THE ASSOCIATION OF RAT PREVALENCE AND COMPOSTING IN THUNDER BAY'S URBAN NEIGHBOURHOODS

by

Brooke Rajala

Faculty of Natural Resources Management
Lakehead University

April 26, 2023

The association of rat prevalence and composting in Thunder Bay's urban neighbourhoods

by

Brooke Rajala

An Undergraduate Thesis Submitted in
Partial Fulfilment of the Requirements for the
Degree of Honours Bachelor in Environmental Management

Faculty of Natural Resources Management

Lakehead University

April 26, 2023

Major Advisor

Second Reader

LIBRARY RIGHTS STATEMENT

A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the faculty or Lakehead University.

ABSTRACT

Rajala. B. 2023. The association of rat prevalence and composting in Thunder Bay's urban neighbourhoods. 35 pp.

Keywords: composting, deterrents, landfilling, municipal solid waste, Norway rat, *Rattus norvegicus*, Thunder Bay, urban organic waste

Landfilling is the most common municipal solid and urban organic waste disposal method in North America and comes with numerous negative environmental side effects. Encouraging greater participation in community composting could help to minimize or mitigate these effects while also improving social and economic conditions within communities. However, there is still relatively low participation in the practice and apprehension of urban pests may be a significant contributing factor.

In Thunder Bay, ON, the Norway rat (*Rattus norvegicus*) is a common pest that may be contributing to the community's hesitancy to embrace household composting as an alternative waste management strategy. To determine if composting is associated with rat presence and if apprehension of rats is a significant deterrent to household composting within the city, residents of Thunder Bay's urban neighbourhoods were asked to participate in a survey examining their waste disposal habits and subsequent experience with rats.

The survey found that there was no relationship between composting frequency and rat abundance. A significant number of non-composting residents associated their decision not to compost with the fear of attracting rats to their property. Despite these fears, participants that were not composting more frequently experienced rats on or around their property than those who were composting. Other contributing factors to the relatively low numbers of urbanites composting were a lack of education on how to compost properly and a lack of accessibility to composting services for those with too little time or little desire to compost out of their own homes.

ACKNOWLEDGEMENTS

I could not have undertaken this project without the guidance of Dr. Brian McLaren who acted as my supervisor and provided me with invaluable advice along the way. This project also would not have been possible without all the Thunder Bay residents who agreed to participate in the study. I am also extremely grateful to Clayton Temple, who accompanied me during the survey effort. This project would not have been nearly as enjoyable without you. Lastly, special thanks to Martha Dowsley for agreeing to be my second reader. I appreciate you all.

CONTENTS

TABLES

FIGURES

INTRODUCTION

Despite the numerous negatives associated with the practice, landfilling is the most common method of municipal solid waste (MSW) and urban organic waste disposal (UOW) in North America (Adhikari et al. 2010). Landfills are a potent source of anthropogenically produced methane (Höglund-Isaksson 2012; Karanjekar et al. 2015), require ample land area to operate (Omar and Rohani 2015), and pose water contamination risks when mismanaged (Adhikari et al. 2010; City of Thunder Bay 2021). Embracing household composting on a community-wide scale could largely reduce or mitigate these effects (Gonwala and Jardosh 2018) while also having numerous positive outcomes on the local environment and the economy (Andersson 2012; Karanjekar et al. 2015). However, Thunder Bay, Ontario is lagging behind on the composting curve, and apprehension of urban pests may be the explanation.

The Norway rat (*Rattus norvegicus*) is a common pest in Thunder Bay (City of Thunder Bay 2018). Urban rats are typically viewed with disdain by city residents for their notoriety as vectors of various pathogens, their penchant for damaging urban infrastructure, and their skill at entering, eating, and contaminating food in residential areas (Parsons et al. 2017). These activities make them dangerous to the health of urbanites, as well as thorns in the side of local economies, which suffer significant financial losses due to the food loss and property damages induced by their foraging and nesting (Byers et al. 2019).

The urban pest control methods currently in place to prevent these eventualities are often reactive and small-scale, as opposed to proactively integrated on a large scale (Lowe et al. 2019). One of the more prolific methods is pesticides, as they are cheap, easy to implement and provide effective short-term results. However, using rodenticides to control rat populations can be problematic for many reasons. For one, predators that ingest poisoned rats may receive secondary poisoning, resulting in the unnecessary death of other urban wildlife and pets (Smith and Shore 2015). Among the predators that most frequently experience this phenomenon are birds. The anatomy of birds introduces unique and exacerbated risks to the wider environment, as birds can travel vast distances before death compared to other afflicted animals, and therefore increase the range wherein animals are at risk of being exposed to the poison and subsequently killed. Moreover, rodenticide is a short-term solution at best. Traditional methods of integrated pest management, such as traps and rodenticides, have proven largely ineffective in the long-term control of rats in urban communities (Parsons et al. 2017). The effectiveness of these traditional methods is likely to fall even shorter as the rate of urbanization continues to increase and climate change looms.

Thunder Bay is particularly at risk as it resides in the more northern latitudes of the province at the fringes of the boreal forest--a region anticipated to experience some of the most pronounced changes in ecosystem norms due to climate change (Sipari et al. 2021). Among those anticipated changes are shorter winters and a longer growing season (Mellander et al. 2007), which could encourage greater survivability of zoonotic pathogens in northern climes where they were once severely limited in distribution (Sipari et al. 2021). Furthermore, as populations grow and more people move into cities, more abundant food and shelter resources will become available to urban pests like rats, the vectors of these infectious organisms.

Food access to urban pests, including rats, can be limited by more effective means of managing UOW that will also limit their populations. Composting presents an opportunity, but fear over whether the practice acts as more of an attractant than a deterrent to rats may be preventing householders from taking up composting. To understand how the apprehension of rats among Thunder Bay's urbanites might be impacting the uptake of composting in the community, and to determine whether there is any merit to the belief that composting is an attractant to rats, this study will investigate the waste disposal strategies practiced by residents. The study works on the premises that 1) If there is a trend in the waste management strategy practised by households in a given neighbourhood within the city, then the frequency of rats reported in the area will reflect it, and 2) if there is a predominantly negative perception of composting as an attractant to rats, then there will be a low frequency of households composting.

There are many false perceptions of the Norway rat that are unfounded in science. These misconceptions have inhibited successful long-term control of rat populations by encouraging reactive, short-term solutions fueled by fear. There are ways to effectively mitigate the Norway rat pest problem by adjusting our waste management strategies in urban areas. To better understand how household waste disposal in cities impacts rat frequency in residential areas, I will identify an association between household waste management strategy and trends in rat prevalence in Thunder Bay. To identify whether apprehension of attracting rats is a significant deterrent to residential composting, I will determine if the perception of composting as an attractant of rats has impacted the uptake of the practice in the city. This study will aid residents of Thunder Bay by informing them of the waste management techniques known to encourage the presence of rats around their homes. Informing the public of these trends in rat frequency as influenced by waste disposal strategy will prove more effective in controlling rat prevalence in the city than other, more traditional prevention measures.

LITERATURE REVIEW

1. NATURAL HISTORY OF THE NORWAY RAT

Despite the implications of its name, the brown rat or Norway rat (*Rattus norvegicus*) originated in Asia and then immigrated to European countries via Russia (Modlinska and Pisula 2020). The species belongs to the order Rodentia, whose root is derived from the Latin word *rodere*, meaning “to gnaw” (Frohlich 2020). It is one of 60 species belonging to the genus *Rattus*, a genus identified in the fossil record about 40 million years ago when the group diverged from the mice genus (*Mus*) (Modlinska and Pisula 2020).

Archaeological evidence suggests that small populations of the species existed in England as early as the 14th century (Clark et al. 1989 as cited by Modlinksa and Pisula 2020), but before this was known the commonly held belief is that the species was introduced to the country from Norway by ship during the 18th century. It was during this period that the species established itself as an international pest by stowing away on steerage and merchant vessels for the voyage across the Atlantic Ocean to North America and other destinations (Bourne 1998). The exact arrival of the Norway rat in North America was between 1750 and 1775 and it has flourished on this continent ever since (Modlinska and Pisula 2020).

2. CHARACTERISTICS OF THE NORWAY RAT

2.1 Physiological Characteristics

The Norway rat is a burrowing rodent with coarse fur ranging in colour from purely brown or black to reddish-grey above and whitish-grey below (Timm 1994). Newborns, called ‘pups’, are hairless and cannot open their eyes but quickly grow out of this stage, reaching full maturity in just three months. Once adults, the average individual will weigh about 450g, with males usually larger than females.

The burrowing behaviour of these rodents is partially motivated by their lack of sweat glands, as their inability to self-regulate body temperature requires them to burrow underground in hot conditions (Modlinska and Pisula 2020). While performing physical activity, they are predominantly quadrupedal and move on four limbs when walking and running; however, their abilities also extend to jumping, climbing, swimming, and diving. As a primarily nocturnal species, the Norway rat relies very little on its eyesight, and with good reason. Compared to its other senses, the Norway rat's vision is very poor. Its eyes are quite sensitive to light and are only capable of seeing in dichromatic colour. Individuals of this species generally avoid brightly lit, open spaces. Instead, they rely heavily on their sense of touch, smell, and taste (Timm 1994). One of their most effective mechanisms of touch is through their whiskers, which they employ similarly to the way a blind person employs a walking stick. The whiskers of a rat are more vital to its understanding of the physical environment than its eyes (Modlinska and Pisula 2020). These sensory appendages touch the walls of the spaces they traverse so they can navigate in low-light conditions, a tendency that contributes to their preference for confined spaces over open ones. Another sense that the Norway rat relies on quite heavily is their hearing. Individuals can hear sounds between 0.25 and 80 kHz. This ability allows them to communicate via ultrasound at frequencies that are inaudible to the comparatively inept human ear.

2.2 Habitat Selection

Wild Norway rats are often highly affiliated with human settlements and usually live in the immediate vicinity of their human counterparts (Modlinska and Pisula 2020). Their habitats are irregularly distributed within cityscapes and their urban range size can be quite small compared to that of their more rural counterparts. In general, they prefer areas with ample vegetation close to a source of water and are regularly found sheltering in urban structures such as old buildings or sewer systems. The Norway rat uses its proficiency at burrowing to build extensive below-ground tunnels where they nest and breed, though they have also been known to construct nests at ground level (Timm 1994). The rodents scavenge materials such as shredded paper, cloth, or other fibrous materials to line their nests and insulate them. The below-ground nature of their nests provides protection from predators, such as birds of prey, which are considered rodent specialists (Brudzynski and Fletcher 2010). The size of home ranges typically occupied by this species still remains largely understudied and many assumptions are made about the true area occupied by individual rats within their home range because of a lack of understanding about their spatial ecology within urban environments (Byers et al. 2019). Further research is required on Norway rat individual behaviours and the factors influencing them.

2.3 Foraging Behaviour

The Norway rat has a generalist, omnivorous diet and a somewhat inaccurate reputation for eating just about anything (Modlinska and Pisula 2020). Despite commonly held beliefs, the Norway rat exhibits food neophobia, which is a hesitancy to ingest new or unknown foods. This phobia is part of the reason why rodenticides often fail to control rat abundance. Rats will develop an aversion to food that causes adverse effects within six hours of consumption, and the other rats, seeing the effects and identifying the source by the smell of their companion, will adopt this aversion as well. While foraging, rats typically stay within their home range and rarely travel more than 100 m from their burrows for food or water (Timm 1994). On average, all their daily activities occur within an area averaging 9-14 m^2; however, this number does not consider how individuals' habitat use differs by demographic or other factors, such as the time of year (Byers et al 2019). It may be an underestimation of the true area they typically traverse.

2.4 Reproductive Behaviour

The Norway rat has a notoriously fast reproductive rate. Breeding typically peaks in the spring and fall and slows down in the summer. It may come to an outright halt in the winter months, depending on the severity of the climate (Timm 1994). Females go into heat approximately every 4-5 days, bearing litters averaging 6-12 pups just 21-23 days post-conception. Females are able to mate again as quickly as 1-2 days after giving birth. Newborns become completely independent at about four weeks and reach reproductive maturity at three months.

2.5 Social Behaviour

Norway rats are very social creatures, living in groups and forming social connections and bonds resembling those practiced by humans. Their colonies can be composed of hundreds of individuals, each belonging to their own small, territorial groups, called "families" (Modlinska and Pisula 2020). These families live within separate territories, distinguished by members of the wider community by scent, and are typically composed of one adult male, bonded females, and their young. Males defend the broader territory while females protect their nests and young against intruders, with aggression peaking in the post-partum period. Juveniles learn to attack and defend by engaging in play fighting.

Rats in the same family or group will groom one another, sleep in tight groups, and huddle together (Modlinska and Pisula 2020). These behaviours are an important part of inter-group communication as, during these times, rats will develop preferences or aversions for certain foods by sniffing at the mouth and fur of another rat that has just finished eating. Their keen sense of smell also comes into play when deciding whether to accept new individuals into their territory, as rats rely on their sense of smell to determine the sex, age, reproductive status, health, and nutrition of unknown rats.

3. RISKS ASSOCIATED WITH THE NORWAY RAT

There are many risks associated with rats related to their impact on humans. Though they are fastidiously clean animals that engage in frequent grooming, they still have a penchant to become vectors of harmful diseases (Modlinska and Pisula 2020). Bacterial infections carried by rats can be spread directly through bites, or indirectly through contact with their urine, and other harmful bacteria can be spread through other rat-associated organisms, such as fleas (Himsworth et al. 2013). These bacteria can be antimicrobial-resistant and infect humans and various other animals. Examples include Weil's disease (*Leptospira interrogans*), Flea-borne typhus (*Rickettsia typhi*), Bubonic Plague (*Yersinia pestis*), Rat-bite fever (*Streptobacillus moniliformis*), and Seoul Hantavirus. Symptoms of these bacterial infections range from mild fever, rashes, and enlarged lymph nodes to renal failure, jaundice, pulmonary hemorrhaging (bleeding in the lungs), and a range of other potentially life-threatening ailments.

The risks associated with rats also extend to non-point source pollution affiliated with the common pest control methods in place to reduce their populations (Modlinska and Pisula 2020). The use of toxicants such as rodenticides, in particular, poses an intoxication risk to other animals, including protected species, pets, and humans; the toxicants end up accumulating in the food chain (Parsons et al. 2017), resulting in reluctance towards and advocation against the use of rodenticides among animal-loving members of the public. There are also financial and economic risks associated with the species. Rodents are known to infiltrate food stores, spoiling large quantities of food resources intended for human consumption (Byers et al. 2019). As a result, a substantial amount of food is wasted annually due to contamination. As of 1982, commensal rodents cost the global economy $300 billion USD in food losses alone (Stenseth et al. 2003 as cited by Parsons et al. 2017). Adjusted for inflation, that would be approximately $920 billion USD today (Alioth Finance 2023); only a portion of the total costs. The implementation of rat control procedures, mitigation strategies, and repairs to infrastructure contribute additional expenses to the overall cost of food contamination by rats (Byers et al. 2019), not to mention avoidable costs of associated activities such as food transportation, or the ecological strain that such waste places on agricultural lands already being pillaged to meet the demands of mass food production (Thompson 2023).

4. RAT CONTROL AND PREVENTION

Effective rat control and prevention is an objective impeded by boundaries that exist in social, economic, and environmental domains. One of the most prominent boundaries to effective rat control and prevention is the lack of ecological knowledge of rats living in urban areas (Parsons et. al. 2017). Though the species is a notorious model organism in laboratory settings (Modlinska and Pisula 2020), these studies are almost entirely restricted to lab specimens (Parsons et al. 2017) and there has been almost no research done on their individual behaviours or their variance in response to factors such as age, sex, population density, season, and environmental variability within urban settings (Byers et al. 2019).

The public's perception of rats acts as a barrier to overcoming these knowledge gaps. This stems from general misinformation about rats perpetuated by public perception of the group (Parsons et al. 2017). A lot of what is considered 'common knowledge' about rats stems from interactions that humans have had with members of the rat community. What is often forgotten is that rats that are willing to interact with humans are often the boldest or most desperate members of the community and they exhibit behaviour that is not characteristic of the majority of individuals, which are predominately risk-averse. The risk-taking individuals are responsible for the majority of humans' collective knowledge about the group, making rats the target of fear and disgust among members of human society.

Their negative reputation often extends to and stains the reputation of those who are found harbouring rats on or around their property, creating an objective within the pest management industry to eradicate rats as quickly as possible (Parsons et al. 2017). This has created a discrepancy in the understanding of ‘successful’ pest management between those in the scientific community and those in the pest management industry. For the homeowner and pest control companies, successful rat control entails the immediate eradication of rats from the property. The methods employed to achieve these objectives are reactive and typically offer only a short-term solution. Conversely, those wishing to uncover long-term solutions to overabundant rat populations require the persistence of rats in areas where they are not wanted so that they can research the population and address the knowledge gaps preventing effective long-term population control.

There are many common, short-term pest control methods in use for controlling rodent populations, including trapping, rodenticide, biological control, reproductive inhibition, and ultrasonic devices (Modlinska and Pisula 2020). A breakthrough in rat control came with the introduction of anticoagulant rodenticides in the mid and late 1900s. However, the use of poison is, in general, an ineffective mode of population control because organisms frequently develop resistance to them, making their populations even more difficult to control in the long run (Traweger et al. 2006). Moreover, rats often exhibit bait shyness or avoidance of traps and bait stations that can last anywhere from a few days to months on end (Timm 1994), further impeding the success of these rat control methods.

The long-term success of rodenticide and trap use is improved by instating pre-baiting practices (Timm 1994). One approach is to train the rat not to fear the bait and/or trap by primarily setting out non-toxic bait and unset traps to establish familiarity with the devices. Once comfort is established, the toxicant can be applied and the traps set. This reduces the likelihood of sub-lethal doses occurring and, by association, bait-shyness from being learned in surviving individuals. It is also recommended that bait stations and traps be placed near, but not on, rat runways.

Preventative control methods are far more successful at controlling rat populations in the long term. One of the most effective and often neglected integrated approaches is rat-proofing, which entails taking measures to prevent damage caused by rats before it can occur (Timm 1994). For example, using heavy materials that are resistant to gnawing, such as concrete, sheet metal, heavy gauge hardware cloth, or high-density polyethylene to seal access holes leading into the home or waste containers. Proper sanitation, which includes good housekeeping concerning the storage and handling of food materials, animal feed and waste, and garbage is another important and often neglected aspect of rodent prevention and control. In fact, the lack of proper sanitation is one of the most basic reasons for the continued existence of moderate to high rat populations in urban areas.

A related method of rat control is through effective landscaping. Effective planning of a backyard landscape layout can limit access to resources needed by rats so that areas no longer provide the ideal circumstances for their prolonged presence (Colvin et al. 1996). For example, rat burrows in urban areas are more often associated with needled evergreen trees than broad-leaf evergreen or deciduous plants. To prevent rat presence, homeowners can opt for broad-leaf trees rather than evergreens. Other factors, such as dense, contiguous shrubbery, poor plant maintenance, shrubbery touching walls, the presence of litter or food, and open refuse containers have all been associated with the presence of rats.

Although there is little evidence for an association between stored refuse and rat infestation in urban areas (Colvin et al. 1996), certain characteristics of refuse containers and their placement with respect to other landscape features are influential in limiting rat presence. It is recommended that refuse be stored in containers with a top opening at least 0.8 m above ground level. They should contain no lower openings other than a drainage hole, if necessary. If present, drainage holes should be flashed with sheet metal or screened with hardware cloth to limit accessibility. Additionally, containers should be located at least 1 m away from any shrubbery, walls, or fences that could grant access to rats from above, and be placed on a paved surface rather than soil where possible to restrict access from below. Optimal refuse storage bins are made of a heavy-duty material resistant to rust, punctures, or cracks, and have a domed lid.

Used together, preventative and reactive rat control measures can be quite successful. The province of Alberta, Canada is an excellent example of where these methodologies were used in tandem to counteract rat infestations (Bourne 1998). The province first attacked the problem on the social front by gaining the support of the public. They developed a public relations campaign aimed at educating the public about the Norway rat and how to control their populations. Once the public was on board, large-scale rat prevention and control measures were put into action. From there, the Alberta government used the province's landscape features to aid in eradicating the pests. Natural barriers, such as the Rocky Mountains in the west, the unsettled expanse of short-grass prairie in the south, and the mixed-wood, boreal forest in the north were already major obstacles to the Norway rat's attempts to expand their range (Bourne 1998). As a result, the invading rats were restricted mainly along the eastern border of the province, an area the government named the rat control zone. The rat control zone consisted mainly of abandoned farmland and because of its rural nature, Alberta had the unique opportunity to physically destroy rat colonies with fire, heavy equipment, fumigants, pyrotechnics, and firearms. Such methods may not be feasible or legal elsewhere. However, none of Alberta's success could have been possible without the community support and resolve, which inspired legislation to be instated to allow the use of control methods that, today, would most likely be deemed unacceptable due to their unintended side effects on non-target organisms and the extraneous costs of such an operation.

5. COMPOSTING

Composting is a form of recycling wherein organic matter undergoes biological decomposition to produce a rich, humus-like product (Epstein 2017). It is a predominately microbial process, and as such, is influenced heavily by environmental factors such as oxygenation, temperature, pH, moisture, carbon/nitrogen ratio, and the conditioning of starting materials, in addition to the genetic constitution or life cycles of the involved microorganisms (De Bertoldi et al. 1983). Under ideal conditions, the complete breakdown of organic materials should take about one month. The efficiency of this process can be affected by methodology and physical-chemical parameters. There are two main methods of composting: aerobic and anaerobic (Gonwala and Jardosh 2018). Aerobic composting occurs when biodegradable organic matter decomposes in the presence of oxygen and produces heat, water, carbon dioxide (CO_2), and ammonia (NH_3). It can be used on any type of organic matter but requires a 60-70% moisture content, a carbon-nitrogen ratio of approximately 30:1 and sufficient ventilation to break down matter effectively. Important sources of carbon for this method are paper and woody materials while sewage sludge or food waste can provide nitrogen content.

Although ammonia and carbon dioxide are greenhouse gasses in their own right, their global warming potential is much less significant than methane (CH_4) (Andersen et al. 2010). The CO_2 emitted during composting is usually considered neutral with respect to global warming as it originates from decomposing plant materials, which are constantly renewed in the natural environment and are therefore part of the natural carbon cycle. As for ammonia, most living organisms are not capable of harnessing atmospheric Nitrogen (N_2) directly and thus require the fixation of ammonia in the soil to acquire the vital nutrient (Palashikar et al. 2016). Ammonia volatilization, during which ammonia is converted to a gaseous state, is the major cause of nitrogen loss in compost, which can impact how much plants and other organisms benefit from its addition to the soil. However, ammonia volatilization can be reduced by maintaining a high ratio of C: N and a low mean temperature in composting materials (Palashikar et al. 2016). Other key factors controlling ammonia emission rates are pH, moisture content, and aeration rate. To limit emissions of ammonia further, it is recommended that practices limiting the amount of oxygen in the system should be put in place in later stages of compost development (e.g. compaction or coverage), as increased aeration during this time is directly linked to the increased volatilization of ammonia.

The second method of composting is anaerobic, meaning it occurs in the absence of oxygen (Gonwala and Jardosh 2018). The major products of this method are methane gas (CH_4), carbon dioxide (CO_2), and ammonia (NH_3). The methane produced by anaerobic decomposition makes this method of composting ideal for biogas production, during which the methane is reclaimed for power generation (Adhikari et al. 2010). It has been argued that household composters rarely have large enough piles to produce anaerobic conditions so their methane emissions are negligible (USEPA 1998 and Smith et al. 2001 as cited by Andersen et al. 2010).

While gas recapture is the more popular method of energy generation using UOW, recent research is prompting the exploration of UOW as an alternative biomass fuel (Vasileiadou et al. 2021). This could be a potential or partial solution to the catch-22 situation presented in current biomass sourcing that calls for the growth of crops or deforestation of forest land, simply to burn the harvested biomass. Not only is this a waste of valuable natural resources, but it also removes carbon-sequestering elements from the landscape, calling into question the carbon neutrality of the practice (Zanchi et al. 2012).

Aside from its energy-generating potential, perhaps the most popular application of compost is in agriculture. The application of compost into agricultural soils is a way of maintaining and restoring its quality, mainly through its fertilization properties (Gonwala and Jardosh 2018). Composting can also disinfect pathogen-infected organic wastes or other hazardous wastes so they can be safely reintroduced into the environment or reused for other beneficial purposes (Epstein 2017). The addition of properly produced compost to soil can improve plant growth, aiding in carbon sequestration, and reduce the potential for soil erosion, runoff, and non-source pollution. The quality of compost is assessed according to several criteria, such as moisture, heavy metal, and nutrient content, stability, particle size distribution, pathogen levels, and product consistency over time (Gonwala and Jardosh 2018). Ensuring that compost is of good quality before reintroducing it to the soil is essential for avoiding phytotoxicity risks (Palansooriya et al. 2020 as cited by Vasileiadou et al. 2021). Both commercial farmers and backyard gardeners can learn the techniques required to implement good-quality compost into vegetable production and other crops.

6. WASTE DISPOSAL IN NORTH AMERICAN CITIES

In North America, landfilling is the most common method of municipal solid waste (MSW) and urban organic waste disposal (UOW) (Adhikari et al. 2010). This aligns with global trends stating that 70% of all solid waste is landfilled, though this percentage is closer to 90% in some developing countries (Shi et al. 2021). In 2005 alone, North American countries landfilled nearly 164 million tons of MSW (Adhikari et al. 2010). Of that number, Canada contributed 8.05 million tons, 25% of which was organic waste. Since then, the production of MSW and UOW has increased exponentially as a result of economic growth and urban expansion.

There are more than a few issues with landfilling. For one, landfills require a lot of land area, a natural resource that is swiftly becoming more and more finite (Omar and Rohani 2015). This creates allocation issues when land that could be used productively for enterprises such as the implementation of vital human infrastructure, establishing agricultural grounds, and/or performing industrial operations is instead used to store waste. Considerations for land allocation for landfills in a future where waste outputs continue to grow exponentially have yet to be addressed.

Landfilling also has numerous health implications for humanity and the environment at large. On a global scale, landfills contribute about 15% of anthropogenically produced methane globally (Höglund-Isaksson 2012), making them one of the largest sources of the potent greenhouse gas in the world (Karanjekar et al. 2015). The methane generation potential of a landfill site is directly related to its biodegradable organic waste content. Even more alarming is that in northern latitudes, increases in mean annual temperature promoted by climate change stand to increase methane emissions from these sites even more, as temperature increase is linked to enhanced microbial activity. Another issue arising from the mass amounts of improperly disposed of organic waste in landfills is the generation of leachate (Adhikari et al.

2010), which can contaminate groundwater, and, in extreme cases, escape facilities via surface water seepage and flow directly into free bodies of water (City of Thunder Bay 2021). Not only can this effluent cause harm on an ecological scale, but it is also expensive to treat (Adhikari et al. 2010).

Landfills do serve as repositories of renewable energy sources, however (Karanjekar et al. 2015). Some regions outside of North America have even managed to generate improved social and economic security by embracing large-scale integrated waste disposal strategies. Sweden, for example, has not permitted the landfilling of municipal waste since 2005 (Andersson 2012). Half of all Sweden's municipal waste is incinerated to generate heat and electricity for the region, and, excluding a fraction of a percent, the remaining waste either undergoes biogenic treatment (compost and biogas production) or is recycled. The system is so successful that the country is able to import municipal waste and waste wood from other regions, benefitting their economy and improving the energy security of their region. In Canada, legislation has steadily been introduced to divert waste and reduce greenhouse gas emissions from landfills (Höglund-Isaksson 2012). Though these measures vary by province, some examples include the creation of landfill and emissions mitigation criteria, guidelines for environmental monitoring, introduction of recycling regulations, implementation of bans on the disposal of reusable, recyclable, or biodegradable containers or food products, development of region-specific waste diversion programs, and landfill taxes.

Efforts at local scales are being made, as well. In Thunder Bay, a 3.2-megawatt power generation system has been incorporated into the city's landfilling operation (City of Thunder Bay 2018). The facility reclaims the methane gas produced by the city's UOW by using it as fuel for electrical generation. As a result, the power generation station prevents 263 million cubic feet of methane gas from entering the environment each year and generates enough electricity to power 2000 houses.

MATERIALS AND METHODS

Residents living in households situated within Thunder Bay's urban limits were asked to voluntarily and anonymously participate in this study. Households considered for the study (Fig.1) will be chosen according to their presence in areas that have been designated as high, medium, or low rat frequency areas within Thunder Bay. The rat frequency information aiding in neighbourhood selection was informed by citizen-reported rat sightings data shared by the Thunder Bay District Health Unit (Thunder Bay District Health Unit 2017).

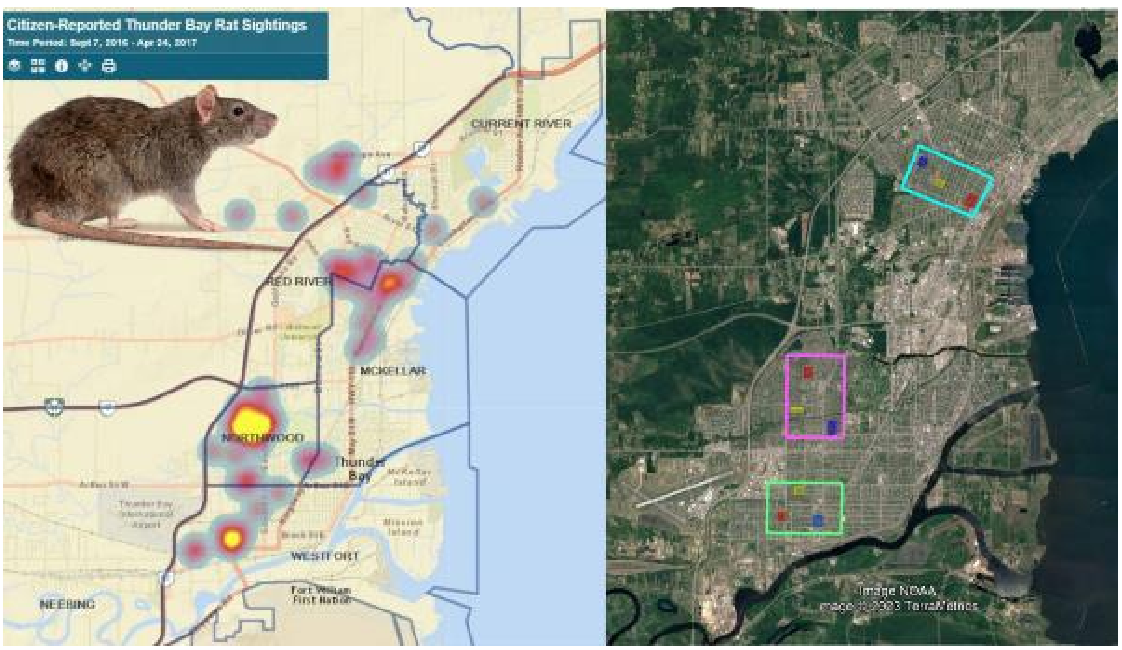

Figure 1. Citizen-Reported Thunder Bay rat sightings (TBDHU 2017) and correlated study areas (Google Earth Pro 2022).

Three neighbourhoods from each study area, located in Westfort, Northwood, and Red River, respectively, were selected for the research, during which time residents were asked a series of questions approved by the Undergraduate Research Ethics Committee of the Faculty of Natural Resources Management as of January 17, 2023. The questions consider their waste disposal strategy (composting vs. curbside pick-up), their rationale for choosing not to compost when this was the case, whether they have had any issues with rats on or around their property, and any preventative measures taken as a result. Their responses answer the two research questions posed by the study: Has the public perception of rats impacted the uptake of household composting in the city? And is there any merit to the belief that composting will attract rats to one's property? Households not wishing to participate were passed over until ten households had been surveyed. A total of 90 households were interviewed (30 households from each study area).

The significance of the abundance of households composting on rat frequency and household experiences with rats were gauged using the chi-squared Test of Independence. Whether the perception of rats by residents has impacted the uptake of composting in the community was judged by determining the dominant rationale behind participants' decision not to compost.

RESULTS

Out of the 90 households interviewed, 30% were composting. The majority of the households composting live in moderate rat frequency areas, with the second highest abundance of households composting in high rat frequency areas, and the lowest abundance of households composting in low rat frequency areas (relationship not significant, chi-squared = 2.95, $p = 0.05$). However, less than a third of the 27 households composting actually had experience with rats being on or around their property. Of those eight, five were situated in high rat frequency areas and three were situated in moderate rat frequency areas. By comparison, 49% of the participating households not composting had experience with rats being on or around their property (relationship not significant, chi-squared = 2.86, $p = 0.05$). The majority of those households were in high rat frequency areas and the minority were in low rat frequency areas (Table 1). The most common reason for not composting was the apprehension of attracting rats. Other popular responses were that households did not know or had not considered composting before, that they had no time to compost, or that they found it easier not to compost (Table 2).

Table 1. The number of households composting and not composting by rat frequency zone and their experience with rats on or around their property.

Rat frequency	Composting	Not composting	Rat experience on/around property	Rat experience and compost
Low	6	24	7	0
Moderate	12	18	11	3
High	9	21	21	5
Total	27	63	39	8

Table 2. The number of households subscribing to each rationale for not composting. [1]

Reasons	Totals
Don't want to attract rats	15
Don't know/never considered	9
No time	8
Easier not to	8
Don't know how	7
No reason to (don't garden)	6
Not enough waste to compost	6
Don't own a composter	6
Don't want to attract animals	2
Not around in the summer	2
Not time effective	2
Odour concerns	1
No space	1
No city composting program	1
Not aesthetically pleasing	1

Of the 39 households that had experience with rats being on or around their property, 29 felt the need to take preventative measures, and one participant who had no experience with rats had pre-emptive measures against rats in place on their property (Table 3). The most popular rat prevention measure by far was setting traps, followed by the use of rodenticide and storing waste

[1] The total number of responses does not equal the number of households not composting, as some participants gave multiple reasons.

inside until the day of garbage pickup. Rodenticide, getting a cat, and improving sanitation were the most successful rat prevention measures after setting traps, but are practiced far less frequently.

Table 3. The number of households subscribing to each rat prevention measure and their levels of success.

Preventative Measures	Households using method	Total Successes
Set traps	18	12
Rodenticide	3	3
Got a cat	2	2
Sanitation	2	2
Let cat outside	1	1
Changed compost container	1	1
Got rid of composter	2	1
Sealed base of composter	2	1
Store waste inside	3	1
Removed bird feeders	2	0
Sonar deterrent	1	0
Got secure lids for garbage containers	1	0
Quit gardening	1	0
Got metal garbage cans	1	0
Filled holes in yard	1	0
Added gravel to yard	1	0

DISCUSSION

There are many false perceptions about rats that have fueled their fear-inducing reputation (Parsons et al. 2017). Most are exaggerated truths fueled by encounters with the most desperate or risk-taking individuals, and others, like the belief that rats have gelatinous or collapsible skeletons, are outright urban legends. The majority of participants in the Thunder Bay study only experienced sightings of the rodents and only a few had extensive damage done to their property either by the rodents themselves or through the methods it took to eradicate them. However, the dominant rationale for not composting among participants was the apprehension of rats. Only two participants cited apprehension of attracting any animals as their reason for not composting. This trend in reasoning shows the inordinately negative perception that people have of rats. Many other animals commonly found in cities pose a similar risk to human infrastructure, health, and economy, but few are held in such negative regard as rats.

In total, approximately 40% of participating households had experience with rats on or around their property, the vast majority not composting. Moreover, most of the people composting were situated in moderate rat frequency areas of Thunder Bay. If composting were the main attractant of rats, there would have been a higher number of people composting in areas of high rat sighting frequency. Although access to food is a contributing factor to rat presence in certain areas, it only skims the surface of what is controlling rat population levels throughout the city. It is possible that prey-predator dynamics are a contributing factor to the distribution of rats throughout the city (Mohd and Noorani 2021). For example, in one moderate rat abundance neighbourhood, many of the participants noted that although they had previous experience with rats being on or around their property, a fox had moved into the area a few years prior and the issue largely disappeared. In another instance, a participant who had taken to keeping their cat indoors let their pet outside again when rats became an issue around their property and again, the issue largely disappeared. Although it is not recommended to allow cats outdoors, understanding how other urban predators, like foxes, are distributed throughout the city could give more insight into where rat populations are more likely to establish. There are also numerous other potential drivers of rat abundance and distribution that have yet to be examined, such as the socioeconomic status of neighbourhoods and the presence of illegal livestock within city limits (ex. chickens). Areas with lower socioeconomic status may contribute to rat abundance by providing more habitat for their populations in the form of old or abandoned buildings (Tamayo-Uria et al. 2014); Domestic dogs may act as a deterrent if they are aggressive towards the pest, or an attractant if their feces are not regularly removed from the yard (Timm 1994); and the feed and feces of chicken may entice rats to areas where they are present.

A shortcoming of this study is that it does not consider the temporal aspect of rat abundance or even rat presence very well due to the limited information available. On more than one occasion, participants relayed that they had had experience with rats in the past, but had not for some time, indicating that the citizen-reported rat sightings map may no longer be accurate to current trends in rat abundance. Since rat abundance is such an issue, their presence in the city is something that should be continuously monitored. Their presence or absence can indicate favourable or unfavourable conditions in the urban environment and inform pest management professionals about what those conditions are and where management action needs to be taken to better prevent their populations from increasing exponentially in the future

The lack of rat abundance data over time also makes it difficult to tell which preventative methods are the most effective. Traps were the most frequently implemented, but only worked two out of three times, whereas other methods, such as rodenticides, getting a cat, improving sanitation/cleanliness, letting the cat outdoors and changing the compost container, though infrequently implemented, were successful each time. Two participant households in this study eliminated their composter and three others altered their compost container, either by sealing the base or changing the container altogether, to address a perceived rat problem. Removal of the composter was successful on one of the two occasions, whereas altering the container was successful two out of three times, demonstrating that altering a compost container can be just as effective, or even more effective, than removing the composter altogether. Although composting alone will not attract rats, improper waste management and poor sanitation will. Some participating households said they had tried composting in the past but gave it up because they did not know how to do it properly or efficiently. Others would freeze their food waste and bring it to someone who they knew composted because they did not know how to do it themselves or didn't want a composter on their property. It is not feasible to educate the entire population on how to compost properly and many residents also do not have the space or time to do so. To make composting a reality for the broader population, it is, therefore, essential to make it accessible through incentives such as community composting centers or city collections. Giving people the correct knowledge and experience will lower the risk of problems associated with composting.

Moreover, having broad scale collections of our city's organic waste increases its potential usefulness. Although Thunder Bay already has a methane-recapture system in place at the landfill (City of Thunder Bay 2018), a facility specifically used for organic waste would make it possible to capitalize on the physical products of that waste, such as fertilizer sales and biofuel production. In combination with methane recapture, UOW can be burned as biomass to generate electricity (Vasileiadou et al. 2021). This action could also relieve or mitigate stress put on natural systems through biomass production when crops are grown or trees are harvested simply to burn them for power generation. It also allows those green components of the environment to remain and sequester the carbon from the burned biomass, creating a truly carbon-neutral system, an aspect of conventional biomass systems which is hotly contested (Zanchi et al. 2012).

CONCLUSION

There is no association between composting and rats in Thunder Bay's urban landscape. Nevertheless, fear of attracting rats to one's property was the dominant rationale for not composting and, overall, there was a markedly lower proportion of those composting relative to households subscribing to conventional waste management strategies. More education is needed to make safe, long-term, and effective rat control a reality for Thunder Bay residents. This study has ruled out composting frequency in areas of high rat abundance as a main factor in explaining rat distribution, but that does little to determine other drivers of their presence or absence, which are essential to know if successful rat control is to be attained throughout the city in the future. Moreover, allowing apprehension of rats to inhibit the broad scale adoption of composting by Thunder Bay residents impedes opportunities to control urban pest populations, embrace green energy alternatives, increase the energy security of Thunder Bay, and aid economic growth in the region.

LITERATURE CITED

Adhikari, B.K., A. Trémier, J. Martinez, S. Barrington. 2010. Home and community composting for on-site treatment of urban organic waste: Perspective for Europe and Canada. Waste Management & Research. 28(11):1039-1053.

Alioth Finance. 2023. "$300,000,000,000 in 1982 → 2023 | Inflation Calculator." Official Inflation Data. https://www.officialdata.org/us/inflation/1982?amount=300000000000. March 6, 2023.

Andersen, J. K., A. Boldrin, T.H. Christensen, & C. Scheutz. 2010. Greenhouse gas emissions from home composting of organic household waste. Waste Management. 30(12): 2475-2482.

Andersson, K. 2012. Bioenergy: The Swedish Experience. Stockholm: Swedish Bioenergy Association (Svebio). 92 pp.

Bourne, J. B. 1998. Norway rat exclusion in Alberta. Proceedings of the Vertebrate Pest Conference. 18(18): 242-246.

Brudzynski, S. M., & N.H. Fletcher. 2010. Rat ultrasonic vocalization: short-range communication. In Handbook of Behavioral Neuroscience. 19: 69-76).

Byers, K. A., M.J. Lee, D.M. Patrick, & C.G. Himsworth. 2019. Rats about town: a systematic review of rat movement in urban ecosystems. Frontiers in Ecology and Evolution. 7(13).

City of Thunder Bay. 2018. Rat Control and Prevention. https://www.thunderbay.ca/en/city-services/rat-control-and-prevention.aspx#Steps-to-control-rat. October 18, 2022.

City of Thunder Bay. 2021. Solid Waste Management Facility – Leachate Treatment Project – Municipal Class Environmental Assessment – Schedule B Project File Report. KGS Group. 251 pp.

Clark, G., L. Costantini, A. Finetti, J. Giorgi, A. Jones, D. Reese, S. Sutherland, & D. Whitehouse. 1989. The food refuse of an affluent urban household in the late fourteenth century: Faunal and botanical remains from the Palazzo Vitelleschi, Tarquinia (Viterbo). Papers of the British School at Rome. 57: 200-321.

Colvin, B. A., R. Degregorio, & C. Fleetwood. 1996. Norway rat infestation of urban landscaping and preventative design criteria. 165-171.

De Bertoldi, M. D., G. Vallini, & A. Pera. 1983. The biology of composting: a review. Waste Management & Research. 1(2): 157-176.

Epstein, E. 2017. The Science of Composting. CRC Press, Florida. 483 pp.

Frohlich, J. 2020. Rats and mice. Ferrets, rabbits, and rodents. 345-367.

Google Earth Pro. 2022. Rat survey study areas in Thunder Bay, ON.

Gonawala, S. S., & H. Jardosh. 2018. Organic Waste in Composting: A brief review. International Journal of Current Engineering and Technology/ 8(1): 36-38.

Himsworth, C. G., K.L. Parsons, C. Jardine, & D.M. Patrick. 2013. Rats, cities, people, and pathogens: a systematic review and narrative synthesis of literature regarding the ecology of rat-associated zoonoses in urban centers. Vector-Borne and Zoonotic Diseases. 13(6): 349-359.

Höglund-Isaksson, L. 2012. Global anthropogenic methane emissions 2005–2030: technical mitigation potentials and costs. Atmospheric Chemistry and Physics. 12(19): 9079-9096.

Karanjekar, R. V., A. Bhatt, S. Altouqui, N. Jangikhatoonabad, V. Durai, M.L. Sattler, S. Hossain, & V. Chen. 2015. Estimating methane emissions from landfills based on rainfall, ambient temperature, and waste composition: The CLEEN model. Waste Management. 46: 389-398.

Lowe, E. C., T. Latty, C.E. Webb, M.E.A. Whitehouse, & M.E. Saunders. 2019. Engaging urban stakeholders in the sustainable management of arthropod pests. Journal of Pest Science. 92: 987-1002.

Mellander, P. E., M.O. Löfvenius, & H. Laudon. 2007. Climate change impact on snow and soil temperature in boreal Scots pine stands. Climatic Change. 85(1): 179-193.

Modlinska, K. and W. Pisula. 2020. The Natural History of Model Organisms: The Norway rat, from an obnoxious pest to a laboratory pet. eLife. 9:e5065.

Mohd, M. H. and M.S. Noorani. 2021. Local dispersal, trophic interactions and handling times mediate contrasting effects in prey-predator dynamics. Chaos, Solitons & Fractals. 142, 110497.

Omar, H., & S. Rohani. 2015. Treatment of landfill waste, leachate and landfill gas: A review. Frontiers of Chemical Science and Engineering. 9: 15-32.

Palansooriya, K. N., S.M. Shaheen, S.S. Chen, D.C. Tsang, Y. Hashimoto, D. Hou, N.S. Bolan, J. Rinklebe, & Y.S. Ok. 2020. Soil amendments for immobilization of potentially toxic elements in contaminated soils: A critical review. Environment international. 134: 105046.

Palashikar, G., A. Ranade, & S. Veerappapillai. 2016. A brief review on emission of gaseous ammonia from composting of various waste materials. International Journal of Pharmaceutical Sciences Review and Research. 38: 97-101.

Parsons, M. H., P.B. Banks, M.A. Deutsch, R.F. Corrigan, & J. Munshi-South. 2017. Trends in urban rat ecology: a framework to define the prevailing knowledge gaps and incentives for academia, pest management professionals (PMPs) and public health agencies to participate. Journal of Urban Ecology. 3(1): 1-8.

Shi, L., H. Chen, H. Meng, R. Cheng, J. Dai, X. Zheng, & Z. Zhang. 2021. How environmental policy impacts technology adoption: A case of landfill leachate. Journal of Cleaner Production. 310: 127484.

Sipari, S., H. Khalil, M. Magnusson, M. Evander, B. Hörnfeldt, & F. Ecke. 2022. Climate change accelerates winter transmission of a zoonotic pathogen. Ambio. 51(3): 508-517.

Smith, A., K. Brown, S. Ogilvie, K. Rushton, & J. Bates. 2001. Waste management options and climate change: Final Report. European Commission, DG Environment. 137-150.

Smith, R. H. & R.F. Shore. 2015. Environmental impacts of rodenticides. In Rodent pests and their control.Wallingford UK: CABI. 330-345.

Stenseth, N.C., H. Leirs, H., S. Mercelis, & P. Mwanjabe. 2001. Comparing Strategies for Controlling an African Pest Rodent: An Empirically Based Theoretical Study. Journal of Applied Ecology. 38:1020–1031

Tamayo-Uria, I., J. Mateu, F. Escobar, & L. Mughini-Gras. 2014. Risk factors and spatial distribution of urban rat infestations. Journal of Pest Science. 87: 107-115.

Thompson, J. A. M. 2023. Environmental and Social Impacts of Agricultural Biodiversity Degradation from the Ultra-Processed Food Industry. InterNaciones. (24): 141-164.

Thunder Bay District Health Unit. 2017. Citizen-Reported Thunder Bay Rat Sighting. Facebook. https://www.facebook.com/TBDHealthUnit/posts/thunder-bay-citizens-have-been-reporting-an-increase-in-rat-activity-lately-http/1323779127703353/. November 20, 2022.

Timm, R. M. 1994. Norway Rats. The Handbook: Prevention and Control of Wildlife Damage. 5:105-120.

Traweger, D., R. Travnitzky, C. Moser, C. Walzer, & G. Bernatzky. 2006. Habitat preferences and distribution of the brown rat (Rattus norvegicus Berk.) in the city of Salzburg (Austria): implications for an urban rat management. Journal of Pest Science. 79: 113-125.

USEPA. 1998. Greenhouse gas emissions from management of selected materials in municipal solid waste. Final Report Prepared for the US Environmental Protection Agency (USEPA) under EPA Contract No. 68-W6-0029.

Vasileiadou, A., S. Zoras, & A. Iordanidis. 2021. Biofuel potential of compost-like output from municipal solid waste: Multiple analyses of its seasonal variation and blends with lignite. Energy. 236: 121457.

Zanchi, G., N. Pena, & N. Bird. 2012. Is woody bioenergy carbon neutral? A comparative assessment of emissions from consumption of woody bioenergy and fossil fuel. Gcb Bioenergy. 4(6): 761-7

APPENDIX

Table A1. Survey responses from the low rat abundance neighbourhood in the Westfort study area.

Household #	Do you compost?	If not, why?	Have you had experience with rats being on/around your property?	Did you take preventative measures thereafter?	What measures were those?	Were they Successful?	May I take a picture of your composter?
1	No	Odour concern from neighbours	Yes	No	N/A	N/A	N/A
2	No	Don't want to attract rats	Yes	Yes	Stored waste inside	Yes	N/A
3	No	Don't want to attract rats	Yes	Yes	Traps; Got a cat	Yes	N/A
4	No	Don't know how; No space; Don't know/Hadn't considered	No	N/A	N/A	N/A	N/A
5	No	No reason (don't garden); Don't want to attract rats	No	N/A	N/A	N/A	N/A
6	No	Don't know/hadn't considered	Yes	No	N/A	N/A	N/A
7	No	Don't want to attract rats	No	N/A	N/A	N/A	N/A
8	No	No city composting program	No	N/A	N/A	N/A	N/A
9	No	Not enough waste to compost	No	N/A	N/A	N/A	N/A
10	Yes	N/A	No	N/A	N/A	N/A	No

Table A2. Survey responses from the moderate rat abundance neighbourhood in the Westfort study area.

Household #	Do you compost?	If not, why?	Have you had experience with rats being on/around your property?	Did you take preventative measures thereafter?	What measures were those?	Were they Successful?	May I take a picture of your composter?
1	No	No reason to (no gardens); Don't know how	No	N/A	N/A	N/A	N/A
2	Yes	N/A	No	N/A	N/A	N/A	Yes
3	Yes	N/A	No	N/A	N/A	N/A	Yes
4	Yes	N/A	No	N/A	N/A	N/A	Yes
5	No	Easier not to	Yes	Yes	Traps: Sanitation	Yes	N/A
6	No	Don't want to attract rats	No	N/A	N/A	N/A	N/A
7	Yes	N/A	No	N/A	N/A	N/A	Yes
8	No	Easier not to; Don't know how	No	N/A	N/A	N/A	N/A
9	No	Don't know/Hadn't considered; Not enough waste to compost	No	N/A	N/A	N/A	N/A
10	Yes	N/A	Yes	Yes	Traps	No	Yes

Table A3. Survey responses from the high rat abundance neighbourhood in the Westfort study area

Household #	Do you compost?	If not, why?	Have you had experience with rats being on/around your property?	Did you take preventative measures thereafter?	What measures were those?	Were they Successful?	May I take a picture of your composter?
1	No	Easier not to	Yes	Yes	Traps	No	N/A
2	No	Don't know how	Yes	No	N/A	N/A	N/A
3	No	Don't want to attract rats	Yes	No	N/A	N/A	N/A
4	No (used to)	Don't want to attract rats	Yes	Yes	Traps	No	N/A
5	No	Don't want to attract rats	Yes	Yes	Got a cat; Traps	Yes	N/A
6	No (considering)	No time; Don't want to attract rats	Yes	No	N/A	N/A	N/A
7	No	No reason (no garden)	Yes	Yes	Traps	Yes	N/A
8	No	No time; Easier not to	Yes	Yes	Let cat outdoors	Yes	N/A
9	No (considering)	No composter	No	N/A	N/A	N/A	N/A
10	Yes	N/A	Yes	Yes	Traps	Yes	Yes

Table A4. Survey responses from the low rat abundance neighbourhood in the Northwood study area.

Household #	Do you compost?	If not, why?	Have you had experience with rats being on/around your property?	Did you take preventative measures thereafter?	What measures were those?	Were they Successful?	May I take a picture of your composter?
1	No	Don't want to attract animals	No	N/A	N/A	N/A	N/A
2	No	Don't know how	Yes	Yes	Traps	Yes	N/A
3	No	Don't know/Hadn't considered	No	N/A	N/A	N/A	N/A
4	No	Doesn't want it in the yard (aesthetic)	Yes	No	N/A	N/A	N/A
5	Yes	N/A	No	N/A	N/A	N/A	Yes
6	No	No composter	No	N/A	N/A	N/A	N/A
7	No (used to)	Don't want to attract animals	No	N/A	N/A	N/A	N/A
8	No	Don't know/Hadn't considered	No *mice	N/A	N/A	N/A	N/A
9	No	Don't know/Hadn't considered	No	N/A	N/A	N/A	N/A
10	No (used to)	Don't want to attract rats	yes	Yes	Got rid of composter, set traps	Yes	N/A

Table A5. Survey responses from the moderate rat abundance neighbourhood in the Northwood study area.

Household #	Do you compost?	If not, why?	Have you had experience with rats being on/around your property?	Did you take preventative measures thereafter?	What measures were those?	Were they Successful?	May I take a picture of your composter?
1	Yes	N/A	No *squirrels	N/A	N/A	N/A	Yes
2	Yes	N/A	No *mice	N/A	N/A	N/A	No
3	No	Not enough waste to compost	Yes	No	N/A	N/A	N/A
4	No	Not around in the summer	Yes	Yes	Traps	Yes	N/A
5	Yes	N/A	No	N/A	N/A	N/A	Yes
6	No (used to)	Don't want to attract rats	Yes	Yes	Got rid of composter, set traps	Yes	N/A
7	Yes	N/A	No	N/A	N/A	N/A	Yes
8	No	No time	Yes	Yes	Traps	Yes	N/A
9	No	Don't want to attract rats	Yes	Yes	Rodenticide; Traps	Yes	N/A
10	No (used to)	Not time effective	No	Yes	Rodenticide, Sanitation	Yes	N/A

Table A6. Survey responses from the high rat abundance neighbourhood in the Northwood study area.

Household #	Do you compost?	If not, why?	Have you had experience with rats on/around your property?	Did you take preventative measures thereafter?	What measures were those?	Were they Successful?	May I take a picture of your composter?
1	No	Not enough waste to compost	No	N/A	N/A	N/A	N/A
2	Yes	N/A	No	N/A	N/A	N/A	Yes
3	No (used to)	Don't want to attract rats	Yes	Yes	Got rid of composter; Gravel (prevent burrowing); Traps; Sonar device; Store trash inside	No	N/A
4	No (used to)	No reason (no garden)	Yes	Yes	Secure lids on garbage	Yes	N/A
5	Yes	N/A	Yes	Yes	Sealed base of composter; Removed bird feeders; Traps	No	No
6	No (used to)	Don't want to attract rats	Yes	Yes	Removed bird feeders; Quit gardening; Got metal garbage cans; Traps	No	N/A
7	No	No composter	Yes	Yes	Traps	No	N/A
8	No (used to)	No time	Yes	Yes	Sanitation; Got rid of composter; Traps	No	N/A
9	No	No time	No	N/A	N/A	N/A	N/A
10	No reason (no garden)	No	No	N/A	N/A	N/A	N/A

Table A7. Survey responses from the low rat abundance neighbourhood in the Red River study area.

Household #	Do you compost?	If not, why?	Have you had experience with rats being on/around your property?	Did you take preventative measures thereafter?	What measures were those?	Were they Successful?	May I take a picture of your composter?
1	No *used to	No composter	No	N/A	N/A	N/A	N/A
2	No	Don't know how	No *mice	N/A	N/A	N/A	N/A
3	No	Don't know/Hadn't considered	No	N/A	N/A	N/A	N/A
4	No (considering)	No time	No	N/A	N/A	N/A	N/A
5	Yes	N/A	No	N/A	N/A	N/A	Yes
6	Yes	N/A	No *mice	N/A	N/A	N/A	N/A
7	No	Don't know/Hadn't considered; Easier not to	No	N/A	N/A	N/A	N/A
8	Yes	N/A	No	N/A	N/A	N/A	Yes
9	No	No composter; Easier not to	No	N/A	N/A	N/A	N/A
10	Yes	N/A	No	N/A	N/A	N/A	Yes

Table A8. Survey responses from the moderate rat abundance neighbourhood in the Red River study area.

Household #	Do you compost?	If not, why?	Have you had experience with rats being on/around your property?	Did you take preventative measures thereafter?	What measures were those?	Were they Successful?	May I take a picture of your composter?
1	Yes	N/A	Yes	Yes	Temporarily stopped composting; Sealed bottom of composter	Yes	Yes
2	Yes	N/A	No	N/A	N/A	N/A	Yes
3	Yes	N/A	No	N/A	N/A	N/A	Yes
4	No	No reason; easier not to	Yes	No	N/A	N/A	N/A
5	No	Not enough waste to compost	No	N/A	N/A	N/A	N/A
6	Yes	N/A	Yes	Yes	Traps; Changed compost container	Yes	Yes
7	No *used to	Away during the summer	No	N/A	N/A	N/A	N/A
8	Yes	N/A	No	N/A	N/A	N/A	Yes
9	No	Don't want to attract rats; Not time effective; Not enough waste to compost	No	N/A	N/A	N/A	N/A
10	No *used to	No composter	Yes	Yes	Traps; Filled holes	No	N/A

Table A9. Survey responses from the high rat abundance neighbourhood in the Red River study area.

Household #	Do you compost?	If not, why?	Have you had experience with rats being on/around your property?	Did you take preventative measures thereafter?	What measures were those?	Were they Successful?	May I take a picture of your composter?
1	No	No time; Lots of effort	Yes	No	N/A	N/A	N/A
2	No	No time	No	N/A	N/A	N/A	N/A
3	Yes	N/A	No	N/A	N/A	N/A	No
4	Yes	N/A	Yes	No	N/A	N/A	Yes
5	No	Hadn't considered/Don't know	Yes	Yes	Store garbage inside	No	N/A
6	Yes	N/A	Yes	Yes	Traps	Yes	No
7	Yes	N/A	Yes	No	N/A	N/A	Yes
8	Yes	N/A	No *mice	No	N/A	N/A	Yes
9	No	Don't want to attract rats	Yes	Yes	Rodenticide	Yes	N/A
10	Yes	N/A	No	N/A	N/A	N/A	Yes