Rodent management

Rationale

Rodents are a key mammalian group, which are highly successful in many environments throughout the world. They constitute more than 42% of the known mammalian species. In many instances rodents provide major benefits to the environment as bio-engineers but the conservation status of quite a number of species is listed by IUCN as at risk, threatened or endangered. However, of major importance are the 5-10% of rodent species that cause significant losses to agricultural crops in many regions of the world. In Asia alone, rodents cause 5-10% of loss to rice, the staple of the human population. This amount of grain eaten by rodents in rice fields each year (based on a 5% loss) would feed 200 million Asians for a year. Many rodent species are also important reservoirs of organisms that cause debilitating diseases in humans and livestock. In SE Asia, 90% of livestock are raised on predominantly rice farms. The two farming systems are inextricably linked. We therefore need to take a systems approach to rodent management and this will be a common theme throughout the course.

The ecology and management of rodent pests is rarely taught in universities in SE Asia and South Asia. Expertise in rodent management is therefore lacking in most developing countries in Asia. Until a recent resurgence in interest and funding, rodent pest management had not progressed in Asia since the 1970s mainly because there had been too little research effort to understand the biology, behavior and habitat use of the species we are attempting to manage. There is a growing demand, particularly in developing countries, for rodent control strategies that either have less reliance on chemical rodenticides or can better target their use. Similar concerns exist with the control of insect and weed pests. This led to the development of the concept of ecologically-based pest management (EPM) which builds on the progress made with integrated pest management (IPM). During the course we will return often to this theme and provide examples where research on the basic biology and ecology of rodent pests has provided management strategies that are more sustainable and environmentally benign, as well as having a positive impact on livelihoods through improving the income and health of rural communities.

Introduction

Rodent pest management went through a period of stagnation in the 1980s and 1990s mainly because was too little research effort to understand the biology, behaviour and habitat use of the species we are attempting to manage. In Asia, rats consume enough rice to feed 180 to 350 million people for a year. Their management is a high priority. Localised heavy losses associated with the patchy destruction of crops by rats, has resulted in major concerns for food stability at the village level. With the expected increase in human population growth in these countries, the situation will become more acute. There is a growing demand, particularly in developing countries, for rodent control strategies that either have less reliance on chemical rodenticides or can better target their use. Similar concerns exist with the control of insect and weed pests. However, there is hope on the horizon through the development of the concept of ecologically-based pest management (EPM) which builds on the progress made with integrated pest management (IPM). We will analyse this idea for rodent pests and consider examples where research on the basic biology and ecology of rodent pests has provided management strategies that are more sustainable and environmentally benign. Ecologically-based management of rodents will be the theme for this module. If in developing countries we can foster the importance of population ecology and an emphasis on management directed at the agro-ecosystem level, then we are confident that the next decade will see rapid advances in rodent pest management.

Currently, broad-scale chemical control is the primary method for managing rodents. This generally provides effective control in the short term. In developed countries the use of chemicals raises a number of concerns such as the risk to non-target species; the humaneness of its action; high usage patterns conflict with marketing a "clean and sustainable" produce; low efficacy of action when high quality food is available. In developing countries these issues also apply, with the additional concerns of affordability, quality control of products and correct usage patterns. Apart from considering ecologically-based management, we will also consider recent advances in biological control of rodents. Of particular interest is the use of a method aimed at reducing the fertility of rodent populations. The method is known as immunocontraception. Progress and prospects for its use will be reviewed.

Ecological management of Rodents in Rice

Rats - Impacts from many fronts

In Asia, rodents, insects and weeds are thought to cause similar levels of pre-harvest and post-harvest losses to rice. In some countries, such as Indonesia, rodents are economically the most important pre-harvest pest. In other countries, such as Vietnam, rodents are an emerging problem and are ranked by farmers in the top three factors that reduce crop production.

Eating their way to notoriety

In Vietnam, areas of rice crop that have suffered greater than 20% damage has increased from 63,000 ha affected in 1995 to 500,000 ha in 2000. In 1997, 22 provinces applied a rat bounty scheme for specific times of the year and 55 million rats were collected. The cost of the bounty scheme was approximately 62 billion dong (approximately USD4.5 million). In 1998, an estimated 82 million rats were killed using bounties and other techniques. In the province of Vinh Phuc alone, over 5 million rat tails were returned from January-September 1998. In this province of only 1.1 million people, the authorities estimated that there were well over 10 million rats; 10 rats for every person.

The impact of rats pre-harvest are best summarised through considering how much rice they consume (Table 1). One can see that rodents are a major competitor with humans for food!

For Indonesia and Vietnam, the rodent problems are chronic – significant problems have occurred in each year of the 1990s. In other countries such as Laos, rodent problems are linked to episodic eruptions of rodent populations. For farmers in mountainous regions of Laos, rodents are the second most important pest problem (behind weeds), yet farmers emphasise that it is the problem they currently have least control over (Schiller et al., 1999). Moreover, rodent damage is often patchily distributed; it is not unusual for a family to lose more than 70% of their crop to rodents. If this occurs to one crop it is a major concern for the financial security of a family, if it occurs two crops in a row then the situation becomes catastrophic.

The impact of rodents does not stop once the crop is harvested; they also consume and contaminate significant amounts of stored grain. In Southeast Asia there are few estimates available of post-harvest losses caused by rats and mice. If the situation is comparable to India where data have been compiled, then we would expect losses to be of a similar magnitude to those that occur pre-harvest. In India alone it is estimated that grain (not just rice) worth USD5 billion is consumed by rodents post-harvest.

Table 1 . Foregone human consumption because of grain lost to rodents prior to harvest, based on 1999 estimates. The production and consumption figures are drawn from IRRI Rice Facts.

Country and Population (million)	Production"rough rice"'000 t	Estimated rodent damage	Production without rodents'000 t	Estimated production loss'000 t	[1]Annual consumption /kg/person /yr(rough rice)	% rice daily calorie intake	People fed/year if no rat loss (million)
ASIA	540,621	5%	567,652	27,031	150	32	181
(3585.4)		10%	594,683	54,062			362
Indonesia	49,534	17%	57,955	8,421	249	52	33.8
(206.3)	(1,895 import)	10%	54,487	4,953			19.9
[2]Vietnam (77.6)	31,394 (3,800 export)	30%-615,000 ha 5%-7 million ha	33,585	2,191	280	67	7.8
		20% - 615,000 ha 5%-3.5 million ha	32,619	1,225			4.4

Notes:

1. Annual consumption is generally given as kg/person/year of milled rice and production relates to "rough rice". Therefore need to convert through dividing production figures, adjusted for exported and imported grain, by total population. For Vietnam, the high export indicates more grain in storage so used 1.7 multiplier based on figures from Asia and Indonesia.
2. Vietnam has average yield of 4.1 t/ha; national figures in 1999 indicated that rats caused high damage (10-75%) to 245,000 ha in the Mekong delta and 370,000 ha in the Red River delta. Low damage of 5-10% was recorded in 610,000 ha in the Red River Delta. Nationally, developed two scenarios. The first assumes an average of 30% loss in areas where damage is high (a reasonable assumption given some crops are not harvested at all) and 5% loss on average elsewhere. The second is conservative estimate, assuming an average loss of 20% of production for 615,000 ha and an average loss of 5% for half of the remaining area of production (i.e. 3,500,000 ha).

Rodents as Carriers of Disease

Rodents can transmit approximately 60 different diseases to humans. Rodents are also carriers of a significant number of diseases that affect domestic livestock. In Asia, Hantavirus, the plague, leptospirosis, rat typhus (Rickettsia) and neuro-angiostrongyliasis (transmitted by lungworm larvae of rodents) are five of the major rodent-borne diseases that commonly affect human populations. There is a rise in concern of rodents as a health risk in rice agro-ecosystems because of increase in travel of people between rural and urban areas and between countries, increased population density which amplifies the ability of a disease to spread through a population, increased clearance of natural habitats which promotes rodent-human contact.

Epidemics of any of these diseases can have a significant impact on a local rural economy. In poorer communities, if a rodent zoonotic causes disability for a poor farmer for a month at a key time then it may lead to no crop, a late crop, or reduced crop yield. Each can lead to a debt treadmill!

From 1995 to 2000, cases of leptospirosis have markedly increased in Northeastern Thailand. In the year 2000, 320 deaths associated with this disease have been reported among rice farmers (www.qld.gov.au; www.cdc.gov/ncidod/dbmd/diseaseinfo). Information on leptospirosis in Mekong Basin countries is extremely limited. The symptoms are flu like and sometimes mimic malarial symptoms. Therefore, the cause of the symptoms can easily be mistaken and neglected in the rural areas until serious damages have occurred. If left untreated patients can develop kidney damage, meningitis, liver failure and respiratory distress. If the leptospirosis is diagnosed early then it is easily treated with antibiotics.

Little is known about:
(i) the status of rodent diseases in Asia that affect humans and/or their livestock,
(ii) which rodents are key reservoir species,
(iii) the persistence of the infective parts of the disease life cycle in rice agro-ecosystems.

Principles of Management

Effective management of rodents will involve strategic actions that limit population growth so that damage is kept below the threshold of economic concern of farmers. Unfortunately, most of the rodent management in Asian countries is reactive – only occurring once a problem has been noticed. Generally this is too late to provide effective management. Many of these reactive actions, such as organising a bounty or application of an acute rodenticide provide farmers with a feeling that they have achieved some measure of success in their fight against rats because they can see dead bodies. However, in reality, once rodent numbers are high the management actions would have to remove at least 70% of the population to have a marked effect on reduction in yield loss to rice crops.

Strategic actions for management are most effective if they are developed on the basis of a sound knowledge of the ecology of the species to be controlled. In the next section we will consider integrated pest management for rodents and introduce the concept of ecologically-based rodent management.

Rodent IPM

There are five guiding principles to rodent IPM which are drawn from the IPM of insects (Singleton 1997),

These are:

- **The management actions are politically advantageous**
  A management action may be both feasible and desirable but is not adopted for local or national political or cultural reasons.
- **Environmentally sound**
  The use of rodenticides are minimised or targeted so as to reduce their impact on non-target species and, depending on the chemical, their entry into the food web.
- **Cost effective**
  This is particularly important in developing countries where farmers have small holdings and little disposable income for management actions.
- **Sustainable**
  Actions need to be environmentally sustainable and consistent with the other demands on farmers. If the actions are too complex, too labour intensive or too difficult to integrate with their farm management system, then farmers are unlikely to either sustain their actions or maintain the requisite quality of actions.
- **Broad scale**
  This is particularly important given the mobility of rodents and their ability to quickly colonise areas where crops are ripening and where rodent numbers have been reduced by local control actions.

IPM the reality

In most cases rodent IPM is simply a combination of monitoring a crop for effect of rats and then reacting when damage is above a certain level by applying a rodenticide. This is not the use of more than one management action and so is not technically IPM.
Moreover, often each rat is treated as the same in its likely response to a particular rodent management action. Is this a reasonable assumption? It is not! And we will consider why by reviewing some of our knowledge on 5 reasonably well studied species of rats.
A rat is not a rat is not a rat…. Table 2.

Weaknesses of IPM for Rats

- Depends primarily on chemicals
- Increasing resistance to chemical use
  e.g. clean & green image for export
- IPM based on insects & weeds
  - confusion re biological aspects IPM
- Social behaviour more complex
- Insufficient effort on biology of pest
  - many rodent spp treated similarly

Ecologically-Based Rodent Management - the Principles

- Safety, profitability & durability
- Stronger focus on biology
- Key is population biology of pest
  - processes of population dynamics
  - how do populations respond to management
- More appropriate for rodents
- Builds on IPM not replacing

Community Trap Barrier System

- Concept of CTBS plus a lure crop (including halo effect)
- Examples of findings and benefit-cost from Indonesia and Vietnam – see Singleton et al 1999 for overview.
- Need for community approach
- Rules for construction – (see ACIAR Research Note on IRRI Knowledge Bank)
  - Fence is a minimum of 60 cm above the ground and dug 10 cm into the ground
  - Multiple-capture traps must be well constructed, especially the cone through which the rats enter
  - Traps must be flush with the fence – rats will use any small gap to enter the enclosure or gnaw to enlarge any small holes
  - Good access to the trap entrance – construct earth mounds partway across the moat, leading to traps
  - Plant the lure crop 2 to 3 weeks before the surrounding crop
- Rules for location: within a crop (0.5 m moat); 1 per 10 ha
- Rules for maintenance
  - Empty the traps early each morning
  - Check the plastic barrier for holes each day and either repair these or install extra traps at the holes
  - Keep the moat free of grass (rats can use this to climb over the fence)
  - Cover traps with straw and supply food to keep rats in good condition (the smell of dead rats will discourage other rats from entering traps)
- Challenges associated with using CTBS
  - Community effort required for maximum effect
  - Daily checking of traps during cropping season
  - Access to water to grow lure crop 2 to 3 weeks early

Ecologically-based INTEGRATED management at COMMUNITY level

- CTBS as simple technology to promote community rodent management
- MUST implement other routine community management actions
  - hygiene around villages
  - keep cover low along the banks of main irrigation canals and control rats along these canals (digging; fumigation or rodenticide)
  - smaller bunds/banks should be less than 300 mm high and wide to reduce likelihood that rats will use them for nesting sites
  - synchrony of cropping (extremely IMPORTANT)
  - rat campaigns at key times

Table 2. Different species indicate different biology and the need to develop specific management programs.

	Distribution	**Nesting Habit**	**Feeding Habit**	**Eruptive**	**Vector of Plague**	**Neophobia**	**Food Informants**	Warfarin susceptible
Rattus rattus	global	houses	trees, fields, buildings	moderate	yes	?	low	
Rattus norvegicus	global	subterranean	buildings	moderate	rare	yes	high	
Mus domesticus	global	subterranean buildings	fields, buildings	high	no	rare	low	
Rattus argentiventer	Asia	subterranean	fields	high	?	?	high?	
Mastomys natalensis	Afrika	subterranean	fields	high	yes	?	high	

Rodent impacts and management

Overview of methods of management

During the IPM course this session begins with an overview of a range of control actions and then asks participants in the course to share their knowledge of actions of rodent management in their countries and regions.

Overview of methods of management:

- various snare and live-traps, usually made of bamboo, that choke a rat or break its back
- bamboo tubes - simply offer cover for rats and either they get stuck or they are caught alive and emptied into a bag.
- digging of burrows to kill rats *in situ*; occasionally dogs are used to locate burrows or to help hunt rats flushed from burrows.
- rat drives or battues – where rats are driven from cover and herded towards nets.
- stalking at night with a kerosene light and a net at the end of a long handle – in Co Dung village of Hai Duong province in Vietnam, farmers apply this method from 1900-2200 hrs at specific times of the year.
- electrocution – electrical wire is strung the length of a rice crop about 10-50 mm above a flooded paddy, wet rats that make contact with the wire are quickly killed. As indicated below, this method presents an unacceptably high risk to human health.
- physical barriers – these usually consist of plastic or metal sheeting and are placed around or along the borders of crops or around areas where grain is stored.
- physical barriers plus traps – live-multiple-capture traps are inserted intermittently at the base of a physical barrier. The traps are placed against small holes in the barrier. Rats enter the traps, attracted to the developing crop or stored food that is on the other side of the barrier (see section 1 for details).
- metal rat guards – sheets of metal are wrapped around the trunk of a tree, higher than 1 m from the ground, to prevent rodents from climbing trees to access fruits. The design of the guards depends on the climbing habits of the rodent species, some are flat against the tree, whilst others are conical or circular metal sleeves, flush with the trunk of the tree but projecting outwards at, or less than, 90° from the trunk.
- scaring devices – white cloth or plastic is attached to a bamboo pole approximately 1.2 to 1.5 m high. The white material flapping in the wind supposedly mimics the flight of owls and therefore frightens rats away from the immediate vicinity. These “scare-owls” are erected in ripening crops where rat damage is evident.
- Chemical control – covered in section 3
- Biological control – covered in section 3

Open forum to share experiences of:

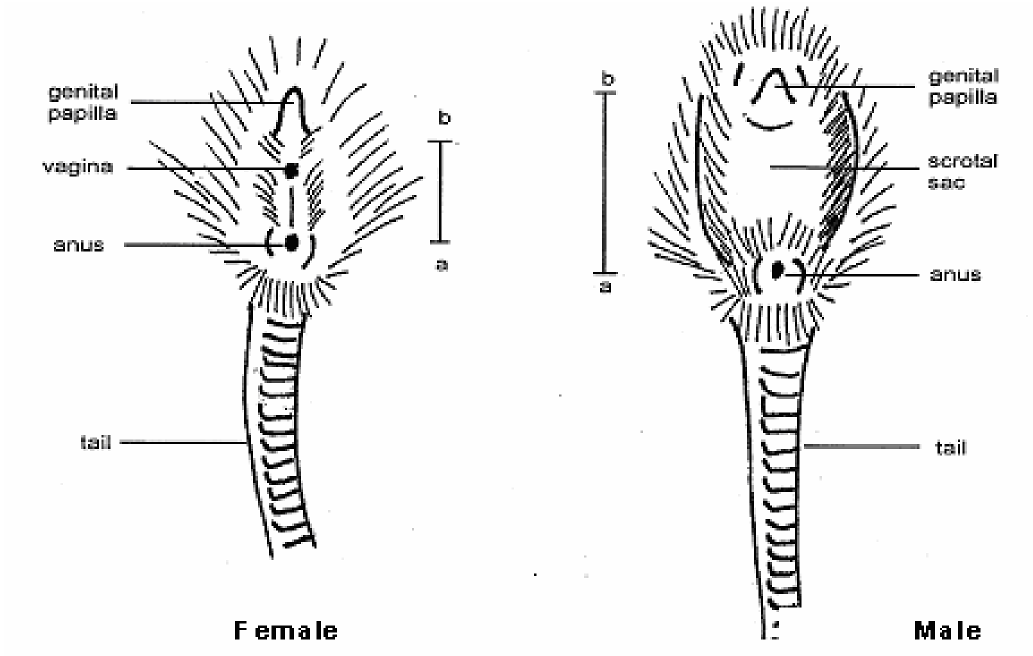
(i) Rodent impacts in different countries please elaborate in briefRodent impacts in different agro-ecosystems please elaborate in brief

(ii) Methods of management in different countries please elaborate in brief
The session concludes with some simple tools regarding problem definition of rodent problems in rural communities. These methods (decision analysis and problem definition) are covered in Norton and Pech (1988).

Ecology of rats

Taxonomy and reproductive biology of rats

- General characteristics of a rodent – Most rodents are small, weighing 150g (5.0oz) or less (see Figure 1). There are only a few large species of which the largest, the capybara, may weigh up to 66kg (146lb). All rodents have characteristic teeth, including a single pair of razor-sharp incisors. With these teeth the rodent can gnaw through the toughest of husks, pods and shells. The name "rodent" comes from the Latin rodere, which means to gnaw. Gnawing is facilitated by a sizable gap, called the diastema, immediately behind the incisors, into which the lips can be drawn, so sealing off the mouth from inedible fragments dislodged by the incisors. Rodents have no canine teeth, but they do possess a substantial battery of molar teeth by which all food is finely ground. Convoluted layers of enamel traverse these often massive and complexly structured teeth. The pattern made by these layers is often of taxonomic significance. Most rodents have no more than 22 teeth, though one exception is the Silvery mole-rat from Central and East Africa which has 28. (see Singleton and Dickman 2001)
- Introduction of key species for different regions of Asia – see summary Table 3
- Use of taxonomic key and link to resources – the CSIRO Rodent Group has produced a rodent key specific for rodents in agricultural landscapes in Lao PDR. A CD ROM using LUCID software is currently under development. Course participants will be shown key characteristics for distinguishing rodent species and then work through a dichotomous key. (Practical)
- How to sex a rat - The sex of adult mice is normally easy to determine, as scrotal sacs, vaginas and teats are all quite obvious, especially during the breeding season. The distance between the genital papilla and the anus (a---b in the diagram) is always greater in males. It is more difficult to determine the sex of a juvenile as the sexual organs are much less obvious. The best way to differentiate is to compare the distance between the anus and the genital papilla. In addition, there is usually a distinct furless line between the vagina and the anus on female rodents.
- Determination of breeding condition of females



Vagina
The vagina will be open if the animal has recently mated (the opening may be small or large) or closed if the animal has never mated or has mated, but not recently.
Occasionally, there will be a *vaginal plug* which looks like a wax stopper in the vaginal opening. This indicates that the mouse has mated in the last 24 hours. Teats

Teats
Teats should be visible on females in breeding condition. To check, blow the fur away from the body or gently rub the fur back with a finger.
If the teats cannot be found the animal is either too young or not in breeding condition.
If the teats are visible but small and surrounded by fur the animal is not lactating.
If the teats are obvious and there is no fur at the base the animal is lactating. Milk can sometimes be expressed at this stage, or dried milk can be seen on or around the teat.

Pregnancy by palpation
When palpating a mouse, hold the mouse in one hand and let the intestine and uterus move between the thumb and index finger. Embryos are smooth to the touch and faeces rough.

Breeding ecology - linked to rice cropping cycle

Ricefield rat (Rattus argentiventer) as a case study

- Basic breeding biology – pregnant for 19-21 days; post-partem oestrus; can give birth every 3 weeks; young reach maturity around 6 weeks of age
- One crop per year then one breeding season; two crops two breeding seasons
- Breeding cued to the stage of the rice crop
- Average litter size around 12
- One female can potentially produce 36 young in one cropping season

Response of the ricefield rat to extension of cropping season by more than two weeks

- Extension of breeding season by >2 weeks will lead to one female producing up to 120 young.

Movement of rats

- Home ranges for males around 3 ha
- Home ranges for females around 2 ha
- Nightly movements up to 500 m

Figure 1: Rodents and Asia

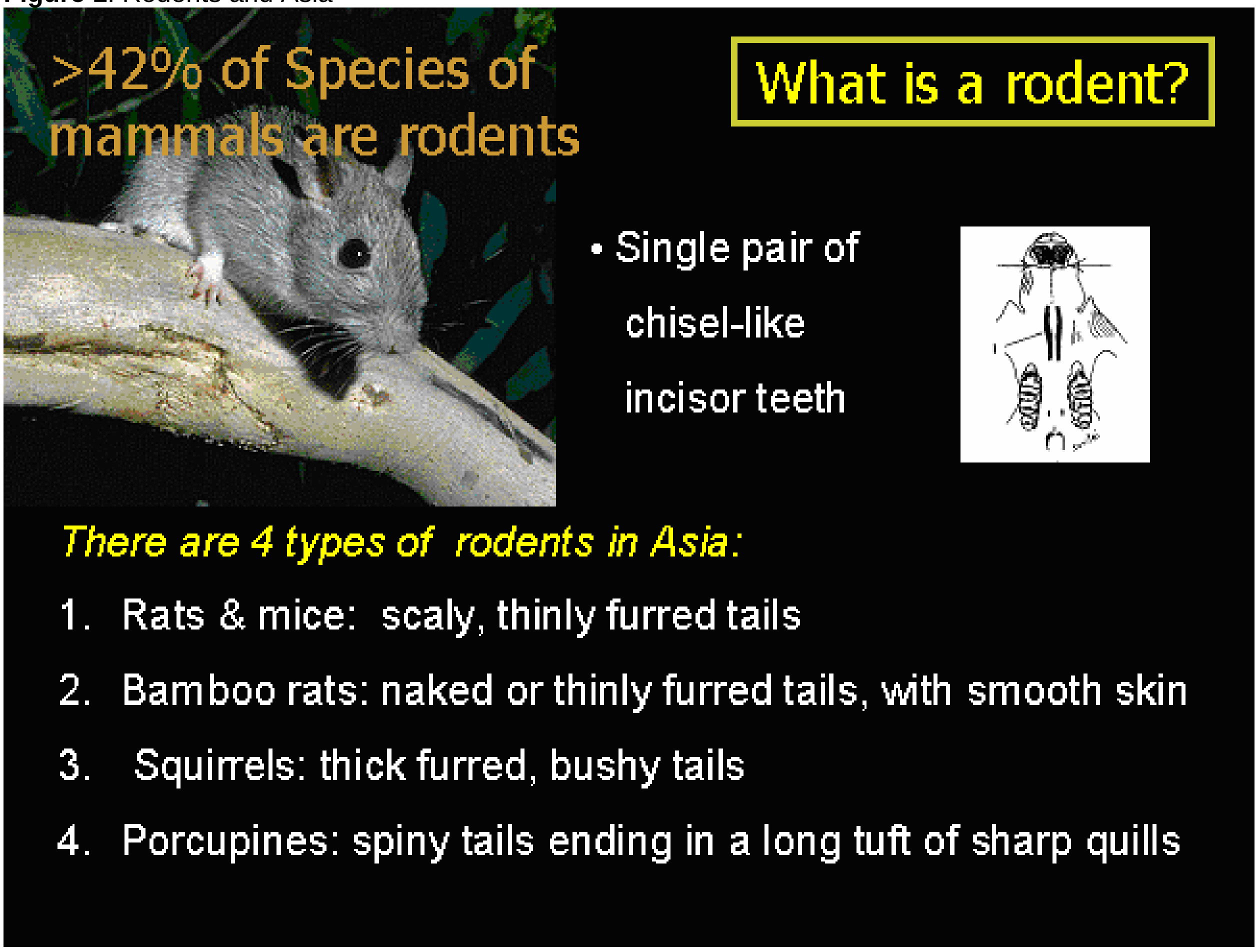


Table 3. Major pest species of rodents and their impacts in Asia.

Pest species	Region	Crops affected	Impact on agricultural production
Rattus argentiventer; *R. losea.*	SE Asia	Rice	Indonesia: 10-20% Malaysia: 2-5% Vietnam: >10% to >500,000 ha Thailand: 6% lowland; 7% upland
Rattus rattus; *R. tanezumi* *Other Rattus spp.*	SE Asia	Rice, sorghum, tuber crops	Lao PDR (upland crops): 10-15%; up to 100% in outbreak years Cambodia: (patchy, no data) Philippines: (patchy) 1-10%; up to 40% at district level
Bandicota bengalensis; *B. indica* *Mus spp.*	South Asia	All cereals and tuber crops	India, Bangladesh: 5-10%; some years >50% at district level
Microtus brandtii *Meriones unguiculatus* *Mysopalax baileyi.*	China	Grasslands	Inner Mongolia: 15-44% Qinghai-Tibet: 0.37 million km2 badly affected
Cricetulus spp *Microtus spp* *Rattus spp* *Myospalax fontanieri.*	China	All cereal; vegetable; nuts	15 million tonne: 5-10%

Habitat use

- During tillering – 75% of time rats were in burrows along banks.
- After maximum tillering – 65% of time rats were in rice paddies.
- Major channels and around village gardens are prime habitats during fallow.
- We need to understand the spatial distribution of rats and their burrow for management of rodent populations.
- Need to understand the dynamics (seasonality) of habitat use. elaborate?

  For example, in Indonesia, monthly trapping of rodents in 5 different habitats indicated that village gardens and the banks of main canals were important breeding habitats (source habitats) for rats. Rat campaigns conducted the week after the rice crops are transplanted are directed at these two habitats. This is when rats aggregate into these habitats following the disturbance of cropping lands during land preparation and planting of the rice crop, AND before the rats begin breeding.

Factors that influence mortality

- Minimum of 2 month fallow between crops (food and cover) reduces the amount of favourable habitat in an agricultural landscape for rodents to survive between breeding seasons.
- Flooding of major habitats in lowland environments may lead to poor survival of rats during the monsoon season. For example, flood waters are critical in re-setting the system at low rat population densities each year in some provinces of the Mekong delta in south Vietnam.
- Predators – there is circumstantial evidence that predators such as barn owls can have an important impact on rodent populations, especially when artificial nest boxes have been provided. However, these studies lack appropriate controls and have not examined possible compensation of rodent populations through better survival and breeding performance of those rats that survive.
- Disease – too few studies have examined the relationship between disease and rodent population dynamics.

Effect of changes in farming systems on rodent population dynamics

- Vietnam in the Mekong delta - In Vietnam, rodents have escalated in their impact on rice production over the past decade. Rodent damage to rice has increased from 63,000 ha affected in 1995 to 600,000 ha in 1998. This increase coincided with farmers changing from growing one rice crop per year to two rice crops, or from two to three rice crops per year. The ricefield rat, *Rattus argentiventer*, has responded positively to these changes in farming systems because their breeding is strongly associated with the stage of the rice crop. If there is one rice crop grown in a region in a year they have one breeding season. If three crops are grown they have three breeding seasons!

Association between damage to rice crops and density of rats

- People often assume that there is a linear response between damage to rice crops and the density of rodent populations. This is probably not the case except at lower damage levels. The few data that are available indicate a curvi-linear response with damage levels beginning to plateau once damage levels are higher than 25%.
- This association sets the level of population reduction required for effective management. For example, if a farmer waits until rodent losses are around 20% before applying control, he would have to kill move than 85% of the rat population before he could lower the population sufficiently to reduce further damage to his crop at around 5%.
- Highlights the need for early tactical management rather than reactive management later in the season
- The association between damage to a crop and loss of crop yield is also an important relationship. Often measures of rodent damage to a crop are done just prior to harvest. However, this will only record the most recent damage to tillers (perhaps the previous week). The limited data available indicate that if you score the percentage of tillers damaged just prior to harvest, then estimates of yield loss can be calculated by multiplying by about 4. So 3% tiller damage at ripening is equal to about a 12% loss in yield.

Compensation by rat populations to mortality control

- Better survival of remaining animals
- Better breeding performance and success in rearing young
- Immigration

Case study - Bounty systems: Examples from Vietnam and Lao PDR (see Singleton et al 1999 for more details)

Reasons for failure of bounty systems:

- Fraud – schemes are abused by people they are supposed to serve.
- Harvesting mentality – bounties are seen as an ongoing source of income rather than a control measure.
- Inefficiency of control – financial incentives promote management systems which provide bodies of animals; as discussed above, there are generally more efficient methods for control.
- Compensatory growth by pest populations – unless more than 50% of a pest population is removed by a bounty, then at best, the pest population will maintain numbers through enhanced survival, higher rates of immigration from uncontrolled areas and better reproductive performance.
- Inadequate benchmarks for success – few programs have appropriate success criteria and so they continue from one campaign to the next with the sole criteria being that they caught heaps of animals doing it this way last time.

Conservation consequences of non-specificity – any tail of a rat will provide a payment. Often there are rodent species that are not pests of rice being killed for the rodent bounty.

Economic analyses required

- assess benefit-cost association
- assess foregone opportunity cost – could the money spent on bounty systems be put to better use for rodent management?

Smart-bounty system

- Restricted season for bounty based on our ecological understanding of the best time and the best habitats for conducting lethal control.

Population estimates

Indices of abundance – active burrow entrances, catch per unit effort, capture-mark-release-recapture, tracking tiles, census cards, etc

Behavior

Rodents are intelligent and can master simple tasks for obtaining food. They can be readily conditioned, and easily learn to avoid fast-acting poisoned baits, often through communication (via carbon disulphide) with other rats. They associate sick rats with foods that those rats had eaten recently and then will avoid those foods. The social organisation of behavior of rodents is amazingly complex within the Rodentia family. Those rodents that are pest species often have an ability to adapt their social organisation to specific circumstances.

- Vision – their vision is poor and they are color blind; only distinguishing shades of gray
- Sound – communication between mother and young is by highly pitched sounds that often are beyond detection of humans. This has led to the development of ultra-sonic devices to control rodents through interfering with their communication, etc. However, rodents quickly adapt to such noise in their environment.
- Smell and touch – rodents rely strongly on an acute sense of smell and also the use of long, touch-sensitive whiskers (vibrissae). Both of these senses assist them in their navigation of their environment and also in locating food from afar.
- Neophobia – many rodent species have a fear of new objects and will avoid them (neophobia). Other rodent species are inquisitive and will explore new objects and foods in their environment (neophilia). *Rattus rattus* and *Rattus argentiventer* are neophobic species and the house mouse *Mus domesticus* is neophilic. Knowing this is very important when developing baiting and trapping strategies for controlling rodents. (see Table 2)

Biological Control of Rodents

Problems of Rodenticide-Based Control

There is a growing demand, particularly in developing countries, for rodent control strategies that either have less reliance on chemical rodenticides or promote better use patterns resulting in lower costs for control, minimal risk of contamination of produce and reduced non-target risks. This demand is driven by three main factors. One is the high cost associated with the persistent use of rodenticides prior to or during the growing of each rice crop. The second is the environmental concerns associated with using chemical rodenticides given their ability to cause both primary and secondary poisoning of a wide range of species of mammals and birds. The third is the domestic and international marketing requirements for clean agricultural produce that is produced in an environmentally-friendly and sustainable manner.

Buckle and Smith (1994), and Buckle (1999) provide thorough reviews of the diversity and use of rodenticides for managing rodent populations.

Acute poisons (ZnPh; 1080; etc)

- efficacy depends on the species and poison that is used
- all cause risk of primary poisoning to non-target species; the secondary poison risks (when other animals consume poisoned rats) depends on how quickly the poisons are broken down.
- lack of antidote
- learned bait aversion

Chronic poisons (anti-coagulants)

- efficacy depends on the species and poison that is used; usually higher than acute poisons
- first (multiple feeds required) and second generation (one feed only required) poisons have been developed
- risk to non-target species through secondary poisoning is higher in the second generation poisons
- vitamin K as an antidote
- no learned bait aversion because it takes a rodent 3-7 days to die after eating the poison
- baiting strategies (continuous baiting programs versus pulse baiting; frequency of checking and applying baits; decision rules when to apply and when to cease application)

Use of bait stations

- minimise primary poisoning of non-target species
- protect for rain
- overcome fear of feeding on new food in their environment by free-feeding before using the poison
- where to place them in the habitat is important and depends on cropping system and behaviour and habitat use of rodent species.

Bio-cides

- Salmonella-based rodenticide (e.g. Biorat); this is used in Cuba, central America and some countries in SE Asia. This product is claimed to be specific to rodents. The data on field efficacy (particularly the shelf life of baits under humid, tropical conditions) is sparse.
- Sarcocystis (see Jaekel et al 1996)
  This is a potential control method that takes advantage of snakes being the definitive host and rodents the intermediate host, and that high doses of the sporocycts that infect rats can kill them. Pythons can be easily reared and fed infected rats to then become a sporocyst factory for producing sarcosystis in rats. The sporocysts have to be delivered in a rodent bait and at high levels of infection. There is residual transmission of sarcocystis to other uninfected rats but not at a sufficiently high enough level to kill them. Hence this is a neat system that fits under the bio-cide label.

The life cycle is nicely described in Boonsong et al. 1999:
Sporocysts of this parasite are shed in faeces of a pythons. Only rats appear to be susceptible to infection through the oral route using sporocysts containing sporozoites, the stage infective for the intermediate host. Infection of rats is usually followed by two rounds of asexual multiplication inside endothelial cells of various organs; a process by which merozoites are formed. About one month after infection, merozoites eventually invade the muscles to form characteristic cysts (so-called sarcocysts) in muscles which contain a third stage, the bradyzoite. Bradyzoites are infective for pythons once the snake preys on rodents. And so the cycle is continued.

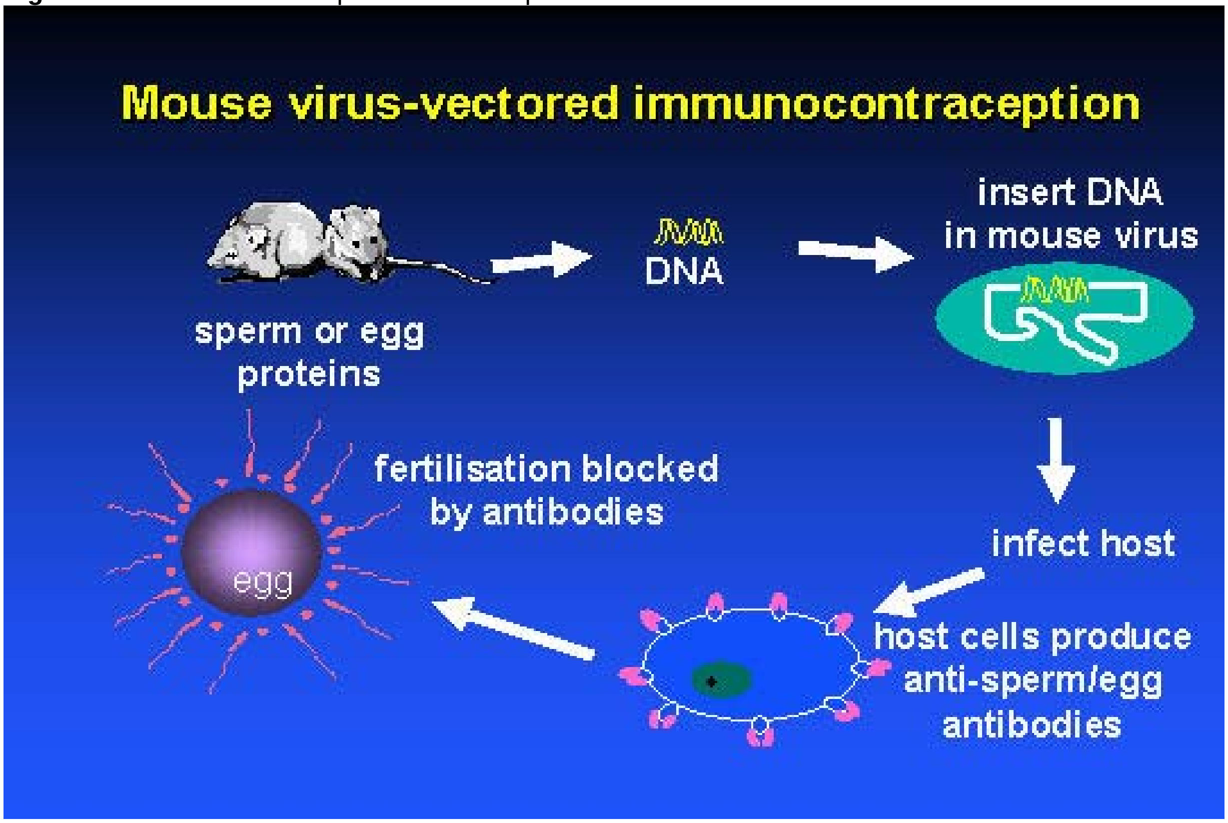
Further studies are being conducted in Thailand, where the focus is on commercialization of this biocide.

Biological control - Fertility control

There are two lines of research: fertility control using either a non-infectious agent delivered in non-toxic oral baits, or infectious viruses as carriers of an infertility agent. In both cases the aim is to vaccinate the animal by delivering an antigen (a reproductive protein) that generates an immune response, with antibodies in the female host blocking fertilisation. In effect the goal is to develop an immunocontraceptive vaccine. Such immunocontraceptive approaches are potentially highly species-specific, are considered humane and are likely to be cost effective in the long term.

Initial research focused on gamete antigens, particularly sperm antigens. However, after several potential sperm antigens had been tested by direct immunisation with minimal effect on the fertility of female rabbits, foxes, and mice, attention turned to the female gamete antigens. Of particular interest are the zona pellucida proteins forming the extracellular coat of the oocyte.

Figure 2: Immuno-contraception: the concept



- proof of concept: house mouse in Australia (see Chambers et al. 1999)
- require ecological context (sets parameters of how many animals need to be sterilized; how and when to distribute; what are likely affects of non-responders or resistance)

Biological control - Predation

Claims of success (mainly barn owls) are not backed up with well controlled and replicated field experiments. More field research is required, especially in an ecological context: to provide experimental data on numeric and functional response of predators and prey.

Management of rodents: ecosystem context

Rodents as pests versus rodents as non-pests (Dickman 1999) see Table 4. The majority (>90%) of rodent species are not pests. They play an important role in the food web and in cycling nutrients through forests and grasslands. Therefore it is important to conserve these beneficial rodents. There are clear parallels here with the development by entomologists of Integrated Pest Management of insect pests based on the fact that there are beneficial insects and that they need to be not only conserved but also be encouraged to flourish.

Some important roles of rodents as ecosystem engineers

1. Influence nutrient cycling
   - hypogeal fungi that form mycorrhizal associations
2. Promote dispersal of seeds
3. Trap seeds through modifying vegetation above ground
4. Influence water flow at micro or catchment scales
   - beaver dams; burrows
5. Provide habitats for other spp
6. Food source: predators, scavengers

Systems approach – require balance between managing pests and conserving beneficial rodents (ecological service)

Table 4. The number of species belonging to the Order Rodentia in Australia, Europe, Africa and selected countries in Asia and the Pacific, those that are considered significant pests of agriculture, and those whose conservation status is of concern (endangered, critical or vulnerable) or insufficient is known to assess the risk. (from Singleton, Brown, Jacob, Aplin and Sudarmaji (In press)).

Continent or country	Number of species of rodents	Rodent species that damage crops	Significant pest species in cropping systems	Conservation status	
				At risk	Little known
Africa	381	77[2]	12-20[3]	60	11
Australia	67	7	4	14	1
Europe	61	16	5	4	
India	128	18	12 (5 wide distribution7 restricted distribution)	21	1
Indonesia (not Irian Jaya)	164	25+	13	11+	28+
Lao PDR	53	12+	4-8	4	14+
New Guinea (not Bismarck or Solomon Is)	73	10+	6	0	9+

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Learning Activities

Key class questions or exercise

Key activities (Class and/or laboratory and/or field)

- Lecture
- Interaction during lecture
- Discussion
- Field visit and demonstration of rodent management activities
- Practical - rodent identification, sample collection, preparation for museum specimens and preservation of material for DNA sequencing.

Review questions/activities used to evaluate learning

- What is the level of impact of rodents in rice cropping systems? What role do rodents play in human disease?
- What are the basic principles of rodent IPM? What is the reality?
- Why are community actions essential for rodent management? What are the key factors for an effective use of a community trap-barrier system?
- Why is it important to understand the biology and ecology of individual rodent species?
- What are some of the key factors that influence survival and breeding of rodents in rice agricultural systems?
- Most rodent species are not pests – discuss whether they serve any useful function.
- What is the association between crop damage and rodent density; crop damage and yield loss?

Training Aids and Facilities Needed

Computer
Multimedia projector
Board and pens
ABS/TBS/CTBS set-up in the field for demonstration
Different kinds of rat traps
Flamethrower
Rodents for using against a taxonomic key; assessing breeding status