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A meeting of mice and men: rodent impacts on food security, human diseases and wildlife conservation; ecosystem benefits; fascinating biological models

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Rodents attract attention often for their negative impacts on the well-being of people as competitors for our staple foods such as cereals (Singleton *et al*. 2010) or as carriers of human diseases (Meerburg *et al*. 2009). They also are pilloried for their impacts on the conservation of wildlife, especially birds and reptiles that nest or dwell on the ground on oceanic islands (Russell and Holmes 2015) or larger land masses (Ruscoe and Pech 2010). However, rodents should be viewed in a much broader context. They make up some 42% of mammalian species and less than 10% of species pose significant impacts on humans in agricultural or urban settings (Singleton *et al*. 2007), and, indeed, many play important roles in ecosystems (Dickman 1999; Werner *et al*. 2015). It is a common interest in the breadth of research questions on rodents that leads to a gathering of international biologists every 4 years. The 5th International Conference of Rodent Biology and Management (ICRBM) held in Zhengzhou, China, in August 2014, was attended by 166 participants from 25 countries. Some 190 presentations and posters were presented on both basic and applied research of rodents in the fields of ecology, behaviour, reproductive physiology, taxonomy and evolution, parasitology (micro- and macro), rodent–plant interactions, community ecology, ecosystem services, genes and neuro-science, chemical communication, and their negative impacts on conservation, food security, and health. There were also symposia on squirrels, subterranean rodents and urban rodents. The 1st ICRBM was held in Beijing in 1998 and the conference has developed considerably in its breadth of topics in the intervening 16 years (see http://www.icrbm.org/previous-icrbms). A selection of papers were published from the 1st ICRBM (Singleton *et al*. 1999), all were peer reviewed and published from the 2nd ICRBM (Singleton *et al*. 2003), and a selection of papers were published from the 3rd ICRBM (Jacob *et al*. 2007) and the 4th ICRBM (Hinds and Singleton 2011). The current issue provides a selection of papers associated with the 5th ICRBM and has an interesting spread, with four being focused on Africa, two on Europe, four on Asia, one on Australia, and one on Canada. To highlight the cosmopolitan mix of contributions, two of the African papers have lead authors from Belgium and New Zealand, and three from Asia have lead authors from France and the United Kingdom.

The conference in Zhengzhou had eight plenary presentations, all of outstanding merit. An interesting development was that the respective plenary presentations by Joel Brown, Jana Eccard and Peter Banks had a strong focus on behavioural ecology, particularly on how rodents manage their 'night to night' activities, given the risks associated with predators, and intra-specific competition for resources. The risks associated with this 'landscape of fear' can have major effects on the spacing behaviour of animals and on their genetic fitness. This is an area of research that has progressed remarkably (see Bedoya-Perez *et al*. 2013 for review) since the seminal paper on giving up densities by Joel Brown (1988). The other areas of behaviour that were covered were the fascinating study of individual behavioural 'personalities' of rodents (Gracceva *et al*. 2014) and how knowledge of the social interactions that influence the use of the landscape by different species could provide a mechanism for using native rodent species to manage a population of the invasive black rat, *Rattus rattus*, in an urban–bushland interface (Banks and Smith 2015). Two other papers in this issue examine behaviour of rodents. One looks at the impacts of permanent marking on movement patterns of the multi-mammate rat, *Mastomys natalensis*, drawing on 17 years of capture–mark–release data (Borremans *et al*. 2015). The second paper examines the functional traits that influence the scatter hoarding by six species of rodents of tree seeds, including those

of wild apricot, walnut, peach and oak trees, in the Donglingshan Mountains in China (Zhang *et al*. 2015).

The presentations on the behaviour of rodents highlighted the progression of theoretical behavioural ecology as an important tool in our armoury to manage the conservation, disease and agricultural impacts of rodent pests. What is lacking is a theoretical framework on how to effectively integrate behaviour into ecologically based approaches for rodent management.

Another interesting area of growth is research on the macro- and micro-parasites of rodents. In 1998, there were only a few papers on rodent diseases and a plenary session at the 1st ICRBM could not be filled. In 2014, there were two plenary sessions on rodent diseases, and to highlight the recent interest, especially zoonoses, Meerburg emphasised in his presentation that their recent review on rodent-borne diseases (Meerburg *et al*. 2009) has been cited 98 times (Web of Science, http://apps.webofknowledge.com/full_record.do?product=UA&search_mode=GeneralSearch&qid=1&SID=X2IrMCwujxbu75zOvJ3&page=2&doc=14, 3 May 2015). The Black rat and the associated species in the *R. rattus* complex (Aplin *et al*. 2011; Pagès *et al*. 2013) have generated a great deal of interest over the past decade as carriers of disease. The paper by Blasdell *et al.* (2015) provides an overview of recent research in South-east Asia on rodent-borne diseases. The review provides a nice summary of some key research findings from a recent project on Community Ecology of Rodents and their Pathogens (CERoPath) in changing environments in Southeast Asia. Their studies have provided a clearer picture of which diseases occur in what species and where. They conclude that lowland irrigated rice agro-ecosystems present the greatest risks of zoonoses. The authors also highlight the challenge of understanding rodent–disease interactions when there are cryptic host species. They promote the use of DNA barcoding for clearer identification of host species. Another study reported in this issue examined rodent–flea interactions in the Rift Valley in eastern Africa where there are foci of human plague, *Yersinia pestis*. The findings highlighted a fascinatingly complex situation involving multifaceted interactions among 13 species of rodents and 26 species of flea (Makundi *et al*. 2015). The advances in understanding rodent–disease interactions are encouraging. Nevertheless, there is one glaring gap in our knowledge; so little is known about the economic impact of rodent zoonoses on rural communities. This is particularly of concern in poor smallholder communities in Asia, where farm sizes are generally less than 1 ha and there are high likelihoods of interactions between rodents and households.

Gregg Howald presented a plenary on the impact of rodents on avifauna on Pacific islands and provided interesting case studies of efforts to eradicate rodent species, principally the black rat. He highlighted the need for more data pre- and post-removal, to provide objective evidence on the conservation value of removal programs. He argued that such data are essential for guiding investments in future eradication programs. In this issue, Ruffino *et al*. (2015) report that 63% of studies ($n = 152$) on rodent impacts on islands involve the black rat. They also report a remarkable increase in studies on rodent impacts on avifauna on islands since 2000. However, they argue that too few studies have collected appropriate long-term data to assess population-level estimates of rodent impacts. They also propose that a better understanding of rodent–avifauna interactions could be gleaned if more effort was devoted to studies on islands where bird species have evolved to co-exist with 'invasive' rodent species.

Ecological approaches to rodent management in agricultural systems

This issue contains four markedly different studies on the impacts of rodent pests and the associated ecological studies conducted to develop a foundation for management strategies. Two studies were undertaken to develop a better understanding of the factors governing population dynamics of rodent pests in cropping systems. The first examined rodent populations in the highlands of Ethiopia where wheat, barley and teff are the main crops (Meheretu *et al*. 2015), and the other was in a rice–coconut lowland system in the Philippines (Stuart *et al*. 2015). Both studies highlighted the importance of understanding the timing and length of the breeding season, and the extent of nesting habitat of the principal pest species when developing management approaches. The third study focused on post-harvest losses to smallholder rice farmers in lowland habitats in Bangladesh and Myanmar (Belmain *et al*. 2015). This study is of particular note because there have been precious few studies of the impacts of rodents on grain stores in developing countries (John 2014). The report of rice losses up to 17% and the ability to substantially reduce losses via coordinated community trapping and environmental management indicate that more research is urgently needed on post-harvest management of rodent pests.

A fourth paper provides a far-ranging review of factors that influence the recovery of rodent populations following population collapse (Hein and Jacob 2015). Their focus was primarily on pest species, and they examined mechanisms, time and rate to recovery of populations. They conclude that patterns of re-population are similar after natural and man-made population collapse and that rapid repopulation by r-strategist, small rodent pest species requires large-scale management action.

Anthropogenic and climatic stresses

The plenary address by Thomas Cornulier on the dampening of small-mammal population cycles in Europe provided a linkage of strong data and good models to evaluate the causes of this observed dampening. Further observations and experiments on this wide-scale collapse of rodent numbers in Europe are essential. The collapse of arctic ground squirrels in the boreal forests of the Yukon is discussed by Werner *et al*. (2015) as a paradigm of the sudden collapse of a common rodent species and the detective work needed to determine the causes of the collapse, being likely due to predation and tying into the problem of a landscape of fear generated by climate change. The Serengeti is well known for its large-mammal populations and community dynamics, whereas data on the 40 species of rodents is much less abundant. Byrom *et al*. (2015) describe how habitat loss in agro-ecosystems surrounding the Serengeti reduces rodent diversity, and make recommendations for mitigating the loss of rare or specialised rodents in this important ecosystem.

The overall message conveyed by many papers in this meeting is that the combination of climate change and anthropogenic stressors will cause many suspected and unsuspected changes to the world's rodents, and these in turn have the potential to affect human livelihoods. Proactive mitigation, continued monitoring and replicated field experiments are essential components for future research and management.

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