Assessment of the impact of rodents on rural household food security and the development of ecologically-based rodent management strategies in Zambézia Province, Mozambique

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Report by:
Dr Steven Belmain, Natural Resources Institute
In collaboration with:
Adrian Meyer, The Acheta Partnership, UK; Remigio Timbrine, Luisa Penicela, Brian Hilton, John Steel, Ricardo Xavier, Tim Russell and Verona Parkinson, World Vision, Mozambique; Ricardo Thompson and Rassul Nala, National Institute of Health, Mozambique

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Executive Summary

This project proceeded in two phases. In the first phase, the impact of rodents upon people's lives was assessed, and information on the ecology of the predominant rodent species was collected. Data was collected from three areas of Zambézia Province: Namacurra, Gurué and Morrumbala Districts. Rodents were shown to have multiple impacts, damaging field crops, causing post-harvest losses, contaminating stored food and water supplies as well as transmitting disease through contamination, through bites to humans and vectoring zoonosis. There were two main commensal rodent species affecting people, *Rattus rattus* and *Mastomys natalensis*, with partially overlapping habitats and resource usage. Impact assessments showed that up to 10% of people had been bitten by a rat in the last six months. Rat bites can transmit disease from the rodent mouth and lead to secondary infections, termed 'rat-bite fever'. Screening of human blood samples showed that previously undocumented diseases such as leptospirosis were found to be actively infecting 17% (IgG) of people surveyed, toxoplasmosis was found in 88% of samples (IgM) and plague antibodies were found in 33% of samples taken. Rodents were also a problem in field crops. Field losses were highly variable with some farmers experiencing higher losses in different years. Field damage by rodents is well-known to be patchy, but when it occurs, farmers can suffer very high losses. On average, rodent losses to rice at the transplant stage were from 5-20%, although a few losses were greater than 50%. Losses at the heading stage were estimated to be from 15-45%. Losses to coconut were very high on plantations with damage by rodents ranging from 30-70%. On the other hand, rodent damage to small-scale coconut and rural coconut was much less severe, ranging from 10-50%. Paprika, grown as a high-value cash crop, is damaged by rodents eating the ripening pods resulting in the downgrading of pods and reducing yields by 20-40%. Although rodents were found to be affecting many aspects of people's lives, the main problem suffered by everyone was losses to grain storage with rodent population densities highest within people's homes and losses estimated at up to 200kg/house/year.

The second phase of the project aimed at developing and testing rodent pest management strategies based upon the information collected during the first phase. Rodenticides were inappropriate because of their expense, their unavailability in rural areas, their difficulty in using them safely and effectively, and that rodents are often eaten by people as their main source of protein. Because many people were already familiar and comfortable with trapping, it was proposed to test whether intensive trapping could be used to reduce rodent populations and their impacts. Chinese-made traps available in Mozambique were known to be of poor quality and low efficacy; so traps manufactured in the USA were imported to see whether they would work under local conditions. Other trap designs from India were also tested. Trapping, when done intensively, was shown to have a positive impact upon people's livelihoods. The incidence of people being bitten by rodents decreased from 10% before trapping to 0% afterwards. Assessments of storage losses indicated that intensive trapping lengthened the period of food remaining in store for most people by up to three months while other assessments showed that storage losses were reduced by 40%. Intensive trapping in paprika fields was able to reduce yield losses by 49% as well as improve the overall quality of the crop harvested.

Background

Rodents are a long-standing problem throughout the world which disproportionately affect the rural poor through consuming and contaminating stored food, transmitting disease, damaging field crops and degrading the built environment. Ecological studies and the practical control of rodent pests in rural agricultural settings have largely involved the use of rodenticides (Makundi et al., 1999). However, especially in rural parts of Africa, there are several constraints to their use. Primarily, rodenticides are not affordable for the rural poor who are most affected by rodent pests. Even when rodenticides are widely available, they are often used inappropriately leading to low efficacy, rodenticide resistance and to human health and environmental risks. Recently, there has been an increased effort to apply our understanding of rodent population dynamics to develop more ecologically-based methods of rodent management (Singleton et al., 1999). Pre- and post-harvest losses of food to rodents are recognised the world over as a serious problem, particularly in third world countries where food availability is already restricted (Mushtaq et al., 1995; Vazquez et al., 1995). Rarely, however, has it been possible to quantify these losses. Textbooks on rodents (McDonald & Fenn, 1994; Meehan, 1984; Prakash, 1988) have concentrated on problems caused by rodents in plantation crops, and post-harvest aspects are usually restricted to problems in large central storage facilities (Harris & Lindblad, 1978). Recent publications can be found on methodologies for estimating field losses caused by rodents (Buckle, 1994). However, methods for estimating storage losses caused by rodents are not established. Rodents are also well-known

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

disease vectors and are involved in transmitting potentially lethal viral and bacterial diseases including haemorraghic fever, leptospirosis (Weils syndrome) and plague.

There are two main problems to be addressed when considering ways to reduce the impact of rodents upon rural livelihoods, 1) understanding the impact which rodents currently have on the food security, health and nutrition of communities as well as the existing knowledge, attitudes and practice of the people regarding their rodent problems and 2) developing cost-effective strategies that can be sustainably implemented by those affected. Because rodents are intelligent, mobile and adaptable, strategies must aim to holistically approach the range of problems at the household and community levels based on knowledge of the rodent's behaviour and ecology.

Farmers in Mozambique have indicated that stored food losses by rodents can be severe and have prioritised rodent pests as one of their most important constraints to improving their livelihoods (Taylor and Phillips, 1995). Baseline surveys in Mozambique showed that rodents were one of the most frequently mentioned problems when considering their aggregate effects to field crops and during storage. Research in southern Mozambique investigating the crop protection problems associated with maize showed that rodents were the most serious pest of maize during the dry season and ranked in the top four field pest problems overall (Segeren et al., 1997). Rodents also live in and around villages on human refuse, potentially contaminating water supplies, affecting livestock and vectoring diseases. Recurrent outbreaks of plague (*Yersinia pestis*) are well-documented to occur in central Mozambique, and it is also known that a variant of the West African disease, lassa fever, can be found in Mozambique known as Mozambican virus. Information on the distribution and impact of rodent borne diseases in Mozambique is not available.

This research project was initiated due to the information collected by World Vision in participatory surveys where many communities within Zambézia identified rodents as a major constraint to improving their livelihoods.*

Project Purpose

The purpose of this project was to develop strategies which improve food security of poor households through increased availability and improved quality of cereal and pulse foods and better access to markets. Specifically, the project purpose is to address rodent pest management issues and sustainably reduce their multiple impacts upon people's livelihoods through the development of ecologically-based and cost-effective rodent management strategies.

Research Activities

In order to facilitate FTR review, project activities are summarised as six separate manuscripts following a peer-reviewed journal format.

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Assessing the impact of rodents upon people's livelihoods and understanding people's knowledge, attitudes and practice about rodent pests

Abstract
The impact of rodents on people's livelihoods and farmer knowledge was assessed by farmer questionnaires, environmental surveys and rodent population monitoring. Although rodents were found to be affecting many aspects of people's lives, the main problem suffered by everyone was losses to grain storage with rodent population densities highest within people's homes and storage losses estimated at up to 200kg/house/year. Other impacts measured were that up to 10% of people had been bitten by a rat in the last six months. Rat bites can transmit disease from the rodent mouth and lead to secondary infections, termed 'rat-bite fever'. Screening of human blood samples showed that previously undocumented diseases such as leptospirosis were found to be actively infecting 17% (IgG) of people surveyed, toxoplasmosis was found in 88% of samples (IgM) and plague antibodies were found in 33% of samples taken. Rodents were also a problem in field crops. Field losses were highly variable with some farmers experiencing higher losses in different years. Field damage by rodents is well-known to be patchy, but when it occurs, farmers can suffer very high losses. On average, rodent losses to rice at the transplant stage were from 5-20%, although a few losses were greater than 50%. Losses at the heading stage were estimated to be from 15-45%. Losses to coconut were very high on plantations with damage by rodents ranging from 30-70%. On the other hand, rodent damage to small-scale coconut and rural coconut was much less severe, ranging from 10-50%. Paprika, grown as a high-value cash crop, is damaged by rodents eating the ripening pods resulting in the downgrading of pods and reducing yields by 20-40%. Despite the problems caused by rodents being well-recognised by people, there has been little local innovation to control them and most farmers did nothing to manage their rodent problems. Rodenticides were not available, and as rodents were widely reported to be eaten by those surveyed, rodenticide usage should be discouraged. Some households owned one or two traps or had cats, but many said that their use did not result in fewer rodent problems.

Introduction
The perceived failure of many technology transfer programmes aimed at natural resource constraints in developing countries could be argued to arise from a poor understanding of the problem and the constraints in causing change to people's knowledge, attitudes and practice (Joshi et al., 2000). The initial stages of this project involved defining the problem with a view to assessing and monitoring rodent problems leading to the provision of low-cost rodent control strategies that could be effectively monitored and implemented by farmers and extension agents. The specific objectives were:

- To assess the potential impact of rodents upon the domestic, storage and field agricultural environments through household-based questionnaires.
- To trap and taxonomically identify the rodent species that were associated with environments where rodent losses and damage were the most severe.
- To introduce a repeatable standardised procedure that would identify base-line levels of rodent activity.
- To make an assessment of the impact of rodents upon the lives, living standards and health of those living within such rural communities.
- To identify potential management strategies which might be appropriate for use in these environments.

Materials and Methods
It was planned to undertake survey and assessment work in three villages which were representative of different agro-ecological zones within Zambézia Province, all of which have rodent problems as determined by previous participatory needs assessment surveys managed by World Vision. Namacurra District lies within a flat lowland rice-growing area, Morrumbala District within a highland plateau maize-growing area, and Gurué District is in a mountainous mixed forest-cropland area (Figure 1). Although rodent pests were known be a problem in all three habitats, it was unknown whether the problems were inherently the same or whether there were manifest differences between them.

It was planned to ask approximately 50% of households in three villages a series of open questions to try to find out as much as possible about their rodent problems, ensuring that both men and women participated in the assessment. Local introductions to village leaders were made by the World Vision

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

extension agent for the area. Visits to family units were made with the extension agent, the local village chief and the World Vision post-harvest specialist for the district. The questions related to the rodent pest problems and other relevant information (Figure 2).

Results and Discussion

Preliminary discussions with farmers indicated that rodents were a problem for everyone. People mentioned that their biggest rodent problem was in their food store. Many indicated that members of their family had been bitten by rats or had found rats drowned in their drinking water inside the house. Importantly, rodents, particularly those caught in the field, were widely eaten by people in all three districts.

Rodent damage to field crops

In all three districts, rodents were considered to be a problem in field crops. However, farmers in the maize growing areas of Morrumbala and Gurué, felt that they had relatively less of a rodent pest problem in their fields than farmers in the rice growing area of Namacurra. All farmers mentioned that rodent damage in field crops was patchy, that some farmers would suffer more than others in a given year and that damage varied over the years. Farmers in Namacurra mentioned that usually rodent damage was low but that sometimes farmers could lose 50-100% of their crop. Rodent damage in field crops is well-known to be uneven and farmers may escape damage one year to then suffer severe damage the next. Unsurprisingly, farmer estimates of rodent damage varied widely from 0% to 100%. When asked to think about rodent damage over the years, farmers usually gave an average damage assessment for maize of around 5-10% and 10-20% for rice. Farmer actions to combat rodent damage in field crops was minimal, and most farmers said they did nothing about rodents in their fields even when damage was considered to be high. When damage was seen to be high, some farmers attempted to trap rodents and dig up their burrows. However, farmers who did try to do something about rodent numbers said that it usually did not reduce the damage, and there was clearly an additional incentive to trap and hunt as the rodents were eaten by the farmers. This type of crisis management of rodent pests in field crops is typical throughout the world. Rodenticides or poisons of any type were not mentioned as being used by anyone for rodent control. Rodenticides were unavailable in all the local markets, and when rodenticides were mentioned as a potential option farmers were reluctant to want to use them because they were thought to be expensive and dangerous. As field rodents are widely eaten, it is unlikely that anyone would consider using poisons. Other crops were also noted to suffer from rodent damage, particularly papaya, coconut and paprika. Crop damage assessments carried out at a later date within the project showed that, on average, rodent losses to rice at the transplant stage were from 5-20%, although a few losses were greater than 50%. Losses at the heading stage were estimated to be from 15-45%. Losses to coconut were very high on plantations with damage by rodents ranging from 30-70%. On the other hand, rodent damage to small-scale coconut and rural coconut was much less severe, ranging from 10-50%. This follows the conclusions of other similar assessments (Wodzicki, 1972). The importance of paprika and severity of rodent damage led to a trial to determine whether rodent impacts on the crop could be reduced (described in a later section).

Rodent damage to food storage

All farmers surveyed in all three districts said rodents were a severe problem in their stores and more severe than insect pests such as the grain weevil, *Sitophilus* spp (Figure 3). Farmers traditionally store their grain inside the house on a raised platform (Figures 4 and 5). Often the cooking fire is below the grain store, the smoke acting as an insect repellent and the heat keeping the grain moisture content low to reduce insect infestation. Members of the household sleep in the same building as the grain store, usually on the floor next to the grain store. Farmers indicated that rats made nests in the roof thatching, coming down at night to forage and eat the stored grain. Householders estimated, on average, that in excess of 50 rats were living in each house, and many understood that the rat population inside the house became higher when new harvests were brought into the house and that the lack of food in the fields could drive rats into their houses to search for food. Their estimates on rodent numbers were made from observations when they removed the roof thatch for repair. They estimated that some 10 - 20 nests were found in the roofs when they were repaired and that the average number of young observed in these nests was 10 - 11. The majority of farmers replaced their roof annually because of the associated rat problems. This estimate of young per litter is about right for the high food availability environments found inside the houses. Further research using traps in people's houses supported the reliability of farmer estimates. For example, the history and frequency of roof replacement was statistically correlated to the number of rats caught within a house, where

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

replacing the roof more often seems to reduce the overall rat population. Householders estimated that they are losing anywhere from 1 to 100kg of food to rats per year. These highly variable estimates would suggest that farmers are rather unclear on how much food they have or lose. However, it is common for people everywhere to underestimate their food losses due to pests. Estimating storage losses is discussed in subsequent sections of this report.

If the average estimate of 50 rats living in each house is correct, the food losses will be well in excess of all the farmer estimates. Because farmer estimates on the number of rats living in their roof were, generally, less variable than their loss estimates, these data are likely to be more reliable for estimating food losses. Trapping trials described below showed that the average weight of rodents caught inside houses was 75g. Generally, the daily food consumption of a rat is 10% of their body weight, therefore the daily food consumption is 7.5g/rat. If we assume that a further 30% of food consumed is lost and wasted during feeding and through hoarding (probably a very conservative figure), we can see that a minimum of 10g of food is lost per day to each rat. If, as the householders claim, there are 50 rats on average in each roof, then each day the rats are removing 50 x 10g of food, or 500g/day. If rat numbers are maintained throughout the year, then a total of 182kg (365 x 500gms) of food is lost per year.

Although it greatly varied between villages, on average, 15% of households currently or in the past had traps which they used inside the house to trap rats. Generally, if farmers had traps they would have only one or two, and these would be used when rodent numbers became noticeably high during the storage period. No one mentioned that they trapped rodents when populations were considered to be low. The only other control method noted was the ownership of cats or cats that belonged to neighbours. It wasn't possible to find out how many cats were present in a village; but it was estimated that there was usually one cat for every 5 or 6 households. The response from villagers was divided on whether they thought cats were effective in controlling rats. There is no scientific evidence that predation is ever an effective pest management tool (for vertebrates or invertebrates) in actually reducing pest density. However, many questioned suggested that cats were effective 'repellents' and scared away more rats than they actually caught, and this could lead to some reduction to rodent damage, particularly in a household environment. Rodenticides were not used for the same reasons as discussed previously.

Rodent damage to human health

Householders were asked if the rats were drinking from their water vessels inside their houses. The answers confirmed that rats were not only found drowned in the water containers, but that they were seen to drink from smaller vessels if water was left in the bottom. It is likely, therefore, that rats are drinking from the water vessels whenever the opportunity arises and almost certainly contaminating the vessels with urine and faeces. Many households are storing water in clay pots inside the house. These are covered with a plate, but many of those surveyed indicated that they sometimes forgot to keep the water container covered. This raises the problems associated with disease in such heavily rat contaminated environments. Rats and mice are generally reported to excrete in excess of 50 droppings (faeces) a day. Thus 50 rats will void 2500 droppings/day or some 900,000 per year, almost all within the houses in which people are living. Similarly, rodents of about 75g will void about 2 litres of urine a year. Thus 50 rats will void 100 litres per year. Again, this is being voided in structures with heavy human occupancy. These figures, together with the fact that the rats must be carrying fleas, other ectoparasites and a range of endoparasites, must raise the question of the health impact of such heavy rat populations living in such close proximity to humans, both adults and children. In Morrumbala, there was a very high incidence of rat bites to the human population where approximately 10% of the population had been bitten in the last six months (Figures 6 to 8). Fewer people reported being bitten in Namacurra (<1%) and Gurué (5%). There were some intriguing variations within these data. For instance, twice as many females were bitten as males, and one third more children were bitten than adults. Rat bites can lead to rat bite fever through transmission of disease from the rat's mouth as well as to secondary infections particularly when the bites are on the hand or foot.

Plague is well-known to occur in the Morrumbala District of Zambézia as well as in other Provinces of Mozambique. Outbreaks of plague appear to be cyclical, but local health workers have little ability to predict when severe outbreaks will occur. The treatment of outbreaks can be very expensive, applying insecticides to kill fleas inside people's homes and treating villagers with long courses of antibiotics. Few cases of death arise from plague as the symptoms of bubonic plague are obvious and

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

understood by most villagers, leading to their seeking treatment. Other diseases carried by rodents were unreported in Mozambique. Diseases such as leptospirosis often go undiagnosed as the symptoms may be similar to flu or malaria. Leptospirosis can be debilitating, particularly for the young and old, and severe cases can lead to liver and kidney failure and internal bleeding (Weil's syndrome). Indeed, there are many diseases transmitted by rodents either through rodent faeces (salmonella), urine (leptospirosis) airborne viruses (haemorraghic fever) and vector insects (plague and murine typhus). Considering the close proximity rodents have with humans in these environments, many rodent diseases are likely to be having debilitating effects which reduce productivity and cause mortality. The impact of rodents on human health will remain unknown until villagers are screened for the presence of such diseases, particularly as many cases of mortality may be assumed to be malaria when no diagnosis is made. Because of the lack of information on rodent diseases, the project initiated some preliminary studies on the prevalence of rodent zoonosis. Samples of human sera (n = 326) were collected from villages in Morrumbala and tested for the presence of leptospirosis, toxoplasmosis and plague. Leptospires were found to be actively infecting 17% (IgG) of people surveyed, toxoplasmosis was found in 88% of samples (IgM) and plague antibodies were found in 33% of samples taken. The incidence of leptospirosis was far higher than expected, particularly when compared to data from the UK where prevalence is thought to be less than 0.001%. The exposure to toxoplasmosis is not surprising considering that rodents are widely eaten. Normally toxoplasmosis is only a problem if contracted during pregnancy. However, cerebral reactivation of the disease is common in immuno-compromised individuals and could become an increasing problem with higher levels of HIV in the population. Plague incidence as recorded in the WHO database of Mozambique is only about 4% for the area surveyed in Morrumbala. Our results would suggest that sublethal cases of plague occur and that resistance to plague is occurring at relatively high levels. The results of this study can be found in Thompson et al. (in press).

Other rodent damage

Rodents were mentioned to cause damage to other things such as clothes, tin cups, radios, furniture and other personal belongings stored within the house as well as to the house itself by digging holes in the walls and degrading the roof thatching. Although the economic importance of such damage may be minimal, it was noted to be a considerable nuisance and source of frustration as well as increasing the amount of household maintenance. Rodents were also a problem for poultry. Chickens and pigeons were kept by the majority of farmers, and rodents were noted to eat the eggs and chicks. Some farmers said that rodents will attack adult chickens, but considering the average size of *R. rattus*, this is more likely due to weasels.

Further data were collected on the environmental status of the household such as the distance to nearest vegetation and distance to nearest refuse (waste food and other materials) and the quality of the building structure. Analysis of these data suggest that there is a correlation between these aspects of the environment. Well-maintained and tidy households were generally further away from rubbish and vegetation. Although this has not been assessed in any way within the project, better household hygiene is likely reduce rodent impacts particularly to stored food and health aspects.

The results of the questionnaire showed that rats form the main source of protein for people (Figures 9 and 10). Nearly all families surveyed said they ate more rat meat than anything else (chicken, goat, fish). The majority of farmers said they only ate field rats, and did not eat the rats that live in their houses. However, the poorer farmers were more likely to eat both house and field rats. Evidence of protein deficiency (kwashiorkor) among children was apparent. The importance of rat protein as a nutritional source is clear for any strategy development relating to rodent control. What should be researched further are the health implications of eating rats. In particular, the handling and preparation of rats for food should be investigated to assess the safety of methods by which the rats are prepared for consumption. Many farmers said they ate the entire rodent including the intestine, kidneys and other organs. Generally, rats were prepared by either roasting (Figure 11), boiling them, or a process that involved steaming and drying the animal for future consumption.

Assessing the rodent population

Although farmers indicated they had severe rodent problems, we saw no visual evidence (greasemarks, droppings, runways) of rodents during household inspections, although we were shown evidence of damage (to maize cobs, household items and bites). Rodents are, of course, nocturnal and their activity largely goes unnoticed during the day. This may explain why rural development projects in the area have tended to ignore a problem which only becomes evident at night and through discussion with villagers. It was also unknown which species of rodent were present. Species identification can help understand the differing levels of neophobia and other behavioural differences among species which may affect the way rodents are controlled. Ethno-ecology information collected from farmers showed that farmers broadly defined rodents into house and field species. The house species lived in their roof thatching and the field species made burrows outdoors. A few farmers indicated that there were different field species indicating that there could be 2 or 3 different species in the field. As other information collected showed that household rodent problems were considered to be the main problem, traps were placed in people's homes to determine relative numbers and the species types present. Ten break-back traps were set in 30 family house/store units/village and were left in place for three nights. Members of the household were instructed on how to set the traps and to keep any rats caught until the morning. The carcasses were collected for identification, sexing and weighing. A number of samples were taken to confirm species identification at the Natural History Museum, UK.

The trapping exercise indicated that three different species were found inside people's homes (Figures 12 and 13). The house species was confirmed to be *Rattus rattus*, often called the roof rat because it is a good climber and is often found associated with human habitation. The average weight of *R. rattus* in these environments was 75 g which is approximately 50% less than the normal weight of *R. rattus* found in most situations. This indicates that there must be some environmental selection which keeps *R. rattus* smaller, probably related to competition and their living in the roof thatching. The main field species was identified as *Mastomys natalensis*. *M. natalensis*, often called the multimammate rat, is commonly found throughout southern and eastern Africa. It is also considered a commensal species and is a known carrier of plague. Farmers were surprised to catch *M. natalensis* inside their houses as they consider it a field species. Although it is clearly living outside the house, the trapping shows that it is immigrating into houses to search for food. The proportion caught of *M. natalensis* and *R. rattus* varied among the three districts, with the majority being *R. rattus*. It was thought that trapping success of the different species may relate to the degree to which trapping was undertaken in more or less rural and isolated areas surrounded by fields and bush vs. more densely populated villages. This issue is discussed further in following sections of this report.

Development of a rodent control strategy

The information collected from villagers clearly indicated that the biggest rodent problem was inside the household. Large quantities of food were stored in areas of heavy human occupancy in an environment that provided safe harbourage for rodents in the roof and water nearby. Because of the level of human access in such an environment, excluding rodents would be impossible. The most effective strategy for reducing the impact of rodents upon people's livelihoods would be to store the harvested grain in a separate granary. Granaries can be relatively easy to rodent proof, thereby reducing storage losses. The use of a granary would subsequently reduce the proximity of rodents to people, reducing the incidence of bites, disease transmission and damage to other household belongings. Such a strategy would probably eliminate future outbreaks of plague in the area as rodents and their fleas would be less prevalent inside households where food resources are minimal. Unfortunately, a strategy for granary use has little chance of success in the short term for a number of reasons. Farmers have traditionally stored their grain inside their households for generations, and the system provides security from theft. Although the perceived threat of food theft may fade with the memories of the civil war, food security will be lessened mainly when households are able to increase production beyond the subsistence level. Extension which has aimed at encouraging separate storage structures has not been enthusiastically taken up in areas where it has been promoted. Another advantage of the current storage system is that the kitchen fire below the store is able to reduce the impact of insect infestation, particularly in areas where grain may not be sufficiently dried after harvest to prevent insect damage.

Another long term strategy which would help reduce rodent infestation inside people's houses would be to replace the roof thatch with sheet metal, thereby removing the main harbourage used by rats inside the home. However despite its durability, the initial outlay costs of sheet metal will be prohibitively expensive for the rural poor. It will also raise the temperature inside the house to perhaps unacceptable levels.

Another possibility would be the introduction of rodenticides. Rodenticides can work very well when they are used correctly. Intensive training of farmers and communities would be essential to make

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

rodenticides work effectively and safely. The expense of training, close monitoring and the cost of the rodenticides will make their use very expensive, and for these reasons are unlikely to be cost-beneficial. Coupled with the fact that rodents are widely eaten throughout Zambézia as an important protein resource, rodenticide usage should be actively discouraged in these communities.

The two management options which are most likely to have an impact on rodent pest problems in these environments are trapping and environmental management. Trapping is not usually a reliable technique because it is labour intensive, fails to eliminate the population and can sometimes lead to the development of trap shy animals. However, in the present circumstances any reduction in rat populations and their damage would be a significant benefit. Because the work can be done within the family household, most farmers were familiar with trapping, and the trapped rats could be eaten, it was considered that trapping could work provided that it was established that trapping could be done intensively enough to remove rats faster than their breeding rate and reduce rodent populations as well as reduce the damage and impact of rodents on people's lives.

The potential impact of better management of the environment around the home could also help contribute to reducing rodent problems. Farmer education with regard to eliminating free water sources available to rodents within their homes would help force rodents to seek water elsewhere. Simply keeping drinking water vessels well-covered at all times will help limit water resources available to rodents, as well as reduce disease transmission. Similarly, most of the farmers surveyed only cleared the vegetation away from their houses to approximately 3 - 4 metres. Immigration of rodents from the field could be reduced if farmers cleared the ground around their house to a distance of approximately 10 metres or more. Some farmers are already doing this, so it should be possible to promote this activity. Likewise, household waste and rubbish near a house attracts rodents. Placing rubbish further from the house could help reduce rodent problems. The quality of the building and its level of maintenance are also factors which could influence infestation levels. Rodent access to buildings could be reduced by ensuring that obvious holes in the mud structure are quickly re-mudded, especially holes in walls at ground level. This won't prevent rodent access, but it should make it more difficult to gain access. Such issues directly impact upon the poorest of the poor as the poorest members in the communities often had the poorest building structures with rubbish and vegetation relatively nearby.

In conclusion, the surveys conducted showed that there was a very significant problem with rats in these homes. The rat infestations were having a significant impact on both the availability of food and on the health status of those who live in these conditions. The project activities further summarised in this report were aimed at testing how trapping could be done effectively within these rural communities and assessing how such a strategy would impact upon rodent populations and their damage.

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 1. Location of rodent impact assessments and rodent management research trials in Zambézia Province. Surveys and trials took place in different villages located with the districts of Morrumbala, Gurué and Namacurra.

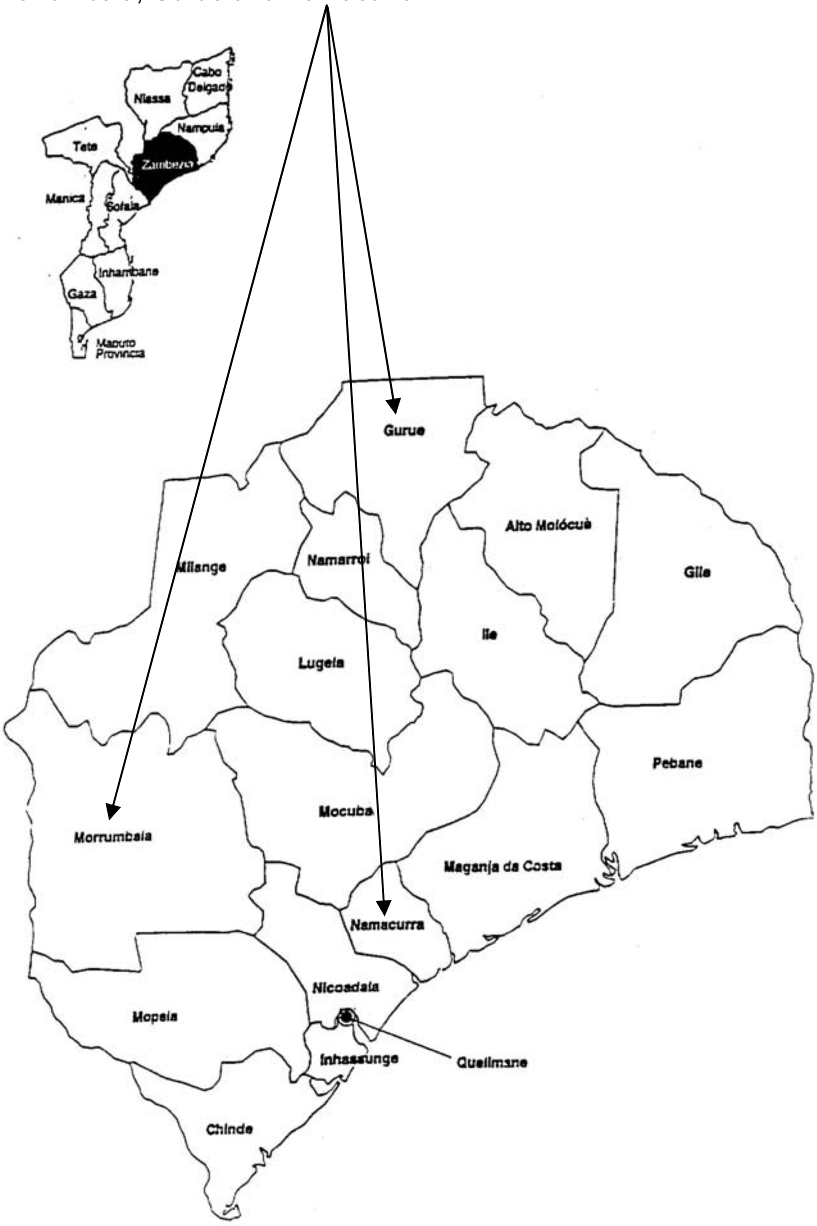

Figure 2. Survey of rodent impacts and farmer knowledge

1. Farmer name.
   - Assign number to farmer with respect to building(s) assessed within the family unit.
2. Number of people living in the building to be assessed?
   - Tabulate data by number of males, females, children and adults.
3. Do you have problems with rodents?
   - Specify and quantify what types of problems, e.g. field, storage, health.
4. Farmer estimate of losses caused by rodents.
   - Question should be posed in terms the farmer can relate to and converted into an approximate figure, related to issues mentioned in question 3.
5. Does the farmer do anything to control the rat problems he has?
   - If they already have traps, cats, etc., find out how many and how and when they are used.
   - Do they think the control they implement has an impact on their rat problems?
6. How often does the farmer replace the thatch on his roof?
   - Why does he replace the thatch?
   - Does he find rats in the roof when replacing it?
   - How many nests does he find?
   - How many young are found in each nest?
   - How many rats in general are caught/seen escaping when replacing the roof?
7. Do they eat rodents?
   - What sorts of rodents do they eat?
   - What proportion of their diet consists of rat meat, e.g. more or less than half of all the meat they eat with respect to other meat (chicken, goat, fish, etc.).
   - What parts of the rat do they eat?
   - How do they prepare the rats for eating?
   - When was the last time they ate rat?
   - Is their rat consumption seasonal?
8. Has anyone living in the assessed building been bitten by rats?
   - It may be useful to quantify the question in recent terms, such as in the last six months.
   - Tabulate data by number of males, females, children and adults.
   - Where do they get bitten?
   - Take photographs of recent bites.
9. Do they ever find rats drinking from water kept inside the house?
   - Do they keep their water vessel covered?
10. Assessment of the environment.
    - Estimate the distances between the building and the nearest vegetation and the nearest refuse pile.
    - Rank the building structure on scale of 1-5 (1=best, 5=worst). This ranking is relative, and ideally, all houses in the village should be ranked by the same person.

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 3. Typical damage caused by rats to stored maize cobs

Figure 4. A typical household structure found in Zambézia Province. The main difference found in some areas is the use of palm leaves for roof thatching. Typically, up to seven or eight people may sleep inside. Food is stored in the same structure on a raised platform within. The cooking fire is often below the platform, providing smoke which is used to reduce insect infestation. Farmers estimate an average of 50 rats live in the roof thatching at any given time.

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 5. Food store platform within a house storing maize with kitchen fire below the store.

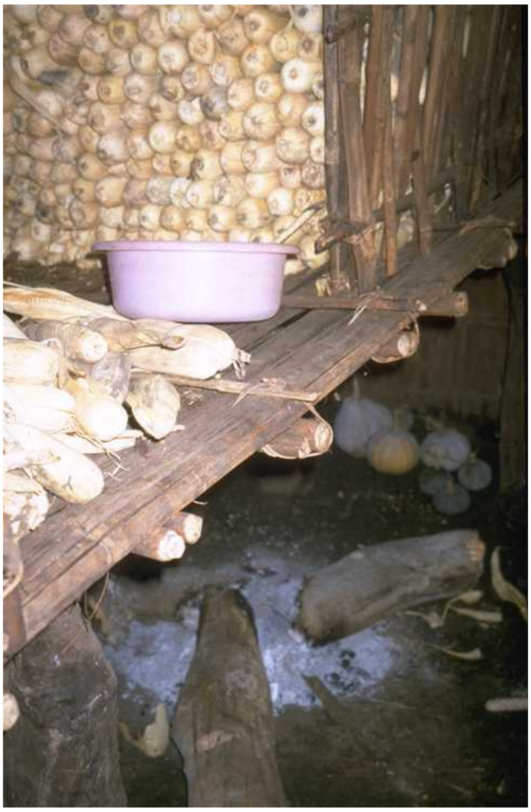

Figure 6. A rat bite on the heel of a young girl obtained the evening before our visit. Rats do not intentionally bite people. During their forage for food, rodents may smell food or sweat on people sleeping within the dwelling. The person then twitches in their sleep, and the rat bites out in self defence.

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 7 A rat bite on a woman's foot from the night before. The prospect of secondary infection is high as the woman had no shoes.

Figure 8. Rodent bites to a girl's neck from the night before.

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 9. Rats which have been prepared for eating by roasting over a fire. The animal is cooked fully intact, including the hair and all internal organs and served with a little salt.

Figure 10. Villagers said that they eat the entire rodent, except the teeth and the tail.

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 11. The most common method of preparing rodents for food is to simply nail them to a stick and roast them over a fire. It is unknown whether these cooking methods are capable of killing leptospires resident in the kidneys and other bacteria in the gut or blood stream. Egg and cyst stages of some internal parasites are known to be partially resistant to high temperatures. Cases of pharyngeal plague have been previously recorded in southern Africa.

Figure 12. The three rodent species caught during the initial surveys in Zambézia Province. The most frequently caught species (top) was *Rattus rattus*, commonly known as the roof rat. *R*. *rattus* was the species villagers accurately referred to as the house rat living in their roof. Two field species, *Mastomys natalensis* (bottom) and *Saccostomus campestris* (middle) were also trapped inside houses. These species burrow in the ground in the surrounding bush entering houses to forage for food. *M*. *natalensis* was the predominant field species in all the districts surveyed.

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 13. The catch from one household during one night where 7 out of the 10 traps caught rats

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Initial studies to determine the feasibility of intensive trapping inside rural households to manage rodent pest populations

Abstract

Field trials involving seventy rural households from three villages in Mozambique were established to test whether intensive daily trapping inside household-level food stores could effectively reduce rodent pest populations. The main species caught inside dwellings where food was stored were *Rattus rattus* [*alexandrinus*], comprising 74.3% of rodents caught over the year, followed by *Mastomys natalensis* (20.1%) and *Saccostomus campestris* (5.6%). Baseline surveys showed that households using 10 break-back traps caught an average of 1.2±0.37 rats/day (mean±sem). Annual trials whereby half of the selected dwellings in each village continuously trapped every day with 10 traps were able to reduce the number of rodents in their house by 50-70% compared to the untreated group of farmers who only trapped for three days every eight weeks. The population reduction caused by intensive trapping was maintained over the remaining duration of the trial. Farmers who intensively trapped rodents (treated group) caught an average 1.27±0.43 rats/day, whereas untreated group farmers caught an average of 2.95±0.71 rats/day. The number of rats and the ratio of species caught by farmers intensively trapping varied over an annual cycle related to seasonal and anthropogenic factors. Variation in the number of rats caught among farmers intensively trapping within a village and variation among villages was significant, showing Morrumbala to have the highest rodent population density (2.7±0.15 rats/day, mean±sem) followed by Gurué (1.0±0.14 rats/day) and Namacurra (0.3±0.07 rats/day). Average daily trap catch initially increased in Morrumbala then decreased as the storage season progressed, whereas populations continually decreased in Namacurra and Gurué. The average weight of rodents caught by farmers intensively trapping was reduced by more than 30% compared to the untreated, falling from 69.5±3.26 g to 41.9±2.02 g. We conclude that intensive trapping can constrain rodent populations which utilise stored grain stocks within rural African households, thereby reducing grain losses. The implications of these results are discussed in the context of implementing ecologically-based rodent management strategies for poor rural communities in Africa.

Introduction

Rodents are among the most important pests affecting human food security and public health in the developing world. Their significance has increased for a number of reasons such as expanding urbanisation and the corresponding growth of peri-urban areas. Consequentially, factors such as the proximity of agricultural areas to human populations and the concentration of open sewage and human refuse are exacerbating rodent problems. Despite this, research on rodent management strategies has been relatively stagnant for several decades. Most of the ecology and control of rodent pests in rural agricultural settings concerns rodenticide use (Makundi et al., 1999; Macdonald and Fenn, 1994). However, especially in rural parts of Africa, there are several constraints to their use. Primarily, rodenticides are not affordable for the rural poor who are most affected by rodent pests. Even when rodenticides are widely available, they are often used inappropriately leading to low efficacy and to health and environmental risks. Recently, there has been an increased effort to apply our understanding of rodent population dynamics to develop more ecologically-based methods of rodent management (Singleton et al., 1999).

Most households in Mozambique traditionally store their food inside their dwelling for security and spiritual reasons. However, this storage practice makes it difficult to exclude rodents from the food store, exacerbating food losses and contamination caused by rodents. Food losses based on the number of rodents caught in our research (50 to 1150 rats/year/dwelling) and estimates of the number of rats living in the roof at any one time (50 to 100) would conservatively indicate losses of stored food in the region of 200 to 400 kg/year/dwelling. In addition to food losses, annually recurrent outbreaks of plague (*Yersinia pestis*) occur in parts of Mozambique; however, the impact of other rodent-borne diseases such as leptospirosis (*Leptospira icterohaemorrhagiae*) remain undocumented (Hugh-Jones et al., 1995).

The development of ecologically-based rodent management strategies that are affordable and easily implemented by the rural poor of Africa could substantially improve public health and local economies. The objectives of our research have been to test management strategies that attempt to reduce rodent pest populations in rural areas. Intensive trapping has often been argued to be an ineffective management tool (Sullivan and Sullivan, 1986; Stenseth, 1981; Krebs, 1966). However, in this paper

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

we test whether it can significantly reduce local populations under certain circumstances, particularly under the high density populations found in household level food stores.

Materials and Methods

Three villages in different districts of Zambézia Province, Mozambique were selected for involvement in the trials based on reports from farmers indicating rodents were a significant pest problem, particularly after harvest when crops are stored within the dwelling. The village of Zimbi in Namacurra District lies within a flat lowland rice-growing area, the village of Cozombo in Morrumbala District is found in a highland plateau maize-growing area and the village of Insurupe in Gurué District is in a mountainous mixed forest-cropland area. Each village has approximately 200 domestic dwellings which typically consist of a mudded timber-frame rectangle (approx. 4 x 5 metres) with a grass or palm-leaf thatched roof. The open-plan interior contains a raised platform where food is stored, a cooking fire and a sleeping area for up to 8 people.

Baseline population data of rodents inside houses were obtained during April to May 1999 when farmers in each village were approached to participate in the study. This coincided with the start of the food storage season when their main commodities of maize and rice are harvested. Thirty farmers in Cozombo and twenty farmers in each of the other villages were randomly chosen and asked a series of questions to determine potential anthropogenic factors influencing rodent population dynamics. At the same time, 10 break-back traps (big snap-e-trap™, Kness Manufacturing Ltd., USA) were placed in each of the dwellings along interior walls and walkways, especially in places where food is usually stored. Farmers were given individual training on the operation of the traps and instructions to set them each evening. Dwellings were visited each morning for three days to record the number of rodents caught including their sex, weight and species type. Representative samples of species types were collected for later taxonomic identification.

After obtaining these baseline data, dwellings were randomly assigned to either the treated or untreated group. Dwellings in the treated group continued to trap with ten traps every day for the duration of the trial and were instructed to set the traps each evening as before. Treated dwellings continued to be visited each morning to collect data on the number, sex, weight and species type of rodents caught. All traps were collected from dwellings allocated to the untreated group. Every eight weeks, ten traps were redistributed to the untreated dwellings, and data were collected as indicated for the treated group. After a period of three trapping nights, the traps were recollected from the untreated dwellings, with the process repeated for an entire year.

Results

Taxonomic identification of the rodents trapped from all three areas showed that the main species was the house rat, *Rattus rattus* [*alexandrinus*] (74.3% of total caught). As commonly found in other rural areas in the tropics, *R. rattus* nested in the thatching of the roof. Two other species were also trapped, *Mastomys natalensis* (20.1%) and *Saccostomus campestris* (5.6%), both of which are known to make burrows in grassland areas. The numbers of each species caught varied over the year (Friedman $\chi^2 = 84.1$, df = 2, $P < 0.01$). Field preparation by setting fires that spread uncontrolled through the bush were largely responsible for the increase in the proportion of *Mastomys natalensis* caught during the months of August and September (Figure 1).

Results of the questionnaire showed that several anthropogenic factors influenced rodent populations within dwellings. The main control strategy adopted in all three areas involved removing the thatching from the roof and killing as many of the nesting rats as possible before replacing the thatch. Farmers replaced the roof thatching anytime between every six months and two years, and the frequency of roof replacement for the house was weakly correlated with the number of rats caught within the house during the baseline survey (Spearman's $\rho = -0.45$, n = 60, $P < 0.05$). Less than 5% of dwellings had 1 or 2 locally-made traps for rodent control, and less than 2% of dwellings had one or more cats. No other forms of physical or chemical control were used by dwellings. Farmers consistently indicated that anywhere from 50 to 100 rats would nest in their roof at any given time, that up to 100kg of stored food was lost to rodents, and that up to 10% of the population had been bitten by a rat in the last six months. The main anthropogenic factors influencing rodent population dynamics were considered to be the storage of all harvested food within the dwelling, the location of refuse and vegetation near to the house, the provision of open water supplies within dwellings, and the preparation of fields by burning in advance of the planting season. The cyclical effects of food storage practice and field preparation were noted to correlate with rodent populations inside dwellings in Morrumbala (Figure 2).

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

The number of rodents caught during the initial baseline survey did not significantly vary among dwellings within villages or among the three villages (Kruskal-Wallis, $P > 0.05$), and an average of 1.2±0.37 rats/day (mean±sem) were caught per dwelling over the three days when using 10 break-back traps. Likewise, the sex ratio and mean weight of rodents caught did not vary significantly among dwellings or villages showing a 1 to 1.06, male to female, sex ratio and a mean weight of 69.2±6.51 g.

The number of rats caught by dwellings that trapped intensively trapping (treated group) varied temporally and spatially over the course of the trial (Figure 2). Variation in the number of rats caught among farmers within a village was significant (Table 1). Variation was also significant among villages (Kruskal-Wallis, $\chi^2 = 119.6$, df = 2, $P < 0.01$), showing Morrumbala to have the highest rodent population density (2.7±0.15 rats/day, mean±sem), followed by Gurué (1.0±0.14 rats/day) and Namacurra (0.3±0.07 rats/day). Regression analysis showed that rodent populations decreased inside houses as the storage season progressed in Namacurra (inverse model, $r^2 = 0.533$, $F = 23.4$, $P < 0.01$) and Gurué (linear model, $r^2 = 0.471$, $F = 29.5$, $P < 0.01$). However, the population initially increased and then decreased in Morrumbala (quadratic model, $r^2 = 0.576$, $F = 29.8$, $P < 0.01$).

Differences in the baseline numbers of rodents caught among treated and untreated groups at each site were not significant (Mann-Whitney, $P > 0.05$). At the first comparison between treated and untreated dwellings conducted eight weeks later, there was a significant difference between the number of rodents caught between treated and untreated dwellings in Gurué (Table 2). Untreated dwellings caught more rats than treated dwellings in all three areas by the time of the second comparison, and the difference in the number of rats caught between treated and untreated dwellings was maintained over the duration of the trial (Table 2). The pattern of increasing difference in the mean number of rodents caught between treated and untreated was similarly noted with respect to the mean weight of rodents caught. On average, rodents caught among untreated dwellings were significantly bigger than those caught at treated dwellings with this difference increasing during the course of the trial (Table 3). No significant differences were noted with respect to changes in the sex ratio of rodents caught between treated and untreated dwellings (Mann-Whitney, $P > 0.05$).

Discussion

Our study showed that intensive trapping of rodents can effectively reduce their localised population densities within rural African dwellings. Although trapping is relatively labour intensive, the relatively low cost of inputs could favour the technique. At the commencement of the intensive trapping trial, it was not known whether rodent population densities would vary among dwellings or areas. However, it was considered likely that density would be generally dependent upon food availability (Krebs, 1999; Boutin, 1990; Prakash, 1988). Thus, rodent populations should have been at their lowest inside dwellings during the harvest season when food is just beginning to be stored, and this moment was chosen for the commencement of the intensive trapping experiment. This trend was most apparent in the intensive trapping data obtained in Morrumbala, whereby a quadratic regression best represented the fluctuation in average trap catch over the year. However, it is not known to what degree populations would have increased or decreased in the absence of intensive trapping, and another less intrusive method of population monitoring would be required to obtain such data (Thomas, 1999).

In Namacurra, the rodent population was relatively low and it appears that 10 traps used on a daily basis were able to remove rodents from the environment faster than recruitment. This also occurred in Gurué, although to a lesser extent, reflected by the shift to a linear regression model representing the change in the average number of rodents caught rather than the inverse regression model representing data obtained in Namacurra. However, intensive trapping was unable to progressively decrease the number of rodents caught in Morrumbala. Increasing the number of traps used per dwelling in Morrumbala might be necessary to achieve the same impact observed at the other two sites. It is likely that the overall differences among the three sites in the number of rodents caught is related to broad differences in habitat and ecology in the three areas (Ferreira and Aarde, 1999).

Despite the observed differential efficacy achieved among the three areas, intensive trapping with ten traps did constrain population growth when compared to the untreated dwellings in the same area. This was reflected in reduced capture rates and reduced rodent weights for treated dwellings. A reduced average weight would indicate changes in age-structure arising from reduced survival. However, it could be argued that both of these factors are explained by the development of trap-shy

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

animals. Nevertheless, the incidence of traps going off without a rodent being caught was virtually zero over the course of the trial, mainly because the break-back trap design is extremely sensitive, catching rodents as small as 15 g. This suggests that no opportunity existed for the development of trap shyness. As commonly suggested, long-term development of neo-phobia could result from an intensive trapping regime (Mathur, 1997; Barnet, 1988). However, results from the experiment indicated the sex ratio of 1.0 did not change over the trial, and this could suggest that neo-phobia would evolve relatively slowly (Ding et al., 1998; Kyelem and Sicard, 1996; Nunney, 1991).

The main species found, *Rattus rattus* and *Mastomys natalensis*, are known to occur in other parts of eastern and southern Africa (Fiedler, 1988). *M. natalensis* is a known carrier of plague (Gratz et al., 1997; Kilonzo et al., 1997), and its foraging inside dwellings could increase the risk of human infection. However, the degree of interactions between *R. rattus* and *M. natalensis* in these environments is unknown, and the pathways of plague transmission could be complex (Mills and Childs, 1998). Villagers in all three areas consumed rats as a significant part of their diet. Plague bacilli are known to survive for several days on dead rodents (Liu, 1991), and thus the handling and preparation of rodents for food could result in plague transmission. When farmers cleared their fields by setting fires, *M. natalensis* was increasingly caught inside dwellings, as few food resources remained outside during this time. The increase in the proportion of *M. natalensis* caught roughly coincides with the annual increase in the documented cases of plague. As the trapping programme increases the number of dying rodents within dwellings and the handling of dead rodents, it is possible that such a strategy could increase plague incidence within the locality (Leirs et al., 1997). Further research is planned to determine anthropogenic and inter-specific factors that impact upon plague outbreaks.

In conclusion, intensive trapping is likely to be part of any integrated and ecologically-based rodent control strategy for rural dwellings in these areas of Mozambique (Makundi et al., 1999). Further research is required to determine the optimal number of traps needed to effectively modulate rodent populations given particular habitat and population parameters as well as accurately measuring the impact upon stored food and human health. The traps used in this experiment were highly durable, and each trap caught over 100 rats/year with no obvious signs of wear, making traps more cost-effective than a comparable value of rodenticide use. Traps are not only more cost-effective, but they are more easily used in a safe way by rural dwellings in Africa. Further studies are planned to incorporate other rodent control strategies that can be cost-effectively and safely implemented by rural communities in Mozambique.

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Table 1. Analysis of the mean number of rats caught per dwelling per day within each area when intensively trapping with 10 traps every day over one year. Rodents were trapped in 15 dwellings in Morrumbala and in 10 dwellings in the other two villages; N is the number of days over which trapping occurred. Values within each column preceding the same letter are not significantly different from each other (Duncan's multiple range, P < 0.05).

Morrumbala n = 291	Gurué n = 369	Namacurra n = 312
2.58 [a,b,c,d]	1.15 [d]	0.16 [a]
2.65 [b,c,d]	1.07 [c,d]	0.29 [b,c]
2.74 [b,c,d,e]	0.99 [b,c,d]	0.21 [a,b]
2.57 [a,b,c]	0.82 [a,b]	0.33 [c]
2.84 [c,d,e]	0.99 [b,c,d]	0.17 [a]
2.92 [d,e,f]	1.54 [e]	0.32 [c]
2.84 [c,d,e]	0.93 [b,c]	0.36 [c,d]
3.00 [e,f]	0.71 [a]	0.46 [d]
2.75 [b,c,d,e]	1.00 [b,c,d]	0.20 [a,b]
3.16 [f]	1.06 [c,d]	0.14 [a]
2.83 [c,d,e]		
2.27 [a]		
2.71 [b,c,d,e]		
2.69 [b,c,d,e]		
2.46 [a,b]		

Table 2. Comparison between the mean (±sem) daily number of rodents caught at treated and untreated dwellings in each area when assessed over three trapping nights every two months (Mann-Whitney, *P < 0.05, **P < 0.01, ***P < 0.001). N is the number of dwellings multiplied by the number of trapping nights.

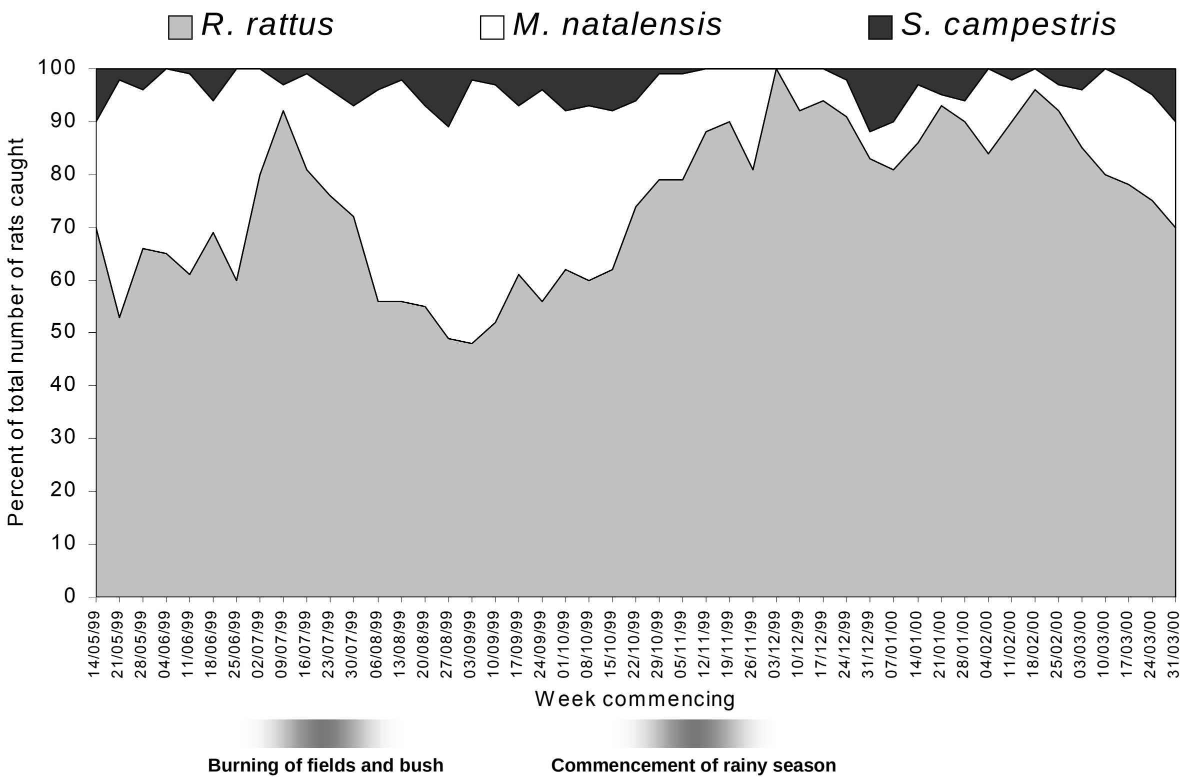
Assessment time	Group	Morrumbala n = 45	Gurué n = 30	Namacurra n = 30
0	Untreated	1.30±0.18	0.96±0.17	1.26±0.24
	Treated	1.37±0.18	1.00±0.22	1.34±0.26
1	Untreated	2.43±.020*	4.00±0.33**	2.00±0.30
	Treated	1.38±0.30	1.90±0.36	0.58±0.23
2	Untreated	3.90±0.26*	4.43±0.26***	2.00±0.19**
	Treated	2.81±0.19	1.43±0.22	0.66±0.11
3	Untreated	5.35±0.17**	4.13±0.40***	1.95±0.20**
	Treated	3.51±0.17	1.64±0.30	0.26±0.09
4	Untreated	5.75±0.22***	2.30±0.36**	1.87±0.19***
	Treated	3.28±0.20	0.96±0.24	0.54±0.12
5	Untreated	4.56±0.27***	3.21±0.21***	1.78±0.21**
	Treated	2.15±0.15	0.93±0.25	0.32±0.13

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Table 3. Comparison between the mean (±sem) weight of rodents caught at treated and untreated dwellings in each area when assessed over three trapping nights every two months (Mann-Whitney, *P < 0.05, **P < 0.01, ***P < 0.001)

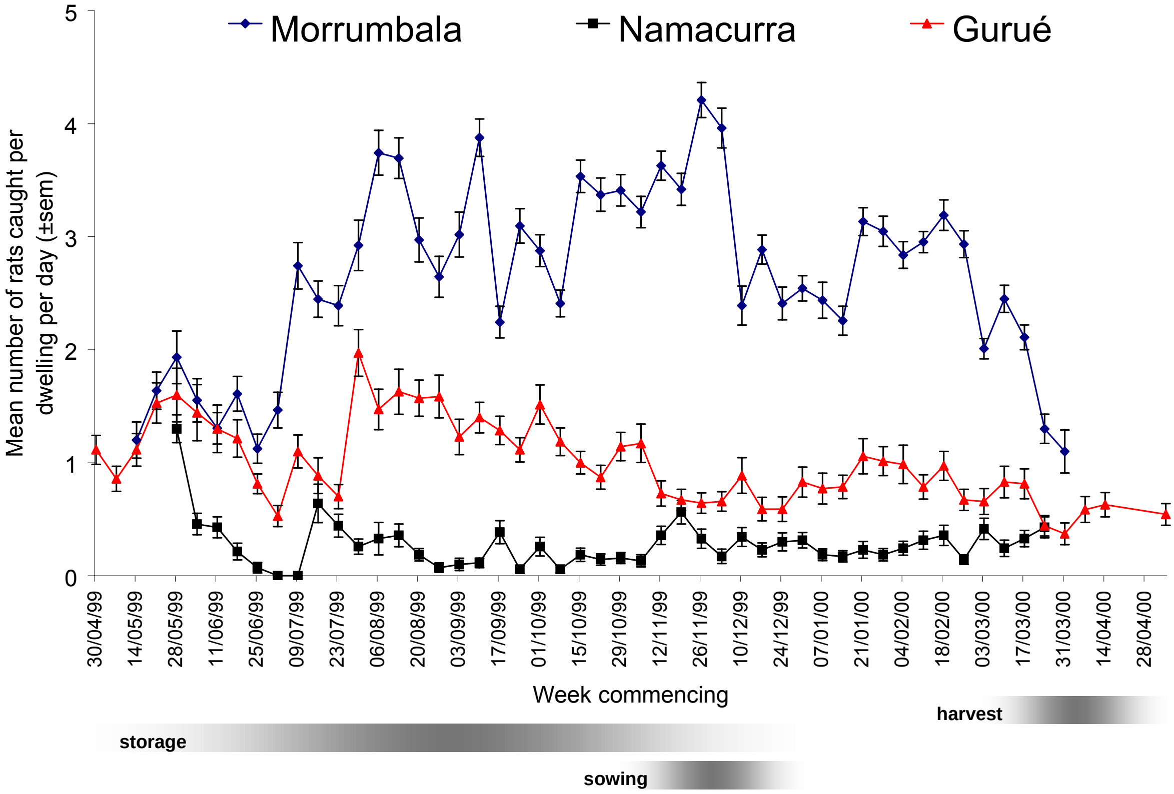
Assessment time	Group	Morrumbala	Gurué	Namacurra
0	Untreated	65.3±4.86	68.2±5.21	66.7±3.54
	Treated	67.2±3.04	66.3±4.45	67.2±3.30
1	Untreated	68.4±6.51*	70.5±5.00*	66.9±2.45**
	Treated	48.5±2.34	50.7±3.89	44.3±3.21
2	Untreated	69.5±3.33**	69.9±2.55**	68.0±4.36***
	Treated	41.9±1.95	42.0±2.15	42.1±3.67
3	Untreated	72.7±4.00**	70.6±3.67***	71.5±3.33***
	Treated	41.6±2.36	41.2±3.40	40.0±2.85
4	Untreated	70.1±3.87***	68.1±3.27***	69.2±3.06**
	Treated	37.4±2.55	40.5±2.87	48.5±2.76
5	Untreated	70.9±4.01***	66.4±4.06***	70.3±3.51***
	Treated	38.4±3.55	38.8±3.63	39.4±3.86

Figure 1. Species composition of rodents trapped by dwellings intensively trapping with 10 break-back traps inside their house in Morrumbala. The increase in the proportion of *Mastomys natalensis* caught within dwellings during August and September is due to farmers setting fires to clear the land.



Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 2. Mean number of rodents caught by dwellings intensively trapping on a daily basis with 10 break-back traps. Regression analysis showed that rodent populations decreased inside houses in Namacurra or Gurué as the trial progressed, whereas in Morrumbala the population increased and decreased following relative food availability patterns inside and outside the house.



Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Effects of community based trapping to manage rodent pests in households and food stores

Abstract
Field trials involving 1200 rural households from three villages (Pinda, Mutange and Mugaveia) in Mozambique were established to test whether intensive daily trapping inside household-level food stores could effectively reduce rodent pest populations. The species caught inside dwellings where food was stored were *Rattus rattus* [*alexandrinus*] and *Mastomys natalensis*. The proportion of each species caught varied among the three villages and over the 16-month duration of the trial. *R*. *rattus* was more abundant inside households in Pinda and Mutange; whereas *M*. *natalensis* was more abundant inside homes in Mugaveia. Pregnant females of both species were caught throughout the year, showing no clear breeding seasonality. Householders that trapped rodents inside their house on a daily basis were able to significantly reduce the level of infestation when compared with householders who did no rodent management. The level of population reduction among households in the same village was similar, but the degree of reduction significantly varied among the three villages. The average weight of *R*. *rattus* trapped inside households through intensive trapping declined by 40% when compared with those caught in households that did not intensively trap; however, no significant weight difference was noted in populations of *M*. *natalensis*. The population reduction caused by intensive trapping was maintained over the duration of the trial, and assessments of food stocks indicated that food remained in store up to three months longer with loss assessments indicating savings of 30-40% when compared with households in which rodents were not controlled. The implications of these results are discussed in the context of implementing ecologically-based rodent management strategies for poor rural communities in Africa.

Introduction
Ecological studies and the control of rodent pests in rural agricultural settings have largely involved the use of rodenticides (Makundi et al., 1999). However, especially in rural parts of Africa, there are several constraints to their use. Primarily, rodenticides are not affordable for the rural poor who are most affected by rodent pests. Even when rodenticides are widely available, they are often used inappropriately leading to low efficacy and to health and environmental risks. Recently, there has been an increased effort to apply our understanding of rodent population dynamics to develop more ecologically-based methods of rodent management (Singleton et al., 1999).

Most households in Mozambique traditionally store their food inside their dwelling for security and spiritual reasons. However, this storage practice makes it difficult to exclude rodents from the food store, exacerbating food losses and contamination caused by rodents. Rural extension programmes have tried to introduce separate food storage structures to the area, but adoption and uptake has been limited. Farmers in Zambézia Province have indicated that stored food losses by rodents can be severe and have prioritised rodent pests as one of their most important constraints to improving their livelihoods (Taylor and Phillips, 1995). In addition to food losses, recurrent outbreaks of plague (*Yersinia pestis*) occur in parts of Mozambique, and preliminary studies have shown that leptospirosis (*Leptospira icterohaemorrhagiae*) prevalence (IgG) can be as high as 17% (Thompson et al., in press).

The development of ecologically-based rodent management strategies that are affordable and easily implemented by the rural poor of Africa could substantially improve public health and local economies. The objectives of our research have been to test management strategies that attempt to reduce rodent pest problems in rural areas. Although some researchers have argued that trapping is an ineffective means of population management (Buckle and Smith, 1994), previous research has shown that trapping can, under some circumstances, be an effective method of rodent management in field crops (Tobin et al., 1993; Gebauer et al., 1992) and grain markets (Ahmad et al., 1995). In this paper we test whether trapping can significantly reduce local populations under the high density of rodents found in household level food stores in Mozambique.

Materials and Methods
Three villages in different districts of Zambézia Province, Mozambique were selected for involvement in the trials based on reports from farmers indicating rodents were a significant pest problem, particularly after harvest when crops are stored within the dwelling. The village of Mutange in Namacurra District lies within a flat lowland rice-growing area, the village of Pinda in Morrumbala District is found in a highland plateau maize-growing area and the village of Mugaveia in Gurué

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

District is in a mountainous mixed forest-cropland area. Each village has approximately 400 domestic dwellings which typically consist of a mudded timber-frame rectangle (approx. 4 x 5 metres) with a grass or palm-leaf thatched roof. The open-plan interior contains a raised platform where food is stored, a cooking fire and a sleeping area for approximately eight people.

Each village was divided into two portions, one half acting as the treated area and the other as the untreated area (experimental control). The 200 households in the treated area were each given ten break-back traps (big snap-e-trap™, Kness Manufacturing Ltd., USA), with all ten traps placed in the dwellings along interior walls and walkways, especially in places where food is usually stored. Farmers were given individual training on the operation of the traps and instructions to set them each evening. Dwellings in the treated area of the three villages were visited each morning, and the number of rodents trapped the night before were recorded daily for the duration of the trial (November 2000 to March 2002). Householders in the untreated area did nothing to manage their rodent problems over this time, and every month a sub-set of 30 households were randomly selected from this area and the occupier set traps in the same manner as in the treated dwellings but over three nights only. The number of rodents caught during these three nights from households in treated and untreated areas was recorded, including their sex, weight, species and whether any females caught were observed to be pregnant. Representative samples of each species were collected for later taxonomic identification. The number of rodents caught among farmers and villages was analysed by ANOVA with a post-hoc LSD test to separate the mean values. Comparisons between treated and untreated areas in the same village were analysed using an independent sample T-test evaluating the number of rodents caught, and their average weights. The potential interactions between populations of *R. rattus* and *M. natalensis* within each village were evaluated by linear and non-linear regression models using the data obtained on the total number of each species caught in each household during the trial.

A sub-sample of ten randomly chosen farmers in each treated and untreated area in Pinda were selected to store 5 kg of their maize cobs in an open-topped basket. The basket of commodity was placed in the same area of food storage as the main household stocks over the usual storage period (May to December 2001), and householders were instructed not to remove any cobs from the basket. The baskets were weighed every four weeks from May to December 2001. Maize cobs were assessed for rodent damage by counting the number of missing maize grains on ten randomly chosen maize cobs from each basket every four weeks and calculating the percentage of missing grains per cob. Data from treated and untreated areas were evaluated using the non-parametric Mann-Whitney U-test.

Results

The mean daily catch rate by each householder continuously trapping significantly varied among farmers in the same village (ANOVA with LSD, P<0.01) and among the three villages (ANOVA with LSD, P<0.01). However, the daily number of rodents caught in households in the same village was relatively similar compared with the numbers caught among the three villages (Figure 1). Higher numbers of rodents were caught during the first month of intensive trapping in all three villages (2.47±0.05, 1.24±0.04, 3.98±0.07 rodents/day/dwelling (mean±sem) in first 30 days of trapping in Pinda, Mutange and Mugaveia, respectively) when compared with the number of rodents caught in subsequent months (ANOVA with LSD, P<0.01). The decline in the number of rodents caught was most pronounced in Pinda where relatively few rodents were caught after the first month (0.081±0.002 rodents/day/dwelling over the next 15 months of the trial), followed by Mutange and Mugaveia (0.655±0.006 and 2.78±0.01 rodents/day/dwelling, respectively). The two species, *Rattus rattus* and *Mastomys natalensis* were present in all three villages and were trapped inside all households (Figure 2). Approximately equal numbers of *R. rattus* and *M. natalensis* were caught in households in Pinda and Mutange; however, approximately three times more *M. natalensis* were caught than *R. rattus* in Mugaveia. Linear and non-linear regression analyses showed that the relationship between the number of each species caught within a dwelling was best represented by power regression models for data from Pinda (F=215.7, r^2=0.52, P<0.01) and Mutange (F=176.5, r^2=0.47, P<0.01). In these two villages, higher numbers of *R. rattus* were associated with higher numbers of *M. natalensis* (Figure 3). Regression analysis on the data from Mugaveia showed that the relationship between the two species was best represented by a cubic polynomial regression model (F=5.15, r^2=0.42, P<0.01). The number of each rodent species caught in households in Mugaveia indicated that high numbers of *R. rattus* may regulate the numbers of *M. natalensis* present inside dwellings in this village (Figure 3).

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Households within each area of the three villages where continuous trapping did not occur (untreated control) were shown to have greater numbers of rodents inside their houses at each of the three-day monthly assessments when compared with those where trapping was carried out daily (T-test with equal variance not assumed, $P<0.01$, Figure 1). Households that did not trap regularly caught approximately twice as many rodents during three days of trapping as opposed to those trapping every day throughout the trial (Figure 1). On average, householders in the untreated area of Pinda caught 1.49±0.26 rodents/day throughout the 16-month trial duration, with 2.11±0.17 and 5.80±0.35 rodents/day caught in Mutange and Mugaveia, respectively. On average, the weight of *R. rattus* caught in untreated dwellings was significantly higher than that of the same species caught in treated dwellings (75.3±1.6g and 45.9±2.0g, respectively, T-test with equal variance not assumed, $t=7.46$, $df=30.5$ $P<0.01$). However, there was no significant weight difference between the corresponding samples of *M. natalensis* (untreated = 52.3±3.2g, treated = 46.5±3.3g, T-test with equal variance not assumed, $t=1.15$, $df=31.1$ $P>0.05$). No significant differences were noted with respect to changes in the sex ratio of rodents caught between treated and untreated dwellings (Mann-Whitney U, $P>0.05$), showing a 1:1 male:female ratio throughout the year for both rodent species at all three villages.

Weight loss to the standard 5 kg baskets of maize was attributed to both rodent and insect damage (Table 1). The main insect pest found in stored maize cobs was the maize weevil, *Sitophilus zeamais*. Damage characteristics to maize caused by insects and rodents are very distinctive, with rodents completely or partially removing grains from the cob, whilst weevils infest grains internally. All missing grains on cobs were attributed to rodent pests. Rodent damage was observed to occur from the outset of the assessment period, whereas weevil damage only became apparent after three or more months of storage. Damage due to rodents was lower in dwellings that intensively trapped compared with dwellings in the untreated areas while insect damage levels were similar between treated and untreated dwellings. Questionnaires with farmers in the treated and untreated areas of the village indicated that householders that had been intensively trapping maintained stocks of food for approximately three months longer than householders in the untreated area. Farmers that trapped also noted that their food stocks lasted longer when compared with previous years when harvested yields were similar.

Discussion

Our study showed that intensive trapping of rodents can effectively reduce their localised population densities within rural African dwellings. Although trapping is labour intensive, the relatively low cost of inputs and the benefits accrued to the family unit could favour the technique. Household benefits not only included reduced food storage losses as demonstrated in this study, but as rodents are widely eaten by people in Zambézia Province, household trapping was seen to provide families with a reliable source of much needed protein.

At the commencement of the intensive trapping trial, it was not known whether rodent population densities would vary among dwellings or areas. However, it was considered likely that rodent density would be generally dependent upon food availability in the dwelling (Krebs, 1999; Boutin, 1990). Food stores provide an ideal environment for rodents, offering harbourage, and a relatively unlimited food supply. Although building structures and food storage practice were similar in all three villages, there were marked differences in the number of rodents caught among the three villages, the relative abundance of species and in the efficacy of the trapping regime. These differences among the three villages must be related to factors outside the household and to the differing habitats and ecology found in the localities (Ferreira and Aarde, 1999). There are two observations which are likely to contribute to these differences. In all three villages, *R. rattus* made nests in the roof thatching of the dwelling, while *M. natalensis* lived in burrows in the fields. Our research on the field trapping of rodents in the area (to be reported elsewhere) indicates that *R. rattus* is very rarely trapped in the bush or in farmer's fields, and the species appears to be predominantly confined to areas of human settlement. Our research would support this difference in nesting behaviour between the two species *as R. rattus* populations appeared to be more susceptible to the trapping programme inside dwellings. A second factor likely to be important in explaining the observed differences among the villages is the relative distance between dwellings in the village. Buildings in the village of Pinda were relatively close to each other (50-200 m), whereas buildings in Mugaveia were farther apart (500-1500 m). Our results would suggest that *R. rattus* populations are higher when villages are relatively densely populated, and *M. natalensis* are more prevalent in villages where houses are isolated from each other. In a village such as Pinda, intensive trapping on a community level can have a greater impact because rodent immigration/emigration is reduced, and *R. rattus* immigration from the bush will be

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

slow. In a village such as Mugaveia, immigration of *M*. *natalensis* from the surrounding bush is unaffected by community trapping, and trapping will be relatively less effective in modulating household rodent density.

Despite the observed differential efficacy achieved among the three villages, intensive trapping with ten traps did constrain populations when compared with untreated dwellings in the same area. This was reflected in reduced capture rates and the reduced average rodent weight of *R*. *rattus* in treated dwellings. A reduced average weight would indicate changes in age-structure arising from reduced survival. However, it could be argued that both of these factors are explained by the development of trap-shy animals. Nevertheless, discussions with farmers (who hear the traps going off at night as they are in the same room) would indicate that the incidence of traps going off without a rodent being caught was virtually zero over the course of the trial, mainly because of the superior design of the Kness break-back trap compared with other break-back trap designs. As commonly suggested, long-term development of neo-phobia could result from an intensive trapping regime (Mathur, 1997).

The two species trapped, *R*. *rattus* and *M*. *natalensis*, are known to occur in other parts of eastern and southern Africa (Fiedler, 1988). *M*. *natalensis* is a known carrier of plague (Gratz et al., 1997), and its foraging inside dwellings could increase the risk of human infection. Although much higher numbers of *M*. *natalensis* were caught in Mugaveia, plague outbreaks are relatively uncommon there, whereas plague cases are recorded nearly every year in Pinda. The degree of interaction between *R*. *rattus* and *M*. *natalensis* in these environments is unknown, and the pathways of plague transmission could be complex with infected fleas moving between populations of *M*. *natalensis* and *R*. *rattus* in and around human settlements (Mills and Childs, 1998). Villagers in all three areas consumed rats as a significant part of their diet. Plague bacilli are known to survive for several days on dead rodents (Liu, 1991), and thus the handling and preparation of rodents for food could result in plague transmission. As the trapping programme increases the number of dying rodents within dwellings and the handling of dead rodents, it is possible that such a strategy could increase plague incidence within the locality. Using live multi-catch traps instead of break back traps may offer a way to reduce plague-infected fleas from remaining inside the dwelling. Further research is planned to determine anthropogenic and inter-specific factors that impact upon plague outbreaks. Other rodent-borne zoonoses have been recorded in the area, particularly leptospirosis (Thompson et al., in press), and research is planned to determine how zoonosis transmission could be affected by intensive trapping inside rural dwellings.

Rodent losses of stored food were significantly reduced by the intensive trapping. As the baskets of known quantity were placed on top of the household food store, the observed losses in the basket could be an overestimate of the total rodent loss to the overall food store in the dwelling. Some of the observed weight loss is due to a reduced moisture content of the maize as the dry season progresses, particularly in the first three months of storage. However, relative comparisons between households in the treated and untreated areas of the village would argue that rodent pressure on the food store was considerably reduced by intensive trapping because relative weight loss and rodent damage was reduced. Questionnaires with farmers indicated that the effects of trapping were noticeable as the stored food lasted longer than usual, particularly by the most food-insecure households who normally do not produce enough to meet their household requirements. Other benefits were also noted by farmers, notably a regular supply of rat meat and fewer rat bites to family members.

In conclusion, intensive trapping is likely to be part of any integrated and ecologically-based rodent control strategy for rural dwellings in these areas of Mozambique. Further research is required to determine the optimal number of traps needed to effectively modulate rodent populations given particular habitat and population parameters. The cost-benefits of trapping need to be more adequately understood in order to inform and encourage rural communities and agricultural extension programmes to adopt trapping as part of an ecologically-based rodent management programme.

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

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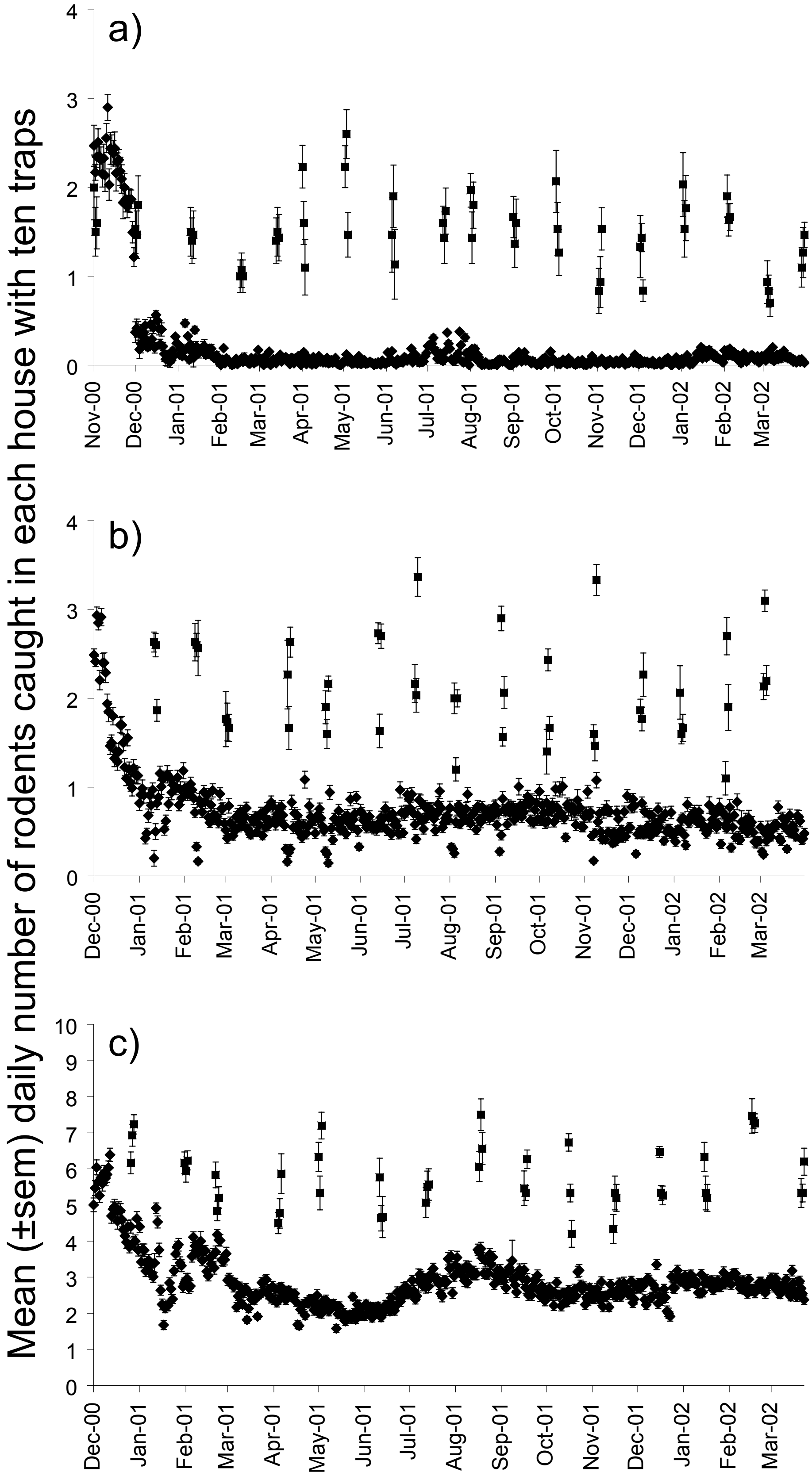
Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Table 1. Comparison between the cumulative percent weight loss and percent damage to 5kg of maize cobs stored in baskets over eight months inside dwellings in the village of Pinda where rodents had (treated) or had not (untreated control) been intensively trapped daily (n = 10). Treated values marked with * are significantly different from the untreated value (Mann-Whitney U, P<0.01).

Assessment period	Percent weight loss (mean±sem)		Percent rodent damage (mean±sem)		Percent insect damage (mean±sem)	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
May	0	0	0	0	0	0
June	2.5±0.04	3.1±0.17	0	1.5±0.03	0	0
July	3.6±0.09	5.1±1.23	0.5±0.01	2.8±0.02	0	0
August	4.1±0.15 *	12.8±3.07	0.5±0.08 *	3.4±0.95	0	0.5±0.07
September	8.2±0.96 *	16.5±3.40	1.4±0.13 *	6.7±1.26	2.0±0.56	2.8±0.77
October	11.0±1.11 *	28.3±5.67	3.3±0.77 *	10.9±3.55	3.1±0.79	3.5±0.92
November	17.0±3.55 *	46.1±5.45	5.5±0.65 *	25.0±4.58	9.2±2.32	10.1±2.01
December	18.9±4.15 *	54.7±5.08	5.8±1.95 *	28.3±3.83	11.7±2.38	12.3±2.18

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 1. Comparison between the mean number of rodents caught by householders setting ten break-back traps each night (treated = ◆, n = 200) and householders that did no rodent management, but where a sample of rodents were trapped over three nights each month from a different sub-set of houses (untreated = ■, n = 30) in the villages of a) Pinda, b) Mutange and c) Mugaveia.



Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 2. Comparison between the mean number of *Rattus rattus* (■) and *Mastomys natalensis* (□) caught inside 200 dwellings in traps set by householders each night in the villages of a) Pinda, b) Mutange and c) Mugaveia.

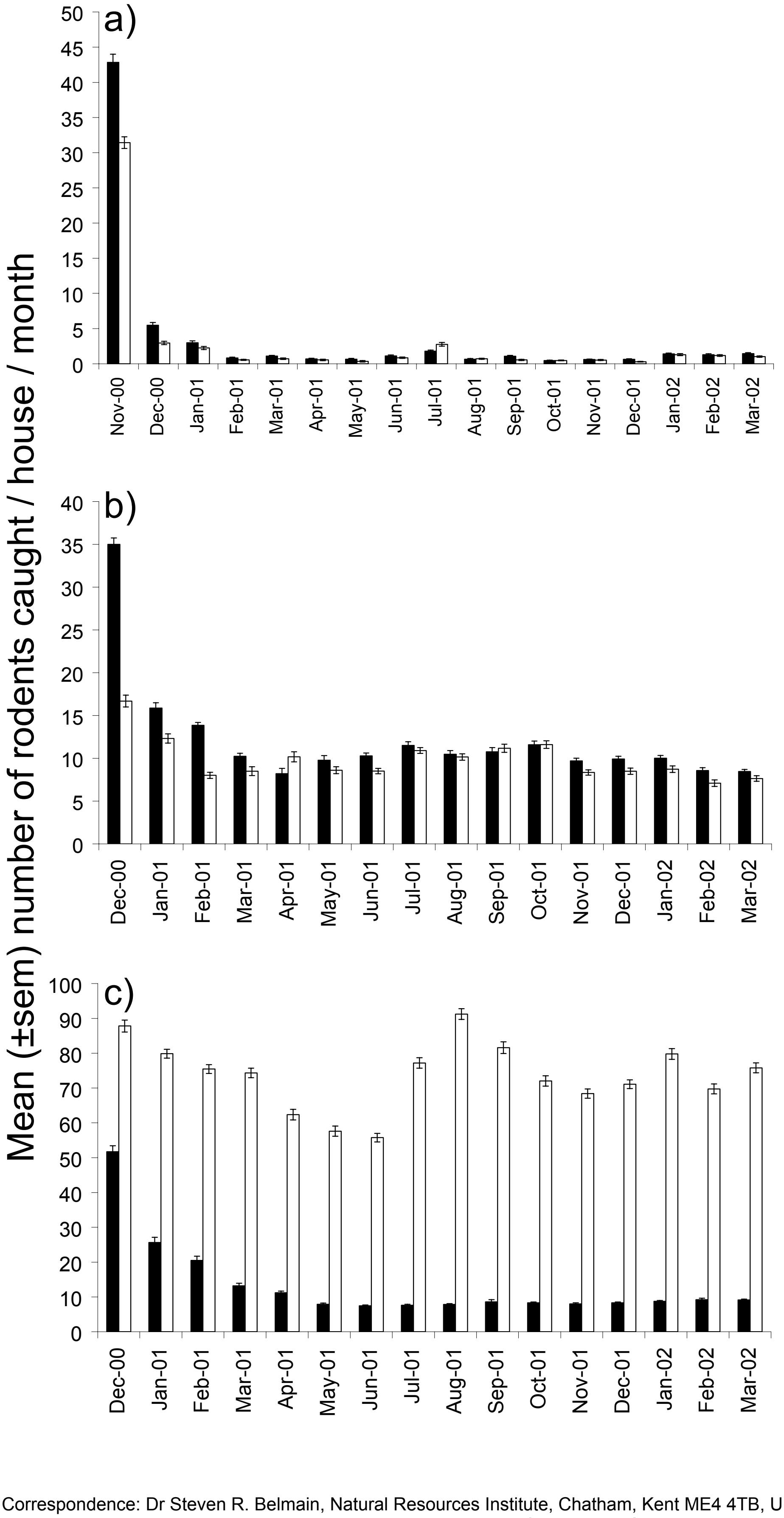
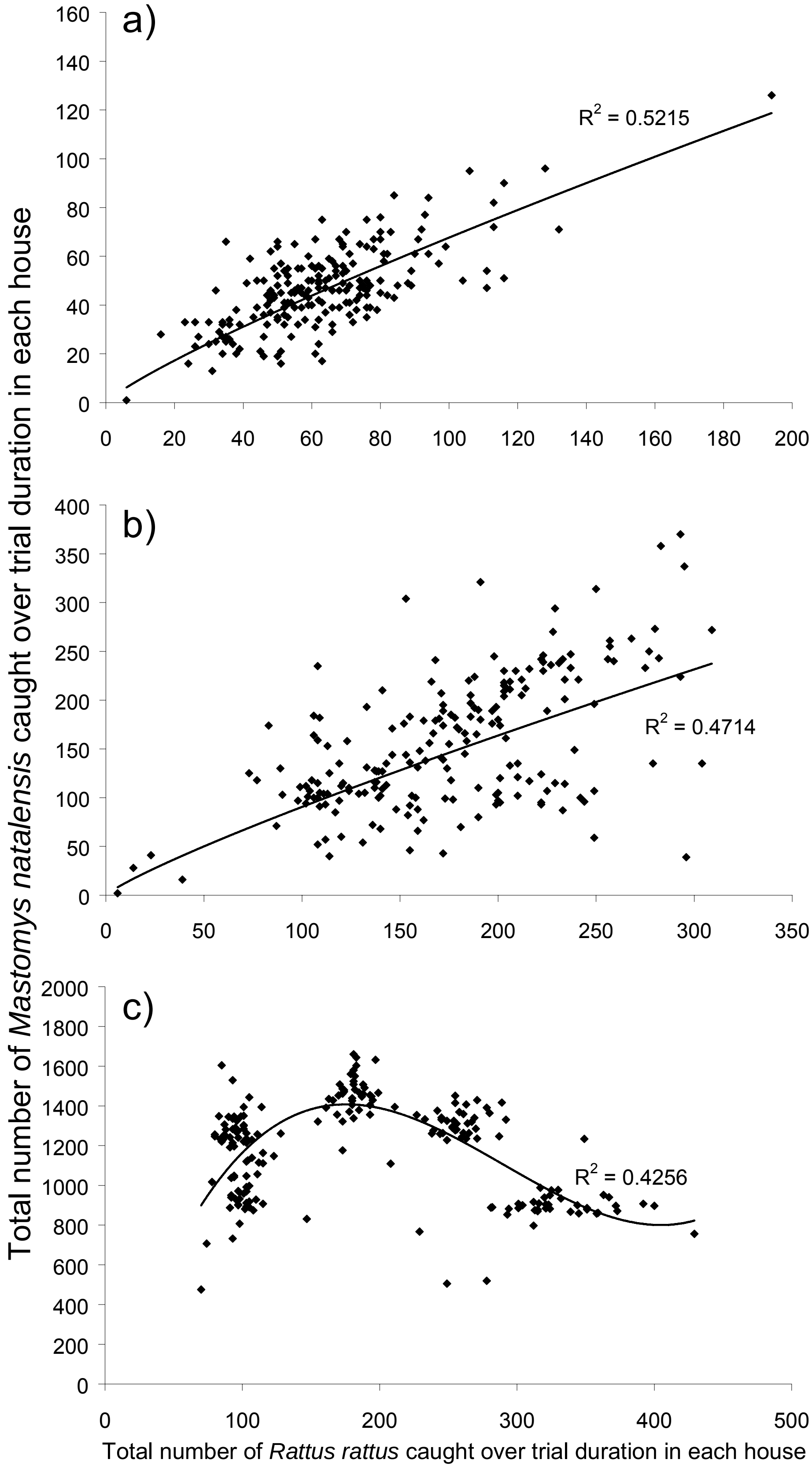


Figure 3. Relationship between the total number of *Rattus rattus* and *Mastomys natalensis* caught in each dwelling (n = 200) trapping daily in a) Pinda, b) Mutange and c) Mugaveia. Regression analysis indicated that data obtained from Pinda and Mutange were best represented by non-linear power models, whereas a cubic polynomial model best represented the data obtained from Mugaveia.



Development of management strategies to reduce field losses to paprika (*Capsicum annuum*) caused by the rodent, *Mastomys natalensis*

Abstract

An on-farm trial was carried out in Mozambique to evaluate whether trapping and improved cultural practice could reduce the impact which rodent pests have upon field crops of paprika (*Capsicum annuum*). Trials involving 15 farmers in Morrumbala District, Zambézia Province investigated the use of snap traps placed around the field and clearing vegetation from around the field to determine whether paprika quality and quantity could be improved in comparison to an untreated control field. The results showed that paprika plots with the trapping and clearance treatments had significantly lower percent damage of fruits by rodents (5.1±1.15% and 9.3±1.85% damage, respectively (mean±standard error of mean)) when compared with the untreated control plots (23.4±1.52% damage). The paprika yield obtained in fields with trapping (0.45±0.01 ton/ha) was significantly higher than the untreated control (0.23±0.05 ton/ha). Although several species of rodent are known to be present in the area, the multimammate rat (*Mastomys natalensis*) was the only species of rodent caught in the paprika fields over the two-month duration of the trial (0.1±0.002 rats/day/trap). The implications of these results are discussed in the context of providing cost-effective and sustainable alternatives to rodenticides for use by resource-poor farmers in Africa.

Introduction

Paprika (*Capsicum annuum*) is an important cash crop in Mozambique. Dried paprika is powdered and exported to Spain for industrial processing and colour extraction (Smith, 1982). Paprika can be cultivated in both rainy and dry seasons depending on the moisture of the soil. Prices paid for good quality paprika average about $0.71/kg which makes it the highest value cash crop grown in Zambézia Province. Under optimal conditions, yields can reach 1.5 tons per hectare; however, most farmers only achieve about 0.5 tons/ha under much less than optimal conditions and minimal inputs. Farmers tend to grow their paprika in small plots (0.25 to 1.0 hectares) interspersed with other staple crops such as maize and sweet potato. Rodents are the major pest of paprika, eating the maturing fruit, and damaging more than they consume by partially eating pods which subsequently drop off or result in their downgrading of quality. It has been estimated that rodent damage can reach up to 30% of the total yield in ripening pods shortly before harvest (Timbrine, unpublished), affecting the quantity and quality of paprika harvested. Due to the heavy losses reported by farmers, the lack of rodenticides available in local markets and their high cost when they are available further afield, a trial was carried out to evaluate the efficacy of trapping and clearing around paprika fields as methods to reduce rodent immigration into the field during the time of paprika pod ripening.

Materials and Methods

The study started during the winter season, June to December 2001. Paprika was grown in seed-beds and transplanted at 21 days. Irrigation was used for supplementary water when required. A randomised complete block design with four repetitions and three treatments (trapping, clearance and control) was used. The 12 paprika plots were maintained by a group of 15 farmers. The distance between plots was 50 m on each side. The adjacent land to each plot was also cultivated, but with a different crop (maize and/or sweet potato). The adjacent land to each plot was generally much more weedy and densely vegetated (representative of local farming practice) when compared to the paprika plots. Each paprika plot measured 50 m X 50 m containing 55 rows with 166 plants/row. The distance between rows was 0.9m with 0.3m spacing between plants. All plots were simultaneously transplanted in July and fully harvested by the end of December.

For the untreated control plots, no management activity was imposed around the field. The 25 meters surrounding the plot on all sides was planted with a crop of the farmers choosing, in all cases being sweet potato and/or maize. The clearance treatment was similar to the untreated control with the exception that there was a three metre area around the perimeter of the plot kept clear of all vegetation including other crops. The cleared area was then surrounded by other farmed crops. The cleared area was monitored on a weekly basis with new weed growth removed as necessary. The trapping treatment was similar to the clearance treatment with the addition of traps. Unbaited snap traps (big snap-e, Kness Mfg, USA) were placed around the perimeter of the plot in two lines placed at one metre and three metres distant from the crop. Traps in each perimeter line were placed at 1.5 m intervals and tied to a stake, giving a total of 250 traps per replicate. Trapping and clearance treatments commenced in early November shortly before fruit ripening and continued until the paprika crop was fully harvested near the end of December. At the end of the trial, the harvested paprika

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

pods were graded according to standard grading methods (CHEETAH Limited, Mozambique), and the total yield from each plot was calculated.

Once per week during the paprika pod ripening stage, the number of damaged and undamaged fruits was assessed by randomly placing a diagonal transept across each experimental plot (Neena and Parshad, 2001; Buckle, 1994). Starting with the first paprika plant on the edge of the field, 20 plants along the transept which were two metres apart from each other were examined, recording the total number of damaged and undamaged pods on the plant. Traps in the trapping treatment were set each evening and checked each morning, and the number and species of rodent caught were recorded. Data on paprika damage and yield were analysed by ANOVA with a post-hoc LSD using the software package MSTAT.

Results

Rodent damage to paprika plants before the pod ripening stage was not evident. As rodent burrows were not located in any of the paprika fields, it can be reliably assumed that rodents immigrated to the paprika field from the surrounding bush, attracted by visual or olfactory cues to the ripening pods. Rodent damage was noted as soon as fruits started to turn red (Figure 3). Cumulative paprika damage as assessed at the end of the trial showed that there was significantly less fruit damage in the trapping and clearance treatments when compared with the control (Table 1). The total paprika yield obtained from each field treatment showed that the trapping treatment produced significantly more paprika than the untreated control, producing approximately 49% more paprika (Table 1). The mean weekly number of rodents caught in the trapping treatment varied throughout the assessment period (Figure 1), showing no clear linear or non-linear trend for the numbers of rodents caught with time. High variance in daily trap catches among the replicates was recorded and may partly explain the non-significance of the data. Over the two-month trapping period, the average catch rate was 0.1 ± 0.002 rats/day/trap (mean$\pm$standard error of mean) caught in each replicate field using 250 traps. All rodents trapped were of the species *Mastomys natalensis*. Damage to paprika significantly increased with time in the control plots (Figure 2). However, damage levels in the trapping and clearance treatments remained relatively stable over the assessment period, with damage levels remaining significantly lower than that observed in the control plots (Figure 2). Paprika fruit damaged by rodents drops automatically to Grade D, the lowest quality paprika with the lowest price (Table 2). Estimated income from paprika sales in the trapping treatment was $338.10 which was more than double the price obtained for paprika in the untreated control plots (Table 2).

Discussion

The overall yields obtained in all the paprika treatments was far below the known optimal yields (1.5 tons/ha) which are possible for paprika. This is largely explained by the minimal inputs that farmers make to their crops. However, growing conditions for the paprika crop were not ideal as transplanting was done relatively late due to widespread flooding in the area, shifting production later into the dry season. Yield loss could also be partly attributed to delayed harvest as this is well-known to affect paprika (Kahn, 1992). During the paprika growing season irrigation occurred once every three days on rotation, and more frequent irrigation could have improved yields (Wiertz and Lenz, 1987).

Although the analysis of the data was unable to show that the clearing treatment significantly improved yields, there was evidence that clearing around the crop reduced pod damage. The overall trend in the data was that clearing did offer some protection to the crop with some improvement in yield (albeit statistically insignificant). As clearance did reduce damage to the crop, the grading of harvested pods was higher than in the untreated control. As clearance is significantly less input intensive than the trapping treatment, it should be relatively easy to make recommendations for using clearance around fields as an appropriate rodent management activity, particularly for a cash crop such as paprika where the returns will be greater and management activity need only focus on a relatively narrow window of time when the paprika pods are ripening. Similar studies on the manipulation of adjacent non-crop habitats have also shown that clearance can reduce rodent damage levels (White et al., 1998). The trapping treatment did provide superior levels of rodent control. However, the number of traps used around the paprika field would pose prohibitive costs for an individual farmer. Growing paprika at the community level could offer one way around this issue. If individuals within a village could be convinced to grow their paprika together in large plots, it would be possible to protect the fields with a single trap barrier system, sharing the costs and the benefits. A community level management system would have the added potential to reduce the likelihood of traps being stolen from the field. Further trials aimed at reducing the number of traps without

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

sacrificing the level of protection could result in a system which requires fewer, more carefully placed traps. As our research suggests that rodents are migrating to the field during the ripening stage, trapping should be an effective management strategy as has been shown for other maturing crops (Kapoor et al., 1999). Despite the large number of traps used, the costs would still be comparable to using rodenticides as a method of protecting cash crops such as paprika. Rodenticide baits would need to be placed around the crop 3-4 weeks before pod ripening began and bait stations would need to replenished until 3 weeks before harvest. Although rodenticides may provide slightly better control, the amounts of rodenticide required for such an activity would far outstrip the costs of purchasing traps. Although other trials in the area showed that the rodent species *Rattus rattus* is present in the locality, it was not caught in the paprika fields. This would support the findings of trapping trials in around village households which indicate that *R. rattus* is confined to village dwellings, living in the roof thatching.

Clearly there is a strong economic incentive for farmers to manage rodent pests in their paprika fields, particularly as *Mastomys natalensis* is also an important food source for villagers in the area. Further studies evaluating different types of trap, such as the multi-catch trap, and modulating trap density could lead to improved cost-benefits of field trapping rodents in high value crops.

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Table 1. Effect of rodent management activity on the damage levels and yield of paprika pods

Treatment	Dry paprika yield (ton/ha)	Fruits damaged (%)	# of rodents caught/ha	
			R. rattus	*M. natalensis*
Trapping	0.45±0.10 [a]	5.10±1.15 [a]	0.00	164 ±77.65
Clearance	0.34±0.08 [ab]	9.30±1.85 [a]	--	--
Control	0.23±0.05 [b]	23.40±1.52 [b]	--	--
CV (%)	23	36		

*Numbers followed by the same letter in the same column are not significantly different from each other, $P < 0.05$.

Table 2: Predicted income based on classification and yield of paprika from each treatment.

Treatment	Yield (ton/ha)	Grade (%)				Total income (USD)
		A	B	C	D	
Control	0.23	70	4	4	22	154.84
Clearance	0.34	83	4	4	9	249.17
Trapping	0.45	87	4	4	5	338.10
Price (USD)/kg	--	0.79	0.65	0.5	0.33	--

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Figure 1. The mean number of *Mastomys natalensis* caught weekly during the paprika pod ripening period with 250 snap traps surrounding each 50m^2 plot of paprika (n = 4).

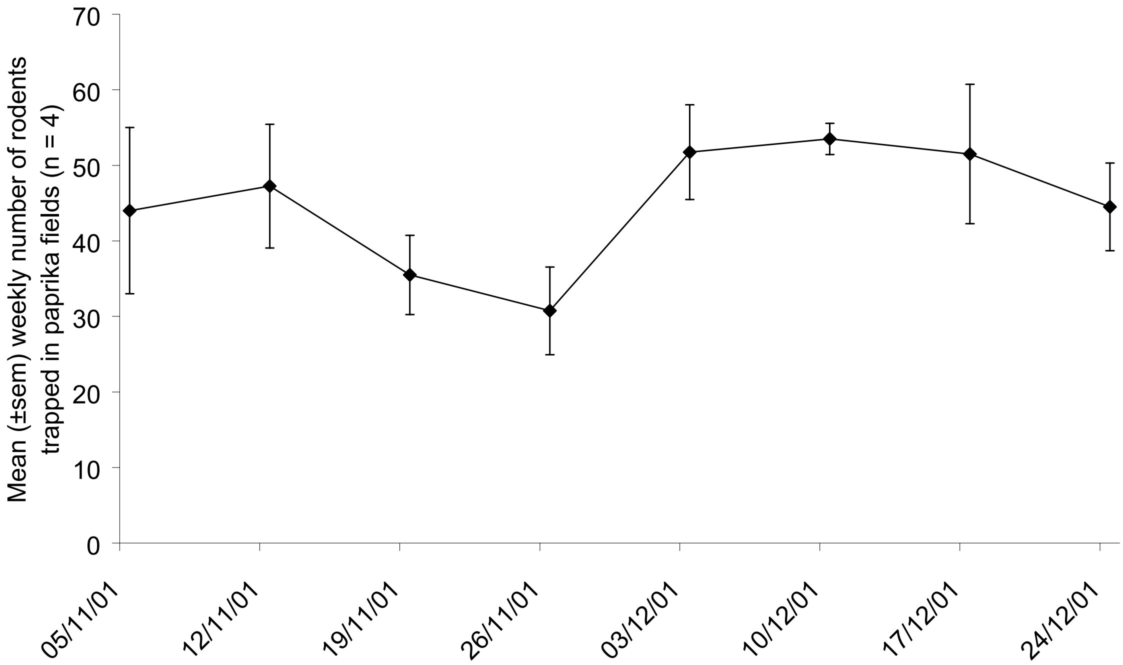
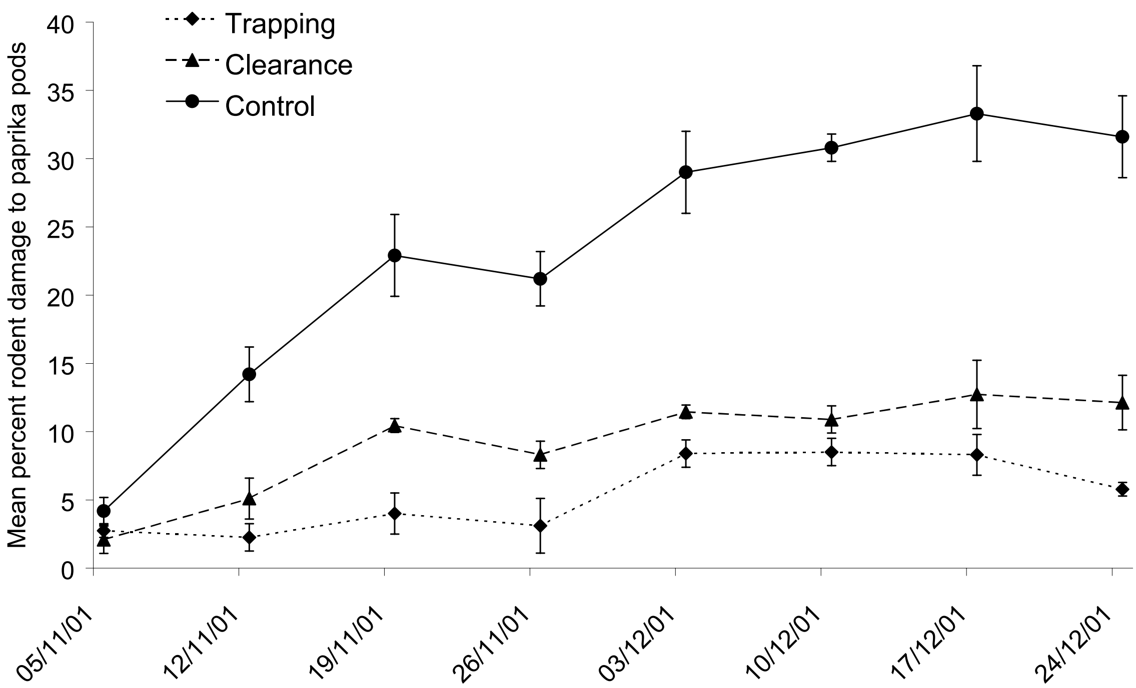


Figure 2. Effect of treatment on the mean percent damage to paprika pods by *Mastomys natalensis* occurring during the pod ripening period in the field



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Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 3. Typical damage caused by rodents to ripening paprika pods

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Evaluation of two different rodent traps for their trapping efficacy within rural households: the Deccan multi-catch trap vs. the Kness snap trap

Abstract

The trapping efficacy of two rodent trap types were compared under conditions found within rural households in Mozambique. One of each trap, the Kness break-back trap and the Deccan multi-catch trap, were placed in 15 rural households in the village of Pinda, Morrumbala District. The number and species of rodents caught on a daily basis were recorded from each trap over a 12-month period. Capture rates for the two traps were similar, except during the months of June, July and August when the Deccan trap caught significantly more rodents than the Kness trap. The higher capture rates coincide with the peak of the food storage period when rodents numbers were at their highest within the household. The results are discussed in the context of provided easily manufactured and affordable traps to rural farmers in Africa.

Introduction

Previous research indicated that the Kness snap trap was efficient, durable and easy to operate. However, as the trap was manufactured in the USA, importation costs of fully assembled traps would double the cost of the trap, putting the purchase price beyond the reach of average Mozambicans. Different tactics were taken to try to resolve this issue such as discussing with companies whether it would be possible to import parts to be assembled locally, or locally manufacturing a similar trap which maintains the quality and efficiency of the Kness trap. Different types of trap which are more easily manufactured from local materials could also be a way to ensure the supply of suitable traps. The Deccan multi-catch trap is widely used in India and many other countries (Corrigan, 1993). It is made from wire and small pieces of metal (Figure 1). The size of the trap can be adapted to different rodent species, and it is usually able to trap several rats at once. Live capture traps such as the Deccan trap often have lower efficacy than snap traps as it requires rodents to overcome their neophobia to enter the trap. Increases in potential capture rates can, therefore, be traded against increases in potential neophobia. Another potential advantage of using a live capture trap inside people's homes would be that flea loads would not disperse as happens with a kill trap, possibly reducing the transmission of plague. However, other research has argued that multiple live capture traps could increase the spread of hanta viruses (Calisher et al., 2000). The objective of this trial was to test whether the capture rates of the Deccan and Kness traps were similar under the conditions found in rural households.

Materials and Methods

The trial took place in the village of Pinda, Morrumbala District starting in February 2001 and completing in March 2002. Fifteen farmer households were randomly selected from one part of the village to be involved. Each household was given one Kness trap and one Deccan trap, instructing householders how the traps are used. Households were visited each day to record the number of house (*Rattus rattus*) and field rodents (*Mastomys natalensis*) caught from each trap.

Results

The results showed that the Deccan trap was marginally better than the Kness trap only during the months of June, July and August (Figure 2, Wilcoxon matched pairs signed ranks test, $P < 0.05$). During all other months the catch rate between the traps was comparable. Higher numbers of *R. rattus* were caught in the Deccan trap than in the Kness trap (Wilcoxon matched pairs signed ranks test, $P < 0.05$), whereas the number of *M. natalensis* trapped was comparable between the two traps (Figure 3).

Discussion

Although the Deccan trap has the potential to catch more rodents per night than the Kness trap, capture rates were usually no different between the two traps. This may be partly explained by the generally low capture rates experienced by both trap types which could imply that overall rodent populations in the area were too low to exploit the additional trapping potential of the Deccan trap. Low population density would be supported by the relatively high variance level found even when daily capture data were averaged over each month. This trial coincided with a large scale trapping trial that was implemented in another part of the village which caused a dramatic reduction in rodent numbers. Although speculative, if the large scale trapping caused a halo effect, it could be that rodent numbers were reduced in other parts of the village as well, adversely affecting the results of this comparative trial. Different results from those reported here may be likely when baseline rodent density is relatively higher, in which case one would argue that the Deccan trap should outperform the Kness trap (Singleton et al., 1998). The increased numbers of *R. rattus* caught with the Deccan trap during the months of June, July and August would

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

coincide with the storage season when numbers of *R. rattus* should be at their highest, supporting the above argument.

In conclusion, this trial has shown that the Deccan trap works atleast as well as the Kness trap. Although the Deccan trap is more bulky than a snap trap, which could potentially limit its use in tight areas, it is more easily manufactured in Mozambique than the Kness trap, and production costs should be lower. Cheap supplies of wire to make the traps will be essential in order to keep the cost of the trap down if the Deccan trap is to be promoted for rodent pest management in rural areas.

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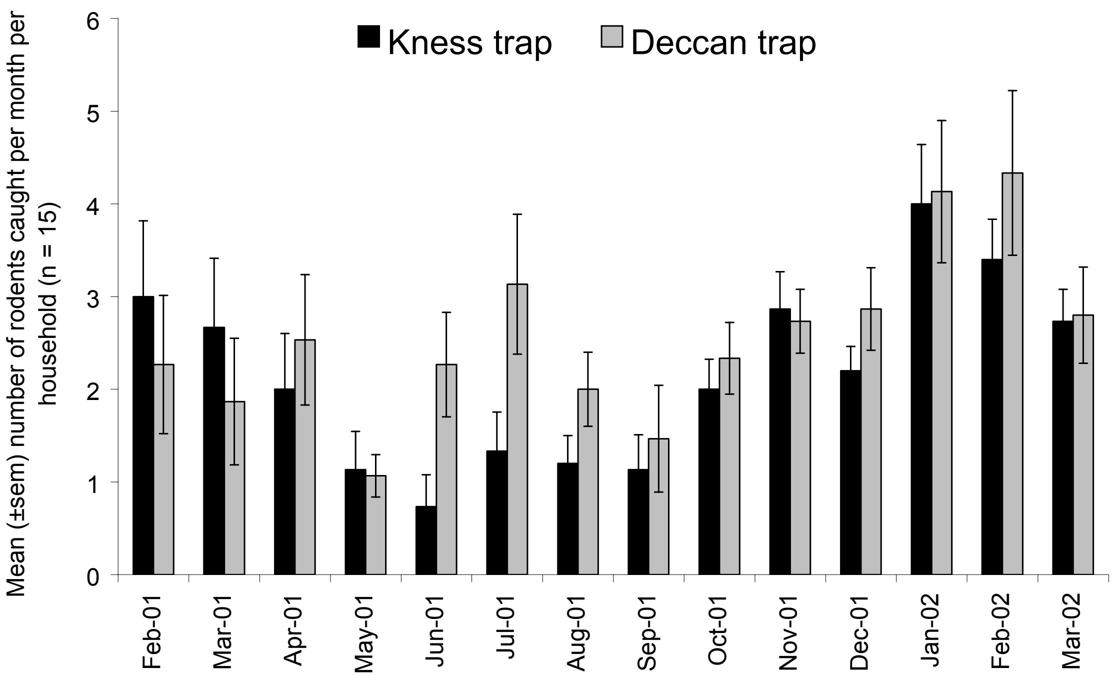
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 1. A Mozambican-made version of the Indian Deccan multi-catch trap. Rodents enter the trap through an opening (left side of picture), their weight triggering a treadle which allows them access to the food bait. The treadle is counter-weighted so that it closes, preventing the rodent from exiting the trap.

Figure 2. Comparison between the catch rate of a Deccan multi-catch trap and a Kness break back trap when a single trap of each type is placed within the same household over a twelve month period.



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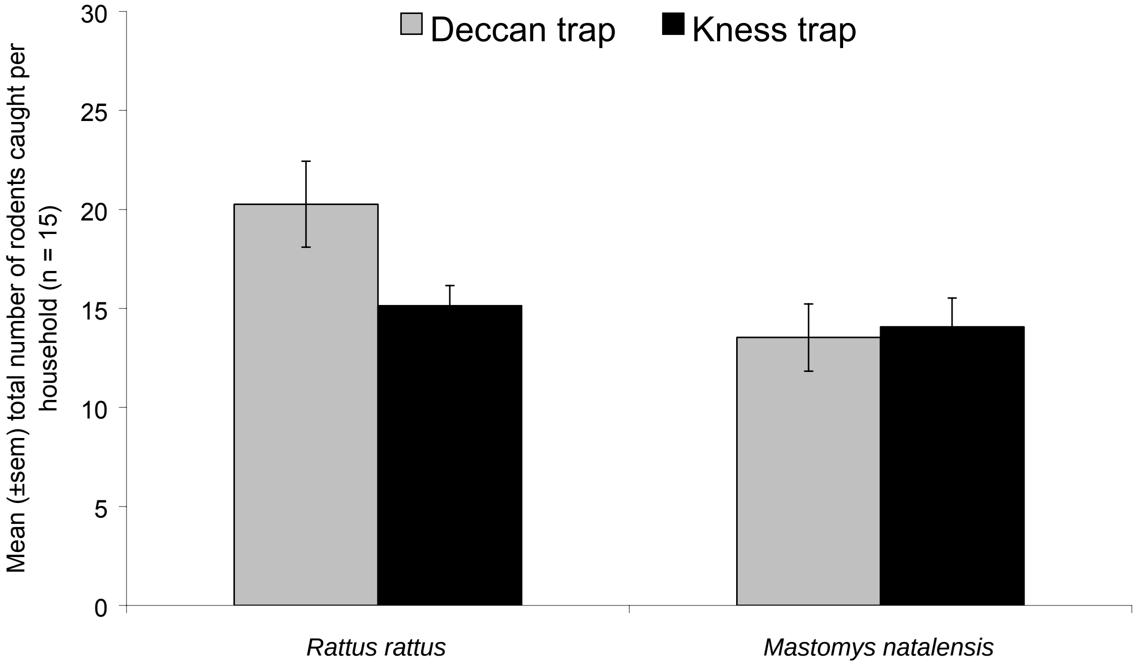
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 3. Comparison among households using one Deccan trap and one Kness trap to trap rodents on a daily basis inside their house/food store in their capture rates of the two rodent species found in the area, *Rattus rattus* and *Mastomys natalensis*.



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Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Immigration potential of the two commensal rodent species, *Rattus rattus* and *Mastomys natalensis*, infesting rural households and food stores

Abstract
Rodent trapping trials in three villages of Zambézia Province, Mozambique were established to determine the extent of potential interspecific competition between the two main rodent species, *Mastomys natalensis* and *Rattus rattus*, prevalent in rural households and food stores. Trials which trapped inside peoples households (n = 10) and outside the immediate area surrounding the house with four trap lines (n = 12 each) showed that *R*. *rattus* was largely confined to the interior of households, whereas *M*. *natalensis* was found both inside and outside the household. Relative rodent species abundance was similar in two of the villages surveyed with more *R*. *rattus* caught inside the house, with the third village showing very high numbers of *M*. *natalensis* caught both inside and outside the house. The implications of these results are discussed in how the impact of the agro-ecological environment could affect the prospects of using intensive trapping as a method of rodent pest management.

Introduction
The multimammate rat, *Mastomys natalensis*, is found throughout Africa. In West Africa *Mastomys* spp. are known to live in people's houses, nesting in the roof thatching, and have been shown to carry and transmit several hanta and arena viruses including well-documented outbreaks of Lassa Fever (Gratz et al., 1997). Although *Mastomys* spp. are considered to be commensal rodents, they are also found in areas far from human settlement. The most recent research on *M*. *natalensis* has been in Tanzania as the main field pest to maize crops (Leirs et al., 1997; Makundi et al., 1999). *Rattus rattus* is one of the most cosmopolitan rodent species having spread around the world through the commercial shipping trade (Fiedler, 1988). *R*. *rattus* is often found in urban areas, closely associated with human refuse and sewage, but it is also commonly found in plantation crops of sugar cane, fruit, nut and vegetable crops as well as grain and legume crops (Buckle and Smith, 1994).

Research in Zambézia Province, Mozambique has shown that *R*. *rattus* and *M*. *natalensis* are the two predominant species associated with rural settlements. Discussions with farmers in the area and trapping trials in households and field crops would suggest that *R*. *rattus* is predominantly living inside people's houses and nesting in the roof thatching. Whereas *M*. *natalensis* is predominantly found in the field, making burrows in dense vegetation and earth mounds. However, in most cases significant numbers of *M*. *natalensis* are also caught inside households, and it is suggested that they are immigrating into households in search of food but not taking up residence within the roof because of the presence of the larger species *R*. *rattus*.

The objectives of our research were to compare the number of rodents caught inside households with those outside in the immediate vicinity surrounding the house. Information on the immigration and emigration of the two species in and around households could help understand the re-infestation potential of houses which are trying to reduce the impact of rodents inside their house as well as the potential interactions in resource allocation between the two species.

Materials and Methods
Five households were selected from each of three villages in different districts of Zambézia Province, The village of Mutange in Namacurra District lies within a flat lowland rice-growing area, the village of Pinda in Morrumbala District is found in a highland plateau maize-growing area and the village of Mugaveia in Gurué District is in a mountainous mixed forest-cropland area. Each village has approximately 400 domestic dwellings which typically consist of a mudded timber-frame rectangle (approx. 4 x 5 metres) with a grass or palm-leaf thatched roof. The open-plan interior contains a raised platform where food is stored, a cooking fire and a sleeping area for approximately eight people. A total of 58 break-back traps (big snap-e-trap™, Kness Manufacturing Ltd., USA) were placed in and around each household (Figures 1). Ten traps were placed inside the house and positioned in places near evidence of rodent presence, near stored food and along walls. Eight traps were placed around the outside perimeter of the house, two traps on each outside wall. Four trap lines outside the house were positioned as follows. Each trap line consisted of five stakes that were five metres apart, placed in a line perpendicular to the centre of each side of the house (Figure 5). Two traps were tied to each stake with a 1 m long piece of twine, giving a total of 10 traps per trap line and 8 traps per stake position. All snap traps inside and outside the house remained unbaited and were set each evening and checked each morning. The number and species of rodent caught were

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

recorded each day noting the location from where rodents were trapped, with stake #1 nearest to the house.

Results

The results showed that traps inside the house caught more rodents per trap than traps positioned anywhere outside the house in all three villages (Figures 2 to 4, ANOVA with LSD, $P < 0.05$). As described in previous research, more *R*. *rattus* were caught inside houses than *M*. *natalensis* in the villages of Pinda and Mutange; whereas more *M*. *natalensis* were caught than *R*. *rattus* in houses in Mugaveia. The relative numbers of each species caught at different positions outside the house significantly varied among the villages and trap positions (ANOVA with LSD, $P < 0.05$). In Pinda, the number of *R*. *rattus* caught declined with increasing distance from the house, and the number of *M*. *natalensis* was higher on stakes furthest from the house than around the outside perimeter and stakes closest to the house (Figure 2). In Mutange, *R*. *rattus* numbers were equally low at all trap positions outside the house; whereas *M*. *natalensis* numbers increased with increasing distance from the house (Figure 3). In Mugaveia, the numbers of *R*. *rattus* and *M*. *natalensis* did not vary with trap position with more *M*. *natalensis* caught than *R*. *rattus* at all positions (Figure 4).

Discussion

It was expected that traps inside the house would catch higher numbers of rodents than traps placed outside. This is because traps inside the house are working in a relatively more confined space and operating at a higher trap density than the traps placed in the four trap lines surrounding the house. As the household food store provides optimal foraging opportunities for rodents, it could be argued that the house acts as a magnet drawing rodents to it from surrounding areas (Meserve, 1976).

The results of this trial would support the hypothesis that *R*. *rattus* is confined to residing inside dwellings. Relatively few *R*. *rattus* were caught outside the house in Pinda and Mutange when compared to inside the house, and data from these villages would indicate that the movements of *R*. *rattus* are largely confined to a small area around the house. This would suggest that *R*. *rattus* does not travel far from the household, and households which are able to reduce the population of *R*. *rattus* inside their home will experience fairly low levels of *R*. *rattus* immigration In both of these villages, higher numbers of *M*. *natalensis* were caught further away from the house, supporting the argument that *M*. *natalensis* resides in the bush (Lin and Batzli, 2001). High numbers of *M*. *natalensis* were still caught inside the house, presumably attracted to the grain store within. Although relatively fewer numbers of *M*. *natalensis* were caught inside houses in Pinda than in Mutange, the immigration potential of *M*. *natalensis* appears to be higher in Pinda than in Mutange, indicated by the more dramatic increase in numbers of *M*. *natalensis* with increasing distance from the house in Mutange.

The situation was quite different in Mugaveia where very high numbers of *M*. *natalensis* were caught inside the house. Data collected from large-scale household trapping in Mugaveia (reported previously) showed that initial numbers of *R*. *rattus* were relatively high inside the home during the first month of intensive trapping, but while *R*. *rattus* numbers subsequently declined, there was no parallel decline in the numbers of *M*. *natalensis* (Tristiani et al., 1998). Far higher numbers of *M*. *natalensis* were found in the environment than in the other two villages, both inside and outside the house suggesting that the agro-ecological environment in Gurué District is able sustain much higher rodent densities. The data would suggest that *M*. *natalensis* is strongly drawn towards houses and the food within. In such high rodent densities both immigration and emigration from houses will be high, indicated by the equal numbers of rodents caught at different positions outside the house in Mugaveia.

In conclusion, our research provides evidence that *R*. *rattus* is more susceptible to household rodent management activities than *M*. *natalensis*. This is because *R*. *rattus* is residing inside the house and does not travel far from the household, thereby reducing its immigration potential. A second factor likely to be important in explaining the observed differences among the villages is the relative distance between dwellings in the village. Buildings in the village of Pinda were relatively close to each other (50-200 m), whereas buildings in Mugaveia were farther apart (500-1500 m). Our results would suggest that *R*. *rattus* populations are higher when villages are relatively densely populated (as immigration among houses will be greater), and *M*. *natalensis* are more prevalent in villages where houses are isolated from each other. In a village such as Pinda, intensive trapping on a community level can have a greater impact because rodent immigration/emigration is reduced, and *R*. *rattus* immigration from the bush will be slow (Fernandez, 1999). In a village such as Mugaveia, immigration of *M*. *natalensis* from the surrounding bush is unaffected by community trapping, and trapping will be

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

relatively less effective in modulating household rodent density. However, as villagers prefer to eat *M. natalensis* as opposed to *R. rattus*, trapping in households with large numbers of immigrating Mastomys will still be seen as a favourable activity.

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 1. Location of snap traps inside and outside the household (5 households from 3 villages each). All 58 traps/house were left unbaited and checked daily between Nov. 2000 and March 2002.

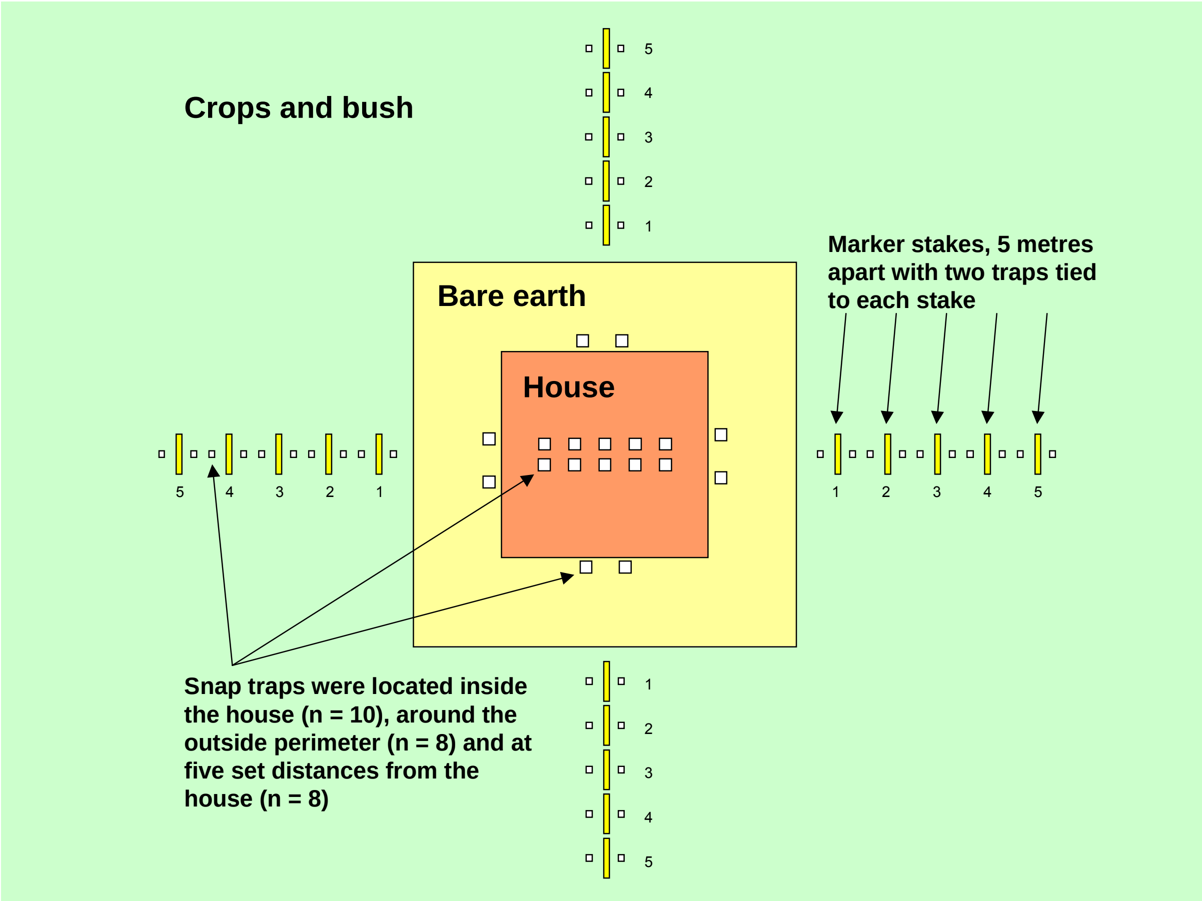
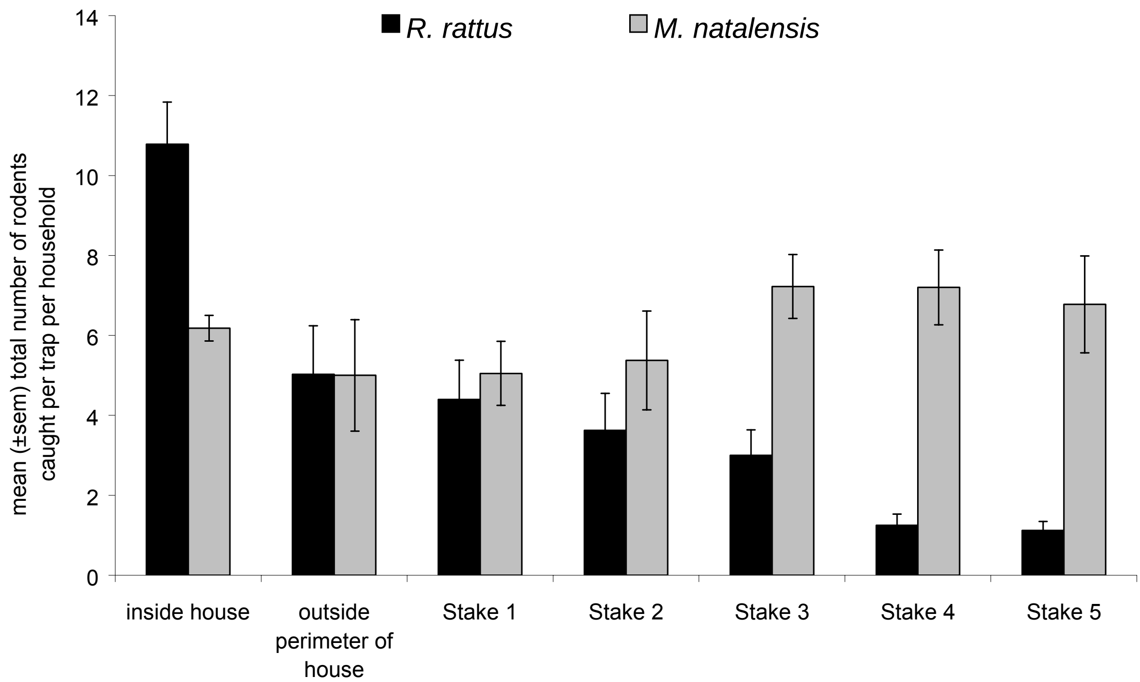


Figure 2. Comparison between the mean number of rodents caught daily at different positions outdoors away from the household (n = 8) with those caught from traps set inside the house (n = 10) in the village of Pinda, Morrumbala District between November 2000 and March 2002.



Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 3. Comparison between the mean number of rodents caught daily at different positions outdoors away from the household (n = 8) with those caught from traps set inside the house (n = 10) in the village of Mutange, Namacurra District between December 2000 and March 2002

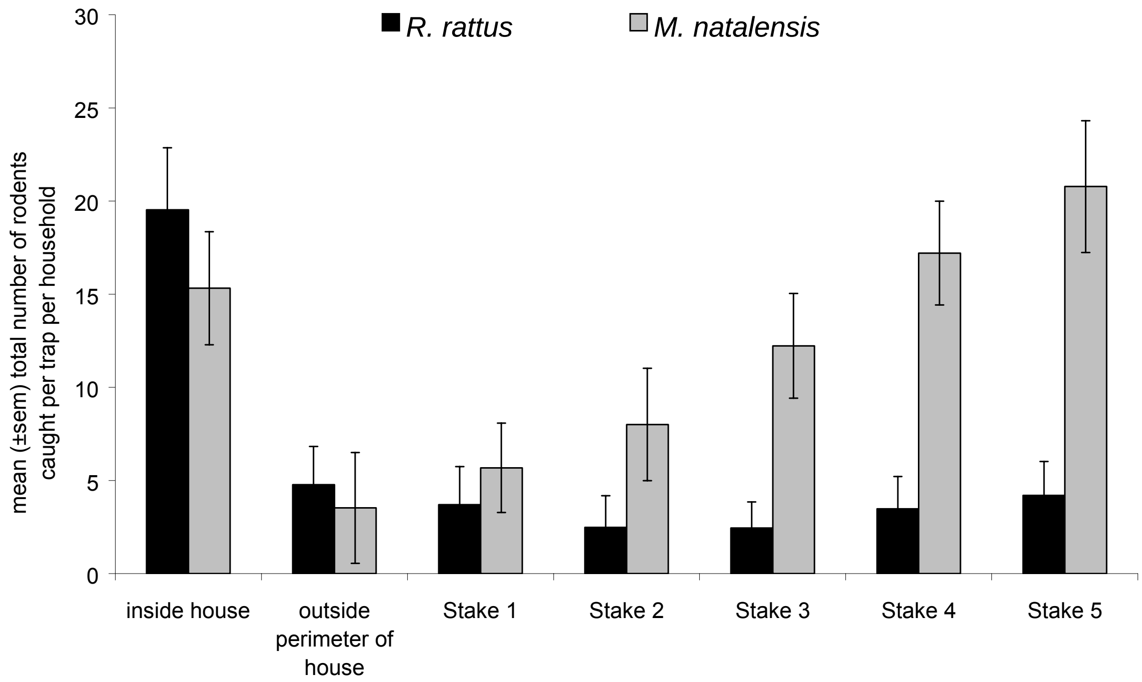
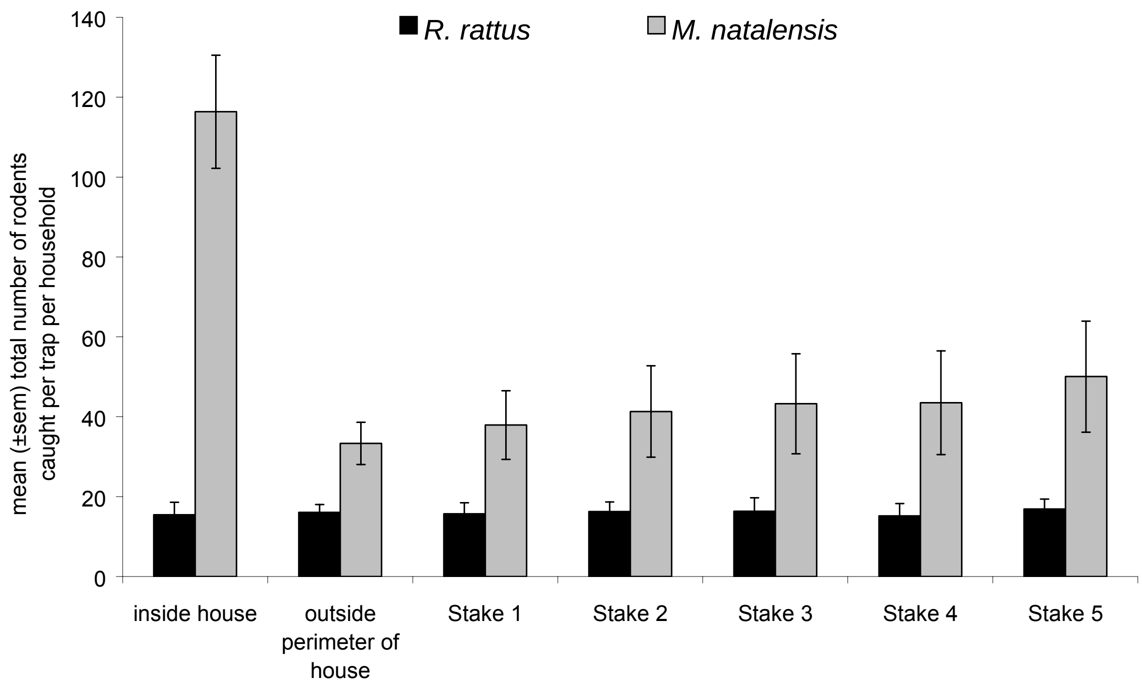


Figure 4. Comparison between the mean number of rodents caught daily at different positions outdoors away from the household (n = 8) with those caught from traps set inside the house (n = 10) in the village of Mugaveia, Gurué District between December 2000 and March 2002



Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Figure 5. Photograph showing one trap line of five stakes as positioned at a house in the village of Pinda

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

Outputs

This project had three outputs:

1) Baseline data obtained on the impact of rodents on rural communities based on PRA surveys in two areas of Mozambique.
2) A cost effective methodology developed to assess farm-level post-harvest losses caused by rodents in the major food staples and the impact of rodents on rural health and nutrition.
3) Potential strategies for limiting rodent numbers described and projects developed to test the strategies.

All the project outputs were achieved as described in the previous section. The goal of the project to "improve the efficiency of commodity storage and management, processing, marketing and credit systems" was addressed by increasing and improving the management options available to small-scale farmers who store their commodities on-farm. This will help farmers to minimise their post-harvest losses, storing their commodities for a longer period of time, and thereby selling their grain later in the season to obtain a higher price. Subsistence farmers can also be assured of preserving the quantity of grain for home consumption without resorting to the use of rodenticides which are not only expensive but difficult to use effectively and safely without close training and assistance. Because rodenticides are easily misused, the project has provided methods which are more easily understood while reducing risks to human and environmental health and providing households with a source of protein as rodents are widely eaten in central and northern regions of Mozambique.

Contribution of Outputs

The project was successful in demonstrating that rodent management strategies could work under the local conditions found in three distinct agro-ecological areas and provide sustainable benefits to the people living within them. Project assessments would indicate that rural communities would gladly purchase traps if they were available. Therefore, promotion of trapping as a valid form of rodent pest management should be recommended. However, there are issues which remain to be addressed. It is unknown what price structure would be sustainable, particularly if more than one trap needs to be purchased per household to effectively manage the rodent population inside the home. Surveys would be needed to inform the market on what prices could be sustainable in rural areas. The optimal number of traps required to sustainably reduce the impact of rodents to acceptable levels will depend upon the agro-ecological system, rodent ecology and whether community-based trapping is a viable option. What this means is that providing low-cost, durable and effective traps is only the first step. Rural communities with rodent problems will need to be assessed on a case-by-case basis to measure the factors which could influence the success of trapping in the area, making recommendations as to how rodent management should proceed. Therefore, the promotion of the project outputs will require the provision of:

1) a pest control industry capable of making environmental assessments and supplying advisory support
2) the provision of suitable (cost, efficiency, durability) traps to the local market
3) and a policy assessment on the allocation of costs and benefits of rodent management.

There is a pest control industry within Mozambique, but this is largely confined to more urban areas and involves the provision of physical inputs (e.g. fertilisers and pesticides). Preliminary discussions with some players indicated a high interest in increasing their advisory support and rodent management inputs, i.e. traps. However, as is often the case, it is unlikely that such an approach will target the poorest of the poor in relatively inaccessible areas. Considerable changes in policy would be required to make commercial involvement in the supply of knowledge and advisory services reach the rural poor. Government extension and NGOs are likely to be more involved in the provision of the knowledge and support required for effective farmer training in rodent pest management through farmer field schools and other 'right's-based' or empowering approaches. The lack of an off-the-shelf approach to rodent pest management will require some change as to how rural extension manages its health and agricultural programmes so that initial rodent impact assessments are carried out with a view to understanding how rodents cause the observed damage.

Traps manufactured in the USA were shown to be durable, sufficiently sensitive and were cost-effective (based on the number of rodents caught per trap) when compared to alternatives such as rodenticides. However, the US-made traps would only be sustainable if they could be manufactured or assembled locally. The American manufacturer entered discussions with a Mozambican company on developing a partnership for the supply of traps. However, the Mozambican company did not maintain their interest in the venture. Franchising or joint ventures with the American manufacturer are still very real options if the right company can be found, which is perhaps more likely in South Africa. Potentially similar traps could

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

be produced and distributed to rural market towns throughout the southern Africa region. Market assessments and commercial involvement and/or partnering with NGOs would be required to address the market needs of supplying the appropriate inputs and tools as well as the training to understand the timing and type of rodent management strategies to be used.

Costs and benefits of rodent management accrue to different levels within society, and it should not be assumed that the individual solely stands to gain from implementing rodent management, or that the full cost of rodent management should be borne by the individual. For example, central government expenditure on the cleanup of plague outbreaks could be more effectively directed towards the prevention of outbreaks and supporting long-term rodent management activities. Such an approach away from the current crisis management of rodent outbreaks would undoubtedly be more cost-effective and could potentially lead to the elimination of plague outbreaks. Government policy and its involvement in the agricultural and health sectors with regard to rodent pest management expenditure should, therefore, be reviewed. Our research has indicated that, in some instances, rodent management in household-level food stores is improved when a community acts together. By acting together, the overall costs to the individual can be reduced by reducing the number of traps each individual would need to buy while still maintaining a high level of rodent control, thereby favourably increasing the ratio of cost-benefits. Although currently unknown, community trapping is also likely to reduce the risk of plague outbreaks. A strong sense of community and local leadership would be required to make community level trapping possible. Farmers and their households which intensively trap rodents stand to gain savings in food storage while also increasing their protein intake by eating the captured rodents. Farmers also remark that they have fewer problems with getting bitten by rodents, find fewer holes in their clothes and less damage to personal belongings. Further assessments could show significant improvements to overall family health by reducing the prevalence of debilitating diseases transmitted by rodents. As individual incentives to manage rodents through trapping is high, it will be possible to target individuals interested in controlling their rodents even if support at the community and government levels is not present.

The technology to control rodents is out there already. Understanding the application of the technology and deciding what technology is most appropriate for a particular situation are what has been lacking in rodent management for the last decades throughout the world. The situation for rural households in Mozambique is that rodent pest problems are having multiple impacts upon people's livelihoods, which are well-recognised by the people themselves. Intensive trapping can go some way towards reducing many of the pest impacts, as long as well-designed traps are affordable (accounting for initial cost and durability), and proper advisory support is available in rural areas.

List of publications currently produced from the project

BELMAIN, S.R., MEYER, A.N., TIMBRINE, R. and PENICELA, L. (in press) Managing rodent pests in households and food stores through intensive trapping. Invited Symposium Address. In: *2nd International Conference on Rodent Biology and Management*, *Canberra*, *Australia*, *February 2003*. pp. 000-000, (eds. G.R. Singleton and L. Hinds) ACIAR Proceedings Series #00, Canberra, Australia. ISBN 0000000000. [peer-reviewed conference proceedings]

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The radio broadcast and electronic version of the notes are available via the following websites:
http://www.bbc.co.uk/worldservice/sci_tech/features/field/progs_three.shtml

Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk

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Correspondence: Dr Steven R. Belmain, Natural Resources Institute, Chatham, Kent ME4 4TB, UK
Tel: (+44) (0) 1634 883 761, Fax: (+44) (0) 1634 883 567, Email: S.R.Belmain@gre.ac.uk