Environmental factors associated with increased rat populations:

A Focused Practice Question

Michelle Ng, Analyst, Research & Policy
Eric Tram, Analyst, Research & Policy
Louise Aubin, Manager

Environmental Health
Region of Peel Public Health

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Region of Peel
Working for you

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Key Messages

1. The availability of food and harbourage is associated with increased rat populations, particularly in impoverished urban neighbourhoods.

2. Climate and season can affect rat populations/infestations independent from reproduction.

1 Issue & Context

Rats are urban pests that have long been associated with a variety of diseases that can affect humans. The most common rat species are *Rattus norvegicus* (also known as the Norway rat or brown rat) and *Rattus rattus* (also known as the black rat or roof rat). A background literature review conducted on the human health risks associated with exposure to rats in an urban setting found that rats are capable of transmitting various bacterial infections (e.g. rat bite fever, gastrointestinal illness), viral infections (e.g. Seoul hantavirus), and parasitic infections (e.g. toxoplasmosis) (**Appendix A**). The review also found that impoverished urban populations are disproportionately affected by rat-associated illnesses, which may be influenced by several factors including inadequate standard of living, poor sanitation, crowding, and homelessness. Although the incidence of rat-associated illnesses is likely low in Peel region, many cases may go under-reported as most of these are not required to be reported to public health units. In Peel region, pathogens most likely to be spread by rats are bacteria causing gastrointestinal illnesses such as *Salmonella* spp and *Campylobacter* spp since the incidences of these pathogens are high in Ontario and rats are capable of carrying these pathogens. The presence of rats around dwellings may also be a source of anxiety and stress for building occupants.

In 2015-2016, Peel Public Health's Environmental Health Contact Centre received an increased number of calls related to rat complaints. Similarly, other jurisdictions such as Toronto Public Health[1] and pest control companies in Montreal, Toronto and Halifax[2] have also been reporting increases in rodent-related complaints, particularly rats.

Therefore, a review of the literature was conducted to understand what potential environmental factors are associated with increased rat populations in urban settings.

2 Literature Review Question

What are the environmental factors associated with increased rat populations (Norway and black rats) in an urban setting?

3 Literature Search

A search of the peer-reviewed literature was conducted in July 2016 in Medline and Environment Complete for English-language synthesized research articles (reviews and guidelines) published from 2005 to 2016 on environmental factors associated with rat populations (see **Appendix B: Search Strategy** for details). The Vancouver Rat Project website (www.vancouverratproject.com) was also searched for recent research. Grey literature sources including TRIP database, Google Scholar, and a variety of health agency websites were also searched.

4 Relevance Assessment

Relevancy of the articles was assessed by two independent reviewers and determined through discussion and consensus based on the following criteria:

Inclusion criteria:

- Norway (*Rattus norvegicus)* and black (*Rattus rattus)* rats
- Urban setting in developed countries

- Similar weather/climate to Peel region

Exclusion criteria:

- Does not discuss environmental factors associated with rat populations (i.e. biological, evolutionary, genetic)
- Rural setting
- Different climate from Peel region (i.e. tropical)

5 Results of the Search

The literature search resulted in 22 articles based on title and abstract screening. Two literature reviews met the relevancy criteria. See **Appendix C: Literature Search Flowchart** for details.

6 Critical Appraisal

The quality of each of the included articles was assessed by two independent reviewers using the CASP (Critical Appraisal Skills Programme) tool for reviews. Any discrepancies were resolved through discussion and consensus. One review was rated as moderate quality[3], and the other review was rated as weak to moderate quality[4]. Both articles were included in this review.

7 Description of Included Studies

Data extraction tables for the two reviews can be found in **Appendix D**.

Feng and Himsworth (2014): *The secret life of the city rat: a review of the ecology of urban Norway and black rats (Rattus norvegicus and Rattus rattus)*[3]

The objective of this literature review, rated as moderate, was to compile, summarize and evaluate published literature regarding the ecology of rats *(Rattus norovegicus* and *Rattus rattus)* in urban centres. This review described the population dynamics, behaviour, and movement of rats, and environmental factors that affect rat populations.

Bonnefoy et al., World Health Organization, (2008): *Public health significance of urban pests*[4]

The objective of this report by the World Health Organization (WHO) was to identify the public health risks posed by various urban pests and appropriate measures to prevent and control them. The WHO invited international experts in various fields including pests, pest-related diseases and pest management to provide evidence to develop policies to manage and reduce the risk of exposure to urban pests including rodents. The quality of the literature review was rated as weak to moderate. There was a chapter in this report on commensal rodents (Chapter 12), which includes the brown rat (*Rattus norvegicus),* the roof rat (*Rattus rattus),* and the house mouse (*Mus musculus)*. The review described the behaviour and biology of rodents, the population growth, socialization and movement of these rodents, and the association between rodents and urban infrastructure. The public health risks and the control of rodents, and the legal framework for rodent control were also discussed.

8 Synthesis of Findings

The following environmental factors that affect rat populations have been described in the literature.

- **Availability of food and harbourage is associated with increased rat populations.**
    - Availability of food sources influences the abundance of rats. Improperly stored or disposed food and organic waste, dishevelled gardens, and presence of domestic animals (e.g. dogs, cats, pets, livestock) in residences, gardens or city blocks are correlated with rat infestations[3,4].
    - Availability of harbourage determines whether a population becomes established. Structures that are easily accessible or abandoned may act as a source of infestation [3,4]. Accessibility to shelter such as holes/cracks in roofs, walls, ceilings, building foundation, access points near utility lines and sewer systems, and particularly abandoned structures are associated with rat infestations [3]. This is particularly the case with older-aged housing and aging of community infrastructure such as defective drains[4]. Defects in sewer systems and inadequate sewer baiting also contribute to surface infestations[4]. Presence of soil is a strong predictor of Norway rat populations, since they can create their own harbourage by burrowing[3]. In contrast, black rats are more common in areas with high building density since they are good at scaling vertical structures and creating nests out of artificial materials. Higher housing density is associated with urban rodent infestations likely because

the dispersal and colonization of one home can affect surrounding dwellings. Rats are also more likely to disperse successfully over short distances[4].

- Impoverished neighbourhoods are disproportionately affected by rat infestations. Suitable harbourage and food sources for rats tend to be most abundant in neighbourhoods of lower socioeconomic status, where properties may be aging, dilapidated and abandoned, and public services including waste disposal may be inadequate, leading to unhygienic environments that could be a source of food[3].

- **Climate and season can affect rat populations/infestations independent from reproduction.**
  - Studies have suggested that the winter season is associated with increased rat-related complaints as rats move indoors to seek shelter. Increased growth rates in urban rats may be higher in the winter, which may be attributed to decreased competition (increased access to food) from an overall reduced population size during the winter, and decreased decomposition of garbage from colder ambient temperatures[3].

References

[1] Hudes, S. “Rat complaints on the rise in Toronto restaurants”. Thursday July 7, 2016. The Toronto Star. Last accessed: October 31, 2016. Available at: https://www.thestar.com/news/gta/2016/07/07/rat-complaints-on-the-rise-in-toronto-restaurants.html

[2] Tremonti, AM. “Rising urban rat population pose health risks to humans, says researcher”. Tuesday June 14, 2016. The Current, CBC Radio. Last accessed: October 31, 2016. Available at: http://www.cbc.ca/radio/thecurrent/the-current-for-june-14-2016-1.3634082/rising-urban-rat-population-pose-health-risks-to-humans-says-researcher-1.3634124

[3] Feng and Himsworth. (2014). The secret life of the city rat: a review of the ecology of urban Norway and black rats (*Rattus norvegicus* and *Rattus rattus)*. *Urban Ecosyst,* 17:149-162.

[4] Bonnefoy et al. (2008). Public health significance of urban pests. Copenhagen: World Health Organization, Regional Office for Europe. Available at: http://www.euro.who.int/__data/assets/pdf_file/0011/98426/E91435.pdf. Last accessed: August 18, 2016.

Appendices

Appendix A: Background Reading

Appendix B: Search Strategy

Appendix C: Literature Search Flowchart

Appendix D: Data Extraction Tables

Appendix A: Background Reading

Issue:

What human health risks are associated with exposure to rats in urban settings?

Background:

Rats are significant urban pests that are widely distributed throughout the world. *Rattus norvegicus* (aka Norway Rat, Brown Rat, Sewer Rat, Wharf Rat) and *Rattus rattus* (aka Black Rat, Ship Rat, Roof Rat, House Rat) are the most common rat species of public health significance[1]. Rats benefit from close association with humans for food, water and shelter. However, people do not derive any direct benefit from this association. Rats are reservoirs for bacterial and viral pathogens[2] as well as parasites that either live on the host such as lice and fleas or parasites that infect the host such as tapeworms. In urban environments the close association between humans and rats increases the potential for zoonotic disease transmission capable of causing significant morbidity and mortality[1].

In 2015-2016 the number of rat-related complaints reported to Peel Public Health was higher compared to previous years. This upward trend in rat sightings does not appear to be unique to Peel region. A focused practice question is being conducted to review the environmental factors associated with increased rat population in urban cities.

The background literature review summarizes the human health risks associated with exposure to

urban rats. This review will inform the focused practice question by describing the public health rationale for the need to understand the environmental factors associated with increased rat populations. Articles focused exclusively on rat zoonoses in the rural setting, developing countries, or disease pathogenesis were excluded to ensure that the information is as relevant as possible to Peel region.

Current Status:

Public health inspectors (PHIs) have the legislative authority under the Ontario *Health Protection and Promotion Act* to reduce or eliminate any conditions that constitute a health hazard except in circumstances where private residences are concerned. Peel PHIs routinely inspect food premises for pests including rats and respond to public complaints of rat activities. As part of the inspection process, a PHI conducts risk assessments on the potential for the presence of rats to adversely affect the health of the community. In cases of rat complaints on private residences the PHI provides education to residents on prevention and control measures. The PHI may also work in collaboration with the municipal by-law department if a private residential property is the source of a rat infestation.

In Canada, communicable diseases are identified by the federal, provincial and territories' governments as priorities for monitoring and control efforts[2]. Each year National Notifiable disease data are voluntarily submitted by the provinces and territories through the Canadian Notifiable Disease Surveillance System (CNDSS). In Ontario, the communicable diseases reportable to the local Medical Officer of Health are listed under *O. Reg. 559/91*: *Specification of Reportable Diseases* under the *Health Protection and Promotion Act*. Therefore surveillance data can

potentially be used to explore provincial and/or national trends of rat-associated zoonoses case counts and rates if the disease is reportable.

Summary of the Literature:

Description of included research

- Three relevant review articles were retrieved from the literature search
- Two out of three were systematic reviews
- Two out of three publications reviewed zoonoses associated with *Rattus norvegicus* and *Rattus rattus* in the general populations of urban centres while the third reviewed zoonoses associated with *Rattus norvegicus* and *Rattus rattus* and other important vectors on homeless populations in urban centres

Summary of the literature on Rat Zoonoses

Rats are carriers for bacterial, viral and parasitic pathogens. One of the most important risk factors for rat-associated zoonoses is the country of origin[3]. Rat-associated zoonoses are more common in developing countries compared to developed countries. The warmer and wetter climate of developing countries is one contributing factor but a stronger determinant appears to be residence in areas with high rates of urban poverty[3]. The residents of these urban areas experience inadequate housing, urban decay, sanitation, and limited access to health care. These factors facilitate urban rat infestations leading to close contact with humans and consequently an increase in the risk of disease transmission[3,4].

In developed countries, the incidence of rat-associated zoonoses is generally low. However, an understanding of potential rat-associated zoonoses is important because, despite being caused by diverse groups of pathogens, these diseases have similar and often non-specific clinical manifestations which can lead to under-diagnosis and misdiagnosis by health care practitioners[3]. The problem is compounded by the fact that the patients themselves may be unaware of rat or rat-vector exposures when providing a detailed history. Under-diagnosis and misdiagnosis can lead to a delay and/or inappropriate treatment as well as under-reporting, which ultimately increase the health burden of rat-associated zoonoses[3].

There is evidence to suggest that while the general population in developed countries, irrespective of socioeconomic status, can acquire rat-associated zoonoses, it is those with low socioeconomic status and the marginalized populations who are at the highest risk for exposure and infections[3]. Inadequate standard of living, poor sanitation and hygiene, crowding, homelessness, intravenous drug usage and immunosuppressive diseases (e.g. HIV/AIDS) are contributing factors[3,4]. The following sections will provide a summary of the most common rat-associated zoonoses in urban centres.

Bacterial zoonoses

Leptospira interrogans causes leptospirosis in both animals and humans and is considered the most widespread zoonotic disease in the world[3]. While *Leptospira* species are able to infect wild and domestic animals, rats are the most common source of human infection in the urban environment[3]. Infection is spread through direct contact with rat urine or indirectly with water, soil

or food contaminated with rat urine[4]. The bacteria can gain entry through breaks in the skin and/or via mucous membranes (e.g. mouth, nose, and throat). Most rat populations around the world asymptomatically carry *Leptospira* species, but human disease is most common in the tropics of Southeast Asia, Oceania, the Indian subcontinent, the Caribbean, and Latin American[3]. However, evidence of infection with *Leptospira* has also been reported in case studies of homeless and marginalized populations in the United States[4]. Symptoms of leptospirosis include high fever, headache, muscle aches, chills, vomiting or diarrhea. The illness may progress to Weil's disease, a syndrome characterized by jaundice, kidney or liver failure with a mortality rate of 5-15%[3]. *Leptospira* species are also associated with a pulmonary hemorrhage syndrome with mortality rates of up to 50%[3]. Leptospirosis is not reportable in Ontario or has ever been nationally notifiable.

Yersinia pestis is the etiological agent for the plague. *Rattus norvegicus* and *Rattus rattus* are the most common urban sources of infection[3]. The rat flea (*Xenopsylla cheopis*) is the classic vector responsible for spreading the bacteria between rats and to people in the urban setting[3,4]. A bite from an infected flea spreads bacteria to the local lymph nodes resulting in swelling (i.e. buboes) followed by systemic spread to organs. The symptoms of bubonic plague include fever, headache, chills, malaise and may eventually lead to sepsis and death[3]. The pneumonic form of plague can be transmitted from person-to-person through aerosols. Currently the major foci of enzootic plague are in Africa, Southeast Asia, and South America[3] where human cases still occur with mortality rates of up to 20%. Plague is a reportable disease in Ontario and nationally notifiable. Wild animals are occasionally known to carry the plague bacteria but there has not

been a human case of plague in Canada reported since 1939[2].

Rickettsia typhi is found in rat populations worldwide particularly in the tropics and subtropics and in port cities and coastal regions. *R. typhi* is transmitted between rats and to people via the rat flea (*Xenopsylla cheopis*)[3]. *R. typhi* infection is spread by flea bites or host scratching that introduces flea fecal materials into the skin. In humans, *R. typhi* causes murine typhus which is a self-limiting illness characterized by fever, headache, lethargy, myalgia, arthralgia, nausea, vomiting and a skin rash[3]. Without appropriate antibiotic treatment, the mortality rate of murine typhus reaches about 4% (1% with the appropriate treatment)[3]. Murine typhus is not reportable in Ontario and rickettsial infections have not been nationally notifiable since 1978[2].

Bartonella genus consists of over 30 characterized bacterial species[3]. *Bartonella* species are adapted to diverse mammalian hosts including rats. *Rattus norvegicus* and *Rattus rattus* can be concurrently infected with several *Bartonella* species including *B. elizabethae*, *B. trobocorum*, *B. rochalimae*, *B. phocensis*, and *B. rattimassiliensis*[3]. Rats worldwide are thought to be infected with the bacteria[3] but the number of published articles on human cases related to rat-associated *Bartonella* species infections is limited. Available research suggests that *B. elizabethae* and *B. rochalimae* may be linked to endocarditis and neuroretinitis and febrile illness, respectively[3]. There is some evidence that rat fleas (*Xenopsylla cheopis*) may be responsible for spreading infections from rats to people. Rat-associated *Bartonella* species have also been identified in arthropod vectors such as lice, mites, and ticks although the roles that these vectors play in transmission are unclear[3]. Bartonellosis is not reportable in Ontario or have ever been nationally

notifiable.

Streptobacillus moniliformis is part of the normal commensal flora of the rat upper respiratory tract. *S. moniliformis* is the predominant bacteria carried by rats in North America and is the primary cause of Rat Bite Fever following a bite from an infected rat[3]. This is also known as Haverhill fever if illness is due to patient ingesting food or water contaminated with rat saliva[3]. Symptoms of illness are non-specific and include fever, headache, chills, vomiting, muscle pain, joint paint, and skin rash. Septicemia may occur with untreated *S. moniliformis* infection with a mortality rate of 7-13%[3]. In both urban and rural settings in the United States, the close association between human and rats results in reports of hundreds of rat bites each year[4]. This number is estimated to be under-reported by a factor of at least ten[4]. Rat bite fever is not reportable in Ontario or has ever been nationally notifiable.

Bacteria causing Gastrointestinal illnesses

Escherichia coli, *Salmonella spp*. And *Campylobacter spp* are common etiological agents of gastrointestinal illnesses in Canada and around the world. Rats can be infected with these bacteria and shed them in the stool[3]. There is also evidence that antibiotic-resistant strains of these bacteria are commonly associated with rats although the public health significance of this observation is not known at this time[3]. Confirmed cases of these pathogens must be reported to Peel Public Health and tracked by Public Health Ontario. Based on surveillance data from Public Health Ontario report for September 2016[5], the year-to-month 5 year average (2011-2015) rate of confirmed cases of Salmonellosis, Campylobacteriosis and *Verotoxin-producing E. coli* including

Hemolytic Uremic Syndrome (HUS) was 121.5, 144.9 and 6.8 cases per 1,000,000 population, respectively. However, it is unknown how many of these cases are directly attributable to rats as vectors.

Viral zoonoses

Seoul hantavirus (SEOV) is a species of the genus *Hantavirus*. *Rattus norvegicus* is the primary reservoir for SEOV and spreads the virus in bodily fluids including urine, saliva and in the feces[3]. Zoonotic transmission occurs through the inhalation of aerosolized rat urine, droppings, saliva or dust from rat nests or exposure to rat bodily fluids onto broken skin or mucous membranes[3]. SEOV may also be transmitted indirectly through contaminated food, water, or fomites[3]. SEOV is responsible for about 20% of all hemorrhagic fever with renal syndrome (HFRS) and has a case fatality rate of 1-2%[4]. HFRS is characterized by fever, myalgia, and headache and may progress to low blood pressure, renal failure and hemorrhagic manifestations[3]. SEOV is globally distributed in rats and widely identified in rats and other rodents in the United States and Europe[4], but human cases of hemorrhagic fever with renal syndrome (HFRS), for the most part, is geographically limited to China, Russia and Korea[3]. Nevertheless serological studies of injection drug users and the homeless urban populations in Baltimore, Maryland in the United States indicate that human exposure to SEOV in an urban North American setting does occur[4]. The evidence also suggests that even in the absence of HFRS, SEOV infection in the urban population can be associated with long-term renal dysfunction including proteinuria, end-stage renal disease and hypertensive renal disease[3,4]. HFRS caused by SEOV and spread by rats should not be confused with Hantavirus Pulmonary Syndrome (HPS). The majority of cases of HPS in US and Canada are caused by the

Sin Nombre Virus and spread by the white-footed mouse (*Peromyscus maniculatus*). All viral hemorrhagic fevers (VHF) including those caused by SEOV are reportable in Ontario and nationally notifiable. No cases of VHF have been reported in Canada from 1979 to 1982 and since national surveillance resumed in 2002[2].

Parasitic zoonoses

Rattus norvegicus and *Rattus rattus* are the main reservoirs for the parasite *Angiostrongylus cantonensis*. The parasite is mainly found in Southeast Asia, the South Pacific, Australia and the Carribean[3]. There are also endemic foci in other parts of the world including the United States[3]. The parasite is spread by the feces of the rats and must be ingested by a molluscan intermediate host (e.g. snails or slugs) to become infectious. Humans consuming raw or undercooked molluscs, paratenic hosts (i.e. an amphibian or crustacean that consumed the infected mollusc) or contaminated vegetation can become infected[3]. The main clinical manifestations of infection are eosinophilic meningitis or ocular angiostrongyliasis[3].

Rats are reservoirs for the zoonotic tapeworms *Hymenolepsis* spp and *Rodentolepsi* spp which is spread through rat feces and cause enteritis in humans[3]. Rats are also reservoirs for the nematode *Capillaria* spp. that infects rat liver. The parasite eggs are released into the environment upon a rat's death or can spread through the fecal-oral route of transmission from animals that prey on infected rats[3].

The presence of rats also increases the risk of human toxoplasmosis[3]. Rats are intermediate

hosts for *Toxoplasma gondii* and can spread the parasite to definitive hosts which includes stray and domestic cats. *T. gondii* oocyst is shed in cat stool and may be ingested by people handling cat litter boxes or through contact with contaminated soils (e.g. gardening, unwashed fruits and vegetables). Toxoplasmosis is of significant concern for pregnant women infected following conception because the parasite can be passed to the fetus resulting in developmental delay, blindness, epilepsy in infancy or later in life[6]. Rats are also being investigated as a potential reservoir for zoonotic *Cryptosporidium* spp. which causes gastroenteritis in people[3]. Currently none of these parasitic infections are reportable in Ontario or have ever been nationally notifiable.

Other rat-associated health risks

The presence of rodents in the home may contribute to increased levels of indoor allergens causing allergic asthma and rhinoconjunctivitis[1]. The presence of rats around dwellings can also affect mental health, because awareness of rat presence can be a source of anxiety for building occupants[1]. The stress may disproportionately affect those living in poverty and those who are socially isolated whose health status is already compromised[4].

Conclusion:

Rattus norvegicus and *Rattus rattus* are urban pests associated with significant public health risk as they are able to transmit zoonotic bacterial, viral, and parasitic infections. The literature review demonstrates that rat-associated zoonoses are far more common in developing countries with tropical climates and disproportionally affect impoverished urban populations. Therefore in Peel Region the incidence of many of the rat-associated zoonoses discussed in this report is likely low

but under-reported as they are not reportable to Peel Public Health nor tracked by Public Health Ontario. Based on available surveillance data the pathogens most likely to be spread by rats in Peel region are the bacteria causing gastrointestinal illnesses such as *Salmonella* spp and *Campylobacter* spp. The incidence of these pathogens in Ontario is high and can be carried and spread by rats through the fecal-oral route of contamination. Direct contact with rats and rat bites may also increase the likelihood of diseases such as Rat Bite Fever as *S. moniliformis* is part of the natural commensal flora in the rat upper respiratory tract. Rats may also be a source of anxiety and stress for building occupants.

As Peel region experiences a trend of increased rat sightings, the incidence of rat-associated zoonoses may be expected to rise due to closer contact between rats and people and their pets in urban neighbourhoods and from infestations adversely affecting food premises. Therefore this background literature review underscores the need to understand the environmental factors associated with increased rat populations observed in Peel region.

Date: October 17th, 2016

References

1. Bonnefoy, X., Kampen, H. & Sweeney, K. (2008). Public Health Significance of Urban Pests. World Health Organization, Copenhagen. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0011/98426/E91435.pdf

2. Government of Canada (2016). Notifiable Diseases Online. Retrieved from http://diseases.canada.ca/notifiable/

3. Himsworth CG, Parsons KL, Jardine C, Patrick DM. **(**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 Zoonotic Dis.* 13(6):349-59.

4. Leibler JH, Zakhour CM, Gadhoke P, Gaeta JM. (2016). Zoonotic and Vector-Borne Infections Among Urban Homeless and Marginalized People in the United States and Europe, 1990-2014. *Vector Borne Zoonotic Dis.* 16(7):435-44.

5. Public Health Ontario (2016). Monthly infectious diseases surveillance report volume 5 issue 9 (September 2016). Retrieved from https://www.publichealthontario.ca/en/DataAndAnalytics/Documents/PHO_Monthly_Infectious_Diseases_Surveillance_Report_-_September_2016.pdf

6. Heymann D.L., (2008). Control of Communicable Diseases Manual, 19th Edition. Washington, DC, American Public Health Association.

Appendix B: Search Strategy

Medline Search Strategy

Database: EBM Reviews - Cochrane Database of Systematic Reviews <2005 to July 13, 2016>, Global Health <1973 to 2016 Week 27>, Ovid Healthstar <1966 to June 2016>, Ovid MEDLINE(R) <1946 to July Week 1 2016>, Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations <July 19, 2016>

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1 exp rats/ (1741112)

2 exp rodentia/ (3438833)

3 rodent*.ti,ab. (126936)

4 rats.ti,ab. (909213)

5 "rattus rattus".ti,ab. (1703)

6 "rattus norvegicus".ti,ab. (4692)

7 1 or 2 or 3 or 4 or 5 or 6 (3545432)

8 exp ecology/ (81421)

9 ecology.ti,ab. (47428)

10 exp ecosystem/ (178354)

11 ecosystem*.ti,ab. (66718)

12 neighbourhood.ti,ab. (9900)

13 neighborhood*.ti,ab. (34927)

14 resident*.ti,ab. (277215)

15 urban.ti,ab. (249520)

16 "population growth".ti,ab. (15760)

17 socioeconomic.ti,ab. (145081)

18 exp socioeconomic factors/ (768322)

19 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 (1607289)

20 review*.ti. (628614)

21 "meta analys*".ti. (113247)

22 guideline*.ti. (118208)

23 synthes*.ti. (329713)

24 20 or 21 or 22 or 23 (1147042)

25 7 and 19 and 24 (392)

26 remove duplicates from 25 (288)

27 limit 26 to yr="2006 -Current" (94)

28 exp rats,sprague-dawley/ (279780)

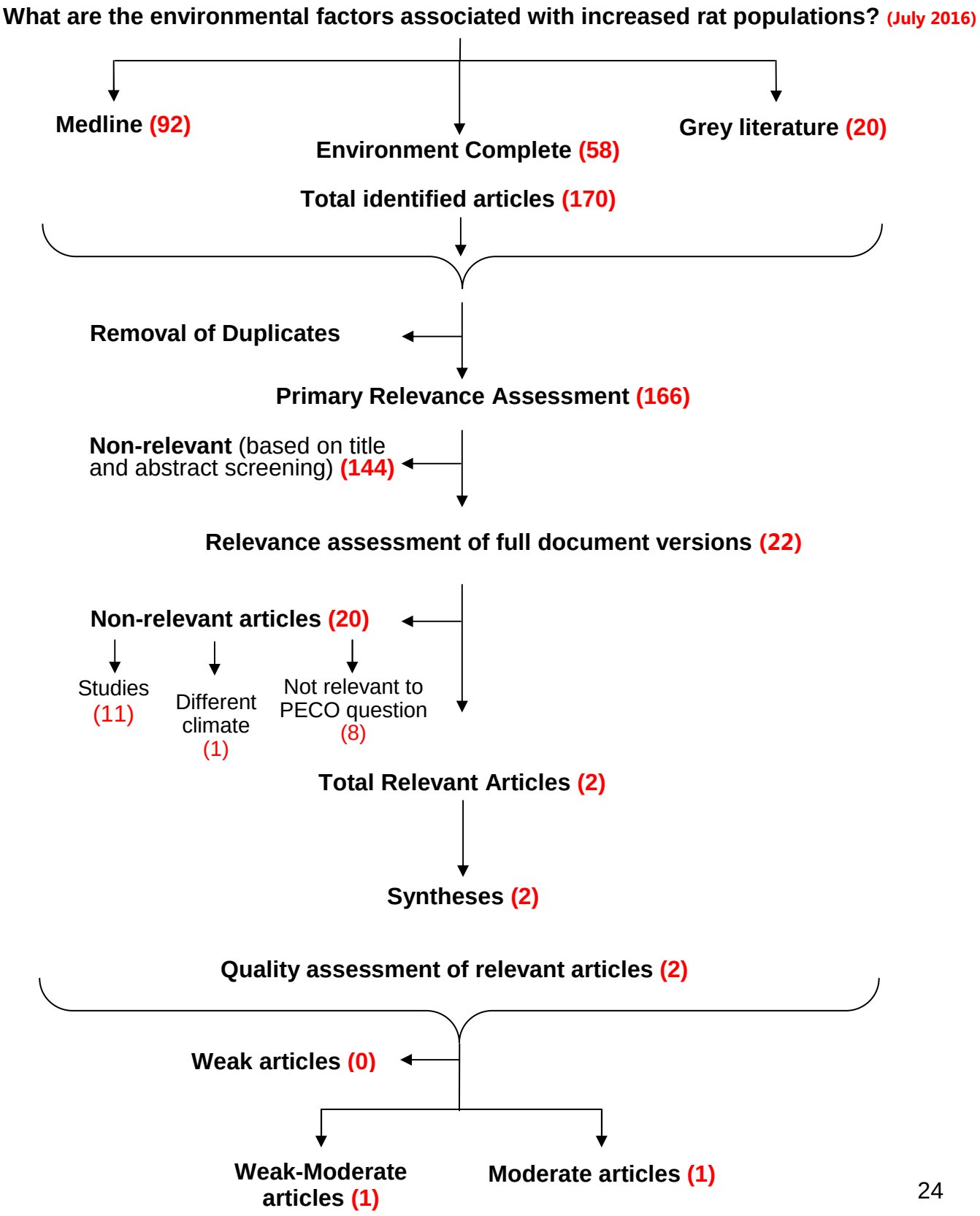
29 27 not 28 (92)

Note: A similar search strategy was conducted for Environment Complete by adapting the Medline search terms.

Grey Literature Databases / Websites

TRIP database, Google Scholar, the World Health Organization (WHO), Centers for Disease Control (CDC), the National Collaborating Centre for Environmental Health (NCCEH), public health department/agency websites including Public Health Agency of Canada (PHAC), Health Canada, Public Health Ontario, New York State Public Health department, Public Health England, and the National Association of County and City Health Officials (NAACHO), and the National Institute for Health and Care Excellence (NICE).

Appendix C: Literature Search Flowchart



Appendix D: Data Extraction Tables

Items reviewed	**Review #1 of 2:** The secret life of the city rat: a review of the ecology of urban Norway and black rats (*Rattus norvegicus* and *Rattus rattus)*
General Information & Quality Rating	
Author(s), Date	Feng and Himsworth, 2014
Quality rating	Moderate (using CASP tool for reviews by 2 independent reviewers)
Objective of review	To collate, summarize and evaluate published literature regarding the ecology of rats (*Rattus norvegicus* and *Rattus rattus)* in urban centres. Note: The remainder of this table focuses on environmental factors affecting rat populations.
Details on methodology	
Number of included primary studies	90 total (23 relevant)
Types of studies	Unknown
Search period	No limit
Search sources	• Databases including CAB Direct, JSTOR, Medline, BIOSIS Previews, Zoological Records Plus, Web of Science • Reference lists
Inclusion/exclusion criteria	Inclusion: Pertaining to ecology of Norway and black rats in urban centres Exclusion: Non-English language papers; papers that did not focus primarily on rat ecology (e.g. rat control and extermination studies); papers that involved rat species other than *Rattus norvegicus* and *Rattus rattus*; papers that pertained primarily to rural or agricultural situations
Study population	Norway rat (*Rattus norvegicus)* or black rat (*Rattus rattus)*
Relevant exposure	Ecology of Norway and black rats (environmental influences)
Primary outcome	Norway and black rat populations
Relevant review methods	Thematic analysis (using methodology for narrative synthesis by Arai et al., 2007[a])
Results & Limitations	
Relevant results of review	• Climate and season has an influence on rat populations, independent from reproduction. Studies have suggested that the winter season is associated with increased rat-related complaints as rats move indoors to seek shelter. Increased growth rates in urban rats may be higher in the winter, which may be attributed to decreased competition (increased access to food), and decreased decomposition of garbage from colder ambient temperatures. • Availability of adequate harbourage, food, and water may increase rat populations. o Improperly stored or disposed food and organic waste and presence of domestic animals in residences may attract rats.

	o Accessibility to shelter such as holes/cracks in roofs, walls, ceilings, building foundation, access points near utility lines and sewer systems, and particularly abandoned structures are associated with rat infestations. Presence of natural soil is a strong predictor of Norway rat populations, since they can create their own harbourage by burrowing. In contrast, black rats are more common in areas with high building density since they are good at scaling vertical structures and creating nests out of artificial materials. o Suitable harbourage and food sources for rats tend to be most abundant in neighbourhoods of lower socioeconomic status, where properties may be aging, dilapidated and abandoned, and public services including waste disposal may be inadequate. Thus, impoverished neighbourhoods are disproportionately affected by rat infestations. • The exact factors or combination of factors of the built environment that promote or deter rat infestations remains unclear.
Comments/limitations	• The study designs of included studies were not described. • It is unknown whether the included studies have been assessed for quality.

[a] Arai et al. (2007). Testing methodological developments in the conduct of narrative synthesis: a demonstration review of research on the implementation of smoke alarm interventions. *Evid Policy,* 3:361-383.

Items reviewed	**Review #2 of 2:** Public Health Significance of Urban Pests
General Information & Quality Rating	
Author(s), Date	Bonnefoy et al. (World Health Organization), 2008
Quality rating	Weak to moderate (using CASP tool for reviews by 2 independent reviewers)
Objective of review	To identify approaches to urban pest prevention and control that beneficially reduce the impact of these pests on public health. Note: The remainder of this table focuses on environmental factors affecting rat populations (Chapter 12: Commensal Rodents).
Details on methodology	
Number of included primary studies	Unknown
Types of studies	Cross-sectional surveys, rodent studies
Search period	No limit
Search sources	• Databases including Medline and Medscape • Grey literature (unpublished literature and experts)
Inclusion/exclusion criteria	Unknown
Relevant study population	Rodents including the Norway rat (*Rattus norvegicus),* the black rat (*Rattus rattus),* and the house mouse (*Mus musculus)* in developed countries in Europe and North America
Relevant exposure	Factors associated with size of rodent population
Relevant outcome	Rodent infestation/size of rodent population
Relevant review methods	• In 2002, a steering committee was established, which agreed on the scope and purpose of the report and workplan. • Institutions were consulted and identified. Authors were chosen based on their credentials and contribution to peer-reviewed literature. • In 2005, the initials drafts were produced by the authors. • Final drafts were reviewed by the steering committee in 2006. • Each chapter was peer-reviewed.
Results & Limitations	
Relevant results of review	• Factors that increase food availability may affect the size of a rat population such as excess litter, carelessly discarded food waste, presence of dogs and feral cats in city blocks, and presence of pets or livestock kept in the garden. • Factors that increase harbourage availability are associated with rat infestations such as areas where vandalism, dishevelled gardens, and neglected and vacant buildings were widespread. Increased housing density was also associated with urban rat infestations. Older age of housing and aging community infrastructure such as defective drains are associated with outdoor rat infestations. • Urban sewers are ideal habitats for rats due to availability of food and harbourage. Inadequate sewer baiting may also contribute to the presence of above-ground rat infestations. • Incomplete extermination of a rat population can lead to increased reproduction within the population due to

	rapid breeding of the remainder of the rat population.
Comments/limitations	• Not intended to be a systematic review of the literature. The literature search could be more comprehensive. • Methodology of literature review has not been described adequately. It is unknown whether the quality of the included studies has been assessed.