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Municipal tree risk assessment in the United States: Findings from a comprehensive survey of urban forest management

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Awareness of tree risk assessment and management has risen in the United States in recent years. This has been prompted by publications such as the American National Standards Institute (ANSI) standard for tree risk assessment (ANSI A300 Part 9 – Tree Risk Assessment) and the accompanying International Society of Arboriculture (ISA) Tree Risk Assessment Best Management Practices, as well as the subsequent development of the ISA Tree Risk Assessment Qualification. How this increase in awareness has broadly translated into common practice in communities, is not well understood. This paper reports findings from a recent survey of urban forest operations as they directly pertain to tree risk assessment. The survey consisted of a 109-question long-form questionnaire that was sent to 1727 communities, followed up by a truncated version to non-responding communities. Six hundred and sixty-seven (38.6%) communities responded to the survey – 513 to the full survey and 154 to the truncated version. Communities that reported having a certified arborist on staff (p-value = .010), a strategic plan (p-value = .002), an updated inventory (p-value < .001), collecting risk data (p-value = .004), and having a past claim for damage or injury (p-value < .001) were more likely to regularly conduct tree risk management activities.

Keywords: tree risk assessment; storm preparation; tree inventory; urban forestry survey

Introduction

The merits and pitfalls of urban tree risk assessment have been discussed openly for several decades (National Tree Safety Group, 2011; Norris, 2007; Paine, 1971; Smiley, Matheny, & Lilly, 2011; Wagener, 1963). The phrase “tree risk management” itself is relatively new to the tree care industry and has gradually replaced its predecessor “hazard tree management” as the process has evolved (Hartman, Pirone, & Sall, 2000; Paine, 1971; Pokorny et al., 2003; Smiley et al., 2011; Wagener, 1963). Regardless of the phrasing, the need to evaluate trees for defects and to take action to address conditions of concern has long been recognised. This has been outlined in books like *The Tree Doctor* (Davey, 1907) *The Care of Trees in Lawn, Street, and Park* (Fernow, 1911), and *Pirone's Tree Maintenance* (Hartman et al., 2000; originally published in 1941), all of which have contributed to the contemporary understanding of the process. These texts discussed defects in trees and the appropriate reasonable action the arborist (e.g. Tree Surgeon) could perform. Fernow (1911) stated … “that the tree surgeon will often be

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called upon to exercise his knowledge and ingenuity in the direction of mending old damage". The concept of tree stabilisation with threaded bracing rods to reduce the likelihood of failure was documented by Davey (1907) over a century ago. Campana (1999) provides evidence that bracing, guying and propping were used to stabilise trees for centuries.

The Quantified Tree Risk Assessment system and the Common Sense Risk Management of Trees in the United Kingdom have been used and refined over the past several decades (Ellison, 2005; National Tree Safety Group, 2011). In 1974, the Health and Safety Act at Work law recognised the expertise of the arborist. Additionally, the National Tree Safety Group (2011) publication states

> … people's safety in the face of risk of death or injury suggests that the operators, in this case tree owners and managers, are the people best placed to assess the risk and take the necessary action to reduce it to a reasonable level.

Systems to identify and judge or rate trees for risk of failure in the United States were proposed by Wagener (1963) and Paine (1971) for recreational sites. Loading events (e.g. wind, snow and ice), wood strength, species differences and examining approaches were discussed. The Colorado Tree Coalition system is another approach that has been in place for over several decades (Norris, 2007). Other systems (e.g. the original International Society of Arboriculture [ISA] system, visual tree assessment), were also used by practitioners to abate the "Hazard Tree" (Fink, 2009; Matheny & Clark, 1994).

During the past two decades, the topic of tree risk assessment has gained greater attention among researchers and professionals in the United States. The Urban Tree Risk Management project team commenced discussions concerning the concept of Tree Risk that resulted in a publication (Pokorny et al., 2003). In 2009, the ISA organised a *Trees and Risk Researcher Summit* in Charlotte, North Carolina (Koeser, 2009). Three years later these same partners continued the discussion in Lisle, Illinois, hosting an international tree biomechanics conference designed to address the current state of research and identify future research needs as they relate to tree failure potential (Dahle et al., 2014).

In addition to these efforts to advance the science of tree risk assessment, ISA and other industry entities in the United States worked cooperatively to help define practices through the creation of the first American National Standards Institute (ANSI) standard for tree risk assessment (ANSI A300 Part 9 – Tree Risk Assessment) in 2011. Coinciding with the release of this standard was the publication of the ISA Tree Risk Assessment Best Management Practices (BMP) guide (Smiley et al., 2011). This BMP included a systematic framework for tree risk assessment based on a series of decision matrices and represented a notable departure from the formulaic approach found in the earlier ISA risk assessment method developed by Matheny and Clark (1994). Two years after the release of the ANSI risk standard and its associated BMP, ISA initiated a Tree Risk Assessment Qualification (TRAQ), which includes the ISA BMP risk assessment method among its training materials (Dunster, Smiley, Matheny, & Lilly, 2013) and methodology. This system built upon the Tree Risk Assessment and Exam system used in the Pacific Northwest region of North America prior to TRAQ (Dunster, 2009).

How these various initiatives translate to common practice in the United States is unknown. Are communities conducting routine risk management efforts? Do they employ arborists and urban foresters with the new industry credential? Have risk assessors transitioned to the new risk BMP method of conducting visual assessments? In previous years, researchers have conducted comprehensive surveys of urban forest management practices in the United States (Giedraitis & Kielbaso, 1982; Kielbaso, Beauchamp, Larison, & Randall, 1988; Ottman & Kielbaso, 1976; 1993 Report by Tschantz and Sacamano, 1994). These efforts largely precede the current interest in tree risk assessment and management, and contain few insights into past risk management activities. As such, it is not possible to gauge the full impact of recent industry efforts (e.g. the release of the tree risk BMP).

The goal of this work is to provide baseline data that highlights the current state of risk assessment in community forestry programmes in the United States. Specifically, findings are from a recent survey of urban forest operations as they directly pertain to tree risk assessment. Additionally, a logistic regression model was created to identify factors linked to communities that regularly conducted risk management. In addition to offering baseline data, this effort is aimed at assisting urban foresters and municipal arborists in identifying key objectives as they transition from reactive/semi-routine to proactive/regular risk management.

Methods

Survey distribution

Information on urban tree risk management and storm preparation/response was collected in 2014 as part of a comprehensive, national (United States) survey of municipal forestry operations. A 109-question long-form questionnaire was mailed with a self-addressed envelope to 1727 communities. Sampling level varied by population. All communities of over 50,000 people received the questionnaire. Communities below 50,000 people were randomly sampled. Half of communities with populations between 25,000 and 49,999, and 10% of communities with populations between 2,500 and 24,999 were included in the sample. All communities were generated from the Community Accomplishments Reporting System (CARS) maintained by the United States Department of Agriculture Forest Service (http://apps.fs.fed.us/NICPortal/default.cfm?action=Login). As the departments and job titles for individuals managing urban trees can vary significantly from community to community, key contacts for the communities were identified by state urban and community forestry coordinators for 40 states. In states for which contact information was not available and for communities for which coordinators did not have a key contact person, municipal websites were searched to identify the person(s) or department(s) responsible for municipal trees care. Lacking this information, an individual with senior administrative responsibilities (i.e. city clerk, city manager, mayor) was sent the survey.

Following the multiple contact approach outlined by Dillman, Smyth, and Christian (2014), our survey included a pre-notice letter, the survey (with a cover letter), a reminder email, a second survey (with cover letter) for non-respondents, and a final postcard reminder for non-respondents. Communities who did not respond to this first survey attempt were sent a 53-question short-form version of the questionnaire (with cover letter). A single email reminder was given for this truncated survey.

Analysis

In addition to summarisation of responses using general descriptive statistics, a logistic regression model was run to assess what factors were linked to communities who conduct regular tree risk management. The analysis was fitted as generalised linear model with a binomial distribution using the (generalised linear model) glm () function in R Core Team (2013). The maximal (full) model is shown in Table 1.

A combined backward/forward stepwise elimination function based on Akaike information criterion was run to determine an initial minimally adequate (final) model (Sheather, 2009). An additional non-significant factor, median income, was removed for the sake of model parsimony (all conclusions were made at an $\alpha = .05$ level of Type I error). Marginal model plots were produced via the (marginal model plots) mmps () function in R and used to diagnosis model validity (Fox & Weisberg, 2010). In addition, standardised deviance values and leverage values were plotted for each observation to determine if any outliers were unduly influencing the model (Sheather, 2009). Finding none, the final (minimally adequate) model was selected.

Results

Six hundred and sixty-seven (38.6%) communities responded to the survey. Of the responding communities, 513 replied to the 109-question long-form survey questionnaire. The remaining 154 respondents completed the truncated short-form questionnaire sent later in the surveying process. Response rate varied by population group (p-value < .001; Table 1), and communities with populations ranging from 5,000 to 9,999 people had the lowest figures at 25.4% (Table 2). In contrast, communities with populations ranging from 250,000 to 499,999 people had the highest response rate at 54.7% (Table 2).

Table 1. Initial logistic regression model variables.

Variable	Definition	Mean (standard deviation)/count (na)
Risk management	Response variable, does the community regularly conduct risk management	291 (na)
Population[a]	Population of community	101,305 (382,076)
Area	Area of community (in sq. miles)	39 (94)
Median Income[b]	Median income of residents (in USD)	51,598 (20,610)
ISA Cert Arb	International Society of Arboriculture Certified Arborist on staff	171 (na)
Ordinance	Community has an ordinance related to trees/tree management	460 (na)
Risk ordinance	Community has an ordinance related to the abatement of hazardous or public nuisance trees	280 (na)
Strategic plan	Community has a written strategic plan	240 (na)
Risk plan	Written strategic plan addresses risk management	80 (na)
Tree inventory	Community has a tree inventory	361 (na)
Updated inventory	Community regularly updates inventory	240 (na)
Risk data	Inventory contains risk data	182 (na)
Windshield survey	Community conducts limited visual or “windshield” surveys	141 (na)
Known claim	Community had a past claim for damages or injury	240 (na)

Notes: Model was built to determine what factors are associated with communities that regularly conduct risk management as part of their urban forestry operations. Data only includes long-form respondents (n = 513).
[a]Community population used the 2010 census as maintained in the CARS dataset and the United States Census Bureau (2010).
[b]Median income and city area data also came from the United States Census Bureau (2014).

Table 2. Response rate and proportion of communities that regularly conduct tree risk management by population group.

	Community size/10^3 (%)										
	2.5–4.9	5.0–9.9	10.0–24.9	25.0–49.9	50.0–99.9	100.0–249.9	250.0–499.9	500.0–999.9	>1,000	Overall	Significance[a]
Communities sampled	241	193	187	400	438	196	41	23	8	1727	n/a
Surveys returned	69 (30.3%)	48 (25.4%)	49 (27.8%)	163 (42.5%)	183 (43.4%)	88 (49.5%)	20 (53.7%)	11 (47.8%)	3 (37.5%)	634 (38.6%)	<.001
Respondents that regularly conduct tree risk management[b]	20 (29.0%)	22 (45.8%)	28 (57.1%)	97 (59.5%)	111 (60.7%)	61 (69.3%)	15 (75.0%)	7 (63.6%)	2 (66.7%)	363 (57.3%)	<.001

Notes:[a]Tested across community size class using the prop.test() function in R (R Core Team, 2013).
[b]Percentage based on number of surveys returned.

As with response rate, the proportion of respondents who noted they regularly conducted tree risk assessment varied by city size (p-value < .001; Table 2). With no clear pattern to this difference, city size was not a significant predictor in our final logistic regression model (Table 3). Rather, we found that having a certified arborist on staff (p-value = .010), having a strategic plan (p-value = .002), having an updated inventory (p-value < .001), collecting risk data (p-value = .004), and having a past claim for damage or injury (p-value < .001) were significant variables that explained if a community regularly conducted tree risk management or not (Table 3). With odds ratios ranging from 1.762 to 2.270 (Table 3), the addition of each factor essentially doubled the likelihood (i.e. 2:1 odds) of a city engaging in regular tree risk management.

Beyond the broader umbrella of actions qualifying as "regular tree risk management", city representatives were asked about specific management activities (Table 4). Some activities like conducting routine inspections to remove high-risk public/private trees (p-values = .233 and .420; respectively), having a written risk management plan (p-value = .171), having a strategic plan for risk management (p-value = .667), collecting tree risk inventory data (p-value = .127), and using inventories to prioritise removals (p-value = .0826) did not vary by population (Table 4). In contrast, having ordinances (p-value < .001), risk abatement ordinances (p-value = .004), strategic plans (p-value < .001), and tree inventories (p-value < .001) did vary by population. In general, these activities were more common as community size increased (Table 4).

In identifying statements which best reflected tactics used for risk inspection (n = 636), 97.4% of respondents indicated that they respond to citizen complaints. Less common, though still significant, was the use of windshield surveys to identify high-risk trees (78.1%) and the inspection of trees during other routine maintenance activities. Finally, just over half of respondents (53.2%) indicated that their municipality inspected trees for risk as part of a routine inspection programme.

When asked which risk assessment method was used, the most common response (37%) was "no system used" (Figure 1). Nearly 22% of respondents noted that they used the ISA BMP system (Smiley et al., 2011). The ISA BMP was used more than the older ISA system developed by Matheny and Clark (1994) (13.1%) and the United Stated Department of Agriculture Forest Services approach (2.4%) (Pokorny et al., 2003). Over 8% of respondents noted "Other" as their main risk assessment system (Figure 1). Other responses were typically a combination of the above systems.

Unacceptable tree risk was used as a justification for tree removal by 12.3% of respondents ($n = 452$; Figure 2). Other reasons for removal related to tree risk and health included: tree declining or dead (46%), insect or disease problem (11.9%), storm damage (9.1%), and sidewalk damage (5%). Land clearing and site development was listed as a reason for removal by 8.6% of respondents. Homeowner requests were listed as a reason for removal by 4.8% of respondents. Removal of high-risk public trees (85.9%) was more common than removal of high-risk private trees (22%; Table 4).

Discussion

An interesting, though not necessarily surprising, predictor of regular risk management activity related to the occurrence of a past claim filed for damage or injury (Table 3). Throughout the model building process and its multiple iterations, this factor was consistently significant. When respondents were asked if their community had experienced any claim for injury or property damage from public trees, approximately half (52%, $n = 463$) responded in the affirmative (i.e. "yes"). Of the claims paid by respondents ($n = 110$), the maximum amount compensated was $176,000 (USD). However, the median claim was considerably lower at $5,000, with the mean ($13,290 ± $2,463 SE) skewed towards the bigger awards.

Another significant predictor of regular tree risk management related to the in-house employment of an ISA Certified Arborist. In a survey of community tree programmes in the state of Illinois (United States), Schroeder, Green, and Howe (2003) found that 15% (overall) of the communities surveyed had Certified Arborists on staff. Those studies occurred in 1995 (small community survey), and 1999 (large community survey), and coincided with the initiation of the ISA Certified Arborist credential in 1992. Not surprisingly, this percentage increased with city population. Half (50%) of communities with populations ranging from 25,000 to 50,000, 75% of communities with populations ranging from 50,000 to 100,000 and 100% of communities with populations over 100,000 reported having Certified Arborists on staff.

In our survey of the programmes throughout the United States, we found that 61% (overall) of communities had Certified Arborists on staff. This ranged from 60% for communities with populations ranging from 25,000 to 49,000 to 100% for cities over 1,000,000. Thus, the ISA Certified Arborist credential is becoming very common and communities that regularly conduct tree risk management are likely to have a Certified Arborist on staff.

Table 3. Final logistic regression model variables.

Variable	Coefficient	Standard error	*p*-value	Odds ratio	95% CI lower	95% CI upper
Intercept	−.981	.204	<.001	–	–	–
ISA certified arborist – yes	.567	.219	.010	1.762	1.146	2.709
Strategic plan – yes	.624	.202	.002	1.866	1.255	2.772
Updated inventory – yes	.820	.215	<.001	2.270	1.492	3.463
Inventory risk data – yes	.642	.226	.004	1.900	1.222	2.971
Past claim – yes	.693	.248	<.001	1.999	1.340	2.992

Notes: Model was simplified to only include factors associated with communities that regularly conduct risk management as part of their urban forestry operations. Data only include long-form respondents ($n = 513$).

Table 4. Per cent of communities performing various risk management activities by population size.

	Community size/10^3 (%)										
Risk management activity	2.5–4.9	5.0–9.9	10.0–24.9	25.0–49.9	50.0–99.9	100.0–249.9	250.0–499.9	500.0–999.9	>1,000	Overall	Significance[a]
Routinely inspect and remove high risk public trees	76.1%[b] (46)[c]	73.1% (26)	90.3% (31)	89.2% (130)	88.0% (150)	83.5% (79)	88.9% (18)	87.5% (8)	100% (3)	85.9% (491)	.233
Routinely inspect and remove high risk private trees	15.2% (46)	7.7% (26)	19.4% (31)	26.2% (130)	22.7% (150)	21.5% (79)	27.8% (18)	37.5% (8)	0% (3)	22.0% (491)	.420
Have a written risk management policy	13.4% (67)	6.4% (47)	14.6% (48)	13.7% (161)	14.3% (182)	13.8% (87)	35.0% (20)	27.3% (11)	0% (3)	14.2% (626)	.171
Have a municipal tree ordinance	64.3% (70)	71.4% (49)	85.7% (49)	92.9% (168)	95.8% (189)	97.9% (96)	100% (22)	90.9% (11)	100% (3)	89.5% (657)	<.001
Have an ordinance to abate tree risk	50.0% (44)	36.4% (33)	62.5% (40)	54.9% (153)	65.9% (179)	60.6% (94)	81.8% (22)	63.6% (11)	0% (3)	59.2% (579)	.004
Have a strategic plan	21.5% (65)	35.1% (37)	48.7% (39)	47.7% (155)	54.7% (179)	66.3% (86)	70.0% (20)	70.0% (10)	100% (3)	50.3% (594)	<.001
Have a strategic plan for risk management	30.0% (10)	14.3% (7)	54.5% (11)	33.9% (59)	35.6% (73)	36.2% (47)	46.2% (13)	25.0% (4)	0% (3)	35.2% (227)	.667
Have a tree inventory	29.6% (71)	41.7% (48)	59.2% (49)	68.0% (169)	76.3% (186)	79.4% (97)	100% (22)	81.8% (11)	66.7% (3)	66.6% (656)	<.001
Inventory includes risk assessment data	46.7% (15)	41.7% (12)	47.8% (23)	58.3% (96)	43.1% (116)	60.0% (65)	36.8% (19)	85.7% (7)	50.0% (2)	51.3% (355)	.127
Inventory used to prioritise removals	57.9% (19)	55.0% (20)	62.1% (29)	66.7% (111)	50.4% (133)	73.6% (72)	50.0% (18)	55.6% (9)	50.0% (2)	60.3% (413)	.083

Notes:[a]Tested across community size class using the prop.test() function in R (R Core Team, 2013).
[b]Percentage based on number of surveys returned.
[c]Number of communities noting activity occurs.

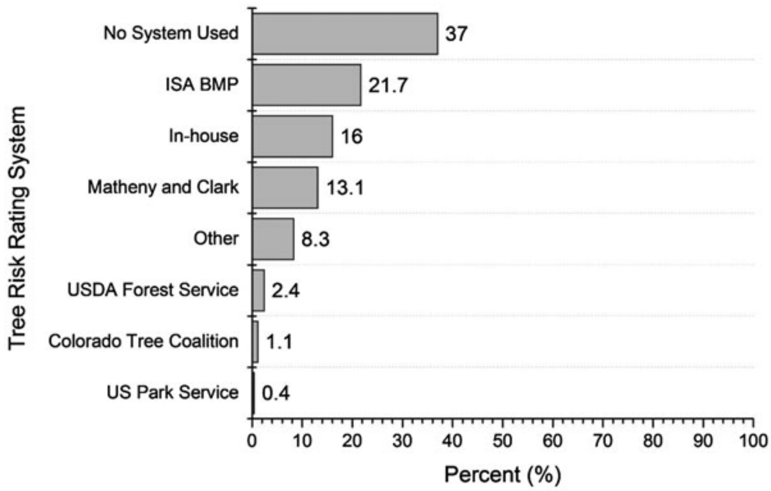

Figure 1. Risk Assessment Systems used by responding communities (n = 457).

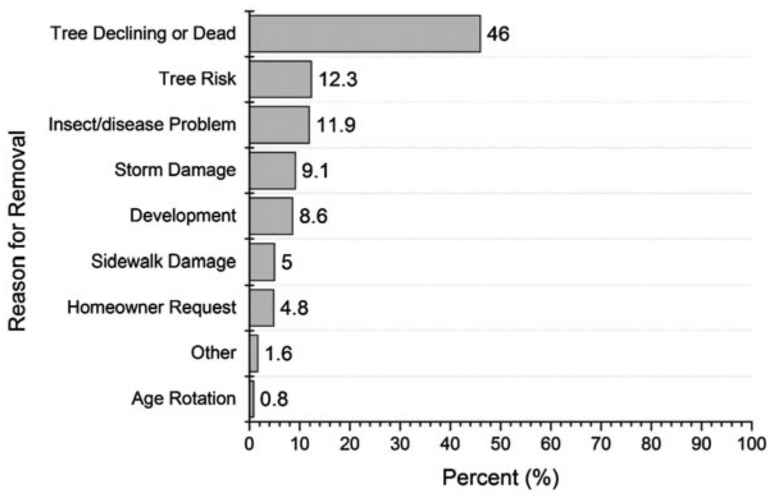

Figure 2. Reasons for tree removal reported by responding communities (n = 452).

Our model also showed that communities who were diligent with their inventories were more likely to conduct regular risk management activities. Inventories are a fairly common management activity among communities in the United States (Table 4). Treiman and Gartner (2005) found that 60% of communities in the state of Missouri (United States) counted, measured and monitored some portion of their urban trees. Schroeder et al. (2003) found only 20% of communities conducted inventories in Illinois. However when looking at communities, over 25,000, 47–67% of respondents noted they had a tree inventory. Similarly, a survey in Utah (United States) found that 45% had inventories (Kuhns, Lee, & Reiter, 2005). When looking at communities over 10,000, this percentage rose to over 70%.

Often it seems that urban tree inventories are conducted to capture stand conditions for one point in time, possibly for the calculation of ecosystem services to include in a report. In such instances, the findings may or may not influence actual management activities. To be useful in regular risk management, inventories must be regularly updated to include plantings, removals, and changes in tree condition. Obviously, this includes the collection of data that goes beyond what is needed to conduct a basic ecosystem assessment. Our survey revealed that tree inventories were commonly used (60%) to prioritise removals (Table 4). However, the regression model indicated that having just some form of inventory was not sufficient as the more ambiguous "tree inventory" factor was dropped from the model (Tables 1 and 3). In contrast, the presence of an actively updated inventory was a key differentiation, which helped predict which programmes regularly conducted tree risk management (Table 3).

What urban tree-related risk data are collected and what method of risk assessment is utilised varies from city to city. We found that most communities have no system at all (Figure 1). Of the standardised risk assessment methods currently available in the practice of urban forestry, the relatively new ISA BMP was the most common approach adopted by our respondents (22%, Figure 1). The seminal and older ISA system created by Matheny and Clark (1994) remained the third most common method of assessment among our respondents (13%, Figure 1). Most of the remaining communities preferred a customised "in-house" system using some other approach to risk assessment (Figure 1). From experience, many in-house systems are modified versions of standard risk assessment or appraisal methods. Respondent comments showed that many of the methods marked as "other" were in actuality, combinations of the standardised risk methods listed as choices in the question (data not shown). Thus, our findings show that no one system prevails over the other with regard to widespread adoption. Rather, individual communities implemented the system that best met their management objectives.

The communities surveyed indicated that they primarily focused on public trees when conducting removals based on tree risk. Approximately 86% of respondents routinely inspected and removed high-risk trees on public property, whereas only 22% of respondents inspected and removed private trees. The percentage of communities willing to conduct removals on private property was lower than previously reported by Schroeder et al. (2003). In their work, the researchers found that 55% of cities in Illinois (United States) acknowledged removing high-risk trees on private property (Schroeder et al., 2003). The development of a policy to require the abatement of a high-risk tree on private property is usually carried out for reasons related to public safety (Miller, Hauer, & Werner, 2015). Why some cities elect to address public trees but do not address private trees in relation to tree risk is not known and is a topic worthy of further research. It would seem likely, however, that those communities who require the abatement of private trees related to tree risk may have experienced both a previous tree failure and a related injury or damage to property, which stimulated the creation of a policy.

Urban Tree removals are a significant component of risk mitigation, both in their costs to communities and in their consequences to the surrounding landscape. Nali and Lorenzini (2009) found that 86% of residents surveyed in the Italian cities of Pisa and Livorno recognised the risks posed by dead or diseased trees. Given this community awareness, it is not surprising that Rines, Kane, Ryan, and Kittredge (2010) found that Massachusetts (United States) tree wardens prioritised the removal of high-risk trees over other management actions like planting or preventative maintenance. Our survey indicated that the top three reasons for removal were all linked to tree health and structural integrity (Figure 2).

Conclusion

Findings from this study identify the current state of urban tree risk management in the United States, as well as the factors which either cause or are associated with regular tree risk management. These factors include the employment of credentialed staff, the development and implementation of strategic management policies, and an investment in the collection and analysis of relevant urban tree data, to make informed decisions. In addition to these proactive measures, cities also tend to engage in regular tree risk management activities in reaction to past claims of damage or injury.

Ideally, a municipal programme designed to address tree risk management should be developed in a proactive manner, before an incident involving a tree-related failure (and ensuing claim) occurs. Once implemented, the programme should help to reduce the risk associated with personal injury or property damage. While urban tree-related risk cannot be eliminated, reasonable, systematic measures implemented at the local level that include taking appropriate actions within a reasonable period when an unacceptable tree risk is identified, will help to limit risk and protect against liability. Results from this study can be used to help support which variables communities should be concerned with as they develop their local urban tree risk management programme.

Disclosure statement

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