problems)

Rank	Abiotic/environmental problem	Effect	
1 (Most trouble)		☐ Tree death	☐ Failure
		☐ Expenses	Other_____
2		☐ Tree death	☐ Failure
		☐ Expenses	Other_____
3		☐ Tree death	☐ Failure
		☐ Expenses	Other_____
4		☐ Tree death	☐ Failure
		☐ Expenses	Other_____
5		☐ Tree death	☐ Failure
		☐ Expenses	Other_____

Any comments on "abiotic/environmental tree problems"? _____

_____

7) Please, let me know **if I have left out of this questionnaire** SOMETHING THAT IS A MAJOR ISSUE/PROBLEM/A WHOLE CLASS OF PROBLEMS in tree management in your area

_____
_____
_____
_____
_____