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Ecologically-Based Rodent Management 15 Years On: A Pathway to Sustainable Agricultural Production

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ABSTRACT: Food security is a major concern at a global level. The impacts of rodents pre- and post-harvest are legendary, as too are their incursions on the day-to-day lives of people. As vertebrate pest managers we need to move beyond the rhetoric and provide effective management approaches. If on an annual basis we can reduce by 5% the food that rodents eat and spoil globally, then this could save 70 million tons of grain. From the 1960s to the mid 1990s the dominant paradigm for rodent control was the widespread use of chemical rodenticides. Rodent biologists were forced to rethink this reliance on chemical rodenticides because of human health and safety issues, lack of efficacy, detrimental effects on non-target species, and the development of resistance to the anticoagulant rodenticides. Some 15 years ago, ecologically-based rodent management (EBRM) was formally described based on adaptive research conducted to manage irruptions of mouse populations in Australia and rats in Southeast Asia. EBRM builds on foundation work conducted in the 1940s and 1950s by ecologists such as Elton, Chitty, and Davis; research that was marginalized with the advent of cheap and effective rodenticides. EBRM has had a significant impact since its formulation: it has been formally adopted by the governments of Indonesia and Vietnam as their national policy for rodent management in agricultural systems, and is the main rodent management paradigm in at least 30 countries. A challenge is to address not only chronic rodent problems in agricultural landscapes but also the acute outbreaks that cause tremendous impacts on rural communities. An important component of EBRM has been the incorporation of sociological research. I provide a retrospective view of what has been achieved by ecologists and sociologists over the past 15 years, identify countries where progress has been promising, and then provide thoughts on some promising global research challenges.

KEY WORDS: agriculture, Asia, ecology, ecologically-based management, food security, rice, rodents, rodenticides

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IMPACT OF RODENTS ON FOOD SECURITY

"For every 10 rows of rice that I plant, I plant seven for my family, two for the rats and one for the birds"

Filipino farmer's acceptance of the impacts of rodents

The food crisis in 2008, when the price of staples such as rice tripled, highlighted that we could no longer tolerate the losses caused by rodents to our cereal crops. In developing countries in Asia, the chronic and acute impacts of rodents have a major impact on food security, particularly on the chronic poor (earning less than US\$1.25 per day) (Singleton et al. 2010a). And the situation is becoming more challenging, with the number of chronically undernourished people rising from 842 million in the early 1990s to more than 1 billion in 2009 (FAO 2009). What does this mean for vertebrate pest managers? Globally, in countries where under-nourishment is prevalent, the total cereal production is almost 1.4 billion tons. In Asia alone, rodents cause, on average, annual pre-harvest losses in rice crops of 5-10% (Singleton 2003). Occasional outbreaks of rodent populations escalate these losses substantially in the areas affected, and for millions of small landholders (<2 ha of crop land) losses can be greater than 50% leading to major food shortages (Aplin et al. 2006, Singleton et al. 2010b). If we focus on undernourished people, then an annual reduction by 5% of the food that rodents eat and spoil globally could save 70 million tons of grain and feed approximately 280 million people for a year (Meerburg et al. 2009b).

There are common challenges in developed and developing countries associated with maintaining global

food security (Witmer and Singleton 2011). Firstly, there is an aging population of farmers because the youth prefer to pursue other vocations opened up through better education opportunities, or they simply prefer the job opportunities offered by cities. This in turn has driven up the cost of agricultural labor. Secondly, there are substantial annual losses of prime agricultural land to urban housing and industrial development. In 2013, in Indonesia alone, some 50,000 ha of agricultural land were lost. Thirdly, agricultural production is experiencing growing competition for water from cities and industry; irrigated rice crops in Asia are grown on 50% of the land used to grow rice yet they provide 75% of production. The loss of irrigation water for the production of irrigated staple crops is a major concern. Finally, there is a suite of other factors, including climate change; increased monocultures that lead to reductions in biodiversity and an associated loss in the level of ecosystem services they provide; and the use of prime agricultural land for biofuel production. These challenges further emphasize that we cannot tolerate the losses caused by rodents consuming and spoiling food – both in the field and post harvest.

Note that we know little about the magnitude of rodent losses to cereals post harvest in recent time. A few studies were published in 2013 (Brown et al. 2013, Mdangi et al. 2013) but prior to these, there had been little published since the early 1970s. Post harvest losses will not be considered further in this paper.

DIVERSITY OF RODENTS: FOES AND FRIENDS

Rodents are a diverse group of species – there are about 2,277 species and the numbers are increasing each

year (Wilson and Reeder 2005). To many people, the only good rat is a dead rat. Yet if not for research on laboratory rats and mice, many medical advances would not have occurred, and many pharmaceutical and cosmetic products would not be available. Moreover, globally only 5-10% of rodent species are significant agricultural pests (Stenseth et al. 2003, Singleton et al. 2007). The non-pest species need to be protected, because most play an important role in the ecosystem. Indiscriminant use of poisons in agricultural landscapes will place at risk the beneficial rodents.

PESTICIDES: OPTIONS AND CONCERNS

Much has been written about the benefits and usage options for chemical rodenticides (see Buckle and Smith 2014). The use of second-generation anticoagulants has been particularly effective in eliminating introduced rodent species on small islands where they pose significant conservation risks (Howald et al. 2007), particularly on New Zealand islands (Towns and Broome 2003). There is, however, growing concerns about the safety of second-generation anticoagulants in both mainland Europe and the USA. In the early 2000s, there were in the vicinity of 10,000 annual reported cases in the USA of rodenticide incidents involving children in the home (February 8, 2013 Pesticide & Chemical Policy Week in Review). The US EPA in a recent report also highlighted poisoning incidents of federally listed threatened and endangered species, including the San Joaquin kit fox, the northern spotted owl, and the bald eagle (US EPA 2008). The 2008 US EPA report on rodenticides drew attention to the second-generation anticoagulants brodifacoum, bromadiolone, difenacoum, and difethialone. The US EPA report considered carefully the implications of the long half-life of brodifacoum and ruled that “In the USA except for use around livestock facilities, baits will only be applied by professional operators and applications must be made no further than 50 feet away from any building”. The report also recommended that “integrated pest management (IPM) is essential for effective management of rodents in and around households” and highlighted affordable management actions other than rodenticide use (US EPA 2008).

Other factors that need to be carefully considered when considering usage of rodenticides are the humanness of the poison and the development of resistance by the target species.

ECOLOGICALLY-BASED RODENT MANAGEMENT

Ecologically-based rodent management (EBRM) had its basis from the work in the 1940s and 1950s of Elton, Chitty, and Barnett in the UK (see Crowcroft 1991), and Davis in the USA (Davis and Christian 1958). The advent of rodenticides, particularly anticoagulant rodenticides, redirected research on rodent management for decades away from ecological studies. This began to be redressed in the 1990s. The principals of EBRM were described by Singleton (1997) and were further refined in 1999 (Singleton et al. 1999). EBRM promotes a detailed understanding of the behavior and population ecology of the target rodent pest species so that management can be

targeted for specific environments at key times in a sustainable manner with minimal risk to non-target species. The emphasis is on low reliance on chemical rodenticides with a high focus on community actions. Effective progress has been made in managing target rodent species in cereal systems in Australia (Brown et al. 2010); Asia (Jacob et al. 2010, Singleton et al. 2005); and Africa (Stenseth et al. 2003, Makundi and Massawe 2011), and in forest systems in Europe (Huitu et al. 2009) and the USA (Engeman and Witmer 2000). See Witmer and Singleton (2011) for a review of progress in specific countries and continents.

A fascinating variation of EBRM is understanding the ecology and behavior of the pest species and determining whether a native, non-pest species could competitively exclude the pest species. The black rat, *Rattus rattus*, is a major pest species globally (see Banks and Hughes 2012, for review) and in southern temperate Australia, a native bush rat, *R. fuscipes*, was able to minimize the recolonization of the black rat after the density of the black rat population was substantially reduced (Stokes et al. 2009). This led to the development of a biotic resistance hypothesis, and a large-scale experiment is underway to see whether the removal of the black rat followed by the reintroduction of the bush rat into urban and peri-urban areas of Sydney harbour can prevent the black rat from re-establishing (Peter Banks, pers. comm.). The hypothesis is that native birds and bats will benefit from reduced predation of nests and roosts, and that the cases of rodent-borne lungworm infection in children, pets, and wildlife will fall. Lungworm, *Angiostrongylus cantonensis*, can be fatal to young children (Prociv et al. 2000) and native wildlife (Monks et al. 2005).

TEN PROMISING GLOBAL RESEARCH CHALLENGES RAISED BY EBRM

In the concluding section of their review of the challenges for managing rodent damage to enable sustained agricultural production, Witmer and Singleton (2011) provided a long list of areas for promising research. I return to this list, together with my 30 years experiences in Australia and Asia, to provide 10 global research challenges that further strengthen the focus for ecologically-based rodent management.

- 1) There is still a paucity of knowledge on the biology and ecology of most rodent pest species in developing countries. A major contribution to this situation is that there are few effective rodent wildlife ecologists in these countries. So, it is a combination of capacity building and knowledge gaps that need to be urgently addressed.
- 2) We require better prediction of rodent outbreaks so that there is sufficient time to implement proactive tactical interventions rather than reactive actions. Once pest densities are high, then often chemical control is one of the few management tools that remain for farmers, even though the effectiveness is often not well documented.
- 3) In forestry, a major challenge is finding effective methods for protecting root systems from damage by tunneling rodents.
- 4) The approach of “biotic resistance” described above

- for managing “invasive” black rat populations in peri-urban areas around Sydney harbour warrants similar studies elsewhere. The interactions between invasive and native rodents in agricultural systems that are interspersed with forest patches or hedgerows offer interesting possibilities.
- 5) Better estimates of losses caused by rodents in agricultural systems and rigorous economic analyses of the costs and benefits of EBRM are required.
 - 6) Our research on rodent population dynamics is often confined to pest management in either the context of agricultural or conservation (natural) habitats. There has been too little research on rodent communities and their respective population dynamics at rural-urban and rural-forest interfaces.
 - 7) Although there are more than 60 diseases that can infect humans (Meerburg et al. 2009a), precious little is known about rodent zoonoses, the basic host-parasite epidemiology, and the effects of rodent-borne diseases on the livelihoods of rural households.
 - 8) Community action is the key to effective rodent management in agricultural systems in Asia dominated by small-holder farmers (Palis et al. 2011). We need more sociological studies on the factors that promote or hinder adoption of EBRM.
 - 9) Global food security places greater demands on intensive agricultural systems. As managers, we need to anticipate how rodents will respond to changes in intensive production that are designed to meet increased food demands.
 - 10) What will be the effect of climate change? Major climatic events can lead to conditions that are conducive to rodent outbreaks (see Htwe et al. 2013). There are likely to be an increased frequency of major climatic events, and we need to have a better understanding of how rodent populations respond to changes in land use associated with these events.

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