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Urban Forest Governance in the Face of Pulse Disturbances—Canadian Experiences

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Abstract. The sustainable provision of urban forest benefits can be threatened by the occurrence of sudden, major disturbance events, such as forest fires, insect outbreaks, and extreme weather events, which are considered to be "pulse" disturbance events from a socio-ecological systems perspective. Sound urban forestry programs are needed to prepare for these disturbances and reduce their negative impacts. To investigate the role of governance in building more resilient urban forest socio-ecological systems, the relation between pulse disturbances and urban forest governance was studied in 4 Canadian cities. Our study of local urban forestry included expert interviews with local urban forest governance actors, document analysis, and site visits. The Policy Arrangement Approach was applied to structure and analyse urban forest governance. Findings show that all cities had seen a development of their urban forestry programs and governance over time, such as development of staff and formal plans, as well as alliances with key partners. Pulse disturbances seem to have played an important role in the development and sometimes reorientation of urban forestry programs. Although disturbances often had devastating impacts, having a strong urban forestry program in place, including strong alliances with, e.g., industry partners or NGOs, was considered important for handling the aftermath of these events. Efforts had also been made to be better prepared for future disturbances through further professionalisation, development of plans, guidelines, and best practices, capacity building through partnerships, and setting up better real-life information systems in support of decision making. Results can inform urban forest governance and urban forestry programs in Canadian cities and elsewhere.

Keywords. Disturbance; Environmental Decision Making; Policy; Pulse Dynamics; Urban Forestry.

INTRODUCTION

Urban Forests as Socio-Ecological Systems Impacted by Disturbances

It has become well documented that urban forests and other vegetation provide many benefits to urban communities (Roy and Byrne 2012; Duinker et al. 2015; Ferrini et al. 2017). The recent urgency of adapting cities to climate change and offering health-promoting settings during the global COVID-19 pandemic (Honey-Rosés et al. 2020) has made the role of urban trees and associated vegetation even more prominent. However, those responsible for the planning and management of urban forests are also faced with increasing pressures on urban forests and their capacity to provide different ecosystem services.

Urban forests are complex socio-ecological systems (Livesley et al. 2016; Vogt 2020), comprising both natural components, such as trees and other vegetation, and human components (people living and working in urban areas). Given the close integration of nature and humans in cities, urban forests cannot be properly understood and managed without taking a socio-ecological perspective. Collins et al. (2010) also argue for a more integrative, socio-ecological approach to natural ecosystems in general, bridging the biophysical and social domains. They expand the "press-pulse dynamics" to socio-ecological systems to enhance our understanding of how human behaviours affect "press" and "pulse" dynamics and ecosystem processes. Socio-ecological systems such as urban forests can transform incrementally and at times predictably, implying that it is easier to integrate these in system management (press dynamics). Other changes are less frequent, more sudden, larger in magnitude, and spatially extensive, substantially altering socio-ecological systems for long time periods (pulse dynamics). The latter can come in the form of large fires or sudden pest outbreaks, but also due to

changed zoning practices that drive land-use change. The management of socio-ecological urban forest systems requires careful consideration of this press-pulse dynamics perspective of system change, as highlighted by Roman et al. (2018). While press dynamics can be more easily integrated into an adaptive management approach, pulse dynamics will be more difficult to handle due to their sudden, infrequent, and less predictable nature.

In urban forestry, pulse disturbance events can lead to major, rapid mortality of urban trees, resulting in loss of canopy cover and the ecosystem services provided by the urban forest. From a political, governance, and management perspective, such pulse disturbances pose major challenges to urban forestry. There are many examples of urban forest pulse disturbances, ranging from the devastating effects of earthquakes, as in the case of Christchurch, New Zealand in 2010–2011 (Morgenroth and Armstrong 2012), to hurricanes, as in the case of Hurricane Sandy in New York, USA (Justus 2013) and, more recently, Hurricane Irma in the Caribbean and Florida, USA (Landry et al. 2021). In Canada, the Stanley Park Windstorm in Vancouver (Kheraj 2007) and the hurricane that caused major damage to Point Pleasant Park in Halifax (Steenberg and Duinker 2010) both had devastating effects. Other pulse disturbances have been the result of, among others, sudden pest and disease infestations (e.g., Dutch elm disease [*Ophiostoma novo-ulmi*] and emerald ash borer [EAB, *Agrilus planipennis*]), floods, fires, or sudden droughts. In line with Collins et al. (2010), a sudden change of a zoning code can also be included here, as it can result in rapid loss of urban forests in rezoned areas.

Building System Resilience

As pulse disturbances, jointly with the more predictable but longer-term press disturbances such as climate change, pose a major threat to urban forests and the provision of essential ecosystem services, urban forest managers need to be as prepared as possible to anticipate, manage, and recover from these events to the best possible capacity. Obviously, this is not easy, as pulse disturbances come unexpectedly, are external challenges to the urban forestry system as such, and often cannot be avoided. A central aspect of this endeavour is to enhance socio-ecological system resilience, i.e., the system's overall capacity to recover from anthropogenic and natural disturbances (Huff et al. 2020). Resilience in this case not only refers to the urban forest itself, but also to the human communities that inhabit it and to its governance and management systems. Part of the latter will be developing a comprehensive and well-informed urban forestry program, which also includes sound governance and decision making in addition to an adaptive management approach (Stankey et al. 2006). This implies that appropriate, well-informed decision making is in place to manage disturbances to the best possible capacity, as well as to lead the recovery effort in rebuilding urban forests.

Literature has highlighted the importance of sound governance in natural resource management, and to some extent in urban forestry as well (Lawrence et al. 2013; Konijnendijk van den Bosch 2014; Sheppard et al. 2017). Recent studies have looked at good practices in urban forest governance, as well as success factors (Ordóñez et al. 2020; Wirtz et al. 2021). Studies have started to investigate which governance models fit best to specific local contexts, interests, challenges, and opportunities (e.g., Buijs et al. 2019). However, linking governance to urban forest resilience, and to managing pulse disturbances in particular, has been less well developed until now, although some studies have been undertaken on this aspect (see for instance Tidball and Krasny [2014] who focus on green recovery efforts after violent conflicts and disasters). The present study aims to contribute to further enhancing our knowledge in this area.

An Urban Forest Governance Framework

Governance has been defined as "strategic decision making by different actors, and more specifically to the setting, application and enforcement of rules" (Kjær 2004). Definitions of governance vary widely. However, they all recognise the involvement of different governmental, business, and civic society actors' strategic decision making (e.g., Arnouts et al. 2012; Lawrence et al. 2013; Sheppard et al. 2017). Governance comprises the interactions, relationships, and networks, both horizontally and vertically, among different sectors (i.e., the government, the private sector, and civil society) and involves decisions, negotiation, and power relations among stakeholders to determine who gets what, when, and how (UNDP 2009). In a recent paper on urban forest governance, Ordóñez et al. (2020) state that governance can be broadly understood as the collection of institutions,

rules, and processes of collective decision making that allows stakeholders to influence and coordinate their needs. Vogt (2020) describes the polycentric nature of urban forest governance and management, as there are typically many overlapping yet independent centres of decision making that exist in urban areas.

To structure the analysis of urban forest governance in this study, the Policy Arrangement Approach (PAA)(Van Tatenhove et al. 2000; Leroy and Arts 2006) was applied as an analytical "lens." A policy arrangement is defined as "the temporary stabilisation of the content and organisation of a particular policy domain at a certain policy level or over several policy levels—in case of multi-level governance" (Leroy and Arts 2006). Here we follow the line of Arnouts et al. (2012), who applied PAA within a wider governance context, thus providing an indication of how the approach can also be used to analyse governance arrangements. In earlier work, we have built on this approach and applied a governance arrangement perspective to urban forestry in different countries (e.g., Krajter Ostoic 2013; Molin 2014; Fors et al. 2015; Sheppard et al. 2017). Governance arrangements can change—and be analysed—according to 4 interlinked dimensions: (1) actors and their coalitions involved; (2) division of power and other resources between the actors; (3) rules of the game; and (4) discourses. For clarity, "rules of the game" refers to institutions and the regulations, legislation, and procedures relevant to a certain governance domain; this dimension deals with how strategic decision making is arranged and can include, for example, different levels of public involvement (Sheppard et al. 2017). A discourse is "an ensemble of ideas, concepts and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices" (Hajer and Versteeg 2005), representing leading "storylines" in governance.

In this study, urban forest governance is analysed in terms of past and present governance arrangements and governance models, including the actors and alliances involved (e.g., studied through network analysis), the rules of the game set for decision making, the leading discourses, and the power and resources involved in governance. For studies of specific governance arrangements and governance models (i.e., subgroups within governance arrangements), the work of Molin (2014) and Buizer et al. (2015) provides guidance, for example, in describing co-governance and other models for collaborative governance approaches that include more than just governmental actors (governance with government, or even governance without government).

In a North American context, urban forest decisions in the public realm still depend on the view of municipal managers, even though governance typically involves a complex range of actors (Steenberg and Duinker 2010; Roman et al. 2018; Ordóñez et al. 2020; Wirtz et al. 2021). Municipal urban forest managers make decisions both strategically and on a day-to-day basis about trees in public areas, including streets, parks, woodlots, forest patches, and forested riparian areas, among other types of green spaces (Roman et al. 2018; Johnston et al. 2020). Municipal managers that make decisions impacting urban forests operate at different levels of the municipal organisation and within different departments, including, e.g., planning, public works, and environment. This decision making by non-elected public officers is obviously also impacted by the decisions made by elected officials, e.g., in the city council or within a parks board. This study focuses on those municipal managers that have a more direct mandate for the planning and management of urban forests, such as municipal urban foresters or arborists. According to Ordóñez et al. (2020), knowledge of how municipal managers of urban forests make decisions and what influences their decisions is dispersed across disparate bodies of knowledge and case studies.

Urban forest governance does not only rely on municipal actors, however. Municipal managers will often find themselves in governance processes with other public actors, as well as civic society groups and businesses (Sheppard et al. 2017). As discussed by Vogt (2020), the often polycentric nature of urban forest governance and management can also contribute to the sustainability and resilience of urban forests by creating redundancies in the management of urban forests: if one of these actors is unable to act on behalf of the urban forest, others may be able to step in (Vogt 2020).

Some recent work has explored the idea of successful or "good" governance in urban forestry. Ordóñez et al. (2020) state that urban forest success is a broader concept and is commonly defined as providing more ecosystem services to the community via

the planting and maintenance of urban trees. However, generally, measures of performance or success in the reviewed studies are either unclear or not objective. In a recent paper (Wirtz et al. 2021) which is also linked to the present study, we used a Delphi approach to let municipal managers and other key urban forestry actors identify and rank success factors in urban forest governance, resulting in factors such as sufficient funding, a sound information basis for decision making, and clear objectives and targets for programs being ranked the highest.

This study examines urban forest governance through the lens of (responses to) pulse disturbances impacting urban forest socio-ecological systems. Using the Policy Arrangement Approach as an analytical lens, the role of different actors, institutions, strategies, mobilisation of resources, and governance arrangements in preparing for pulse disturbances as well as in managing their impacts are investigated.

The Canadian Context

This study is focused on 4 Canadian cities. The focus of urban forest governance studies in Canada and elsewhere has often been on the largest cities, but in the present study, emphasis is on "typical" cities that are either part of a larger urban agglomeration (as in the case of Surrey in the Vancouver Metropolitan Area of British Columbia and Oakville in the Greater Toronto Area of Ontario) or smaller-sized interior cities (Fort McMurray in Alberta and Prince George in British Columbia). Fort McMurray experienced a large-scale forest fire in May 2016, resulting in a mass evacuation and the destruction of a large share of the town's houses. For the urban forest, the fire led to the loss of 10,000 municipal trees, with thousands of other mature trees in need of replacement, and peri-urban woodland being destroyed as well (Tree Canada 2016). Prince George experienced a massive infestation of mountain pine beetle (*Dendroctonus ponderosae*; MPB) from the 1990s onwards (e.g., Aukema et al. 2006), which also made the urban forest more prone to drought and wildfires. Between 2001 and 2007, for example, 733 logging trucks of beetle-attacked pine trees were removed from city and school sites (Coady and Picketts 2012). Substantial funding was allocated to deal with the outbreak and the dramatic tree loss. Surrey and Oakville both have had to deal with rapid urbanisation, wind events, and—especially in the case of Oakville—a major pest outbreak (EAB) that resulted in the death of most of the town's 43,000 ash (*Fraxinus* spp.) trees (Town of Oakville 2021).

MATERIALS AND METHODS

Comparative Case Study Approach

Information about the 4 Canadian case study cities is provided in Table 1. As mentioned previously, the cities are located in different parts of Canada and they represent 2 rather typical types of Canadian cities: interior cities and larger suburban cities that are part of major urban agglomerations. Oakville (ON) and Surrey (BC) are larger municipalities situated in a greater metropolitan area, while Fort McMurray (part of the Regional Municipality of Wood Buffalo [RMWB], AB) and Prince George (BC) are population centres in Canada's forested interior. Case study selection was also guided by the presence of past major urban forest disturbances over the past 2 decades.

Analysis of each case study comprised document and policy review and analysis, site visits, and semi-structured expert interviews with key urban forest governance actors (including municipal managers). Relevant documents and policies were identified via Internet searches as well as during interviews.

Methods

Interviews were carried out either on site in person or via the telephone during the first 4 months of 2019. In some cases, 2 people were interviewed at the same time. Although pulse disturbances experienced by each city guided the selection of the case studies, interviewees were asked to identify relevant disturbances and were not prompted to discuss specific ones. An overview of the interviews and participants is provided in Table 1. Interviews followed a semi-structured protocol, organised according to key topics (see Appendix; please note that the term "calamities" was used in the interviews to describe pulse disturbances), and lasted about 1 hour each. For each interview, 2 of the researchers were present, allowing for better prompting, note taking, and debriefing. All interviews were recorded and transcribed verbatim using a professional transcription service, followed by verification of the transcript by the study team. The transcriptions were then analysed via a thematic and inductive coding process using Excel. All authors reviewed the extracted themes and

Table 1. Overview of the case study cities and their interviewees.

City	Inhabitants (and national rank)	Population growth 2011–2016	Municipal area	Municipal status	Landscape/urban context	Type of pulse disturbance and its impact (initial scoping)	Interviewees
Regional Municipality of Wood Buffalo (including Fort McMurray), AB	71,589 (80th)	9.2%	63,637.5 km^2	Specialised municipality	Interior, boreal forest landscape/smaller town as part of larger spread-out municipality set in large forested area	Forest fire. Loss of 10,000 trees, destruction of buildings, mass evacuation.	7 (3 MUN, 2 NGO, 1 CONS, 1 CONS/ COM)
Oakville, ON	193,832 (27th)	6.2%	138.9 km^2	Town	Interior, lakeside deciduous forest landscape/suburban, part of larger metropolitan area	Pest outbreak (EAB). Most if not all of the town's 43,000 ash trees are now dead or dying.	8 (2 MUN, 5 CONS, 1 NGO)
Prince George, BC	74,003 (76th)	2.8%	318.3 km^2	City	Interior sub-boreal spruce zone/smaller town in forested landscape	Pest outbreak (MPB). Most of the city's pine trees (a major part of the urban forest at the time) died during outbreak.	10 (3 MUN, 5 CONS, 2 UNI)
Surrey, BC	517,887 (12th)	10.6%	316.4 km^2	City	Coastal, Pacific Maritime forest region/suburban, part of larger metropolitan area	Rapid urbanisation. One of the fastest growing cities in Canada. Gradual loss of trees to development over the year, but also compensated by tree planting on both public and private land.	7 (3 MUN, 2 NGO, 1 UNI, 1 CONS/ COM)

Population and municipal area for 2016 (based on national census data).
MUN = municipal manager or other municipal employee; COM = community member actively involved in urban forestry discourse; CONS = consultant in urban forestry, conservation, forestry; UNI = university faculty; NGO = representative of non-governmental organisation. In some cases, interviewees were former municipal managers/employees (2 in Prince George, 1 in Surrey, 1 in Oakville).

provided credibility checks throughout the process. The analytical framework as described above guided the structuring of the thematic coding process and analysis of all data.

Respondents had all dedicated at least part of their professional time to urban forestry activities and decision making, although their urban forestry experience ranged from 2 to 30 years. Interviewees included municipal officers; consultants in urban forestry, forestry, or conservation; university faculty; representatives of environmental non-governmental groups; and local community members (who were also conservation experts) who had taken active part in urban forestry discussions (Table 1).

RESULTS

Results are presented below in narrative format to allow for the synthesis of findings from the document and interview analyses, as well as on-site observations. Key findings per case are also summarised in Table 2.

Table 2. Overview of urban forest governance in the face of pulse disturbances per city.

Case study	Discourses with focus on pulse disturbances	Leading actors and alliances	Rules of the game	Resources	Governance arrangements
Regional Municipality of Wood Buffalo, AB	Building up an urban forestry program for a developing city; impact of major wildfire	RMWB (parks division); private landowners; First Nations	Urban Forest Management Plan under development (in 2019); important role of FireSmart strategy	Program under development, dedicated staff (and growing team), suite of plans and guidelines under development	Governance with government, primarily through some public engagement processes
Oakville, ON	Maintaining a healthy canopy cover in the light of, e.g., EAB, urbanisation; also, past impact of ice storm	Town of Oakville (parks and green); Oakville Green as key ally; politicians as champions	Urban Forest Management Plan (2009); strategies for biodiversity, invasive control, etc.	Substantial information technology and decision-support systems; i-Tree assessment; dedicated urban forestry staff	Governance with government/ co-governance approach, with strong role of local NGO
Prince George, BC	Dealing with pests and diseases and MPB in particular	Municipality (parks and recreation); private companies during pest outbreak	Former urban forest management plan and new under development; integrated pest management strategy; FireSmart strategy	Dedicated staff, but decrease after initial focus on urban forest after pest outbreak; guidelines for, e.g., pest and fire control; strong capacities in private forestry companies	Mostly governance by government, but governance with government, e.g., during the MPB outbreak, collaboration with private sector when needed
Surrey, BC	Maintaining the urban forest under rapid urban growth and densification; also, smaller-scale disturbances such as windstorms	Municipality (parks, recreation, and cultural; advisory boards; other departments); some role for local NGOs	No comprehensive urban forest strategy yet, but suite of other policies and plans (for shade trees, biodiversity, etc.); advisory boards	Suite of policies, plans, guidelines, bylaws; dedicated staff	Governance with government, with strong municipal lead but involvement of range of other actors (including NGOs), role of advisory boards, etc.

Urban Forestry Context

Two of the municipalities, Oakville and Surrey, are situated in greater metropolitan areas (of Toronto and Vancouver, respectively), and both suburban municipalities have faced rapid growth during recent years (see Table 1). Surrey is in fact one of the fastest growing cities in Canada in terms of population. This growth and the need to create more housing has an impact on the local urban forest. The situation in Fort McMurray (part of the larger RMWB) and Prince George is somewhat different, as these are smaller-sized cities situated in the midst of a vast forested area. However, Fort McMurray has also faced rapid growth due to the development of the oil sand industry, resulting in both a larger resident population and also the need to cater for a large transient population of industry workers, often based in special camps outside of the city. The town of Fort McMurray is part of the Regional Municipality of Wood Buffalo, and both names are used throughout this article. The analysis of urban forest governance focused on Fort McMurray, but policies and municipal procedures typically relate to the entire municipality.

Interviewees in both Oakville and Surrey unanimously characterised their cities as "urban forestry friendly," in terms of municipal programs and initiatives and citizen engagement. As also mentioned by the interviewees and known to the authors, Oakville has been widely considered a good practice example for Canadian urban forestry for some time. The characterisations by respondents in Prince George and RMWB were more mixed, although the fact that both cities are placed within a large, forested area means that many residents appreciate the recreational opportunities offered by urban and rural forests. Prince George also has a strong forestry industry.

Discourses with Focus on Pulse Disturbances

When asked about which recent pulse disturbances had had the greatest impact on the local urban forest (and urban forestry practice), interviewees in 3 of the 4 cities consistently identified a specific major disturbance: the large wildfire in Fort McMurray in 2016; the MPB infestation in Prince George (starting in the late 1990s); and the EAB infestation in Oakville (starting in the late 2000s). In Surrey, rather than mentioning a single, prevailing pulse disturbance, several smaller disturbances where highlighted, including windstorms, droughts, and pests and diseases. Also in Surrey, the very rapid pace of urbanisation and densification was mentioned as a disturbance of relevance by several of the interviewees. In the other 3 cities, other disturbances were mentioned as well, such as ice storms in Oakville, fires and pests in Prince George, and pests in Fort McMurray/RMWB. The (temporary) loss of urban forest cover was considered a major problem from the perspective of resilience and especially the provision of important ecosystem services. In the cases of pest infestations, one or only a few tree species were impacted, but these tended to make up a large share of the urban forest at the time the outbreak hit. It did give cities the opportunity to change the species composition of their urban forests.

Interviewees were also asked whether they had experienced changes in urban forestry (and urban forestry decision making in particular) during recent years. In Oakville, urban forestry had become much more professional and structured during the past 2 decades, as the town grew and the need for proper urban forest management emerged. A similar development was noted for Surrey, especially with the setting up of its first real urban forestry program during the early 2000s. Prince George especially saw a (temporary) strengthening of its urban forestry program during the second part of the 2000s, partly in response to the MPB outbreak. Because of changes in key staff and political influences, however, this push for a more comprehensive urban forestry program declined during the next decade. RMWB/Fort McMurray also saw a strengthening of its urban forestry program when a first urban forester was hired during the mid-2000s. The urban forestry program and staff were under development when the 2016 wildfire hit, which led to some refocus of activities (e.g., with greater emphasis on wildfire management). At the time of this study, the municipality's first urban forest management plan was under development.

Actors and Alliances

All 4 cities had dedicated staff for their urban forestry activities. Urban forestry programs and staff were typically part of a municipal parks and/or open space and recreation department or division (which in its turn was sometimes part of a larger department, e.g., public works), sometimes under a specific forestry section (as in the case of Oakville). In some cases, such as in Surrey, urban forestry experts were also part of the planning department. The cities, perhaps with the exception of Prince George, had seen steady expansion of their urban forestry and arboricultural staff over time. Interviewees in RMWB mentioned that it had been difficult to recruit qualified staff for its new urban forestry and arboricultural positions, perhaps because of the remote location of the municipality. The parks department/division was typically responsible for public woodland, parks, and street trees, with institutional and privately owned green spaces and trees falling outside of their direct management. Three of the four cities had a dedicated (and experienced) municipal officer responsible for leading the urban forestry program (similar to a "city forester" position). This position was less clear in Prince George. Both in Surrey and Oakville, a specific position existed for a city forester/urban forester reporting to a manager who also had responsibility for city parks.

Elected officials often played an important role in the development of urban forestry programs. The long-time mayor of Oakville, for example, had been a strong champion for the expansion of the city's tree canopy cover. In other cases, political changes also seem to have resulted in a reprioritising of urban forestry activities.

In both Oakville and Surrey, strategic alliances were formed between municipal officers and local community groups. Oakville is perhaps the best example of this, as the city's urban foresters developed a strong alliance with a non-governmental organisation (NGO) called Oakville Green over the years. Oakville Green played a crucial role in developing the city's urban forestry program through enhanced urban forest stewardship, tree planting, and awareness raising. The organisation was also an

essential partner for the city when EAB hit. In Surrey, the city's first urban forester set up advisory committees for urban forestry in which local citizen groups could participate. The citizen group that succeeded in protecting the Green Timbers urban woodland against development, for example, was an important initial ally in building the local urban forestry program. Environmental and citizen groups also played a role in RMWB and Prince George, although perhaps less prominently. In both cities, however, local educational institutions had been urban forestry actors and sometimes important knowledge partners for the city. The strong forestry industry in Prince George, including a host of consultancy companies, proved essential during management and salvage operations under the MPB infestation. Several of the cities, and perhaps especially Prince George, also have a strong First Nations presence and co-stewardship of local community forests.

When pulse disturbances occurred, there was sometimes a temporary greater involvement of provincial and even national actors. This was the case, for example, for pest management authorities in the case of most cities, and of the province of Alberta in the case of the Fort McMurray fires. In the latter case, the national NGO Tree Canada also played a role in the recovery and replanting operation, mobilising funds and raising public awareness and support. Some of the interviewees mentioned that they would like to see more involvement in urban forestry at the provincial and federal level, e.g., through policy guidance and financial and other support.

Rules of the Game

The Town of Oakville adopted its first urban forest management plan in 2009. Prince George has had an urban forest management plan since 2003, but at the time of the study, this had not been adopted. When the interviews were conducted, RMWB was in the midst of developing its first comprehensive urban forest management plan. The same holds true for Surrey, although the city had had a series of relevant plans in place for several years, including a shade tree management plan, biodiversity conservation plan, green infrastructure strategy, and natural areas management plan. All cities had some form of tree (protection) bylaw in place as well, although in RMWB, tree issues were not covered in a single, comprehensive bylaw.

Interviewees also mentioned a suite of other plans that were of direct relevance to urban forestry activities. Some of these were of particular interest within a pulse-disturbance context, such as wildfire prevention and management strategies, and pest management and invasive species strategies or plans. The role of provincial and national plans was also highlighted (e.g., for biodiversity, environment, water), although it was widely recognised that urban forestry governance is mostly done at the municipal level.

In terms of public involvement, the municipalities follow the Canadian regulations for statutory planning, but there are large differences between involvement efforts and levels. Oakville seemed to have the most elaborated public involvement set-up, although interviewees also mentioned that the intensity of engagement had changed over time. Surrey had been engaging with its community and the large number of environmental and community groups and had established advisory boards for channeling public inputs. Interviewees also did mention, however, that more could be done. Both RMWB and Prince George seemed to have less-elaborated public participation structures, although there was some resident engagement and concern when the cities experienced their major disturbances. Public consultant sessions were held when RMWB/Fort McMurray developed its first urban forest management plan.

Resources

Perhaps with the exception of Prince George, all cities had seen their urban forestry programs and staff grow over time, often in parallel with population growth. Programs had also become more professionalised, and tree bylaws and urban forest management plans were developed, as were best management practices and a series of technical guidelines. Municipalities had highly trained staff, as well as arborists and urban foresters trained and certified under the programs of the International Society of Arboriculture. Municipal interviewees regularly attended professional conferences and seemed well aware of the latest developments in the profession. All cities had collaborated with external experts, including consultants and faculty and students from (local) universities. Efforts had also been made to improve the information base and information systems for decision making. When Oakville developed its first urban forest management plan, it included an analysis of its

urban forest and urban forest benefits through i-Tree, a suite of tools related to urban forest ecosystem services developed by the US Forest Service (i-Tree 2021).

Public awareness raising and engagement was highlighted as a key resource when disturbances hit, as well as for urban forestry in general. Public awareness can foster public engagement (e.g., in rebuilding the urban forest after a disturbance), generate better understanding of urban forestry activities, as well as help generate political attention. Engaging with the public can also help manage conflicts over the urban forest, as in cases such as Surrey, where trees fall victim to urban development, or Fort McMurray, where new fire management regulations removed trees from the direct vicinity of many houses.

Specific resources and tools had been set up in the cities. In Surrey, for example, a green fund was established to use compensation funding from tree removals due to development for new tree planting. In Oakville, a new information system was developed that can guide the management of future disturbances by having real-time geospatial data on tree removal and maintenance needs. The need for technical guidelines and best management practices was also mentioned by many interviewees. In the case of RMWB, new so-called FireSmart guidelines to making the municipality less vulnerable to wildfire damage can be highlighted.

Governance Arrangements and Changes over Time

All 4 cities have—at least during some periods of time—adopted forms of collaborative governance (e.g., Molin 2014) to urban forestry decision making, with the municipality as lead actor through its parks and open spaces department or division. As discussed above, the level of collaboration with other, non-governmental actors differed amongst the cities. In some cases, the prevailing governance model can perhaps be best described as closed co-governance (Arnouts and van der Zouwen 2012), with a selected group of actors driving most of the decision making. In Oakville, for example, the municipality formed a strong alliance with Oakville Green during a crucial part of the development of the urban forestry program. In Prince George, the municipality collaborated with a group of industry partners and consultants when the MPB outbreak occurred. In Surrey, the city made efforts to institutionalise public involvement by setting up advisory boards for urban forestry. Also in Surrey, in the case of specific urban forest areas such as Green Timbers, a local community group became a strong player in urban forest governance.

When asked about recent changes in urban forest governance (including in public participation), most interviewees agreed that some changes had occurred. Moreover, some of these changes seem to have been triggered by pulse disturbances. In Oakville, for example, the partnership with Oakville Green became stronger as the first urban forest management plan was developed and the EAB outbreak occurred. Interviewees in both Prince George and RMWB mentioned how wildfire prevention and awareness led to changes in how decisions are made, and on what basis. So-called FireSmart principles and guidelines (FireSmart 2021) had become an important component of urban forestry over the years, also increasing the involvement of additional actors (e.g., fire departments, provincial actors). In Surrey, wider cross-municipal collaboration has occurred over time, resulting in better integration of sectoral plans and the inclusion of urban forestry staff in the planning department. The pulse disturbances also resulted in new policies/plans, as in the case of Prince George's integrated pest management strategy and its initial urban forest management plan, and RMWB's FireSmart strategy. The development of better geospatial decision-support systems in Oakville can also be mentioned here.

Interviewees in both Oakville and Surrey mentioned that the presence of strategic objectives, plans, and a strong urban forestry section did probably prepare the city better for disturbances such as the EAB outbreak and windstorms, for example in terms of guiding recovery efforts and building on existing partnerships. In Oakville, the urban forest management plan helped prepare the city by raising awareness of the importance of the urban forest and the need to deal with threats, as well as establishing a program, budget, and diagnostic tools. In Prince George, most of the efforts were focused on removals after the MPB outbreak, and here rapid use could be made of local networks of companies. The wildfire in RMWB was truly devastating, but having an urban forestry plan in place as well as staff did help especially with some of the salvage activities. The local urban forester became involved in overall decision making on future fire prevention and management activities as well, working together with relevant actors such as the fire department.

Interviewees also stressed that having an urban forest management plan would probably help with keeping a longer-term perspective and vision, which would then also be useful when dealing with pulse disturbances. In addition, these disturbances can cause serious setbacks to the delivery of program objectives, and urban forest management plans can help build these back in the longer term after initial management and recovery activities have been undertaken. They can also inform decision making related to tree species and management system choices, the prioritisation of new planting sites, and the like.

DISCUSSION

Success Factors in Urban Forest Governance

The importance of understanding and strengthening the governance of urban forests has been highlighted in the literature (Sheppard et al. 2017; Ordóñez et al. 2020). As shown in this study, the need to deal with pulse disturbances impacting urban forests—which could very well become more common due to climate change and increasing urbanisation and encroachment on forests and other natural areas—should be part of "good" governance in urban forest systems.

In earlier work (which was part of the same research project), a Delphi approach was used among the same group of interviewees (i.e., urban forest governance actors in the 4 cities) to identify success factors for "good" governance. Perhaps not surprisingly, factors such as having sufficient funds for urban forestry programs scored highest, as did the need for sound and up-to-date information as a base for decision making. Moreover, the need for clear objectives and targets for urban forestry was also frequently mentioned. In line with this, all 4 municipalities had been working on urban forestry strategies and related plans and guidelines, often based around a set of clear objectives and targets, which helped guide recovery from pulse disturbances. Increasing the municipality's canopy cover is one such target. In their comprehensive study of municipal forestry programs in US municipalities, Hauer and Peterson (2016) noted a growth of more systematic approaches to urban forestry over the years, with 55% of American municipalities having some sort of systematic (rather than reactive) management in place. About half had strategic plans pertaining to urban trees in place, and in 25% of all municipalities, specific canopy targets had been set. For the Nordic countries, Randrup and Persson (2009) also highlight the importance of more strategic management approaches for municipal green space management in general, but most Nordic green space managers dedicate only a limited part of their time to more strategic issues.

The need for sound, accurate, and up-to-date information also emerged as an important part of good governance, not in the least in times when pulse disturbances hit. Accurate and up-to-date information is particularly important for managing risk related to pulse disturbances in the short term and for directing recovery efforts in the medium to long term. The efforts of Oakville to build a new geospatial information system can be mentioned here, but also the efforts of other cities in terms of developing best practice manuals and urban forest assessments. Hauer and Peterson (2016) also highlight the issue of sound information systems, e.g., pertaining to having an up-to-date tree inventory as well as disturbance-related information on pests and risks.

Although not ranked very highly in the Delphi study (Wirtz et al. 2021), the importance of clear responsibilities for urban forestry and for good leadership emerged from this research and would be worth further study. Having a central point of focus for urban forestry within the municipal organisation, jointly with a clear urban forestry strategy, will be important. In the 4 cities, urban forestry programs were led from within parks and recreation departments or divisions, but other parts of the municipal organisation also played important roles. The importance of good collaboration with these other departments (e.g., planning, roads and infrastructure) was highlighted by interviewees. Hauer and Peterson (2016) found that a mean of 2.7 departments were involved in urban forestry in US cities. In the context of pulse disturbances and emergency response, collaboration becomes especially important, as demonstrated by the case of Prince George where the head of the parks department became a central player in an ad-hoc emergency response unit and where the fire department became heavily involved in decisions pertaining to trees. Hauer and Peterson (2016) mention that in 46% of US municipalities, emergency managers discuss trees in the event of storms. Moreover, 55% of all municipalities had some form of emergency response system in place which included trees.

An important difference that could have impacted a municipality's capacity to manage disturbances is that of continuing urbanisation and densification. These both play out more suddenly over the short term, as in the case of substantial canopy being removed when areas are developed or densified, and over the long term in terms of continuous demand for land for building. Oakville and Surrey have both experienced this, and urban foresters have had to deal with a continuous pressure on the local urban forest and finding novel ways of ensuring urban forest resilience. Potentially, this experience and capacity also prepared them better when pulse disturbances occurred and assisted in recovery efforts. However, our study does not provide specific evidence that supports this assumption.

The Importance of Leadership

The characteristics of the person leading the urban forestry program will be of relevance as well, as shown in earlier work on the leadership characteristics of urban park managers in Denmark by Nuppenau (2008). In the Danish study, important factors for enhancing the impact on decision making by professionals were found to be a capacity to join decision-making processes at the right time, a strong professional and educational background, informal networks, and status/recognition within the municipal organisation. Several of the cities studied in the present research have seen their urban forestry programs led by professionals with a strong, Canada-wide reputation in urban forestry. In addition to these municipal "champions," the importance of urban forestry advocates and leaders amongst elected officials and with, for example, NGOs is an important factor. The need for educating and training urban forestry professionals that fit the above profile has become recognised also in Canada.

Strengthening Mosaic Governance

Urban forest governance seems to have become more complex in the 4 cities studied; although periods have also occurred when interest and investment wane, and public participation and involvement from industry decrease. Based on a European study of urban green space governance, Buijs et al. (2019) introduce the concept of mosaic governance, in which the increasing role of active citizens in contributing to urban green space planning and implementation is recognised. There can be different pathways, as highlighted by Buijs et al. (2019), for upscaling innovative discourses and practices from local communities to formal policy or to other cities. This would then require combining long-term, more formalised, and higher-scale strategic approaches with more incremental approaches that correspond with localised, fragmented, and informal efforts of local communities. Although this type of collaborative governance between municipalities and active citizens and citizen groups is not without its challenges, there will be important benefits, such as mobilising support and knowledge and building a more environmentally just urban forestry program. There are some signs of mosaic governance emerging in urban forestry in the 4 Canadian cities studied, for example, via the involvement of local NGOs, citizen advisory committees, and localised policies designed to respond to local needs and dynamics, but this aspect can be developed further to prepare better for future urban forest pulse disturbances that may have differential impacts in different parts of urban forest socio-ecological systems.

Study Limitations

Governance of any kind is a complex matter, and the same holds true for the governance of urban forests as socio-ecological systems. Therefore, the present study has had its limitations, for example due to its limited time frame and the fact that only a selection of urban forest governance actors was interviewed. We attempted involving elected officials in the study, but this turned out to be very difficult. In some cases, the aftermath of disturbances could have made some of our inquiries of a more "politically sensitive nature"—something which we already perceived when arranging interviews with some of the municipal officers. Future research should expand the scope of inquiry to include additional governance actors across other sectors of municipal government and society. A greater voice for local residents would also be helpful, particularly in analyses of the potential for mosaic governance to increase urban forest resilience to pulse disturbances. As the study cities recover more fully from the pulse disturbances they experienced, it would be helpful to revisit the cases to examine which aspects of urban forestry governance were more helpful in building socio-ecological systems over the long term.

Perspective

Although findings are specific to the 4 Canadian case study cities, some lessons can be drawn for urban forest governance in other cities in Canada, North America, and elsewhere. These relate, among others, to the importance of a well-structured and well-staffed urban forestry program, as well as of strategies and policies that help guide urban forestry work towards longer-term objectives, even when disturbances or other temporary setbacks occur. Having an urban forestry strategy and strong urban forestry program in place does not prevent pulse disturbances from happening, of course, but they can provide important guidance in the aftermath and recovery efforts, as well as in the development of a more diverse and resilient urban forest.

This study also highlighted that municipal urban foresters cannot do it all by themselves, and they will benefit from building alliances with diverse urban forestry actors, including community groups and NGOs, industry, as well as with colleagues from other municipal departments. Those cities and societies that understand the collective benefits of urban forests, and our collective responsibilities to manage and maintain them, will likely experience greater resilience as climate change and urbanisation pressures continue to challenge the health of our urban forests.

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Résumé. La génération durable de bénéfices par les forêts urbaines peut être menacée par l'occurrence de perturbations soudaines et significatives, telles que les incendies de forêt, les invasions d'insectes et les incidents climatiques extrêmes, considérés comme des perturbations "pulsées" dans la perspective de systèmes socio-écologiques. De solides programmes de foresterie urbaine sont nécessaires afin de bien se préparer à ces perturbations et réduire leurs impacts négatifs. Pour étudier le rôle de la gouvernance dans la mise en place de systèmes socio-écologiques forestiers urbains plus résilients, la relation entre les perturbations "pulsées" et la gouvernance des forêts urbaines a été étudiée dans quatre villes canadiennes. Notre recherche de la foresterie urbaine locale a inclus des entretiens d'experts avec des acteurs locaux de la gouvernance des forêts urbaines, une analyse documentaire et des visites. Les dispositions de l'arrangement politique ont été appliquées pour structurer et analyser la gouvernance des forêts urbaines. Les résultats montrent que toutes les villes ont connu un développement de leurs programmes de foresterie urbaine et de leur gouvernance au fil du temps, dont le développement du personnel et de plans d'action formels, tout autant que des alliances avec des partenaires clés. Les perturbations "pulsées" semblent avoir joué un rôle important dans le développement et parfois la réorientation des programmes de foresterie urbaine. Bien que les perturbations aient souvent eu des effets dévastateurs, disposer d'un solide programme de foresterie urbaine, y compris des alliances fortes avec, par exemple, des partenaires de l'industrie ou des organismes non-gouvernementaux (ONG), a été jugé important pour faire face aux conséquences de ces aléas. Des efforts ont également été déployés pour mieux se préparer aux futures perturbations par une professionnalisation accrue, l'élaboration de plans, de lignes directrices et de meilleures pratiques, ainsi que par le renforcement des capacités par le biais de partenariats et la mise en place de meilleurs systèmes d'information sur la base de situations concrètes à l'appui de la prise de décision. Les résultats peuvent éclairer la gouvernance de la forêt urbaine et les programmes de foresterie urbaine dans les villes canadiennes et ailleurs.

Zusammenfassung. Die nachhaltige Bereitstellung von Leistungen des städtischen Waldes kann durch das Auftreten plötzlicher, größerer Störungen wie Waldbrände, Insektenausbrüche und extreme Wetterereignisse bedroht werden. Aus der Perspektive sozio-ökologischer Systeme werden diese Störungen als "Impuls"-Ereignisse betrachtet. Um sich auf diese Störungen vorzubereiten und ihre negativen Auswirkungen zu verringern, sind solide Programme für die städtische Forstwirtschaft erforderlich. Um die Rolle der Verwaltung beim Aufbau widerstandsfähigerer sozio-ökologischer Systeme in städtischen Wäldern zu untersuchen, wurde die Beziehung zwischen Impulsstörungen und der Verwaltung städtischer Wälder in vier kanadischen Städten untersucht. Unsere Studie über die lokale städtische Forstwirtschaft umfasste Experteninterviews mit lokalen Akteuren der städtischen Forstverwaltung, Dokumentenanalyse und Ortsbesichtigungen. Zur Aufgliederung und Analyse der städtischen Forstverwaltung wurde der Policy Arrangement Approach (PAA) angewandt. Die Ergebnisse zeigen, dass alle Städte im Laufe der Zeit ihre Programme für die städtische Forstwirtschaft und deren Verwaltung weiterentwickelt haben, z. B. durch den Aufbau von Personal und formellen Plänen sowie durch die Bildung von Allianzen mit wichtigen Partnern. Impulsstörungen scheinen eine wichtige Rolle bei der Entwicklung und manchmal auch bei der Neuausrichtung der städtischen Forstwirtschaftsprogramme gespielt zu haben. Obwohl Störungen oft verheerende Auswirkungen hatten, wurde es als wichtig erachtet, über ein starkes städtisches Forstprogramm zu verfügen, das auch starke Allianzen mit z. B. Partnern aus der Industrie oder Nichtregierungsorganisationen umfasst, um die Folgen dieser Ereignisse zu bewältigen. Es wurden auch Anstrengungen unternommen, um auf künftige Störungen besser vorbereitet zu sein, und zwar durch weitere Professionalisierung, die Entwicklung von Plänen, Leitlinien und bewährten Verfahren, den Aufbau von Kapazitäten durch Partnerschaften und die Einrichtung besserer Informationssysteme zur Unterstützung der Entscheidungsfindung in der Praxis. Die Ergebnisse können für die Verwaltung des städtischen Waldes und für städtische Forstwirtschaftsprogramme in kanadischen Städten und anderswo von Nutzen sein.

Resumen. La provisión sostenible de beneficios forestales urbanos puede verse amenazada por la ocurrencia de eventos de perturbación repentinos e importantes, como incendios forestales, brotes de insectos y eventos climáticos extremos, que se consideran el "pulso" de los eventos de perturbación desde una perspectiva de sistemas socioecológicos. Se necesitan programas sólidos de silvicultura urbana como preparación para estas perturbaciones y reducir sus impactos negativos. Para investigar el papel de la gobernanza en la construcción de sistemas socioecológicos de bosques urbanos más resilientes, se estudió la relación entre las perturbaciones y la gobernanza de los bosques urbanos en 4 ciudades canadienses. Nuestro estudio de la silvicultura urbana local incluyó entrevistas de expertos con actores locales de gobernanza forestal urbana, análisis de documentos y visitas al sitio. Se aplicó el enfoque de arreglo de políticas para estructurar y analizar la gobernanza de los bosques urbanos. Los hallazgos muestran que todas las ciudades habían visto un desarrollo de sus programas de silvicultura urbana y gobernanza a lo largo del tiempo, como el desarrollo del personal y los planes formales, así como las alianzas con socios clave. Las perturbaciones "pulso" parecen haber desempeñado un papel importante en el desarrollo y, a veces, la reorientación de los programas de silvicultura urbana. Aunque los disturbios a menudo tuvieron impactos devastadores, un fuerte programa de silvicultura urbana en

marcha, incluyendo alianzas sólidas con, por ejemplo, socios de la industria u ONGs, se consideró importante para manejar las consecuencias de estos eventos. También se han hecho esfuerzos para estar mejor preparados para futuras perturbaciones mediante una mayor profesionalización, la elaboración de planes, directrices y prácticas óptimas, el fomento de la capacidad mediante asociaciones y el establecimiento de mejores sistemas de información de la vida real en apoyo de la adopción de decisiones. Los resultados pueden informar la gobernanza de los bosques urbanos y los programas de silvicultura urbana en las ciudades canadienses y en otros lugares.

Appendix on following page

Appendix. Urban Forest Governance and Calamities: Interview Questions

Thank you for agreeing to conduct an interview as part of our research. We are conducting these interviews to learn more about the local context of urban forestry in your city. We would particularly like to gain your perspectives on urban forest policy and strategic decision making, and on-the-ground urban forest management and operations. We would also like to learn about urban forest policy and operations in the face of pressures and events, such as forest fires, pest outbreaks, and rapid loss of urban trees due to urbanisation. For the purposes of this interview, we define urban forests as the trees and associated vegetation in the urban environment. Please note that you may skip any questions that you cannot or do not want to answer.

Demographic Information

Education

Organisational Information and Urban Forest Background

How many years have you worked/volunteered in urban forestry?

What is your current job title and organisation?

How long have you been in your current position?

In your current role, what are your primary responsibilities?

What percent of your work is related to urban forestry?

How long have you lived in this city?

How has urban forestry decision making changed during the past X years (based on time in city and job above)?

Would you consider your city to be urban forestry friendly? Please explain.

If participant works for the municipality:

- Who is responsible for street trees in your municipality?
- Who is responsible for trees in parks?
- Who is responsible for woodlands/natural areas?
- Who is responsible for institutional lands (e.g., schools, hospitals)?
- Where does your city's urban forestry/parks department fit into the municipal organisational structure?
- Does the city have an urban forest management plan?
- Does the city have other related plans or policies that affect urban forestry?
- What are your organisation's urban forest priorities?
- Are these priorities formalised in a policy document(s)?

Urban Forest Governance

How is urban forest policy created? (What is the strategic decision-making process?)

Who are the principal actors (e.g., institutions, organisations, individuals) involved in creating urban forest policy in your city? What are their levels of influence? *(Ask about non-municipal actors if they don't come up, e.g., NGOs, businesses.)*

How are operational decisions made? (What is the operational decision-making process?)

Who are the principal actors involved in on-the-ground decision making (operations)? What are their levels of influence? *(Ask about non-municipal actors if they don't come up, e.g., NGOs, businesses.)*

Are there any people or groups who influence urban forest policy or operations that we have missed? How do they influence policy and/or operations, and what is their level of influence?

What is the role of public participation in urban forest policy? I.e., how can or do individuals influence urban forest policy in the city?

What is the role of public participation in urban forest operations? I.e., how can or do individuals influence urban forest operations in the city?

Urban Forest Calamities and Resilience

Has your municipality experienced an urban forest calamity (i.e., urban forest pressures or negative events) in the past? Please list them for me. *Prompt additional events once listed (e.g., fire, windstorms, insect outbreak, development pressure, drought).*

If no, skip to the final question.

For EACH calamity:

When did this calamity or calamities occur and what happened?

How did your organisation respond to the calamity? (Short term, long term.)

Was your urban forest governance and management system/arrangement prepared to deal with the calamity and respond effectively? Please explain. What were the strengths and weaknesses?

Did your response involve any policy changes or new relationships/partnerships? Please describe.

Were there any changes in the responsibilities and roles of people involved in urban forest policy? (For example, were there changes in who is leading strategic urban forest decision making and policy-development processes?)

Were there changes in public involvement after the calamity? If so, please describe these changes.

Have urban forest operations in your city changed in response to the calamity? Please describe.

Do you think your organisation is prepared to deal with future calamities? Are your policies and procedures set up for dealing with calamities? Please explain.

Are your urban forest operations set up to deal with future calamities? Please explain.

Who would be your key partners in case a calamity happens?

Do you think your city is prepared to deal with future unknown urban forest calamities? Please explain.