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Impacts of rodent outbreaks on food security in Asia

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Abstract. Since 2007, a spate of rodent outbreaks has led to severe food shortages in Asia, affecting highly vulnerable and food-insecure families. Little has been documented about wildlife-management issues associated with these outbreaks. The aims of the present study were to synthesise what we know about rodent outbreaks in Asia, and identify important gaps in our knowledge. We compiled information from agencies of the United Nations, non-government organisations and the authors. The authors conducted site visits to areas affected by outbreaks of rodent populations, and convened an international conference in October 2009 to share knowledge. Bamboo masting is clearly implicated as the primary cause of the rodent-population outbreaks that led to severe food shortages in Mizoram (India), Chin State (Myanmar), Chittagong Hill Tracts (Bangladesh) and upland provinces of Lao PDR. In Laos, emergency food assistance was required for 85 000–145 000 people. In 2009, high rodent losses occurred also in lowland irrigated rice-based systems in the Philippines, Myanmar and Indonesia, not related to bamboo masting. Asynchronous or aseasonal growing of rice crops was a common element in these outbreaks. In the Ayeyarwaddy delta, Myanmar, 2.6 million rats were collected in 3 months through community activities; this outbreak appeared to be related to an extreme climatic event, Cyclone Nargis. There are two key features of rodent outbreaks that make the future uncertain. First, climate change and extreme climatic events will increase impacts of rodents on agricultural production. Second, there is food-security pressure in some countries to grow three crops per year. Increased cropping intensity will reduce fallow periods and create ideal conditions for rodents to breed nearly continuously. Implications of the research are as follows: (i) rodent outbreaks are a consequence of enhanced reproduction and natural mortality is of minor importance, particularly with rapidly increasing populations; therefore, we need to focus more on methods for disrupting reproduction; (ii) a stronger understanding of the ecology of pest species and community dynamics will enable ecologically sustainable management; (iii) we need landscape approaches that focus on crop synchrony, and timely coordinated community action to manage pest species and conserve desirable species; and (iv) a simple monitoring system can help implement ecologically based rodent management.

Rodents – a continuing menace to food security

> 'Nature has sent the rats to our homesteads by thousands, and farmers are being eaten off the face of the earth by them.'

This quote from H. C. Bartley (1911) appeared in his book *Studies in the art of rat catching*. After a career spent catching rats and rabbits in England for a living he wrote this book as a reference for teaching this *profession* at schools. The book was dedicated to the Headmasters of Eton, Harrow, Westminster and Rugby. A modern version of this book is urgently needed in Asia, where rodents are continuing to cause both chronic and acute impacts to the livelihoods of smallholder farmers (Singleton 2003; Palis *et al*. 2008; Jacob *et al*., in press), and there is a dearth of people with the skills to assist farmers manage the problem (Singleton 2003). These farmers typically have holdings of less than 1.5 ha in the intensive lowland agro-ecosystems (Maclean *et al*. 2002) or 5–10 ha of marginal cropping lands in the sloping uplands (Brown and Khamphoukeo 2010). In Asia, more than 640 million people suffer from chronic hunger (FAO 2009) and the majority rely on agriculture for their subsistence.

Globally, in countries where under-nourishment is prevalent, the total cereal production is almost 1.4 billion tonnes. A recent analysis indicated that what rodents eat and spoil globally could feed ~280 million people in developing countries for a year (Meerburg *et al*. 2009*a*). In Asia, rodents cause, on average, annual pre-harvest losses of 5–10% in rice crops (Singleton 2003). However, occasional outbreaks of rodent populations can lead to severe crop losses, particularly in upland environments where such losses can lead to major food shortages (Aplin *et al*. 2006; Normile 2010).

Not included in these estimates of rodent impacts are the substantial economic and human hardships associated with debilitating rodent-borne diseases (Meerburg *et al*. 2009*b*). Diseases such as leptospirosis, murine typhus and scrub typhus are readily treated if diagnosed early. However, in many Asian and Pacific countries diagnosis is often too late and the death rate in some instances is greater than for higher-profile illnesses such as HIV-AIDS (Table 1). In 2008 in Fiji,

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Table 1. Cases and deaths from HIV-AIDS and leptospirosis in the Philippines

Source: Philippines Integrated Disease Surveillance, National Epidemiology Center, Department of Health, Philippines, and http://www.doh.gov.ph/node/2204 (accessed January 2010)

Disease	2008		Jan–Oct 2009	
	Cases	Deaths	Cases	Deaths
HIV-AIDS	528	4	629	1
Leptospirosis	832	41	2777	161

HIV-AIDS prevalence per 1000 women among 15–24-year-old pregnant women was 0.02, whereas leptospirosis prevalence was 3.8 (http://www.health.gov.fj/-annual-reports.html, accessed January 2010). One development of particular note is the linkage of an outbreak of rodent zoonoses with an unusual weather event. Manila, Philippines, experienced equivalent to their monthly rainfall in September in just 18 h on 26 September 2009. This led to vast quantities of stagnant water over the ensuing month and resulted in an outbreak of leptospirosis. In Manila alone, from 1 to 25 October, there were more than 2000 human cases that led to 192 deaths. The surge in cases of leptospirosis in 2009 was contrary to a marked decline in cases reported in the Philippines since 1999 (http://www.gideononline.com/2009/10/17/leptospirosis-in-the-philippines/, accessed January 2010). Global warming has led to an increase in extreme weather events and the 10 countries most affected by weather-related loss events (e.g. storms, floods, cyclones, heatwaves) from 1990 to 2008 are developing countries (Harmeling 2009), where our knowledge of, and ability to respond to, rodent zoonoses are the weakest. The impact of climate change on the outbreaks of rodent species is uncertain; however, the evidence for other pests shows that climate change will most likely increase the severity and impact of pests on agricultural production systems (Easterling *et al*. 2007). We believe there is sufficient evidence to suggest that rodent impacts are likely to be exacerbated directly and indirectly by global climate change. More research is urgently needed to test this contention.

History has provided sobering reminders of the seriousness of rodent outbreaks. One example is bamboo-masting events in Bangladesh, India, Myanmar and Lao PDR, which have led to massive population outbreaks of rodents, causing severe famine (e.g. Schiller *et al*. 1999). Some 50 years ago in the Mizo Hills of India, a severe regional famine led to civil unrest and catalysed a 20-year civil war against central Indian authority. This eventually led to a change in the government and the creation of Mizoram State in 1986 (Nag 1999).

A second example in recent times is the food crisis in 2008 when the price of cereal staples tripled, and farmers could ill-afford losses of 5–15% caused by rodents (Meerburg *et al*. 2009*a*). This seriousness of the food-security situation is further highlighted by projections to 2050, which indicate that cereal production has to increase globally by 50–70% to simply meet the current population-growth trajectory (FAO 2009).

All this is happening within a framework of increasing agricultural production. There is a nexus between increasing agricultural production and the loss of valuable land to urbanisation and factories, which means that more food needs to be produced from ever-reducing agricultural land resources. The strategies to overcome this is through greater yields of existing crops, and also through increasing the intensity of cropping, so that two crops are grown per year instead of one, or three crops instead of two. There is also a recommendation by the Government of Indonesia in their 2020 vision for rice production to have four rice crops per year in some circumstances (Departemen Pertanian 2008). This increased cropping intensity will reduce fallow periods and create ideal conditions for rodents to breed nearly continuously because of the strong association between the breeding of rodent pest species and the availability of rice crops (Leung *et al*. 1999; Singleton *et al*. 2004).

Calls for more effort by wildlife biologists on rodent management have appeared periodically (Prakash 1988; Buckle and Smith 1994; Singleton *et al*. 1999), and international donor agencies such as the Australian Centre for International Agricultural Research have provided sustained support for research on a couple of the major rodent pest species in two South-east Asian countries. However, donor interest is wavering at a time when rodents have caused startling impacts on smallholder agricultural communities in Asia. We will report briefly on some of these developments, the challenges and a way forward.

A significant issue is that in Africa, Australia, Europe, and a range of countries in Asia and the Pacific, the proportion of rodent species that are significant agricultural pests is <10% of all species (see Singleton *et al*. 2007 for review). The majority of rodent species have little adverse impact on human interests, and in some cases, are in danger of extinction as a result of human activities. This makes it more important to better understand the rodent species causing the problems and to put in place appropriate management that does not harm sympatric rodent species of conservation concern.

Recent severe outbreaks of rodent populations

Upland communities

Since 2005, severe food shortages due to rodent outbreaks have been reported in Mizoram (India), Chin State (Myanmar), the Chittagong Hill Tract region (Bangladesh), and Oudomxay, Luangnamtha, Xayabury and Luang Prabang provinces (Lao PDR). These outbreaks appear to be linked to bamboo-masting events and have affected highly vulnerable and food-insecure families (World Food Program 2009; Normile 2010).

Mizoram was the only government that made preparations to try and avoid widespread crop losses and subsequent food shortages by implementing a multi-million dollar 5-year 'Bamboo flowering and famine combat scheme' (BAFFACOS) http://mizoram.nic.in/dept/planning/Baffacos/Action%20Plan%20on%20Baffacos.pdf (accessed April 2010). The masting event is now over in Mizoram and although government support was triggered relatively early, many people still suffered devastating losses to their crops (K. Aplin, pers. obs.; government report http://www.cag.gov.in/html/cag_reports/mizoram/rep_2009/civil_chap1.pdf, accessed April 2010). The government report indicated that BAFFACOS funds were distributed in an *ad hoc* manner, did not address adequately the livelihoods of affected farmers, monitoring was lax, and there was no evaluation of the program.

As of January 2010, the masting event is still continuing in Bangladesh and Myanmar. Consequences of the current bamboo masting are not well managed in the Chittagong Hill Tracts (CHT) of Bangladesh and in the western states of Myanmar (Chin, Rakhine States), where food insecurity as a result of these outbreaks has been well documented (Belmain *et al*. 2008; Hellen Keller International 2008*a*, 2008*b*; Zohir 2008). More rodent outbreaks are expected in parts of the CHT in 2010 because new areas of bamboo flowering occurred in late 2009 (S. Belmain, pers. obs.) and there are 6–9 months between bamboo flowering and a high build-up in rodent numbers.

In Myanmar, the FAO and the World Food Program of the United Nations reported in January 2009 (ftp://ftp.fao.org/docrep/fao/011/ai478e/ai478e00.pdf, accessed April 2010) that farmers in Chin State, who mainly practice shifting cultivation, experienced serious losses of upland crops because of rat damage. Some farmers reported 100% loss and others could harvest only 10% of their crops.

Lao PDR also experienced rodent outbreaks and food-security issues caused by bamboo masting of different species of bamboo that flower on different cycles than the *Melocanna* species found across the Mizo–CHT–Chin border area. A World Food Program (2009) report highlighted that this rodent outbreak was the worst in 20 years and identified that emergency food assistance was required for 85 000–145 000 people. For these people, rice stocks were gone, wild food was being depleted and people were eating only one or two poor-quality meals a day.

Lowland communities

Lowland irrigated rice crops in Vietnam and Indonesia have chronic losses due to rodents. For example, in West Java annual losses to rice crops are typically between 10 and 15% (Singleton *et al*. 2005). In addition, from 1995 to 2008, there were 2 years when there were rodent outbreaks in West Java. One outbreak, in 1998, was associated with an El Niño year; losses were ~22% and the population outbreak was due to the intermittent rains requiring a release of irrigation water over 12 weeks rather than 6 weeks, leading to a marked asynchrony of the rice crops. The second outbreak in 2001 led to losses of 25–31% and was associated with too much rain just after the monsoon crop had been harvested, leading to a volunteer rice crop. In both instances, the outbreaks were due to an extension of the availability of high-quality food that lengthened the breeding season of rats (Sudarmaji *et al*. 2010).

In 2009, high rodent losses were reported also in the Philippines, Myanmar and south-eastern Sulawesi (Indonesia); these were not related to bamboo flowering (G. R. Singleton, unpubl. data). There is little previous documentation of the factors leading to these population outbreaks, their impacts, and the successes and failures of management actions.

In the Philippines, the lowland-rice cropping systems have losses to rodents that are patchily distributed. In recent years, on the main island of Luzon there have been regular reports of losses in restricted areas of 15–30%, although generally in different areas each year. The evidence from outbreaks in Albay and Legaspi in 2009 suggests that high crop losses are associated with asynchrony of rice cropping that again lengthens the main breeding season of rats (G. R. Singleton and N. M. Htwe, unpubl. report).

A recent widespread and severe outbreak in the irrigated lowlands of the Ayeyarwaddy delta in Myanmar appears to be related to the delayed effects of Cyclone Nargis. Nargis hit the delta in May 2008. The timing of planting of rice crops after the cyclone varied markedly from place to place, leading to asynchronous and aseasonal planting. Some 2.6 million rats were collected through community action in five townships (700 villages) from July to September 2009. One suggestion is that the cyclone led to the death of many predators of rodents, which then led to an outbreak of rodent populations. This is supposition with no field data. Indeed, there is little evidence that predators can impose a major effect on the population dynamics of rodents in agricultural landscapes (e.g. Sinclair *et al*. 1990; Vibe-Petersen *et al*. 2006). A more likely hypothesis is that the asynchrony of planting extended significantly the main breeding season of the main pest species, *Bandicota bengalensis*; however, this needs to be validated.

Ecologically based rodent management – a cause for hope

In the 1960s, a wide range of chemical rodenticides became available on the global market. Research then focussed on the toxicity of the poisons, on making them more palatable to the pests and less attractive to non-target species. Ecological studies of rodent pest species were an exception. In the mid-1990s, attention turned back to ecology because of the development of resistance and increased tolerance of rodents to rodenticides, public concerns over their humaneness, and an increased awareness of ecological and human-health issues associated with their use. Ecologically based rodent management (EBRM) has now taken centre stage in Asia, Australia and eastern Africa (Stenseth *et al*. 2003; Brown *et al*. 2004; Singleton *et al*. 2004, 2007; Sluydts *et al*. 2009). For the lowlands in Vietnam and Indonesia, we are more certain about what interventions are required (Singleton *et al*. 2005; Brown *et al*. 2006; Jacob *et al*. 2010), although there are major differences between the rodent species found in each country and their impacts on cropping systems (Singleton 2003). Therefore, we urgently need to extend EBRM to other countries and also build capacity in all countries across Asia and in Africa.

At last, there is now scientific agreement about the linkages between bamboo masting, rodent outbreaks and famine (Normile 2010; references reported here). In some areas, all the bamboo masts in one year, whereas in other years, the masting event takes 2–3 years to complete, prolonging the famine. It is not clear whether this difference in synchrony is related to different strains of the same bamboo species. The rodent species involved in the outbreaks have been identified. However, there are still many gaps in our knowledge of the breeding biology and dynamics of these species, and we know little of their movement patterns and over what scale they move (Belmain *et al*. 2008). The current strategy has been disaster management through providing food aid. There are extreme difficulties in assessing the prevalence of outbreaks and their impacts because of the remoteness of most affected communities. Therefore, the response is likely to be far smaller than the need. More research is needed, particularly long-term studies on the basic ecology and dynamics of rodent populations. If we obtain a stronger understanding of the relationship between rice-cropping systems and the timing of bamboo seed production, then it may be possible to harvest crops before they are destroyed by rats.

We have reached four tentative conclusions that have implications for rodent management in Asia. These are listed below, and should be considered as hypotheses for further testing on agricultural systems in Asia.

(1) Rodent outbreaks are a consequence of enhanced reproduction, and natural mortality is of minor importance, particularly in rapidly increasing populations. Changes in cropping intensity that provide high-quality food (e.g. rice crops at the generative stage) for longer periods of time per year will lead to an increase in the frequency of rodent-population outbreaks because females will breed for longer each year. This conclusion supports approaches to agricultural management that focus on the factors limiting reproductive output for rodents in agricultural systems and the development of methods of disrupting reproduction in pest species (see Cowan and Hinds 2008).
(2) A stronger understanding of the ecology of pest species and community dynamics will enable ecologically sustainable management. This will result in the development of appropriate management strategies that minimise damage to crops, reduce the reliance on rodenticides, and lead to better economic and social outcomes for farmers.
(3) Rodent damage to agricultural production is a landscape problem that can be managed only by a widespread landscape approach that focuses on crop synchrony, and timely and coordinated community actions. The tools of landscape ecology should be deployed for these problems. The success of community-based approaches to managing rodents in the lowland intensive-agricultural systems needs to be promoted (see Palis *et al*. 2008). In addition, the management of biodiversity in agricultural landscapes must be oriented to the conservation of desirable species and the reduction in the abundance of pests (e.g. Ong and Rickart 2008; Stuart *et al*. 2008). The patchy structure of native and agricultural land can alleviate or enhance crop damage by pests.
(4) A simple monitoring program that can serve as an early warming system for EBRM (see Kenney *et al*. 2003) and a decision-support system for local farmers that flows from the monitoring data should be developed for rodents, as it has been developed for insect control. Many useful systems for managing crop pests are already in place for farmers (e.g. Heong and Hardy 2009, and references therein); simple systems need to be developed for rodents.

Concluding remarks

Currently, there are at least eight major rodent pest species in the lowland rice-based ecosystems of South-east Asia. During the past decade, there has been good progress in strengthening our knowledge of the ecology of many of these lowland pest species. This has enabled the development of effective EBRM practices for chronic rodent problems and, to a lesser extent, for sporadic acute rodent outbreaks. In the uplands, our knowledge of which species cause problems and their ecology, is limited. Our options for intervention will depend on the ecology of the pest species.

There are two potentially significant external drivers that are likely to exacerbate the severity and impact of rodents on agricultural production at a global level and at a regional Asian context. First, climate change and extreme climatic events are likely to increase the impacts of rodents on agricultural production and on the health of poor smallholder communities. Second, there is political and food-security pressure in some countries to grow three crops per year (where only one or two were grown previously) and reduce fallow periods, thus creating conditions ideal for rodents to breed nearly continuously throughout the year. This will lead to increased frequency of rodent outbreaks unless we strengthen our investment in training and research on rodent biology and management in developing countries.

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