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SHORT COMMUNICATION

Potential public health benefits from eradicating rats in New Zealand cities and a tentative research agenda

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ABSTRACT

The eradication of some introduced pests such as rats, stoats and possums in New Zealand seems increasingly feasible with successful action to date in various cities (e.g. Wellington City) and with the government's national 2050 predator-free goal. Here we specifically detail the potential benefits of urban rat eradication and find these cover a wide range of topics including a potentially reduced risk of infection from at least seven zoonotic diseases (e.g. leptospirosis, toxoplasmosis, trichinellosis, murine typhus; and three enteric diseases). Other potential benefits include: psychological benefits from increased native bird life in cities; reduced damage to food supplies; reduced rat damage to building insulation and to building walls and roofing; and reduced fires in buildings associated with rat damage. However, there is considerable uncertainty on the size of such impacts and so we outline a tentative research agenda as a first step towards quantification of the likely key public health benefits of rat eradication.

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Introduction

There have been recently announced plans for a New Zealand government goal for national eradication of introduced rats, stoats and possums by 2050 (Department of Conservation 2017) and for a 'predator-free' Wellington City (Wellington City Council et al. 2016). Such efforts refer to both the introduced Norway/brown/sewer rat (*Rattus norvegicus*), and also the ship/roof/black/bush rat (*Rattus rattus*). These developments are part of a long-term trend that has seen successful eradication of some introduced mammal predators from many of New Zealand's offshore islands and in 'mainland islands', where some or most of the designated pest species are controlled to a low level, and at some sites are excluded by physical barriers (Clout & Russell 2006; Russell et al. 2015). Within cities there has also been the successful eradication of possums (*Trichosurus vulpecula*) from the Miramar Peninsula in Wellington City since 2006, and apparently successful rat control in the Wellington suburb of Crofton Downs (Wannan 2015). Indeed, the geography of Wellington City is well suited for an incremental approach with the

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initial plans announced in 2016 including rat (*R. norvegicus* and *R. rattus*) eradication on the Miramar Peninsula, which is separated from the rest of the city by a geographical isthmus containing an airport.

Although complete eradication of rats might be difficult for many New Zealand locations, the experience in selected settings in this country has been favourable to date. For example, although there are large numbers of people visiting islands in the Hauraki Gulf (e.g. around 100,000 visitors to Rangitoto per year; Bassett et al. 2016), the rat-free status (both species) of many of these islands has largely been maintained with successful interceptions at control points (e.g. via trapping and checking of boats; Bassett et al. 2016). Reinvasions of rats in this region typically only occur where small rat-free islands are close to larger islands where rat control has not been attempted (e.g. Aotea/Great Barrier and Waiheke; Bassett et al. 2016). Also of note is the experience of Alberta (Canada), which has been able to halt the westward spread of *R. norvegicus* from neighbouring Saskatchewan since the mid-20th century. In Alberta the importation of rats in vehicles such as trains and trucks from neighbouring provinces is relatively uncommon, and the usually single rats that cross the boundaries are identified and eliminated (Bourne 2002).

A further reason for optimism regarding rat eradication is the positive public attitude towards rat control. This is confirmed by the most recent report of an ongoing systematic survey series of people's perceptions of the state of the New Zealand environment (Hughey et al. 2016). A case study in this report dealt with predators including rats, and rats were widely reported as prevalent near respondents' homes and almost all respondents attempted to control rats near their home (mainly through use of poisons). The strongest motivation for respondents' rat control actions was the fact that they are considered a nuisance as they are a potential cause of environmental problems and human disease. Survey respondents were strongly in support of maintaining or increasing citizen and agency effort to control rats as well as the other priority predators.

To inform what might be the potential health benefits of eliminating introduced rats (as part of predator-free New Zealand urban area plans), we conducted literature searches using PubMed and Google Scholar on 31 May 2017 (covering the period since 1 January 2000). Search terms included various groupings of: 'Zealand' and 'human' and 'health' and 'rats'/'rattus'. We also considered the three major monographs and reports on this topic area that were identified from the reference lists of the articles found in the search (Singleton et al. 2003; King 2005; Bonnefoy et al. 2008). We built on our initial more general comments in a blog post (Wilson et al. 2016) and aimed to generate a tentative research agenda (logically derived from our reading of the literature) to guide further research from a public health perspective.

Predator control and eradication methods

New Zealand is both unique in lacking native land mammals (apart from bats, that are now endangered) and in being a world leader in the development and application of predator-mammal control methods (Owens 2017). Successfully applied methods include ground control using traps and toxins, aerial control using toxins, and creation of mainly predator-free mainland sanctuaries surrounded by multi-species predator-exclusion fences. These initiatives are backed by greatly expanded scientific knowledge

gained from effective predator control operations on offshore islands and mainland areas (Brown et al. 2015; Russell & Broome 2016).

Predator eradication in urban areas is likely to rely heavily on use of trapping, which doesn't carry the risk of secondary poisoning of non-target animals and is likely to have greater public acceptability than other methods. In the past, concerns have been raised about the humaneness of trapping and, in response, standards for traps that focus on minimising animal suffering, notably the National Animal Welfare Advisory Committee (NAWAC) guidelines, have been developed (Fisher et al. 2010). Toxins are still likely to be needed in some sites for eradication or even effective control of rats and possums. But they can be applied in highly targeted ways through use of carefully placed bait stations (Brown et al. 2015). Ultimately there is also potential for the use of gene-editing tools to disrupt reproduction in target species or make them more susceptible to a specific poison (Owens 2017).

Potential health benefits from eradicating rats in cities

The likely types of health benefits we identified for eliminating rats in New Zealand cities are detailed in Table 1. These span a wide range of categories including psychological benefits for citizens from the increased presence of native birds and other wildlife in cities; social capital and resilience benefits from collective community action to control rats (often as part of wider predator-free initiatives); and the potentially reduced risk of at least seven zoonotic diseases associated with rats in New Zealand.

There is, however, a marked lack of quantification of all these impacts in the New Zealand situation and they probably overlap to some extent with the problems arising from other pest animals such as possums (*T. vulpecula*) and house mice (*Mus musculus*) in cities. The international literature also appears to be limited. That is, we found no detailed literature on the health-related experience of other large initiatives such as in Alberta (Canada) in keeping *R. norvegicus* out of the province (Bourne 2002; Saskatchewan Ministry of Agriculture 2012), and for the city of Budapest in Hungary, which has particularly intensive rat control (Bajomi et al. 2013).

Possible health downsides of urban rat eradication efforts

Predator–prey relationships are complex and often not well understood (Ostfeld & Holt 2004). Nevertheless, the eradication of rats in cities is likely to allow urban mice populations to increase. Indeed, there is specific New Zealand evidence for rat control (*R. rattus*) resulting in increased mice populations (Ruscoe et al. 2011), though the evidence is not necessarily fully relevant to urban settings. Even so, this relationship may mean that some of the benefits of eradication of rats listed in Table 1 would be less than expected in predator-free urban areas.

A potential downside of increased bird populations in rat-free urban areas is that birds can themselves spread zoonotic diseases. For example, an outbreak of salmonellosis in humans has been linked to contact with dead sparrows in New Zealand, among other risk factors (Thornley et al. 2003). Furthermore, infection with *Campylobacter jejuni* is common in urban ducks and starlings in this country (Mohan 2015), as is infection with *Yersinia* spp. in wild urban passerines, a grouping which includes sparrows (*Passer*

Table 1. Potential health benefits of local eradication of introduced rats (both *R. rattus* and *R. norvegicus*) in urban areas of New Zealand.[a]

Potential health benefit	Possible mechanisms	Additional comments
Psychological benefits to people of the increased presence of native birds and other wildlife.	Increased wildlife presence and visible/audible indicators such as bird density and birdsong levels will probably have psychological benefits for some people (Fuller et al. 2007; Keniger et al. 2013; Shanahan et al. 2016). In particular, hearing birdsong may have psychological benefits and it is increasingly being used in various ways for this purpose (Winterman 2013).	See research agenda section for details.
Social capital and resilience benefits from collective action by citizens.	Participation in collective community action to achieve pest-free goals in urban areas (e.g. with home trapping and pest surveillance) is likely to build neighbourhood links and social capital. This activity could have direct psychosocial benefits and may allow for a more effective community response in emergency situations (such as natural disasters which are relatively common in New Zealand). Furthermore, 'social cohesion' is described as a potential benefit from increasing contact with nature in urbanised societies (Hartig et al. 2014).	As above.
Potentially reduced risk of existing zoonotic diseases.	In New Zealand, rats are infected with the following zoonotic pathogens: *Giardia* in *R. rattus* (McKenna 2009); *Cryptosporidium* in *R. rattus* (McKenna 2009); *Leptospira* in both *R. rattus* and *R. norvegicus* (Hathaway et al. 1981); and *Salmonella* in *R. norvegicus* (King 2005). *Rattus norvegicus* is known to be infected with *Toxoplasma gondii* internationally (King 2005), and so is likely to also be infected in New Zealand. It is spread to cats which prey on rats—a likely paratenic host (Strube et al. 2013). Toxoplasmosis commonly infects people in New Zealand (Zarkovic et al. 2007), and also harms New Zealand agriculture (by causing abortion in sheep). Murine typhus is another rat-borne disease (*R. rattus* and *R. norvegicus*) that seems currently restricted to the Waikato (Lim et al. 2016), but probably includes Hamilton City (Sekra et al. 2010). *Trichinella spiralis* infects *R. norvegicus* in New Zealand (McKenna 2009), but human infections (e.g. possibly via infected non-commercial pork) appear to be rare in New Zealand (Richardson et al. 2009). Despite all the above, the likely total disease burden from such rat-related zoonoses for New Zealand citizens from transmission within urban areas remains to be properly quantified and differentiated from other species (possums, mice and birds).	But there may be a counter issue with increased populations of house mice (*M. musculus*) if rats are eradicated[b] (e.g. mice in New Zealand are also commonly infected with *Giardia* [Marino et al. 1992]; and they can also carry *Leptospira* and *Salmonella* [King 2005]).
Protection of the microbiological quality of roof-collected water.	Roof-collected rainwater is the source of drinking water for some households on the urban fringes of cities, and is also promoted as a post-disaster resilience measure (e.g. in Wellington; Stewart et al. 2016). Such water is often of poor microbiological quality in New Zealand with some of the above named pathogens (e.g. *Salmonella*,	But rat-free urban areas may have more mice,[b] birds, frogs, and lizards —all of which can also adversely impact on the microbiological quality of roof-collected water (Stewart et al. 2016).

	Giardia and *Cryptosporidium*, as reviewed elsewhere; Stewart et al. 2016). Rat eradication may reduce some of these risks and so could protect the microbiological quality of such water for both regular use and in disaster situations.	
Protection against future zoonotic diseases that might reach New Zealand (e.g. associated with climate change).	Global climate change could lead to increased problems with pathogens due to changing distribution of predator species, arthropods and their associated pathogens (e.g. for rodents; Meerburg et al. 2009). This issue includes an increased risk of new diseases reaching and becoming established in New Zealand. If some of these involve rats as hosts (with rats being implicated in a long list of zoonotic diseases that are not endemic in New Zealand; Bonnefoy et al. 2008; Centers for Disease Control and Prevention 2010), then predator-free areas would be at lower risk. Furthermore, future bioweapons (e.g. weaponised plague) could potentially be spread by flea-infested rats (both *R. norvegicus* and *R. rattus* in New Zealand are infested with the plague transmitting flea *Xenopsylla cheopis*; King 2005). However, pneumonic plague is probably the form that is more likely to be weaponised (Wilson & Lush 2002), and this is spread from person-to-person.	But there may be a counter issue with mice which are relatively hard to eradicate.[b]
Reduced rat bites.	The New Zealand medical literature has reported on occasional cases of rat-bite fever, for example from *Streptobacillus moniliformis* (Sakalkale et al. 2007) and from *Spirillum minus* (Dow et al. 1992). However, the size of the rat-bite problem in New Zealand is very uncertain.	Marked under-reporting of rat bites to humans is described in the international literature (Bonnefoy et al. 2008).
Reduced damage to food supplies.	Rats can damage domestic gardens and can deplete and spoil food in houses. Rodents average 50 droppings per day (Drummond 2001) and contamination of food with faeces and urine is a major mechanism for generating food spoilage and therefore wastage.	Ibid regarding mice.[b] See research agenda section for details.
Reduced rat damage to building insulation and to building walls and roofing.	Insulation of housing benefits health (Howden-Chapman et al. 2007) and, given that it also saves heating costs and reduces greenhouse gases, is highly cost-beneficial in New Zealand (Chapman et al. 2009). But rats (especially *R. rattus*) can damage building insulation and hence reduce its insulating properties. Damaged roofing and other parts of buildings can result in leaks and holes, which can contribute to mould in houses (with mould being a risk factor for poor respiratory health; Sharpe et al. 2015).	Ibid regarding mice.[b]
Reduced fires associated with rat damage.	Rats (especially *R. rattus*) can gnaw through electrical wiring and so contribute to building and home fires, and also electrocution risks (Bonnefoy et al. 2008). No estimate of the size of this problem for New Zealand could be identified, but there are local reports of this cause of fires (Tranter 2016).	Ibid regarding mice.[b]

(*Continued*)

Table 1. Continued.

Potential health benefit	Possible mechanisms	Additional comments
Reduced mental health impacts of rat infestations.	A World Health Organization report has noted that: 'It should also be recognized that the awareness of rats and mice in and around a dwelling can be a source of anxiety for its occupants … Thus, the presence of rats and mice also affect mental health' (Bonnefoy et al. 2008, p. 400). Furthermore, the presence of hungry rats approaching people in New Zealand picnic areas appears to have nuisance impacts (Smallman 2016). The smell of dead rats inside walls/roofing is also a nuisance (Weekes 2017).	Ibid regarding mice.[b]
Reduced damage to water and sewerage system infrastructure.	Through their tunnelling activities rats (*R. norvegicus*) can damage sewer and water lines. Even minor damage may increase the risk of these systems failing when stressed by other events such as earthquakes (a regular occurrence in New Zealand).	The scale of this problem seems highly uncertain for New Zealand.
Reduced landslide and flooding risk.	Vegetation levels in urban areas may increase (slightly) with rat eradication as rats eat seeds and buds. This may help stabilise areas at risk of slips and reduce flooding risk via vegetation holding more rainfall and reducing the speed of run-off. The scientific literature does provide evidence that vegetation levels can reduce flood risk (discussed elsewhere; Wilson et al. 2015). Also of note is that burrowing by rats (*R. norvegicus*) can cause landslides on embankments as well as causing the collapse of banks of canals and ditches, leading to flooding (Bonnefoy et al. 2008). Flooding events cause drowning and other injuries to New Zealanders (Ministry of Civil Defence and Emergency Management 2007), can mobilise pathogens and contaminants, and have adverse psychosocial impacts as per a study of the Manawatu floods (Smith et al. 2011).	However, many other factors influence the risk of floods and landslides (e.g. the level of paved surfaces in urban areas and extensiveness of parks).
Enhanced carbon sequestration.	Potentially increased vegetation levels (as per the above) will tend to mean more carbon can be sequestered in urban vegetation.	This is relevant given that climate change is a major threat to global health.

[a]This list is still incomplete. For example, exposure to rat allergen is a known problem in housing in some countries (for asthma), but this issue has not been well studied in New Zealand.
[b]House mice populations might increase if rats are eradicated in urban areas (see the main text). Mice can be eradicated from islands, but this seems to be harder than eradicating rats (MacKay et al. 2011).

domesticus) (Cork et al. 1995). Nevertheless, the risks from these sources could plausibly be managed by interventions such as teaching children not to handle dead birds and more intensive efforts to keep birds off outdoor café tables etc. There may also be greater nuisance impacts from larger bird populations, for example from fouling caused by starlings and waterfowl. Growing populations of some native birds such as kākā may bring pleasure to citizens but can also have nuisance impacts (e.g. damage to trees; Charles & Linklater 2014).

It is plausible that increased rat eradication efforts using trapping and poisoning pose potential health risks to the public (e.g. as a result of hand injuries from certain types of traps). However, we have not identified any data on these risks from eradication efforts to date on New Zealand islands and in urban areas, and assume any impact from this to be rare.

A possible health research agenda

Priority areas for international research around rodent pests have been described (Capizzi et al. 2014), and there is still a need to expand studies on predator species biology in urban New Zealand (as per research on both *R. rattus* and *R. norvegicus*; Innes et al. 2016). But here we focus on potential research domains of relevance to human health in the New Zealand context. These can be summarised as follows:

- Quantification of the current health burden of rats in New Zealand urban areas could be attempted so that the size of the potential benefits of eradication could be better estimated (e.g. from the zoonoses, rat bites and mental health aspects). This work could also include where health and economic impacts may overlap, such as with: infrastructure damage; fire damage; damage to homes; damage to vegetable gardens; and damage to stored food (e.g. building on work in the UK; Battersby 2004) and from data on expenditure on rodent control (Bonnefoy et al. 2008). More specifically, the current 'natural experiment' of there being both inhabited rat-free islands in the Hauraki Gulf (Bassett et al. 2016) and other inhabited islands with rats, could be utilised for comparative research to investigate the scale of the rat problem in contemporary New Zealand. A supplementary approach could be to expand preliminary inventories of predators in specific cities, such as has been undertaken in Hamilton (Morgan et al. 2009).
- Potential benefits for increased social capital from community participation in local predator eradication could be studied. There are potential case study suburbs (e.g. Crofton Downs in Wellington City) where comparisons could be made with 'control' suburbs not involved in such collective rat control. Recent biosecurity efforts in New Zealand have actually successfully used community-based marketing approaches for the control of invasive insect species (Gamble 2016) and a recently published Biosecurity Direction statement specifically refers to a 'biosecurity team of 4.7 million—a collective effort across the country' (Ministry for Primary Industries 2016).
- Psychological benefits of more bird life in urban areas with rat control could be studied in the New Zealand context (e.g. at least in terms of it being perceived as beneficial by citizens). For example, residents with varying soundscapes associated with differing distances from urban fenced sanctuaries, could be surveyed. Similarly, for the 'natural experiment' of inhabited islands with and without rats as mentioned above.

Of course this preliminary list of research topics is tentative and could benefit from such further steps as: 1. further critique and prioritisation by expert panels (e.g. as done in other research areas in New Zealand; Wilson et al. 2012); 2. small pilot studies to assess feasibility and likely costs of larger projects; and 3. specific requests for research proposals by research funding agencies (e.g. the Health Research Council).

Conclusions

There appear to be many potential public health advantages of eradicating rats in urban areas of New Zealand. Perhaps the most important might be the psychosocial connections created by engaging communities to work together for a common goal. But, like the other potential benefits that we have identified, there is considerable uncertainty on the nature and size of these. Further research on this topic seems warranted so that such health benefits can be better quantified to inform decision-making around optimal investment in local predator-free initiatives that are currently occurring in New Zealand.

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