

## Editorial

### **Rodent biology and ecologically-based rodent management (EBRM) – 25 years of progress through promoting multi-disciplinary research**

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**Running title:** Rodent biology and ecologically-based rodent management

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*“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 7<sup>th</sup> 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 & BTD), and the Institute of Pest Management, Sokoine University of Agriculture, Morogoro, Tanzania. The 1<sup>st</sup> 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 7<sup>th</sup> ICRBM was a hybrid conference with live and virtual presentations. In total there were 107 oral presentations (44% students) and 35 posters (70% 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 (6<sup>th</sup> ICRBM) held in Potsdam, Germany, in 2018.

Not unexpected was the strong African flavour to 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 6<sup>th</sup> 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 reflect 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 2<sup>nd</sup> 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 This issue). Two papers focussed more specifically on recent results assessing the effects of synthetic steroids, either a combination of synthetic oestrogen (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 1<sup>st</sup> ICRBM in Beijing) (see recent review by Jacoblinnert *et al.* 2022) and has led to research on EP-1 in other rodent species in Africa, Indonesia, and South Asia. In this volume, Liu Jing *et al.* (2023) showed that the effects of EP-1 on the Pacific rat, *Rattus exulans*, was greatest in

males, but that dose and palatability of food baits containing the steroids requires 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 This issue) showed that 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 ZONOSSES – 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 socio-cultural issues that increased 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 This issue). Such an understanding provides insights for 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 (Awonyi *et al.* 2022; Costa *et al.* 2021).

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 Ming *et al.* 2023 This issue), 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 that 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 This issue).

## **CONSERVATION, ADAPTATION, TAXONOMY, PHYSIOLOGY AND BEHAVIOUR**

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 increasing the areas of land protected by such fencing is expected to increase until New Zealand has been cleared of the invasive rat species (Innes *et al.* 2023 This issue).

In his plenary Peter Taylor (Department of Zoology & Entomology & AfriMontane 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 This issue). 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 favoured 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 of 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 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 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, 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 the secondary plant compounds (Schramm *et al.* 2023 This issue).

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 & 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 behavioural 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, *Microtis arvalis*, to develop regional forecast models for population outbreaks. This work 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 effects of different land-use intensities on rodent community dynamics, how these dynamics affect disease transmission within rodent populations (see Bujnoch *et al.* 2023 This issue), 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) (This issue) 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) (This issue) provide insights on multi-annual changes in the population dynamics of the red backed vole *Clethrionomys rutilus*, based on a staggering 50-years long-term data series. The authors provide tantalising 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 (from 1976 to 2000) to 18/ha. 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 food supply to which the voles respond, or whether there are small mammals that do not fair as well under increased temperature such as the arctic ground squirrel (Werner *et al.* 2015), which preys on voles. And then there is the question as to what causes the population cycles? Fifty years of data on the populations 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 recognised researchers

have provided long term scientific leadership and research excellence often across several disciplines within their own countries and internationally. At the 7<sup>th</sup> 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 Steve 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 8<sup>th</sup> ICRBM, which will be held in Canberra, Australia, in September 2025.

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