PROTECTING HRM TREES: A LOOK INTO MECHANICAL DAMAGE

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Executive Summary

The urban forest is simply defined as every tree within a city. Urban trees provide numerous benefits, however they are also extremely vulnerable because of many threats, including loss of woodlots, air pollution, water pollution, vandalism, and mechanical damage from grass maintenance equipment. Of these various threats, the least understood and researched is mechanical damage. This report takes a closer look at the issue of mechanical damage, specifically in HRM. The effects of mechanical damage are explored, and then an HRM case study is discussed.

The case study consisted of routinely checking 844 trees in 5 urban forest neighbourhoods in HRM for the presence of recent mechanical damage. When damage was visible, additional information was recorded including the size and type of damage and the location of the tree. This information was then input into Microsoft Word and Excel to attempt to identify trends. Although data from only one grass-cutting season does not provide enough information to make any grand conclusions, several patterns were identified and discussed. In future years, this protocol should be repeated to see if the same patterns, or new ones, emerge. The results of this research can then be used in HRM urban forest management to better protect trees from the preventable threat of mechanical damage.

Recommendations outline three areas in which HRM should focus its efforts: prevention, protection, and accountability. The most important of these is prevention in the form of education. Mandatory education regarding mechanical damage should be written into future grass-cutting tenders to ensure everyone is on the same page regarding expectations. Second, the current protection measures used by HRM (trunk guards and mulching) should be continued and special attention should be paid to “problem areas” identified through inspections. Increasing the protection in these areas could reduce the instances of mechanical damage. Lastly, in cases where damage has already occurred, HRM should use the penalties already outlined in the tenders to their fullest extent ($100 per 2.5 cm square of damage) to encourage better compliance.

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Introduction

1.1 What is an urban forest?

"Urban forests are small pockets of green in a gray landscape. They are ribbons of life meandering through a largely artificial environment. They are enclaves of serenity and biological diversity tucked within suburban development and busy streets." (McPherson et al., 1997, p. 1).

Many people believe that an urban forest is a specific, densely wooded area within a city. However, this definition does not properly encapsulate the true meaning of the urban forest; to put it simply, the urban forest can be defined as every tree within the city (Ordonez et al. 2010). "The urban forest is where we live, work, and play. It's in our back yard, our front yard, and our parks. It's by the river, by the office building, and on the street corner." (Tree Canada, 2016a, n.p). These forests are under intense pressure from human activity, but also provide direct benefits to the urban population (Kenney & Rusak, 2016)

In the case of Halifax Regional Municipality (HRM), the urban forest includes over 57 million trees spanned across over 69,000 hectares of land (HRM, 2013). Although Nova Scotia is within the Acadian Forest Region, HRM's urban forest, like most urban forests, contain a combination of native and non-native species. The HRM urban forest includes street trees, trees in parks and public spaces, peri-urban forests (hinterland stands), and privately-owned trees (HRM, 2013).

1.2 The importance of urban forests

Urban forests provide a multitude of benefits to the urban population. Aside from the obvious aesthetic benefits- almost anyone would agree that trees enhance the beauty of an urban landscape- trees also provide economic, ecological, social, and psychological benefits. This section will outline several of these benefits.

Air quality benefits

Trees are able to trap and absorb noxious gases and particulates, which can significantly improve the air quality of a city (Kenney & Rusak, 2016). The healthier the tree and the greater the foliage surface area, the more it is able to remove air pollutants (HRM, 2013).

Biodiversity benefits

This benefit is multi-faceted in that it refers to improving species diversity of trees in an area, but also other organisms, such as birds, small mammals, plants, and insects (HRM, 2013). Trees provide habitat, food, and protection to plants and animals that would otherwise be very vulnerable in an urban environment.

Carbon sequestration benefits

Trees capture and accumulate carbon-based greenhouse gases in their roots, stems, and branches through carbon sequestration (HRM, 2013). Therefore, trees can help mitigate climate change. The average Canadian urban tree is estimated to remove about 200 kg of carbon over an 80-year period (City of Kelowna, 2009).

Economic benefits

Trees provide measurable financial benefits for homes, businesses, and industries (HRM, 2013). The presence of trees can increase property values of well-landscaped homes by up to 20% (City of Kelowna, 2009). Furthermore, shoppers have indicated that they are willing to spend up to 12% more for products in business districts with appealing urban forests (City of Kelowna, 2009).

Energy use benefits

Thoughtfully-placed trees near homes and buildings can provide energy conservation benefits in both the summer and winter (Kenney & Rusak, 2016). During warmer months, the shade from trees can reduce air conditioning needs by up to 30% and can save owners 20-50% in energy usage for heating (City of Kelowna, 2009). During colder months, trees can act as windbreaks and reduce energy usage by 10% (HRM, 2013).

Health benefits

The health benefits provided by trees in an urban landscape are quite varied. The shade provided by trees mitigates the negative effects of sun exposure such as sunburn, sunstroke, and skin cancer (HRM, 2013). As previously mentioned, trees improve air quality through carbon sequestration and trapping and absorbing air pollutants (Kenney & Rusak, 2016; HRM, 2013). The presence of trees has also been shown to reduce stress, and hospital patients with views of trees heal significantly faster and with fewer complications that those without such favourable views (Ulrich, 1984).

Hydrological benefits

Urban forests moderate storm water and flood damage, improve water quality, reduce erosion, and reduce storm water treatment costs (Novak, 2006). Urban forests allow infiltration and the immediate absorption or retention of rainwater by tree roots systems, keeping polluted storm water from entering the sewer systems (Kenney & Rusak, 2016). This improves water quality and reduces pressure on storm water treatment systems.

Road benefits

Trees benefit our roadways in two major ways. First, they make streets safer in terms of vehicle traffic. A tree-lined street gives the illusion that the street is narrower and generally calms traffic (Wolf & Bratton, 2006). Furthermore, trees reduce the glare of headlights from oncoming traffic (HRM, 2013), and reduce stress for drivers, likely resulting in better decision-making and improved awareness while driving (HRM, 2013). Second, trees enhance the longevity of our streets; a road surface that is 20% shaded has its pavement condition improved by 11% (HRM, 2013). After 30 years, this results in 60% savings on resurfacing (McPherson et al., 1999).

Social and psychological benefits

Urban forests provide a vital natural and aesthetic setting for our urban lives and are a defining feature of a successful, 21st-century city (HRM, 2013). Treed neighbourhoods have been shown to be less stressful and have lower crime rates and an enhanced sense of community (Kenney & Rusak, 2016). Even brief encounters with nature can improve a person’s ability to concentrate; Attention Deficit Disorder symptoms in children have been shown to be reduced after spending time in nature (City of Kelowna, 2009).

1.3 HRM Urban Forest Master Plan

After a series of intense, unforeseen, destructive events during the early 2000s that deeply impacted HRM’s urban forest, including Hurricane Juan, a longhorn beetle infestation, and a succession of severe storm events the need for an urban forest master plan was fully realized (HRM, 2013). Around the same time, Sustainable Urban Forest Management (SUFM) research was beginning to expand and evolve, and people world-wide were beginning to realize both the economic and health benefits of the urban forest, as well as the ever-growing list of threats that affect urban trees (HRM, 2013). Thus, in 2006 the Regional Council adopted Policy E-20 within the HRM Regional Municipal Planning Strategy (HRM, 2013). This policy stated “HRM shall prepare an Urban Forest Functional Plan to identify design guidelines and a management strategy to maximize the urban forest.” (HRM, 2006).

After many years of hard work, Halifax Regional Council unanimously approved the Urban Forest Master Plan (UFMP) in September 2012 (Halifax Regional Municipality 2016). The overall goal of the UFMP is to ensure a sustainable future for our urban forest (HRM, 2013). It was developed using a multiyear community engagement process and research initiatives, which resulted in an integrated social, ecological, and economic strategy that thrives to incorporate the values of the HRM population (HRM, 2013).

The geographic area of the plan is approximately 15 km outwards from Halifax Harbour and is specifically defined as the HRM communities that receive water and wastewater services (HRM, 2013). This area was chosen because in general, communities that receive such services are associated with urban living and compact development (HRM, 2013). HRM's urban forest is a natural resource that spans all public and private trees within the following 11 communities:

Table 1: The 11 urban forest communities designated by HRM UFMP

Bedford	Beechville	Lakeside	Timberlea
Dartmouth	Cole Harbour	Eastern Passage	Halifax Peninsula
Halifax Mainland	Sackville	Spryfield	

(Adapted from HRM, 2013)

Each community comprises a number of urban forest neighbourhoods, with 111 neighbourhoods being managed in total (HRM, 2013). Every neighbourhood was assessed individually to determine the current state of the urban forest, the desired state of the urban forest, and the treatments necessary to bridge the gap, as well as the priority level of the neighbourhood itself. The plan is extremely detailed and mindful of neighbourhood-specific needs.

2. Urban Trees

2.1 Tree anatomy: How trees grow

In general, trees consist of four main parts: leaves, branches/twigs, roots, and trunk. In order to understand how a tree grows, and more specifically, what can prevent a tree from growing, a basic understanding of these parts is needed.

Leaves

The primary role of leaves on a tree is to carry out the metabolic process of photosynthesis, which creates food for the tree, while releasing oxygen into the air (NADF, 2016). The green color of leaves is due to the abundance of chlorophyll, which is the pigment that acts to capture energy from sunlight (PSU, 2009). The amount of photosynthesis that can occur is highly dependent on the surface area of the leaves (NADF, 2016) because the leaves need surface area to “capture” sunlight for the process, as well as carbon dioxide through pores, which are called stomata (PSU, 2009).

Branches/Twigs

Branches and twigs grow out of the tree trunk and serve as necessary support structures for leaves, flowers and fruit (NADF, 2016). They also allow for materials to be transported from the trunk and leaves (NADF, 2016). The shape and size of branches on a tree can be very indicative of its function, i.e. A tree with a lot of branches and leaves, will likely have a high rate of photosynthesis and grow quickly.

Roots

The roots of a tree play several integral roles. Perhaps the most intuitive role that roots play is anchoring a tree in ground so it remains upright (NCFA, 2016). Additionally, roots absorb water and nutrients from the soil, and store sugars (food reserves) for the winter when there is less sunlight for photosynthesis (NCFA, 2016). Tree roots generally branch out laterally, and remain in the top metre of soil. They often extend beyond the drip line, sometimes occupying an area up to four times as big as the crown (NADF, 2016).

Trunk

The trunk supports the crown and gives the tree its shape and strength (NCFA, 2016). It is composed of five layers: outer bark, inner bark (phloem), cambium, sapwood, and heartwood (NADF, 2016; USDA, 2016). Each layer of the trunk has an innate function, which contributes to the trees overall health.

The outer bark is the part of the trunk that we can normally see- it is the trees protection from the rest of the world (NADF, 2016). It is continually renewed from within and helps keep out moisture during precipitation, and prevents the loss of moisture when the air is dry (NADF, 2016). It is an insulator against extreme heat and cold, and wards of insects and other enemies (NADF, 2016). The inner bark, or phloem, is found directly below the outer bark. It is the pipeline through which food is transported to the rest of the tree (NADF, 2016). It is a short lived layer, which then dies and turns into cork to become part of the protective outer bark. Figure 1 shows the layers of a trunk and presents the outer and inner bark as one layer, labelled “bark”.

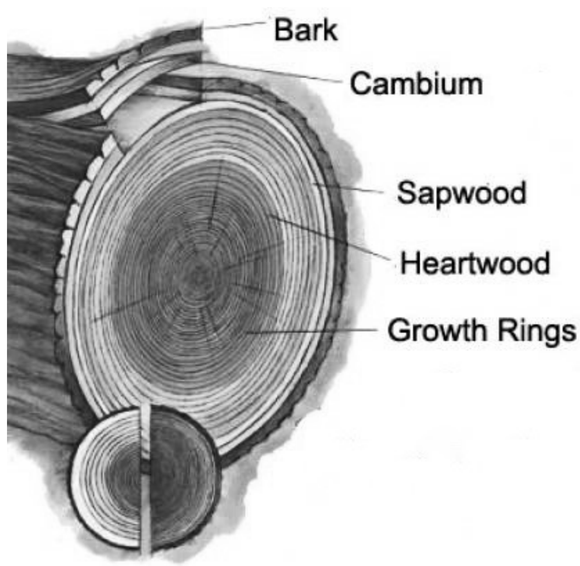

Figure 1: The layers of a tree trunk (Adapted from: USDA, 2013)

The cambium cell layer, which is located directly beneath the bark, is the growing part of a tree. It annually produces new bark and new wood in response to hormones that pass through the phloem (NADF, 2016). The hormones, called auxins, stimulate cell growth and are produced by leaf buds as soon as they start to grow in the spring (NADF, 2016). The position of this layer is precarious- it allows for growth to occur outward, but it is vulnerable if the bark is damaged. Damage to the cambium can lead to a stunted growth of a tree, which will be further discussed later in this report.

The sapwood is the tree’s water pipeline (NADF, 2016). This layer is often referred to as the xylem and it allows water to reach from the roots to the leaves. Sapwood is new wood, and as newer rings are laid down, inner cells lose their vitality and turn into the final layer, heartwood (NADF, 2016). Heartwood is the innermost layer and creates the central, supporting pillar of the tree. Although technically dead, it does not decay or lose strength as long as the outer layers remain intact (NADF, 2016). This layer is extremely strong- its is a composite of hollow, needle-like cellulose fibers bound together by the chemical lignin, which acts as a glue (NADF, 2016).

2.2 Threats to trees in urban landscapes

In general, urban landscapes are highly developed and contain a lot of grey infrastructure; there are a lot of human-made structures, including houses, commercial and residential buildings, roads, bridges, and railways. The presence of this grey infrastructure, in combination with a high population density, can make urban landscapes a challenging place for trees to thrive. Trees in cities face many different challenges than trees in forests.

One such threat is urbanization and the loss of woodlots/naturalized areas due to development, which causes an immediate loss of canopy, and a loss of future growing space for trees (Tree Canada, 2016b). Another major threat is air pollution: trees filter and remove fine particulate matter from the air and these particulates can accumulate on the leaves, which may impair photosynthesis and thus affect the trees function (Tree Ottawa, 2016).

Air is pollution is not the only concerning form of pollution that an urban tree is exposed to; water runoff in cities contains an array on contaminants that can have adverse affects on trees. These include salts from the road, motor oil, gas, heavy metals, and pesticides from lawns and parks (Tree Ottawa, 2016). As water runs over a variety of surfaces, it picks up these contaminants and this water often comes in contact with tree roots, which then absorb these damaging pollutants (Province of Manitoba, n.d; Tree Ottawa, 2016).

The final threat that will discussed in detail in this report, is a problem unique to trees in urban settings: vandalism and mechanical damage. Tree vandalism of many forms occur on trees in cities, and mechanical damage occurs primarily during grass cutting activities. The remainder of this report will focus on mechanical damage to trees in urban settings.

3. Mechanical Damage

3.1 The problem

Mechanical damage is a threat that goes by many different names: “lawnmower blight” in the United States, “Sheffield blight” in the United Kingdom, and “mechanical wounding” in New Zealand (Morgenroth et al., 2015). There have been very few formal studies investigating the prevalence of this problem, despite anecdotal evidence that it is widespread and significant (Morgenroth et al., 2015).

For this report, mechanical damage will be defined as any damage that a tree incurs from mechanical equipment used for grass-maintenance. The damage can range in severity, from minor (only affecting the outer bark) to severe (damage reaching the cambium cell layer or sapwood). Mechanical damage can affect the overall health of a tree and its ability to grow. But trees are resilient, and thus one, minor instance of mechanical damage may not lead to severe, detrimental affects to the trees health. The potential impacts of the damage increases as the number of occurrences increase (Morgenroth et al., 2015).

Recently, there was a study conducted in Christchurch, New Zealand which focused on mechanical damage to urban trees. In this study, 1018 trees in 308 plots were assessed and the following information was obtained: species, diameter at breast height, number of wounds (if any), age of wounds (old or new), location of wounds on trunk, and the presence or absence of 4 attributes: mulch, herbicide spray rings, surface roots, and/or grass cut-outs (Morgenroth et al., 2015).

The results of the study showed that a staggering number of trees in the city were affected by mechanical damage: 62.9% of trees measured had at least one wound (Morgenroth et al., 2015). In fact, 17.8% of trees measured had over ten wounds (Morgenroth et al., 2015). The strongest correlation found in terms of the attributes of the tree and the presence of damage was a relationship was related to the presence of surface roots (Morgenroth et al., 2015); of the 389 trees measured that had surface roots, 93.6% had at least one mechanical damage wound, in comparison to 43.9% of trees that did not have surface roots present (Morgenroth et al., 2015). Although this is only one case study, it shows that mechanical damage has the potential to be a significant problem for urban forest management.

3.2 The effects

Mechanical damage affects a tree's physiology and thus impacts its ability to grow and thrive. When the cambium cell layer is injured, activity in this area is disrupted and following this the tree undergoes a series of defensive and wound-healing processes (Arbelley et al., 2012). The healing begins from the wound margin and goes inward to shield the now-exposed xylem with healthy, new tissue (Arbelley et al., 2012). After wounding, a tree's functional priorities shift to re-establishment of the mechanical strength and xylem safety from death, which occurs at the expense of water and food transport and thus future growth (Arbelley et al., 2012).

Compartmentalization is often the primary defensive mechanism a tree uses in response to mechanical damage. By compartmentalizing wounds, injuries are isolated, preventing the spread of pathogens, which could more easily enter a tree through a mechanical damage gateway (Morgenroth et al., 2015). However, the trade-off is that the tree is expending energy for compartmentalization that can now no longer be used for normal growth (Morgenroth et al., 2015).

If the wounding has reached the cambium layer, then it has undoubtedly penetrated the inner bark, which means the tree's ability to transport food has also been compromised. Depending on the severity of the damage, this can have detrimental effects on tree growth above the damage site. If the damage reaches past the cambium layer and to the sapwood (xylem), the trees ability to transport water has now been affected and intuitively, the effects may be more severe (Morgenroth et al., 2015).

There has been very little research regarding the effects of mechanical damage on trees. However, it is reasonable to state that damaging any part of a tree's bark with grass maintenance equipment will affect the tree and have some form of lasting impacts. The trees response can range from compartmentalization and slowed growth, to complete failure and fatality. The size of damage, location of damage, presence of other environmental stresses, and age and species of the tree will all have an impact on the tree's response to the mechanical damage.

4. HRM Case Study

4.1 Methodology

To assess mechanical damage in HRM, five neighbourhoods were selected for inspection. These are the five neighbourhoods that are currently being focused on in the UFMP for planting: North End/Peninsula, Crichton Park, Colby Village, Clayton Park, and Eastern Passage. Within these neighbourhoods, the inspection routes were chosen by the HRM planner in charge of the implementation of the UFMP, John Charles. The routes vary in length, but were selected based on the same common criteria: along each route the grass is primarily maintained by HRM grass-cutting contracts, and there are a high proportion of HRM-planted, caliper trees (smaller trees that have a diameter at breast height that can be measured using a caliper). In total, 844 trees were inspected for each round of mechanical damage surveys, and four rounds were completed between mid June and late September. The dates of the inspections were chosen based on our availability, with an effort to spread the inspections throughout the grass cutting season. The following table summarizes the number of trees on each route and the length of the routes.

Table 2: The length of each mechanical damage survey and number of trees on route

Route	Number of trees	Length of route (km)
North End/Peninsula	369	5.03
Crichton Park/Mic Mac Blvd	15	0.83
Colby Village	102	1.50
Clayton Park	310	5.25
Eastern Passage	48	0.90
Total	**844**	**13.51**

The inspection protocol was quite simple; each tree was observed for the presence/absence of recent mechanical damage. Mechanical damage was identified as either the bark being scuffed or the bark being removed. A conscious effort was made to only record recent damage- which was identified by the color and appearance of the damage (before beginning the mechanical damage surveys, the team was taught how to recognize if the damage was recent by an HRM arborist).

Generally, only the lowest 50 cm of trunk was observed. If there were no signs of mechanical damage observed, no further information was collected.

If there were signs of mechanical damage, the following information was collected: location of tree (closest civic), type of damage (scuff or bark removal, and severity), size of damage (measured with tape measure), and any other information deemed pertinent (species, site condition, etc.). Pictures of the damage were often taken to supplement the information collected. Appendix B contains pictures showing examples of the types of mechanical damage seen during inspections. All information was hand written in the field and then transcribed into Microsoft word and excel at a later date.

4.2 Results

Total number of trees inspected: 844

Total number of trees showing mechanical damage: 71

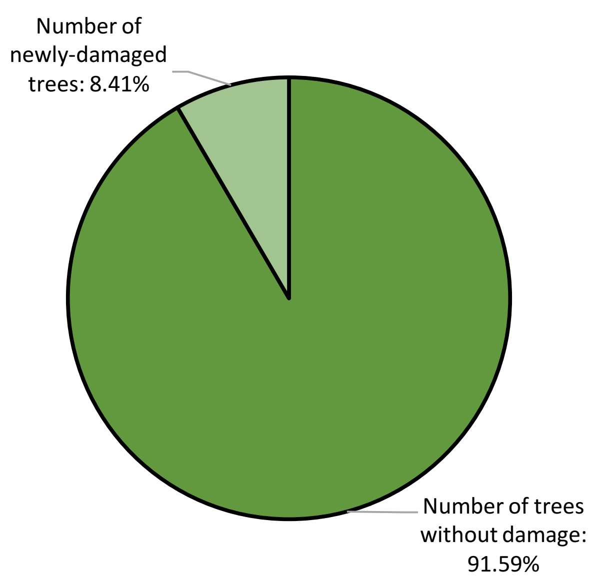

Figure 2: Percentage of trees showing signs of recent mechanical damage

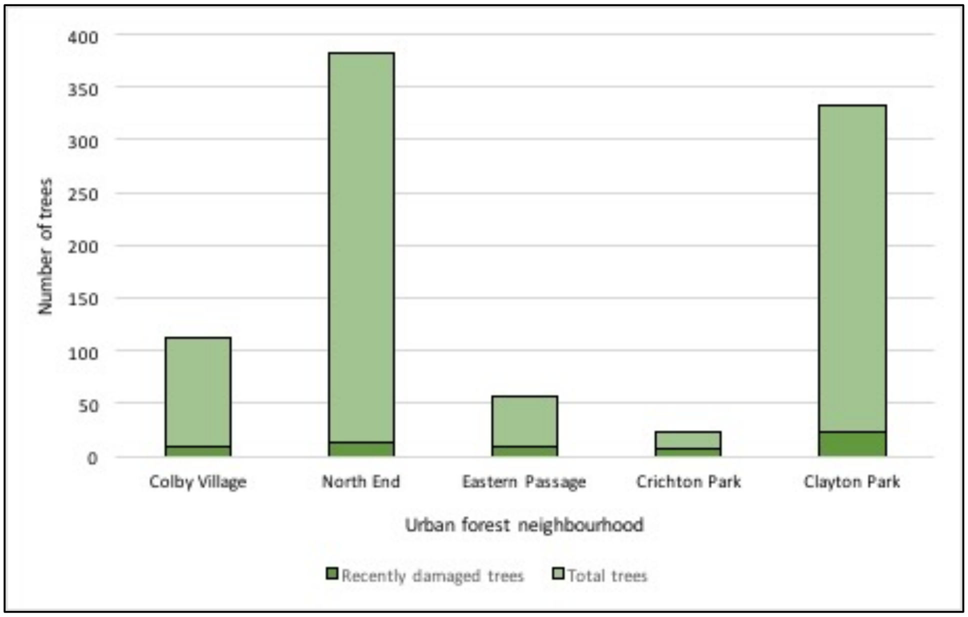

Figure 3: Number of recently-damaged trees by UFMP neighborhood

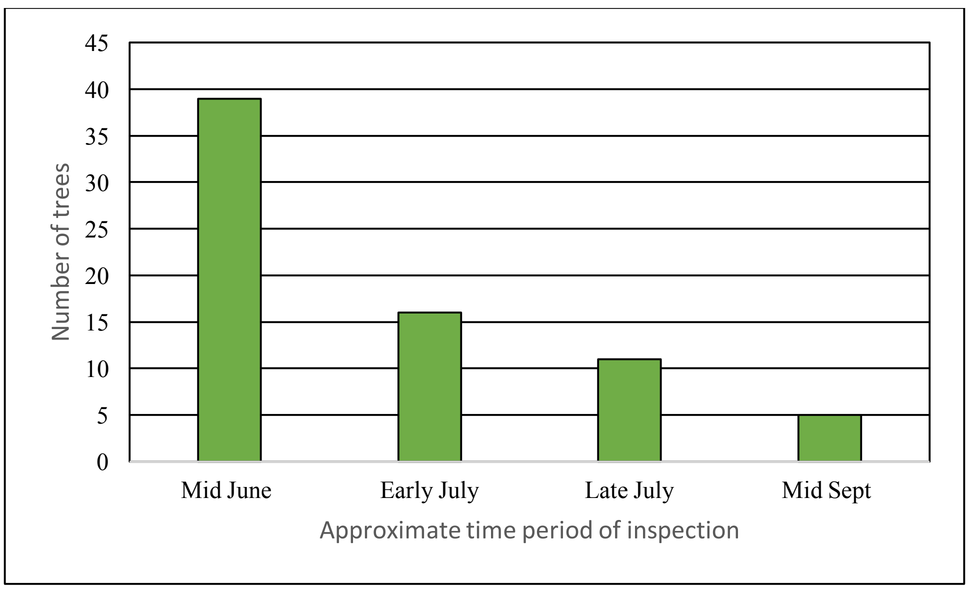

Figure 4: Number of recently-damaged trees by inspection date

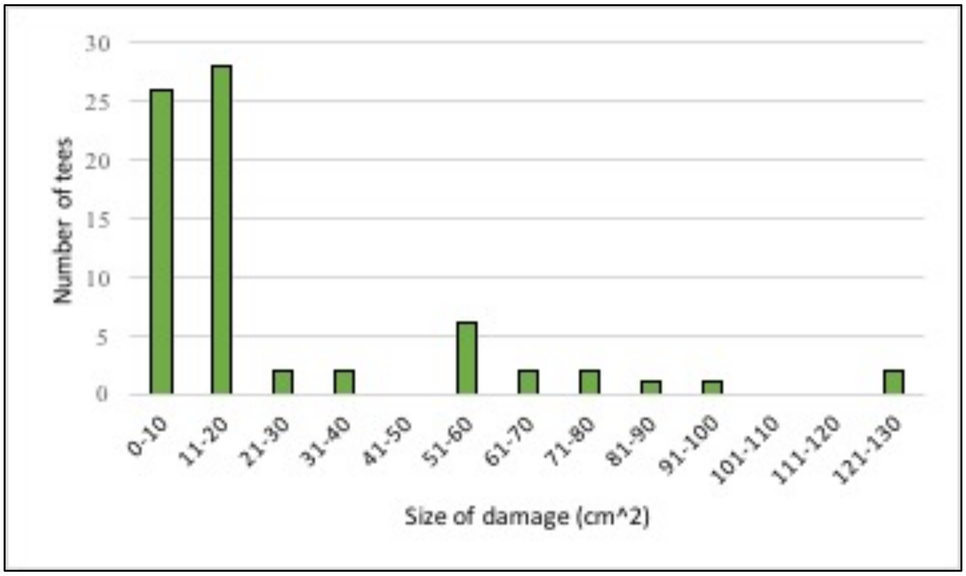

Figure 5: Number of newly-damaged trees by size of damage

4.3 Discussion

The results of this case study indicate that mechanical damage is a significant problem in HRM. Of the 844 trees assessed (four times each), 71 showed evidence of new damage at some point throughout the inspection season (mid June to Mid Sept). As seen in Figure 1, this equates to 8.41% of trees showing signs of mechanical damage that was significant enough that it could be seen and measured. Although under 10% may not seem noteworthy, it is important to consider the vulnerable environment in which these trees reside.

As discussed in section 2.2, urban trees are subject to many threats including, but not limited to, loss of woodlots, air pollution, water pollution, and vandalism. Considering these challenges facing urban trees, the fact that 8.41% of HRM trees studied this summer also have to survive being damaged by mechanical grass maintenance equipment, is concerning. These trees are being bumped, scraped, and hit with equipment causing lasting, irreversible damage. This is something that must be addressed.

It is important to note that during this study, only recent mechanical damage was measured and recorded. In many cases, trees showed evidence of older damage from earlier in the season or previous years. These instances were not assessed because there would be no way to pinpoint which contractor was responsible and when the damage had occurred. Although no data was recorded, it can be said very confidently that if all signs of mechanical damage, old and new, were recorded, the number of instances would have been much higher. Based on this anecdotal evidence, mechanical damage has undoubtedly been an issue for at least several years prior to 2016 in HRM.

Currently, HRM has a penalty in place for mechanical damage of $100 CAD per square 2.5 cm of damage (HRM, 2016). This penalty is outlined in the tender and the contractors are aware that is is available for HRM to use, however HRM does not presently use these penalties to effectively improve the issue. Based on the results of this case study, if HRM were to fine contractors to the fullest extent, there would have been over $27,000 worth of damages between the 71 trees. This could be valuable information to have for the future, because HRM can make contractors aware that the inspections are being done and the fines will be implemented if necessary, and that the amount of money is not negligible, but in fact is significant and could be impactful to their business'.

Since this is the first summer in which mechanical damage was researched in HRM in a regimented, consistent way, it would not be sensible to make any grand conclusions from any trends that were noticed. In order to make any concrete conclusions about spatial or temporal trends, at least several more years of studies must be conducted. However, we can delve into this one data set to see if there are any potential trends emerging to look out for in future years.

As seen in Figure 3, which shows the number of trees showing signs of mechanical damage within each urban forest neighbourhood, Crichton Park had the highest proportion of trees with recent damage. The neighbourhood with the second highest proportion of damaged trees was Eastern Passage. Although very little can be concluded from this information after only one year of surveying, once there has been several more years of data collected, "problem areas" (areas with the highest rates of damage) could be identified and special attention could be given to these neighbourhoods. Recommendations on how to address the issue of mechanical damage in these areas will be made in the following section.

Figure 4 shows the number of trees exhibiting signs of recent mechanical damage by inspection date. The most instances of mechanical damage were seen during the first inspection in mid June- 39 cases of recent damage were recorded. In mid July there were 16 cases recorded, in late July there were 11, and in mid September there were just 5. Thus, the trend seen this season was that the number of damaged trees went down significantly throughout the summer. Although it impossible to know right now whether this trend will be replicated in future seasons, discussions with the HRM urban forestry team and the HRM supervisors of the grass-cutting contracts revealed that this was not a surprising result.

As is the case with many plants, grass grows quickest at the beginning of the growing season and its growth rate slows throughout the summer and into the fall. Thus, the grass requires much more frequent maintenance in the spring and early summer than it does in the latter part of the growing season. If the grass is being cut more, then there is simply more potential for mechanical damage to occur. This makes sense with these data, which show that over half the instances of mechanical damage had already occurred by the mid June inspection. Although this was not a surprising trend to see, this is important information because it indicates that the problem is starting very early and perhaps next year the mechanical damage surveys should begin before mid June.

The final figure in the results section, Figure 5, shows the number of damaged trees by the size of the damage itself. Evidently, most of the damage that was recorded was less than 20 cm^2. Although small, any damage can have a significant impact on a tree. What is most concerning however, is that there were 14 instances where the damage recorded was over 50 cm^2; and more specifically, there were 3 trees that showed damage that was over 90 cm^2. In these cases, the trees were either entirely, or almost entirely girdled around the trunk. Unfortunately, these trees will have an exceptionally difficult time surviving the damage, because as previously discussed in section 3.1, damage causes the functional priorities of the tree to shift away from food and water transport. For these trees that are almost or entirely girdled around the whole trunk, there is little to no area for these functions to shift to- so there may be no way to transport food and water to any part of the tree above the damage, which will eventually lead to total failure and fatality.

5. Recommendations

Through this HRM case study, it has been found that mechanical damage is a significant problem in HRM that should be addressed. Since there is a lot of funding and effort given to the maintenance and improvement of the HRM urban forest, it is intuitive to focus on protecting trees as much as possible from preventable injuries and fatalities. The most important recommendation is to continue this study in future years to better understand the extent of the issue in HRM. Further recommendations have been subdivided into three categories, based on level of importance; the primary focus should be preventing mechanical damage from occurring, then efforts should be made to physically protect the trees in case of damage, and lastly, there must be more accountability placed on those injuring the trees, when it unfortunately occurs.

5.1 Prevention

In order to eradicate mechanical damage to trees, HRM must focus on preventative measures and education. By addressing the issue through education before the damage has occurred, ideally the number of occurrences can be significantly reduced and thus the need for physical protection and accountability through fines and penalties will be minimized.

Mandatory education for both the landscaping company managers and the grass-cutters themselves should be added as a stipulation for the next grass-cutting tender that is developed for HRM. It is important to focus on both the managers and the grass-cutters because everyone must be on the same page in terms of expectations. Ideally, HRM can use the information from this case study to create educational materials that could be useful for hired landscaping companies. Creating a standardized information pamphlet and presentation would ensure that all companies that successfully win a tender will have the same information and will be held to the same standards.

Education can also occur through the means of articles in trade magazines and presentations at trade conferences, such as those put off by organizations like Landscape Nova Scotia. Mechanical damage is not a well-researched or well-documented issue right now and thus it is important to expose the significance and implications of the problem to those involved as much as possible to help prevent it from continuing.

5.2 Protection

Protection against mechanical damage occurs in the form of physical barriers on trees and changing the ground surrounding trees. HRM currently uses two forms of physical protection: plastic trunk guards and mulching. The use of plastic trunk guards (in this case perforated drainage tile) is a new addition to HRM's tree planting protocol; it was introduced two years ago (John Charles, personal communication, December 13th, 2016). The major benefit of using drainage tile is that the trees can withstand minor bumps and hits from grass-maintenance equipment while they are smaller and vulnerable. Furthermore, the materials required for these trunk guards are relatively inexpensive and can be purchased in bulk, so the costs associated with protecting trees in this manner is likely much less than the costs associated with replacing trees that succumb to mechanical damage.

However, this technique is not without its flaws. The presence of the drainage tile may lead to grass cutters being more aggressive with their equipment near the trees since they believe the tree is fully protected. Although plastic covers can protect bark against some wear and tear, strong bumps could still affect the integrity of the outer and inner bark, and perhaps even the cambium cell layer.

When new trees are planted through HRM contracts, mulch is initially placed on the ground surrounding the trunk. The presence of much is an excellent deterrent for grass cutting equipment because it means there is simply no grass close to the trunk to cut. However, mulch is often washed away and/or eventually becomes overgrown with grass, rendering its protective qualities useless.

As previously mentioned in this report, mechanical damage inspections should continue in future years and then "problem areas" can be identified. In these areas, it is recommended that extra protection is put in place. The best protection would be a combination of solutions: to continue mulching after the first year, until the tree is stronger and less vulnerable, and to do routine checks to ensure the drainage tile is still in place and effective. Research could also be undertaken to identify alternative ways of protecting trees as there is always new technology emerging which may prove useful.

5.3 Accountability

If prevention and protection are not effective, the focus then needs to shift to accountability. Currently, HRM grass-cutting contracts outline the types of unacceptable damage and the penalties associated with them. These penalties should be used at the fullest extent to ensure contractors maintain contract integrity and put forward a reasonable effort to avoid damaging trees. The following is an excerpt from one of the most recent HRM grass-cutting tenders (16-019):

> "Trees are living organisms and damaged tissue remains within a tree for the rest of its life. The Contractor shall exercise proper care and caution to avoid contact with outer bark during the performance of all work and specifically when cutting and/or whipping grass around the tree.
>
> If an HRM tree is damaged the municipality may take action against the responsible party liable. This may include but is not be limited to the following penalty:
>
> Penalty for damaging an HRM Tree: Damages may include but are not limited to limb and branch breakage, bark tear, bark loss due to mechanical impacts and root damage. A penalty of $100.00 per 2.5 square centimeter of damaged tissue shall be levied when the Contractor is found to be responsible for causing the damage. In the case of tree limb or root, the measurement will take place where the affected tree limb or root attaches to the parent stem.)

> If HRM Urban Forestry assesses a tree, and finds it unstable or no longer structurally sound or viable due to the actions of an HRM Grass Contractor or sub-contractor, HRM will seek compensation for the tree in accordance with HRM policy." (HRM, 2016)

Although these rules are already in place, they are not being used to their full effect. Based on the results of this case study, the simple presence of these rules is not a strong enough deterrent to grass cutters and thus the full extent of the penalties should start being exercised in order to encourage better compliance. In combination with improved education, it would be entirely fair to start penalizing the contractors the full amount because they will be completely aware of the expectations surrounding mechanical damage and HRM trees.

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Appendix A

Example of raw data transcribed into Microsoft Word

Location Description: North End/Peninsula
Starting/Ending Point: End of North Ridge Road to North St @ Macdonald Bridge
Date: July 28, 2016
Assessed by: Kelsey and Natalie
Number of Trees Assessed: 369
Number of Trees with Mowing Damage: 2

Tree Sample	On Novalea, civic 5507	On Novalea, 1st tree south of Kenny on east side			
Type of Damage Observed	Outer bark completely removed	Outer bark completely removed			
Area Affected	2.5 x 5 cm	2.5 x 4 cm			
Additional Notes/comments	Sugar Maple	Sugar Maple			

Appendix B

Photos of mechanical damage from North End/Peninsula neighbourhood

Figure A. Example of bark scuffing seen during second inspection on July 4th, 2016 (Photo credit: Kelsey Hayden)

Figure B. Example of bark removal seen during second inspection on July 5th, 2016 (Photo credit: Kelsey Hayden)