Rodent biology and ecologically based rodent management (EBRM)–25 years of progress through promoting multidisciplinary research

Article *in* Integrative Zoology · December 2023

DOI: 10.1111/1749-4877.12792

CITATIONS
0

READS
79

4 authors:

Grant R Singleton
Natural Resources Institute University of Greenwich
306 PUBLICATIONS **10,968** CITATIONS
SEE PROFILE

Lyn A. Hinds
The Commonwealth Scientific and Industrial Research Organisation
178 PUBLICATIONS **3,998** CITATIONS
SEE PROFILE

Rhodes Makundi
Sokoine University of Agriculture (SUA)
242 PUBLICATIONS **3,843** CITATIONS
SEE PROFILE

Steven R Belmain
University of Greenwich
210 PUBLICATIONS **5,276** CITATIONS
SEE PROFILE

Integrative Zoology 2023; 0: 1–6 doi: 10.1111/1749-4877.12792

INTEGRATIVE ZOOLOGY

EDITORIAL

Rodent biology and ecologically based rodent management (EBRM)—25 years of progress through promoting multidisciplinary research

"During rodent outbreak years in eastern Africa, locally, more than 80% of the potential harvest may be lost, but even in non-outbreak periods, rodents cause chronic damage to crops…. The pest rodent story in Africa involves several species embedded in a broad and variable landscape with highly variable densities." (Leirs *et al.* 2010).

Rodents make up approximately 42% of mammalian species and their domestication has provided many scholarly and health benefits (Singleton & Krebs 2007). However, rodents are better known as frightful pests, a scourge of human populations. Their presence in urban, rural, and natural environments causes major negative economic, social, health, and biodiversity impacts. Interestingly, less than 10% of rodent species are involved in these negative impacts at a global scale (Singleton *et al.* 2007) and less than 5% of rodent species in Africa (Makundi *et al.* 1999). Nevertheless, the impacts are of major concern to both smallholder farmers in developing countries (Leirs 2002; Massawe *et al.* 2011; Singleton *et al.* 2021) and broad-scale farmers in developed countries (Brown 2007), and the effects on health and food security are concerning (Meerburg *et al.* 2009a,b).

The quote above together with the broad framework of impacts of rodents provide an apposite framework for this special issue of papers from the 7th International Conference on Rodent Biology and Management (ICRBM) that was held in July 2022 in Arusha, Tanzania. The conference was hosted by the Africa Centre of Excellence for Innovative Rodent Pest Management and Biosensor Technology Development (ACE II–IRPM and BTD), and the Institute of Pest Management, Sokoine University of Agriculture, Morogoro, Tanzania. The 1st ICRBM was held in Beijing, China, in October 1998, so this special issue comes 25 years since this conference and the associated book "*Ecologically-Based Management of Rodent Pests*" (Singleton *et al.* 1999).

The 7th ICRBM was a hybrid conference with live and virtual presentations. In total, there were 107 oral presentations (44% of students) and 35 posters (70% of students). The presentations were drawn from Africa, Europe, Asia, Australia/Oceania, North America, and South America. In this brief introduction to the special issue, we set the scene by making special reference to the developments since the previous conference (6th ICRBM) held in Potsdam, Germany, in 2018.

Not unexpected was the strong African flavor of the conference presentations with one session devoted to rodent biology and biodiversity in African highlands and mountains. An African influence was noticeable in each of the six different symposia, which was especially pleasing, as was the high percentage of presentations by young African scientists. Twenty-five years on, the interest and energy for studies on the biology and management of rodents is still strong! The conference had eight plenary presentations, and all were of excellent quality. Five of the papers in this special issue are associated with these plenaries: Bujnoch *et al.* 2023, Innes *et al.* 2023, Massei *et al.* 2023, Schramm *et al.* 2023, and Taylor *et al.* 2023. We will come back to these papers.

What has been the change of focus since the 6th ICRBM? First, the focal species changed considerably. In Potsdam, the four main species (in order) covered in presentations were the bank vole (*Myodes glareolus*), the Norway rat (*Rattus norvegicus*), the field vole (*Microtus agrestis*), and the house mouse (*Mus musculus*). In Arusha, the main species were the multimammate rat (*Mastomys natalensis*), the black rat (*Rattus rattus*), the house mouse, and the typical striped grass mouse (*Lemniscomys striatus*). The increase in focus on the black

rat and the house mouse, and to some degree the multimammate rat, reflects a considerably stronger coverage of rodent diseases, especially zoonoses, and developments in research on rodent biodiversity, including evolutionary relationships and impacts of rodents on conservation biology. The high prevalence of papers on the multimammate rat and the typical striped grass mouse also reflects a stronger African focus.

RE-EMERGENCE OF INTEREST IN FERTILITY CONTROL

Another interesting development was the resurgence in research on fertility control of rodents. Prospects for fertility control, particularly around the development of self-disseminating, genetically modified species-specific viruses expressing reproductive proteins had a high profile at the 2nd ICRBM in Canberra, Australia, in 2003, but in subsequent conferences, the interest had eased. Resurgence in the topic likely reflects reduced community tolerance for the ongoing widespread application of rodenticides (safety issues, non-target effects, animal welfare impacts etc.) and heightened public recognition of the need for alternative methods of rodent management. The plenary presentation by Giovanna Massei (Botstiber Institute for Wildlife Fertility Control, Department of Environment and Geography, University of York, UK) presented a comprehensive framework for researchers and their stakeholders considering developing fertility control for their species of interest. From the outset, a strong understanding of the pathway to potential success is essential—the selection of the fertility control agent is simply the beginning of a long, resource-intensive, and iterative program of laboratory, enclosure, and multi-year field studies. In parallel, regulatory and governance issues as well as public acceptance must be a consistent part of the conversation (Massei *et al.* 2023). Two papers focused more specifically on recent results assessing the effects of synthetic steroids, either a combination of synthetic estrogen (quinestrol) and progesterone (EP-1), or quinestrol alone. Research on these steroids for rodent fertility control was pioneered in China by Professor Zhibin Zhang (host of the 1st ICRBM in Beijing) (see recent review by Jacoblinnert *et al.* 2022b) and has led to research on EP-1 in other rodent species in Africa, Indonesia, and South Asia. In this volume, Liu *et al.* (2023a) showed that the effects of EP-1 on the Pacific rat, *Rattus exulans*, were greatest in males, but that the dose and palatability of food baits containing the steroids require further development before field studies on islands would be feasible. Liu J. *et al.*'s results reflect the need to directly assess the response of a species to a control agent that has been tested in several other species (Jacoblinnert *et al.* 2022; Massei *et al.* 2023). Sidhu and Singla (2023) showed that the consumption of quinestrol alone for 10 days by male lesser bandicoot rats, *Bandicota bengalensis*, in the laboratory reduced their fertility for more than 30 days, with partial reversibility by 60 days. A small-scale field assessment yielded promising results but further, more broad-scale studies integrating the use of rodenticide and then fertility control are required.

RODENT ZOONOSES—A ONE-HEALTH APPROACH

The increased interest in research on rodent-borne zoonoses was supported by a strong emphasis on "One Health" moving from theory to practice. Most of the 20 papers in this symposium included aspects of disease ecology, epidemiology, human social sciences, and environmental health. The plenary presentation by Sandra Telfer (School of Biological Sciences, University of Aberdeen, Scotland) on "Rodent-borne zoonoses: Drivers of infection and exposure in linked rodent-human populations" was exemplary in the One Health approach. She covered drivers of rodent-borne infections and factors that influence human exposure, including a variety of sociocultural issues that increase risks of rodent–human interactions. A case study on human plague in Madagascar (see Valès *et al.* 2020; Rahelinirina 2021 for more details) provided a nice overview of the potential effectiveness of a One Health approach. Related to this case study, research on the breeding dynamics of *R. rattus* in agricultural systems in the Central Highlands of Madagascar demonstrated the importance of detailed knowledge of the biology and ecology of your pest rodent species in various habitats (from fields to households) and during different seasons before applying management (Scobie *et al.* 2023). Such an understanding provides insights into the best times to apply EBRM and avoids unintended consequences that may arise if there are density-dependent and density-independent responses in population dynamics.

In the disease arena, there were seven studies in urban parks, slums, or rural villages, whereas in 2018, there were only two studies reported. Rodent studies in urban slums are particularly challenging, and it is pleasing that there appears to be an increased effort in this field (Costa *et al.* 2021; Awonyi *et al.* 2022).

Research on rodent control in the context of improved disease prevention was considered in the paper "The

combined effect of bromadiolone and ivermectin (iBr) in controlling both rodents and their fleas" (Liu *et al.* 2023b), which highlighted that the use of rodenticides on their own could exacerbate the release of ectoparasites transmitting diseases such as plague or typhus. By combining a rodenticide with an antiparasitic drug that also has insecticidal properties (ivermectin), it was shown that the number of fleas could be reduced at the same time as reducing rodent populations. This means that potentially fewer infected ectoparasites are released into the environment, which could cause a disease spill-over event. Another study on rodent zoonoses in this special issue examined the association between the composition of rodent communities in four different regions of Germany on the population dynamics of bank voles and the subsequent seroprevalence of *Puumala orthohantavirus*. Bank voles are important reservoirs for the transmission of this hantavirus to humans. The 4-year study revealed that competition from other small rodents could reduce the population abundance of bank voles and hence reduce the likelihood of human infections (Bujnoch *et al.* 2023).

CONSERVATION, ADAPTATION, TAXONOMY, PHYSIOLOGY, AND BEHAVIOR

Although most rodent management around the world attempts to reduce the impacts of rodents on agricultural production, disease prevention, and to limit damage to infrastructure, John Innes (Manaaki Whenua—Landcare Research, Hamilton, New Zealand) provided the conference with an overview of New Zealand's attempt to eradicate invasive rodents to conserve the country's endemic wildlife. His plenary on "Rodent management in Aotearoa New Zealand: Approaches and challenges to landscape-scale control" highlighted that unmanaged invasive mammalian pests, including rodents, cause ongoing declines of unique indigenous species that evolved with no native terrestrial mammal predators. A wide range of tools have been implemented including large-scale fencing to keep rats out, primarily the black rat, *R. rattus*, once they have been eliminated through poisoning and trapping campaigns. These ring-fenced ecosanctuaries have prevented most reinvasions after eradicating the pest mammals, and the areas of land protected by such fencing are expected to increase until New Zealand has been cleared of the invasive rat species (Innes *et al.* 2023).

In his plenary, Peter Taylor (Department of Zoology and Entomology and Afromontane Research Unit, University of the Free State, South Africa) and his co-authors used micro-computed tomography x-ray to investigate adaptations of rodent sensory systems to elevational gradient, and this provided insights into variations in the endocranial volumes of North American cricetid mice and African murid rodents (Taylor *et al.* 2023). These studies showed highland rodent species had smaller endocranial volumes than lower-elevation rodents and that the brain size response to elevation gradient had a stronger genetic basis but a weaker environmental effect. Thus, it was explicitly suggested that selection favored reduced volume of the brain at high elevation implying a reduction in the costs of growing and ongoing maintenance of a large brain.

A fascinating plenary that reviewed recent developments in the taxonomy of rodents associated with the increased use of genomic tools was presented by Josef Bryja (Institute of Vertebrate Biology of the Czech Academy of Sciences, Czech Republic). He provided an African focus on issues that are raised with the use of genomics to classify rodent species. African rodent taxonomy lags behind other continents. This was a timely presentation of the advantages and pitfalls of a genomic approach. Josef highlighted that rodent species are important in defining the biodiversity of regions and that more needs to be done on rodent taxonomy, particularly in potential biodiversity hotspots.

Another plenary presented by Denise Dearing (School of Biological Sciences, University of Utah, Salt Lake City, USA), considered the topic of "Eating and not dying: Strategies for dealing with dietary toxins." Specialist herbivores have evolved detoxification systems to process the high concentrations of secondary compounds in their diet. In a cross-over experiment, two closely related species of *Neotoma* (wood rats), one an obligate specialist and the other a generalist forager, were fed diets of two different juniper species. The authors showed that obligate specialists have evolved unique and efficient biotransformation mechanisms for dealing with secondary plant compounds (Schramm *et al.* 2023).

Recent developments to harness the natural olfactory abilities of the African giant pouched rat (*Cricetomys ansorgei*) were presented in a plenary by Cindy Fast who is Head of Training and Behavioral Research at APOPO HeroRATs, a Belgian NGO based at Sokoine University of Agriculture in Tanzania. Their research has demonstrated that giant pouched rats can be trained to use their noses to sniff out landmines, deadly diseases like tuberculosis, and other pathogens. These behavioral traits can be exploited further through training the rats to clean up the environment by identifying contaminated soils, discovering illegally trafficked wildlife, and finding humans

trapped in collapsed building structures following natural disasters like earthquakes. Trained giant pouched rats are currently working in Mozambique, Angola, and Cambodia to help clear land mines, and they are involved in the clinical detection of tuberculosis in samples collected from humans in Tanzania and Ethiopia.

LONG-TERM FIELD STUDIES—TURNING A HABIT INTO EXCELLENT SCIENCE

"Excellence is an art won by training and habituation..… We are what we repeatedly do. Excellence, then, is not an act but a habit." Aristotle (approximately 335 BC).

Long-term population studies (greater than 10 years) of rodent species provide an important foundation for understanding key factors that limit rodent populations as well as insights into how pest species could be effectively managed (Leirs *et al.* 2023). Christian Imholt (Julius Kühn-Institute, Federal Research Centre for Cultivated Plants, Rodent Research, Münster, Germany) in his plenary "Long-term rodent monitoring in Germany: History, predictions and synergies" provided an excellent overview of the value of long-term studies on the common vole, *Microtus arvalis*, to develop regional forecast models for population outbreaks. This work is built on previous studies of long-term data sets to understand population outbreaks of field voles (*M. agrestis*) and bank voles (*M. glareolus*) in German forests (Imholt *et al.* 2017). His talk covered the effects of different land-use intensities on rodent community dynamics, how these dynamics affect disease transmission within rodent populations (see Bujnoch *et al.* 2023), and environmental drivers of rodent populations. Together, such long-term studies increased the predictive power of rodent damage to crops and also human infection risk of rodent zoonoses.

Calfayan *et al.* (2023) provide a fascinating study of environmental drivers of the population dynamics of the red hocicudo mouse (*Oxymycterus rufus*) based on a 30-year data set collected in pampas grasslands northeast of Buenos Aires, Argentina. There were marked increases in the population abundance and habitat use by the red hocicudo mouse. Of particular interest from a pest management perspective was the spread of the mouse from riparian habitats to agricultural land. The authors considered the possible impact of climate change, but not surprisingly, it was local climatic effects rather than national climatic trends associated with global climate change that appeared to influence the population dynamics of the mouse.

Moving from pampas grasslands to the boreal forests above the Arctic Circle in the Yukon, Canada, Krebs *et al.* (2023) provide insights on multi-annual changes in the population dynamics of the red-backed vole *Clethrionomys rutilus*, based on a staggering 50-year long-term data series. The authors provide tantalizing findings; there has been a consistent 3- to 4-year cycle in population dynamics, and also in the most recent 25 years of the study, the peak population density has increased from 8 ha^{-1} (from 1976 to 2000) to 18 ha^{-1}. Food supply determines the rate of summer growth of the vole population. This then raises the fascinating questions of whether climate change could be influencing the food supply to which the voles respond, or whether there are small mammals that do not fare as well under increased temperature, such as the artic ground squirrel (Werner *et al.* 2015), which preys on voles. Then there is the question of what causes the population cycles? Fifty years of data on the population dynamics of a small rodent is indisputably rare. We direct you to this fascinating paper to find out more.

FURTHER RECOGNITION OF EXCELLENCE

One of the most rewarding and pleasurable activities at the end of ICRBM conferences is the recognition of members of our rodent research community. The recognized researchers have provided long-term scientific leadership and research excellence often across several disciplines within their own countries and internationally. At the 7th ICRBM, well-deserved recognition was given to the research and leadership contributions of Professors Rhodes Makundi and Apia Massawe from the African Center of Excellence for Innovative Rodent Pest Management and Biosensor Technology Development Institute of Pest Management, Sokoine University of Agriculture, Morogoro, Tanzania, and Professor Steven Belmain from the Natural Resources Institute, University of Greenwich, United Kingdom.

We look forward to presentations on further global developments on rodent biology and management at the 8th ICRBM, which will be held in Canberra, Australia, in September 2025.

Grant R. SINGLETON
Natural Resources Institute, University of Greenwich, Kent, UK

Lyn A. HINDS
CSIRO Health and Biosecurity, Canberra, ACT, Australia

Rhodes MAKUNDI
African Centre of Excellence for Innovative Rodent Pest Management and Biosensor Technology Development, Sokoine University of Agriculture, Morogoro, Tanzania and Institute of Pest Management, Sokoine University of Agriculture, Morogoro, Tanzania

Steven R. BELMAIN
Natural Resources Institute, University of Greenwich, Kent, UK

Correspondence: Lyn A. Hinds, CSIRO Health and Biosecurity, GPO Box 1700, Canberra, ACT 2601, Australia.
Email: Lyn.Hinds@csiro.au

REFERENCES

Awoniyi AM, Venegas-Vargas C, Souza FN *et al.* (2022). Population dynamics of synanthropic rodents after a chemical and infrastructural intervention in an urban low-income community. *Scientific Reports* **12**, 10109.

Brown PR (2007). Reducing the impact of feral house mice in agricultural ecosystems. In: Lunney D, Eby P, Hutchings P, Burgin S, eds. *Pest or Guest: The Zoology of Overabundance*. Royal Zoological Society of New South Wales, Mosman, NSW, Australia, pp. 8–15.

Bujnoch FM, Reil D, Drewes S *et al.* (2023). Small mammal community composition impacts bank vole (*Clethrionomys glareolus*) population dynamics and associated seroprevalence of *Puumala orthohantavirus*. *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12782

Calfayan LM, Cavia R, Fraschina J, Guidobono JS, Gorosito IL, Busch M (2023). Environmental drivers of long-term variations in the abundance of the red hocicudo mouse (*Oxymycterus rufus*) in Pampas agroecosystems. *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12721

Costa F, Zeppelini CG, Ribeiro GS *et al*. (2021). Household rat infestation in urban slum populations: Development and validation of a predictive score for leptospirosis. *PLoS Neglected Tropical Diseases* **15**, e0009154.

Imholt C, Reil D, Plašil P, Rödiger K, Jacob J (2017). Long-term population patterns of rodents and associated damage in German forestry. *Pest Management Science* **73**, 332–40.

Innes JG, Norbury G, Samaniego A, Walker S, Wilson DJ (2023). Rodent management in Aotearoa New Zealand: Approaches and challenges to landscape-scale control. *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12719

Jacoblinnert K, Jacob J, Zhang Z, Hinds LA (2022). The status of fertility control for rodents-recent achievements and future directions. *Integrative Zoology* **17**, 964–80.

Krebs CJ, Kenney AJ, Gilbert BS, Boonstra R (2023). Long-term monitoring of cycles in *Clethrionomys rutilus* in the Yukon boreal forest. *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12718

Leirs H (2002). Management of rodents in crops: The Pied Piper and his orchestra. In: Singleton GR, Hinds LA, Krebs CJ, Spratt DM, eds. *Rats, Mice and People: Rodent Biology and Management*. ACIAR, Canberra, Australia, pp. 183–90.

Leirs H, Kirkpatrick L, Sluydts V *et al.* (2023). Twenty-nine years of continuous monthly capture-mark-recapture data of multimammate mice (*Mastomys natalensis*) in Morogoro, Tanzania. *Scientific Data* **10**, 798.

Leirs H, Sluydts V, Makundi R (2010). Rodent outbreaks in sub-Saharan Africa. In: Singleton GR, Belmain SR, Brown PR, Hardy B, eds. *Rodent Outbreaks—Ecology and Impacts*. International Rice Research Institute, Los Baños, Philippines, pp. 269–80.

Liu J, Tu F, Liu M, Wang J, Zhang Z (2023a). Antifertility effects of EP-1 (quinestrol and levonorgestrel) on Pacific rats (*Rattus exulans*). *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12774

Liu M, Wan X, Liu W, Ma, X, Zhang Z (2023b). The combined effect of bromadiolone and ivermectin (iBr) in controlling both rodents and their fleas. *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12762

Makundi RH, Oguge NO, Mwanjabe PS (1999). Rodent pest management in East Africa. In: Singleton GR, Hinds L, Leirs H, Zhang Z, eds. *Ecologically-Based Management of Rodent Pests*. ACIAR, Canberra, Australia, pp. 460–76.

Massawe WA, Mulungu LS, Makundi RH *et al*. (2011). Spatial and temporal population dynamics of rodents in three geographically different regions in Africa: Implication for ecologically based rodent management. *African Journal of Zoology* **46**, 393–405.

Massei G, Jacob J, Hinds LA (2023). Developing fertility control for rodents: a framework for researchers and practitioners. *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12727

Meerburg BG, Singleton GR, Kijlstra A (2009b). Rodent-borne diseases and their risks for public health. *Critical Reviews in Microbiology* **35**, 221–70.

Meerburg BG, Singleton GR, Leirs H (2009a). The year of the rat ends – time to fight hunger! *Pest Management Science* **65**, 351–52.

Rahelinirina S, Scobie K, Ramasindrazana B *et al*. (2021). Rodent control to fight plague: Field assessment of methods based on rat density reduction. *Integrative Zoology* **16**, 868–85.

Schramm K, Skopec M, Dearing D (2023). Metabolomic evidence of independent biotransformation pathways for terpenes in two specialist mammalian herbivores (genus *Neotoma*). *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12734

Scobie K, Rahelinirina S, Soarimalala V *et al*. (2023). Reproductive ecology of the black rat (*Rattus rattus*) in Madagascar: The influence of density-dependent and -independent effects. *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12750

Sidhu A, Singla N (2023). Antifertility effects of quinestrol in male lesser bandicoot rat, *Bandicota bengalensis* and potential in managing rodent population under field conditions. *Integrative Zoology* **19**, https://doi.org/10.1111/1749-4877.12733

Singleton GR, Brown PR, Jacob J, Aplin KP, Sudarmaji (2007). Unwanted and unintended effects of culling: A case for ecologically-based rodent management. *Integrative Zoology* **2**, 247–59.

Singleton GR, Hinds LA, Leirs H, Zhang Z (1999). *Ecologically-Based Rodent Management*. ACIAR Monograph 59; ACIAR, Canberra, 494 p.

Singleton GR, Krebs CJ (2007). The secret world of wild mice. In: JG Fox, C Newcomer, A Smith, S Barthold, F Quimby, M Davidsson, eds. *The Mouse in Biomedical Research—History, Genetics and Wild Mice*, vol. 1. 2nd edn. Elsevier, San Diego, CA, pp. 25–51.

Singleton GR, Lorica RP, Htwe NM, Stuart AM (2021). Rodent management and cereal production in Asia: Balancing food security and conservation. *Pest Management Science* **77**, 4249–61.

Taylor PJ, Nengovhela A, Denys C, Scott GR, Ivy CM (2023). Adaptation in brain structure, respiratory and olfactory structures across environmental gradients in African and North American muroid rodents. *Integrative Zoology* **19**, https://dor.org/10.1111/1749-4877.12788

Vallès X, Stenseth NC, Demeure C *et al*. (2020). Human plague: An old scourge that needs new answers. *PLoS Neglected Tropical Diseases* **14**, e0008251.

Werner JR, Krebs CJ, Donker SA, Boonstra R, Sheriff MJ (2015). Arctic ground squirrel population collapse in the boreal forests of the Southern Yukon. *Wildlife Research* **42**, 176–84.

Cite this article as:

Singleton GR, Hinds LA, Makundi R, Belmain SR (2023). Rodent biology and ecologically based rodent management (EBRM)—25 years of progress through promoting multidisciplinary research. *Integrative Zoology* **00,** 1–6. https://doi.org/10.1111/1749-4877.12792