A review of deaths in Australia from accidental tree failures

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Abstract

Managing and reducing risk from accidental tree failure (Tree Failure) is an important function in most facets of modern arboriculture. As a result, trees are routinely inspected, pruned, and removed in an attempt to reduce risk. However, there is only limited data relating to the risk to people from Tree failure.

The digital age has increased the awareness of the risk associated with trees. In response, arborists need to answer questions such as, "*How significant is this risk?*", "*What factors contribute to the risk?*", and "*What can we do to effectively manage or reduce the risk?*". Only then can we develop reasonable and proportionate programs to effectively manage the risk. We demonstrate the use of the Database of Australian Fatalities associated with Tree Failures (the Database) for this purpose.

Background

Arborists and society as a whole are more aware of the risk from trees than they were 20 - 30 years ago. Images of fallen trees, crushed cars, damaged houses and reports of close calls or fatalities are readily and rapidly transmitted via electronic media.

As arborists, it is not uncommon to hear of deaths from Tree Failures, or at least that appears to be the case. With the advent of increased discussion and focus on risk from trees in the 1990s, we saw a shift and development in the understanding of risk by arborists. Hazard assessments (Matheny & Clark, 1991) were commonplace and often confused or mislabelled as risk assessments.

The concerns about risk and the potential for litigation in some ways started to drive the development and growth of the arboriculture profession. Arboriculture, in Australia at least, started to shift from filling cavities to removing trees with cavities. Likewise, the risk associated with falling cones of a Bunya Pine (*Araucaria bidwillii*) that had been traditionally managed by posting signs or installing temporary barriers, were now being managed by removing every cone.

In the late 1990s two individuals, Mike Ellison and Julian Dunster, working with colleagues, started to refine the risk-based approach to Tree Failure. Both groups were aware that, in spite of the massive numbers of trees and Tree Failures, very few Tree Failures resulted in significant harm.

Inspired by Ellison's quantified approach to risk in the late 1990s, the team at the Arborist Network (based in Sydney Australia) started to compile the Database of Australian Fatalities associated with Tree Failures (the Database). Initially, these records were driven by media reports, but over time it was expanded as resources and opportunity allowed. The Database is now the primary data set of this paper.

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Method

An initial database was compiled of fatalities commencing in 1997. These were compiled using media reports. Regular Google searches were then used to supplement the initial data set, and over time these started to provide information about historic fatalities, and a decision was made to extend the database to include all Australian fatalities from Tree Failures.

It was decided to limit the Database to deaths rather than looking at injuries, because deaths were absolute and relatively comparable in their consequence. In contrast, injuries varied widely in their extent from insignificant scrapes to permanent disability. In most instances, the available descriptions of injuries were incredibly broad with phrases such as "was injured" or "was taken to hospital" (n.b. It is important that the reader is aware that there were numerous serious injuries, and this is briefly addressed in this paper).

A paper on deaths and serious injuries to those in outdoor recreational activities (Brookes, 2007) provided a list of seventeen fatalities over a forty-year period. This was the first published list of deaths from Tree Failures in Australia.

The digitisation and public availability of historic newspapers by the Australian National Library in 2008 gave access to most of the deaths that predated those provided by Brookes (2007). However, copyright restrictions limited this service to papers published before 1955.

A request was made to the National Coroners Information Service (NCIS) for access to fatalities caused by Tree Failure for the years 2000 to July 2012. The information was provided in a format that was anonymous. However, with the limited number of fatalities and the extensive media reporting that usually accompanies tree-related deaths, it was possible to correlate many of the fatalities in the NCIS database with those in the media reports.

A decision was made to limit the use of the NCIS database to test the error rate of recent fatalities and to better inform the tree and risk assessment process, without compromising confidentiality. Where a Coroner's findings were made public, as has occurred on some occasions, the details provided in the Coroner's findings has been used along with information from any other source.

The basic details provided in the NCIS data was checked, and a number of the fatalities were eliminated. For example, it included the death of individuals collecting firewood[2] and even the death of an individual when a log rolled off a truck.

[2] Unless information was available to the contrary, when evaluating the death of individuals collecting firewood it was assumed that some of these were cutting down a tree. We have assumed that this tree felling killed a third or more of those gathering firewood. This seems a reasonable and conservative approach given that the likelihood of otherwise being hit by a falling tree or tree part is very small.

The NCIS database only included cases where a coronial inquiry had been finalised. As a result, some of the early NCIS data relates to deaths that occurred before 1st July 2000. Likewise, some deaths that occurred before 2012 were not finalised by coroners before the end of 2012.

In 2017 the Database was published on Wikipedia (**http://tinyurl.com/y7lepzhd**) to allow for public comment and editing. (The link was circulated through the forum of Quantified Tree Risk Assessment (QTRA) users, and feedback sought.)

In preparation for this paper, the Sydney Morning Herald digital service was used to find incidents between 1955 and 1999. The digital searches were repeated. All data and references were checked.

Population data was obtained from the Australian Bureau of Statistics (ABS 2014) for each year from 1877 – 2014 and the relevant figures used to determine the mortality rate.

A database was compiled that initially contained over 250 incidents. This database included deaths from trees that failed from degradation during fires, subsequently killing someone that was working at controlling or mopping up the fires. It also included some unusual industry related deaths.

A decision was made to isolate this fire-related subset because of the unique cause of failure. However, where the fire was being used to remove a tree (a common practice in times gone by), and this process caused a fatality these were deemed to be a fatality that arose from performing work on a tree and were not included in the Database.

The initial database also included numerous fatalities that arose from working on trees. These were retained and isolated to a separate database to assist users of the Database in comparing work related and accidental tree failures.

This same principle was applied to those who died hitting a tree as a passenger or driver in a vehicle. The exception to this was if the tree appeared to have fallen across the route immediately before being impacted such that the person in control could not have stopped.

The fatalities were also included if the tree failure was an obvious and unavoidable contributing factor to the death. For example, where a lady was hit by a tree branch and knocked into the water or where a tree brought down electrical wires onto the deceased.

Findings

The NCIS dataset included sixty-three fatalities. One of these involved a student climbing a tree, one involved a log falling from a vehicle, four involved firefighting activities. In addition, at least six, and potentially nine, deaths involved individuals engaged in activities that contributed to the tree failure such as impact from machinery or cutting trees for firewood.

The adjusted NCIS data contained fifty-one fatalities for the twelve-and-a-half-year period examined. The Database collected from the media also contained fifty-two deaths, but it is almost certain that there are several unique entries in each data set due to the Database recording deaths and the NCIS data being a record of completed inquests. Regardless, the similarity in numbers shows that most deaths from Tree Failures are reported in the media. It is suggested that this may be the case because such deaths are unusual and therefore journalists and media organisations consider them newsworthy.

During this twelve-and-a-half-year period of the NCIS data, the average population was 20,947,994 (ABS, 2008). This results in an annual mortality rate from Tree Failure during this period in the order of 1 in 5 million (5,134,312). If this rate is extended over the period of the Database, it would contain 255 fatalities. At the time of writing[3], for the period 1858 to 2017, the Database contains 242 incidents that resulted in 273 fatalities. This equates to 1.13 fatalities per incident. While it is almost certain that there are some deaths that have not yet been discovered it is unlikely that the number is significant[4].

The figures demonstrate that the media, since the beginning of the 21st century, reported almost all, if not all fatalities that resulted from Tree Failures. Prior to this time, the media coverage appears to be almost as efficient. However, there is a greater difficulty in recovering earlier fatalities, even with the digitisation of historical media.

Implications of the data

While the information was often scant, some distinct patterns are apparent in the data. The validity of these observations is reinforced with the smaller, but more detailed, 21st-century data and the data from the NCIS.

Strangely, the NCIS provided weather conditions for only twenty-eight of the fifty-one fatalities. Not surprisingly, storms or strong winds were associated with 68% of the fatalities that recorded weather and a further 18% involved saturated soils or severe wind on the day of the failure or the immediately preceding day. This results in a total of 86% of occasions where the weather was a significant contributing factor. This pattern is similar to the data contained in the Database.

[3] 24th July 2018

[4] Significant here means 30% or more.

The media appears to pay greater attention to the death if it occurred during fine weather or when a younger person was involved. Perhaps the most notable incident was the tragic death of a young schoolgirl (Bridget Wright) in the school playground in 2014. This attracted copious media attention. Her name, and the words 'tree' and 'died' yields just under 5,000 hits in Google. In contrast, a dead and highly decayed tree trunk beside the road fell during strong winds in 2012 killing John Lawton (Image 1). This was considered by the investigating police to be "*a freak accident*" and received only two minor mentions in the media.

Image 1: The base of the tree that fell on John Lawton in 2012

Weather and deaths

The weather was available for 116 (42%) of the 273 deaths in the database. The weather was calm or involved conditions such as light winds or windy without mention of a storm in eight (8.5%) of the incidents. Twenty-two (23%) of the events involved wind, but no mention of rain and one (1%) mentioned rain, but no mention of wind. Inclement weather (storms cyclones etc) made up the remaining sixty-three (67%) of the events. Combined, wind and inclement weather accounted for eighty-five (90%) of the incidents.

Without question, weather contributes more significantly to the likelihood of being killed by Tree Failure more than any other factor. Guidance regarding being outdoors during storms is becoming more commonplace (Schmidlin, 2009). We believe that there is still room for improvement in this area. In particular, a better understanding of the impact and timing of microbursts is likely to be of benefit (Hartley, 2018).

Age, gender and deaths

The age of the decedent was disclosed for 187 (68.5%) of the deaths. Where the age of the decedent was provided this information was collated into groups of 25 years. Of these known ages, eighty-six (46%) were 0 to 24 years, fifty-three (28%) were 25 to 49, forty-five (24%) were 50 to 74, and three (2%) were 75 years or older.

The heavy bias towards those in the 0 to 25-year bracket motivated us to examine this group in more detail. They were divided into 5-year brackets. In this 0 to 25-year age bracket, fifteen (18%) were 0 to 4 years, eleven (12.8%) were 5 to 9 years, eighteen (21%) were 10 to 14, twenty-four (28%) were 15 to 19, and eighteen (21%) were 20 to 24. Under further investigation, there appeared to be no significant subgroup.

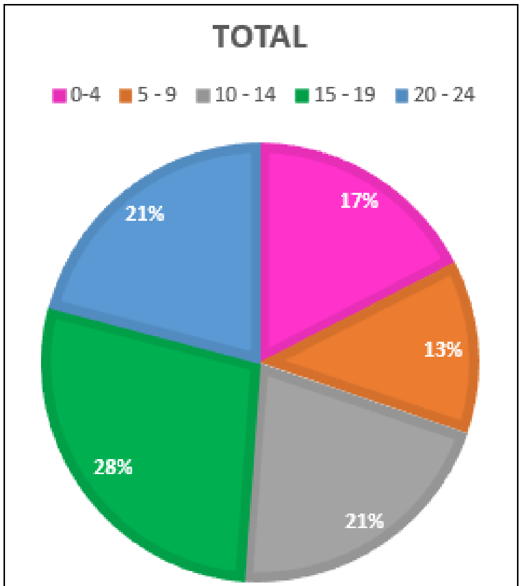

Image 2: Death by age bracket.

The gender was reported in only 96% of the deaths. Of these deaths, 69 (26%) were females and 194 (74%) were males. Males are clearly more likely to be a target. However, an age-related correlation was observed in the female population. The age was available for 53 of the 69 females that were killed. Thirty-two (60%) of the females that died were under 25, thirteen (25%) were 25 to 49, eight (15%) were 50 to 74 and there were no deaths in the 75 plus age group.

Activity or location and deaths

The activity/location at the time was available for all but six deaths in the database. In 152 (56%) of the deaths the decedents were involved in outdoor activities (other than transiting), sixty-two (23%) of the fatalities involved transportation, twenty-seven (10%) were in tents at the time of being hit, twelve (4.4%) were in some form of shed, shack or basic structure, seven (2.6%) were in houses, four (1.5%) were in caravans, three (1.1%) were cycling.

Based on the Database there have been seven deaths inside a house with at least six of these houses being clad structures. Even so, based on the Database, the annualised risk of death inside a house from Tree Failure is in the order of 1 in 189,000,000. This was not too dissimilar to earlier estimates based on a twenty-one-year timeframe (Hartley 2011).

A small number of deaths occurred on private property (about 7%). The majority of these deaths involved individuals cleaning up during or after a storm. The lesson from this is clear. Stay indoors until the storm has passed and exercise great care and stay alert when trees may have been damaged.

After noting the age and gender bias, the data alerted us to look at deaths in tents based on gender and found the following. Of the 69 females killed, eleven (16%) were inside a tent. In contrast of the 194 men that died, sixteen (8%) were inside a tent. Equally as interesting was that nine (82%) of the eleven females killed in tents were under 25. This group also accounts for 28% of the fatalities of females under the age of 25.

Even more alarming is that all these females are older than fourteen. Cautiously, we suggest that some additional guidance in outdoor activities should be provided to this age group before they go camping.

The NCIS data revealed that only 20% of fatalities occurred in major cities. 71% of the fatalities occurred in inner and outer regional areas. This is perhaps not surprising. These areas probably contain more trees and are often further from emergency assistance and medical support.

Death rate over time

The death rate was examined in sixteen ten-yearly increments. This was not overly revealing, perhaps due to the very small numbers of deaths in any year. However, when the deaths were grouped into four forty-year blocks, the trend was more obvious (see Image 3 and 4).

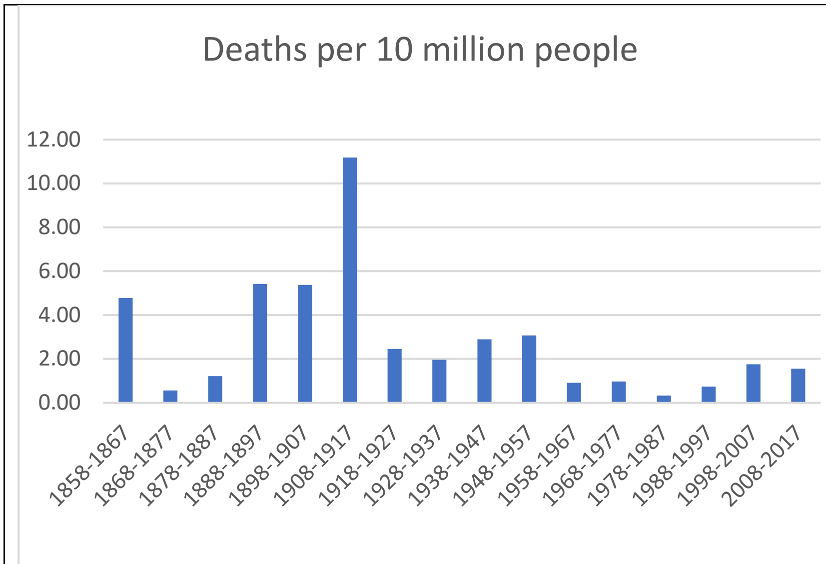

Image 3

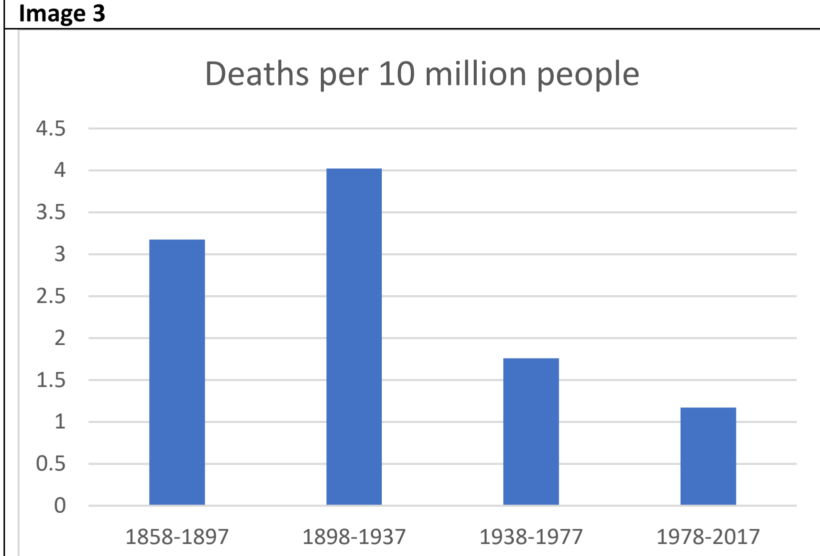

Image 4

At first glance, it may appear that arborists are doing a wonderful job of lowering the rate of death from Tree Failure. However, this may not be the case. Ignoring a spike at the beginning of the 19th-century, the greatest drop occurred in the period post-1948, and this was three to four decades before arboriculture started to flourish in Australia. Likewise, as arboriculture started to focus on risk from the late 1980s onwards, we see an increase in deaths.

There are many things that may account for these trends. Wars, the Great Depression, and improved literacy all may have had some impact. It is suggested that perhaps an improved awareness of the risk associated with trees and the need to exercise caution has been of benefit. This same pattern is also observed in other outdoor causes of accidental death such as a lightning strike.

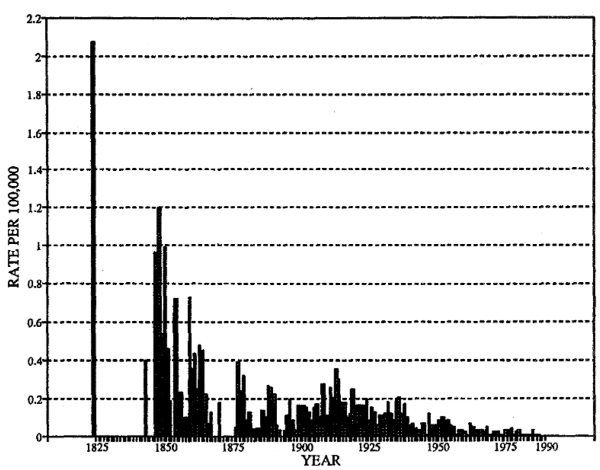

Fig. 4. Annual lightning fatalities in Australia per 100 000 population, 1824–1991.

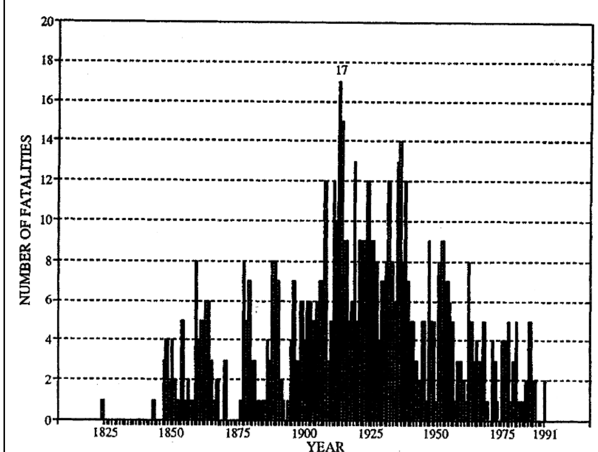

Fig. 3. Annual lightning fatalities in Australia, 1824–1991.

Discussion

Replicating the process elsewhere

The International Classification of Diseases, 2010 (ICD-10) is used to collect data relating to illness and death. The category (W20[5]) that covers deaths and injuries from falling trees and tree parts is a shared category. The data for this category also includes injuries and deaths from various causes including working on trees, falling rocks, and the collapse of a building. Therefore, most, if not all governments worldwide, do not collect or compile records relating to injuries or deaths arising from accidental tree failures. This data is only available through research such as this paper.

[5] W20 of ICD-10 is defined as follows:
Struck by thrown, projected or falling object Including: # cave-in without asphyxiation or suffocation, # collapse of building, except on fire, # falling: rock, stone, [or] tree [but] excluding.: # collapse of burning building, [or] # falling object; in cataclysm, machinery accident, [or] transport accident, [or] # object set in motion by: explosion, [or] firearm # sports equipment

The compiling of the database was not a quick process. On average, more than three hours were spent on finding, investigating and documenting each death. In the case of a small population such as Australia or Canada, going back a little over a century is not so daunting. However, for a country with a larger population such as the USA or with a long history like the UK, such a task may be more challenging. It may be worth considering that the most reliable data appears to be easier to obtain since the turn of the 21st century.

There is likely to be some variation in data from country to country or region to region. For example, analysis by Ball and Watt (2013) showed that driving was the activity that was most likely to be taking place when killed by Tree Failure in the UK. Outdoor recreation was the second highest activity. While this may seem at odds with the Australian data, this may not be the case. We suggest that because of the climate and lifestyle differences, significantly more time is spent outdoors in Australia. The implications of the difference between Australia and the UK is important not just for each country but for various regions as well. The risk of death increases where outdoor activities and tree cover is greatest. A similar observation is well illustrated by Schmidlin (2009 Fig 4).

When collecting data, it is important to consider that the mortality rate is likely to be a relatively small number (1 in 5,000,000 in the case of Australia). Small numbers such as this are subject to a problem sometimes referred to as "*The law of small numbers*" (Tversky & Kahneman, 1971). As a result, limiting the data collection to a period that is too short is problematic. Typical of the "*Law of small numbers*," the data for Australia has years where no deaths occurred and some years with abnormally high numbers of deaths. A good example of such differences can be seen in the data where fourteen deaths occurred in the five years 2001 – 2004 inclusive, while there were nine deaths in both 2005 and 2016.

The risk is small

Even though more deaths may still come to light, the 273 deaths in the last 160 years provide us with some valuable insights. The Database establishes some benchmarks for deaths from Tree Failure. In addition, the information helps us to better understand these Tree Failures and associated deaths. The data also provides a meaningful benchmark that allows a more robust approach to risk assessment and tree management.

The Database shows that the majority of fatalities occur as a result of storm damage. As a result, the greatest harm from trees is likely to occur when large trees are plentiful and when people are spending time outdoors driving or recreating during a storm or high wind event.

What is apparent is that the mortality rate from Tree Failure is quite small. Ball & Ball-King (2011, p47) point out, '*tinkering with already small risks opens the possibility of opening some new, unintended risk, which is worse than that previously existing.*' Pruning and the removal of branches is an excellent example of the principle of unintended consequences associated with very small risks. Such intervention may appear desirable but, in some cases, interfering with a tree's natural processes may increase and not lessen the likelihood of branch failure (Wells, 2017).

Serious injuries

The use of mortality figures allows us to compare the overall risk from Tree Failure with other risks. For example, using UK figures, almost 1,000 people a year die falling from or onto stairs (Hill et al., 2000); while deaths from Tree Failure averages at just under six a year or 1 in 10,000, 000 in the UK (Ball & Watt 2013).

In the same manner, patterns associated with a given class of injuries can be compared where the data is available. Continuing with the above examples, stairs resulted in twenty-two times (2,200%) more serious injuries[6] than deaths (Hill et al., 2000). Tree Failures resulted in four serious injuries for every 10 deaths (Ball & Watt 2013). From this, we might conclude that being hit by a tree or tree part is much less likely than being hurt falling down stairs. However, if you are unfortunate enough to be hit by a tree the consequences are, understandably, likely to be worse when compared to the consequences of falling down stairs.

The only injury figures from Australia resulting from Tree Failure in Australia involves Hospital admissions for the Hunter Region (Walsh & Ryan 2017). While Walsh & Ryan (2017) record a death in their data set "*it was definitely not due to accidental tree failure*" (Walsh pers com 2017) it was a "tree-related death" and this is consistent with the Database.

Walsh & Ryan (2017) record four admissions from Tree Failure. These four represented 16.7% of the 25 injuries from trees. 62.5% of these involved tree work and 20% contained insufficient details. If this 20% is allocated proportionately, this still results in no more than five hospital admissions due to Tree Failure. This equates to an annualised admission rate of 0.12 per 100,000 people or about 6 people requiring hospital administration per 5,000,000 people or per death from Tree Failure.

As has already been pointed out, the extent of injuries requiring hospitalisation can range from a concussion requiring extended observation to permanent disability. Walsh & Ryan (2017) looked at the entire IDC-10 code W20 data for all admissions. Based on the data for the main injury sustained only a small percent involved permanent disability.

In considering the data provided by Walsh & Ryan (2017) and Ball & Watt (2013) it is acknowledged that the number of incidents is small. As a result, the data is subject to "*The law of small numbers*" (Tversky & Kahneman 1971). It seems reasonable to speculate that a much larger dataset would result in a figure somewhere between these two. It is highly unlikely, however, that Tree Failure is resulting in a similar number of permanent disabilities.

Fires and Tree Failures

The rapid loss of strength in trees associated with fires is problematic for those that are fighting fires. This loss of tissue is likely to be most severe where a tree is hollow and has a basal opening. Once alight, these hollows can produce considerable draw and burn rapidly,

[6] Serious injuries are those that required admission into hospital.

often without detection. While the inside burns the tree loses wall thickness and if it continues long enough, the tree will fail.

Hollows in trees are ecologically valuable, and there is no satisfactory solution to prevent internal fires. As a result, great care needs to be exercised when fighting fires. This risk increases as the internal tissue continues to burn. This means greater caution needs to be applied in the mop-up stages of a fire. Likewise, there is an increased risk during strong winds after a fire, even if the fires have been extinguished.

An excellent visual guide has been produced to assist firefighters in recognising high-risk trees (Victoria. Department of Environment, Land, Water and Planning 2017.). This publication also establishes a standard system for marking higher risk trees. In addition, firefighters receive ongoing training to help identify hazard trees to help reduce this risk.

Perhaps the most common thread amongst the fire deaths is that the individuals are almost always busy and in a noisy environment. As a result, they may miss important visual and audible cues. Where possible keeping noise levels low, and the use of third-party spotters and the use of infrared imaging may assist in picking up early signs of imminent failures.

Shortage of information

In most instances, there is a great deal of information that is lacking that would assist in better analysing and reducing the likelihood of fatality. Improved details about the weather would be desirable including the overall weather conditions, the wind speeds, and how long after the storm started the incident occurred. If the weather was calm, it would be useful to know when the last storm event occurred.

Where the failure occurred during severe weather events, there was a tendency to ascribe the failure to an act of God or *force majeure.* In these instances, there appeared to be much less attention given to the tree or any tree related factor that may have been present.

In some instances, the investigating police assessed the tree without arboricultural input. When arborists were engaged to undertake the forensic investigation, the process of obtaining arboricultural information was often *ad hoc*.

A detailed analysis of the failure and any tree related factors that contributed to the failure would assist in determining if there were factors that needed to be considered more carefully. In most cases, the analysis undertaken appeared to be superficial. It seldom involved accurate measurements and almost never involved cross sections, preparation of samples or microscopic examination.

The need for a systematic and detailed forensic approach is vital. For example, without the preparation of proper samples, items such as internal cracks (Harris, Clark & Matheny 2004 p414), reorientation of xylem structure (Mattheck 2015 pp219 - 234) and even prior partial failures are often missed.

The risk from Tree Failures in context

All trees pose some level of risk. The overall risk from trees is very small. The risk of being killed or seriously injured by a tree is greatest during or immediately after a severe weather event. The Database revealed that tree failure caused less than one death in 25 million during normal weather conditions.

The mortality rate from storm-affected Tree Failures is only in the order of 1 in 6 million and this is the period in which most Tree Failures occur and associated deaths occur. In many cases, any attempt to manage risk this small is problematic. Ball and Ball-King (2011, p12) point out that the effort and cost required to in any way reduce the risk of harm from trees, in real terms, would require '*a massively precautionary programme of tree pruning and felling which would have destroyed many places of beauty.*'

As has already been discussed, when the risk is small, there is an increased likelihood of an unintended consequence when trying to manage that risk (Ball & Ball-King 2011, p47). The removal of lower branches over a building serves as a good example of this principle. Removing the lower branches over a roof to reduce risk can result in a higher branch which may have previously been slowed or stopped, now being able to freefall onto the roof and do even more damage. For this reason alone, it would seem appropriate to minimise the extent of any unnecessary interference with the trees.

The UK Health and Safety Executive (HSE, 2007) states, '*The risk, per tree, of causing fatality is of the order of one in 150 million for all trees in Britain or one in 10 million for those trees in, or adjacent to areas of high public use*.' Norris (2010) determined the '*urban fatality rate for the 53 months of five and hence a societal risk of 1:17.7 million per annum*' from Tree Failure in the urban environment. This is similar to the figures reported by the Health and Safety Executive (2007) and by Schmidlin (2007).

In trying to determine the per tree mortality rate for Australia, the figures for Canberra were used. Canberra has a population of just over 350,000. '*Transport Canberra and City Services manages over 700,000 trees in residential streets, major road verges, urban parks and other open space areas throughout the city*' (Unknown n.d.) Ignoring trees located on private property, that equates to two trees per person or one death per ten million. If private trees are included, the death rate form Tree Failures will be closer to 1 in 15 million.

A death rate per tree in Australia that is smaller than Britain's may surprise many Australian arborists who consider Eucalypts to be 'widow makers'. It would appear that Eucalypts may provide no greater risk and perhaps a lower risk than the average tree in Britain. An alternate possibility is that the British rate is substantially overestimated.

To effectively reduce the risk of death from Tree Failure, we would need to find the offending 'killer tree'. While this may appear to be a 1 in 10 to 15 million chance it is much smaller than this. As will be seen from the '*Coronial comments and advice'* a number of the trees that caused fatality gave no hint that they posed an elevated risk. Furthermore, as we have discussed above, weather is a significant contributing factor in 90% of the deaths.

At best, given our current rate of five deaths a year, perhaps two deaths a year may have been preventable. However, to find these two trees is no small task since we are looking for two trees in 50 million (5 deaths times 10,000,000 trees). Ball & Ball King (2011 p11) state, '*the risk to the public of harm from falling trees is miniscule* [sic], *and the reality that the prospects of reducing the risk below the current level are remote and comparable to finding a microscopic needle in a gargantuan haystack.*'

The cost of trying to find a 'killer tree' is disproportionate to the risk posed. In addition to the cost of inspecting trees, there is the cost of undertaking any work required to mitigate the risk associated with any factor[7] present that the assessor believes substantially increases the likelihood of Tree Failure. Even if work is recommended for as little as 0.1% of the tree population, this still means that some form of work would be required on 50,000 trees.

Such inspections are likely to result in the recommendation to remove trees at a greater rate than this. In the case of the death of Bridget Wright in a school playground, the ensuing inspection of all trees in the 2,500 or so public schools resulted in the removal of 9,000 trees. The coroner found that '*There was nothing to indicate any specific concerns about the large Red Forest Gum tree in the playground on that day.'* Had the tree been inspected before the death, it is likely that the tree would still have been there, and the death would have occurred in any case.

The cost of the inspections and removals exceeded $32,000,000 ignoring the value of the trees and the benefits they provided. In addition to this there are unintended costs. For example, it is conceivable that at some stage we will see a small spike in melanomas as a result of the loss of trees. In some schools, the loss of trees was sufficient enough to have caused other health issues such as an increase in the rate of asthma attacks (Alcock et al. 2017).

The NSW school inspections demonstrate that the cost of tree work arising from tree inspections is likely to be grossly disproportionate to the risk posed. Most significantly, we suggest that there is a reasonable likelihood that more than two arborists will die in the performance of the tree work required to prevent two fatalities.

While the odds of locating, or even inspecting, a tree that will kill someone are very small, there are things that can be done to increase the odds in our favour. Most obviously, as is pointed out by Ellison (2015), focussing on areas with the highest occupancy rates first is important. In Australia, this is likely to include high use camping grounds and caravan parks, larger urban retail areas, and major roads in our cities and larger towns.

It is likely that a more cost-effective solution would be to better educate and inform the public about high-risk periods and how to behave during these periods. In simple terms, as has already been suggested (Schmidlin 2009), avoiding or limiting outdoor movements and

[7] The word "factor" is used rather than "defect" in order to clarify that many defects are not a factor that leads to an increased likelihood of failure.

driving during storms or seeking open areas free of trees during these events. Education and awareness of the public are likely to have a significant impact on the mortality rate from Tree Failures, and we suggest that this has been a part of the reduction in mortality rates over the last 120 years.

Benchmarking and understanding risk from Tree Failure

The adoption of commonly used risk assessment terms such as high medium and low can be meaningless without a context. As a result, being able to benchmark the risk from a tree against known benchmarks is of benefit, not only for the tree owner or manager but also for the risk assessor (Stewart, O'Callaghan & Hartley 2013). The information obtained from the Database allows us to do this. In short, there is a benefit to understanding the risk of harm from the average tree against other societal risks.

Most people are comfortable being exposed to risks many times greater than the risk posed by Tree Failure. Most individuals struggle to see the risk from trees in the context of other risks. The following mortality rates (figures rounded) are for Australia, but similar examples are available for most countries.

- melanoma in 2017 - 1 in 13,500 (AIHW 2017b),
- driving in 2017 - 1 in 20,000 (BITRE 2017),
- asthma – 1 in 60,000 (AIHW 2017a),
- murder – 1 in 100,000 (Australian Institute of Criminology 2017),
- fallingA re from a bed in 2011 – 1 in 420,000 (ABS 2013),
- animals – 1 in 830,000 (NCIS 2011),
- fall involving a chair in 2011 - 1 in 1,000,000 (ABS 2013),
- accidental tree failure - 1 in 5,000,000 (this paper),
- accidental tree failure while inside a house - 1 in 189,000,000 (this paper).

While such figures may not provide comfort, they do demonstrate the incredibly low risk associated with trees. Ironically, there will be some who lie awake in bed worrying about the tree that may kill them as they sleep, unaware that, on average, the very bed they lie in is 450 times more likely to cause their demise.

If we apply the principle of benchmarking to the inspections and management of trees it should be apparent that there are issues. For example, in NSW schools, after the death of Bridget Wright, we can see significant issues with the assessments and decisions that were made. The inspections resulted in the removal of 9,000 trees and many more trees were also pruned in some manner.

If we assume that there were 100 trees in each school and 2,500 public schools, this means that there was a total of 250,000 trees. If we adopt the mortality rate of one per 10 million trees, we would expect there to be 0.025 killer trees. If we suggested a thousand times more trees be removed than needed to ensure that we eliminated the killer tree we would still only have needed to remove 25 trees.

For this reason, the NSW Department of Education and Training (DET) was advised by Arboriculture Australia that it should treat any report that recommended the removal of more than three trees with some degree of scepticism. Despite the advice provided, the DET approved the removal of 9,000 trees, with some schools losing twenty-five or more trees. More importantly, this demonstrates that the consultants assessing the trees, on average, overestimated the risk from trees by more than a factor of 100,000.

The process of benchmarking can also be applied in reverse. Let us conservatively assume that 12,500 trees were pruned or removed because they posed an unacceptable Risk of Harm (RoH) and that the level of risk varied between 1 in 1 and the risk threshold. Let's also assume the unacceptable risk threshold is 1 in 100,000 (a little less than ten times smaller than the RoH associated with driving).

Using these assumptions, the average RoH from each of these would be 1 in 50,000 and based on the 12,500 trees means that we should have been seeing a death about every 4 years (1/50,000 x 12,500 = 0.25) arise because these 12,500 trees had not been pruned. Again, this was not the case.

Conclusion

The compilation and analysis of fatalities from Tree Failures in Australia is a valuable tool in undertsanding the risk associated. The comparatively small mortality rate of 1 in 5,000,000 associated with these failures can be used to inform tree managers and owners, as well as assist in better communicating with the media and the public.

Based on the data, it is likely that a detailed risk assessment on most trees is not likely to be effective in reducing the mortality rate from Tree failure. Where a decision is made to assess larger groups of tree focus should be given to trees where there is the greatest occupation rate by people.

On average, it would appear that arborists undertaking tree risk assessments in Australia are far more risk averse than is justified by the data. The use of benchmarking against known benchmarks or the assessment of other arborists may assist in preventing unnecessary tree removal.

Preventing deaths

While it appears possible that arborists may cause more harm than good in undertaking tree risk assessments there are several things that can be done to reduce the risk from Tree Failure. When given the opportunity, arborists should focus the greatest effort on trees adjacent to areas that have the highest rate of outdoor human occupation.

Arborists can be more methodical and detailed when inspecting failures that cause deaths or serious injuries. Consulting arborists should not undervalue the importance of data collection, making appropriate measurements, and preparing and examining cross sections.

Arborists can play a more active role in communicating about the more obvious factors that increase the likelihood of Tree Failure. This message is perhaps most important for those who are under 25 along with the adults that interact with them in planning outdoor recreational activities.

Without question, the most significant impact on reducing the risk from Tree Failure will come from broad spread public education. Changing people's behaviour so that they avoid or limit being outdoors or driving during storm events has the potential to make significant improvements in reducing the risk from Tree Failure. Likewise communicating the message that when you are driving or recreating, and there is a severe storm[8] warning you should not seek shelter under trees but should find an opening, stay alert and be ready to move until the storm subsides.

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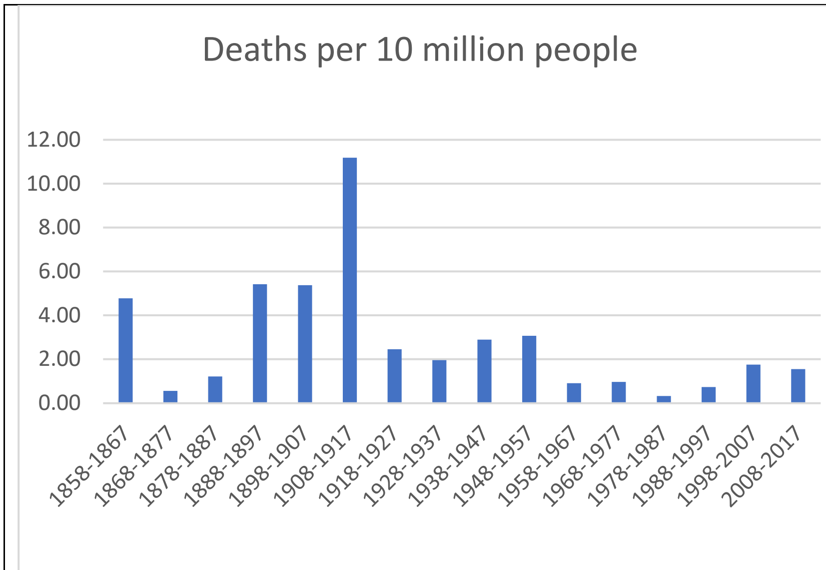

Image 3

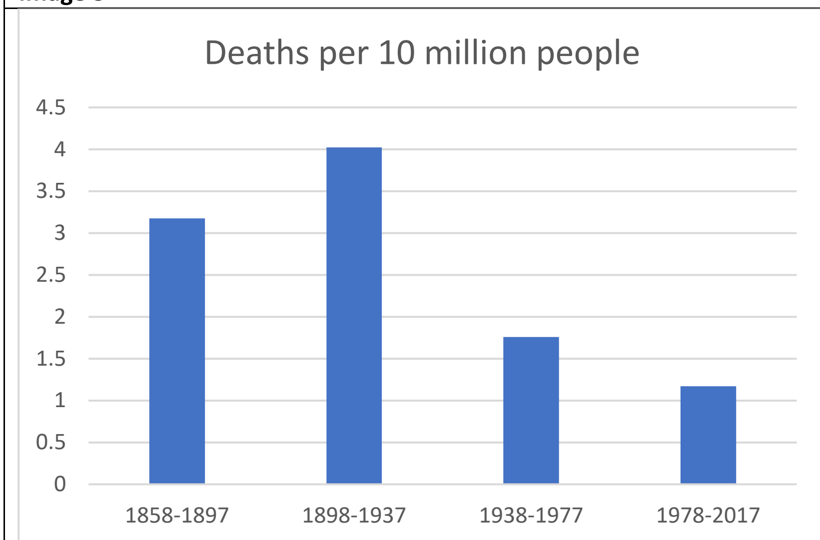

Image 4