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Commentary

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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

Michael H. Parsons,[1,2,*] Peter B. Banks,[3] Michael A. Deutsch,[4] Robert F. Corrigan,[5] and Jason Munshi-South[6]

[1]Department of Biology, Hofstra University, 1000 Fulton Avenue, Hempstead, NY 11549, USA, [2]Department of Biological Sciences, Fordham University, 441 East Fordham Road, Bronx, NY 10458, USA, [3]School of Life and Environmental Sciences, University of Sydney, Sydney 2006, Australia, [4]Arrow Exterminating Company, Inc., 289 Broadway, Lynbrook, NY 11563, USA, [5]RMC Pest Management Consulting, Richmond, IN 47374, USA and [6]Department of Biological Sciences, The Louis Calder Center—Biological Field Station, Fordham University, Armonk, NY 10504, USA

*Corresponding author. E-mail: parsons.hmichael@gmail.com

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Abstract

City rats are among the most important but least-studied wildlife in urban environments. Their presence, compounded by the rate of human urbanization and effects of climate change, frequently bring potentially infectious organisms into contact with people and other wildlife. Urban rat control, however, is ineffective, largely because so little is known about their ecology. It is therefore, essential that we exploit new research avenues if we are to better understand and manage these risks. The hallmark of robust science includes replication at the level of the individual and urban landscape, allowing researchers to study behaviors and populations over time. However, unlike most wildlife, urban rats are confined to environments where there are numerous incentives to exterminate, but few reasons to study them. Thus, gaining access to rats presents an exceptional challenge for researchers. To address this problem, we first identified prevailing knowledge gaps in the literature and then used a five-step 'wicked problem' framework to define the issues, identify stakeholders, and systematically examine options for remediation. We discuss pest management professionals (PMPs) as an important conduit between private enterprise and the research community and suggest that businesses supporting research be rewarded through part-compensation, or allowances (credits) from the health department. This allows urban rats to be studied like all other ecological research subjects—in the field, while animals are alive. Appropriate incentives could enable scientists and PMPs to work together toward 'smart' ecologically based rodent management, hereby enhancing options for control while preparing for the challenges of continued urbanization.

Key words: disease transmission, ecologically based rodent management (EBRM), Norway rat, *Rattus norvegicus*, urbanization, wicked problems

Introduction

The present rate of human urbanization, compounded by climate change and inefficient rat control is leading to a proliferation of rodent-related risks (Harvell et al. 2002). From 2000 to 2030, the global human population is expected to grow by 2.2-billion, with 2.1 billion of this increase in urban areas (Cohen 2003). By 2050, almost 70% of all people will live in cities. These densely packed cities will inevitably proliferate the resources that support commensal or anthropo-dependent wildlife (Hulme-Beaman et al. 2016), especially rodents (Childs et al. 1998). In 1982, commensal rodents already cost the world's economy more than US$300 billion (Stenseth et al. 2003). These costs, however, were estimated from food losses and did not factor the impact on native or threatened wildlife (Banks and Hughes 2012; Smith, Dickman, and Banks 2016), fires of unknown origin (from gnawing of wires; Pimentel, Zuniga, and Morrison 2005), or the lack of medical assays to directly associate rat-caused diseases with their vectors (Corrigan 1997). By comparison, the number of deaths caused by air pollution, historically considered 'extreme', amount to US$225 billion (Bank 2016). Compounding this problem, climate forecasts suggest an increasing trend in terrestrial temperatures (McMichael, Woodruff, and Hales 2006), resulting in longer warm seasons and shorter cool seasons (Gray et al. 2009). These seasonal changes limit the cold-stress that influences the range and distribution of insects and arachnids (Bale and Hayward 2010). Taken together, these trends suggest rodents will be exposed to more people, while the arthropod fauna and infectious organisms they vector will persist longer (Lau et al. 2010). Conversely, humans are increasingly vectoring antimicrobial resistant microbes back into wildlife via rodents and rodent-predators (Vittecoq et al. 2016). The science behind mitigating these expenses and risks (e.g. efficient rat control and pathogen monitoring) has not progressed as fast as the wildlife are evolving (Himsworth et al. 2013b).

Traditional methods for rat control have been ineffective in the urban landscape, as evidenced by the low confidence rodent control experts have for poison control over the long-term (Himsworth et al. 2013a). Following decades of traditional approaches to Integrated Pest Management (IPM), metropolitan areas such as Baltimore, MD, USA, have as many rats today as they did in the 1950s— despite improvements in both income and human density (Easterbrook et al. 2005). These concerns have been recognized for over two decades. In 1996, the Board of Agriculture of the US-based National Research Council suggested that IPM plans were not faithful to their underlying principles (Singleton et al. 1999a). Three theoretical problems have been commonly cited. (1) As long as rat populations have access to food and harborage, they rapidly rebound from any void in their densities (Emlen, Stokes, and Winsor 1948). (2) By attempting to control rodents through poison baits, we place selective pressure on them to evolve counter-mechanisms such as neophobia or resistance (Damin-Pernik et al. 2016; Takács, Kowalski, and Gries 2016; Takeda et al. 2016). (3) Poisons are not species-specific and often end up bio-accumulating in the food chain. For instance, the anticoagulant brodifacoum persists up to 6 months in organ tissues and thus readily accumulates in non-target wildlife (Eason et al. 2001, Hoare and Hare 2006). Finally, there has been increasing trends in reticence by vocal members of the public who are against killing animals (Simberloff 2014). Clearly, our current strategy for defense against rodents is inefficient, if not a liability.

Singleton et al. (1999a) have suggested the principal reason for so much emphasis on poisons and so little attention given to management is because the latter approach requires an ecological knowledge-base that is not yet available due to the lack of science. Similarly, Makundi and Massawe (2011) have indicated that an essential strategy for improved rat control is to build scientific capacity. Yet, in the face of increasing population growth, at a time when more exotic vectors are carried across borders—researchers are finding deeply rooted knowledge gaps that persist generationally across the urban rat behavior and ecology literature (Banks and Hughes 2012; Feng and Himsworth 2014; Parsons et al. 2015; Cornwall 2016).

The early literature

Classic field studies in the 1940s attempted to address a few of these needs, but these studies employed methods that would likely be no longer feasible today due to ethical and logistical concerns. For instance, Davis, Emlen, and Stokes (1948) marked, released and recaptured dozens of wild rats in Baltimore, USA, to determine how far they were moving. However, the practice of releasing rodents in the city would be seen as risky by contemporary standards. His team later captured and released unfamiliar rats into wild colonies to monitor whether they survived or were expelled (Davis and Christian 1956). These studies would often result in immigrants being mauled in violent conflicts with resident animals. Calhoun (1948) mitigated these risks by capturing and maintaining urban rats in captivity. He was particularly interested in learning the point at which animals must either emigrate or attack each other when deprived of food, potentially valuable information. Yet captive animals rapidly lose their wild-type behaviors from both acclimation to new conditions and rapid genetic adaptation (Calhoun 1950). Furthermore, like the other classic experiments, one would also be hard-pressed to run such experiments within contemporary animal ethics guidelines (Sikes and Gannon 2011). As we move forward, ethical concerns will become even more prominent as rodents become linked to pro-social behaviors (e.g. the possible ability of rats to experience social empathy, contentment, remorse and sorrow (Bartal et al. 2014; Langford and de C Williams 2014; Sivaselvachandran et al. 2016).

Prominent knowledge gaps

Owing to logistical difficulties, there has been waning interest in studying urban rats. It has been over 40 years since Jackson (1972) called for behavioral-based rodent control applications, and 30 years since Macdonald (1985) suggested pheromones might be used to disrupt rat mating tactics—if only we understood how rats respond to scents in the urban environment. Since this time ecologists have identified a number of persistent knowledge gaps in the literature. For instance, new research is required to lend insights into rats' decision-making metrics, gender and age-dependent behaviors, changes in behavior over time (e.g. disambiguating learned behaviors) and factors driving social structure and conflict (Parsons et al. 2015). Additionally, research is badly needed regarding reproductive parameters (lactating females), seasonal behaviors and immigration patterns (Gracceva et al. 2014), and the degree to which rat-produced scents (pheromones) may influence their movements and behaviors (Macdonald, Mathews, and Berdoy 1999; Parsons et al. 2015, 2017). Others recommend multimodal techniques such as pup calls (Takács, Kowalski, and Gries 2016) and scents (Takács et al. 2016) to increase the trappability of rodents, while scant research has been done on monitoring the long-term impacts of rodent control programs (Panti-May et al. 2016). Finally, Walsh (2014) suggested more effort be made to identify and

block potential points of contact between rodents and humans. The growing body of literature on rat-transmitted diseases has been sufficiently reviewed (Himsworth et al. 2013b) and will not be repeated here. However, because rats serve as reservoir hosts for a number of pathogens (Costa et al. 2014), a broad call has been made by researchers for systematic, broad-scale disease monitoring of serum and arthropod borne disease vectored by rats (Firth et al. 2014) and the arthropods they carry (Frye et al. 2015; Puckett et al. 2016).

Addressing these long-standing questions is essential for ecologists to better understand and develop more effective ways to understand and control urban rats and the organisms they vector. This is especially true in the case of ecologically based rodent management solutions (EBRM: Singleton et al. 1999b, 2015). These 'smart tactics' have been successful in mitigating the impacts of agricultural rodents pests in Asia (Palis et al. 2015) and Africa (e.g. see Stenseth et al. 2001; Jacob et al. 2010), costing 75% less than (IPM) approaches, while using fewer chemicals (Heong et al. 2003) with greater effectiveness (Brown et al. 2006). One particular success was the eradication of the coypu (*Myocaster coypus*), an invasive semi-aquatic rodent in Britain (Singleton et al. 1999a). Using a long-term study of population ecology and associated costs, a comprehensive strategy for trapper deployments were pre-simulated with costs calculated, and incentives pre-prepared for stake-holders. The authors stated 'a complete solution of the problem was obtained in less than six years through integrating knowledge about the animal's biology and behavior with a well-organized control scheme with attractive incentives for trappers.' Other recent successes include fertility control by immuno-contraceptives (Jacob, Singleton, and Hinds 2008; Liu et al. 2013), however, there has been insufficient research on mechanisms to effectively delivery the active ingredients (Jacob, Singleton, and Hinds 2008). There are several other successes outlined by Singleton et al. (1999a), yet no EBRM approach has been applied to an urban system in the developed world. The potential for EBRM appears to be limited only by the lack of ecological information we have available.

It has been almost two decades since Colvin and Jackson (1999) lamented that public and scientific interest in rat control research was low, while the need continues to be at its greatest. Indeed, almost 70 years since the seminal papers in rat behavior (Calhoun 1948), we are almost bereft of knowledge about individual rat behaviors, and the variance of behaviors within the urban environment. A prominent veterinary scientist (Chelsea Himsworth, Vancouver Rat Project) has suggested we probably know more about polar bear ecology than that of city rats (Engelhaupt 2016). These striking gaps persist generationally because of the exceptional challenges of studying animals deemed as pests in the urban environment.

The 'wicked problem' of urban rat research

The general public will recognize media headlines promoting murophobia (fear of rats and mice) and excoriating rats that have ostensibly reached historic population sizes around the world. With so many rats to study, and the billions that rats cost the world's economy (Pimentel, Zuniga, and Morrison 2005), how could there possibly be insufficient research? There are social, historical and logistic reasons for this perplexing problem. The issue warrants use of the label 'wicked problem' (Head 2008), a term reserved for societal problems that are so complicated, they require social, ecological, and economic trade-offs in order to address the situation. Examples of 'wicked problems' may include environmental pollution or carnivore management in farmlands. These problems tend to historically reappear, have no right or wrong solutions, and involve stakeholders with widely differing definitions of success (Jentoft and Chuenpagdee 2009). A 'tame' problem, by comparison, is one where science alone can provide a solution (Kuhn 2012). The wickedness of the problem is related to the number of different stakeholders involved in the issue (Lach, Rayner, and Ingram 2005).

Social and historical dimensions

Rats are the 'pariahs' of the animal kingdom, linked with disease, poverty and fear, topics that society may wish to avoid. A 2016 report from the Department of Health and Mental Hygiene (DOHMH) noted that 23% of 7776 restaurants in Manhattan, USA showed signs of rat activity (Cuthbertson 2016). Each of those restaurants would have been embarrassed, cited for active rat signs (ARS) and/or faced fines or possible closure. Humans detest rats enough so that an association with rats causes more depression than does crime (German and Latkin 2016). The entities that harbor rats have strong incentive to quickly hide or exterminate rats. The property owners or managers rarely have reason to study rats, an option that requires rats to persist in areas they are unwanted, and only offers hope of a better solution in the long-run rather than immediate gratification of their demise. Unfortunately, this wicked problem has historically kept rat research from being taken seriously enough by the public, funding agencies or researchers.

The historical dimension is more complex. City inhabitants often believe they know more about rats than they actually do. Nearly all urban-dwellers see rats on a frequent basis and assume familiarity with these animals. However, due to the tendency to overgeneralize and the challenge of identifying individual rats, a few rats (the most brazen and risk-taking individuals) are responsible for most of our collective knowledge. For instance, the public comes into contact with a minority—the boldest and the most desperate rats—and rarely the 'silent majority' which consists of many more risk-averse animals (Kagel et al. 1986). These over-generalizations fueled by anecdote and popular social media, are becoming entrenched in lieu of ecological knowledge. Compounding this problem, a cursory search through the literature will identify thousands of research papers on rats. Rats are the most common models for human illness and metabolism. Further, studies of rat physiology and behavior are also well-represented. However, the vast majority of these studies are performed on lab rats due to their similar sensory acumen. The sheer volume of these papers may lend the false impression that we know more about urban rats than we truly do.

Logistic problems

If we are to avoid overgeneralizations, it is essential that we practice good science by replicating studies at the level of the individual, population, and urban landscape (i.e. city)—allowing us to understand variation within and between populations—and documenting changes in behavior of each animal and dynamics of each population over time. For instance, in our research we record behaviors of males, females and juveniles of assorted social ranks for as long as possible prior to extermination, in order to document their production of, and responses to, scents. Of particular importance is determining at what point, if any, individuals change their behaviors when

interacting with a scent from another individual (e.g. change their response due to habituation or sensitization to a stimulus). This is especially important if we are interested in managing animals via sensory-based tools (Parsons et al. 2017). An ecologist's primary tool for monitoring cryptic, or difficult to identify, animals is through tag and release programs (Cheatham and Allbritten 2015, Adimey et al. 2016). However, the researcher is usually aided by sparsely populated natural settings, where live captures are performed safely away from the public, and where remote-sensing equipment can be protected from vandalism or theft. In fact, wildlife research on introduced and other pest species in wild settings has led to major advances in our understanding of fundamental ecological processes (Sax et al. 2007). However, such research on urban wildlife poses major logistical challenges that impede research progress.

Indeed, having originated in Asia, urban rats have evolved over thousands of years to be commensal. Their migrations have followed our migrations (Puckett et al. 2016), and they are mostly restricted to human-built environments (Banks and Smith 2015). Thus, in the city, they inhabit artificial environments owned by multiple private entities (municipal commerce and dwellings). Here, the very act of locating a private area with a rat infestation, and then gaining entry to this area can be prohibitively difficult in the city. When municipal entities do have problems, they hire private companies that specialize in pest management, and do so under the guise of confidentiality. This explains why pest management professionals (PMPs) (Colvin and Jackson, 1999; Himsworth et al. 2013a), and potentially some health departments, may represent an untapped resource for research—if all involved parties have sufficient incentive.

The wicked problem framework

By its very nature, a wicked problem cannot be solved in a traditional, linear fashion (Lach, Rayner, and Ingram 2005; Head 2008; Jentoft and Chuenpagdee 2009). Rather it requires reassessment of former approaches for dealing with the problem. In the past, each researcher was independently burdened to find clever approaches to gain access to rats (sometimes 'reinventing the wheel'). For instance, researchers independently approach pest management companies and city agencies with various incentives in order to study rats before, or during, extermination. However, these successes have been limited because of non-declared mismatches in what each party expects from the relationship. Researchers recognize that a job deemed successful by the PMP (defined as 'quickly eradicating rats') would minimize research progress, while a poor/leisurely job by the PMP would be in the best interest of research. However, the economic burden of research would be borne by the customer who may be paying fines to local authorities such as the health department, in addition to costs for the pest management company. This conflict of interest may compromise research because the researcher, customer and PMP each have different definitions for success. This conflict-oriented dynamic begs a reassessment of the way we have been working with this problem.

As with any wicked problem, the economic burdens and social factors must first be defined and addressed. One first clearly defines the problem, identifies all stakeholders and costs to each, and defines as many incentives as possible for all parties involved, encouraging collaboration across as many borders (local, national, international) as possible (Head 2008; Jentoft and Chuenpagdee 2009).

Step #1. Identifying the problem

Knowledge of urban rat ecology is severely limited because researchers do not have regular, controlled access to municipal or privately owned infested properties.

Step #2. Identify all stakeholders

There are at least four groups of stakeholders. Level #1. Society, including the general public and elected/appointed officials—ramifications for society include compromised information on disease monitoring, transmission and rat control mechanisms. Level #2. Rat-infested property (customer) —in the absence of 'smart ecological tactics', the property manager's control options are limited to tools created through commercialism, minimally supported by science (e.g. hot peppers, ultrasonic shrills, scary predator shapes, scented garbage bags). Level #3. Pest management company and public health agencies—similar to Level #2, pest management companies would welcome new ecologically based 'tools in the toolkit' to support their current IPM approach (surveillance, exclusion, removal, baiting, monitoring). In particular, tools that influence microscale movements such as attractants [for improved trapping (Parsons et al. 2015) or enhanced delivery of immunocontraceptives (Jacob, Singleton, and Hinds 2008)] and efficacious repellents. Level #4. Researcher—the ecological researcher is limited in knowledge that is required to manage, control and monitor rats and their fauna. These include decision-making metrics of rats, circumstances that drive immigration/emigration and muricide (Calhoun 1948), preference for harborage, feeding aggregations and regional aggregations, proclivities to scents (Hurst and Beynon 2004) and habitat manipulation (Leirs, Lodal, and Knorr 2004; Makundi and Massawe 2011); all topics that need to be better understood to enable improved control and surveillance. There are no obvious mismatches or conflicts of interest between the four levels, except on a temporal scale. Society (Level #1) may not experience the impact of the problem as rapidly as the other three levels.

Step #3. Identify economic and social costs for each discrete entity

There are two strata of economic and social costs: (1) the direct costs of rat incidence and (2) indirect costs of not carrying out further research. For our purposes, we will focus on the costs of rat-incidence. Level #1. Society—the commensal rats are an economic burden worldwide (Pimentel, Zuniga, and Morrison 2005), strongly associated with depression, disease and fear (German and Latkin 2016). Level #2—rat infested property (customer). Properties may be cited, fined and/or closed if they have repeated incidence of ARS (active rodent signs), even when rats emanate from another owner's property. Level #3. Pest management company—pest service depends on the incidence of pests such as commensal rodents. Therefore, prevalence of rats may represent profit more so than costs unless the rats persist long after the extermination period. Level #4. Researchers—scientists depend on availability of rats to justify urban field sites. There are possible (at least temporary) conflicts of interest between Levels 1 and 2 with Levels 3 and 4. While all groups wish to temporarily control or even permanently eradicate rats, PMPs and scientists require rats in order to carry out their work.

Possible solutions

The principal means to solve wicked problems is to directly involve all stake-holders (Australian Public Service Commission 2012) by providing incentives to individuals or entities who would otherwise be disadvantaged if rewards were not offered,

in the case of rat control—by recognizing and removing any conflicts of interest between stakeholders. Each of the stakeholders, urban business and dwellings, the public health authorities, the general public the authorities try to protect, and the researchers tasked with filling the significant knowledge-gaps in the literature, should all have tangible incentive to work toward solving the problem.

As a case example, we previously designed a biological assay that allows us to acquire individual rat histories and record their behaviors over time (Parsons et al. 2016). Our research program seeks to fill several long-standing gaps in the literature, including how rat social structure influences the production of—and behavioral responses to—social scents (Macdonald, Mathews, and Berdoy 1999; Hurst and Beynon 2004). During the process, we investigate how rat scents influence other rats, and for how long. In order to identify urban field sites, we contacted Arrow Exterminating Company and requested research sites from their customers. We understood that select sites with large numbers of rats would allow us to carry out research in limited areas, while PMPs exterminated rats in other areas. To initiate this relationship, Arrow offered discounts for their services to the client. The process was partly effective. The researchers published pilot studies establishing new remote-sensing techniques for working with city rats (Parsons et al. 2015; Parsons et al. 2016) and in the process, developed a longer-term relationship with Arrow. The client, who remained anonymous within a completely confidential study, received discounted pest eradication. The pest management company ultimately benefited by being on the cutting-edge of new approaches to pest management. Unexpectedly, the pest management company also received additional benefits when their business was promoted through publications resulting from the study, and their business moved up in search engine results (Michael Deutsch, Pers. comm.) where future clients could locate them more easily.

While promising, this solution on its own is not a sustainable one for research. For instance, few client sites provide the opportunities for large eradication programs whereby rats can be researched in some areas, while exterminated in others. Furthermore, if we submit our case example through the framework of the 'wicked problem', we can identify several mismatches that may have limited our success. For the researcher, time is a commodity (30–45 days per study), while the PMP and client wish to eradicate at a much faster pace. Additionally, the researcher must be ready to commence studies as soon as a new site is identified. Managers or pest management companies are rarely willing to wait while researchers go through the typical process of science (ordering equipment or training students). This leads to step #4, considering broader and more tangible incentives for more individuals and entities across all four levels.

Step #4. Propose tangible incentives at each level

The previous case example may have been more successful had the client and PMPs had more incentive to wait longer for the extermination. This delay would require clear and obvious benefits to pest management companies. These include opportunities to be at the cutting edge of research with new and more efficacious management tools, while at the same time potentially increasing promotion of their businesses. The client must not only appreciate the long-term advantages of participating in research, but may receive immediate incentives through 'credits' provided by local authorities such as the health department. Pre-existing government programs already provide wildlife research permits; this system would require a similar approach aimed at providing permits to provide incentive for select urban entities (business or dwellings). For instance, one might offer an offset whereby rat violations are not incurred due to scientific use. In this case, forward thinking authorities might acknowledge that the value of research for long-term, social needs outweighs the risks of a prolonged period of extermination. The public authorities benefit by supporting long-term approaches that assist the needs of all stakeholders while ultimately empowering society for a future that includes continued urbanization on a scale not previously seen (Cohen 2003).

Step #5. Initiate collaboration across borders

The most important, but simplest, step for solving a wicked problem is to solicit help broadly and exchange experiences and solutions, while increasing replication. Rodents have traveled broadly to follow human settlements, and do not recognize legal geographic boundaries. Collaboration is necessary to help determine the maximum risks to the problem (Palis et al. 2011), as well as to encourage perspectives from the most diverse group of stakeholders possible (Potter, McClure, and Sellers 2010). Collaboration should also extend across as many borders as possible (O'Flynn 2013), particularly in areas that differ in their social norms. For instance, in parts of Asia, rats are appreciated as food sources (Meyer-Rochow, Megu, and Chakravorty 2015), and rats' presence is often not associated with breaking social norms. Some of our best insights are extended from Asian countries (Singleton et al. 1999a) where rodents are perceived as less taboo than in western countries.

From a scientific perspective, collaborations allow replication at the level of the urban landscape or city, where the *n* (sample size) is the number of cities in which rat populations are examined. This type of research effort would be coordinated by public health agencies, national/international funding agencies, and result in the most generalizable information for pest control in urban settings. It is currently unknown how much city rat populations will differ based on infrastructure, climate, and socioeconomics, but such questions are tractable. The field of Urban Ecology, in general, needs to move towards multi-city replication to be a more predictive and robust science.

Risk mitigation

There is an important caveat to this approach. Researchers have a duty-of-care to the welfare of society to not put them at risk while carrying out research. One PMP stated that, if he learned researchers were working with rats in areas under his purview (Darren Van Steenwyk, Clark Pest, CA, USA), then he would be obligated to remove the rats. Researchers must exercise precaution and due diligence anytime we consider a new research site, especially if we are purposefully allowing rats to survive beyond a time when they would otherwise be exterminated. Part of the solution may be to mitigate any immediate threats posed by rats, perhaps controlling numbers below a critical damage/threat threshold to allow study at the same time as managing the worst impacts. One important avenue might be to focus on uninhabited, city-owned properties that are infested.

Conclusions

The most difficult challenge of urban rat research is finding suitable research sites (e.g. municipal businesses and dwellings) to obtain access to rats long enough to generate robust science. This problem is directly responsible for some prominent knowledge gaps that continue to accrue in the rat ecological literature.

However, due to the importance of these gaps, and the long-term limitations of contemporary rodent control, we may persist at our own peril if we do not consider new approaches to urban rat research. Exploring new management tools, underwriting 'smart' ecological tactics (EBRM) and systematic pathogen monitoring are each essential as humans densely inhabit cities where rats thrive—despite our best efforts to control them. From a theoretical perspective, urban rat research provides an under-appreciated opportunity to investigate evolutionary processes in rapidly changing environments (Hulme-Beaman et al. 2016).

We have identified some of the most important knowledge gaps, as well as rationale for the surprising lack of research, and why the public (and many scientists) is unaware of this problem. We then took the first step in addressing the problem, by defining the issues within the framework of the 'wicked problem', and then identified principal stake-holders while considering their highly divergent definitions of success. Thus, we have also noted conflicts of interest on the temporal level, whereby society and private businesses may not recognize the value of rat research as expediently as public health officials and researchers.

Currently, the principal means to work in the municipal environment is to identify suitable areas where there are rats, where researchers can store equipment apart from vandalism and theft, and live-trap and release animals over a period of weeks rather than days. One mechanism to support this approach is to incentivize private business or dwellings that own the properties. To enable this, state-certified PMPs may be empowered by local authorities to provide discounts for increased business while the business received credits for participation, researchers benefit by running full-scale robust research, while society benefits through risk management of new disease and associations with animals that contribute to fear and depression. All levels of the social, economic and ecological dimensions may then receive benefit.

This also opens up the PMPs to use their routine work to develop important data. For instance, rat counts are currently reported through a 311 system (less efficient) and subject to error—often with people conflating rats as mice (Walsh 2014), whereas rat counts from PMPs would be far more accurate, and the rat-catch logs that many PMPs complete would be indispensable for researchers. It is important to note that this possible solution is only intended to initiate the broader conversation, rather than to promote a singular focused solution. Our case example was only partly effective, yet each opportunity for research that arises may be beneficial, profitable and offer new discovery. Most importantly, we hope to entice others to share their experiences and successes for the benefit of empowering new urban rat research.

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