CROP PROTECTION PROGRAMME

Extension of ecologically-based rodent management in South Africa

R 8441 (ZA 0665)

FINAL TECHNICAL REPORT

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Executive Summary

This project is an extension of the technology transfer and promotion of ecologically based rodent control strategies project that was conducted in South Africa's Limpopo Province from 2002 to 2005 [R8190 (ZA0506)]. The current research project was based on developing sustainable strategies for rodent management in rural communities of South Africa and consisted of a single output that was addressed by four separate activities. Three of these activities: training, demonstration of rodent management tools and public-private partnerships were successfully completed and positively evaluated by stakeholders. The fourth project activity, to create and broadcast a series of radio programmes on rodents, was not completed by the time of writing this report. Although significant amounts of audio material were collected, it has not yet been broadcast. This is largely due to delays in getting radio stations signed up and committed to the editorial process of production, and the project team will continue to work with radio stations until the activity has been successfully achieved.

Adaptive research trials were instigated in KwaZulu-Natal Province where needs assessment surveys with communities prioritised rodents as the major natural constraint. In a short trapping period it was demonstrated that efficient and sustainable rodent control can be achieved through the process of continuous trapping. Even for poor communities, the use of two break back traps would be cost effective as this tool is now produced locally in South Africa, making them independent of the monetary exchange rate. Molecular systematic tools have confirmed recordings of a new species in South Africa of the *Rattus rattus* complex which has renewed scientific interest in research on commensal rodent species.

The foundation of a public-private service partnership was developed to promote rodent management knowledge and tools. In this partnership a series of training workshops for service providers were held in urban and rural centres. The attendance by local government's environmental health and agricultural extension and the private sector is indicative that these sectors will take the acquired information further to their clients. Better cooperation between the sectors is envisaged. Links established between the trap manufacturer and a milling company with retail outlets in remote areas will ensure that distribution of the rodent management tools evaluated in the project can reach farmers and households in rural communities. The manner of uptake of this break back trap by agro-chemical manufacturers and by distributors will increase the incentive of end users to adopt this rodent management tool. The participation of these role players in the training component of the project has resulted in the amendment of the national pest control operator's registration act to include rodent management as a separate specialised subject. Therefore, the quality of rodent knowledge among practitioners stands to be significantly advanced through improvements to course material and provision of more detailed knowledge about rodent biology and management. This government amendment for an expansion of required training on rodents should be seen as a major success of the project activities by creating a learning environment focussed exclusively on rodent pest management. The new national requirement will have long term impacts on increasing rodent awareness and improved delivery of rodent pest management in South Africa.

The results of completed activities have led to long-term changes in capacity and infrastructure related to rodent management. Not only has the training knowledge instigated a continued demand and recognition for more and better training, it has cultivated increased interaction and partnership between government agencies and commercial pest control. Changes to the pest control registration act enacted by the South African government in response to the project actions will ensure that future training provided on rodent pest management is relevant and sufficiently detailed for the needs of rodent pest control service providers.

Background

Rodent pests affect people's lives by destroying crops, transmitting diseases to people and livestock, contaminating food and water, and damaging buildings and other possessions. Although effective rodent management tools and techniques exist, their poor application and adaptation to particular agro-ecological situations often results in treatment failures, leading to apathy and widespread acceptance of rodent pests in the environment (Kirsten & Von Maltitz, 2005). Using rodent management tools and techniques requires a good understanding of rodent biology and their localised impacts upon people's livelihoods. This knowledge facilitates the development of cost-beneficial strategies where the input costs can be shown to lead to substantially increased food security, financial and health benefits. Rodent pests disproportionately affect the poorest people who are less likely to possess appropriate knowledge and access to proven technology (Belmain, 2005).

Current rodent control practices are often based on the use of rodenticides. In southern Africa unregistered compounds with acute vertebrate toxicity are commonly used to kill rodents. Documented cases of these poisons used for suicide, murder and killing dogs has recently increased pressure on pesticide companies to become more pro-active in delivering appropriately packaged and more effective rodenticides. However, acute poisons are often perceived to be more effective at killing rodents than chronic poisons, and changing these misinformed perceptions is one of the major challenges facing experts working to improve rodent management in regions where acute poisons are widely used.

Other rodent management methods involving trapping and environmental management have been assessed through CPP and CPHP funding in South Africa and Mozambique. Research funded by the CPP since 2002 in South Africa's Limpopo Province has had three main objectives: 1) to provide households and farming communities with sustainable and environmentally benign management of rodent pests 2) to improve the food security, financial, socio-economic and health constraints posed by rodents within these communities and 3) to create market-led promotion of cost-beneficial rodent management strategies that can be sustainably implemented by resource-poor farmers. Research and promotion has, therefore, focussed on improving institutional frameworks responsible for the provision of rodent knowledge, evaluating appropriate management tools, and increasing the availability of rodent management knowledge to service providers and end users. One of the problems the project has focussed on, is how to integrate rodent knowledge that remains disparate and unlinked between different service providers involved in rodent management.

The official training given to service providers from all sectors is of variable quality and often limited relevance. None of the service providers are really able to focus on the rodent problems experienced by rural farming communities, and a more integrated approach is required to supply rodent management knowledge and inputs to rural and peri-urban farmers.

Through workshops with service providers and community meetings, CPP-funded research has begun a process to address the knowledge gaps relevant to small-scale farming and how knowledge and inputs could be more appropriately delivered to resource-poor communities. Project linkages with agro-chemical manufacturers and distributors interested in rodent pests have led to an important partnership with a local manufacturer to supply low-cost and effective rodent traps and to develop a policy framework on rodent control and technology transfer strategies. The project has engaged with radio and the local media to disseminate key messages about rodent biology and management, and further campaigns have been recommended. The project has been able to create rodent knowledge foci in each target village involved in the project through the training of extension officers and members of the community that have been involved in managing research activities related to the evaluation of rodent management methods, such as trapping, for their efficacy and sustainability. However, adaptive research trials have been affected by a cycle of drought, and there was considerable merit in repeating and extending research to a different region of South Africa to ensure recommendations on rodent management are temporally and spatially robust with changing agro-ecological conditions.

Pathways for rodent management knowledge and input delivery were however not designed to meet the needs of resource-poor communities. Knowledge currently reaches poor communities through interaction with agricultural extension and environmental health officers, and possibly through pesticides retailers. By extending the CPP project to another Province allowed the project to directly work with the rodent management service providers of the Province to advance knowledge improvements and integration. A priority issue for CPP-funded work in Limpopo Province was to develop sustainable systems of knowledge and input promotion through the involvement of private commercial institutions. The funding extension allowed the project to formally involve pest control operators as project collaborators which would help increase the capacity of the private sector to deliver public rodent management services for which the development of public-private partnerships will be essential.

The North Region of KwaZulu-Natal has been identified as one of the poorest of the South African Provinces where food security is a major issue. This project addresses many of the Presidential imperatives (Agricultural Research Council, 2001) such as rural development, job creation and urban renewal.

ARC-PPRI in collaboration with KwaZulu-Natal Department of Agriculture and Environmental Affairs (KZNDAEA) had carried out baseline needs assessment surveys in KwaZulu-Natal that have shown communities prioritise rodent pests in the top two natural constraint categories. Household questionnaire surveys that specifically dealt with rodent problems indicated that 51% of respondents used a preventative method against rodent damage of which the most common method (94%) was the occasional single-dose use of a chronic rodenticide in and around the house and food store (Von Maltitz, 2004).

Project Purpose

The purpose of the project was to develop strategies which improve food security of resource-poor and small-scale farmers and their communities through increased availability and improved quality of maize, which is the staple food of these households in the Province. Specifically the project aimed at providing poor households and small-scale farming communities with sustainable and environmentally benign management of rodents pests, which was identified as a major constraint in a Participatory Rural Appraisal survey.

The main objective of this project was to: Increase the uptake and adoption of cost-beneficial rodent management tools appropriate for small-scale farming communities in rural South Africa.

To fulfil the project objective, four major project activities were conducted:

1. Training of Environmental Health Officers, Agricultural Extensionists, Pest Control Operators and farmers.
2. Demonstrate and evaluate rodent management tools and strategies.
3. Develop public-private service provision.
4. Disseminate results through the production of radio programmes

Research activities and Outputs

1. Training of Environmental Health Officers, Agricultural Extensionists, Pest Control Operators and farmers

Introduction

The policy on good pest control service industry in South Africa is in place. This is regulated by the Pest Control Service Industries Board (PCSIB). The board consists of representation by the National Departments of Agriculture, of Health, of Labour and of Environmental Affairs, Pest Control Association (SAPCA), Crop Protection and Animal Health Association (AVCASA) and the Tshwane University of Technology (TUT).

At a one-day workshop organised with stakeholders and role-players in the rodent control industry in Pretoria on 6 February 2004, training was identified as a being a problem. Especially the lack of practical training, lack of specialised training on rodent control and the need for an independent body to examine trainees. An interim committee appointed from the workshop, proposed the following recommendations to the industry and to the PCSI Board which (in partnership with TUT and SAPCA) is responsible for developing Pest Control Operators (PCO's) training courses and curricula:

- Upgrade the existing PCO course to include rodent control as a separate specialised module divided into components for industrial and domestic rodent control. The content of the course needs to be refereed by industry.
- Practical training essential to the course.
- Annual registration should include attendance of a workshop to update on new technology and trends.
- National and local government personnel responsible for rodent control should also complete the rodent control component of the PCO course.

Although service providers do acquire theoretical knowledge about rodent biology and management, there is very little official training in South Africa on how to apply this knowledge in practice. The rodent management service providers in the country can be roughly grouped into four types:

- Pest Control Operators (PCO's) are private companies that may or may not subscribe to representative associations with limited regulatory powers. PCO's are subcontracted by industry, government departments, public institutions and private individuals. Rodent management is focussed on urban, industrial and/or commercial farming (mainly premises). Rodent management training is part of a module provided on a PCO course operated by a single institution (TUT) in Pretoria.
- Rodenticide distributors of multinational pesticide companies who supply rodenticides and knowledge on product usage, particularly to commercial farmers, PCO's and the other pest management service providers. Staff may or may not have attended the PCO course, other rodent management courses and/or received in-house training on products but limited knowledge on rodent biology and correct usage
- Environmental Health Officers (EHO) of Local Government (Provincial Department of Health) and municipalities who deal mainly with urban and peri-urban rodent management in public areas of cities, townships and villages. Rodent management is often not given to EHO's
- Agricultural Extensionists (AE) of Provincial Departments of Agricultural & Environmental Affairs deal mainly with rodent problems focussed on pre-harvest agriculture in rural farming areas. Extensionist may have had pest management as a subject during tertiary training or through general courses for extensionists run by the DAE.

Training to service providers through this project was intended to be of an applied nature using real situations commonly experienced by staff. Training focus is on decision making processes and monitoring the pest problem before implementing rodent management and the subsequent monitoring of the management actions to determine efficacy. This process will be used to develop a training method module that could be formally recommended to policy makers for incorporation into official training programmes for staff involved in rodent pest management.

Material and methods

A two-day training workshop on rodent control was presented at six different venues during 2005. Training was presented by international rodent expert Adrian Meyer (NRI associate, UK) with additional information of current local conditions presented by a local professional pest control operator and pest control manufacturer (Scientific Pest Control Services) and/or a local manufacturer and distributor of rodent control products (Coopers Environmental Science (Pty) Ltd). Dr. S.R. Belmain (NRI, UK) co-presented the first two workshops which were primarily directed at agricultural extensionists.

The training course consisted of five parts *i.e.* Introduction; Rodent Biology and Behaviour; Rodent Damage; Rodent Control; and Hygiene & Proofing. The training course material was adapted from the Natural Resources Institute's rodent biology and control training material (Appendix 5). Much use was made of visual material including videos. The theoretical training was substantiated with practical demonstrations at farming communities or at urban public centres such as a hospital or abattoir. Time was allotted for discussion and participation by the audience and in this way experiences were shared. Various rodent control tools available on the local market were also exhibited at most of the venues.

Farmers and interested households of the communities where the rodent trapping trials were demonstrated (see chapter 2) were given informal training on rodent control. This consisted of the basic principals of rodent biology, behaviour, differences in commensal and sylvatic species, some aspects on rodent zoonosis, human and storage hygiene and the correct use of rodent management tools. The field staff trained to conduct the trapping trials, were also supplied with information to supply to farmers. Information transfer is of an on-going process for the project staff.

Results

The first two workshops, specifically for government agricultural extension and environmental health personnel, were presented over a period of two weeks in February 2005 at Thohoyandou (Limpopo Province) and at Vryheid (KZN North Region) respectively. Twenty representatives of the two government departments attended the workshop at Thohoyandou, while thirteen agricultural technicians representing all eight district of the KwaZulu-Natal's North Region attended at Vryheid. Practicals consisted of the inspecting the kitchen facilities of a hospital near Thohoyandou and successive visits to homesteads in farming communities nearby. During successive visits to small-scale farmers, rodent trappings and tracking tools could be set up and inspected for rodent activities the next day.

In June and in November 2005 workshops on rodent management for pest control operators, environmental health officials, representatives from pesticide manufacturers and/or distributors and other interested members of the pest control industry were advertised in the SAPCA newsletter, directly to the PCSI Board and through other associations of the pesticides industry, municipalities and local environmental health departments. The training workshops in June were held at the PPRI's conference facility at Roodeplaat (Pretoria) and at the premises of the Vector Control Section of the eThekwini City Health Department (Durban). The November workshops were held again at Roodeplaat and at the Durbanville Conference Centre near Cape Town, Western Cape.

The practical demonstrations consisted of inspection visits to a slaughterhouse, hospital, grain silo and in Durban at rodent hotspots in the street of the city centre.

At all four venues the audience was restricted to a group of 25 on a first come first serve base and seats were quickly taken up with a number of requests turned away. From as far as Swaziland, Mozambique and Zambia requests to attend were made, while some local pest control operators travelled as far as 400 km to attend.

Discussion

The workshops were well attended, with numerous latecomers disappointed at missing the opportunity. Pest management service operators from at least five provinces representing private PCO companies, pesticide manufacturers, municipal health departments from four major cities, state hospitals, the milling industry, an University and the PCSI Board attended the courses. Many PCO companies intended to send all their staff members to attend.

Feed back comments were positive with praise of the excellent course material and on the presentation style of the experienced Mr Meyer. One attendant honoured the course by writing an article for the SAPCA newsletter (Plate 3.1). Requests were made for similar courses on other pests such as industrial insect pest control and agricultural pests.

The extensionists who had attended the course were not only empowered to train farmers and communities in their respective wards, but also to transfer information to their colleagues.

Plate 1.1. Rodent control workshop attendants reporting on their impressions after inspecting the kitchen of a hospital near Thohoyandou, Limpopo Province.

Plate 1.2. KwaZulu-Natal North Region agricultural extensionist attending the rodent control workshop at Vryheid

Plate 1.3. Rodent control workshop attendants observing 'rodent hotspots' in the Durban city centre, KwaZulu-Natal.

Plate 1.4. Practical training during the workshop at Durbanville.

Plate 1.5. Attendants of the rodent control workshop inspecting a grain silo in the Western Cape.

Plate 1.6. Rodent damage to a door in a hospital near Pretoria.

Plate 1.7. Rodent gnawing damage to municipal dustbins

Plate 1.8. Rodent damage to maize cobs in crop fields in the Vryheid district of KwaZulu-Natal.

Plate 1.9. Roof-rat smear marks on the rafters in a slaughterhouse near Pretoria.

2. Demonstration and evaluation of rodent management tools and strategies.

Introduction

Adaptive research trials had been limited to four communities (representing three regions) in Limpopo Province. Although the trials had shown positive impacts on rodent population dynamics and damage levels, drought had severely restricted crop production activities across southern Africa. Widespread drought will affect sylvatic rodent species more acutely than commensal species, and the data from the trials suggested this had occurred in the trial areas. Scientific merit in extending trials to a larger number of communities is to confirm previous results as well as to verify whether the recommended rodent management activities are adaptable to situations where numbers of sylvatic and semi-domestic rodent species are likely to be much higher with greater impacts on crop production systems. The collection of further data related to rodent ecology and impacts of rodents and management systems was done in parallel with an expansion of geographic focus.

As with many knowledge-intensive management systems and action research programmes, further refinements and understanding can be achieved through repeating seasonal trials and increasing replicate sizes to increase the robustness of data and the parameters of intrinsic variability. By using the methodologies developed for reducing rodent populations and monitoring rodent damage and impact in Limpopo Province for trials based in KwaZulu Natal, it was hoped that recommended strategies are appropriate for relatively more diverse agro-ecological conditions. By further increasing the seasonal data set, the statistical evaluation would also be improved.

Material and methods

Two sites (three villages) representing the geographical and the vegetation types of the region were identified from the two central rural districts in North Region of KwaZulu-Natal. These were Mvuzini village (28° 00 S 30° 40 E) (Plate 2.3) in the southwest of the Vryheid district and at Tholakele (Plate 2.6) and its neighbouring village Ophuzana in the east of the Paulpietersburg sub district. Mvuzini is in the in the flat basin of the upper White Umfolozi River with Sour Sandveld grass vegetation type while Tholakele and Ophuzana are on the Piensrant escarpment in the east of the Paulpietersburg sub district. According to Acocks (1988) the dominant natural vegetation type on the Piensrant is Piet Retief Sourveld (false grassveld) with patches of bush and scrub forest that merge into the Lowveld of the steep valleys (see map Appendix 1).

Candidates nominated by the community to serve as project field staff were trained in the skills needed for the execution of the trapping trials (Plate 2.5). The course included theoretical and practical aspects of rodent biology, ecology, identification, some aspects on rodent zoonosis, dissections, data recording, handling of trapping equipment and human safety aspects. Agricultural extensionists who had earlier attended the course in Vryheid (see chapter 1) and who were assigned to the respective villages, gave further assistance during the trial.

The impact of rodents on the livelihoods of households was assessed by a household questionnaire survey with 200 households in the survey area at the start of the trapping trial. The questionnaire was the same as was used in the Limpopo Province.

Baseline population data of rodents was obtained through daily trapping at fifty volunteer households selected to serve as the treated group, from each of the Mvuzini and

Tholakekele villages. To make the trial community based trapping instead of individual households, an attempt was made to select volunteer households together from a geographical section of each village. At Mvuzini the treated group was the north-western section while at Tholakele the treated group was from the Makalibethe ward. Ophuzana served as the untreated group (control) for Tholakele; while a further fifty households from Mvuzini east served as its untreated group. Trapping commenced in October 2005 and is to continue until March 2006.

In collaboration with home-owners, premises and structures of the homestead were inspected for signs of rodent activity and for sites for best possible placement of traps. In each of the fifty households, two break back traps (big snap-E® trap, Kness Manufacturing Ltd., USA) were placed. The home-owner or a person in the household designated to manage the traps was given training on the correct setting of the traps and instructions to activate them each evening. Homesteads in the treated group continued to trap with two traps every evening for the duration of the trial. In the untreated (control) group trapping was done once a month for three consecutive nights for the duration of the trial. For this group all the traps were removed from the households after a trapping session. Traps were baited with material available at the trapping site such as maize kernels, peanut-butter or left-over meals.

Field staff conducted the daily trapping while the project staff conducted the monthly trapping as a means of monitoring the accuracy of data and to be aware of trends or developments as well as maintaining regular contact with the field staff. Collected data was also discussed with field staff and the agricultural extensionist enabling them to share information between the village communities and project staff. Random inspection of traps, trapping location and trapping procedure, as well as other equipment was undertaken. Broken or missing traps and equipment were repaired and/or replaced.

Homesteads were visited each morning after a trapping night, to record the number of rodents, sex, reproductive condition, weight, body length, species of rodents caught and location of trap. The skulls of all mammals trapped were collected for study material. The skulls were detached, cleaned, tagged and sent to the Transvaal Museum for identification and curating. Specimens were further dissected for organ tissues of which the liver was preserved in vials with 95% ethanol. Initial samples of the organ tissues were sent to the Zoology Department of the University of Pretoria for cytogenetic analysis with the bulk of the organ tissue samples put into storage for later use depending on the results of the taxonomy based on the skull morphology and dentition.

Due to lack of rain at the start of the crop production season, farmers had delayed maize planting and thus trapping for rodents in crop fields was not done.

Results

<u>Rodent impact assessment</u>

The respondents of the survey replied that rodents were a problem to everyone. Rodents damaged: field crops (maize) after planting, at harvesting and in storage; vegetables in gardens and building structures. In the homestead clothes, furniture and food containers were damaged. Young chickens were at risk at night and some people had been bitten. The majority of respondents had applied rodenticides, but claim it being not effective. In one village half the respondents had tried ‘black poison’ (an acute nematicide illegally traded and used for rodent control), stating that it had initially killed rats, but became ineffective after a week’s use. A small number of respondents had used snap traps with mixed results and some relied on cats. Dead rodents are usually dropped down the pit latrines or thrown away in a hole, a ditch or in the field. Householders recognised large rodents (ibunzi) living between rocks outside the village, or living in holes in the store room (tool shed, grain crib), outside pit latrines (Plate 2.1) or in the roof, and smaller house mice live in rooms. Rodents are often observed at night moving about or gnawing on utensils and plastic containers. Some farmers have reduced the impact of rodent feeding damage on their grain crops by using metal tanks for maize storage (plate 2.4).

Most households have access to water through a tap, either in the yard or through standpipes in the street. Most households stored water in containers (closed plastic drums) in the house and the washing was usually done in the yard (Plate 2.2). A few respondents at washed in the rivers nearby. Food was cooked daily and food leftovers were often given to the animals in the yard. Agricultural waste was dumped, fed to animals or used for compost, while other waste was dumped. Accumulated dumped waste was usually burned.

On the question whether householders had recommendations on how rodents could be controlled, the majority stated they had no idea as they had tried the known methods (traps and poison) and had failed. Some would try new chemicals or were hoping that government would come with the solution. Volunteer households in the trapping trial were however very pleased with their trapping results.

<u>Trap success</u>

Trapping results are presented in terms of trap success; the number of traps used multiplied by the number of trapping nights. For households with multiple catches (where traps were reset during the night after catches were removed), these were treated as ‘additional traps’ and were added to the total number of traps for the trapping period. The effects of intensive trapping in the treated households are compared to the three-consecutive trap nights per month of the untreated households.

In both villages trap success declined soon after intensive trapping was started in October of 2005. This sustained decline in capture rates is compared with the trap success trend of the untreated households per village in figures 2.1 to 2.2.

The rodent male to female ratio trapped, for daily trapping and for the control except for Ophuzana (control), was an average of one male to 0,9 females. At Ophuzana (control) the number of females trapped was higher than that for males (Table 2.1).

Table 2.1. The total number of rodents caught monthly and the rodent male to female gender ratio trapped in households in the villages of Mvuzini and Tholakele.

	Mvuzini				Tholakele			
	Daily trapping		control		Daily trapping		control	
Month	total	ratio	total	ratio	total	ratio	Total	ratio
Oct/Nov	90	1:1,1	30	1:0,9	165	1:0,9	100	1:2
Nov/Dec	38	1:0,4	27	1:0,8	61	1:0,8	51	1:1,4
Dec/Jan	25	1:0,7	44	1:1	58	1:1	55	1:1,7
Total	153	1:0,8	101	1:0,9	284	1:0,9	206	1:1,8

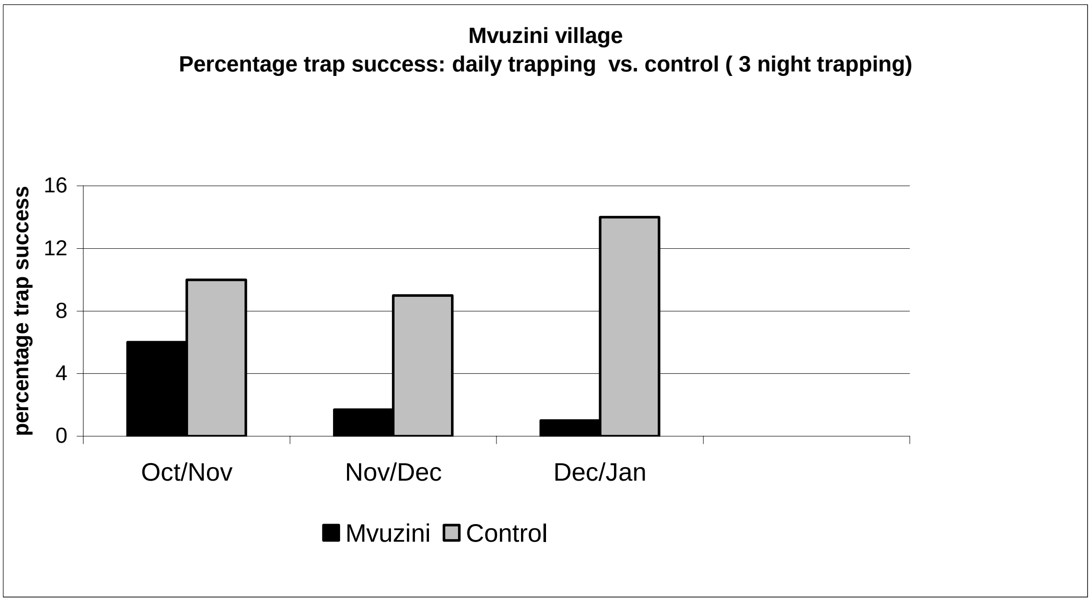

Figure 2.1. Trap success of all rodents caught in households in Mvuzini village

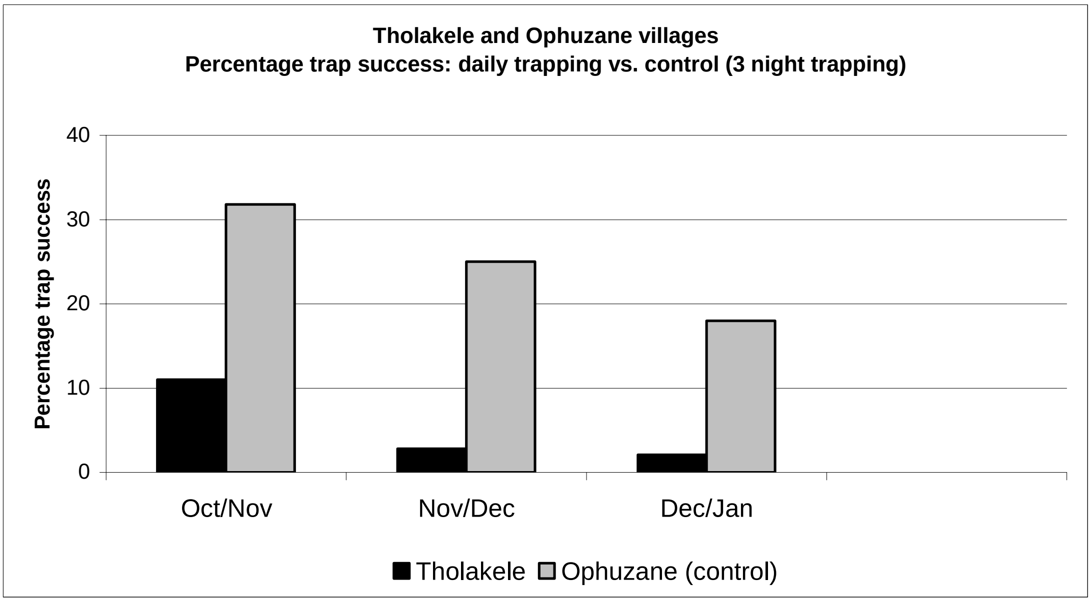

Figure 2.2 Trap success of all rodents caught in households in the villages of Tholakele (treated group) and in Ophuzane (untreated group or control)

Species composition

Taxonomic identification of rodent skulls was not completed at the time of completing the FTR. A disadvantage in the use of the break back traps for trapping was that the skulls of a number of rodent catches were crushed by the trap's mechanism, making it difficult for taxonomic use.

Due to the high cost of cytogenic analyses, only a random sample of organ tissue collected from each of the three villages were analysed. Of the 35 specimens for which the nucleotide sequence of the cytochrome-B gene was determined, 33 tested positive for *Rattus tanezumi*. This is a first recording of the oriental rat in the KwaZulu-Natal Province.

From observation notes made of the rodent morphology during trapping, obvious external colour and marks such as stripes, the 'head+body' and tail length proportions combined with weight, and the number and position of mammae of adult females were used to quickly classify catches. However, variations in external appearance such as the body colour occurred in the *Rattus* species complex. Catches of this species ranged from bodies with an all over grey fur to shades of brown dorsal hair and to catches of large individuals with creamy-white belly fur. (Plate 2.7). The number of catches of the *Rattus* species complex far outnumbered catches of other rodent species.

The other rodent species identified were the indigenous multimammate rat *(Mastomys natalensis*) and the striped mouse *Rhabdomys pumilio*, both confirmed with cytogenic analyses. The fourth species identified was the commensal house mouse *Mus musculus*, of which families were regularly trapped in certain households.

Discussion

Continuous trapping for rodents with break back traps in the households over a period of five months demonstrated to the communities and agricultural extensionists the effectiveness of trapping as a rodent management tool. With only two traps per household compared to the ten traps used per household in Limpopo Province, more households could participated actively in the trials and with less traps to set each evening, homeowners were more likely to continue setting traps, even when no catches were taken as the number of rodents in these households declined after two months. Capture results might be a truer estimation of trap success compared to the trials in Limpopo Province where households did no longer set all ten the traps daily when they no longer observed rodents.

By actively participating in the trapping trial, household developed a better understanding of rodent pest damage levels, and this would ensure that recommended strategies are socially and financially acceptable.

The average cost of rodenticides, depending on product, varies from approximately R6.00 to R20.00 per 100g dosage unit as used in once-off applications by householders in the survey area. The cost of the break back trap used varies from R15-25.00 per item depending on the amount purchased. While rodenticides need to be replaced regularly, the same trap can be used daily with no further cost input.

Rodents were trapped in all the sites in households, although the majority of home owners set traps in store rooms and kitchens. The dominant rodent species in the households of both representative areas was the commensal rat *Rattus* spp. Cytogenic analyses identified these as the oriental rat *Rattus tanezumi*. As in Limpopo, this is a first recording of the species in the KwaZulu Natal Province. Furthermore, the new recording is also the dominant rodent species in households. Live specimens trapped were sent for kariotyping at the eThekwini Natural Sciences Museum in Durban. But pending completion of a comprehensive taxonomic study of the related *Rattus* species with from 38 to 42 chromosomes, the term *Rattus rattus* Complex should be used as was suggested by Aplin *et al.* (2003).

Renewed interest into commensal rodents in South Africa has been sparked with the 'discovery' of *Rattus tanezumi* through this project. From the surprise initial recording of eight specimens in a single village in Limpopo to this species being the dominant rodent in catches taken from the KwaZulu Natal survey area in the present project. Further recordings of *R. tanezumi* were also made near Durban and near Pretoria. *R. tanezumi* has however not replaced *R.* rattus as positive cytogenic identifications of *Rattus rattus* have also been made in Limpopo and Pretoria.
The University of Pretoria has tasked a zoology PhD student with a study of the local *Rattus rattus* Complex.

Plate 2.1. Rodent droppings in a pit latrine

Plate 2.2. Washday blues – the washing is done in the yard

Plate 2.3. The Village of Mvuzini in the Vryheid district

Plate 2.4. Maize storage in corrugated metal tanks   Plate 2.5. Training on rodent dissection

Plate 2.6. The village of Tholakele on the Piensrant in the Paulpietersburg district

Plate 2.7. Colour variation in the *Rattus rattus* Complex trapped in the KwaZulu-Natal North Region

3. Development of public-private service provision.

Introduction

The problem with commercial involvement in the delivery of rodent management targeted at rural communities is whether such activity is profitable to private companies and how the quality of service delivery can be monitored. Partnerships between the local government departments of Environmental Health, and Agricultural and private Pest Control Operators are a novel way of increasing the promotion of rodent management knowledge and tools. In practice, establishing such partnerships is a challenge; however, local councillors and provincial authorities in Limpopo and KwaZulu-Natal were supportive of the proposal, and a commercial company (Scientific Pest Control Services) was willing to commit resources to a joint venture. Past CPP-funded activities had established the foundations for the implementation of public-private partnerships for the delivery of rodent management, and the scheme was to be trialled within the project extension. The initial training with agricultural extension and environmental health in the Limpopo Province held in February 2005 was successful and it was then proposed to be extended to KwaZulu-Natal.

A South African rodenticide manufacturer was approached to modify and manufacture break back traps similar to those from an US based company, which were successfully used in Mozambique (DFID project R7372) and in this project. These traps are sufficiently sensitive and cost-affective (based on the number of rodents caught per trap) when compared to alternatives such as rodenticides. The engagement of a local manufacturer also ensures sustainability and a pricing structure independent of the Rand – US Dollar exchange rate.

Material and methods

A partnership between government, research (represented by PPRI and NRI), manufacturers of rodent management tools and pest control industry was established to present training to agricultural extension, environmental health officials, pest control operators and municipalities. Due to the importance of maintaining a high standard of training for the extension of the project to the end of 2005, NRI and its associate were made the leading collaborators (see chapter 1).

A South African rodenticide manufacturer has agreed to manufacture break back traps. The PPRI managed CPP project was the manufacturer's first big client and by placing a large order for break-back traps, gave impetus to the manufacturer's decision on the costly production of the mould to mass produce the tool for the relatively small South African market environment. A further order was placed for single-capture live-traps (box traps) as was to be used in the RatZooMan project.

Results

Thirty agricultural extensionists and provincial health officials attended the training courses on rodent management (see chapter 1) presented in the rural centres of Thohoyandou and Vryheid during February 2005. At the four workshops in the urban centres during June and November, 103 people representing pest control industry, agrochemical manufacturers, municipalities, environmental health, milling and research, attended.

Agricultural extensionists met with the manufacturers/distributors (course partners) of rodent management tools to strengthen the link of client/product distribution and information exchange.

The training course presented in Durban at the premises of the Vector Control Section of the eThekwini City Health Department, presented an opportunity for a guided tour of the premises and activities were explained. Many of the course attendants commented that they had no prior knowledge on the function of the centre and this sharing of activities and problems would create better cooperation in future. Working together will not only give a better recommendation but can also benefit you business-wise (Botma, 2005). After the training course, it was stated “that if the only achievement of the course was to introduce pest controllers of the public and private sectors to work together, the course would be a success” (see Appendix 2).

At the course presented in Pretoria, the new marketing manager of a pesticide manufacturer was linked to a major stakeholder in the grain post-harvest industry of Limpopo Province which has retail centres and cooperatives in most of the towns and communities and also more remote rural areas in the Province. This would conclude the long awaited process of supplying small-scale and subsistence farmers with one of the grain protectants which proved to be very successful in the CPHP project (ZB0242) conducted in on-farm farmer-managed trials in the Limpopo Province (Von Maltitz *et al.*, 2002). This pesticide will be retailed in smaller units affordable and accessible to farmers and households who store staple grain crops on-farm in bags or in granaries.

This milling company was also a role-player in the rodent control industry workshop held in Pretoria in February 2004, and had committed its support of any rodent control action in the Province. This partnership will further provide a vehicle for the distribution of break back traps from the local manufacturer to end users in communities in rural areas.

The local manufactured break back traps were used in the rodent trapping trials and were compared with the imported trap. Their sensitivity and durability were tested under local conditions by end users. Project trappers and project staff made recommendations on the improvement of these traps. The traps are sufficiently sensitive and cost-effective (based on the number of rodents caught per trap) when compared to alternatives such as rodenticides. The manufacturer is at present in a further process of patenting a ‘new and better’ designed break back trap.

On the strength of the successes of the project rodent trapping trials, the major manufacturer/distributor of rodent management tools in the country has started to import the break back trap from the USA for local distribution. This company (a partner in the above training courses) further presents training on their products as a service to their clients and thus will promote the use of environmental benign and sustainable trapping as a rodent management tool.

Discussion

The partnership established between the stakeholders presented a training package of a high standard which was well received and highly recommended by the industries represented at the courses. The training courses also functioned as an opportunity to introduce members of private PCO industry to health officials from the municipalities and provincial government who have the same objectives and problems in pest control. Better cooperation between the two sectors is envisaged.
The links introduced also provided vehicles for pest and rodent management tools from manufacturers to end users, especially for poor communities. The engagement of a local manufacturer to produce break back traps also ensures sustainability and a pricing structure independent of the monetary exchange rate. These traps proved to be user-friendly compared to older types of snap trap available locally, which would be an incentive when a

choice for one rodent control tool is made by a small prospective buyer. One trap would be more sustainable and effective than one dosage of rodenticide.

On the strength of the project's involvement in rodent control training, PCSIB invited the project to participate in setting unit standards for rodent control for approval by the South African Qualifications Authority (SAQA). A publication of regulations regarding the registration of pest control operators was published in the Government Gazette of September 2005 for comment (Appendix 3). The major amendment to the act of concern is that rodent control would become one of eight separate subjects for which pest control operators would need to complete the National Certificate. Therefore, the quality of rodent knowledge among practitioners stands to be significantly advanced through improvements to course material and provision of more detailed knowledge about rodent biology and management. This government amendment for an expansion of training on rodents should be seen as a major success of the project activities by creating a learning environment focussed exclusively on rodent pest management. The new national requirement will have long term impacts on increasing rodent awareness and improved delivery of rodent pest management in South Africa.

4. Dissemination of results through the production of radio programmes

Introduction

The dissemination of knowledge to end users in South Africa is a big challenge as interaction with service providers is usually very limited. Radio was identified as one of the key ways in which end users, particularly resource poor communities in rural areas can be reached in the country.

Material and methods

A variety of taped recordings were made of conversations with role players in the Limpopo rodent survey area. In villages where rodent trapping trials had been conducted, farmers and households that had participated in the trapping trials were asked for their comments on the impact of rodents on their livelihoods before and after the trapping trials and/or rodent information sessions. At the Thohoyandou market, conversations were recorded with shopkeepers, farm produce vendors, sellers of rodent control products as well as shoppers. Recordings were made with project field staff, agricultural extensionist, and research specialists who had participated in the rodent projects conducted in the Province.

Material for a radio play was designed as a series of short stand-alone 'spots' each with a duration of 5 to 7 minutes that would focus on different aspects of rodent biology, damage and management (Appendix 4). The 'spots' were to be incorporated into local radio schedules for repeated delivery at different times and in different local languages, using music and humour in the production process. These short programmes would help raise awareness about rodent damage (disease, crop loss, contamination) the dangers of existing illegal management practices and help rural communities learn about better ways of controlling rodents (chronic poisons, trapping, monitoring) and where to seek further information.

The Limpopo DA&E Media centre and three broadcasting companies in the Province were approached. The national broadcaster (SABC) based in Polokwane consists of three 'relatively' independent radio stations for each of three language groups in the area. Two independent smaller regional radio stations are based at Universities; Radio Turf at University Limpopo (the former University of the North) near Polokwane and Radio Univen in Thohoyandou.

Results

Initial discussions with the various radio stations approached suggested that there was broad enthusiasm and support for a series of radio programmes on rats. The provincial DAE media liaison group was interested but found it progressively harder and costlier for its own material to be given air time in the restricted time slotting it had with the national broadcaster. The two regional university based broadcasters were also interested but uncommitted through lack of resources. Of the three language stations at the national broadcaster, two were not interested in such programmes while the third (ThobelaFM) expressed interest but was vague on commitment even after repeated attempts to discuss the details of production. It had been generally agreed that the project would pay for production costs and that the stations would use the base material for translation into the different local languages and broadcast the programmes during appropriate time slots, e.g. during farming or educational slots. Despite these discussions it became apparent that the radio stations expected to be paid for airtime to broadcast the material. It was emphasized that the radio programmes were not commercial in nature and that the project production team did not stand to gain any financial benefit from the airing of the programmes. Despite attempts to clarify that the programmes were designed for increasing public awareness, education and to be entertaining, further communications with radio stations remained one-sided (on the initiative of the project team), and it was not possible to obtain any indication of motivation or commitment to the radio series by the end of the project timeframe.

Discussion

A significant quantity of audio material was collected by the project team with reference to appropriate storyboards. This material could be easily edited into a series of programmes which would raise awareness about rodent pest problems and the best ways to manage rodents. Unfortunately it was not possible to engage the regional radio stations which appear to be under increasing pressure to operate under strict commercial guidelines. Although editorial and production time of radio station staff could have been commissioned and paid for by the project, this did not appear to be a significant incentive for station staff or directors. Nor did it appear that providing a series of radio programmes "free of charge" to radio stations would encourage stations to broadcast the material without also paying airtime fees. The project team felt that the radio stations were being unreasonable to expect broadcast fees for educational material, particularly when the stations' Charters had clear education obligations and remits. It is still possible that further discussion and negotiation could lead to an agreement with radio stations to produce and broadcast the material which has been collected. However, time ran out within the project before it was possible to get a radio station committed to the process. It may be that further incentives to help train editorial staff could facilitate the programme production. Therefore, the project team will continue to discuss the dissemination of rodent knowledge through radio with interested stakeholders in order to achieve the stated aims of this activity in the near future.

Plate 4.1 Recording an interview on the impact of rodents in a Mapate household's livelihood.

Plate 4.2. Recording an interview at the Thohoyandou market on the impact of rodents on a market vendor's livelihoods.

Plate 4.3 Recording an interview with a seller of 'rat poison' at the Thohoyandou market.

Outputs

The project had four main outputs. The activities focussed on training of staff that are responsible for rodent management activities and integrating their knowledge and interaction to improve service delivery to rural farming communities.

The first output of this process was the partnership formed between research (represented by PPRI and NRI), manufacturers of rodent management tools and pest control industry, with NRI and its associate as the leading collaborators for the duration of the project, to present training to agricultural extension, environmental health officials, municipalities and pest control operators. The practical system of training which was recommended to senior policy makers within the Departments of Health and Agricultural & Environmental Affairs and to the Pesticide Registrar (overseeing PCOs) to institutionalise mechanisms of ensuring appropriate training was given to staff providing rodent management services. Officials from local government (the above Departments), Municipalities and from various companies and services from the private sector attended the training courses that were presented in the urban centres of Pretoria, Durban and Cape Town, and the rural centres Thohoyandou and Vryheid.

The training workshop was a practical system of training that was recommended to senior policy makers within the Departments of Health and Agricultural & Environmental Affairs and to the Pesticide Registrar (overseeing PCOs) to institutionalise mechanisms of ensuring appropriate training is given to staff providing rodent management services. The lack of specific and practical training on rodent pest control was silently acknowledged and a policy change was introduced with the Pest Control Operators national certificate course amended to include rodent control as a separate entity.

From this partnership a rodent management tools manufacturer had modified and started to produce break back traps locally which ensures sustainability and a pricing structure affordable to poor communities. These traps were also used by the project research staff in the trapping trials conducted in rural communities.

A further link was formed between a Milling company which trades in grain with small scale farmers and has a valuable network of retail points in rural communities, and a pesticide manufacturer for the distribution of grain protectants. This will further also serve as a vehicle for the distribution of local manufactured break back traps. It is expected that these institutions will further encourage the improvement of knowledge provision as the primary means of improving rodent pest management in South Africa.

The methodologies developed for reducing rodent populations, monitoring rodent damage and their impact on sustainable livelihoods in Limpopo Province were extended to rural and peri-urban communities in a region in KwaZulu-Natal. One short season's trapping trial effectively demonstrated to end users in poor rural communities a better understanding of pest damage levels and socially and financially acceptable management strategies. This will help ensure that recommended strategies are appropriate for relatively more diverse agro-ecological conditions. The trials also delivered usable scientific data to add to the seasonal data set.

The dissemination of knowledge to end users in South Africa can be a big challenge. Material on rodent management knowledge together with the successes experienced by end users in rural communities was compiled to be incorporated into local radio schedules. With some further refinements and with accord from a willing broadcaster, this knowledge can be broadcast to the target audiences.

Contribution of Outputs to Developmental Impact

It was demonstrated that efficient and sustainable rodent control can be achieved through the process of continuous trapping. Even for poor communities, the use of two sensitive and durable break back traps would be cost effective. The uptake of the break back trap by agrochemical manufacturers and distributors will increase the incentive of end users to adopt this rodent management tool.

The attendance by local government's environmental health and agricultural extension and the private sector of the training workshops was indicative that these sectors will take the gained information further to their clients. The participation of the role players in the training has resulted in the amendment of the pest control operator's registration act as was published in the Government Gazette.

The recording of the new species in the country of the *Rattus rattus* Complex has renewed scientific interest in the research on commensal rodent species.

Material on rodent management knowledge together with the successes experienced by end users in rural communities was compiled to be incorporated into local radio schedules. With some further refinements and with accord from a willing broadcaster this can be broadcasted to the target audience

From this project extension, the following publication was produced:

BASTOS, A.D.S., CHIMIMBA, C.T., VON MALTITZ, E., KIRSTEN F. & BELMAIN, S. 2005. Identification of rodent species that play a role in disease transmission to humans in South Africa. Proceedings of the Southern African Society for Veterinary Epidemiology and Preventive Medicine. pp. 78-83.

BASTOS, A.D.S., CHIMIMBA, C.T., VON MALTITZ, E., KIRSTEN F. & BELMAIN, S. 2006. *Rattus rattus* Complex in South Africa; first record of *Rattus tanezumi*. Genes and Genetic Systems. (in prep.)

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AGRICULTURAL RESEARCH COUNCIL. 2001. The Agricultural Research Council delivers on the Presidential Imperative Programmes. Agricultural Research Council, Pretoria, 41 pp.

BELMAIN, S. 2005. Ecologically-based rodent management for diversified rice-based cropping systems in Bangladesh. Final Technical Report Project R8184. Natural Resources International, Aylesford, U.K. 131 pp.

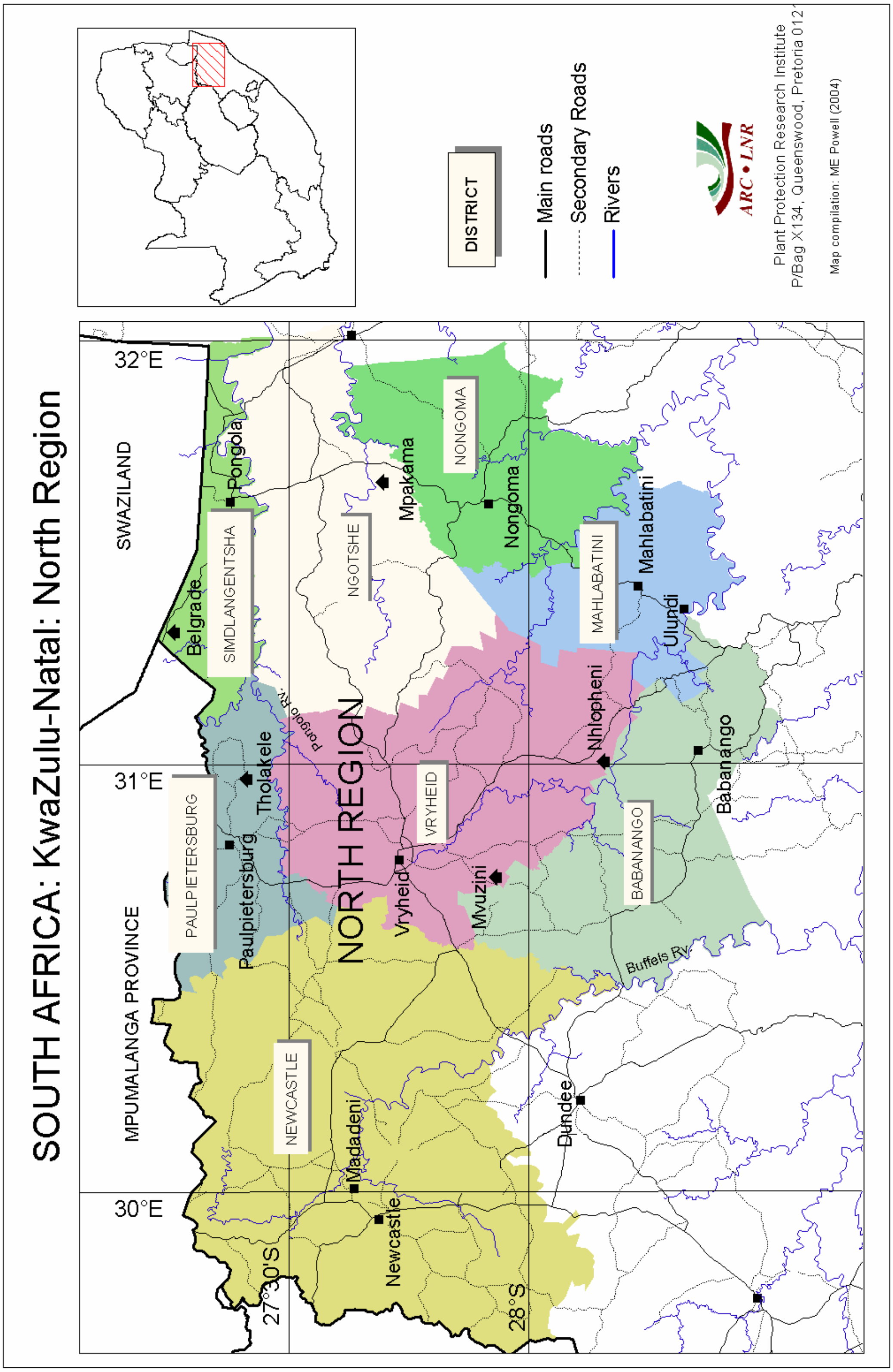
BOTMA, C. 2005. Wish you were there. Pest News. South African Pest Control Association, Centurion. 8 pp. <http://www.sapca.org.za>

KIRSTEN, F. and VON MALTITZ, E.F. 2005. Technology transfer and promotion of ecologically-based and sustainable rodent control strategies in South Africa. Final Technical Report, Project R8190. Natural Resources International, Aylesford, U.K. 85 pp.

VON MALTITZ, E.F. 2004. Crop Post-Harvest Programme for North Region, KwaZulu-Natal: Needs assessment of small-scale food production systems. Technical Report, SRL Project L12609. ARC-Plant Protection Research Institute, Pretoria. 61 pp.

VON MALTITZ, E.F., KIRSTEN, J.F. and SANDMANN, E.R.I.C. (compilers). 2002. The integration of DFID-funded Crop Post Harvest Programme Outputs to address constraints of small-scale food production systems in South Africa's Limpopo Province as identified by the current DFID funded project R7777. Final Technical Report, Project ZB0242 (linked to R7777). Natural Resources International, Aylesford, U.K. 35 pp.

Appendix 1: Map of the rodent survey area in KwaZulu-Natal



Appendix 2: Article in Pest News

This article appeared in the 'Pest News', published by the South African Pest Control Association dated 'Winter 2005' (www.sapca.org.za), on the Rodent control course presented by PPRI at the premises of the eThekwini City Health Department in Durban. The author of the article confused the course presenter Adrian Meyer with 'Richard'.

WISH YOU WERE THERE . . .

Chris Botma
KZN PCO

eThekweni Rodent Control Course.

Hi to one and all of the Pest Control community.

I was fortunate enough to have attended a rodent biology and control course on the 22nd and 23rd of June in KZN hosted by our eThekweni pest control division.

I'm sad to say that there could have been more companies present, thus the reason for my insert.

The course was brilliantly presented by a seasoned rodent control specialist from the UK (Richard) and ended up being more than just a manual, slideshow and fact based presentation. Yes people, we actually learned a lot and got a bit more done, being the interesting part.

The course:

Commensal Rat:
Derived from the Latin words, 'co'-with and 'mensal'-table.
That's right, "an animal living with or of mans table!"

This causes the following problems:
- Transmission of disease.
- Structural damage.
- Rodentaphobia.
- Agricultural damage and loss:

The four main rodents discussed were:
-The Norway rat. (Rattus norvegicus)
-The roof rat. (Rattus rattus)
-The house mouse. (Mus domesticus)
-The multimammate rat. (Mastomys natalensis)

Details on these four rodents, (habits, biology and control methods) were discussed by all the people present and we learned valuable facts that will not be found in books or manuals but only through listening to the variable personal experiences and ideas.

...a bit more...

On Wednesday the 22nd we had a practical look at applying control measures out on the field and what we realised is very valuable to us as PCO's.

Ever had the problem of treating a site were you take all the measures possible but you keep getting re-invested from a neighbouring parking lot, open field or garbage dump. These areas belong to the municipality; therefore we feel that it's their responsibility to gain control there, not true? Good news! The municipality agrees and they feel the same way about private areas that are normally controlled by contractors.

This is where we realised that we are faced with an opportunity to butter both sides of the bread. Working together, for example arranging a site meeting with a municipal PCO will not only give a better recommendation but can also benefit you business wise. You can be the first person being contacted by the municipality if the roles are reversed.

Richard commented, "if this is all that this course has achieved, that we work together, the course would be more than a success!" and I can not agree more!

Appendix 3 Government Gazette 48 No. 27991 of 9 September 2005

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DEPARTMENT OF AGRICULTURE

FERTILIZER, FARM FEEDS, AGRICULTURAL REMEDIES AND STOCK REMEDIES ACT, 1947

(ACT No. 36 OF 1947)

PROPOSED REGULATIONS REGARDING THE REGISTRATION OF PEST CONTROL OPERATORS

1. Definitions
Words and phrases in these regulations shall have the meaning assigned hereto in the Act, and unless the context otherwise indicates:
"pest control operator" means a pest control operator who is registered in terms of section 3(2) (c) of the Act;
"the Act" means the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act No 36 of 1947).

PART 1

REGISTRATION

Application for registration

2. (1) An application in terms of Section 3(1) of the Act for the registration of a pest control operator shall be submitted to the registrar on a form which is obtainable from the Registrar for the purpose or on a clearly legible facsimile thereof.

(2) Such application shall
(a) be made by a person who is resident in the Republic or who is in possession of a temporary permit issued to him in terms of the Immigration Act 2002 (Act No. 13 of 2002),and who complies with the requirements referred to in subregulation (3);
(b) be accompanied by the applicable application fee, and
(c) in the case of a pest control operator referred to in subregulation (3) (b), also be accompanied by any written proof, in the form of an affidavit, that such a person has administered agricultural remedies satisfactorily for at least two years continuously, with an indication of the pest control which
were personally performed, the types of pests which were combated and the types of apparatus and agricultural remedies which were used in combating such pests;
(d) further be accompanied by certified copies of any other documents relating to the skill of the applicant concerned in the administration of agricultural
remedies and the handling of the appropriate apparatus.

(3) An application shall be made by a person who
(a) has obtained a National Certificate accredited with the relevant South African Qualification Authority Body in one of the following subjects, namely:
(i) aerial application - advisory or application;
(ii) plant pests and diseases;

(iii) weed control - agricultural or industrial;
(iv) structural pest control;
(v) fumigation - stored products or Marine or soil or structures or furniture
(vi) wood preservation
(vii) rodent control; or
(viii) any other relevant specialisation

(b) in the course of a business in the presence and under the supervision of a
registered pest control operator, has administered agricultural remedies continuously for at least two years,

(c) is at least 18 years of age, unless agreed otherwise in writing by the Registrar Period of registration

3. (1) Subject to the provisions of section 4, a registration in terms of section 3 of the Act shall in the case of a pest control operator, be valid until 30 June in each year. Provided that if a registration is granted within three months prior to 30 June, it shall be valid until 30 June in the following calendar year.

(2) If the Registrar deems it in the public interest, determine that the registration shall be valid for a shorter period indicated on the certificate of registration concerned.

(3) the holder of the pest control operator certificate shall perform only those uses that the certificate authorises the holder to perform and no other uses.

Renewal of registration

4. (1) An application in terms of section 3(4) (a) of the Act for the renewal of the registration of a pest control operator shall be submitted to the registrar on a form which is obtainable from the Registrar for the purpose or on a clearly legible facsimile thereof.

(2) Such application shall
(a) be made by a person who possesses a certificate of registration in terms
of subregulation 2.
(b) be submitted to the Registrar not later than 14 days prior to the expiry date of the registration concerned but not more than three months prior to such expiry date;
(c) be accompanied by
(i) the certificate of registration concerned as issued by the Registrar;
(ii) the applicable application fee

(3) An application made in terms of subregulation 4(1) which
(a) is received by the Registrar after 30 June, but not more than 30 days after such expiry date, shall be considered only if it is addition to the applicable application fee referred to in subregulation (2)(c)(ii), also be accompanied by the applicable additional late application fee or
(b) which is received by the Registrar after the days of grace referred to in
paragraph (a) expired, shall not be considered and an application for the registration of a pest control operator concerned may be made anew in terms of regulation 2: Provided the fact that such pest control operator registered previously, shall not necessarily imply that it will again be acceptable for registration.

Return of certificate of registration

5. A certificate of registration which is returned in terms of section 4A (3) of the Act shall reach the Registrar within 14 days of the date on which
(a) the Registrar notified the holder in writing given personally or by post of a suspension or cancellation of the certificate in terms of section 5 of the Act if satisfied that
(i) the holder made a false statement or furnished false information in applying for certificate; or
(ii) the holder has been found guilty of an offence against the Act or these regulations or any law relating to pesticides; or
(iii) the holder is for any other reason no longer fit and proper to hold a licence.
(b) the registration of a pest control operator concerned has lapsed in terms of section 4A (2a) or (2B) of the Act, as the case may be.

PART II

APPEALS

Submission of appeals

6. (1) An appeal in terms of section 6 of the Act shall be submitted to the Director-General: Agriculture within 60 days of date of which the reasons for the decision against which is appealed, were furnished in terms of section 5 of the Act.

(2) Such appeal shall
(a) be in the form of a written statement which is sworn to;
(b) state the reference number and date of the document by means of which such applicant or person was given notice of that decision.
(c) state the grounds on which the appeal is based;
(d) be accompanied by the documents relating to the subject of the appeal and;
(e) be accompanied by the applicable application fee.

(3) If such appeal is submitted by a person other than the person in respect of whom the decision concerned was furnished, the appeal concerned shall be accompanied by a statement in which the person concerned discloses his/her interest in that decision or action.

(4) The amount referred to in subregulation (2) (e) shall be paid by cheque, postal order or money order made out in favour of the Director-General: Agriculture: Provided that if the appeal concerned is delivered by hand, such amount may be paid in cash.

Address for submission of appeals

7. An appeal referred to in regulation 6(1) shall
(a) when forwarded by post, be addressed to the Director-General, Department of Agriculture, Private Bag x343, Pretoria 0001; and
(b) when delivered by hand, be delivered to the Director-General, Department of Agriculture, Agriculture Place, Beatrix Street, Pretoria.

PART III

PEST CONTROL OPERATORS

Skill

8. (1) A pest control operator shall be skilled in
(a) the use and calibration of the apparatus particular agricultural remedy;
used for the application of a
(b) the calculation and measurement of the applicable dosages;
(c) safety precautions and first agricultural remedy; and aid relating to the use of a particular
(d) the handling of poisonous chemicals.

(2) The registrar may request a pest control operator to do a test in the use of agricultural remedies at the time and place which he/she may determine in order to ascertain whether such pest control operator has the skill as contemplated in subregulation (1) and whether knowledge of the applicable provisions of the Act and of the applicable codes of premise for the use of agricultural remedies, as compiled by the South African Bureau of Standards, is of such a standard that it would be in the public interest that applicant be registered.

Records to be kept

9. (1) A registered pest control operator or business which instructs a pest control operator to administer an agricultural remedy shall in respect of each separate administration of an agricultural remedy, keep comprehensive records of
(a) the name and address of the owner or person in charge of the place where
agricultural remedy was administered;
(b) the place where such administration was performed, description and identification of such place;
(c) the size, expressed in cubic metres, square metres or hectares, as the case may be, of such a place;
(d) trade name of agricultural remedy used with "L" registration number;
(e) the purpose for which such place was treated and, if applicable, the crop
grown thereon or the commodity kept therein at the time of the administration concerned;
(f) the approximate extent to which the place, crop or commodity was infected
with the pest concerned at the time of the administration concerned;
(g) the date and time on which the administration concerned commenced;
(h) the quantity of agricultural remedy which was used and, if applicable, the
rate of dilution in the final mixture which was administered;
(i) the type of apparatus used for the administration concerned;
(j) the particulars of which the owner or person referred to in paragraph (a)
was notified in terms of section 10(1) of the Act: Provided that a copy of the written notice referred to in section 10(2) of the Act may be attached to
the particulars to be recorded in terms of this subregulation; and
(k) if applicable
(i) any spillage of the agricultural remedy concerned which occurred during the administration concerned;
(ii) any case of poisoning of a person or animal resulting from the administration concerned; and
(iii) any complaint received in connection with the administration concerned.

(2) The documents in which the particulars referred to in subregulation (1) are recorded, shall be preserved at the address of the registered pest control operator or business referred to in subregulation (1) concerned, or at such other place as may on application be approved by the registrar, for at least two years after the day on which the administration concerned was made: Provided that if a complaint was received in connection with such administration, the records in respect thereof shall not be destroyed within two years after the date of such complaint.

PART IV

GENERAL

Offences and penalties

10. Any person who refuses or fails to comply with the provisions of regulations shall be guilty of an offence and liable on conviction to a fine or imprisonment for a period not exceeding two years or to both such fine and imprisonment.

Payment of fees

11. (1) The postage on and delivery costs of any application or document submitted in terms of these regulations, as well as on or of anything else pertaining thereto, shall be paid by the consigner.

(2) Any fee payable in terms of these regulations shall be paid by means of a cheque, postal order or money order made out in favour of the Director-General: Agriculture: Provided that if such fee is delivered by hand, it may be paid in cash.

(3) Fees which are paid in terms of these regulations shall subject to section 6 of the Act, not be refundable.

Address for submission of documents

12. Any application or document or anything else pertaining thereto, which is required in terms of these regulations to be submitted to the Registrar shall (a) when forwarded by post, be addressed to;
The Registrar: Act No. 36 of 1947, Private Bag X343, Pretoria, 0001.

Appendix 4 Radio storyboard outlines

Ratland, South Africa
Potential radio programme topics and storyboard outlines

1) Impact of rats on people's lives
Music [something local which starts and ends each programme of the series]
Presenter: Welcome to Ratland, South Africa. I'm XX and I will your presenter for this five part series where we will be exploring one of our worst enemies, the rat. Rats are a problem all over the world from New Delhi to New York, Polokwane to Port Elizabeth, causing problems in cities and the countryside. In this series will be looking at the problems rats cause for South Africans and speak to some well-known rodent experts in order to discuss ways to effectively control rats and minimise their impact on the people of South Africa. In the first part of this series we take you to the rural agricultural village of Mapate in the Venda Region of Limpopo Province to find out what sorts of rodent pest problems and damage people suffer from. [music fades]

Villager testimonies: My name is XXX and I'm a farmer/housewife/market trader/etc. in the village of Mapate. [Person goes on to tell about rat problems……. At minimum probably best to get a man talk about rat problems in crops and a woman to talk about problems around the house. Someone running a food business would also be interesting.]

Presenter: As we have heard, rats can cause many different problems for people in a village such as Mapate. People notice pest rodents attacking their crops, stored food and damaging personal belongings such as blankets, baskets, clothes and furniture kept inside their homes. This type of rat damage is easy to observe. However, some of the problems rats cause can be more hidden and not obvious to the average person. Frikkie Kirsten from the Plant Protection Research Institute of the Agricultural Research Council in Pretoria tells us more.

Frikkie: My name is Frikkie Kirsten and I am a scientist who has been conducting research on rodents in collaboration with farmers from a number of villages in Limpopo Province for a few years now. Our objective has been to find the best ways for small scale farmers in rural villages to manage their rat problems. To do this, it is important to first know how serious the rat problem is in order to design appropriate control strategies. In our work with villagers, we have found that people are good at identifying many of the problems, such as crop loss and household damage but less so at quantifying the scale of the problem. For example, it is difficult for people to say how much of their stored maize or sorghum is eaten by rats during storage. They know they have a rat problem in their food store but they can't say whether rats eat 10% or 50% of the store as the losses happen gradually over time. Our research has shown that farmers can experience rodent losses as high as X% to maize crops before harvest and another X% can be lost during storage. Another impact of rats on people's lives is that rural communities have a low awareness about diseases that can be spread and transmitted by rats. We have been doing research on some of the diseases that people can get from rats, but we still don't know enough about these diseases and how common they are in rats and people suffering from them in certain areas of South Africa.

Presenter: Rats are known carriers of more than 60 different diseases that can be transmitted to people. Some, but not all, of these diseases are known to be present in South Africa. Lorraine Arntzen from the National Institute of Communicable Diseases which is part of the National Health Laboratory Service in Johannesburg is an expert on many of these rat-borne diseases.

Lorraine: As many people know laboratory rats and mice are often used in medical research in order to develop new drugs to treat human diseases. Rodents get used for these tests because they are so similar to people… so if a drug works in a rat, it is likely to work for a person as well. These similarities between rats and people mean that many of the disease organisms that cause illnesses in humans can also survive in rats. One of the most famous diseases carried by rats that can affect people is Bubonic Plague. Several hundred years ago, bubonic plague killed tens of thousands of people in Europe, and the disease still persists in many places around the world. It has historically been a problem in South Africa, and the last confirmed case in the country was in 198X. Although there have been no human cases of the disease since then, we still don't know whether the disease can still be found in wild rodents. So far our surveys and tests have not detected plague in wild rodents, but it remains a worry whether the disease is out there and could lead to future human disease outbreaks.

Certain areas of Mozambique continue to have human cases of plague so it is possible that the disease could easily reach South Africa again.

Music [something local]
Presenter: You are listening to Ratland, South Africa… a five part series exploring rodent pest problems in South Africa and how to effectively control them.

Presenter: We have just heard that rats not only affect crop production and damage personal property but can also spread many dangerous diseases to people such as bubonic plague. Although plague is not an immediate worry for South Africans, other diseases such as leptospirosis and XXX are real dangers. They are also known to spread gastroenteric diseases such as salmonella so ensuring good hygiene and reducing the numbers of rats in the environment can help prevent people contracting diseases from rats.

Lorraine: Plague is just one of many diseases carried by rats. Plague is usually contracted by people coming into contact with rat fleas or by hunting and handling dead rats. Other rat-borne diseases can be contracted by food or water that has been contaminated by rat urine and faeces. The symptoms of many of these diseases can be similar to malaria or food poisoning but some can lead to more severe problems such as internal bleeding and organ failure. Fortunately many of these diseases can be easily treated with commonly available antibiotics if they are detected in their early stages.

Presenter: So rats are a well-recognised problem in agriculture, but rats also cause many problems for the health of our families by spreading and transmitting diseases. These diseases can also be a problem for the health of our livestock.

Small-scale chicken farmer: My name is XX from the village of Mapate, and I raise about XX hundred chickens per year. [goes on to talk about problems of rats in his chicken coop, health of his chickens, etc.

Large-scale pig farmer: My name is XX from…..

Presenter: As we have heard, the problems and damages by rats are many, making rats one of our most serious pest problems in rural villages and urban settlements alike. When you add up the damage rats cause to field crops and food stores, their damage to clothes and furniture, and the risks of disease transmission to people and livestock, the incentives to control rats are strong for people suffering from rats in their environment. People can often feel frustrated when trying to control rats to reduce the damage they cause. Rats are very mobile and smart but they can be controlled in most situations in a cost-beneficial and safe way. If you want to get rid of rats, you need to arm yourself with knowledge about rats and the tools available such as poisons and traps.   I'm XX, and I'll hope you join us for the next programmes of this series where we will discuss the best as well as the some of the worst ways in which rats can be effectively controlled.

2) Rodent ecology and behaviour
Music [something local which starts and ends each programme of the series]
Presenter: Welcome to Ratland, South Africa. I'm XX and I am your presenter of this five part series where we are exploring one of our worst enemies, the rat…..In the second programme of the series we are taking a closer look at what makes rats such a challenging adversary to control. In the war against rats, knowing the enemy is the key to reducing the impact of rats on our livelihoods.
Emil/Frikkie: Evolutionary history of rodent/human interactions.
Chris Chimimba/Peter Taylor: Discussion of the different species, highlighting that many species are not pests, importance of knowing which species – habits and preferences, i.e. good climbers, burrowers, like to live up high or on the ground. A bit about breeding, neophobia, and abilities of rats.
Villagers/urbanites: anecdotes highlighting abilities of rats. Lee Ashford and Dominic Sauvage will be good sources. You can even stop people on the street of Thoyando and other towns to get this sort of stuff.
Presenter: why it is important to know abilities of rats – neophobia impact on acute poison use and use of traps…. Breeding rate impact on efficacy of control operations……meaning hygiene and proofing are often best methods of control by reducing carrying capacity of environment.

3) Rat poison and how to use it
Music [something local which starts and ends each programme of the series]
Presenter: Welcome to Ratland, South Africa. My name is XX, and I'm your presenter of this five part series where we will be exploring one of our worst enemies, the rat. In today's story we will be looking at one of the most common ways of dealing with rats…..killing them with poison.

Discussion about acute and chronic poisons and weave in stories of aldicarb and local experiences of using rodenticides. Address fear of poisons -perhaps justified in case of acutes but not in case of chronics - what is the best way to use poisons, people's expectations.

Lee Ashford:
Environmental health officer:
Ministry of Health person:
Ag extension officer:

4) Ecologically-based management of rats
Music [something local which starts and ends each programme of the series]
Presenter: Welcome to Ratland, South Africa, a five part series where we explore one of our worst enemies, the rat. As we have heard in previous programmes of this series, rats threaten farmer's livelihoods, they eat people's crops and stored food and spread disease, making rat control a truly global issue. In rural areas, rats move freely between field and house and to control them is easier said than done. In this fourth programme of the series we will be looking at how rats can be cost effectively managed in ways that are environmentally sustainable and safe. Emil von Maltitz from the Plant Protection Research Institute of the Agricultural Research Council in Pretoria tells us more. [music fades]

Emil: Rats are difficult to control because of their intelligence and mobility. They can learn how to avoid hazardous situations and are normally cautious when exploring new things in their environment. Rats easily migrate in search of food, moving between the field and village as crops are harvested and brought into storage so rat control must be addressed in a holistic way. Farmers have many problems when they try to control rats…….

Villagers: People talking about how they try to control rats, what do they use, how they use it do they think it is effective. What happens when they stop using?.... [need to collect as many stories as possible]

Presenter: People have had problems with rats for generations but it is possible to control them. A research project in Limpopo Province and more recently in KwaZuluNatal involving scientific experts from the ARC-PPRI, the Natural Resources Institute in the UK and extensionists from the Department of Agriculture and the Environment are working in co-operation with village communities to reduce rat problems for the benefit of local farmers and their families. The project looks in detail at the whole interaction between rats, people and their shared environment to develop cost-effective and environmentally friendly ways to control rats. Phanie Malebana from the Plant Protection Research Institute of the Agricultural Research Council will tell us more…..

Phanie: My name is Phanie Malebana and I have been working with communities to understand the rat problems they face and help develop strategies to control rats. Rats are a big problem because we humans make their lives very easy. We grow crops which rats like to eat, we produce lots of rubbish which rats like to eat and they like to live in our buildings which provide a safe place for them away from their natural predators such as birds or snakes. Rats also breed very quickly when there is abundant food, water and shelter. Each female rat can have a litter of 8-12 babies every month and each of her babies is ready to breed when they are one month old. To effectively control rats we must, therefore, kill more than 80% or 90% of the total rat population. Otherwise those rats that remain will continue to breed so quickly that the number of rats will grow to what it was before in two or three months.

Presenter: So rats need what we ourselves need…. food, water and shelter. Although many farmers have problems with rats and try to do something about it, they are often disappointed with the results. Using poisons to control rats must be done carefully and must follow established protocols.

Phanie: Poisons can be dangerous if they are not used correctly, and many farmers are worried about their children or livestock accidentally eating rat poison. There are many types of rat poison available on the market and some are safer and more effective to use than others. Poisons that act quickly and result in lots of dead rat bodies being found nearby are actually the least effective method of rat control. So although the farmer may think he has killed lots of rats, he has actually only killed a very small percentage of the total population. Because these poisons kill quickly they cause rats pain, and this pain often makes the rat stop eating before he has eaten enough to kill him so the rat survives and remembers never to eat that poison again. These quick acting poisons are also the most dangerous to people and should really only be used after receiving training and in conjunction with other control methods. Farmers who use quick acting poisons are invariably wasting their money as the rodents remaining will very quickly breed and increase the rat population and most rats will avoid eating the bait because it makes them feel sick.

Rat poisons that act more slowly and where the farmer doesn't see lots of dead rats lying around are safer and more effective. Dead rats are not found lying about because the poison works more slowly so rats die in their burrows. These poisons are better because the rats don't feel ill and will continue to eat enough of the poison to kill them. Farmers should quickly see the amount of poisoned bait removed by the rats and the farmer must remember to keep putting out the bait until no more is eaten. Buying one dose of this type of ready made bait will not be enough if there are lots of rats around so it is important to keep filling up the bait until it remains untouched.

Music [something local]
Presenter: You are listening to Ratland, South Africa… a five part series exploring rodent pest problems in South Africa and how to effectively control them. We have been hearing about a project where scientific experts from the ARC and the UK are working with the DAE and local communities to develop more sustainable and cost-effective rodent management strategies. We've also heard that rat poisons can work, but that they must be used in the right way in order to kill the maximum number of rats. Using poisons without advice and training will be a waste of money and could be dangerous for your family and the environment. But there are other ways besides poisons that can be used to reduce rat problems. [Frikkie/Emil/Phanie] from the ARC will tell us more….

Frikkie/Emil/Phanie: Using rat poisons cost-effectively is a problem for most rural farmers. We have, therefore, been investigating whether farmers can use traps to kill rats fast enough to reduce the crop damage and storage losses that rats are causing for them. Traps are certainly safer for the environment and human health compared to rat poisons. However, it is important that people trap intensively on a daily basis. The best results are achieved when communities all trap together. If each house in a neighbourhood was to have one or two traps and religiously set these every night, the rat population will go down. Trapping does work as long as there are enough traps around in a community and used every day, even when rat numbers are low.

Villager worker: I'm XX from the village of XX. Tells about the trapping programme and number of rats caught when trapping first started and how the number of rats caught seems to have declined with time.

Presenter: Trapping rats looks like a promising way to reduce the problems caused by rats. Although there is the initial cost of buying a number of traps, they should last for many years and this cost should be offset by that normally spent on rat poisons. Because good quality traps are not always available in local markets, new designs of traps which are more effective at killing rats are now being produced in South Africa.

Lee Ashford: talk about traps, where to buy them, how much they cost etc. why they are better than the usual traps.

Phanie: Trapping or poisoning rats will work better before rat populations grow very large, so the timing of the control is also very important and often needs to be done before the rat problem becomes obvious. It is important to remember that preventing rodent access to stored food and water supplies and maintaining good standards of hygiene will do more to reduce rodent numbers and damage than any amount spent on poisons or traps. The best way to control rats is by integrating a number of different control strategies together, improving hygiene and proofing, and using a combination of traps and modern slow-acting poisons.

Presenter: You have been listening to Ratland, South Africa. I'm XX and I hope you'll join us next time for the final part of the series on rodent pest and their control in South Africa.

5) Ratland Soap
Music [something local which starts and ends each programme of the series]
Presenter: Welcome to Ratland, South Africa. My name is XX, and I'm your presenter of this five part series where we are exploring one of our worst enemies, the rat. In today's story we will be looking in on one families experience of rat control.

[village sounds, pounding grain in distance]
[Woman] Screams.

[Man out of breath] What's wrong?

[Woman] A huge rat just ran over my feet while I was getting some grain out of the store to make our breakfast.

[Man, exasperated] The rats are eating more of our food than we are. They're everywhere, in the field, the granary, the kitchen and even eating the chicken's eggs.

[Child] Daddy, there's a big rat hole in the floor under my bed, can you get rid of it. I don't want it biting me like before.

[Man] That's it, after breakfast I'm going to the market to buy some rat poison

[Woman] We don't have much money, and you know we've got to get the…...

[Man] I'll buy that black-market stuff which is really cheap and always produces lots of dead rats in the morning.

[Woman] You know I don't like using that stuff with the children around. What if they pick some up and put it in their mouth.

[Man] Do you want the rats to eat all our food? You know we have less and less because of this drought. You'll simply need to keep the children away from the areas I put the poison.
[sounds of market]

[Man quietly] Can you let me have some rat poison, you know, the black market stuff that works really well.

[Market seller] Sorry, we're fresh out. It's getting harder to get hold of that poison now. You know it's actually been banned. Not only is it really dangerous to use, but apparently it doesn't work all that good either.

[Man] What d'you mean, it doesn't work? I've used that stuff before and there has always been lots of dead rats around the next day.

[Market seller] There was a guy round from the city just the other day distributing information leaflets on how to control rats. You know, they guy who usually brings down the poisons and fertilisers for us. He was chatting to a number of us market sellers for quite a while. Let me see if I can find one of those leaflets. Yes, here, [in English] Acute vs. Chronic rodenticides, how to use rat poisons safely and effectively.

[Man] what does 'acute' and 'chronic' mean?

[Market seller] I have no idea. But maybe if we read this leaflet it will tell us. Hmmm, it says here that acute rodenticides are rat poisons that act quickly…..

[Man, interrupting] That's what it want, I need to get rid of those rats fast, they're eating us out house and home.

[Market seller] Will you stop interrupting and let me finish? It says here [as if he's reading] that fast acting rat poisons are not very effective because it makes the rats feel sick before they have eaten enough of the poison to kill them. Although lots of dead rats may be found the next day after eating the poison, many more have stopped eating the poison after only a few mouthfuls because they feel ill.

[Man, interrupting] Well, dead or sick rats is fine by me, I prefer them dead of course, but sick rats will hopefully leave us alone too.

[Market seller] Man, what did I say about interrupting me while I'm reading. Do you want to get rid of your rats or not?

[Man] Yes, yes, sorry go on, but hurry up, the rats will be looking for their lunch pretty soon.

[Market seller] It says here that the sick ones don't die because they haven't eaten enough of the poison before they felt it acting. The survivors learn never to eat that poison again and will avoid it for the rest of their lives.

[Man] The clever little buggers. So what are we supposed to do?

[Market seller] Well that's where the leaflet moves on to describing chronic rodenticides. It says these are poisons which are more effective because they act slowly and the rodents do not become sick from eating it. Because the rats don't get sick, they eat enough of the poison to kill themselves. It also says that the user should not expect to find lots of dead rats around when using these slow acting rat poisons because the rats go back to their burrows before they die.

[Man] Well, I suppose that does have an advantage in that my wife won't have to pick up all the dead rats the next day.

[Market seller] laughs. It also says these slow acting poisons are safer and are less likely to accidentally kill people or harm other animals

[Man] Well, my wife will be pleased with that, she was worried about the children getting into that black market stuff I was intending to buy. So do you have any of these slow acting poisons?

[Market Seller] Sure, we've always stocked these, lots of other people in the village buy them. You know, Rattex [names of those available]………..They're all listed here in this leaflet.

[Man] But I've tried Lanirat before and it doesn't work, the bait gets all eaten up and there are still loads of rats around. It simply doesn't kill the rats.

[Market seller] But remember what I just told you, you won't find lots of dead rats around
[Market seller and Man together] they die in their burrows.
[Market seller] The leaflet says you also need to keep putting bait out as long as rats keep eating it. So if the bait is all eaten up the next day, you must put more there to ensure that all the rats have eaten enough to kill themselves. The rats won't get sick so will keep eating the bait as long as it is there, but if they haven't eaten enough of the bait they'll recover and survive and your poison will have been wasted.

[Man] So I've got to keep putting this slow acting poison out until I notice that none of it is being eaten?
[Market seller] That's right. That means all the rats that have been eating the poison will be dead. It also says you should put the poison in more than one place in areas that you think the rats are going, but far out of reach of children, animals and away from food and water. It says it's also important not to keep moving the bait location around, that it might take a few days for the rats to find it and start

eating it. Once you notice that the bait is being taken by rats, you need to ensure that the bait doesn't run out for about 7 to 10 days.

[Man] Well, okay I'll try it like that and see what happens. Why don't you give me 5 packets of Lanirat for now and I'll come back for more if it all gets eaten up.
[Market seller] Sure, here you go, and take one of these leaflets too in case you forget what to do. Good luck!

[Woman] Well it sure took you long enough to buy some rat poison. You know you're supposed to be fixing the ….. You procrastinating…..
[Man] Woman, don't give me such a hard time. I was learning about how to get rid of our rats. Look at this leaflet, it says that black market stuff is no good. Anything that kills rats quickly only kills a few of them while making most of them sick so that they avoid eating the poison, not to mention that these acute poisons are dangerous.

[Woman] I'm the one that told you they're dangerous. You know what happened to the child of the ……. when he accidentally ate some of that stuff.

[Man] Don't worry, I haven't bought anything like that. These chronic rodenticides like Lanirat….. are safer.   It says here on this leaflet they kill rats by causing internal bleeding. People have to eat a lot of it to have the same effect on us and there are cures if someone accidentally eats a lot.   But of course we still have to keep the kids away from the stuff. I'll make sure it's all put in places the kids can't reach.

two weeks later…..
[Market seller] So you back to buy some more rat poison?

[Man] No, I was passing by and thought I'd say thanks, that chronic poison you sold me did the trick once I knew how to use it correctly. My wife hasn't seen a rat since a week after I started putting the poison out and there aren't the rat droppings all over the kitchen and food store like there used to be.

[Market seller] I'm glad to hear it. Those leaflets have been a real hit. I'm going to have to see if I can get some more of those, they've been good for business.

[Man] If everyone else in the village is as successful as I've been in getting rid of the rats, you'll soon be out of the poison selling business.

This programme was supported by ……. in collaboration with…..

Appendix 5: Rodent training course material

Rodent Biology and Control: An overview of the basic knowledge required to understand rodents and the management options available to design sustainable control strategies

RODENT BIOLOGY AND CONTROL *

Introduction
The rodents are a large group of mammals with over 1500 representative species world-wide. The range of species within the order Rodentia stretches from beavers, chinchillas, squirrels, gophers, porcupines, voles, hamsters, gerbils, rats and mice. The word ‘rat’ may properly apply to any of about 500 species of animal, and the word 'mouse' to at least 130 species. The principal identifying feature of a rodent is that one pair of incisors above and below are greatly enlarged and used for gnawing. In fact, the taxonomic name of the order is derived from the Latin *rodere*, meaning to gnaw or chew. In tropical stores, the main rodent pests are two rat species and several species of mice although in some parts of the Indian sub-continent, South-east Asia and China bandicoots are also very common. The accepted names for the three most common pest species are the common, brown, sewer or Norway rat (*Rattus norvegicus*), the black, ship or roof rat (*Rattus rattus*), and the house mouse (*Mus domesticus*). Common names based on colour may be deceptive, since *R. rattus* is not generally black and there is a black form of *R. norvegicus*.

These three common pests have been commensal or synanthropic, that is, essentially dependent on man for their food and shelter for many centuries, and we now tend to regard them as part our environment. There is a rich folk-lore concerning them, strains of two of the three have contributed to our scientific progress through their use as laboratory animals. Nevertheless, we know relatively little of their origins and exactly when and how they became dependent on man.

It seems likely that the house mouse was once a wild species somewhere on the borders of Persia and the USSR, and gradually spread from there with the practice of agriculture some thousands of years ago. Some non-commensal types of *M. domesticus* are still found in those parts. *R. rattus* originated in South-east Asia, where there are still a number of recognisable species living in the wild state. *R. norvegicus* probably came from farther north than this, in Central Asia, and did not originate in Norway, despite its species name.

In Western Europe, these three cosmopolitan rodents are considered to pose a potential threat to the health of man and domestic animals as well as causing extensive damage to stored food, animal feed and a wide range of building materials including the fabric of warehouses and even electric cables.

As rapid urbanisation occurs in parts of East and West Africa, a huge increase in the activities of these commensal species has occurred. *R. rattus* is present in towns and villages throughout the continent and have become serious pest and disease reservoirs. *R. norvegicus* is more frequently found in ports and highland settlements, although it is widespread in North Africa. In Egypt, both these species move freely into irrigated crop areas where they damage a range of crops including cereals and citrus.

India provides an interesting example of how a number of rodents have shifted habitats and in doing so have affected the success of others. For instance, the bandicoot (*Bandicota bengalensis*), which is essentially a field rodent, has ousted *R. rattus* as the major pest of grain warehouses in Bombay and Calcutta at least. Conversely, *R. rattus* which is primarily a commensal species has shifted to coconut palm estates in some areas of India such as the Western Ghats. Similarly in the Philippines *R. norvegicus* has started to invade rice fields, as well as its traditional haunts of cities, ports and stores.

Rats and mice are now present throughout the world. Their adaptability has enabled them to survive extremes of climate from the frozen tundra to dry arid desert. Whilst the majority of rodents live in harmony with their environment, from time to time conditions change and some populations can increase rapidly causing the well known rodent 'plagues'.

In many places rat meat is highly regarded as human food, in the rice growing districts of Thailand farmers catch the giant rat *Bandicota indica* to supplement their diet. In other Asian and African countries the field rat is considered a delicacy.

* This material is extracted from an MSc training course operated by the Natural Resources Institute, UK.

Rats and mice were amongst the first animals to be fired from the earth in rockets and they will probably still be man's fellow-travellers as and when space travel becomes commonplace.

Biology and behaviour of commensal rodents

As with all pest species, a full knowledge of rodent habitat requirements, reproductive capabilities, food habits, life history, behaviour, senses, movements and population dynamics, is essential for the design and implementation of effective population management.

Physical characteristics of rodents

Rodents are most easily distinguished from other mammals by the characteristic arrangement and form of their teeth. They have only a single pair of incisors in both the upper and lower jaws and no canines. The wide gap (diastema) between the paired incisors and the molars (or back-teeth) gives the rodent skull an unmistakable appearance (Fig. 8.1).

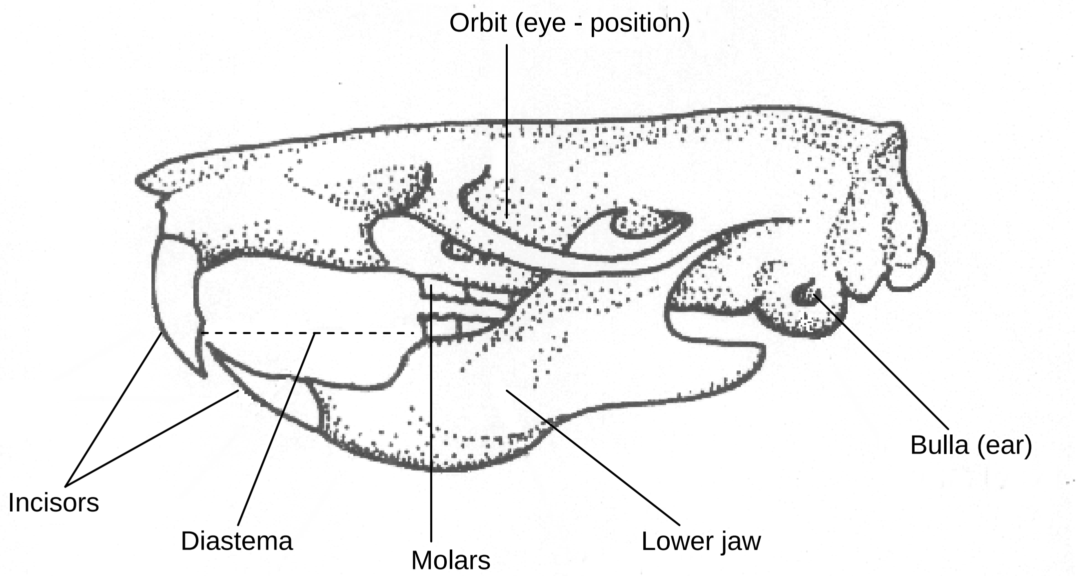

Figure 8.1 Diagram of a rodent skull

The incisors are the clue to the tremendous success of rodents within the animal kingdom. Rodent incisors have three basic characteristics that together, distinguish them from the teeth of most other animals; they are strongly curved, they grow continuously throughout the animal's life, and they carry a thick layer of enamel on one side only. The fact that rodent incisors grow continuously means that they must also be worn away continuously. It is often stated that rodents must gnaw in order to prevent their incisors becoming too long, but this is not necessarily true. Rodents can wear away their incisors by rubbing the lower set against the upper set; this results in the softer dentine being worn more rapidly than the hard enamel, giving a chisel-like outer edge to the teeth. The effectiveness of the chisel-action of rodent incisors can be seen in the work of beavers which fell small to medium-sized trees, and in the gnawing of rats and mice which, given an edge to bite on, can penetrate soft metals such as lead and aluminium. The diastema allows rodents to close off their incisors from the rest of their mouth by sucking in their cheeks, which enables them to gnaw on non-food items with no danger of ingestion.

Differences between mice and rats

The major differences between rats and mice is their size, other differences between the most common species are shown in Figure 8.2. The length of an adult rat excluding the tail is at least 200 mm, an adult mouse being half this size, the characteristically larger feet of rats help to differentiate between young rats and mice.

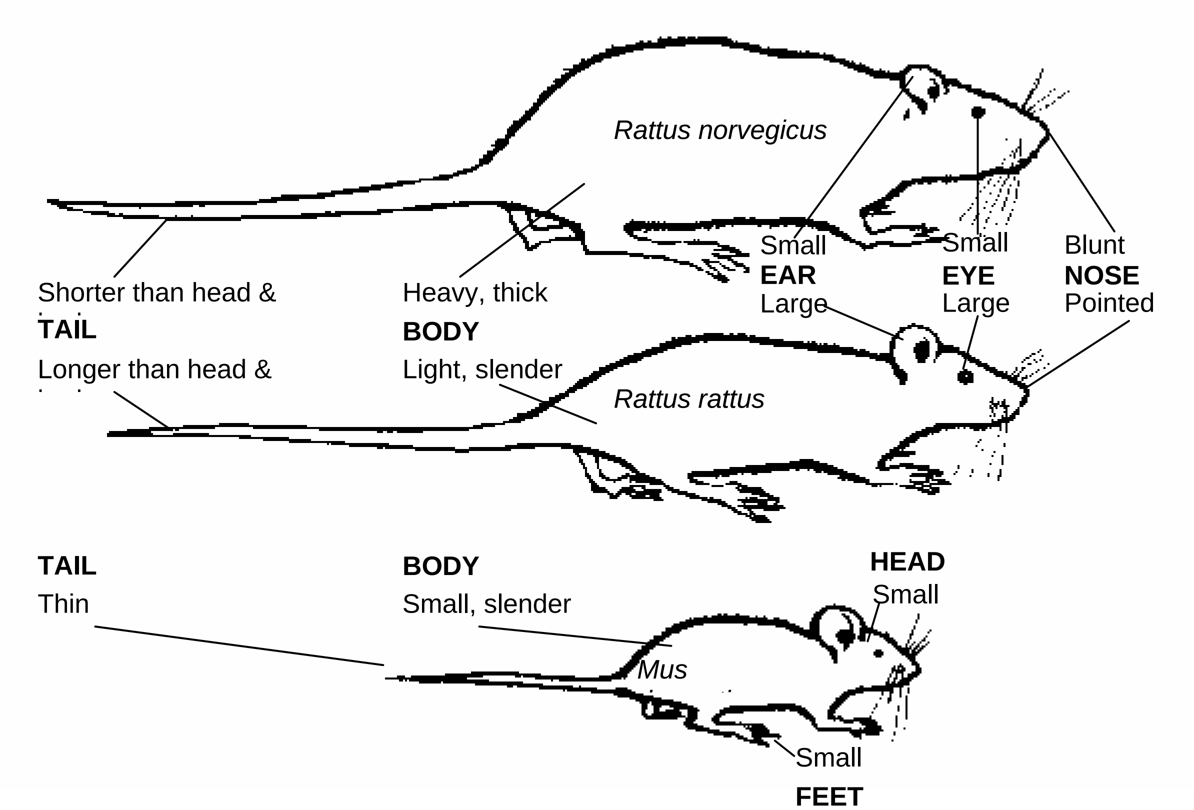

Figure 8.2 Differentiating characteristics of rats and mice

If rodent damage is found in a store, the size and shape of the droppings can be used to decide whether rats or mice (Fig. 8.3) have caused the damage. Rat droppings are on average about 15 mm long, whilst mouse droppings are only half this size. Rats need to drink water every day, are more active than mice are, and therefore leave more signs. Mice can remain inside stacks of grain, as they can obtain sufficient water from the grain itself and do not need to move around. However, if the moisture content in a mouse diet is only 12%, and no free water is accessible, the animals start dying after only two days. Further information about the most common commensal species is provided later in the chapter.

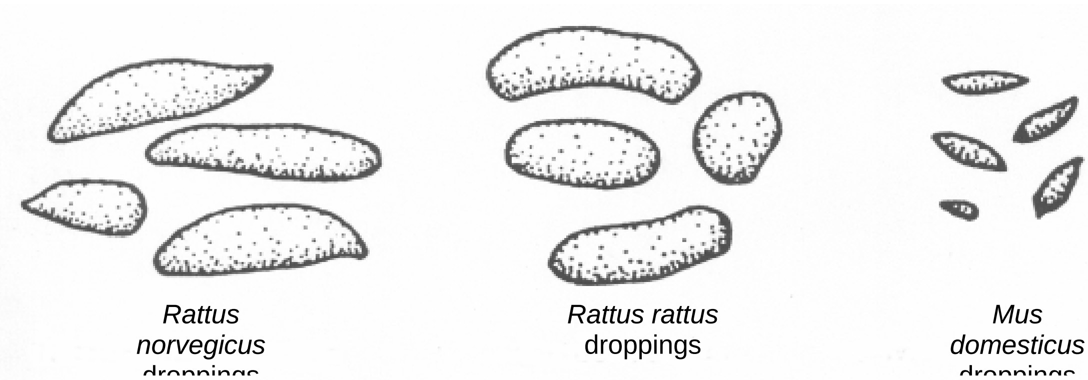

Figure 8.3 Droppings of the three most common commensal rodent species

Habitats

Diversity in climate, weather, soil, topography and vegetation has produced a wide variety of habitats occupied by an equally diverse rodent fauna. Rats and mice can adapt to a wide range of environments, as is evident by the fact that they can be found everywhere from sub Arctic/Antarctic regions to the Tropics. The nests that rodents build can enable them to control the temperature of their immediate surrounds, even at outside temperatures of -3°C the temperature inside a mouse nest can be >17°C. Rodents have been found at high altitude and even observed in mines 610 metres below the surface.

R. norvegicus are far more active burrowers but less efficient, although capable, climbers than the other two species. In urban areas, their burrows, which average around 8-10 cm in diameter and often comprise a complicated tunnel system with several exits, are typically found around the outside walls of buildings, in basement floors and amongst surrounding terrain in such places as embankments, hedgerows, rubbish tips and tall undergrowth. *R. norvegicus* often gain entry to buildings via their burrows. They are also commonly found inhabiting sewer systems.

R. rattus are more adapted to a climbing way of life. In buildings they are mainly found living at roof height and almost invariably so when *R. norvegicus* are also present. In the absence of the latter species, *R. rattus* also sometimes burrow beneath the walls of buildings and underneath rocks, but rarely invade sewers. In forests, plantations and gardens, *R. rattus* usually live and nest in the tops of, and around the bases of trees, in rotting vegetation and in nearby undergrowth.

Rats and mice are quick to take advantage of cavities in the walls, roof spaces and ducts of buildings, for shelter. In bag stores, they frequently nest in the crevices between sacks and, where possible, in the sacks themselves. Mice can shelter in crevices and holes in cultivated and uncultivated ground, and in hedgerows and undergrowth. They also occur regularly in newly harvested cereal and hay crops that are stored in the open.

It is important to recognise that access to appropriate nesting sites is as important as the availability of food in the establishment and maintenance of a rat or mouse infestation.

The jumping and climbing capability and relatively small size of the three species allows them to range freely in most environments and to find safe harbourage. They can enter buildings at ground level through small openings in the fabric, and at roof height by climbing the walls directly or with the aid of unguarded cables and external pipework (Fig. 8.4a and b). Barriers erected against them must be substantial, for the rats can jump to a height of almost 60 cm and mice to 25 cm. The three species swim readily and well, so open water does not necessarily hinder their movements.

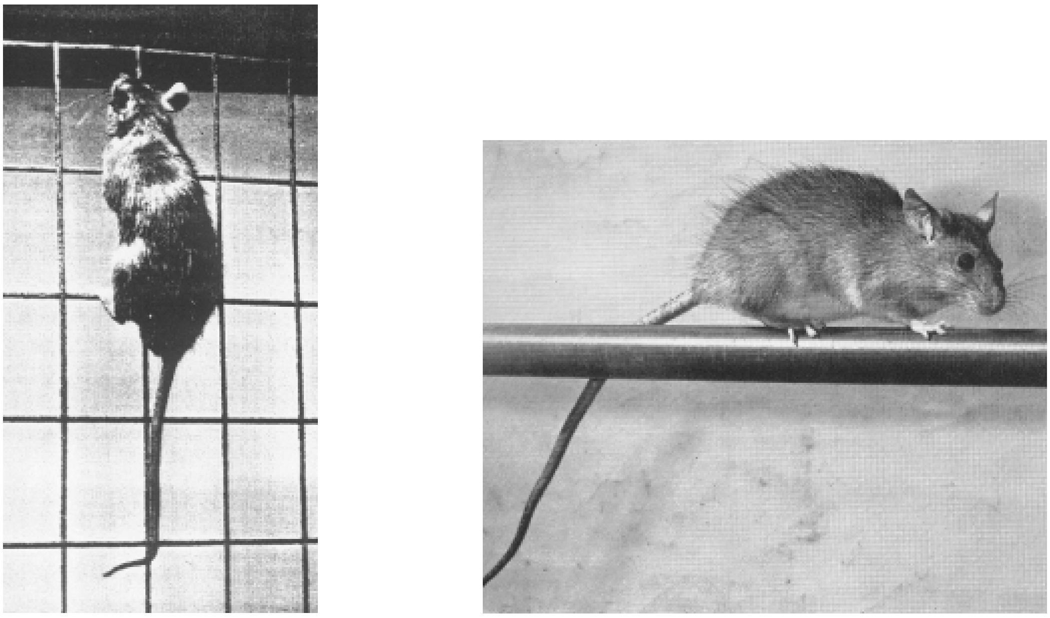

Figure 8.4 a & b. Rodents are excellent climbers and can walk along narrow pipes or wires using their tails for balance

Reproduction and development

Under optimum conditions of climate, surplus food, free water and shelter, rats and mice may breed throughout the year. If no action is taken to control them the numbers of rats and mice in a store can increase rapidly.

Rats normally live for about one year and females can begin to breed when they are three months old (Fig. 8.5), often producing five families in their lifetime. Young rats are born naked, blind, with their ears sealed, completely helpless and unable to walk or fend for themselves. They develop quickly and are weaned after 3-4 weeks, although for the next month their activity is mainly confined to the area of the nest. The gestation period in both species is only about three weeks and females can produce several litters a year; the number of young in a litter varies according to environmental conditions but averages between six and seven. Even newly born rats can survive temperatures down to 3°C., for quite long periods. They are cared for entirely by the mother rat: the male has no interest in them except to eat them if food is scarce. Under laboratory conditions, a single pair of *R. norvegicus* has produced over 1,500 progeny in twelve months.

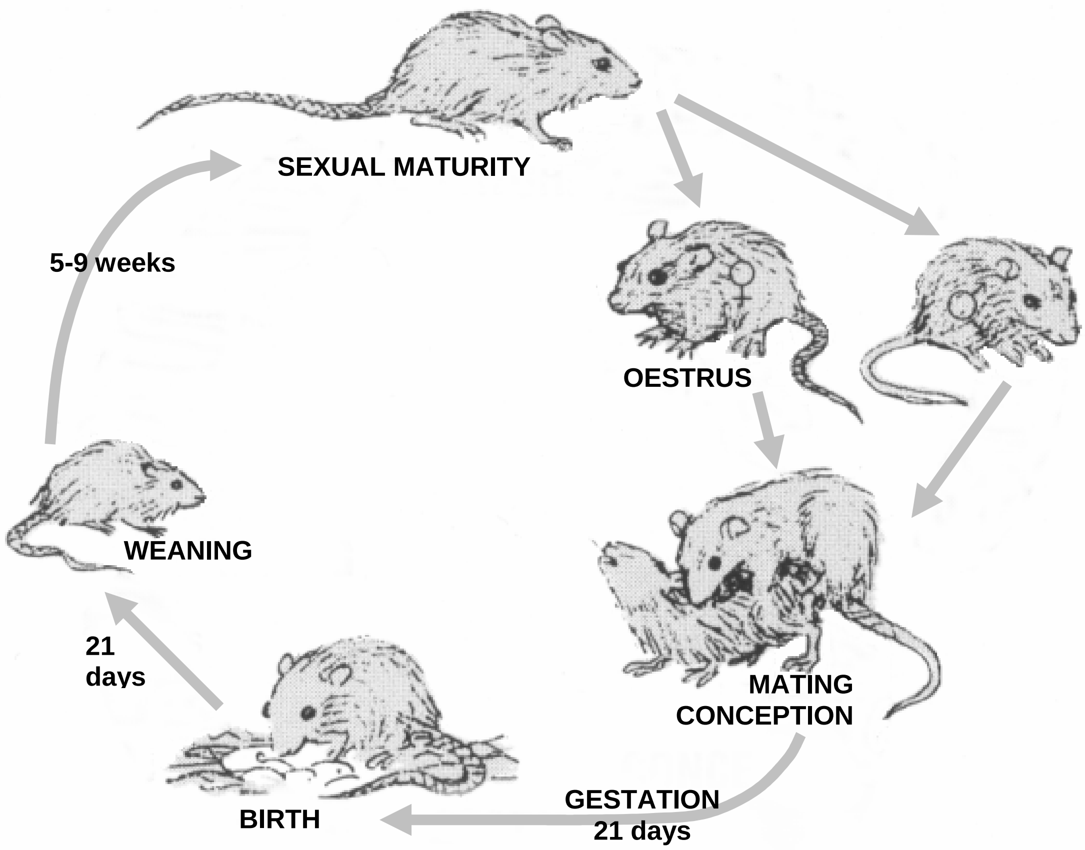

Figure 8.5 The breeding cycle of rats

The gestation period of the mouse is one of the shortest of all mammals - ranging between 17 and 20 days - and a female may become pregnant again only two days after she has given birth. If pregnancy occurs during the lactation period, the birth of the second litter is usually delayed. When excess food that is rich in protein, and nesting material are present, temperatures as low as -10°C have little influence on its fertility. Under exceptionally good conditions, a female mouse can produce as many as 10 litters (about 50 - 60 offspring) in a year, which at five weeks old become independent of their mothers, and are themselves capable of reproducing at the age of two months. At birth young mice weigh about 1 g and are bright pink and hairless. By about two weeks, the eyes and ears have opened, the body is covered in hairs and the incisor teeth are fully emerged.

In unfavourable conditions, female house mice adjust their breeding habits to maintain a high reproductive rate. Studies have shown that mice continued to breed even when kept at extreme temperatures of –6°C or 34°C. When nesting sites are limited they often share nests, 50 young mice have been found in one communal nest, the adult females will indiscriminately feed any of the young.

When population densities become very high, litter sizes are often reduced and reproduction may even cease altogether.

Senses

New-born rats and mice respond to touch, this is probably the most useful of their senses since their eyes do not open and they make little responses to sound until they are 10-12 days old. Compared with their other senses, sight seems to play a minor role in the life of rats and mice; the main functions of the eyes appear to be in detecting movements at close quarters and in appreciating light intensities. Rats and mice have an acute sense of hearing, and are particularly sensitive to any sudden noise and to high frequency sounds. They also have a well-developed sense of smell, and it is likely that much of the information about their environment is obtained in this way or through a combination of smell and taste. Smell is important in the location of food, and taste in discerning the palatability of food including poison baits. The rejection of foods previously recognised as either distasteful or as having been associated with illness - as might occur after the ingestion of a sub-lethal dose of poison - may be on the basis of smell alone. The sense of smell is also used in the detection of runways, in the identification of other individuals and in the delineation of territories. Rats ‘freeze’ when they detect cat odour, although there is no reaction when the cat is in sight but its smell imperceivable. In contrast, the urine of cows, horses and pigs tend to be attractive to rats. Human odour appears to have little effect on the behaviour of wild *R. norvegicus*.

Away from the nest, touch is probably helpful in judging the shapes of objects and in the recognition of landmarks. The long whiskers (vibrissae) of the nose are particularly sensitive to touch and help rats and mice to travel next to walls and in burrows in the dark. Rodents also have an excellent sense of balance.

Feeding behaviour

All three species are omnivorous and are capable of feeding on a wide range of foods, including cereals, nuts, fruits, vegetables, invertebrates, fish and even manure depending on their habitats. Both *R. norvegicus* and *R. rattus* sometimes supplement their diet by eating such items as worms and crabs, and occasionally take unusual substances such as soap, glue, plaster and putty. They thrive and reproduce best in localities that provide them with a rich and varied diet containing proteinaceous foods, and least well on single items lacking in certain vitamins. In comparison with the other two species, *R. rattus* prefers a diet containing some fruit.

When they have access to succulent foods, rats and mice can subsist without free drinking water. *R. norvegicus* is most prone to suffer from water shortage, but under extreme conditions of deprivation the fertility of the other two species also declines. Indoors, rats and mice may obtain water from uncovered fire buckets, dripping taps and via leaking roofs, sources which can all be made unavailable to them.

Adult rats eat about 20-25 grams of dry food a day and mice 3-4 grams. In general, rats have rather more regular feeding habits than mice and they have a greater tendency to hoard food and to eat it under cover. Unless food is in short supply, rats are also more strictly nocturnal than mice and in general their two peak periods of activity - after sunset and before sunrise - are largely left undisturbed (as in closed warehouses) by man. Rats regard strange objects placed in their surroundings with suspicion and investigate them cautiously. The term 'new object reaction' or 'neophobia' has been applied to this behaviour and it may be several days before rats will, for example, enter traps or bait-containers and feed freely. Because of this behaviour, pre-baiting with a non-toxic bait is often carried out before a control program, to enhance later acceptance of a toxic bait.

Mice are light and sporadic feeders, the two main feeding periods are at dusk and before dawn, although shorter feeding periods occur during the day. Individual mice vary in their feeding behaviour. Mice are very curious and readily feed at new baiting stations, in contrast to rats they do not suffer from ‘new object reaction’ and the regular moving of baiting stations can actually increase the amount of feeding at these stations. If a baiting station is left in one place only, mice may stop feeding there.

Population dynamics and activity

The movements of rats and mice are largely determined by climatic conditions and the availability of food, water and harbourage. Mass migrations occur infrequently and are usually associated with sudden and drastic changes in environmental conditions such as crop failures or floods. However, seasonal movements of *R. norvegicus* and mice occur regularly in countries that have marked seasonal climates. In very arid climates, a decline in population may take place during very hot weather, while rain may increase rodent population levels and the incidence of associated rodent borne diseases in these situations.

Although rats sometimes travel considerable daily distances between shelter and food, extensive wanderings are not the rule. In situations where food and harbourage are adequate, rats and mice tend to have a restricted range and to follow regular routes. Their ranges tend to be smallest when they are living at high densities in such localities as food stores where food and cover are co-incident.

Intra- and inter- specific competition for food and harbourage influence the dynamics of rodent populations. Reproduction of *R. norvegicus* is inhibited by crowded conditions, where a pituitary-adrenal feedback mechanism has a negative effect on the reproductive organs. Following its introduction to Britain in the 1700s, *R. norvegicus* largely displaced *R. rattus,* presumably because it was stronger, hardier and able to burrow and live outdoors. In the Pacific area, both *R. norvegicus* and *R. rattus* have to some extent ousted the indigenous *Rattus exulans*.

Rats and mice are major pests because they are so well-adapted to man-made environments. They can tolerate a wide range of conditions and, because of their high fertility rates, have considerable powers of population recuperation. Since rats and mice have rapid population growth rates, a control operation must reduce their numbers to a very low level, otherwise they will reproduce rapidly and often soon exceed their former density. Unless the suitability of the rodent's habitat is destroyed by improved sanitation and proofing, control methods have to be unrelenting if they are to be effective.

Rodent populations may also be influenced by predation. Common predators include hawks, falcons, owls, snakes, monitor lizards, cats, dogs and jackals. If the pest rodent population is large, the effect of predation is negligible; if the pest rodent population is small, it is not usually profitable for the predator (in terms of energy spent) to hunt and kill these species. However, predators may still be important in specific situations; for example, households with cats are rarely visited by rats, and if predators can be attracted to specific sites, they may be used to disturb breeding colonies of rats and mice. Snakes are particularly beneficial in this regard as they are one of the few predators that can hunt rodents in their burrows and nests.

In urban and agricultural areas, it is human interference (the effective use of rodenticides and traps, and habitat manipulation) that most affects rodent populations.

Social behaviour

When they become numerous, rats can be very aggressive with members of their own kind. Dominant males will exclude other males from the burrow, which may be occupied by several females. The more dominant males feed at their time of choice, whereas the less fortunate individuals occupy more marginal habitats and feed only when the dominant rats are not present in the area. This accounts in part for rats being seen in daylight when rat populations are very dense. Male and female rats are polygamous, and young rats gain their initial sexual experience with adults.

Indoor populations of house mice seem to be territorial, and fighting can occur between individuals of different populations.

Common commensal rodent species

Further details about the common commensal rodents, *Rattus rattus*, *Rattus norvegicus*, *Mus* spp., *Mastomys natalensis*, *Bandicota bengalensis* and *Rattus exulans* are provided below. Whilst the initial three rodent species listed are the most common and widespread on a global basis, there are other locally abundant commensal species that can also cause a great deal of harm.

Rattus rattus - *roof, ship or black rat*

R. rattus is a global species, which probably originated in equatorial Southeast Asia. The species was certainly present in Europe during Roman times (AD 100). As one of its common names implies, it was reliant upon the old shipping and trading routes for its spread and is most associated with coastal and trading centres.

In temperate zones it is more likely to be found indoors, although in these areas there has been something of a decline in its population over the last fifty years. In tropical and sub-tropical areas it can frequently be found out of doors and can be a serious pest of some agricultural crops.

It is not as likely to burrow as *R. norvegicus*, and is more commonly found sheltering in roofs and other hollow places in the upper parts of buildings, its climbing powers are excellent, especially in leaping horizontally and downward from heights above the floor.

Figure 8.6 ***Rattus rattus***

Rattus norvegicus - *Norway, common, brown or sewer rat*

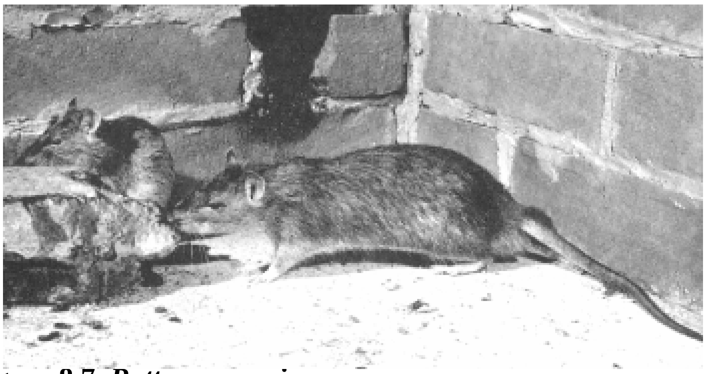

Figure 8.7 ***Rattus norvegicus***

R. norvegicus is a relatively recent companion to man and only started its global spread in the early 1700s, probably from areas north of the Caspian sea. Today it is found in most developed areas of the world and continues to extend it range.

It is omnivorous and whilst favouring the environments that man creates, it prefers to live outside, although is perfectly capable of living indoors when the situation requires. It can often be found living out of doors, but feeding on available food supplies within buildings. *R. norvegicus* is a very efficient burrower and its burrow may extend horizontally for many feet, although it does not normally go deeper than 60 cm. *R. norvegicus* is also a good climber and can scale the outside of rainwater and soil ventilation pipes, and has been known to jump and grip the top of a1 m high barrier. *R. norvegicus* is a also a strong swimmer.

Its size and behaviour enable it to live happily on rubbish tips, in sewers and drains, in hedgerows and on river banks. It is a truly cosmopolitan species.

Mus *spp. - house mice*

Figure 8.8 ***Mus domesticus***

There are several species of house mice but their respective distributions are not all that clear because they are so difficult to tell apart.

House mice are known to have been present in the Middle East 12,000 years ago and to have spread slowly to other Mediterranean areas up to 2,000 BC. At this time they became established in Southern Europe and have since spread to most parts of the world; they continue to extend their range.

House mice are omnivorous and prefer warm, dry conditions. They are however able to live in cold conditions as long as they have access to warm harbourage. They live mainly indoors in temperate regions, but when conditions are dry and warm are able to develop extensive burrow systems and to live out of doors, much as they might have done in their original habitats. They very rarely live in sewers. House mice are fairly active during both day and night. Unlike the above two species of rat, the house mouse can live and breed without drinking provided its food has a fairly high moisture content.

Mastomys natalensis - *the multimammate rat*

M. natalensis is the most economically important rodent pest species in Africa. Found throughout western, central and eastern Africa to the southern tip. *M. natalensis* is able to live both outside, where it is often associated with field crop damage, or inside where it plays a role in the transmission of disease, loss of stored foods and structural damage. Storage problems increase after harvest, indicating that reduced food and shelter brought about by harvest influence the movement of this rat to village dwellings. This species has a particularly high breeding rate, due to their large number of mammae (up to 12 pairs), which can support litters of up to 24 offspring. Their very small size leads to them often being referred to as mice.

Bandicota bengalensis - *the lesser bandicoot or black field rat*

B. bengalensis is found in South and Southeast Asia and looks and behaves in ways that are very similar to *R. norvegicus*. The size is usually similar to *R. norvegicus* but can vary from region to region. One different characteristic is the visible presence of very large and distinct guard hairs over its body, which it displays when cornered to make itself look larger.

Figure 8.9 ***Mastomys natalensis***

B. bengalensis is happy to live in damp and wet areas and is a very good swimmer. During the flood period in Bangladesh, this species lives on water (rice fields and water hyacinths expanses) where it builds spherical nests, the size of soccer balls. Over the last 100 years its range has spread and the species has become increasingly commensal, even replacing *R. norvegicus* in some urban environments. It does not settle indoors as easily as the other main commensal rat species, but burrows extensively out of doors, causing serious damage through its extensive digging. It is able to carry a range of diseases and causes very similar concerns as the other commensal rats.

Figure 8.10 ***Bandicota bengalensis***

B. bengalensis is known to directly attack a huge range of agricultural field crops and stored products. Its burrowing activities cause considerable damage to seed beds and seedlings, an individual *B. bengalensis* can cut 100-200 rice tillers per night.

Rattus exulans - *the Polynesian rat or Burmese house rat*

R. exulans is found in South and South-east Asia, mainly between the Tropics of Cancer and Capricorn, although it can be found as far south as some of the New Zealand islands, and as far north as Bangladesh.

It is a small rat, with a maximum adult weight of about 60-80 g. It measures about 120 mm in body length and has a tail of about the same length. It is agile and because it lives in warm climates is able to live both indoors and out of doors, causing all the normal range of problems in both urban and rural environments.

Figure 8.11 ***Rattus exulans***

Some of the main characteristics of these commensal rodents are summarised in Table 8.1.

Table 8.1 Characteristics of common commensal rodent species

	Average adult weight	Tail length	Ears	Snout	Colour	Life expectancy
Rattus norvegicus Norway, common, brown rat	About 330 g (a specimen of 725 g is known)	Shorter than head and body (150-220 mm)	Thick, opaque, short with fine hairs	Blunt	Brownish grey, but may be black: grey belly	About one year
Rattus rattus Ship, black, roof rat	Less than 250 g (a specimen of 360 g is known)	Longer than head and body, except in some foreign forms (180-240 mm)	Thin, translucent, large, hairless	Pointed	Grey, black, brown or tawny: may have white belly	About one year
Mus domesticus House mouse	Usually less than 25g (average perhaps 15-16 g)	Usually longer than head and body (60-110 mm)	Large, some hairs	Pointed	Brownish grey lighter shades occur	8-10 months
Mastomys natalensis Multimammate rat	Ranges between 35 – 110 g	Usually the same length as head and body (90-150 mm)	Large	Pointed	Brown grey black: grey or white soft fur on belly	About one year
Bandicota bengalensis Lesser bandicoot, black field rat	Similar but usually larger than *R. norvegicus*	Black, shorter than head and body	Small	Blunt	Dark brown/ grey back: grey belly	About one year
Rattus exulans Polynesian, Burmese house rat	Less than 80 g	Dark and longer than head and body	Large	Pointed	Brownish grey back: grey belly	About one year

Losses caused by rodents

It is common knowledge that rats and mice damage foods, crops and buildings, including structures such as sewers. Nevertheless, there are no reliable data, and astronomically high figures are often quoted for financial losses due to rodent damage. We have no idea of the total rat and mouse population in any country, nor do we know to what extent it lives 'off the country' on natural foods and by scavenging. Even if we knew how many rats and mice there were, calculations based on how much grain an 'average rat' and an 'average mouse' eats would be unrealistic. It is obvious however that the potential loss is considerable and cannot be tolerated. Apart from what rats and mice eat, we know from experience and experiment that the cost of cleaning and repackaging stored and processed commodities that have been attacked by these pests often exceeds the cost of foodstuffs actually eaten.

To obtain some idea of the complexity of the issue, the following problem areas need to be considered individually:

- direct consumption of food
- food contamination and damage
- structural damage
- rodent-borne diseases
- sources of re-infestation of adjoining areas
- cost of control
- loss of goodwill
- initiation of further damage

Direct consumption of food

Rodents eat food directly intended for human consumption or for consumption by domesticated livestock. The impact of direct consumption may be relatively limited in developed countries, but can be a major problem in developing countries where food is scarce and alternative supplies may not be found in time to prevent hardship for the human population.

On average, rodents need to consume about 10% of their body weight per day, but consumption will vary with the size and species of rodent, and with the prevailing climatic conditions. Adult *R. norvegicus* eat about 28 g of dry food a day. A population of 100 adults would therefore consume just over 1 tonne of dry food a year.

Although it is relatively easy to estimate the theoretical food consumption of a rodent population, the actual consumption of a population of rodents is difficult to estimate with any degree of precision.

Food contamination and damage

Rodents damage and contaminate far more food than they consume. Through their gnawing activity they damage the sacking, packaging and storage facilities used to store and transport the food. Food is lost through spillage and wastage and also thrown away as unsuitable for human consumption. Although this food is not consumed by the rodents it is nevertheless made unavailable for human and livestock consumption and is therefore effectively lost.

One of the most unpleasant and damaging results of a rodent infestation is the contamination of the infested commodities. This can take gross forms such as rodent bodies or even live rodents in bagged products, or it can be less obvious in the form of hairs, urine, sebaceous secretions and droppings. The scale of this latter type of contamination can be enormous. A rat or mouse produces some 50 droppings and innumerable hairs every day, and over a year a single rat voids about 3.5 litres of urine. Such rodent filth is sometimes impossible and always expensive to remove from raw materials and products, because droppings are similar in size and shape to cereal grains and feed pellets, hairs are detectable only on microscopic examination and urine is rapidly absorbed by dry substrates.

If even a few droppings find their way into food intended for human consumption there is a chance that the food will be rejected as unsuitable and its value significantly reduced. Hairs are also extremely difficult to remove and contamination by sebaceous secretion or urine is difficult to detect. If the stored produce is marketed, the loss of reputation due to publicly discovered contamination can be of great consequence to the vendor.

Estimates of stored food losses vary considerably and are dependent on commodity, site and the way in which the calculations of loss are made. Estimates range from losses as low as zero or a fraction of a percent, to losses as high as 50% or more in some situations. Many estimates lie in the range 1-10% and invariably include total losses due to consumption as well as spillage, damage and contamination. On a world-wide basis it has been estimated that some 33 million tonnes of cereals in storage were lost to rodents every year. In Bombay, each month, food grains sufficient to fill 1500-1600 grain sacks have been swept up in areas around railheads and warehouses due to spillage from rat-damaged sacks. The saving in grain resulting from rat control measures was sufficient to provide food for 900,000 people.

There are few examples of reliable figures on the relative losses due to direct food consumption by rodents and indirect loss due to spillage and contamination. Some estimate that up to ten times as much food is lost as a result of spillage and contamination as is lost to direct rodent consumption. Although these estimates of loss are valuable, another way to view the scale of the loss is to estimate the number of rodents needed to eat the same amount as an adult human. Using an adult human mixed dietary requirement of 600g, an infestation of only 25 *R. norvegicus* will eat the same amount of food as a human being. If estimates relating to spillage, contamination and spoilage are correct, then it takes even fewer rats to remove or make unavailable the food required to feed a human being for a day. In areas of high rodent infestation and restricted food availability this reduction may be critical.

Probably the factor with greatest influence on rodent numbers in food stores is the method of storage. A well-managed store will provide the minimum possible harbourage, or access for rodents. The storage structure must be sound in every respect and in particular doors, chutes and augers should be opened only when they are actually in use. If possible, floors should be of concrete and spillage of stored products should be cleared away immediately.

Within the store itself, produce should be stored in bulk rather than in small lots. It is common practice throughout the world to store produce in small containers made from locally available materials. However, storage involving small receptacles is more susceptible to rodent infestation and damage than bulk storage, as spaces between the containers provide cover for rodents, the fabric provides nesting materials and the contents provide food. In bulk storage, particularly of loose grain, the rodents cannot burrow in the produce. Even in uncovered silos, only the surface is open to attack, and this can conveniently be inspected for droppings and other signs of rodent activity.

Structural damage

Damage to structures by gnawing is widespread (Fig. 8.12). Almost any kind of material may be attacked. The enamel on the outer surface of a rat’s incisor is very hard (5.5 on the 'scratch scale' of Moh), while the dentine behind is somewhat softer (about 3.5) and thus a very efficient chisel-like edge is always present. Lead pipes and metal-sheathed cables are sometimes gnawed through, causing interruption of services. *R. norvegicus* has also been known to damage the structure of drains and sewers, by burrowing between joints and behind brick sewers in the surrounding earth, sometimes this even causes roads to collapse. The list of structures and commodities that have been gnawed is long and varied. It includes, earthenware drain pipes, waxworks, candles, soap, cork insulation of cold stores, plaster eggs, pitch fibre pipes, curtains, sheet aluminium alloy, and plastics. The proverbial church mouse has been known to stop a church organ by its gnawing, even attacking the keys!

Damage to roofing, walls, insulation, foundations and doors of buildings reduce the efficiency and security of the storage facility. Damage to a roof allows water to enter the building, whereas damage to

walls, doors, foundations and floors not only weakens the structure of the facility, but also increases the likelihood of infestation of that facility by both rodents and other pests. Effective control of insect pests by fumigation is also prevented if the store floor is not gas-tight, necessitating the use of a ground sheet.
Rodents frequently damage electrical wiring, causing electrical failures and fires. Once again, no reliable data are available on the financial implications of this damage, but it is considered that the majority of fires on agricultural premises are due to rodent damage to wiring (Fig. 8.13). Many stores depend upon electricity for light, heat, air conditioning, ventilation, feed supply (in the case of animal units) and general management. If this electrical system is damaged and the power supply lost, then the facility not only ceases to function, but the potential exists for great damage to and loss of the commodity that is being stored.

Figure 8.12 Rodent damage to store floor

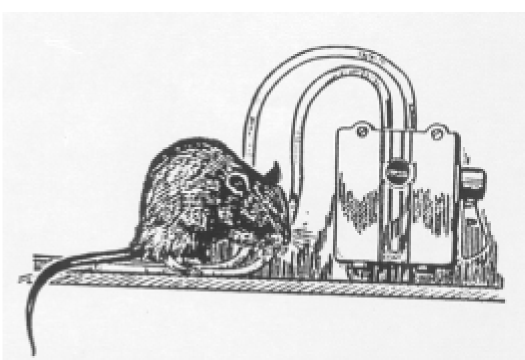

Figure 8.13 Electrical cables can be chewed by rodents resulting in a fire

Gnawing by rodents is not necessarily associated with the search for food or water. Their incisor teeth grow throughout life, and gnawing is part of their innate behaviour. If the incisors become accidentally displaced so that they are not opposed, normal wear is prevented, resulting in grotesque tusk-like growths. Individuals so affected eventually die either from being unable to feed or from in-grown teeth. Since the incisor teeth of rats and mice project well beyond the lips, gnawed material is not necessarily swallowed or even tasted; this makes it very difficult to find 'repellent' substances to prevent gnawing activity.

Rodent-borne diseases

Rodent infestations present a health hazard to both humans and other animals. The nature of the hazard and severity of the risk will vary with the species of rodent and the geographical position. Any disease or infection that is transmitted to humans from a vertebrate animal is called a ‘zoonose’. This term embraces all the diseases people can catch from rats and mice; the causative organisms may be bacterial, rickettsial, viral, protozoan, helminthic or trematodan.

Bacterial diseases

Of the many diseases carried by rats and mice, **plague** at once comes to mind. The ‘Black Death’ (plague) destroyed a quarter of the population of Europe in the Middle Ages, and has since killed millions in Asia and Africa. The causal organism *Yersinia pestis* is spread from rats to man by a flea, *Xenopsylla cheopis*. When rats are dying of plague, this flea will accept man as an alternative host and transmit the disease to him. Between human outbreaks a reservoir of the disease persists among wild animals. These plague reservoirs are to be found at present in South-western USA, South America, Congo, South Africa, Kenya, Madagascar, India, Java, North China, Iranian Kurdestan, and the USSR. Usually plague is carried to man by *R. rattus*, but occasionally *R. norvegicus* has been found to be an important carrier, and in some areas of eastern Africa plague was present prior to the known arrival of *R. rattus* and was associated with *M. natalensis*. It is possible that rodent control operations have contributed to plague outbreaks, when fleas were not controlled.

Leptospiral jaundice (Weil's disease) is well known in certain trades, yet relatively unknown by the general public, except when there is a fatality. The causal organism, *Leptospira icterohaemorrhagiae*, is excreted in rats' urine, and apparently does not harm rats (Fig. 8.14). Up to 60% of individuals in rat population samples have been found to be infected. Human infection can occur from contact with wet, rat-infested surfaces. Historically, Weil’s disease has been associated with agricultural workers, sewer-men, fish-cleaners and coal-miners - and others who work in damp places frequented by rats. More recently there has been a rise in the number of cases amongst those involved with increasingly popular water sports (swimming, skiing, sailing etc.), once again rat infestations associated with damp conditions being the source of infection.

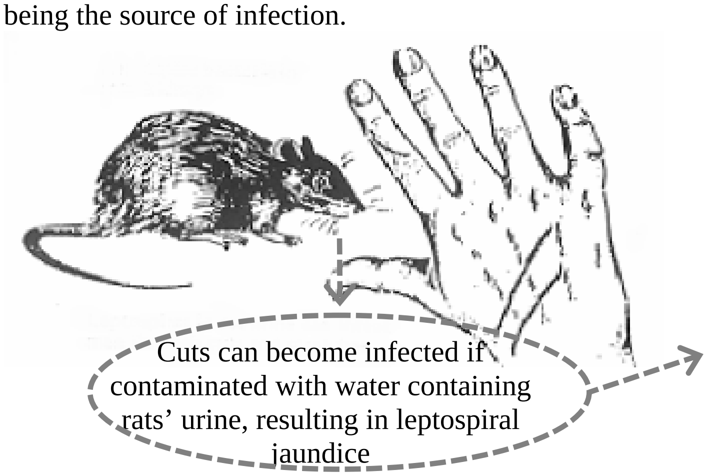

Figure 8.14 Leptospires are present in rats’ urine and can infect humans through cuts and scratches

Salmonella bacteria, which can cause food poisoning, can be carried in the excreta of rats and mice. In many places in the world rats live in sewers, septic tanks and cess pools, but visit kitchens and stored food at night, spreading salmonellosis.
There are two illnesses called **rat-bite fever** caused by bacteria carried in the saliva of rats and mice. Both involve swelling of lymph glands and muscular pains, and relapses may occur long after apparent recovery.
Even non-infective **rat bites** are painful, likely to leave ugly scars, and are prone to turn septic. Rat bites occur most frequently in babies, small children and the bed-confined elderly, and are often the result of rats trying to get food from their hands or faces. The majority of rat bites are on the hands of young children presumably because they try to pick the rats up.

Rickettsial diseases
The causative organism of **Murine typhus** is *Rickettsia typhus*, as with the plague the bite of the rat flea (*Xenopsylla cheopsis*) is responsible for transmitting the disease to man. Infected faecal matter from the flea is rubbed into abrasions caused by scratching the bite. This disease is found world-wide.
Scrub typhus is also spread by rats and mice, but is confined to Asia, Australia, Japan and other parts of the Far East. The causal organisms *Rickettsia tsuntsugamushi* live in the tissues of certain trombiculid rat mites, without harming them, and pass from generation to generation of the mites. The disease is transmitted to man by the bite of infected trombiculid mites.

Viral diseases
A rather uncommon but serious virus infection of human beings (especially children) known as **lymphocytic choriomeningitis**, is carried by house mice. Disease transmission occurs by mouse bites, contamination of food or hands with faeces, and the inhalation of dust containing dried mouse faeces. The symptoms resemble those of influenza, but in some cases meningitis can become apparent.
Lassa fever is a fatal virus infection, which can be transmitted through the urine of infected *M. natalensis*, *R. rattus* and *M. minuitoides* in Africa. Person to person infection is also possible during acute stages of the illness.

Protozoal diseases
Leishmaniasis (*Leishmania tropica* cutaneous type) occurs in most of Africa. It is transmitted to man by sandflies, which have fed on the blood of infected rodents or other mammalian hosts.
Other protozoan diseases with rodent reservoirs include **American trypanosomiasis** (Chaga's disease), **African trypanosomiasis** (sleeping sickness) and **toxoplasmosis**.

Helminth and Nematode diseases and infections
Shistosoma spp., blood flukes, whose larva develop in fresh water snails, emerge to penetrate the skins of humans in fresh water bodies, have been found in several African rodents, although the epidemiology is not well described.
Mice also serve as the hosts of numerous intestinal parasites, the two small **tapeworms** *Hymenolepsis nana* and *H. diminuta* can be transmitted to man. Infection occurs when food is eaten that has been contaminated by mouse droppings containing, the microscopic eggs of the tapeworm.
Trichinosis is a disease associated with the encystment in human muscles by a small parasitic nematode worm, carried by rats. Transmission occurs when garbage containing infected rat faeces is fed to pigs; humans contract the parasitic nematode by eating inadequately cooked meat of infected pigs.

Fungal diseases
Favus, a skin disease of fungal origin, may be contracted from mice, or indirectly through cats.

Many additional diseases, including **foot and mouth disease**, **Korean haemorrhagic fever**, **Aujeszky's disease** (pseudorabies), and **brucellosis** can be carried by rodents and transmitted to a range of domestic and agricultural animals.

Source of re-infestation of adjoining areas

By their very nature stores are potentially able to support significant rodent populations, from which some rodent emigration will take place. Where units are situated close to human habitation or field crop production, the potential exists for the transmission of disease and field crop damage. Control of peripheral infestations is unlikely to be effective while the focus of infestation remains. Conversely of course, these peripheral sites may have been the source of the original infestation. Due to the mobility of rodents it is important that neighbouring sites try to co-ordinate their control strategies.

Cost of control

The costs of maintaining a rodent-free storage environment must be borne in mind when discussing the total costs of rodent infestation. If rodents gain access to stores, significant commodity and financial losses can occur because of consumption, contamination and spillage of food, in addition to physical damage to the facility and the transmission of diseases. These are the costs of no, or inadequate control.

Loss of goodwill

The discovery of rodents or their contaminants in food can lead to problems between farmers, food processors and consumers, with contractual agreements often terminating unceremoniously.

Initiation of further damage

Damaged grain is more susceptible to further attack by some storage insects and moulds.

Signs of rodent infestation

The signs made by rats and mice that are of most use in determining their distribution and relative abundance are droppings, runways and tracks, smears, holes, and the damage caused to foodstuffs, packaging materials and the fabric of buildings.

Droppings

The droppings of the three commensal species can usually be distinguished on the basis of their size and shape (Fig. 8.3), although those of very young rats can be confused with mouse droppings. Droppings are normally found in any area that has been visited by rats and mice, but in buildings they are frequently concentrated in favoured places such as corners, along the edges of, and on the tops of walls, and in crevices between bagged foodstuffs. When fresh, the droppings appear soft and shiny but within a few days, depending on climatic conditions, they become hard and dull. Occasionally, rodent urine stains show on hessian or other fabrics.

Runways and tracks

Close examination of rat and mouse infested premises will almost certainly reveal their footprints and tail marks, particularly where the rodents have travelled through dusty places. In dim light these and other signs are most readily discovered with the aid of a torch. To help confirm the presence or absence of rodent infestation, chalk, flour or talcum powder can be laid in smoothed patches (about 30 cm long by 10 cm wide) along the suspect areas and the patches examined later for fresh prints. Outdoors, runways appear as narrow paths where the vegetation has been trampled down. A well-used run, whether indoors or outdoors, will be free of debris and cobwebs.

Smears

Individuals tend to follow much the same route when travelling inside or entering a building, so that dark coloured smears gradually accrue along well-travelled runways, around holes, and along beams and girders, where the grease and dirt on their fur has rubbed off. Thick, shiny and widely distributed smears are indicative of a heavy infestation. Smears are often best seen where rodents have moved beneath ceiling joists (Fig. 8.15) and it is often possible to determine the species present from the characteristic appearance of the loops made there. Mice loop smears are similar but smaller than those made by *R. rattus*. In places where mice have been present for a considerable time, it is also sometimes possible to find small mounds called 'urinating pillars' that consist of a mixture of droppings, dirt, grease and urine.

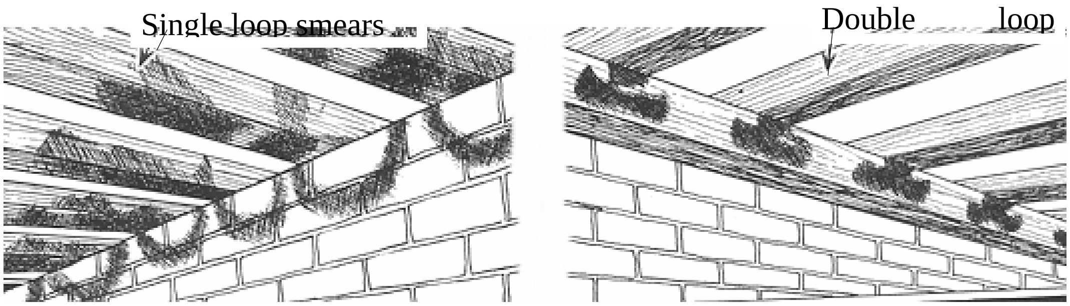

Figure 8.15 Single loop smears left by *R. norvegicus* and double loop smears left by *R. rattus* as they climb around under the floor joists

Holes

In and around food stores, holes are commonly found along outside walls, beneath foundations and in undergrowth, embankments and hedgerows. Occasionally, footprints may be found at the entrance to a rat hole indicating that the latter is in use; accumulation of debris points to the contrary. Confirmation one way or the other can be obtained by covering holes with soft earth and by noting which ones are re-opened, although interfering with the hole may cause the rodent to use another entrance/exit to its tunnel system.

Damage and gnawing marks

Unfortunately, often the first clear evidence of the presence of rodents is the discovery of partially eaten, spilled or hoarded foods, holed or shredded packaging materials, and other signs of recent gnawing (Fig. 8.16). Experience has shown that when such signs are apparent on the outside of stacks, the latter are often heavily infested by rodents and the internal damage is usually severe.

Figure 8.16 Grain spillage caused by rodent feeding; more grain is contaminated than eaten

Control of rats and mice

The history of rodent control in England shows that in very early times curses were thought effective and Shakespeare mentions the practice of rhyming rats to death. In the reign of Queen Elizabeth I a bounty was offered of one penny "*for the heads of everie three rattes or twelve myse*". There is no doubt that at that time *R. rattus* was a common pest in England.

Cats have been esteemed in Britain for rodent control at least since the year 930, when the Welsh King, Howell the Good, regulated the prices of cats according to their age and experience as mouse-catchers. Even today, there is no doubt that they have a use in preventing re-invasion of buildings cleared of rodents by other means. Cats by themselves do not usually clear an infestation, but merely keep down the number of rats or mice once they have been reduced to acceptable levels by other methods. An early experiment, done on a series of farms, confirmed the value of cats - but as a preventative measure only.

The present day approach does not condemn old-fashioned methods merely because of their antiquity, but seeks, through a study of rat and mouse behaviour and by the use of modern chemical technology, to put rodent control on a rational basis. Stripped of folklore some methods have not been supported by the results of objective investigation. Part at least of the principles now established have been used for a long time by certain 'vermin-killers', without the latter knowing the reasons for their efficacy.

The control of rodents in food stores is clearly complicated by the existence of one factor above all others, food, in plentiful usually unlimited quantity. In addition, particularly in food stores that have not been specifically constructed to exclude rodents, shelter is usually available either within or nearby the store.

Integrated rodent management strategy

An integrated rodent management (IRM) strategy is simply the plans that will most efficiently and effectively enable a particular storage facility or group of storage facilities to be kept free of rodents.

To be effective the plan should define strict objectives and then clearly identify the step-by-step approach required to achieve these objectives. The strategy must include a method of monitoring so that progress towards the objectives can be identified.

It is unusual to find a storage facility anywhere in the world where a rodent problem of any significance exists and in which no control measures have been taken. Why then does loss, contamination and damage continue at levels of up to 10% and sometimes higher?

Part of the problem is certainly the perceived high cost of applying some of the more recently developed rodenticides, resulting in a reliance on less effective techniques. However, this perception is frequently incorrect and the benefits of applying effective, but perhaps more costly control over cheaper but less effective techniques greatly exceeds the costs. The major cause of control failure, is the lack of appreciation that effective long-term rodent control has to be supported and directed by a sound infrastructure. Essentially this means that the appropriate management structure should be in place and that staff should be adequately trained in aspects of rodent control. Only then will it be possible to utilise the most appropriate control techniques effectively.

Management

The first step in any strategy is to develop a clear line of command that will be responsible for both developing and implementing the strategy, and for failure if the strategy does not meet the objectives that have been set.

Training

Training to an appropriate standard is essential. The managers responsible for developing the strategy must be fully trained not only in management techniques but also in the essential practical techniques applied by those they manage. Formal academic training, field training and visits to comparable facilities/ organisations will be necessary. The managers must then ensure that staff are trained, to the standard appropriate to their intended role and that training is maintained throughout the long-term rodent control strategy.

Implementation

Once managerial expertise is developed and staff are trained, details of the integrated rodent management strategy can be considered. Any integrated rodent management strategy should take account of the following points:

- Survey
- Management of the environment around the store
- Rodent proofing the storage structure
- Management of the stored product within the store
- Application of rodent control measures
- Monitoring and prevention of reinfestation
- Cost benefits of rodent control in grain stores

Survey

The objective of the survey is to identify the species of rodent, and the severity and extent of the infestation before any control techniques are applied. The nature of the control techniques are so specific to the behaviour, biology and susceptibility of specific rodent species that without this knowledge it will be difficult to achieve successful control. Underestimation of the extent of an infestation is the other common cause of failure.

The most reliable method of identifying the pest species involves the collection of either a live or dead specimen, failing this a good sighting of the pest may provide enough information for a reliable identification to be made. Since rodents are largely nocturnal and secretive, sightings are quite rare. In the absence of a specimen or sighting, the surveyor will have to use signs and traces such as droppings, smears, runs, footprints, smell, holes etc. to identify the species present and the extent and severity of the infestation. All areas should be surveyed both inside and outside the facility. Movement of rodents into the area outside should be noted and taken account of. It is quite possible that several species of rodents may be infesting the same storage facility. If this occurs it is usually because the species in question are not competing for food, water or shelter. If competition does occur, the larger and more aggressive species will usually exclude or even predate upon the weaker.

As well as identifying rodent activity, the survey may reveal that control techniques will be more effective if there is a general improvement in the tidiness and hygiene at the site. Removal of spillage and alternative foods as well as elimination of harbourage may be appropriate. This should not, however, be undertaken if it is likely to make control more difficult by changing the rodents established behaviour pattern. Faults with rodent proofing may also be identified during the survey. Some faults may be best corrected before or during the control operations and others after completion of the control. Ways of rodent-proofing are described later in this chapter.

A survey will only identify the existing pattern of rodent activity. However, rodent populations are dynamic and if control measures are applied, activity patterns will change. Continual and regular resurveying of the site will be necessary.

Records should be kept of all findings. Areas of rodent activity should be marked on a map and defects in hygiene and proofing recorded. It is essential to remember that storage environments are three-dimensional and therefore the survey and subsequent control must take account of the degree to which the three dimensional habitat is being used by the rodent species involved. Managers need access to records to ensure that the most appropriate control techniques are applied.

Management of the environment around the store

The environment outside the store must be clean, tidy and free from vegetation and other encumbrances as is possible. In practice this means that there should be an absolutely clear zone around the outside of the store of at least 10m and ideally 30m. This zone will not act as a barrier to rodent movement, but will act as a deterrent. Rodents do not like crossing open space where they may be seen and exposed to predation. The grazing of a heard of goats around a food store in Sri Lanka for a few days each month, not only reduced all the vegetation, but also destroyed the *R. norvegicus* burrows. This resulted in a significant reduction in the rat infestation, at no cost.

It is also essential not to allow any trees or other structures to overhang the store, providing rodents with easy aerial access.

In general, the two factors that are of most importance in controlling rat and mouse populations are food and shelter. If one or the other can be eliminated the rodents must go elsewhere. Hence the importance, for rodent control, of strict attention to hygiene. Whenever possible food should always be kept in rat- and mouse-proof containers. Edible refuse and empty food tins should be placed in bins with tightly fitting lids while waiting for collection. Where food has to be stored in bags or other containers vulnerable to rodents, it should be stowed in such a way that it can be inspected at frequent intervals, and the building in which it is housed should be proofed. Piles of rubbish, timber, bricks and other materials should not be allowed to accumulate - either indoors or outside - if rats and mice are to be denied shelter (Fig 8.17).

Figure 8.17 Rubbish attracts rats. If sealed containers are not available, place rubbish inside deep pits and cover it with earth

Rodent proofing the storage structure

The objective of rodent proofing the store is simply to prevent rodents gaining access. Entry of rats and mice into buildings may occur in several ways. Rodents are good climbers and can jump very effectively. They can easily gain access to most traditional grain stores because the materials used for store construction provide little or no barrier. Rodents can chew holes in baskets and woodwork of stores and burrow through mud floors and walls to get at stored grain. Grass and palm thatched roofs can provide ideal nesting sites for rodents. Rat guards can be placed on the legs of grain stores (Fig. 8.18). Rat guards will only work if the store is raised at least one metre off the ground and there are no plants or poles close to the store up which the rats and mice can climb. The stores legs should be made of smooth materials, any ladders needed to access raised stores should be removable and stored elsewhere once access has been completed. The store should be built at least one metre away from buildings or trees.

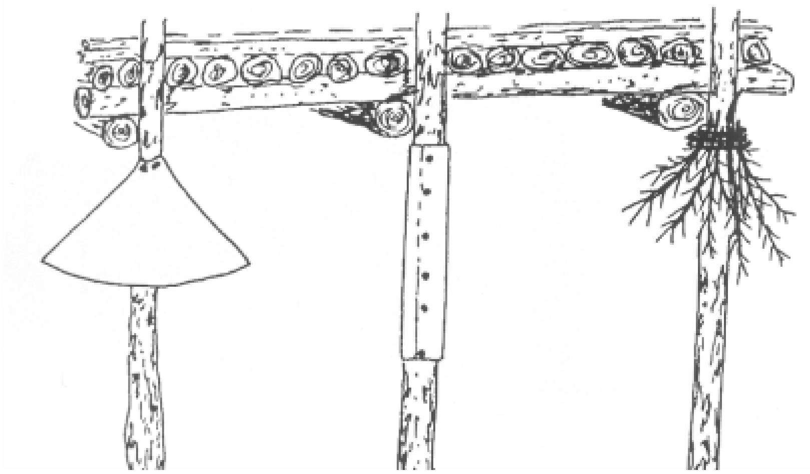

Figure 8.18 A variety of rat guards that can be placed on the legs of grain stores

Crib storage of crops can also be extremely effective in preventing rodent damage and may be more suitable for storage of particular items than the common silo. In Nigeria, researchers designed a village maize crib raised four feet above the ground on a bamboo framework, which being smooth, prevented rodents from reaching the contents. Rat guards can also be placed on the legs of cribs. Ideally silos should be constructed of materials impenetrable by rodents, such as sheet metal, and they should be built on good foundations away from other buildings or rubbish which may provide harbourage. If in an existing building, they should nevertheless be provided with an integral cover that totally encompasses the stored crop. If materials such as mud and straw or breeze blocks are used, it is important to carry out regular inspections and repair of any rodent damaged area.

In larger stores rodents might enter from the sewers via a drain. Make regular checks to ensure that all water seals and caps are in position and effective. Repair any breaks in the line of drains or sewers, replace broken manhole covers and fresh air inlet grids, remove or restore to good condition any disused or broken WC pans, basins, sinks and other sanitary apparatus. Rodent entry by climbing up the inside of ventilation and rain water pipes can be prevented by fitting wire balloon shaped guards at the top.

Access to roof tops via the outside of vertical pipes close to walls can be circumvented by fitting 20-gauge metal pipe-guards tightly to the pipe using an adjustable metal collar. These guards should project about 23 cm from the pipe. Cone guards must lie snugly against the wall, while square guards are best built into a brick joint and should have the edges turned down about 5 cm for strength.

Rats and mice can also enter buildings by climbing the face of rough stonework and brickwork, through defective doors, windows, broken air-bricks and ventilators, by tunnelling under walls and through foundations, and by walking along telephone lines, other cables and the branches of trees. Rats and mice also get carried into warehouses and other buildings on lorries or in merchandise, or may use a bridge of lengths of timber or similar objects left leaning against the wall. A small mouse will pass through 9 mm wire mesh and so all openings in excess of about 7 mm should be proofed. Since rats will jump to a height of 80 cm to 90 cm all possible points of entry below 90 cm from the ground should be closed.

The painting of a 15 cm deep band at least 60 cm up the brickwork of the wall may help to minimise climbing. A high gloss paint should be used for the final coat and, if necessary, the bricks should first be rendered smooth with cement. The foundations of outside walls should be carried down 60 cm to 90 cm below the ground. Holes in concrete floors and in foundations should be filled in with fine concrete or cement mortar, to prevent rodents reopening the holes during setting, broken glass can be added. All

joints in brick walls should be filled solid with mortar, and cavity walls should be entirely closed to prevent any rodents from entering the cavity. Joists, girders, pipes, pipe-sleeves and similar structures bearing on or passing rough brick walls should be built in tightly.
Ventilation grids and air-bricks should be proofed externally with 6 mm mesh, 24-gauge expanded metal (Fig. 8.19). Doors and windows should be close fitting and any broken panes should be replaced.

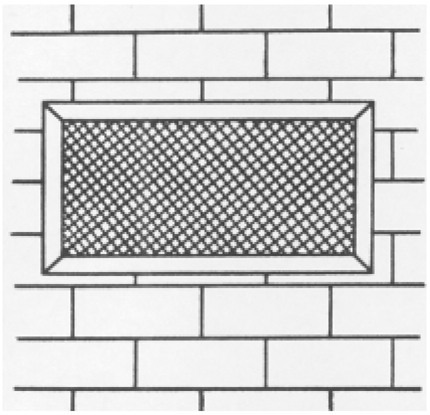

Figure 8.19 Screens to keep mice out must have a small mesh size

Gnawing at the bottom of doors can be prevented by fitting a 30 cm high 20-gauge, metal kick plate on the outside (Fig. 8.20). This should have a maximum clearance of 7 mm from the ground. A similar plate should be fixed to the door frames to provide a continuous band of metal. Windows, fanlights and ventilators that are permanently open should be meshed over as described for air-bricks.

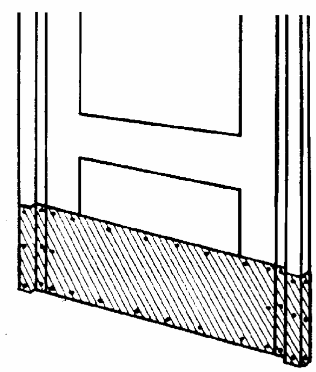

Figure 8.20 Wooden doors and door frames need to be protected against chewing by rats and mice

Horizontal pipes and cables between buildings can be fitted with circular 20-gauge metal guards as recommended for vertical pipes.

The following spaces are favoured rodent harbourage sites inside buildings:

- in the ceiling space;
- behind skirting boards;
- in hollow partitions;
- in ducts and conduits of various kinds;

- in holes in lagging; and
- in timber and plastic casings to pipes and cables.

Rats and mice often nest in the insulation in the walls, ceilings and floors of refrigeration rooms.
In warehouses, hollow ceilings are best avoided, but where this is impossible all access holes should be sealed. The same applies to skirting and hollow partitions. Pipes passing through inside walls should be tightly built in or carried in built-in sleeves; having an internal diameter of about 1 cm more than the pipes they have to accommodate. Looser fitting sleeves can be packed with crumpled up hexagonal wire mesh. Vertical pipe trenches can be packed at floor and ceiling level in the same way or fitted with sheet metal plates. The latter should also be fitted round pipes to radiators. All types of lagging, such as felt, plastic, magnesia, packed slag-wool and fibreglass that may harbour rats or mice should be examined at intervals and made good if damaged.
As changes to the habitat will make rats wary of new objects (including rodenticide bait), proofing should not be carried out immediately before or during the application of rodenticides, but should be undertaken as soon as possible afterwards.

Management of the stored product within the store

It is essential that high levels of store management are maintained within the store. Any spillages that may leave food lying around must be removed immediately.
Access to water by the rodent population should be prevented. In the case of rats, and also of mice living on food with a moisture content below about 15%, this will lead to death in a very few days without the need for any rodenticide treatment. On the other hand, in the case of mice living on food with a high moisture content, cutting off the supply of water; from fire buckets, roof gutters and dripping taps, might make it easier to poison them by means of liquid baits.
If food is to be stored in stacks they should be relatively small stacks that can be individually inspected and monitored. These stacks should be at least one metre apart and one metre from any walls to facilitate inspection, monitoring and the application of rodent control measures. Where there is evidence of rodent activity in the roof areas the stacks should be kept at least two metres from adjacent walls and at least two metres from supporting beams and other structures. All stacks should be stored off the ground on pallets or similar supports. All stacks should contain material that entered the store at the same time. Different aged stocks should not be stored together. Returned goods should be stored separately. Good records of all stacks, their contents and their history should be maintained. If rodent activity is found in any stack then rodent control measures should be applied immediately. If such measures are not considered likely to provide 100% control within the stack then the stack should be dismantled and removed. Measures must be taken to prevent rodents escaping into adjacent stacks while dismantling takes place.
Rodent control techniques

Although high standards of proofing, store management and hygiene are essential to maintain a rodent free store, infestation will still occur and it will be necessary to have effective rodent control measures available. A range of control techniques are available and these will be dealt with as either chemical or non-chemical methods of control.
The objective should be to achieve 100% elimination of the rodent population, otherwise the residual population may rapidly build up to previous levels. Non-chemical techniques, although providing a method of removing some individuals from the population are rarely likely to achieve 100% elimination. Their use may be required in situations where the use of toxic chemicals is considered hazardous to non-target species, including man, but in these instances their application must be very intensive, leading to high labour costs. Even then, complete removal of sizeable rodent populations is difficult to achieve.
The chemicals or pesticides that are used to kill and control rodents are called rodenticides. The chemicals selected as rodenticides have a high level of toxicity to rodents. However, rodents like humans

and many of the other animals important in our livelihoods are mammals. Inevitably these rodenticides can also be toxic to these other, non-target mammals as well as to other animals such as birds. It is therefore essential that rodenticides are only used by trained personnel following the recommendations on the rodenticide label, and that maximum attention is paid to safety at all times.

It is particularly important to remember that in food storage environments it is not only the non-target animals that need to be protected, but also that it is essential that the food in the store does not become contaminated with the rodenticide. A major problem with rodent control in stores is ensuring that the rodenticide bait is sufficiently palatable to attract rodents away from the normally available food source on to the rodenticide in order that the rodents will consume a lethal dose.

Chemical control techniques

Until the early 1950's only **acute poisons** (i.e. single doses) were used for rodent control. At one time the most common way of using these was by 'direct' poisoning: that is to say, by simply putting down baits containing poison without any preliminary attempt to condition the rat or mouse colony to feed. This method does not give a consistent high percentage kill. Study of wild common rats, in their usual haunts and in the laboratory has shown that they react in a characteristic manner to any object or source of food new to them. At first they will generally avoid bait altogether, or eat only very small amounts, continuing to feed mostly elsewhere. This is called 'new object reaction' or 'neophobia'. On successive nights (rats are mainly nocturnal) the amount eaten usually increases, reaching a maximum on about the fourth and fifth night. The rats then continue to feed confidently at the new source. If now the food or its container is altered or any new object is introduced into the rats' run, consumption may decrease once more. Mice behave differently and regularly moving the baiting stations can actually increase consumption. If rats or mice feed so slowly on poisoned bait, that they experience unpleasant symptoms and cease feeding before having taken a lethal dose, they may be difficult to poison again. Often they will not accept the same bait or poison again for several months. This phenomenon has been called 'shyness'. To overcome it, a system of poisoning known as 'pre-baiting' is used. Pre-baiting involves the initial application of the unpoisoned bait. The rodents are allowed to find and feed on this bait, gradually overcoming their neophobia. This may take a few days in house mice and up to two weeks or more for rats. When consumption has been maximised, the unpoisoned bait is removed and is replaced with the same bait base, but containing the acute rodenticide.

Unfortunately there remains some neophobic response in the rodents, particularly when they detect the taste and/or smell of the acute rodenticide in the bait. It is thus very difficult to obtain the target 100% mortality with the acute rodenticides. Average mortalities of about 80% are obtained if thorough pre-baiting has been applied. This is not ideal, but may be acceptable if there are no available alternatives.

For those rodents that do not exhibit neophobia the problem persists. Mice tend to be inquisitive and ready to feed on new baits, but feed only very sparingly from any particular bait point. Thus a similar problem occurs, a sub-lethal does in consumed, symptoms develop soon afterwards, feeds stops and shyness follows recovery.

A number of acute rodenticides are available around the world, they are frequently cheap to produce and buy and are often readily available (Table 8.2).

Table 8.2 Acute rodenticides

Alpha-Chloralose
Sodium (mono) fluoroacetate (1080)
Fluoroacetamide (1081)
Red Squill
Thallium sulphate
Zinc Phosphide
Norbormide

Alpha-Chloralose is a narcotic drug and acts by retarding the metabolic processes, death results from hypothermia. It is most effective when used at temperatures below 14°C, but is not available for use out-of-doors. Alpha-Chloralose is recommended for use against mice and not rats, as the larger body size of rats makes it less effective. The rapid onset of symptoms with this rodenticide frequently results in sub-lethal poisoning and subsequent problems with bait shyness. It is usually applied at concentration of 2-4%.

Sodium (mono) fluoroacetate (1080) is highly toxic, and works by blocking the tricarboxylic acid cycle, causing accumulation of citric acid and hence leading to convulsion and respiratory or circulatory failure. It is used at concentrations between 0.08-0.5%. Due to its high toxicity and the absence of any antidote its use is strictly regulated in most countries.

Fluoroacetamide (1081) is effective against all three common commensal rodent species. It is an analogue of 1080 and is very similar in most respects. However it is slightly less toxic and is therefore applied in baits at a concentration of 1-2%. Both 1080 and 1081 are odourless and tasteless and can be used without prebaiting. These same characteristics make them a greater threat to non-target animals and in the UK they are restricted to use in sewers, ships and locked dock premises.

Red Squill is an extract from the bulbs of the Mediterranean plant, *Urginea maritima*. It causes death by convulsion and is banned in some countries as a cruel poison. It is available in a purified form as *Silmurin* and is used in baits at concentrations of 0.015-0.05%.

Thallium sulphate is recommended for use in baits at concentrations of 0.5-1.5%, it does not induce bait shyness as it is relatively tasteless. However this makes it highly toxic to non target animals, and it is not widely available as there is no antidote.

Zinc Phosphide is one of the most commonly used acute rodenticides world-wide and is widely available to non professional users. It is usually marketed as a very fine grey-black powder that smells of garlic, and is recommended for use at concentrations of 1-5%. It works through the liberation of phosphine in the stomach, which subsequently enters the blood stream, causing heart failure and organ damage. It is relatively fast-acting and should be used in conjunction with pre-baiting to give best results.

Norbormide is very toxic to *R. norvegicus*, less so to *R. rattus* and essentially non-toxic to a number of other common mammals and birds. The early promise of this rodenticide has not been realised, largely as a result of poor palatability, physiological tolerance and fast action which leads to symptoms of poisoning before a lethal dose being ingested.

Theoretically, an acute poison so toxic that even a trace of bait would be fatal to rats, could eliminate the need for pre-bait. Such a substance however would be too toxic in concentrated form to use in ordinary circumstances, except under close supervision, unless it was found to be rat-specific.

The results of control exercises using acute poisons can sometimes be spectacular. In an area of 700 hectares on the island of Mindoro (Philippines), about 183,000 rat corpses were collected from the fields after massive treatment. This is equivalent to a population density of more than 260 animals per hectare. But massive control with acute poison is only temporarily successful, unless new invasions from neighbouring areas can be prevented.

Subacute rodenticides are similar to acute rodenticides except that the symptoms they induce are slower to appear and less dramatic than those exhibited by the acute rodenticides. Hence, a lethal does not need to be consumed in a single feed and feeding may continue for 24 hours or more. Death is normally delayed for several days.

A period of anorexia may be induced in animals that have taken both lethal and sub-lethal doses. Which leads to these compounds being sold as stop-feed products. However this is only a benefit if a lethal dose was consumed prior to the cessation of feeding. If a sub-lethal dose was consumed, death will not occur. Bromethalin and Calciferol are subacute rodenticides.

Bromethalin works by uncoupling oxidative phosphorylation in cells of the central nervous system causing tremors, paralysis of the hind limbs and convulsions. Death usually occurs within 24 hours. It is a pale yellow crystalline solid, used in baits at concentrations of 0.005 -0.01%.

Calciferol is a naturally occurring, fat soluble vitamin in tow forms: ergocalciferol (Vitamin D2) and cholecalciferol (Vitamin D3). It can be used to control both rats and mice. Death is caused through hypercalcaemia and particularly through renal failure following calcium deposition in these tissues, this process is slow and can take 2-3 days. The stop-feed action of calciferol is apparent in rats but less so in mice where effective control can be achieved without pre-baiting.

In 1950 a great advance occurred in rodent control. This was the introduction of the **anti-coagulants**. Anti-coagulants of various kinds have been used in medicine for some time in the treatment of thrombosis and other illnesses. It was in Britain that the idea originated of using them as rodenticides, and the first to be tested was dicoumarol. This substance was discovered in the USA to be the cause of haemorrhages in cattle that had eaten spoiled sweet clover hay. Research later showed that dicoumarol was not as effective a rodenticide as a related anti-coagulant, 3-1-Phenyl 2-acetylethyl-4-hydroxycoumarin. This was thoroughly studied in America at the Wisconsin Alumni Research Foundation, and the name 'warfarin' is derived from the initial letters of that institution. Warfarin is now used all over the world.

The success of the anti-coagulants as rodenticides depends on the fact that when they are eaten by rats and mice at low concentrations in bait, symptoms of illness are slow to appear and the animals do not therefore associate them with their food. Thus low level feeding continues daily until a lethal dose has been absorbed. At the strength at which anti-coagulants are used the bait may need to be eaten for several days before this happens (and death may occur later still). Hence, the use of the term **chronic poisoning** to describe the control technique. The average time to death is seven to eight days. If other aspects of the rodenticide treatment have been applied correctly, 100% mortality can be achieved.

The use of the chronic rodenticides is based upon a technique known as saturation baiting. Put simply, this means that the infestation is thoroughly surveyed and bait-points laid to cover the infestation effectively. Revisits are then made to the bait-points frequently enough to ensure that there is always bait available to the rodents. In this way we try to ensure that the rodents have regular (daily) access to the bait points even though they may not feed extensively at any one point or on any one day.

Chronic poisons are safer than acute poisons where non-target animals are concerned, since a single feed of bait is usually (but certainly not always) insufficient to kill. On a weight-for-weight basis, however, the anti-coagulants appear to be roughly as toxic to man and other mammals (such as dogs, cats and cattle) as they are to rats and mice, and great care is required in their use.

Anti-coagulants interfere with the production of a substance known as prothrombin, which is necessary for blood to clot quickly when blood vessels are broken. Animals poisoned with anti-coagulants may therefore die of haemorrhages resulting from the minor damage to blood capillaries that occurs in the rough and tumble of everyday activity. Or they may die from some more localised but more violent injury. Obviously, rats and any other animals that have just had, or are about to have litters are especially vulnerable to anti-coagulants. Some anti-coagulants are also used in human medicine when there is a danger of blood clot formation after surgical operations.

The prothrombin content of the blood, after anti-coagulant poisoning, may be restored by dosing with Vitamin K_1 that is therefore an antidote.

A wide range of anti-coagulant rodenticides are available world-wide (Table 8.3).

Table 8.3 Anti-coagulant rodenticides

		Warfarin	}
		Chlorophacinone	}
		Diphacinone	} First Generation
		Coumatetralyl	}
		Coumachlor	}
		Pindone	}
		Difenacoum	}
		Bromadiolone	}
		Difethialone	} Second Generation
Pulsed Baiting	}	Flocoumafen	}
	}	Brodifacoum	}

The earlier anti-coagulants were widely and very successfully used in the first ten years or so after their introduction. In the late 1950's and early 1960's, however, problems with physiological resistance to warfarin were detected in both rats and mice. Put simply, the rodents could feed on warfarin baits without adverse effects. When similar anti-coagulants were tested against these populations it was found that they, like warfarin, were not able to control the resistant populations. We now term these anti-coagulants the first (1st) generation anti-coagulants.

The arrival of difenacoum on the market in the mid 1970's provided an anti-coagulant that proved capable of controlling these warfarin or 1st generation resistant rodent populations. Other anti-coagulants arriving on the market since difenacoum have also proved to be successful against the resistant populations. We term these newer anti-coagulants the second (2nd) generation anti-coagulants. In areas of the world where resistance has not yet developed, 1st generation rodenticides can still be used successfully and are often cheaper than the 2nd generation anti-coagulants.

The development of the two newest anti-coagulants (brodifacoum and flocoumafen), has brought with it the opportunity to introduce a new baiting technique, this has been termed pulsed baiting. These two anti-coagulants have rodent toxicities that are higher than the other anti-coagulants. The toxicity is so high in fact that it is relatively easy for a rat or mouse to ingest a lethal dose at a single feed, however, death is still delayed and no extreme symptoms are apparent, thus no poison or bait shyness develops. It is important to remember however, that although the rodents may ingest a lethal dose in a single feed, not necessarily all the population will do so and a portion of the population may continue to require more than one feed. The higher toxicity and other characteristics of these anti-coagulants, means that fewer and less frequent visits to top-up baits are required, resulting in potential savings in labour and material costs.

The increased toxicity of the anticoagulants does not result in faster control. The minimum time to death (2-3 days) and average time to death (7-8 days) remain the same as for the first generation anticoagulants. Similarly, the time taken to control the typical *R. norvegicus*, *R. rattus* or *Mus* spp. infestation remains about 21 days.

The higher toxicity of brodifacoum and flocoumafen has resulted in a perceived increased hazard to non-target species. Both have therefore been restricted to use in indoor situations. In most cases, poisoning of rodents with rodenticides is not recommended at the small farm level, as although rodents are killed more may soon arrive.

The mammalian toxicity of some of these rodenticides is shown in Table 8.4.

Table 8.4 Comparative toxicity data for a range of rodenticides

Rodenticide	Acute oral LD50 (Rats) mg/kg	Concentration %
Acute rodenticides		
Sodium fluoracetate	0.2 - 2.5	0.25
Strychnine	6	-
Thallium sulphate	16	1.5
Zinc Phosphide	41	2.5
1st Generation anti-coagulant rodenticides		
Warfarin	50 - 323	0.025
*(Warfarin x 5 days)**	*1*	*0.025*
2nd Generation anti-coagulant rodenticides		
Difenacoum	1.8	0.005
*(Difenacoum x 5 days)**	*0.18*	*0.005*
Bromadiolone	1.125	0.005
Flocoumafen	0.25	0.005
Brodifacoum	0.26	0.005
*(Brodifacoum x 5 days)**	*0.06*	*0.005*

*Data in italics provides information about the chronic toxicities (in a 5 day period) of some of the anti-coagulant rodenticides.

Anti-coagulant resistance

The knowledge regarding anti-coagulant resistance changes continuously and research in this area is active.

In very general terms however we may assume that as far as house mouse, *Mus domesticus* is concerned, resistance to all the 1st generation anti-coagulants is widespread. The picture with regard to the 2nd generation anti-coagulants is less clear, it is likely however that intensive use of these 2nd generation anticoagulants will lead to selection for resistance to these rodenticides. Indeed, reports already indicate that there may be resistance to bromadiolone, and difenacoum, both in the more intensively controlled central urban areas, as well as some rural and farm situations.

The situation with regard to *R. norvegicus* is less clear. Within England, pocketed resistance to the first generation anti-coagulants is present, particularly in central Wales, some areas of South-east England and the Midlands, although no recent extensive survey has been undertaken. There is also known to be extensive resistance to difenacoum with, cross-resistance to bromadiolone, in the rat populations in the counties of Hampshire, Berkshire and some areas of Wiltshire. The full extent of this resistance is not yet known. In many situations, however, resistance can be overcome provided bait acceptance is adequate. Nevertheless, animals that are for practical purposes unaffected by bromadiolone and difenacoum, are known to exist in certain populations.

Rodenticide formulations

All the rodenticides mentioned are available in a range of formulations. Some formulations provide advantages in particular situations, others may vary in their effectiveness and palatability. It is important that those using rodenticides are familiar with the product being used and the alternatives. It is also essential that the instructions on the label of the container are followed exactly. These instructions have legal backing and products may only be used as instructed.

The main formulations available are:

- **Edible baits**
- **Contact rodenticides**
- **Liquid rodenticides**
- Edible baits

There is an increasing range of ready-made edible bait formulations available. The main formulations include: loose cereals and other foods; pellets; wax blocks; and gels and pastes.

It is generally accepted that loose baits are the most palatable of the formulations and provide the best opportunity of control. However, concerns relating to the safety of loose cereal bait formulations particularly in an area where food is stored mean they require careful application.

Wax bait blocks may be a safer alternative, because many of them are produced with a central hole in them that allows them to be fixed to the baiting site, which reduces the chances of them contaminating the stored food. However, they may not compete well with the more palatable and familiar food that is being stored. Wax block formulations may also be more costly.

An alternative to ready made formulations is to purchase a rodenticide concentrate and mix an edible formulation using a locally available, possibly cheaper loose food bait. In such cases the instructions on the label for mixing the bait must be followed. The temptation to increase the concentration at which the rodenticide is used may be counter productive, as palatability may be reduced. It may be necessary to try out several types of bait material in order to attract the rats and mice in your store. Vegetable oil, banana, mango, other local crops or dried fish can be used. There may be an advantage in using a bait which the rodents are already feeding on, as the rodents will be familiar with this food and it is likely to compete well with the alternatives. However, it is essential to ensure that the poisoned bait does not become mixed in with the stored food.

Baits mixed with poisons should be laid in baiting or feeding stations to protect them from the influence of the weather and non-target species. Some illustrations of different baiting stations can be found in Figure 8.21. In recent years there has been a move towards the use of specifically constructed tamper resistant bait containers.

Figure 8.21 Examples of baiting stations

Placement of the bait is also important. Rats are particularly neophobic and are reluctant to take risks. They do not like to encounter new objects and are reluctant to feed on unfamiliar foods. Placing baits often involves placing unfamiliar foods, at unfamiliar points in unfamiliar containers. It is important to try and make it easy as possible for the rodents to find the bait and then for them to feed on it.

The hoarding behaviour, characteristic of most rodents, involves their taking food from where they find it, to somewhere they feel they can hide it or feed on it more safely. The evidence suggests that *R. norvegicus* feels most secure feeding in its burrows or harbourage, and if they can do this they are more likely to feed on baits that are not particularly palatable. It appears that in stable environments, such as food stores, they may be particularly neophobic and reluctant to take risks. The nearer the bait can be placed to areas where they do feel safe, the more likely they are to feed on it. The objective in placing baits must therefore be to identify where the rats are living and to ensure that baits are placed in these areas, if it can be done safely.

Baits must be inspected every two or three days and more added if the bait is being eaten. Baiting should continue until no more is eaten. Baits must not be left for long periods without inspection. After about a week, they should be removed and disposed of preferably by burial. Because the new ready-to-use chronic poisons such as brodifacoum (Trade names: Klerat and Finale) are not mixed with food-bait they will not become stale quickly and it is not necessary to replace them every few days. They are best laid in small quantities at many locations in a store, where rats and mice regularly run (alongside walls or bag stacks), and inspected and renewed once a week. All types of poison used in stores for killing rats and mice should be covered or sited so that they cannot become mixed with food grains or be eaten by domestic or farm animals, or by children (Fig 8.22).

Dead rats and mice should be collected, but must not be handled with bare hands because of the risk of fleas that can carry diseases. The bodies should be buried or burnt.

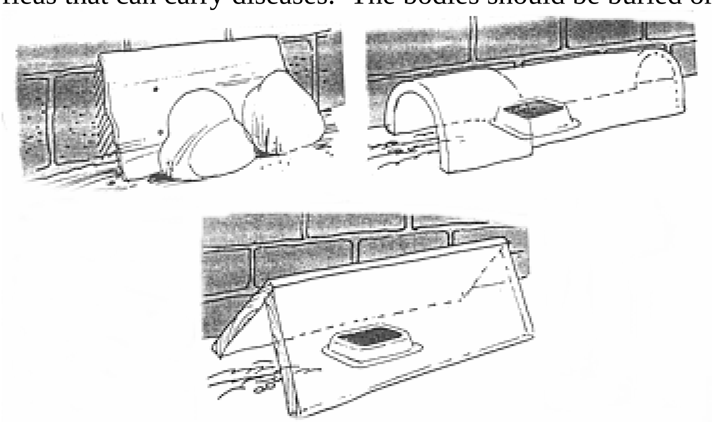

Figure 8.22 All baits must be protected

- Contact rodenticides

Rodenticidal contact dust is the main form of contact rodenticide available. This is a specially formulated dust containing the active rodenticide. It is placed in areas where rodents are active so that the rodent runs through it, picking up the dust on its fur as it does so. When the rodent grooms itself it will simultaneously ingest the rodenticide.

However, rodenticidal contact dusts are not suitable for use in areas where food or the surfaces against which food is stored may become contaminated by the dust. Such contamination may occur directly or through rodents running over the dust and then over the food.

A contact gel formulation is also available, although its availability is commercially restricted. The contact gel was specially formulated for the control of *R. rattus* in high and inaccessible areas.

Additional forms of contact rodenticide include a contact wick technique for the control of house mice. The wick is impregnated with brodifacoum and placed in a tube, as the mice run through the tube they rub against the wick. Subsequent grooming results in ingestion of the brodifacoum.

- Liquid Rodenticides

Liquid rodenticides are soluble forms of the rodenticide presented to the rodent in a drinkable form. They can be very effective in food stores, particularly in large stores where water and access to water may be in short supply. It is essential however to ensure that the stored food does not become contaminated.

Regular replenishment of drinking points is also necessary to compensate for evaporation as well as liquid that might be drunk by the rodents. The concentration of liquid should not be allowed to increase too much, as this will reduce palatability.

An alternative to toxic liquid formulations is to use plain, un-poisoned water in a drinking point adjacent to rodenticide bait points.

Maintenance

A common reason for ineffective control of rodents in food stores is failure to maintain control operations on a consistent basis. Multiple feed anti-coagulant rodenticides, for instance, require regular visits to the bait. If, regular visits are not made the rodenticide baits are eaten, spilt or become unpalatable and the rodent population begins to recover from any impact the rodenticide may have had. As a rule of thumb, treatments may be terminated once there have been two visits where there are no signs of feeding at the bait station and no other indications of current activity can be found.

It is essential that once started, the control treatment is applied appropriately and is taken through to completion, otherwise the risk of resistance developing is high, due to exposure to sub-lethal doses of rodenticide. There is little point in commencing control unless resources are available to complete the task. The need for effective management and training is particularly important in this phase of the operation.

Using rodent poisons safely

It must be remembered that all poisons used for killing rats and mice are harmful to humans and to domestic and farm animals. Only trained operators should be permitted to use and handle poisons, especially if this involves mixing concentrated poisons with food-bait. The manufacturer's instructions must always be read and followed carefully. New rodent poisons should only be used if full instructions are provided by the manufacturer. When preparing food-baits to which concentrated poisons are added it is essential to keep these poisons off the skin and to wash away any spillage or residues with plenty of water. Gloves should be worn or plastic bags placed around the hands during handling.

Chronic poisons kill rodents by preventing clotting of the blood and will cause the same problem in human poisoning. Treatment to restore blood clotting in humans is with Vitamin K1 that can either be taken by mouth or by injection.

When laying poisons in a store, care must be taken to ensure they can not be reached by cats, dogs, and other small animals or by children. Warning signs about the poison must always be provided and when poisons are going to be used in rented stores the owner should be informed. Some poisons contain a bright coloured dye so that it is obvious to humans which food has been baited, blue is often used as it is less palatable to humans Due to the poor eyesight of most rodents they can not detect this dye. During the poisoning programme it is advisable to keep the stores locked at night, and during the day if the store is not in regular use. All poisons should be kept in a secure and locked store (Fig 8.23) and a register of their use kept. Only responsible and trained persons should have access to rodent poisons.

As mentioned above, gloves should be worn when collecting and disposing of dead rodents to reduce the risk of disease transmission.
If you are involved in regular programmes to control rats and mice, identify a doctor or hospital that can provide emergency assistance in the case of suspected accidental poisoning, and ensure that stocks of Vitamin K1 are available.

Figure 8.22 Poisons should be kept in a locked store

Other methods of rodent control

Rodenticides are often seen as the main method of reducing rodent populations; however it is important to be aware of the range of alternative methods which include:

- Traps and hunting
- Fumigation
- Repellents
- Predators
- Chemosterilants
- Gassing
- Ultrasound
- Electromagnetic devices
- Traps and hunting

Trapping must be amongst the oldest of the control methods employed against rodents as can be testified by the many traditional live and kill traps in different parts of the world. These include pitfall, deadfall, snare and the various types of cage traps. There are pottery traps in the museums of several Middle East countries that date back to the 3rd millennium BC.
Traps have a small but important place in rodent control, and are particularly useful inside domestic premises. They may have to be used where there is a danger of poisoned animals dying in inaccessible places - such as under floors and in cavity walls - and causing offensive odours. Traps are also commonly used in areas where rodents are eaten as an important source of protein in the local human diet. Various types of traps exist and local designs are often found to be effective. Although, trapping techniques can be used to reduce the numbers of rodents in an infestation, they are very labour intensive and unlikely to be completely effective on their own, especially in large stores where rodent populations may be high.

Killing traps are active traps usually working on the break back principle. A spring, triggered by the activity of the rodent on the trigger mechanism, drives down a metal bar, breaking the back of the rodent. Break-back traps (Fig. 8.24) are quite common and should be set at right angles round the base of the walls of a room where rodents usually run, rather than in open places. For rats they should be put down unset and baited for a few days before they are set, but for mice they can be set straight away. For the best results plenty of traps should be set close together for a few days rather than a few traps operated for weeks at a time. Baits used to trap rodents include breadcrumbs, flour, oatmeal, banana, and cubes of coconut or sweet potato.

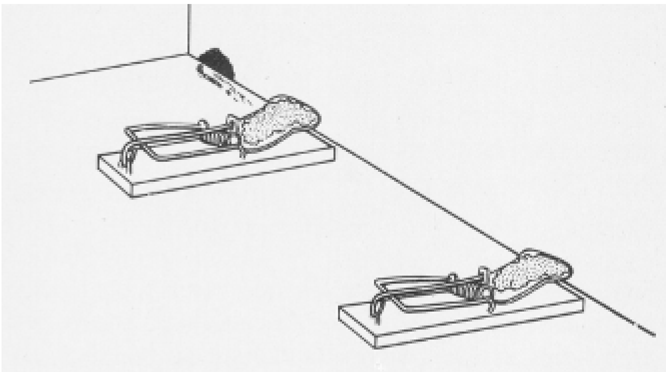

Figure 8.24 Break-back traps placed at right angles across rat runways, around the base of walls, and set lightly

If the trap is triggered before the rodent is in the correct position, or if the spring is not strong enough to kill the rodent, the rodent will have survived. In surviving it will have gone through an unpleasant, painful and frightening experience and in exactly the same way as with 'shyness' induced by the acute rodenticides, it will learn to avoid the trap in the future and will become 'trap shy'. This will subsequently make it much more difficult to trap the same animal in a similar trap. It is also likely that some individual rodents are naturally trap shy, this may simply be an extension of their normal neophobic behaviour.

For these reasons it is very difficult to eliminate a rodent population of any size by trapping alone. It may however be possible to eliminate a small population. Intensive break back trapping with a well designed trap suitable for the species being trapped can however have a significant impact on the size of a rodent population in a food store or home. Recent work in Mozambique found that intensive break back trapping, undertaken on a continual daily basis, in home food stores can reduce the rodent population by 70% at low cost and with a significant reduction in food storage losses.

Live capture traps work on a variety of designs, the principle being to entice the rodent into a container of some kind, from which it can not escape. Some live capture traps incorporate spring mechanisms that help to retain the rodent, usually mice, by some form of trip mechanism triggered by the animal. If the rodent is not properly retained and escapes, it may develop induced shyness. Those rodents, which are naturally trap shy would be unlikely to enter the trap. To prevent undue suffering and starvation the traps should be visited at least once a day and any rodents caught disposed of.
Glue or sticky traps also exist which consist of an area of glue on a board placed along a rodent runway. When the rodent runs across the glue it becomes stuck. The technique is cheap and easily applied, but is not a very efficient form of control as many rodents avoid the glue. However it can reduce rodent populations and is useful in areas where other techniques are either not proving successful or cannot be used for safety reasons. The use of these traps is prohibited or controlled in some countries on the grounds of cruelty.

Traps have a clear part to play in the control of rodents in food storage environments, as they are non toxic and will not contaminate the food. They will be most effective however if they are used intensively, placed carefully in areas where the rodents are active and if thought is given as to how to use the traps to best advantage.
A hunting approach requiring not more than a few dozen people with sticks or machetes to encircle the affected area is often used to reduce rodent populations. The animals are, preferably in the evening, driven to the centre and killed. However impressive the number of killed animals may be, these drives are usually only temporarily effective.

- Fumigation

Fumigants are sometimes used in rat control, though generally only in conjunction with other control strategies or when poisoning methods are hazardous, impractical or ineffective.
Occasionally fumigation is used to control rodents in stores or ships. Fumigation is usually carried out under gas-proof sheets as this enables a high concentration of gas to be maintained for long enough to ensure complete penetration of the commodity. Methyl bromide and hydrogen cyanide are the fumigants most commonly used for this purpose. Such fumigation is a highly specialised procedure and is normally only carried out by servicing companies properly equipped and trained for the work. Such a procedure is costly and also carries the risk of rodents dying in inaccessible places. Aeroplanes are also fumigated to eradicate rodents that may chew through electric cables. Because fumigation is an expensive operation it is not normally used as a method for killing rats and mice (except in special cases such as aeroplanes), but is an extra benefit in pest control programmes against insects infesting stores. Dead rodents will often be found around the edge of fumigated bag stacks when the sheet is removed and should be taken away immediately and buried or burnt. Dead rodents should not be picked up with the hand unless gloves are worn.

- Repellents

Rats have an initial aversion to some odours, but the use of repellents to solve a rat problem is seldom practical. Odour-producing substances, if effective at all, generally have only short term effects. Where a rat population is high and on the increase, any attempt to protect an area, food commodities, or other gnawable materials with odour repellents cannot be expected to succeed. Repellents detected by taste may be effective if they can be coated or impregnated on or into packing materials. These may be particularly beneficial if they create some physiological ill-feeling that the animal associates with initial contact with the repellents. Potential chemical repellents have been studied for a long time, but very few have ever been marketed.

- Predators

In some situations the use of predators may have a part to play in the control of rodent infestations. However, this is unlikely to be the case in food stores, which are artificial environments where predator levels would have to be maintained artificially. In addition, the predators would contaminate the store and the food with their own droppings and urine.

- Chemosterilants

Chemosterilants (anti-fertility agents) are not commonly used for rodent control.

- Gassing

Gassing powders that produce hydrogen cyanide gas when they come into contact with moisture have sometimes been pumped into rat burrows. This method is of doubtful value against the common rat as some individual rats tend to bolt, and cyanide is extremely toxic to man and may get into waterways. This procedure should only be carried out by servicing companies properly equipped and trained for the work.

- Ultrasound

Instruments are available to deliver ultrasonic waves that are claimed to deter rodents from entering or moving about in buildings. These instruments have been extensively investigated by the Department of Agriculture in the USA and found to be largely ineffective and of little practical use.

- Electromagnetic devices

A range of devices are sold throughout the world that claim to produce electromagnetic fields that deter rodents. These devices have not been proven to be effective.

Monitoring and prevention of reinfestation

Continual monitoring must be undertaken in order that the manager knows the status of infestation at any point in time. A comprehensive survey and recording system will help ensure that the degree of rodent infestation in any store can be identified at any time. A well-designed system will allow the manager to monitor progress and to relate the benefits of the strategy to the costs of the operation. During the initial survey a three dimensional map is made onto which details of any signs of rodent infestations are added. Details of the control techniques applied need to be recorded including: numbers of control points; (baits, traps); rodenticide; position; amount of bait laid; and dates. These control points should then be visited at regular intervals, dependant on the technique being used. At each visit a record should be kept of the rodent activity and the actions taken as a result. Over time the activity at each control point should reduce, as the control begins to have an effect. As control measures are applied, rodent activity patterns will change, making it necessary to regularly resurvey the site.

A good method of monitoring for presence of rodents is to use un-poisoned dust, such as sand or chalk dust. If these dust are placed carefully in rodent runways, they will show footprints or other marks if the rodents move over them. This technique can be used easily when monitoring stacks of food. Bands of dust can be laid around the base of the stack and any movement into or out of the stack will be evident.

Similarly rodents may enter bait boxes used for presenting rodenticide baits safely but they do not necessarily have to eat the bait. In such cases there is no evidence that the rodent has entered the box. A new technique (Roguard) for monitoring house mouse activity is now available in some countries, incorporating a small plastic strip in the entrance of the bait box. The position of the plastic strip indicates whether or not a mouse has entered the box.

Reinfestation may occur both as a result of breeding of a residual population or, perhaps more rapidly, as a result of invasion from outside the treated area. Invasion may be encouraged by some particular event that can be avoided, or at least anticipated. For instance, rodents may move into buildings during poor weather, or after harvest, and between fields as a result of different crops (or stages in growth), or flooding.

Reinfestation can be reduced by making the habitat less advantageous to rodents. This will include the destruction of harbourage (e.g. rubbish in stores, weeds on field perimeters) and nesting materials, and prevention of access to food. Buildings can be proofed against rodents entering through cracks in the floor, walls or roof, along wires and cables, through drains or central heating ducts and so on.

Reinfestation can also be reduced by use of ‘permanent’ baiting stations in the area or surroundings.

Cost-benefits of rodent control in grain stores

Lack of reliable information on losses in stores makes it difficult to justify the costs of control.

The world-wide survey of rodent damage and control in stores carried out during the 1970s produced the following estimates. In Africa, a control programme in stores in Lesotho is reported to have achieved a saving of £1,888 at a cost of some £503 (cost: benefit ratio, 1:3), whereas in Swaziland a fumigation undertaken at a cost of £125 is reported to have saved £994 (cost: benefit ratio, 1:6). In Bangladesh, a rodent control programme undertaken in stores and houses is reported to have saved £26,740 at a cost of £13,370 (cost: benefit ratio, 1:2). In a larger operation in India undertaken in Gujarat state a saving of £294,117 is reported with the expenditures of £16,042 on anti-coagulant rodenticides, although the additional costs of labour etc. are not reported. A common characteristic of all these reports is that significant cost: benefits have been obtained even in situations of relatively low overall percentage losses due to rodents.

One of the most comprehensive surveys of the costs and benefits of rodent control was undertaken in Cuba. During the study, careful monitoring of rodent control operations in six warehouses identified very high cost: benefit ratios varying between 1:22 and 1:51. These savings were achieved on a relatively low pre-control loss averaging less than 1%, reinforcing the argument that significant cost: benefits can be obtained by effective control, even when original losses are relatively low.

The available evidence on cost: benefits suggests that there are significant savings to be made by implementing effective rodent control strategies in stores. It is important therefore that apparent high financial costs are not permitted to restrict the effectiveness of a strategy without first assessing the eventual savings that can be made.

Useful website

Detailed notes and photographs on rodent morphology and taxonomy exist in the University of Michigan's Animal Diversity Web.

http://animaldiversity.ummz.umich.edu/site/accounts/specimens/Rodentia.html