Evaluation of planning and management approaches for limiting residential encroachment impacts within forest edges: A Southern Ontario case study

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Abstract Studies increasingly document degradation and loss of publicly owned urban forest area following adjacent development due to residential encroachment. Little is known about prevailing approaches for limiting these impacts. Taking Southern Ontario as a case study, long interviews were conducted among Ontario planners, landscape architects, forest managers and bylaw officials within six Ontario municipalities to determine prevailing goals, tools, and strategies for addressing residential encroachment. Few municipalities had explicit goals, and none had objectives for addressing encroachment. Bylaws were the primary tools for addressing existing encroachments, but field studies indicated infrequent enforcement. Boundary-focused structures, such as fences, were the primary means of preventing encroachment; however, they were applied to a minority of forests with adjacent housing. None of the municipalities had a strategy for implementing their tools to protect targeted ecological, social or economic services provided by urban forests. Recommendations for improved approaches for managing residential encroachment impacts within forest edges are provided.

Keywords Residential encroachment · Urban natural area planning and management · Forest edges · Green infrastructure · Greenways · Indigenous vegetation

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Introduction

Studies indicate an increasing appreciation for the important economic, social and ecological functions played by remnant urban forests. They provide important recreation facilities (Florgard and Forsberg 2006) and enhance human health and well-being (Tzoulas et al. 2007). They have also been recognized for their ecological services. For example, they manage storm water runoff (Correll 1999); cleanse and cool the air (Brown and Gillespie 1995); sequester carbon (Nowak and Crane 2002); and reduce energy use in adjacent structures (Simpson 2002). They also support native local and regional biodiversity (Vaha-Piikkio et al. 2004). Furthermore, in some European countries they play important economic roles as timber producers (Konijnendijk 2000).

In recognition of their importance, governments have protected significant remnants from being developed into more intensive urban land uses (Florgard 2007). For example, in Ontario the provincial, regional and municipal governments have developed increasingly rigorous policies to protect remnant forests they consider significant, for the long term (e.g. see Ontario Ministry of Municipal Affairs and Housing 2005).

Studies demonstrate significant impacts to forests with adjacent urban development. For example, when an area of farmland adjacent to a forest fragment is developed into a housing subdivision, human activities intensify relative to those that previously occurred within the farmland. This leads to human activity-associated impacts within the adjacent forest edge. According to landscape ecology boundary theory, this edge effect occurs because of the dissimilarity between the human activities occurring within the housing area relative to those occurring in the forest (Forman 1995). The area of habitat affected by increased human activities is referred to as edge habitat, while that unaffected is referred to as interior habitat (Forman 1995). Many studies have demonstrated the different edge habitat conditions that result between dissimilar landscape elements (e.g. Murcia 1995).

Forest ecosystems, particularly deciduous forests, are sensitive to human activity impacts (Kuss and Hall 1991). One study found that when housing is constructed adjacent to large forest fragments, 95% of impacts related to both yard and public recreation activities extended a mean distance of 67 m from forest borders (Matlack 1993). However in many urban areas, human activity impacts often affect the entire forest because forests tend to be small in area or narrow. People frequently leave authorized trail systems (Tonnesen and Eversole 1997). Damage caused by off-trail use includes compaction and erosion of soils; changes to hydrological regimes; loss and damage of vegetation (Liddle 1997); reductions in the regeneration success of trees (Lehvävirta and Rita 2002), and the spread of exotic plants and animals (Hobbs and Humphries 1995; Coleman et al. 1997).

Planners, landscape architects and forest managers expect increased recreation impacts to occur with adjacent housing development, but want to keep impacts within acceptable limits. Accordingly, they have developed management guidelines (e.g. Forestry Commission 1992). Tools often include well-designed access areas, circulation systems and facilities (for example, see Cole 1993), or structural elements, such as trees or rocks, that concentrate and direct human disturbance (Lehvävirta 1999).

Many of these strategies are based on the results of recreation ecology studies within the forests of less developed landscapes. Strategies seek to manage total impact of recreational activities by manipulating the spatial extent and/or intensity of impacts (Cole 2003). Concentrating impacts in a particular area, or segregating them from sensitive areas, reduces spatial extent of impact. The intensity of impacts is reduced by decreasing the number of times activities occur, or by regulating the type of activity, how it occurs, or the ecosystem or season in which it occurs. Regulating the type of activity or how it occurs (e.g. through an

education program), is believed to be one of the best strategies for reducing the intensity of impact (Cole 1993, 2003). Certain types and behaviours of impact account for a high proportion of the total impacts occurring in outback forests (Cole 2003). For example, motorized recreational vehicles cause much more impact on vegetation than either horses or hikers (Weaver and Dale 1978); and people with dogs (particularly when dogs are unleashed), cause more disturbance to wildlife than people without dogs (MacArthur et al. 1982). However, many recreation ecologists believe the most effective strategy for reducing total impacts within forests with high usage are those that reduce the spatial area of impact (McEwen and Tocher 1976; Cole 1981; Cole and Monz 2004; Leung and Marion 1999).

Studies have also measured the negative impacts on urban forests that occur with abutting residential land uses. These impacts, commonly referred to by Ontario municipalities as encroachment, are spatially associated with forest borders. Encroachment is defined as the impacts on natural areas resulting from adjacent resident activities within their yards and in the natural area edge (McWilliam et al. 2010). Encroachment impacts include private edge resident recreation impacts (e.g. unauthorized pathways connecting edge resident yards with the publically-owned forest), but do not include impacts that may have resulted from the public recreational use of the forest. This distinguishes encroachment from human activity impacts measured in Matlack's study (1993). Matlack's study (1993) measures both sources of impact. Studies demonstrate encroachment impacts extend up to 50 m from forest borders (McWilliam et al. 2009) and cover 26% to 50% of the forest floor within the first 20 m (McWilliam et al. 2011). However, like recreation-related impacts, they may occur through-out urban forests that are less than 50 m wide. Impacts associated with adjacent residential housing include harmful chemicals (Exner et al. 1991); erosion and compaction of soils and trampling or removal of vegetation (Moran 1984; Matlack 1993; McWilliam et al. 2010); suffocation of forest vegetation by human waste materials and replacement of public forest area with private residential land uses (Matlack 1993; McWilliam et al. 2010); exotic garden plant invasions (Seidling 1999; McWilliam et al. 2010), and disturbance of wildlife (Friesen et al. 1995).

Studies within the forests of less developed landscapes have also measured the impacts resulting from adjacent land uses (Janzen 1986; Schonewald-Cox and Bayless 1986). According to Schonewald-Cox and Bayless (1986), two of the key factors that protect adjacent forests from adjacent land use impacts are natural and human-generated boundary filters that reduce or impede edge conditions. For example, forest vegetation or a fence may impede human activities from entering forest borders. Surveys of forest borders in Southern Ontario municipalities demonstrate multiple human-created boundary structures between residential yards and municipal forest borders (McWilliam et al. 2011). Residents installed most boundary structures; however, municipalities installed some as well (McWilliam 2009). Studies demonstrate human-generated boundary treatments, such as fences, significantly filter some residential land use impacts, reducing their spatial area (McWilliam et al. 2009, 2011). However, it is not known whether municipalities use boundary treatments as tools to reduce encroachment impacts.

Encroachment impacts have been recorded in the urban forest remnants of Southern Ontario, Canada (McWilliam et al. 2009, 2011); Northeastern United States (Matlack 1993; Moran 1984; Sharpe et al. 1986); Western Australia (Stenhouse 2004), and New Zealand (Bagnall 1979). However, little is known about government approaches for protecting the functions of public forests from significant residential encroachment. The aim of this study is to determine whether municipal governments have goals, objectives, tools and strategies for addressing residential encroachment impacts, and if so, to evaluate the efficacy of these approaches. Approaches are revealed through long interviews with key municipal staff within six Southern Ontario municipalities. Their efficacy is determined by comparing the

intent of their approaches with the level of encroachment occurring within their municipal forests (McWilliam et al. 2009, 2011). Efficacy is also evaluated by comparing these approaches with successful approaches developed by recreation ecologists and forest managers for limiting similar human activity impacts within the forests of less developed landscapes. Recommendations for improving municipal approaches for limiting encroachment impacts are provided.

Methods

Study municipalities

Study municipalities are located in the Greater Toronto Area and include Cambridge, Guelph, Kitchener, Mississauga, Oakville and Waterloo. They range in population between 100,000 and 700,000 people. These municipalities were chosen for the study because initial contact with officials indicated they had established policies or practices for limiting residential encroachment within their forests.

Surveying methods

Twenty-six long interviews with key informants were conducted in 2005 lasting an average of 70 min in length. To refine and remove bias from questions, pilot interviews were first conducted within Burlington, Ontario, a non-participating municipality. The pilot revealed key informants differed in their understanding of the terms: goal, objective, strategy and tool. To ensure a consistent application of the terms, informants were asked to respond to questions according to the following definitions. A goal is a general long-term direction for progress that is frequently difficult to measure (Hodge 2003). In contrast, an objective is a measurable target indicating the goal has been achieved, or that progress has been made toward its achievement (Hodge 2003). A strategy is a broad conceptual approach to planning, design or management of a resource for achieving an objective or goal (Manning 1979). A tool is a device or implement used to carry out a particular function (Oxford University Press 2011). For example, the implementation of a strategy involves taking a tool and putting it into action in order to meet a goal, its intent and/or an objective (Pressman and Wildavsky 1973).

Key informants were chosen non-randomly through purposive and snowball sampling methods. The interview sample was selected from the resulting list of potential candidates, and consisted of those judged knowledgeable and sufficiently experienced in their respective areas. Interviewees had an average of 14 years experience in their expertise. They were selected from five groups within municipalities: 1) development planners, 2) environmental planners, 3) park planners and landscape architects, 4) forest or park managers, and 5) bylaw enforcement and real estate managers.

The interview design was semi-structured, with pre-determined questions asked in a systematic order (Frankfort-Nachmias and Nachmias 1992). Questions were mostly open-ended, allowing respondents to answer in their own words and to express whatever they felt was most important (Del Balso and Lewis 2001). Some closed-ended questions were also asked after related open-ended questions to avoid biased answers (Jackson 1999).

Transcribed data was analyzed repeatedly for themes and sub-themes of related information. Six themes were revealed during the analysis of the data: 1) encroachment definitions; 2) concerns of municipal staff and residents; 3) encroachment significance; 4) goals and objectives; 5) tools (policies, bylaws and practices); and 6) strategies.

Findings

To preserve their anonymity, interviewees are referenced in the following text according to a code that identifies them by number and role in their municipality (Table 1).

Do municipalities have goals and objectives for addressing forest encroachment?

A majority of interviewees said their municipality did not have a written goal for addressing encroachment, and none had an objective. Most believed their municipal goal was to eliminate encroachment based on their bylaw prohibitions of encroachment activities; However, most did not believe this goal could be achieved. They suggested their municipalities maintained this goal to clearly communicate to residents that encroachment is prohibited, but had no intension of meeting this goal.

As a result of the lack of explicit goals, many forest manager and designer interviewees said they, or their departments, currently operated under an unwritten goal of reducing or minimizing the occurrence of encroachment,

> We don't have a goal I could even cite that would say that, you know, we have a zero tolerance policy or something like that. I think that it's inferred, but it's, in practice, it's not practical. So, our goal, our non-enunciated goal, is to deal with, to minimize, encroachment.(FM5)

Do municipalities have tools for removing existing encroachments?

Forest managers said they were primarily responsible for addressing existing encroachments through the implementation of their bylaws. Some municipalities, like Oakville, had one bylaw prohibiting all activities deemed harmful within natural areas or parks, no matter the source of impact. Other municipalities, such as the City of Guelph, had encroachment-specific bylaws that defined encroachment, distinguishing it from other impacts such as those related to recreation,

> Encroachment means any type of vegetation, structure, building, man-made object of item of personal property of a person which exists wholly upon, or extends from that person's premises onto, City-owned lands and shall include any aerial, surface, or subsurface encroachments and shall also include, but is not limited to, any activity that results in a removal, addition, subtraction, or material change to the City-owned lands (City of Guelph 2005, Bylaw 17780, p.2).

Table 1 Key to interviewee codes

Code	Role within the municipality
EP	environmental planner
DP	development planner
LA	landscape architecture or park planner (referred to collectively as designers)
FM	forest or park manager (referred to collectively as forest manager)
PM	property manager, bylaw enforcement officer or lawyer (referred to collectively as bylaw enforcement staff)

Still other municipalities addressed different encroachment activities through a combination of corporate policies and bylaws. For example, the City of Cambridge addressed yard extension encroachment behaviours in their corporate encroachment policy, and other encroachment activities, such as edge resident waste disposal, in their Parks bylaw.

Interviewees indicated bylaws were regularly communicated to residents through newspaper advertisements, municipal websites, and mailed pamphlets. Pamphlets were also available in city halls, and were sometimes hand delivered to encroaching residents. Interviewees said they also posted signs prohibiting waste disposal types of encroachment at most natural system entryways (Fig. 1).

Interviewees said their bylaws or policies prohibiting encroachment had been revised over the last 10 to 15 years to include newly identified types of encroachment and to overcome barriers to their effective enforcement. For example, bylaw enforcement staff said their bylaws had been re-worded to clearly prohibit encroachment, to include stiff penalties, and to provide avenues through which municipalities could recover the municipal costs of removing encroachments and restoring forest edges,

> The wording of the Parks bylaw didn't give us the authority, or strong enough authority, to do anything about the situation they described. It was just a provision that said, "You know, you really shouldn't partake in such and such activity in the public space." There were no teeth to it and no process.(BE3)

Interviewees within all six municipalities indicated that encroachment bylaw enforcement required different courses of action depending on the type of encroachment, and circumstances under which it occurred. They said courses of action might include: 1) asking residents to remove the encroachment; 2) asking residents to restore the forest edge; 3) removing the encroachment at no cost to the resident; 4) charging the resident for the

Fig. 1 Signs at natural area entries state bylaw prohibiting waste disposal and removal of vegetation (Photo: Oakville Park, Oakville, Source: W. McWilliam 2005)

removal or restoration; 5) fining the resident (or putting the fee on the resident's municipal taxes if they refuse to pay); 6) authorizing the encroachment for a fee; and 7) selling the encroachment land to the resident. However none of the municipalities had a written procedure for determining which course of action to follow. Within most municipalities, Bylaw enforcement staff recommended a course of action to their municipal council with input from forest management staff. However, ultimately the decision rested with municipal councils.

Within all municipalities, encroaching residents could apply to their municipalities to get their encroachments authorized. Authorization meant the resident could keep their encroachment within the municipal forest, usually through a rental-type agreement and fee. Only two municipalities, Mississauga and Guelph, had written criteria under which encroachments would not be authorized. For example, criteria of both municipalities stated they would not be authorized if they interfered with forest management, or if they increased municipal exposure to liability. Interviewees in both municipalities said written procedures and criteria were essential for limiting the number and arbitrary approval of encroachments by municipal councils.

Do municipalities have tools for preventing new encroachments?

Interviewees indicated there were two different departments, or groups of departments, within municipalities involved with limiting encroachment at different points in the development cycle. Many planner and designer interviewees involved in addressing encroachment prior to and during development said they primarily specified structural boundary treatments to limit encroachment impacts. A minority said they also specified educational leaflets and buffers to limit encroachment impacts within particularly sensitive natural area designations. Forest managers indicated they primarily used education to discourage encroachment, and a few said they sometimes used structural boundary treatments.

Structural boundary treatments

The primary means of preventing encroachment were structural boundary treatment policies. Most of these policies were not official or secondary plan policies, the most authoritative municipal policies. Four of the municipalities had corporate policies and the remainder had departmental practices. Policies of three municipalities, Oakville, Mississauga and Cambridge, required a 1.2 m to 1.5 m high, black chain link fence (Fig. 2).

Two of the municipalities, Guelph and Waterloo, required a living fence or vegetative barrier, and one of these municipalities, Guelph, said their policy allowed them to specify a fence where deemed appropriate. However, Guelph interviewees did not specify under what conditions it would be appropriate. One municipality, Kitchener, required a 1.5 m municipal post at 1.5 m intervals together with a sign identifying the natural area's conservation status, municipal ownership and the prohibition of some encroachment activities. All treatments were placed on municipal land so encroachments could be identified, and fences maintained. Most of these policies were developed between 10 and 15 years ago and applied to housing areas developed since policy development. Within the majority of municipalities, these policies did not apply to forests with housing built prior to their development. Planner interviewees said it was important to install boundary treatments prior to housing occupation because encroachment activities often occurred soon after residents moved into homes.

In addition to these policies, three of the municipalities had a forest management practice of installing municipal boundary posts in forest borders adjacent to existing subdivisions

Fig. 2 Municipal policy of black chain link fence (Note fence does not limit the spread of *Vinca minor*, an invasive exotic plant, into the forest edge from the residential yard) (Photo: Deer Run Park, Mississauga, Source: W. McWilliam 2005)

(Fig. 3). Forest managers within these municipalities said they applied these practices where they deemed it necessary, but could not say when a fence might be appropriate.

Environmental planners and designer interviewees generally favoured living fences such as hedges. They believed residents preferred these treatments. They also argued living fences provided supplemental wildlife habitat and facilitated wildlife movement. However, some interviewees, particularly forest managers and bylaw enforcement staff, were not satisfied with the performance of living fences or posts. They argued some residents removed or altered these treatments and they were ineffective barriers to encroachment,

> The reality is that chain link fences are more effective at preventing yard waste encroachment. I got on-board with the chain link fences in some areas.(EP2)

Education

Both planners and forest managers stated they had educational practices, rather than policies, for limiting encroachment. They indicated the objectives of these tools were to make residents aware of encroachment and its impacts on forests, and of bylaws or policies prohibiting encroachment. Objectives were also to discourage a range of negative resident behaviours within natural areas to encourage forest stewardship.

Many environmental planners and forest managers felt residents needed to change their encroachment behaviours. They argued their municipalities required more resident support in order to reduce encroachments to manageable levels through their policies and practices,

> The social issues have to be addressed first. Like we have all these policies and now we say, "no encroachments," It's the same thing as when we say, "dogs must be leashed." Well, people just don't do it. There has to be more public education.(FM3)

Many interviewees said their municipalities had information or pamphlets available within their city halls, or on their municipal web sites, educating residents regarding

Fig. 3 Municipal Practice of Boundary Post (Note yard extension encroachment to right of post) (Photo: Sugar Bush Park, Waterloo, Source: W. McWilliam 2004)

their bylaws, and encouraging positive behaviours with respect to their natural areas. In addition, environmental planners said they frequently required developers to produce educational pamphlets when developments were adjacent to the most sensitive natural area designations, such as wetlands. Pamphlets described natural area features and functions, and how to minimize resident impacts on the natural area. They were to be distributed by developers to new residents within real estate sales offices. Planners said they were not sure whether new residents were aware of, or had read, the pamphlets. Planners also said park entry signs prohibiting waste disposal activities were elements in their education programs (Fig. 1).

Despite a call for more education among some interviewees, others said they thought educational tools were ineffective in reducing encroachment behaviours. They argued that even educated residents encroached,

> My view on education is that, really, in a lot of cases, it's a wasted effort because you're going to get people, regardless of what they know, behave in the way they want.(EP4)

Forest managers and one bylaw enforcement officer, indicated they occasionally hand-delivered shorter, fact sheets to encroaching residents specifically aimed at discouraging encroachment. They said they sometimes talked to encroaching residents face to face about removing their encroachments. They believed that more focused and personal educational approaches were more effective in achieving encroachment removal than impersonal approaches, such mailed pamphlets, that attempt to discourage a range of resident impacts on adjacent forests. However, none of the interviewees knew of studies assessing the effectiveness of their educational programs for reducing encroachment. They did not know whether their programs had educated target residents regarding the negative impacts of

encroachment or the existence of bylaws, or whether they had resulted in changing encroachment behaviours.

Buffers

Buffers are commonly defined in Ontario as vegetated strips of land set aside from development that separate a natural area from an adjacent land use (Ontario Ministry of Natural Resources 2010, p. 216). Planner and environmental planner interviewees argued that buffers were vital tools for protecting forests from a myriad of development impacts, particularly construction impacts to forest edge trees, and stormwater management impacts following development. Despite the importance placed on buffers for protecting sensitive natural areas from development impacts, planners from only two municipalities, Cambridge and Waterloo, said they specified buffers, in part, to protect forests from encroachment.

Planner interviewees said that buffer characteristics, including their widths, were specified in their policies, or established according to the results of a developer buffer study. For example, according to the Kitchener Official Plan (City of Kitchener 2005), when developing adjacent to significant wetlands, developers were required to make recommendations on the need for, the width of, and compatible land uses within vegetated buffers (City of Kitchener Official Plan 2005, Pol. 7.5.1). Interviewees said that buffer widths increased with the significance attributed to the natural area and ranged from 5 to several hundred metres. They said the guidelines provided by the Ontario Ministry of Natural Resources (Ontario Ministry of Natural Resources 1999) were influential in determining whether developer-suggested widths were considered sufficient for protecting adjacent natural areas from development impacts. According to interviewees, agreed upon buffer widths were typically between 5 and 30 m. Narrower widths of 5 m were believed sufficient to protect edge trees from construction impacts, and wider widths of 15 and 30 m were considered wide enough to protect warm and cold-water stream habitats, respectively. Interviewees said buffer widths were not established in response to studies demonstrating encroachment distances from forest borders.

Both Environmental planner interviewees who specified buffers to protect forests from encroachment said they functioned as receptacles for encroachment impacts, keeping impacts out of designated forest edges. None of the interviewees had policies to limit the occurrence of encroachment impacts within their buffers,

> Do we have a policy on mitigating encroachment onto buffers? You know, that is debatable. We certainly have an approach that we deal through our practices, and we have some things that we try to apply through the design stage to mitigate it, but I'm not aware that we have a specific approach for policy.(EP4)

Do municipalities have strategies for reducing encroachment impacts on forests?

None of the municipalities had strategies for implementing their tools. Interviewees said they did not know whether their intent was to reduce the intensity or spatial extent of encroachment impacts. They indicated they focused on managing encroachment impacts at the fine scale (i.e. at the border between residents and the forest), rather than at courser spatial scales (e.g. by controlling adjacent land use through zoning). Interviewees indicated they did not apply their policies strategically, for example, by focusing their efforts on particularly sensitive forests, or those experiencing high levels of encroachment. Apart from buffers and educational pamphlets (which were applied only to certain designated forests adjacent to

new developments), they said their tools applied to all forests. Many interviewees appeared hesitant to discuss strategies because they did not want to communicate to residents that encroachment was acceptable,

> If you're going to take on when, or how much, it's almost like you saying it's acceptable to do it.(FM4)

Some of the forest managers said that strategies were needed that addressed multiple impacts to natural areas both during and following development, not just encroachment. They said natural areas provided different social, economic or ecological services to their communities, and were subjected to different impacts. They argued different areas required different strategies to address these impacts in the form of individual natural area management plans,

> I think those issues have to be dealt with as a package and as a management plan. I think that if you go into these areas just dealing with encroachments, I think you're wasting your time because it, in some natural areas, encroachment may not be the most serious issue.(FM3)

Discussion

The results of this study indicate few explicit municipal goals and no objectives for limiting encroachment impacts within Southern Ontario study municipalities despite studies that indicate substantial encroachment within their municipal forests (McWilliam et al. 2009, 2011). Further study is required to determine if this is the case in other locations in which encroachment occurs.

Municipal bylaws prohibiting encroachment implied that no encroachment was acceptable. This suggests these municipalities sought to eliminate encroachment impacts through their policies and practices. However, many interviewees and landscape ecology theory indicate this is an unrealistic goal. Edge habitats between dissimilar landscape elements form and will be characterized, at least in part, by the forms and functions of adjacent landscape elements (Forman 1995). The different and more intensive human activities of residential yards relative to adjacent forests lead to areas of human activity impact within forest edges. Thus, encroachment impacts within forests cannot be eliminated, but only managed. This conclusion is supported by studies that found that even with multiple structural elements at forest borders encroachment was not eliminated. Substantial areas of many visible encroachment behaviours continued, particularly those related to forest recreation, waste disposal and garden plant invasions (McWilliam et al. 2009, 2011). Furthermore, encroachment that is not easily visible, such as light, noise, alterations in hydrological or chemical regimes, or pet predation, is unlikely to be affected by structural boundary treatments (Fig. 2). Other planning and management strategies and tools are required to manage these impacts. Further study is required to determine the significance of less visible types of encroachment, and to identify strategies and tools for mitigating them in forest edges.

If no, or insignificant levels of encroachment are acceptable within designated forest edges then landscape elements more supportive than housing could be planned adjacent to forest borders. More supportive elements, in terms of relatively low levels of encroachment, may be those requiring infrequent use of the forest. They may include light industry or professional offices where businesses and employees have little use for adjacent forests. For example, employees may be unlikely to desire forest recreation, or have predatory pets, or

swimming pools that could be drained into adjacent forests. Where adjacent lots are large, and have substantial areas of soft landscape, structures and other hard surfaces could be minimized and concentrated away from forest edges to further discourage user interaction, and avoid less visible encroachments such as light or noise. Furthermore, there may be fewer landowners or landscape managers associated with these land uses, making it easier and less expensive for municipalities to educate land users, encourage forest stewardship, and manage their forest edges. Further study is required to measure encroachment occurring under adjacent landscape elements other than housing in order to identify more supportive adjacent land uses.

Alternatively, wider buffers than currently negotiated could to be established in order to segregate encroachment impacts from designated forest edges. Most planner interviewees said that buffers were not specified to protect forests from encroachment impacts, and studies indicate commonly negotiated widths are insufficient to segregate encroachment impacts from designated forest borders (McWilliam et al. 2009). Depending on the structural boundary treatment, buffers up to 50 m are required to segregate these impacts (McWilliam et al. 2009). However, buffers do not reduce the amount of encroachment occurring within buffers, and there is concern that these impacts may impede other buffer functions (United States Environmental Protection Agency 1995). For example, encroachment activities that result in the erosion or compaction of soil, or channelization of drainage water, may impede stormwater management functions of riparian buffers (United States Environmental Protection Agency 1995). Further study is required to determine whether encroachments degrade these and other buffer functions; and if they are degraded, how to design buffers to maintain functions where encroachment is anticipated.

In forests where some encroachment is expected and acceptable, municipalities could seek to identify acceptable types, behaviours and their spatial areas. Their forest edges could then be planned, designed and managed to ensure impacts stay within limits. However, as one forest manager interviewee argued, encroachment is not the only source of impact within urban forests. Planners, designers and forest managers could work together to develop comprehensive strategies that anticipate impacts and protect valued forest services from the cumulative impacts that occur through time from multiple sources. Further study is required to determine the barriers to developing goals and objectives for addressing encroachment within Ontario and other municipalities experiencing significant impacts.

Interviewees indicated they had multiple tools for addressing and preventing encroachments. Bylaws or encroachment policies primarily addressed existing encroachments; and boundary structures, and sometimes education and buffers, were meant to deter, or protect designated forest edges from, new encroachments. Similar to recreation impacts, encroachment occurs with human activities. Many of its impacts are similar to those occurring with recreation, such as compaction of soils, removal of vegetation and disturbance to wildlife. Despite these similarities, interviewees indicated they had not developed management strategies similar to those recommended by recreation ecologists. For example, they did not know whether the intent of their policies or practices was to reduce the intensity or spatial area of human activity impact. In part, this may have been be due to the lack of clear goals and objectives for addressing encroachment.

Despite current approaches for addressing encroachment within these municipalities, studies within their forests indicated a very high prevalence and substantial spatial area of existing encroachments (McWilliam et al. 2009, 2010, 2011). These encroachments existed despite municipal efforts to communicate bylaws and policies to residents, and improvements to bylaws and policies designed to remove barriers to their enforcement. Further study

is required to determine whether municipalities are aware of, or concerned about, this level of encroachment, and whether there remain barriers to bylaw or policy enforcement.

Tools such as bylaws and encroachment policies reduce the frequency of existing encroachments. According to recreation ecology theory these tools implement a strategy that reduces impact intensity (Cole 2003). In general, these strategies are not considered as effective in reducing the total impact of human activities within forests as those that reduce the spatial area of impact (Cole 2003). Furthermore, unless tools are implemented to deter new encroachments, like structural boundary treatments, encroachments are likely to occur again following bylaw enforcement, either by the same or a new resident. To be effective, frequency reducing tools, such as bylaws or education, need to be combined with tools that concentrate impacts within forest edges, such as boundary treatments. However, within the majority of municipalities, structural boundary treatments have only been applied to forests developed in the last 10 to 15 years, since the establishment of their boundary policies or practices. Similarly, educational programs aimed at preventing encroachment, and buffers, have only applied to some forest designations adjacent to new housing. Further study is required to determine the barriers preventing the wider application of municipal preventative policies and practices.

Most municipal policies specified fences as boundary treatments. Studies demonstrate these treatments significantly reduce the spatial area of encroachment by reducing that occupied by forest recreation and yard extension encroachment behaviours (McWilliam et al. 2011). Fences also concentrate all impacts closer to forest borders (McWilliam et al. 2009, 2011). Recreation ecology studies suggest that tools reducing the spatial extent of encroachment will be more effective in reducing the total impact of human activities within intensively used forests than tools aimed at reducing encroachment frequency, such as bylaws (Cole 2003). Further study is required to test whether living fences or municipal property line demarcation posts alone, or in combination with signs, reduce the spatial area of encroachment. However, interviewees and field study results indicate that unless boundary treatments impede human entry, they are unlikely to significantly reduce encroachment (Fig. 4) (McWilliam et al. 2009, 2011).

Most municipalities specified boundary treatments that contain one element, such as a fence. However, no single element is effective in significantly reducing all encroachment behaviours (McWilliam et al. 2011). Boundary treatments that contain multiple elements are more effective in reducing encroachment behaviours. For example, when combined with fences (no gates), grass strips are effective in significantly reducing the area of encroachment behaviours not significantly reduced by fences alone (e.g. waste disposal, forest border vegetation removal and garden plant invasions) (Fig. 5). They also have the added benefit of allowing municipal access to, and management of, forest borders and edges, making it easier to identify and remove encroachments and hazardous trees. The addition of trails within grass strips further facilitates both municipal and informal resident monitoring of forest borders; however, further study is required to determine whether they significantly reduce encroachment behaviours independent of grass strips (McWilliam et al. 2011).

In some cases forest edge habitat may be lost in the installation of mown grass strips. To be effective deterrents to encroachment, grass strips require mowing since field observations indicate encroachment increases where there is longer grass or forest regeneration (Fig. 6) (McWilliam 2009).

The benefits of mown grass strips may be offset by the drawbacks associated with mowing that include air and noise pollution, and increased carbon emissions and the resources required to manage urban forests. In forests that support high, or sensitive, native biodiversity maximizing habitat area and minimizing wildlife disturbance may be particularly important. Here,

Fig. 4 Softer boundary treatments, such as living fences, unlikely to impede encroachment (Note unauthorized entryway to natural area (*center of photo*) and waste disposal (*right of photo*)) (Photo: Village Wood Park, Oakville, Source: W. McWilliam 2006)

municipalities could retain a forested edge (or require a forested buffer), rather than install a mown grass strip. In these cases, fences could to be supplemented with tools other than grass strips, in order to limit encroachment behaviours not significantly reduced by fences. Tools could include education programs and rigorous bylaw enforcement specifically targeted at reducing these behaviours.

Some interviewees believed that education programs were particularly important tools for altering encroachment behaviours. They argued that municipal efforts alone were not sufficient to limit encroachment impacts to acceptable levels. Like bylaws, educational tools implement strategies that reduce the intensity of impacts. While this strategy is not considered as effective in reducing total impacts as strategies that reduce spatial area of impact, many recreational ecologists argue that education programs can play an important supplementary role in reducing total impacts, particularly when combined with area-reducing strategies. For example, one study demonstrated that a sign educating the reason for a barrier blocking entry to a trail was more effective in discouraging hikers from using a closed trail than just a barrier (Johnson 1989).

Education programs could play a key role in reducing particularly damaging types of human activity impact (e.g. Cole 2003). Certain types and behaviours of recreation are often responsible for a disproportionate amount of impacts occurring (Cole 1993). For example, one study found that 200 passes of a motorcycle through grassland removed nine times more vegetation than 200 pedestrians (Weaver and Dale 1978). Reducing or directing the occurrence of these particularly harmful impacts is anticipated to lead to more substantial reductions in total impact than other tools that reduce the intensity of impact (Cole 2003). Similar to recreational impacts, there are multiple types and behaviours of encroachment, each occupying different spatial areas within forest edges (McWilliam et al. 2009, 2010, 2011). While more study is required to determine the impacts of different encroachment

Fig. 5 Fence with grass strip and pathway reduces the spatial area of multiple types of encroachment (Photo: Margot Park, Oakville, Source: W. McWilliam 2005)
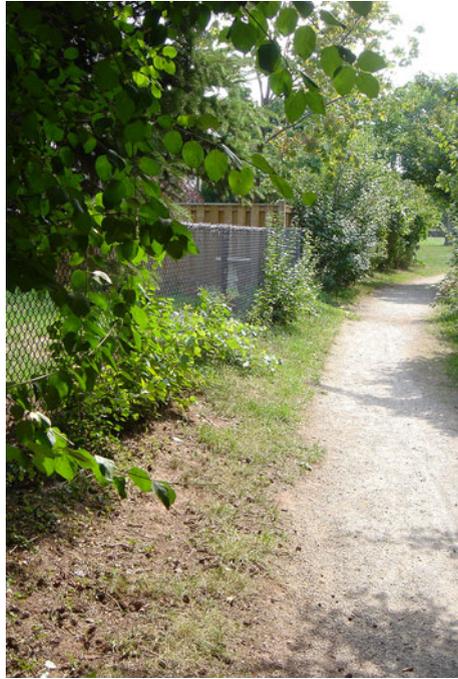
behaviours on the social, ecological and economic services provided by forests, it is anticipated that some encroachment behaviours are more harmful, or of greater concern, than others. For example, municipalities may be particularly concerned about residents installing structures within forest edges (a type of yard extension encroachment). They may result in the total loss of forest habitat for long time periods, and increased municipal liability (Fig. 7) (McWilliam 2009). This type of encroachment may be of greater concern to municipalities than others, such as waste disposal, that results in the suffocation of forest vegetation and is more easily remedied.

Despite support among some interviewees for education programs as tools for limiting encroachment, most believed current programs were ineffective. Studies demonstrating a high level of encroachment within the six study municipalities (McWilliam et al. 2009, 2010) appear to support this conclusion. Interviewees were uncertain why their programs were ineffective. Some believed they were not implemented with sufficient frequency. Others believed their programs lacked focus. They argued their programs attempted to reduce too many negative behaviours at one time. Printed materials addressed multiple forms of encroachment, in addition to other human activity impacts, rather than specific encroachment types or behaviours. Some Interviewees also argued some of their education programs were not adequately focused on edge, or encroaching, residents. Further study is required to determine whether programs are being implemented with sufficient frequency, and whether focused municipal education programs are effective in limiting encroachment, particularly types and behaviours of greatest concern.

According to Cole (1993), an effective education program is one in which its audience becomes aware of the negative impacts of its activities, and knows how to eliminate or reduce them. Furthermore, the audience must act on its knowledge to change its behaviour (Cole 1993). Some interviewees believed encroachment behaviors could be changed if

Fig. 6 Longer grass or forest regeneration areas appear to encourage waste disposal encroachment (Note waste dumped in regenerating area in front of forest border (*right of photo*)) (Photo: McCrae Park, Waterloo, Source: W. McWilliam 2004)

residents had greater awareness of their negative impacts on the ecological, social and economic services provided by urban forests. This belief is supported by studies that indicate people are less likely to act in inappropriate ways if they are aware of the link between their behaviour and the resulting negative impact; they are aware of the appropriate way to act, and they feel responsible for the stewardship of a natural area (Gamman et al. 1995; Johnson

Fig. 7 Yard extensions may lead to more substantial impact than other encroachment behaviours (Note Deck built within forest edge) (Photo: Mississauga, Ontario, Source: W. McWilliam 2004)

and Van de Kamp 1996). Further study is required to evaluate whether current programs are effective in increasing resident awareness of encroachment, its negative impacts, and how to avoid it.

Studies also need to determine whether residents are willing to alter their encroachment behaviours once they are educated. Some interviewees felt that no education program would be effective in significantly altering encroachment behaviours. They argued that many residents were aware of their encroachments and their negative impacts, but continued to encroach. This belief is supported by studies that indicate education programs are only effective in reducing negative activities among people who already feel socially responsible (Gamman et al. 1995). Among people who do not feel responsible, studies have shown that some educational programs are ineffective in discouraging harmful activities and behaviours (Roggenbuck 1992). These results suggest that education programs may not be effective in changing encroachment behaviours among residents who do not feel socially responsible, and that programs may have to be designed to influence the behaviours of different groups of residents. Among residents who do not feel socially responsible, education programs may first have to focus on increasing these feelings. According to Bright (1997) and Fishbein and Manfredo (1992), the characteristics and motivations of the group being targeted for education must be determined in order to arrive at effective goals, objectives, techniques and messages for changing behaviours. Further studies are required to determine if a feeling of social responsibility is a factor in encroachment education program effectiveness, and if so, which goals, objectives, techniques and messages are most effective in increasing this feeling among residents.

Conclusions

Although municipalities have tools for addressing encroachments, many are infrequently implemented, and they have limited effectiveness in addressing encroachment. They also lack the clear goals, objectives and strategies required to spearhead and direct their implementation. Like recreation-related impacts, some level of encroachments impacts need to be viewed by municipalities as acceptable if residential landscape elements are zoned adjacent to forests. Municipalities could identify acceptable types, behaviours and spatial extents of encroachments within their natural systems and plan, design and manage the interface between forest and housing elements to ensure impacts stay within specified limits. In urban forests where human activities are unavoidably intensive, strategies could focus on reducing the spatial area of all impacts, no matter the source, at multiple spatial and temporal scales. Bylaws or encroachment policies may be essential tools for reducing the substantial number of existing encroachments in the short term, but by themselves are less effective in reducing total impacts of human activities than spatial area reducing strategies. Municipal boundary treatments are essential tools for limiting the spatial area of encroachment at fine spatial scales, but could be implemented more widely, and made up of multiple elements (e.g. fences and grass strips), to significantly reduce the spatial areas of different types of encroachment. However, even with these treatments, proactive bylaw enforcement, and targeted education programs may be required to reduce the occurrence of particularly harmful types of encroachment, and those not significantly reduced through structural boundary treatments. Where ecological, social or economic services provided by urban forests are particularly sensitive (e.g. where a forest supports high native landscape biodiversity), buffers with widths up to 50 m will segregate remaining encroachment impacts. In addition, planners could implement courser-scaled strategies to reduce the spatial area of

impact. For example, more supportive or similar land uses could be zoned adjacent to sensitive forest edges or forests. The multi-spatial scaled strategies for limiting human activity impacts developed by recreation ecologists and forest managers within forests of less developed landscapes (e.g. Leung and Marion 1999) could be used as models for accomplishing similar results within urban forests.

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