CHAPTER 10

The 'human factor' in rodent management studies

Introduction

In Chapter 1, we suggested that the viability of any rodent management option should be judged against each of three criteria:

- ecological sustainability
- cultural acceptability
- socioeconomic sustainability.

So far in this volume, we have focused on methods that will allow you to gather information relevant to the first and last (in part) of these criteria. In this chapter, we introduce some methods that should allow you to explore the cultural and socioeconomic context of rodent management. Our treatment of these methods is much less comprehensive than for the biological and agricultural methods. This is partly because we do not have specific expertise in these fields. However, it is also because the consideration of cultural and socioeconomic factors is a relatively new development in the area of agricultural research in general, and even more so in the field of rodent management. We hope that publications listed under Further reading will provide interested readers with a pathway into relevant literature.

A conceptual framework

We can learn much about cultural and social issues by listening to what people say and by observing what they do. In the context of rodent management projects, where the research phase is often of quite short duration, the challenge is to organise and interpret these observations in ways that help us to understand why people would choose to take certain actions and not others.

A useful conceptual framework is available from previous studies of farmers' beliefs and associated decision-making behaviour in relation to insect pest management. These studies in turn draw upon a much larger body of theoretical literature related to **decision-making** as a process or system.

Two simple flow models help to illustrate how decision-making theory can help make sense of human behaviour. The first is an example of what is termed a 'belief model'. It illustrates the notion that people's behaviour is influenced by their perceptions of risks and benefits associated with particular pests and management actions. Each of the four major components of this model (Figure 10.1) can be quantified to some extent, either by calculating the monetary value of potential benefits or losses, or by ranking the importance of various influences on a subjective scale (i.e. as more or less important).

The second model illustrates a broader 'theory of reasoned action' (Figure 10.2). This model emphasises the social context of human behaviour by indicating that a person's behaviour is often a compromise between what they would like to do, based on their personal preferences, and what they feel they 'should' do, based on the beliefs, attitudes and values of other family members, neighbours and the wider society. This compromise is mediated by the strength of each individual's motivation to comply with the societal pressures or 'norms'.

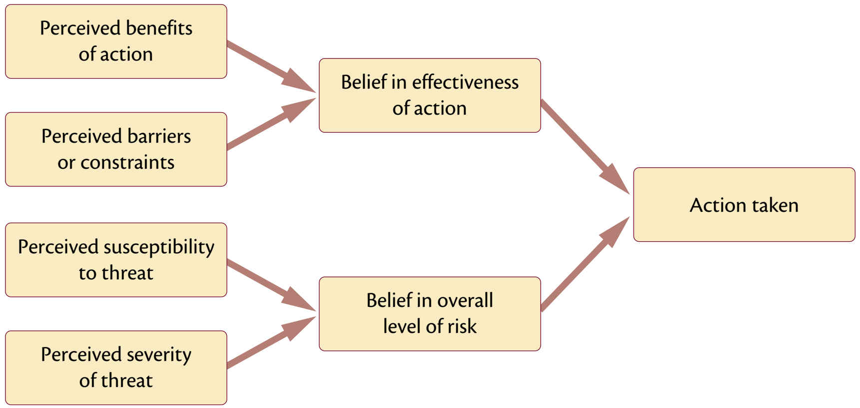

Figure 10.1 Belief model designed for studying behaviour in regard to pest management (modified from Heong and Escalada 1999, Fig. 1).

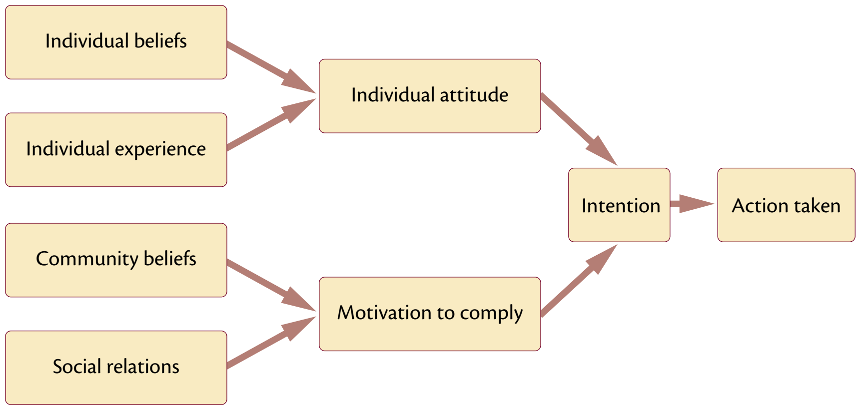

Figure 10.2 Behavioural model based on the theory of reasoned action (modified from Heong and Escalada 1999, Fig. 2).

Some basic tools and methods

Many of the tools and methods that we recommend for exploring the socioeconomic and cultural issues associated with rodent management have a long history of use in the field of participatory research (see Box 10.1). A good general introduction to participatory methods is found in another recent ACIAR monograph (see Further reading: Horne and Stur 2003).

An important aspect of participatory methods is that they allow community members to contribute both to the recognition of problems and to the development of solutions. This creates a sense of ownership and understanding that builds their confidence and capacity for learning. The participatory methods also may help build a close relationship among the team members, such that improved communication can take place in an atmosphere of mutual trust and respect.

Community resource maps

These are a good way to begin in a new project area. You will need large pieces of paper and pens or crayons. Invite a small, representative group of local community members (a 'focus group') to draw a map of the important physical features and resources used by their community. This would normally include infrastructure, such as buildings, roads and canals, and the location of major cropping areas. It should also include features that are particularly important to rodent ecology, such as food storage areas and any areas that people regard as significant breeding habitat. A number of different people should be asked to contribute to the map in order to achieve a balanced representation of local resources (Figure 10.3). The process of compiling the map itself may help you understand how local resources are structured and accessed by different groups within the community and how different people perceive the nature of their rodent problems. The completed map also can be used as a reference point for subsequent activities such as construction of the seasonal calendar and in problem diagnosis.

Box 10.1 Participatory approaches to research

Participatory approaches to agricultural research and development (R&D) arose in the 1980s as it became clear that the adoption of various new technologies by farming communities—especially in traditional smallholder farming systems—was not always as rapid or as high as expected by those who developed them. Researchers started to question whether the traditional R&D approach, where scientists develop new crops or associated methods on research farms and then 'release' them into the wider world, was really the most effective way to help the rural poor. Might it not be better to first consult with farmers about their problems and priorities, and perhaps even to explore the appropriateness of possible solutions before investing time and effort into their development?

From these early steps, a whole new area of research methodology has developed within which we can distinguish various contrasting approaches, such as farmer participatory research (FPR), action research (AR), adaptive management (AM), and even active adaptive management (AAM). These methods share a common emphasis on interaction between the developers and the potential users of proposed new technology or practices, but they differ in two main respects. The first is the nature and extent of the interaction among the various stakeholders (researchers, extension staff, users), which ranges from a process of consultation through to a true partnership or collaboration. The second is the nature of the research process itself, which follows fairly traditional lines (i.e. hypothesis formulation and testing) under FPR, but leans towards the immediate implementation and progressive readjustment of management actions under AR, AM and AAM. However, it is generally agreed by those working in the area that there is no one 'right' way to do participatory research and that the choice of method should depend on both the goals and objectives of the project and the particular socio-cultural context.

Figure 10.3 Participants conferring on their community resource (village) map during a focus-group session in Cambodia.

Seasonal calendars

A seasonal calendar is a simple graphical representation of the important environmental, agricultural and social events that take place during the course of a typical year. The same group of community members that produces the village resource map often produces the seasonal calendar. The same basic materials are required.

A good way to start is to ask when the new 'year' is thought to begin—this may be the planting time of a particular crop, or it may some astrological event such as Lunar New Year. Using this as a starting point, draw a matrix with months along the top. Then invite the focus group to identify the major crop types and write these down the margin. For each of the crop types, the growing phases and associated activities should be recorded month-by-month across the page. For example, in a lowland rice crop production area, the major growth phases are tillering, panicle initiation, ripening etc., and the key activities would typically include seed-bed construction, land preparation, transplanting, weeding, harvest, and threshing. At this stage, it may be useful to ask participants to indicate the timing and severity of rodent and other pest damage in relation to each crop. Because these problems are often more severe in some places than others, it may be useful to relate these observations back to the community resource map (Figure 10.4). At the same time, you might ask general questions about the methods that people are currently using to manage rodents in the various habitats.

Figure 10.4 Cambodian focus-group participants relating their seasonal calendar back to their community resource map.

Major environmental events such as the start of the wet season and likely periods of flooding or water shortage should also be recorded on the calendar. Finally, the calendar should record other key activities that might require significant investment of labour or cash (e.g. fishing, craft activities) or periods of involvement in social activities such a festivals or community work.

Historical calendars

A historical calendar attempts to document some of the major events or changes that have affected a community's livelihood in the recent past. A first draft is often produced in the context of a focus-group meeting, but the calendar can be revisited many times on the basis of new information from as many different individuals as possible. Individual interviews should be sought with the oldest men and women in the community.

A good way to begin is to ask about the visible infrastructure. When did the community come to occupy its current location? When was the school built? By referring to the community resource map, you could ask when certain resources were developed (e.g. when a canal was built, when a particular cropping area was established). A next step could be to ask about major environmental events such as major floods, serious droughts, or particularly extensive forest fires. In many upland areas of Southeast Asia, people will often identify major rodent outbreaks as a kind of historical disaster, but at least in the first instance, you should not prompt such observations but rather allow them to emerge. It is natural for people to emphasise what the particular researcher wishes to hear, hence it is important to avoid leading questions.

In many areas, major political events and associated displacement or movement of people may also have played a major role in shaping the present cultural landscape. You may need to explore these factors in a sensitive manner and perhaps through individual interviews rather than in a group context.

Once the general history of the community is established, you might then inquire about some of the more subtle changes that may have affected people's livelihoods. How has their access to markets changed over the years? Have they been placing more emphasis on certain crops at the expense of others? Have they changed their residential pattern or style of housing or storage of foods? What kinds of rodent control activities did people practise in the past as compared to now? For each of the important changes or trends, you should try to establish a general time frame for the events.

Decision analysis matrices

A decision analysis matrix is simple tool for obtaining an overview of the factors that influence decisions by farmers on their current actions of rodent management. This activity is best done at a focus-group meeting. Ask the farmers to list the type of management actions they use to control rodents. This list should include occasional actions, including those that are only used in years when rat numbers are very high.

Once a basic action list is developed, ask the farmers—for each action—when it is taken, where it is taken (including scale of action), by whom is it done (individual male and/or female farmers; groups; the whole community), whether it is affordable (in terms of economic benefits versus cost), whether it is feasible (e.g. labour available at the right time; water available for early planted crops to attract rats), whether it is socially and politically acceptable (likely response of neighbours, the wider local community and the government), and whether it has any environmental impact (beneficial or adverse). An example is shown in Table 10.1. Enter the information into a large-format table that everyone can read. Encourage people to comment on the information at any stage during the process.

Once the table is complete, ask the focus-group participants to prioritise the current management actions. Which ones do they consider the most important overall for rodent management, and which ones are less important? The ensuing discussion about priorities will often provide important insights into why certain decisions are made by individuals or by the community as a whole.

Table 10.1 Decision analysis for San Jacinto/San Jose, Pangasinan Province, the Philippines, of current actions plus proposed use of a community trap–barrier system (CTBS). Note that the scale of most actions is currently at the individual farmer level.

Actions (what)	Timing (when)?	Who?	Where?	Feasible?	Affordable?	Socially OK?	Politically OK?	Environmentally OK?	Priority
1. Maintain cleanliness (banks, villages etc.)	Year-round	Farmer	Whole village	Yes	Yes	Yes	Yes	Yes	High
2. Rat hunt (dig/flood burrows)	Oct/Nov	Farmer	Major banks	Yes	Yes	Yes	Yes	Yes	Medium
3. Rat drive	Oct/Nov & Mar/Apr	Community	Major banks, long grass	Yes	Yes	Yes	Yes	Yes	Medium
4. Small dikes	Land preparation	Farmer	Small banks	Yes	Yes	Yes	Yes	Yes	High
5. Zinc phosphide	Before harvest	Farmer	Rice fields	?	If >5% loss	?	Yes	No	Medium
6. Racumin	Before harvest	Farmer	Rice fields	?	If >5% loss	?	Yes	No	Low
7. Biological control	Year-round	Farmer	Rice fields	Yes	Yes	Yes	Yes	Yes	High
8. Rat traps	Year-round	Farmer	Rice fields	Yes	Yes	Yes	Yes	Yes	Medium
9. Fumigation	Dry season after harvest	Farmer	Banks	Yes	Yes	No	Yes	Yes	Low
10. Crop timing	Planting	Community	Whole village	Yes	Yes	Yes?[a]	Yes	Yes	High
11. CTBS	2–3 weeks before main crops	Community	Whole village	Yes[b]	Yes	Yes	Yes	Yes	High

[a] Price of rice could drop if everyone harvests at the same time.

[b] Depends on the availability of early irrigation water.

Social mapping and wealth analysis

In many societies, there are obvious differences in livelihood status between individuals or between families. If your goal is to improve the livelihood security of all, or most, members of a community, then it is important that you try to understand the basis of these differences. Knowledge about the social and economic structure of a community should help you to develop new approaches that are appropriate to the resources of the wider community and which do not further disadvantage those who are already worst off.

The pattern of social organisation of rural communities is often highly complex, with a number of parallel systems based on ethnicity, systems of familial descent through either male or female lines, and systems of official accreditation based on government appointments (e.g. village headship, teachers). In addition, communities that have received people from other regions as a result of dislocation sometimes have an added historical element (poorer families have often arrived most recently). Many, though not necessarily all, of these factors may influence a family's degree of access to particular resources such as land, water or labour.

Wealth is generated and controlled within a traditional social system, but wealth can also alter the traditional balance. Increasing access to market economies can sometimes allow people to gain access to external funds (e.g. through the sale of craft materials) which can then be used to gain access to new resources such as hired labour and improved quality seed. In many societies, the systems of social and economic influence are going through a process of rapid change.

Social mapping and wealth analysis are two tools that can help you to understand the complex socioeconomic relationships within and between communities. The challenge in a new project is to quickly identify the most critical opportunities and constraints, but to do so without impinging on sensitive issues.

A good way to begin with social mapping is to ask specific questions about the community resource map. If a large canal passes through the cropping areas, it would be worth asking an open-ended question about usage of the irrigation water. For example—Who uses water from the canal to irrigate their crops? If the answer is that only some people do, then you can follow up with questions that are more probing—What percentage of farmers use the water? What is the relationship among the farmers in that group? A series of general questions about access to key resources should help you to build a general impression of how the community is structured. If possible, it is a good idea to test your ideas through a series of individual interviews, ideally with people representing the full socioeconomic spectrum.

Wealth analysis is a tool that can help you to understand the economic circumstances and capacity of various 'wealth groups' within a community. What is it, in terms of possessions or access to resources, that distinguishes the poorest members of the community from those who are moderately well off and those who are considered to be best off? A wealth analysis can also begin with small group discussions. You could start by asking the participants to each write down the economic attributes of the poorest and the richest families within the community. If possible, this should be done without reference to individual families. You can then assemble these results onto a larger sheet as a series of hypothetical gradients (e.g. possesses no livestock versus owns herd of water buffalo). Each of the key parameters can then be discussed in turn to identify what pathways might exist for someone who would wish to improve their livelihood status. Hypothetical discussions of this kind can reveal much about the socioeconomic dynamics of the community.

Problem-cause diagrams

A problem-cause diagram is a graphical representation of the causes and effects of a particular problem, as perceived by the members of the community. The diagram is typically developed by a focus group, with assistance from a facilitator.

You will need a large board, some cards and marker pens or crayons. The process starts with identification of a specific problem. Try to avoid making this too general (e.g. 'Rats'). In our experience, a more specific problem makes a better starting point. For example, 'Rats attack our dry season crop' or 'Rats eat our stored grain'. Write the problem on a card and stick it to the middle of the board. Then ask the focus group to identify the causes of this problem. Write each cause on a card and pin it above the problem. Oftentimes, focus-group members will be aware that the various causes are interrelated; these linkages should be discussed and indicated by connecting arrows (Figure 10.5a). When this discussion starts to become repetitive, ask the focus group to think about the effects or impacts of the problem. Write these on cards in the same manner and attach them below the problem (Figure 10.5b), again indicating any cross-links that the focus group are able to identify. Remember that this should be a representation of local perceptions of the problem, so be careful to avoid leading questions or adding your own causes, effects or linkages.

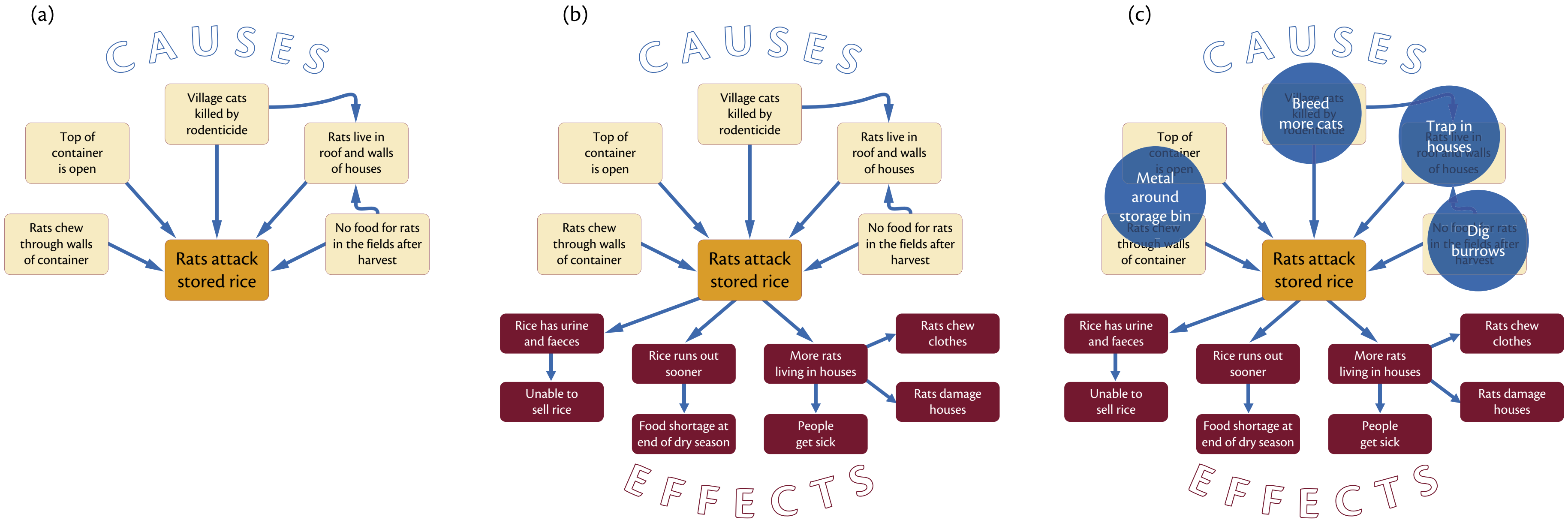

Figure 10.5 An example of a problem-cause diagram created by a focus-group around the problem 'Rats attack stored rice'. As a first step, the focus group have identified five possible causes of the problem (a), some of which are thought to be interlinked. Next, a range of impacts are identified (b), again with some perceived links. In (c), current actions are added to the diagram, the placement indicating the rationale behind each action.

Next, ask the focus group to indicate what they are currently doing to combat the specific problem. Write the current actions on cards and place these over the top of relevant causes (Figure 10.5c). As a final step, you could ask the focus group to think about any other possible actions that might have been tried but abandoned, or discussed but not tried. You could also ask the focus group to speculate as to why these other actions may not be appropriate. The completed problem-cause diagram can be shown to other groups and individual people within the community to gauge the level of representativeness of the focus-group perceptions.

Problem-cause diagrams are a useful method for exploring local knowledge and perceptions of how the agricultural and natural system works, and of finding out about current practices. They can also form a good starting point for subsequent discussions about the project. For example, you could use the diagrams to explain why a particular piece of ecological research is needed, or why certain experimental trials are being conducted. In the later stages of a project, the diagrams might also form a starting point for discussions about the possible benefits and pitfalls of potential new approaches to rodent management.

Individual, structured interviews and KAP questionnaires

The methods discussed above all begin with focus-group discussions as a way of gathering general information and forming a broad impression of the socioeconomic dynamics of a community. Although these activities can be run in ways that reduce the potential influence of one or two dominant individuals, they nonetheless rely on limited and possibly non-representative sampling of opinions within a community. One common means of increasing the sampling of community opinions is to use individual, structured interviews, based on a number of carefully framed but pre-set questions contained within a questionnaire.

One particular kind of questionnaire that has been used with some success in the field of rodent pest management explores the 'knowledge, attitudes and practices' or 'KAP' of a target community (see case studies under Further reading). The first group of questions in a typical KAP survey is designed to establish the basic socioeconomic profile of the respondent (sex, age, some basic wealth parameters). This is followed by questions that explore the respondent's knowledge of the scale and possible causes of rodent problems. Subsequent sections document the kinds of actions that are currently taken to combat these problems and the financial and other costs (actual and perceived) of these actions.

Finally, attitudes towards rodent problems and control measures are explored through questions that range from individual attitudes through to societal norms. Although all KAP surveys tend to follow a similar format, cropping systems are too diverse and cultural sensitivities too variable across the Asia–Pacific region to employ a standard questionnaire in all areas.

The information from KAP surveys can be used to assess various parameters—such as the severity of existing rodent problems, the perceived efficacy of current management actions, and the society's preparedness to try new kinds of actions. Because of the quantitative nature of the information, data from KAP surveys also can be used to compare the impact of rodent management actions on individual and societal attitudes—either by doing a 'before and after' comparison within treatment communities (where new rodent management practices are implemented) or comparing treatment communities with control communities (no change in practices).

KAP surveys usually aim to sample 100 or more respondents, with unbiased representation of males and females, and a good cross-section of 'wealth groups'. These ideals may not be possible in all societies. Wide consultation is needed before the design and implementation of a KAP survey and it is always advisable to do a 'pre-test' of a new questionnaire to make sure that the questions are appropriate in both subject matter and wording.

Pre-tests are also useful in determining how long the survey will take to conduct. Wherever possible, the survey questions and possible responses should be translated into the respondents' first language to reduce any potential for misinterpretation.

Some useful lessons already learned

Several recent rodent management studies in Southeast Asia have included an economic assessment of the various inputs (costs or investments) and outputs (benefits or outcomes), as well as a sociological assessment of the implementation of various methods by community members. These studies have produced some useful insights that you might wish to keep in mind throughout the development of a new project.

Key socioeconomic factors that affect adoption of new methods

Some of the key socioeconomic factors that are likely to influence the economic viability and sustainability of a particular rodent management strategy are listed in Table 10.1. This list is not exhaustive, but it might be a good starting point for consideration.

Examples of short-term and longer-term costs, benefits and constraints are given in Table 10.2. Short-term costs and benefits are relatively easy to quantify. Moreover, by assigning a monetary value to produce and labour, these factors usually can be expressed in terms of a common 'currency'. Similarly, the short-term constraints are usually easy to identify through many of the methods discussed above (e.g. seasonal calendars, wealth analysis).

The long-term costs and benefits of any action are far more difficult to assess. In part, this is due to the difficulty of predicting the long-term or large-scale impacts of rodent management. For example, it may be reasonable to suggest that a reduction in rodents within the fields and village environment would lead to a reduction in rodent-borne diseases such as leptospirosis, and to an increase in the health and fertility of livestock. However, it may be difficult to be assign a monetary value to improvements in human health and even more so for improvements in wider environmental health.

Another very important issue in the assessment of costs and benefits is the concept of **risk**. This in turn relates to the twin concepts of variability and

Table 10.2 A typical list of short and longer-term costs, constraints and benefits of rodent control. Not all of these factors are equally important in every situation and there may be other significant factors apart from those listed here.

	Short-term	Longer-term
Potential costs	• Financial cost of materials • Labour required for actions • Time invested in any associated social activity ('transaction' costs)	• Environmental costs (e.g. impact on non-target species)
Potential constraints	• Other demands on money • Other demands on time • Inability to coordinate actions	• Changing economic or political context • Inability to maintain necessary social structures
Potential benefits	• Increase in agricultural production • Improvement in the quality and value of harvested produce • Reduction in the postharvest loss of stored foods • Reduction in the level of contamination of stored foods • Value that can be assigned to captured rats	• Long-term benefits to human or livestock health (e.g. reduction in the impact of rodent-borne diseases) • Long-term benefits to environmental health (e.g. reduction in chemical use)

predictability. **Variability** is a normal element of all ecological systems, although both the scale or size and the degree of regularity of the changes differ greatly between systems. **Predictability**, the degree to which such variations can be forecast, can relate to either the scale or the regularity of the changes. For example, ecological changes associated with monsoonal flooding are probably quite predictable in terms of timing, but highly irregular in terms of severity. On the other hand, ecological changes that relate to wildfire activity might be predictable in terms of scale but much less predictable in terms of timing.

The economic importance of these concepts can be appreciated from an Australian rodent management example (see Box 10.2). In this case study, farmers can choose from a range of strategies that vary in their degree of associated risk.

The importance of community action and common property resources

In most situations, rodent management will be most effective if appropriate actions are taken over large areas and in a coordinated manner. Where this is not done, there is a real danger that any local impact on rodent numbers will be rapidly and literally overrun by dispersal of excess animals from any adjacent area where numbers remain high.

The application of rodent management over large areas is relatively straightforward in broadacre crop production systems where one farm owner or manager is not only responsible for deciding how and when to act but also has control over all the necessary equipment and budgets. However, across most of Southeast Asia and the Pacific, the situation is very different—the land is typically owned and managed by numerous smallholders and there may be various social and historical factors that make it difficult for people to work collectively towards effective rodent management.

Box 10.2 The economics of house mouse management in Australia

The introduced house mouse (*Mus musculus*) undergoes periodic outbreaks or 'plagues' in some wheat-growing regions of south-eastern Australia, with an average interval of seven years between these events. During plague years, mice cause huge crop losses and other damage to property. However, at other times, mouse numbers are low and they do little damage. Both the severity of plagues and the interval between them vary at any one location.

In normal years, the cost of mouse control outweighs any potential benefit in terms of damage reduction. During plague years, the reverse is always true, but the best benefit-to-cost ratios are achieved when mouse control is started early, before mouse numbers get too high. Farmers now have access to predictions based on probabilistic models, but there is a significant element of risk associated with following these predictions—the models give wrong results (either false alarms or failure to predict a plague) around 30% of the time.

Farmers who live in areas affected by mouse plagues have three main options:

- they can apply mouse control every year—this may well avoid all future plagues, but in six years out of seven they will be wasting their money
- they can apply mouse control only during the predicted plague years, but in the knowledge that these will be in error approximately 30% of the time
- they can reject mouse control altogether and hope that the losses during plague years are offset by the money saved by not applying any control.

The economic consequences of each risk management strategy can be calculated using an individual farmer's potential costs and losses.

The situation may be further complicated where the rodent management system either involves the use of a shared materials or equipment, or else depends on farmers making a contribution of money or labour to activities that will lead to shared benefits. Sociologists use the term **common property resource** in such cases where users share the 'rights' and 'benefits' of resource use, and also share the 'duties' of resource management.

One such system that has been tested in various socio-cultural contexts in Southeast Asia is the community trap–barrier system (CTBS; see Box 10.3). This system was designed and tested in lowland irrigated rice-growing systems in several Southeast Asian countries. Typically, in these regions, farmers own or manage landholdings of 1 ha or less. However, a CTBS unit set up within the boundaries of one farmer's field can be effective in reducing rat numbers and crop damage over a total surrounding area of around 10–15 ha. Hence, many families potentially share the benefits of a CTBS and might be reasonably expected to share in the material and labour costs of installing and maintaining the CTBS.

One study of the CTBS as a common property resource in the Mekong Delta region of Vietnam identified a range of sociological constraints and opportunities for sustainable application of the CTBS. Foremost among these were the social relationships and associated systems of obligation among CTBS participants, and the nature of existing institutions that emphasise cooperation, such as integrated pest management (IPM) clubs.

The role of these social and institutional factors need to be considered in each new socio-cultural context and with a keen awareness of the wider political and economic environment, including the likelihood of change.

Box 10.3 The community trap–barrier system (CTBS)

The CTBS is a physical method of rodent control that was developed to control rat damage in lowland irrigated rice systems in Indonesia, Malaysia and Vietnam. The major pest species in these systems is the rice-field rat (*Rattus argentiventer*) which times its breeding activity in these systems to match the growth and maturation stages of the rice crop. The efficiency of the CTBS system is currently being evaluated in Indonesia, Vietnam, Philippines and Cambodia, with good results to date.

The CTBS consists of a square or rectangular barrier system (typically with each side measuring 50–100 m) that encloses a lure crop (typically, a rice crop planted 2–3 weeks ahead of the surrounding cropping area). Rats are attracted to the early maturing lure crop and are captured in multiple-capture traps placed at entry points along the barrier. By drawing adult rats out of the local population before they start breeding, the rate of population increase of the remaining population is lowered, thereby avoiding the high rat densities typical of unmanaged fields. Empirical studies of crop damage around CTBS units suggest that each unit may be effective in protecting a surrounding area of 10–15 ha. In a large, uniform cropping area, CTBS units ideally would be positioned in a way that achieves overlap between the individual 'halos of protection' of each unit.

CTBS units require regular maintenance to ensure that the fence and traps are not compromised. Ideally, the cost of materials and the tasks of constructing and managing each CTBS unit are shared by all of the people who derive benefit from the unit. In some parts of Southeast Asia, the commercial value of captured rats provides added incentive for daily checking and regular maintenance of the CTBS.

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CHAPTER 11

Review of the major pest species

Introduction

All of the major pest rodent species found in South and Southeast Asia belong to only a handful of genera, among which *Rattus*, *Bandicota* and *Mus*, all members of the family Muridae, are pre-eminent. Other minor pests are found within the murid genera *Berylmys* and *Millardia*, and among members of the family Rhizomyidae, the bamboo rats. Various squirrel species are also regarded as agricultural pests, especially in South Asia, but these are not covered here. A list of the species documented and their general geographical distribution is given in Table 11.1.

The information summarised in these accounts draws upon a combination of published data and the authors' combined field experience in many localities between Bangladesh and Papua New Guinea. As a rule, more detail is available for those species that cause the greatest overall damage. For each species, a few key references only are given. The two species of *Millardia* recorded from Bangladesh (*M. meltada*) and Myanmar (*M. kathleenae*) are omitted from this account because of a lack of information on their habits or pest status in these areas. *Millardia meltada* is a significant pest in parts of India, although mainly in semiarid to arid regions.

The measurements given for each species usually represent the adult range, as measured on fresh specimens. In some cases, only a maximum value is available (e.g. to 35 g), or a mean (sometimes with standard deviation). Individual adult specimens may well be slightly bigger or smaller than the values given. Unless otherwise stated, information on litter size is based on counts of live embryos.

The distribution maps are somewhat generalised. While a species is unlikely to occur far outside of the indicated range, it may not be present at all localities within the range.

Using a taxonomic key

The most common type of key used in taxonomy is a **dichotomous key** in which the user works systematically through a series of predefined steps to achieve a reliable identification. At each step, the user is prompted to choose between contrasting pairs of characters or 'couplets' (e.g. 'pes black' or 'pes white') that serve to progressively narrow down the range of possibilities. In general, the complexity and usefulness of any key will depend on the number of species that it attempts to cover.

Dichotomous keys work best where the character states are discrete (e.g. 'black' versus 'white', rather than 'mostly black' versus 'mostly white') and where there is little or no variation within species. Naturally, for many groups of rodents, this type of key does not work very well. However, their performance can be improved by allowing highly variable species such as *Rattus rattus* to appear multiple times within the key and by allowing some couplets to contain two or more different characters (thereby providing a check on each individual character).

A dichotomous key to the major rodent pests of Southeast Asia and the Pacific is given at the end of this chapter. When using this key, you must keep in mind that it does not cover all of the rodents that occur through this diverse region and will give a spurious identification for any species not included within the key. Accordingly, it is strongly recommended you check any species identification obtained using this key carefully against the descriptive, distributional and ecological information provided for each of the pest species in this chapter.

The terminology and full explanations of the characters used in the dichotomous key are provided in Chapter 4. We recommend that you read that chapter before using the key and species accounts.

Table 11.1 Distribution of pest rodent species by country or region.

Species	Bangladesh	Southern China	Myanmar	Thailand	Cambodia	Laos	Vietnam	Malay Peninsula	Sumatra, Java, Borneo	Nusa Tenggara Fl = Flores Su = Sumba	Sulawesi	Philippines Mi = Mindanao Pa = Palawan	New Guinea	Island Pacific	Distribution map
Bandicota bengalensis	+	–	+	–	–	–	–	*	S*	–	–	–	–	–	124
Bandicota indica	+	+	+	+	+	+	+	*	S*J*	–	–	–	–	–	128
Bandicota savilei	–	–	+	+	+	?	+	–	–	–	–	–	–	–	132
Berylmys berdmorei	–	–	+	+	+	+	+	–	–	–	–	–	–	–	134
Berylmys bowersi	–	+	+	+	?	+	+	+	S	–	–	–	–	–	134
Cannomys badius	+	+	+	+	+	+	–	–	–	–	–	–	–	–	137
Mus booduga	?	–	+	–	–	–	–	–	–	–	–	–	–	–	139
Mus caroli	–	+	+	+	+	+	+	*	SJ	Fl	–	–	–	–	142
Mus cervicolor	?	–	+	+	+	+	+	–	–	–	–	–	–	–	144
Mus cookii	–	+	+	+	?	+	+	–	–	–	–	–	–	–	146
Mus musculus Group	+	+	+	+	+	+	+	+	+	+	+	+	+	+	148
Mus terricolor	+	–	–	–	–	–	–	–	S*	–	–	–	–	–	139
Nesokia indica	+	–	–	–	–	–	–	–	–	–	–	–	–	–	150
Rattus argentiventer	–	–	–	+	+	?	+	+	+	Su	+	Mi	*	–	152
Rattus exulans	+	–	+	+	+	+	+	+	+	+	+	+	+	+	157
Rattus losea	–	+	–	+	+	+	+	+	–	–	–	–	–	–	160
Rattus mordax	–	–	–	–	–	–	–	–	–	–	–	–	+	–	163
Rattus nitidus	–	+	+	+	?	+	+	–	–	–	+	–	*	–	166
Rattus norvegicus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	169
Rattus praetor	–	–	–	–	–	–	–	–	–	–	–	–	+	*	163
Rattus rattus Complex (multiple species)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	172
Rattus sikkimensis	+	+	+	+	+	+	+	–	–	–	–	–	–	–	177
Rattus steini	–	–	–	–	–	–	–	–	–	–	–	–	+	–	163
Rattus tiomanicus	–	–	–	–	–	–	–	+	+	–	–	Pa	–	–	179
Rattus turkestanicus	–	+	+	–	–	–	–	–	–	–	–	–	–	–	181
Rhizomys pruinosus	–	+	+	+	+	+	+	+	–	–	–	–	–	–	184
Rhizomys sinensis	–	+	+	–	–	?	+	–	–	–	–	–	–	–	184
Rhizomys sumatrensis	–	–	+	+	+	+	+	+	S	–	–	–	–	–	184

Note: ? = possibly found in this region, but yet to be confirmed; * = restricted to small areas within this region.

Bandicota bengalensis

(Gray and Hardwicke, 1804)

Common names: **lesser bandicoot, Bengal bandicoot, Indian 'mole rat'**

Bandicota bengalensis is a major agricultural and urban pest across much of South Asia, east to central Myanmar. It occupies communal burrows and can reach very high local population densities. The habitual hoarding of large quantities of cereal grain in subterranean caches is also noteworthy.

morphological features: a medium-size rat with a stocky build and distinctively blunt, slightly upturned snout. The general dorsal fur colour is a pale grey–brown, grizzled with black. The belly fur is pale grey, tipped with cream or buff. The tail is usually 20–30 mm shorter than head+body and is uniformly dark above and below. The pes is clothed in dark hairs and bears long, straight claws. The plantar pads are small and low. The incisors are broad, with orange or cream enamel, and the upper pair projects slightly forwards.

mammae: highly variable, usually 7–9 pairs in Bangladesh but as many as 14–17 pairs in India.

Bandicota bengalensis is distinguished from the similarly sized *Bandicota savilei* by its shorter, upturned snout, its paler forward-projecting incisors, its larger number of teats, and its shorter, broader pes.

other recently applied scientific names: *Gunomys bengalensis*, *Bandicota varius*.

distribution: South Asia, including Sri Lanka, north to Nepal and Bhutan, and east to central Myanmar where it is sympatric with *B. indica* and *B. savilei*. Introduced populations are found on Penang Island, off the west coast of the Malay Peninsula, in the Aceh region of Sumatra and in East Java, Indonesia.

taxonomic issues: there is some variation in chromosome morphology, molar size and fur texture across the geographical range of *B. bengalensis*. Specimens from Penang Island were described as *Bandicota varius*; they are slightly larger than typical *B. bengalensis*.

habitat use: *B. bengalensis* is common in both villages and towns, and in associated cropping areas. It is usually most abundant in higher rainfall areas, and less so in arid regions of Bangladesh where

Adult measurements	Bangladesh	Myanmar
Weight (g)	to 310	to 400
Head+body (mm)	75–254	195–228
Tail length (mm)	44–177	139–188
Pes length (mm)	19–41	33–43
Ear length (mm)	–	21–24

Nesokia indica appears to occupy the same ecological niche. In Pakistan, *B. bengalensis* is recorded from intertidal mangrove forest. There are few estimates of population density, but one study in Andra Pradesh, India, gave figures of 0.5–2.4 individuals/ha. Very high populations of almost 1 individual/m^2 have been recorded in urban grain stores ('godowns') in India.

This species takes a wide range of food items, including molluscs and crabs. However, in feeding trials, it prefers cereal grain over animal foods, and rice over wheat. Stomach contents of wild-caught adults weighed an average of 24.2 g. Daily consumption in captivity ranges from 4–8% of body weight. In a rice-growing area of Pakistan, *B. bengalensis* consumed all stages of the rice plants, including young tillers, the flowers and the ripening grain. Some insects were also consumed.

Bandicota bengalensis is a good swimmer and causes significant damage to deep-water rice crops where it is reported to occupy platforms constructed from cut tillers. However, in most habitats it constructs and occupies elaborate burrow systems. These burrows are occupied for considerable periods and individuals generally only construct new burrows to avoid flooding or when local food resources are depleted. Males relocate their burrows more frequently than do females.

Studies of *B. bengalensis* movement found that most feeding activity was confined to small areas of 12–40 m^2 immediately around a burrow complex. However, individuals with their burrow located in village habitat generally moved greater distances (of 130 m or more) to visit preferred feeding areas in the fields. Most movements occurred at times of little or no moonlight.

Nesting behaviour: burrows are constructed in field bunds, in vegetable gardens and orchards, and in the floors and walls of buildings. In Bangladesh, mudbrick houses or stores infested by *B. bengalensis* are liable to suffer serious structural damage, to the point of collapse.

Individual burrow systems are often very complex, with multiple chambers and entrances (often as many as 12–16 per burrow). The average length of burrows in India is around 5.5 m, with the largest measured being 45 m in total length. Most burrow entrances are sealed during the day but their location is usually obvious from the piles of excavated soil. However, other entrances may be kept clear of soil and used as escape holes. Burrow systems may be used over several generations.

Burrows are usually occupied by one adult male or female, or by a female with her young. However, multiple occupancy is reported in areas of high population density. Breeding chambers are lined with straw and are often accompanied by caches of wheat or rice panicles. Only females seem to cache food but the quantities can be significant. Burrows excavated after harvest in India contained an average of 3.7 kg of stored wheat.

Breeding biology: breeding activity in rural populations is seasonal, with peak activity coinciding with crop maturation. In urban grain stores in India, breeding occurs year-round but with a peak in the dry season. Pregnancy rates in these contexts peak at more than 70% but fall to 13% during the middle of the wet season.

The oestrus cycle is 3–5 days and the gestation period is 21–25 days. The young weigh 3.5–5.0 g at birth. The eyes open on day 14–18 and weaning commences around day 25–28. Sexual activity commences as early as three months of age among females and slightly later among males. In an urban Indian population, sperm production began around 90–170 days after birth. In a rural, rice-growing area of Pakistan, females showed vaginal perforation at body weights of 40–79 g, and the smallest pregnant female was 89 g. Males in this population developed scrotal testes at body weights of 70–159 g, depending on the season.

Reports of litter size from urban contexts in South Asia range from 1–19, with means of 6.2 in the Punjab, 8 in Bombay, and 7.4 in Yangon. The average interval between pregnancies in these populations ranges from 30–35 days in Calcutta to 62 days in

Yangon. The average life span in a Calcutta godown is around 200 days and only 3% of individuals live for longer than one year. In a study in rural Pakistan, the average litter size varied seasonally from 6.7 to 10.2. The pregnancy rate in this population fell to 2–15% during periods of food shortage but rose to a maximum of 44% around rice harvest time. The estimated number of young produced per female in this population is 28.2 each year. In a nearby, sugarcane-growing area, mean litter size was never higher than 6.5 in any month, but due to more continuous breeding activity, the annual productivity was higher, at 43.6 young per female per year. Five pregnant females collected in central Myanmar in March 2003 had 6–9 embryos (mean of 8.0).

population dynamics: populations in rural habitats in India show fluctuations that are directly related to cropping cycles. In West Bengal, where a single wet-season rice crop is grown, *B. bengalensis* shows a single peak in abundance around harvest. In Mysore, with two rice crops, the rats show two matching peaks in abundance.

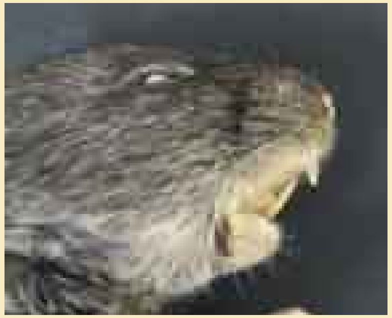
damage to crops: *B. bengalensis* damages all kinds of field crops and also attacks stored grain. In one study, damage to wheat crops in Bangladesh was confined to within a 6–8 m radius of the centre of the burrow system. Yield loss in this system was estimated at 2.5–12%.

Losses due to consumption and hoarding were estimated at 261 kg/ha for wet-season rice crops in West Bengal, India. Yield loss information from wheat-growing areas in Madhya Pradesh, India, put the quantity of grain lost to caches alone at 261–388 kg/ha. These figures equate to around a 10–15% total loss in production.

Adult *Bandicota bengalensis* from Bangladesh.

Pes of adult from Bangladesh; upper surface (left) and lower surface (right).

Adult from central Myanmar.



Adult from Bangladesh, showing forward-projecting incisors.

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Adult female *Bandicota bengalensis* from Myanmar, showing large number of teats.

Portion of tail; adult from Bangladesh.

A pup from Bangladesh: the eyes are about to open.

Bandicota indica (Bechstein, 1800)

Common name: giant bandicoot

Bandicota indica is known throughout South and Southeast Asia for its great size and ferocity when captured, and for its large burrow systems that cause damage to buildings, dams and roadways. It is found in both field and village to urban habitats, and appears to be especially common around permanent water sources. In most areas, population densities of *B. indica* are quite low and it can be regarded as a minor pest. However, in parts of South Asia, it reaches much higher densities and is responsible for significant damage to field crops (grains and vegetables), to poultry, and to stored foodstuffs.

Morphological features: the largest murine rodent in South or Southeast Asia, with adults often weighing 500–1000 g. The dorsal fur is distinctly shaggy and blackish-brown on the back and flanks, sometimes with a reddish tinge. Numerous black guard hairs project through the dorsal fur, especially down the middle of the back and on the rump. The belly fur is usually dark grey, sometimes with a cream or pale-buff wash. The tail is usually shorter but sometimes slightly longer than the head+body and is uniformly dark. The manus and pes are clothed in black hairs and bear strong claws adapted for digging. The pes is broader and heavier in *B. indica* than in the other *Bandicota* species. The ears are large and sparsely furred in Southeast Asian populations but distinctly smaller and better furred in animals from Bangladesh. Juvenile *B. indica* are readily distinguished from all other murids by their proportionally very large feet and their extremely broad incisors.

Newly captured subadults and adults are highly vocal, making a peculiar noise somewhere between hissing and braying. At the same time, the guard hairs are erected to produce a threatening appearance.

Mammae: usually 1+2+3; individuals with 1+2+7 teats are reported from Bombay.

Adult measurements	Bangladesh	Thailand	Cambodia	Southern Vietnam	Northern Vietnam
Weight (g)	to 760	to 545	to 830	to 870	to 830
Head+body (mm)	150–309	to 276	175–285	160–300	to 285
Tail length (mm)	115–267	to 244	140–270	135–248	to 270
Pes length (mm)	42–60	to 56	40.5–54	39–58.5	to 54
Ear length (mm)	–	to 30	24–29	19–29	to 35

other recently applied scientific names: *Bandicota gigantea*, *Bandicota maxima*, *Bandicota indica nemorivaga*, *Bandicota indica setifera*.

distribution: widely distributed across South (including Sri Lanka) and Southeast Asia, through to southern China and Taiwan. *Bandicota indica* is generally absent from peninsular and insular Southeast Asia, except where it has been introduced during prehistoric or historic times—to the Kedah and Perlis regions of the Malay Peninsula and the island of Java in Indonesia. The population on Taiwan may also be a recent introduction.

taxonomic issues: populations of *B. indica* vary in both chromosome number and morphology across its extensive geographical range and this has led several taxonomists to suggest that two or more species are present. Our preliminary genetic studies also point to high levels of divergence between populations within Southeast Asia (e.g. lowland Cambodia and Vietnam versus upland Laos). A full-scale taxonomic revision of the *B. indica* group is clearly needed.

habitat use: found in all parts of the human landscape, including varied cropping systems and village to urban environments. *Bandicota indica* is also reported from uncultivated marshy areas and from patches of forest, although these are never far from human populations. In villages or towns, it is usually found close to ponds or riverside habitats. In Southeast Asia, it is present in both lowland and upland environments.

Bandicota indica is an excellent swimmer and it has been observed diving to retrieve prey items from bottom sediment. This allows it to exploit a wide range of both aquatic and terrestrial foods, including molluscs, crustaceans, water lily fruit, water hyacinths, insects, earthworms, and field crops such as rice, vegetables (including tubers), fruits, and nuts. Attacks on nestling birds and snakes are also reported.

Burrow systems range from short tunnels (to 72 cm) used as feeding retreats, through to elaborate and extensive complexes with multiple chambers and entrances (the largest covering an area of 300 m^2). Burrow entrances are usually left open and are sometimes marked by piles of faeces or food refuse; however, they are sometimes concealed and can even open below water level. Large burrow complexes sometimes contain numerous adults along with their young. Grain hoarding behaviour is reported from localities in India, but it does not seem to be habitual, as it is in *Bandicota bengalensis*. The few studies of movement suggest that *B. indica* individuals usually move only short distances from their burrow systems. However, one study reported nightly movements of around 250 m between a daytime retreat in a village and a feeding area within crops.

There are few estimates of population density, but one study in India recorded an average of 456 individuals per ha in rice fields, with an average of 38 active burrows per ha. This high number presumably included many juveniles. In lowland irrigated systems in Southeast Asia, *B. indica* usually makes up less than 5% of captures either from live-trapping on grids or along transects, or from trap–barrier systems (TBSs). In rainfed lowland rice systems in Binh Thuan Province, Vietnam, the capture rate for *Bandicota* spp. (*B. indica* and *B. savilei*, not distinguished) in TBSs (with trap crops) is much higher—often more than 50% during the early part of the growing season, but falling to around 20–30% by harvest time.

nesting behaviour: pups are born in a 'brood chamber' constructed within the general burrow complex. These chambers are lined with leaves or other soft material, such as paper or cloth. More than one female can bear their young within a single burrow system; indeed, one report from Bangladesh notes eight separate litters within a single, interconnected burrow system.

breeding biology: a two-year study of breeding activity in natural marshland habitat on Sagor Island, off the coast of India, found breeding in all months of the year. The overall adult pregnancy rate was 27%, but this peaked at 50% in October–April and fell to 10% in May–September. Mean litter size did not vary between months.

Litter size is variously reported as 1–8 (mean of 4.8), 1–4, and 'up to 10' for Indian populations, and 2–12 for northern Vietnam. A sample collected in the southern Vietnamese province of Binh Thuan in March 2001 gave live embryo counts of 4–8 with a mean of 5.8.

Wild-caught Indian animals have an oestrus cycle of 4–8 days and a gestation period of 23 ± 1.2 days. Vaginal perforation occurs at 190–210 days after birth, at body weights of 287–345 g. The largest imperforate female in the Binh Thuan Province sample weighed 520 g, while the smallest perforate female weighed only 145 g.

population dynamics: nothing is reported. Capture rates in the Mekong Delta of Vietnam and West Java, Indonesia, are consistently low at all times of the year.

damage to crops: at low population densities, *B. indica* may feed primarily on invertebrates and cause little damage to crops. Indeed, the benefits of its regular predation on molluscs and crabs may outweigh any crop damage. However, at high densities, it is reported to cause heavy damage, both in rice crops (individuals cutting 1–4 m^2 of tillers per night) and in potato (damaging 1–3 kg per night) and peanut fields.

Mean daily food intake over long periods in captivity is 95 g of mollusc flesh or 35 g of paddy. This tallies well with the stomach content yield for wild-caught Indian adults of 23–58 g.

Adult *Bandicota indica* from the uplands of Laos.

Adults from Bangladesh (top) and Cambodia (bottom).

Juvenile from the uplands of Laos.

Incisors of adult from the uplands of Laos.

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Bandicota indica: tail, adult from Vietnam.

Upper surface of manus; adult from Bangladesh.

Pes of an adult from southern Vietnam: upper surface (left) and lower surface (right).

Ear of an adult from Bangladesh.

Bandicota savilei (Thomas, 1916)

COMMON NAME: lesser bandicoot

This species takes the place of *Bandicota bengalensis* in Southeast Asia. It is apparently restricted to lowland areas and is often found together with *Bandicota indica*. *Bandicota savilei* can be locally abundant and is presumably a significant pest species, especially in areas of rainfed rice crops that do not experience any major flooding.

MORPHOLOGICAL FEATURES: a medium-size, terrestrial rat with shaggy, reddish-brown fur on the back and sides, and buff-tipped, grey-based belly fur. The fur is spiny and contains numerous long, black guard hairs that are most conspicuous on the lower back. The tail is usually 20–30 mm shorter than the head+body and is uniformly dark above and below. Rarely, the tail has a short, all-white tip. The ears are relatively large and well furred. The pes of adult *B. savilei* is narrow and 'gracile' compared with similar-size (immature) *B. indica*. As in the other *Bandicota* species, the incisors are broad (>3.5 mm in combined width), the claws on the manus and pes are long and relatively straight, and the plantar pads are small and low compared with all species of *Rattus*.

MAMMAE: 1+2+3.

Bandicota savilei was recently found living alongside *B. bengalensis* near Yezin in central Myanmar. The two species are of similar size and colouration, but *B. bengalensis* is readily distinguished by its more forward-projecting upper incisors, smaller ears, shorter and broader pes, shorter tail and more numerous teats in females. Indeed, *B. savilei* is more similar to *B. indica* in most regards, but can be distinguished by its smaller, narrower feet as noted above, and by its overall smaller size.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES: *Bandicota bengalensis*, *Bandicota bengalensis hichensis*, *Bandicota bengalensis giaraiensis*, *Bandicota banchakensis*, *Bandicota varius*, *Bandicota indica savilei*.

DISTRIBUTION: lowlands of central Myanmar, Thailand and Vietnam; probably present in lowland areas of Laos, within the valley of the Mekong River.

Adult measurements	Myanmar	Thailand	Southern Vietnam
Weight (g)	233–318	to 199	to 292
Head+body (mm)	208–227	145–225	102–228
Tail length (mm)	170–195	75–178	90–185
Pes length (mm)	35–41	33–40	26–40
Ear length (mm)	23–26	20–30	19–26

TAXONOMIC ISSUES: this species has been frequently confused with *B. bengalensis* or treated as a subspecies of *B. indica*. It is morphologically and genetically distinct from both, and occurs together with *B. indica* in many areas. In March 2003, we encountered all three *Bandicota* species living together in a single field complex near Yezin in central Myanmar. The fields held a standing crop of the pulse known as 'black gram', grown as an intercrop for rainfed rice.

HABITAT USE: *B. savilei* is abundant in rainfed rice cropping systems in Binh Thuan Province, Vietnam, where it occurs together with *Rattus argentiventer* and *B. indica*. It appears to be absent from those parts of the Mekong Delta in Vietnam that experience widespread flooding, and may thus be relatively intolerant of prolonged inundation. If so, this would be a point of distinction with the other species of *Bandicota*, both of which might be characterised as semi-aquatic in habits.

An apparently 'natural' population of *B. savilei* is reported from Thailand, living in "grass beneath teak forest".

NESTING BEHAVIOUR: burrows are constructed in large bunds and small 'upland' areas. One report from Thailand mentions "runways through grass" leading to a burrow "only about 18 inches [46 cm] deep".

BREEDING BIOLOGY: little known. In Binh Thuan Province, a high proportion of adult females (48%, *n* = 27) were breeding in March 2001. This was near the end of the dry season, after a prolonged fallow period and with little or no standing crop of any kind. The smallest pregnant females weighed only 75 g, but most pregnancies were in females above 160 g. Embryo counts were 3–10 with a mean of 5.7. Nearly two-thirds of the pregnant females also had uterine scars indicative of one previous litter. A sample of pregnant females collected in central Myanmar in March 2003 had 5–11 embryos.

POPULATION DYNAMICS: nothing known.

DAMAGE TO CROPS: damage to maize is specifically mentioned for Thailand. In Myanmar, ripening seed pods of the pulse 'black gram' were found scattered around conspicuous burrow entrances in low bunds, and fragments of the pulse were observed in the stomach of several individuals of *B. savilei*.

KEY REFERENCES:

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Marshall, J.T. 1977. Family Muridae. In: Lekagul, B. and McNeely, J.A., ed., Mammals of Thailand. Bangkok, Kurusapha Press, 397–487.

Musser, G.G. and Brothers, E.M. 1984. Identification of bandicoot rats from Thailand (*Bandicota*, Muridae, Rodentia). American Museum Novitates, No. 3110, 1–56.

Adult *Bandicota savilei* from southern Vietnam.

Adult from Cambodia.

Adult from southern Vietnam.

Lower surface of pes; adult from southern Vietnam.

Berylmys berdmorei (Blyth, 1851)
Berylmys bowersi (Anderson, 1879)

Common name: white-toothed rats

The genus *Berylmys* contains four or more species, all of which have their primary populations in forest habitat. However, at least two species of this group appear to warrant inclusion as occasional agricultural pests. In northern Laos, *B. berdmorei* constructs its burrow systems within the upland agricultural landscape and the species is identified by farmers as a minor pest. In the same area, *B. bowersi* is said to be confined to forest habitat. However, elsewhere in Laos and across wider Southeast Asia, *B. bowersi* has been trapped within cropping areas and is presumably responsible for some crop damage.

morphological features: species of *Berylmys* can be recognised by their pale-cream or white incisor enamel and their short, crisp-grey or brownish-grey dorsal fur, which is sharply demarcated from a pure-white belly. The ears are moderately large and thinly furred. More specifically, for each of the two pest species:

- *B. berdmorei* has steel-grey dorsal fur, the tail is usually 30–40 mm shorter than the head+body, and the feet are clothed in pure-white or grey hairs
- *B. bowersi* has brownish-grey to dull-tan dorsal fur, and the tail is usually slightly longer than the head+body, is usually slightly darker above than below, and is either plain to the tip or ends in an all-white section.

mammae: 1+2+2 in *B. berdmorei*; 1+1+2 in *B. bowersi*.

Adult measurements	*B. berdmorei* Thailand	*B. berdmorei* Laos	*B. bowersi* Thailand	*B. bowersi* Vietnam
Weight (g)	to 235	118–205	to 420	to 292
Head+body (mm)	to 255	175–207	to 245	240–285
Tail length (mm)	to 192	134–170	to 256	260–310
Pes length (mm)	to 46	36–39	to 55	54–57
Ear length (mm)	to 29	24–26	to 30	30–37

other recently applied scientific names: *B. berdmorei* = *Rattus berdmorei*; *B. bowersi* = *Rattus bowersi*.

distribution: *B. berdmorei* is recorded from scattered localities in southern Myanmar, northern and south-eastern Thailand, Cambodia (Kampot), northern Laos and southern Vietnam (including Con Son Island). It was recently collected in Luang Prabang Province, northern Laos. *Berylmys bowersi* is known from many more localities, from north-eastern India to southern China (to Fukien Province) and ranging through northern Thailand, Laos and Vietnam. It is also found on the Malay Peninsula and on Sumatra, Indonesia.

taxonomic issues: both species show considerable variation across their ranges and may include more than one species.

habitat use: both species are most commonly encountered in upland regions—the main exception being the record of *B. bowersi* from Con Can Island off southern Vietnam. Both are essentially terrestrial and live in burrows, although the longer-tailed *B. bowersi* is a capable climber.

In Luang Prabang Province, Laos, we recently found *B. berdmorei* to be moderately abundant in valley floor and slope habitats, with burrows located both in small bamboo thickets and in a cleared field planted with cassava and sweet potato. Individuals were trapped in these areas but also in an irrigated rice-field complex, suggesting nightly movements of several hundreds of metres.

Berylmys bowersi in Laos appears to be more strictly forest dwelling, although it is occasionally trapped in cropping areas. It is said to be an occasional pest in gardens and orchards in Malaysia. Ecological studies of this species in Malaysian forests suggest a diet of fruit and vegetable matter, with occasional insects and molluscs. Although a capable climber, *B. bowersi* spends most of its time foraging on the ground.

nesting behaviour: burrows of *B. berdmorei* in Luang Prabang Province were several metres in length with two entrances and one central chamber. In three of four cases, the main burrow entrances were concealed beneath leaf litter and lacked any associated mound of soil. However, in each case, an obvious entrance with a conspicuous mound of soil was located several metres away; these all led into short, blind tunnels. Whether these represent aborted tunnels, feeding retreats or decoy tunnels is not known, but the difference in visibility might favour the latter interpretation.

Two of the three excavated *B. berdmorei* burrows contained a large bundle of freshly cut leaf material in the central chamber. No pups were found, but one burrow contained two adults (a female and a probable male that escaped), and two subadults. The other burrows contained solitary, young males.

In Malaysia, nests of *B. bowersi* were located in fallen logs and in burrows situated in drier, more elevated sites.

breeding biology: in Malaysia, female *B. bowersi* have been found with 2–5 live embryos. Maturation of both sexes is very slow in this population, with males developing scrotal testes and showing epipidymal sperm at body weights between 150–300 g. The smallest pregnant female weighed 290 g.

One adult female of *B. berdmorei* (body weight 203 g) collected in Luang Prabang showed 14 placental scars, apparently belonging to two sets. Six other females between 118–182 g all showed perforate vaginas but none had commenced breeding.

population dynamics: nothing recorded.

damage to crops: Lao farmers in Luang Prabang Province claim that *B. berdmorei* damages all crops but especially tubers such as sweet potato. One burrow was indeed located in a sweet potato field and the farmers were able to produce tubers that had been eaten out from below, presumably by *B. berdmorei*. The same farmers gave a credible description of *B. bowersi* but said that it stayed within the forest, where it burrowed but ate fallen fruits.

Nothing specific is reported regarding the damage attributed to *B. bowersi* in Malaysia.

KEY REFERENCES:

Harrison, J.L. 1955. Data on the reproduction of some Malayan mammals. Proceedings of the Zoological Society, London, 125, 445–460.

Marshall, J.T. 1977. Family Muridae. In: Lekagul, B. and McNeely, J.A., ed., Mammals of Thailand. Bangkok, Kurusapha Press, 397–487.

Musser, G.G. and Newcomb, C. 1983. Malaysian murids and the giant rat of Sumatra. Bulletin of the American Museum of Natural History, 174, 327–598.

Manus of adult *Berylmys bowersi* from Thailand: upper (left) and lower (right) surfaces.

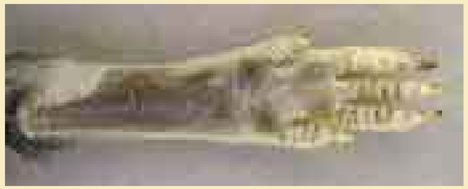
Pes of adult *B. bowersi* from Thailand: upper (left) and lower (right) surfaces.

Tail of adult *B. bowersi* from Thailand.

Adult *Berylmys berdmorei* from the uplands of Laos.

Adult *B. berdmorei* from the uplands of Laos.

Incisors; adult *B. berdmorei* from the uplands of Laos.



Lower surface of pes; adult *B. berdmorei* from the uplands of Laos.

Cannomys badius (Hodgson, 1841)

Common name: **lesser bamboo rat**

Cannomys badius is widespread across the upland regions of Tibet and north-eastern India to southern China and Cambodia. It is a moderately large, stockily built animal with lush orange–brown fur and obvious adaptations to fossorial life. Its deep and extensive burrow systems are often located in slash-and-burn gardens and it inflicts some damage on upland rice crops. There are some also reports of bamboo rats damaging sugarcane, cassava and orchard trees. Farmers excavate many *Cannomys* burrows for their tasty contents and they are often traded along roadsides.

MORPHOLOGICAL FEATURES: in common with the other bamboo rats, *Cannomys badius* has a massively broadened head, a plump body with short limbs, strong claws on both pes and manus, and a short, sparsely haired tail which lacks scales (it is instead covered in soft, wrinkled skin). Other diagnostic features include massive incisors, and small eyes and ears.

Cannomys badius is the smallest bamboo rat and it is easily distinguished from the species of *Rhizomys* by its reddish-brown fur colour, extremely small ears (less than 10 mm) that are hidden in the fur, and smooth rather than granulated plantar pads on the manus and pes.

MAMMAE: 1+1+2.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES: *Rhizomys badius*, *Cannomys badius castaneus*.

DISTRIBUTION: *C. badius* ranges through the uplands of Nepal, eastern Bangladesh and India, Myanmar, Thailand, Laos and Cambodia.

TAXONOMIC ISSUES: subspecies of *C. badius* are sometimes recognised but their validity is untested. The bamboo rats as a whole are in urgent need of revision, especially on account of the heavy exploitation of these species in some areas as commercial food items.

HABITAT USE: the bamboo rats are probably most abundant in the natural bamboo forests that still cover large areas of the uplands of Southeast Asia. Their presence in such areas is always obvious from their large, poorly concealed burrow systems

Adult measurements	Thailand	Vietnam
Weight	0.5–0.8 kg	–
Head+body (mm)	147–265	191–259
Tail length (mm)	60–75	43–73
Pes length (mm)	30–35	30–35
Ear length (mm)	7–10	8–11

in which they shelter through the day. In northern Laos, burrows of *C. badius* are often located within or around the margins of swidden gardens. Local farmers claim that these burrows are present at the time when the garden site is prepared from forest or fallow regrowth, but the concentration of burrows makes it seem likely that some are newly dug, at least around the garden edges. Lao farmers also claim that *C. badius* tunnels below rice plants and consumes the plants from below. The remains of plants destroyed in this way have been observed in upland fields in Luang Prabang Province.

Nesting behaviour: in north-eastern India, the burrows of *C. badius* consist of a single tunnel running at a depth of 60 cm or so below the ground and ending in a large chamber. A second tunnel usually runs partway to the surface; perhaps as an incomplete emergency exit. When the burrow is occupied, the active entrance is closed with freshly piled earth.

Breeding biology: litter size is reported as 3–5 for Thailand.

Population dynamics: nothing known.

Key reference:

Marshall, J.T. 1977. Family Muridae. In: Lekagul, B. and McNeely, J.A., ed., Mammals of Thailand. Bangkok, Kurusapha Press, 397–487.

Adult *Cannomys badius* from the uplands of Laos. The white patch on the forehead is absent in some individuals.

Pes of an adult from Laos: upper surface (left) and lower surface (right).

Mus booduga (Gray, 1837)
Mus terricolor (Blyth, 1851)

Common name: pygmy mice

These are small-bodied mice that sometimes occur together in the agricultural landscape of South Asia. Unfortunately, the two species were only recently confirmed as separate species, hence much of the ecological literature is probably based on mixed observations of the two.

MORPHOLOGICAL FEATURES: both species are small mice with soft fur, pure-white manus and pes, and tails that are distinctly darker above than below. *Mus booduga* has bright, yellowish-brown dorsal fur and a pure-white belly. The tail is usually around 10 mm shorter than the head+body. *Mus terricolor* is even smaller than *M. booduga* and has dull, brownish-grey dorsal fur and belly fur that is light grey with white tipping. The fur on the cheek and lower part of the snout is pale. The tail is usually slightly shorter than the head+body. The pes of *M. terricolor* shows two distinctive features that suggest a strong digger with poor climbing ability—low plantar pads and forward-projecting claws, similar to those of *Bandicota* spp. The inner and outer metatarsal tubercles are positioned close together, unlike the condition in *M. musculus*. The ears of *M. terricolor* are distinctly smaller than those of sympatric *M. musculus*.

MAMMAE: 1+2+2 in both species.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES: (of *Mus terricolor*) *Mus booduga*, *Mus dunni*.

Adult measurements	*M. booduga*, India	*M. booduga*, Myanmar	*M. terricolor*, India	*M. terricolor*, Bangladesh
Weight (g)	to 14	16–17.5	to 11	7–11
Head+body (mm)	to 80	85–93	to 70	66–68
Tail length (mm)	to 70	55–66	to 70	60–62
Pes length (mm)	to 17	15–17	to 16	14–15
Ear length (mm)	to 12.5	16–17.5	to 11.5	–

DISTRIBUTION: not yet fully documented. *Mus booduga* is found in Sri Lanka and peninsular India north to Jammu and Kashmir, and southern Nepal. There is an isolated population in central Myanmar. *Mus terricolor* is widespread on peninsular India, west to Pakistan and north to Nepal. We have collected this species in eastern Bangladesh. An isolated population of *M. terricolor* in northern Sumatra, Indonesia, is probably due to human introduction.

TAXONOMIC ISSUES: the distinction between the two Indian species of pygmy mice was confirmed in 1968 by studies of their chromosomes. There has been no recent review of the morphological differences between the species, and the status of various populations remains uncertain. A population from central Myanmar (described as *Mus lepidoides*) is tentatively associated with *M. booduga*.

HABITAT USE: pygmy mice are found in a variety of agro-ecosystems, including irrigated rice and mixed vegetable cropping. Although they are generally not reported as true commensals, *M. terricolor* has been caught inside village houses in eastern Bangladesh.

Home-range estimates of around 800–1275 m^2 are reported from various localities in India, but it is unclear which species is represented.

NESTING BEHAVIOUR: burrows are located in bunds between damp or flooded fields, but in the floor of dry fields. The burrows in bunds are deep and branched, with 2–4 entrances and 1–2 nest chambers. Those in fields are shallow and have a simple tunnel leading to a single chamber. The entrances of both kinds of burrow are small compared with those of other rodents, rarely exceeding 1 cm in diameter, and they typically feature a small pile of excavated soil pellets.

There are several reports of hoarding behaviour. One study found rice grain in 8 of 10 excavated burrows, and 36–85 individual grains per burrow. Another study reported caches of up to 7 g.

BREEDING BIOLOGY: in Kerala State, India, pygmy mice breed in all months of the year. The pregnancy rate averaged through the entire year is around 20%, but there is a peak in pregnancies (to >70% of adult females) during the monsoon season. The smallest pregnant female recorded weighed 6.5 g.

The gestation period in captivity is given as 19–22 days. Estimates of litter size range from 1–6 to 6–13, suggesting a possible interspecific difference. The interval between litters in one population was found to be 45 days.

POPULATION DYNAMICS: no information available.

DAMAGE TO CROPS: rice grain is often observed in and around the burrows of pygmy mice. Analysis of stomach contents shows a seasonal shift from predominantly leafy material early in the rice cropping season to mixed leaf/grain during the seed-ripening phase of the crop cycle. High population densities are also reported in vegetable fields, but the extent of any damage is not reported.

KEY REFERENCES:

Bhat, S.K. and Sujatha, A. 1991. Population structure and breeding season of the field mouse, *Mus booduga booduga* Gray. Mammalia, 55, 389–396.

Chandrahas, R.K. 1974. Ecology of the brown spiny mouse, *Mus platythrix* (Bennett) and the Indian field mouse, *Mus b. booduga* (Gray). Indian Journal of Medical Research, 62, 264–280.

Rao, A.M.K.M. 1979. Monthly variation in the numbers and reproduction activity of the Indian field mouse, *Mus booduga* Gray around Tirupati. Indian Journal of Rodentology, 1, 35–45.

Rao, A.M.K.M. 1992. The mice, *Mus* spp. In: Prakash, I. and Ghosh, P.K., ed., Rodents in Indian agriculture, volume 1. Jodhpur, Scientific Publishers, 147–164.

Rao, A.M.K.M. and Rajabai, B.S. 1979. Morphological variation in the little Indian field mouse, *Mus booduga booduga* (Gray, 1837), inhabiting two different habitats. Säugetierkundliche Mitteilungen, 27, 317–320.

Adult specimens of *Mus booduga* from central Myanmar.

Adult specimens of *Mus terricolor* from Bangladesh.

Mus caroli (Bonhote, 1902)

Common names: long-tailed rice-field mouse, Ryukyu mouse

Mus caroli can be quite common in and around rice fields and it presumably causes some damage to crops. It is often found together with *Mus cervicolor*.

morphological features: a small mouse with a relatively long, distinctly bicoloured tail (darker above than below), and dark-orange upper incisors. The back is brownish-grey, and the belly is white, with grey bases in the north of its range, but pure white in central and south-eastern Thailand and on Java, Indonesia. The chin and lips are white in all populations. The fur on the back and flanks contains narrow spines and varies in texture from soft to moderately stiff. The pes is relatively large and is either pure white or peppered with dark hairs. The plantar pads on the pes are prominent and the inner and outer metatarsal tubercles are positioned close together.

mammae: 1+2+2.

other recently applied scientific names: *Mus formosanus*, *Mus caroli ouwensi*.

distribution: widespread on mainland Southeast Asia—from central and eastern Thailand, south to the Isthmus of Kra, Laos, Cambodia, and all of Vietnam except the northernmost highlands. Outside this core area, the species is found in widely scattered localities, many of which probably represent human introductions—these include South Kedah State in Malaysia, north-eastern Sumatra, central and eastern Java and Flores in Indonesia, and Hainan Island, Fujian Province, Hong Kong and Taiwan in China, and various islands in the Ryuku Archipelago and in Japan. A population of *Mus caroli* was recently located in central Myanmar.

taxonomic issues: none.

habitat use: common in rice fields and grasslands across its range. *Mus caroli* is also recorded from pine savannah in Loei Province, Thailand.

Adult measurements	Thailand	Cambodia	Southern Vietnam	South Kedah	Central Myanmar
Weight (g)	12	12.5–16	11.5–17.5	to 13	18–19.5
Head+body (mm)	76	72–95	73–86	79	80–87
Tail length (mm)	78	75–89	78–89	84	89–95
Pes length (mm)	18	14.5–19	16–18	18	17–19
Ear length (mm)	14	12.5–14	13	–	12–13

nesting behaviour: burrows are often constructed in rice-field bunds. The burrows typically have two entrances with a central chamber filled with rice straw. The entrances are left open through the day and are marked by small mounds of excavated soil.

breeding biology: nothing reported.

population dynamics: nothing reported.

damage to crops: no specific information. In Cambodia, where *M. caroli* and *Mus cervicolor* occur together, mice as a group are said to climb tillers to feed on individual grains. In Laos, they are said to clean up fallen grains and panicles left behind by larger pests such as *Rattus* and *Bandicota* spp.

key references:

Langham, N.P.E. and Ming, L.Y. 1977. *Mus caroli*, Bonghote, 1902. A new mammal for peninsular Malaysia. Malayan Nature Journal, 30, 39–44.

Marshall, J.T. 1977. Family Muridae. In: Lekagul, B. and McNeely, J.A., ed., Mammals of Thailand. Bangkok, Kurusapha Press, 397–487.

Marshall, J.T. 1977. A synopsis of Asian species of *Mus* (Rodentia, Muridae). Bulletin of the American Museum of Natural History, 158, 173–220.

Adult *Mus caroli* from central Myanmar.

Lower surface of pes; adult from Laos.

Adult from central Myanmar.

Mus cervicolor (Hodgson, 1845)

Common names: short-tailed rice-field mouse, fawn-coloured mouse

Mus cervicolor is a widely distributed species often found together with *Mus caroli* in rice fields. It is distinguished from *M. caroli* by its shorter tail, softer fur and more delicate feet.

morphological features: a small, soft-furred mouse with a distinctively short tail and pale-orange or yellow incisors. The dorsal fur is orange–brown to brownish-grey, and the belly fur is cream with pale-grey bases. The fur around and behind the eye is a gingery colour. Numerous very fine spines are present in the dorsal fur, but these are not obvious to the touch and the fur feels soft. The tail is usually distinctly bicoloured (darker above than below) but it is sometimes mottled. The pes is relatively slender and delicate, but the plantar pads are moderately prominent. The inner and outer metatarsal tubercles are more widely separated than in *M. caroli*. The upper surface of the manus and pes is clothed in white fur, peppered with occasional dark hairs on the pes.

mammae: 1+2+2.

other recently applied scientific name: *Mus cervicolor popaeus*.

distribution: widespread on mainland Southeast Asia, from eastern Nepal through Myanmar, Thailand, south to the Isthmus of Kra, Laos, Cambodia, and southern and central Vietnam. There are scattered records from Bangladesh. Populations in north-eastern Sumatra and eastern Java, Indonesia, are probably the result of human introductions. *Mus cervicolor* is found across a wide altitudinal range.

taxonomic issues: two subspecies are distinguished in Southeast Asia—*M. cervicolor cervicolor* and *M. cervicolor popaeus* for lowland and upland populations, respectively. Laboratory crosses

Adult measurements	Nepal		Cambodia	Thailand
	Male	Female		
Weight (g)	14.1 ± 3.4	12.4 ± 4.3	8–16	14.6
Head+body (mm)	73.2 ± 7.2	70.8 ± 9.7	63–81	82
Tail length (mm)	81.9 ± 6.2	74.1 ± 7.4	53–65	59
Pes length (mm)	17.9 ± 1.1	16.3 ± 1.9	13.5–16	16.2
Ear length (mm)	14.6 ± 0.7	14.5 ± 1.5	12–16	14.6

between Thai individuals of the two subspecies resulted in no apparent reduction in fertility. The Nepalese population is the true *Mus cervicolor cervicolor*. The subspecies identity of the Bangladesh populations is not yet known.

HABITAT USE: in Thailand, the two forms can be found living in close proximity with typical *M. cervicolor* in rice fields and *M. cervicolor popaeus* in nearby forest habitat.

NESTING BEHAVIOUR: in Cambodia, *Mus cervicolor* has been dug from bunds alongside lowland rice fields. The burrows are relatively short but with multiple entrances, usually including one more-or-less vertical hole that opens on the surface of the bund. One burrow contained two young in a central brood chamber that lacked any nesting material.

BREEDING BIOLOGY: nothing reported

POPULATION DYNAMICS: nothing reported.

DAMAGE TO CROPS: nothing reported.

Adult *Mus cervicolor* from Cambodia.

Adult from lowland Laos (tip of tail is damaged).

Adult from Cambodia.

KEY REFERENCES:

Marshall, J.T. 1977. Family Muridae. In: Lekagul, B. and McNeely, J.A., ed., Mammals of Thailand. Bangkok, Kurusapha Press, 397–487.

Marshall, J.T. 1977. A synopsis of Asian species of *Mus* (Rodentia, Muridae). Bulletin of the American Museum of Natural History, 158, 173–220.

Newton, P.N., Rands, M.R.W. and Bowden, C.G.R. 1990. A collection of small mammals from eastern Nepal. Mammalia, 54, 239–244.

Rao, A.M.K.M. 1992. The mice, *Mus* spp. In: Prakash, I. and Ghosh, P.K., ed., Rodents in Indian agriculture, volume 1. Jodhpur, Scientific Publishers, 147–164.

Mus cookii (Ryley, 1914)

Common name: Cook's mouse

This species is often captured in upland rice fields. However, nothing is known regarding its impact on crops and it is probably best regarded as an occasional or minor pest species.

MORPHOLOGICAL FEATURES: *M. cookii* is a moderately large species of mouse with a long, narrow snout, large, broad ears, and a distinctly hairy, weakly bicoloured tail. In upland populations, the dorsal fur is a dark-brown colour and contains numerous broad spines, giving it a distinctly 'stiff' texture. The fur is paler and softer in samples from lower elevations. The belly fur is cream with dark-grey bases in upland Lao populations, but populations with pure-white belly fur are known from elsewhere in the region. The belly fur is said to be dark in juveniles from Thailand. The tail may be slightly shorter or slightly longer than the head+body. The pes is large and hairy, usually with a mixture of white and dark hairs. The plantar pads are prominent and the two metatarsal pads are close together.

MAMMAE: 1+2+2.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES: *Mus famulus cookii*, *Mus palnica*, *Mus nagarum*.

DISTRIBUTION: widespread across mainland Southeast Asia, from north-eastern India, northern Myanmar, central Thailand, Laos, southern China (Yunnan Province) and central Vietnam.

TAXONOMIC ISSUES: Indian populations sometimes distinguished as *Mus nagarum* and *M. palnica* may be local variants of *M. cookii*.

HABITAT USE: reported from grass beneath pine forest, and from upland rice fields and gardens.

NESTING BEHAVIOUR: in northern Laos, *M. cookii* was flushed from straw piles in upland rice fields. However, it is unclear whether the animals were nesting among the straw or in small burrows observed below the straw piles.

BREEDING BIOLOGY: nothing reported.

Adult measurements	Thailand	Laos
Weight (g)	23	16.5
Head+body (mm)	96	77
Tail length (mm)	83	91
Pes length (mm)	19.5	19.5
Ear length (mm)	15	15

population dynamics: nothing reported.

damage to crops: nothing reported.

key references:

Marshall, J.T. 1977. Family Muridae. In: Lekagul, B. and McNeely, J.A., ed., Mammals of Thailand. Bangkok, Kurusapha Press, 397–487.

Marshall, J.T. 1977. A synopsis of Asian species of *Mus* (Rodentia, Muridae). Bulletin of the American Museum of Natural History, 158, 173–220.

Adult *Mus cookii* from the uplands of Laos.

Adult from the uplands of Laos.

Pes of an adult from the uplands of Laos: upper surface (left) and lower surface (right).

Mus musculus Group

Common name: house mouse group

Members of the house mouse group occur as truly wild animals in the northern temperate zone, from Western Europe through to southern China. In South and Southeast Asia, this group of mice is commonly found around human habitation, and only rarely in cropping areas. In some areas, they reach very high population densities and presumably cause significant postharvest losses. They are also said to damage household items such as clothes and bedding.

morphological features: moderately large mice with moderately long tails, soft fur on the back and flanks and distinctive pes morphology. Although colouration is highly variable across the full range of this group, South and Southeast Asian house mice are usually a plain-brown or grey–brown colour, with the belly fur similar in colour to that on the back. Occasional specimens have cream- or buff-tipped belly fur. The ears are relatively large compared with other Asian *Mus* species. The tail is usually longer than the head+body and is either the same colour above and below or very slightly paler below. The manus and pes are usually covered in dark hairs. All of the plantar pads on the pes are small, and the outer metatarsal pad is sometimes absent. When both metatarsal tubercles are present, they are very widely separated and this feature will distinguish members of this group from other Asian *Mus* species.

mammae: 1+2+2.

other recently applied scientific names: *Mus domesticus*, *Mus castaneus*, *Mus musculus castaneus*, *Mus musculus homourus*, *Mus musculus domesticus*.

distribution: widely distributed throughout the region, with populations in most major towns. In some areas (e.g. eastern Bangladesh), house mice are also common in many of the smaller villages. The mapped distribution may be incomplete as many populations may be undocumented and the range is presumably still expanding.

taxonomic issues: a wild member of this group (generally distinguished as *M. musculus castaneus*) is found in agricultural contexts and in natural grasslands of southern China through to central

Adult measurements	Bangladesh	Thailand
Weight (g)	to 26	13
Head+body (mm)	26–95	75.9
Tail length (mm)	45–117	79.4
Pes length (mm)	13–20	16.5
Ear length (mm)	–	–

Asia. However, across most of South and Southeast Asia, members of this group are truly commensal, with populations restricted to towns and villages. These populations are potentially of very mixed origin, with input from Asian *M. musculus castaneus* and one or both of *M. musculus musculus* and *M. musculus domesticus*, of Eastern and Western European origin, respectively. Here we will refer to them as '*Mus musculus*', indicating their uncertain status within the *Mus musculus* group.

HABITAT USE: in South and Southeast Asia, '*M. musculus*' is usually confined to houses and other buildings. It is occasionally captured in village gardens or animal pens, but is generally excluded from cropping areas by the presence of other *Mus* species such as *M. caroli*, *M. cervicolor*, *M. booduga* and *M. terricolor*. In a study of farm household rodent populations at Joydebpur, Bangladesh, *M. musculus* accounted for 53.4% of all captures (otherwise captures of *Suncus murinus* > '*Rattus rattus*' > *Bandicota* spp.). All captures of *M. musculus* were made inside buildings.

NESTING BEHAVIOUR: '*M. musculus*' uses a variety of nesting sites, including burrows excavated in the walls and floors of buildings, or under piles of straw. Nests are sometimes also constructed in piles of grain bags or amongst stored cloth. In India, burrows usually have 1–3 entrances with 1–2 brood chambers measuring 5–7 cm in diameter. No evidence has been found of hoarding behaviour.

BREEDING BIOLOGY: in Rajasthan, India, '*M. musculus*' has a gestation period of 18–21 days with an average interval between litters of 50 days. Female breeding activity usually commences at around 45 days. Breeding is seasonal in the semi-arid environment of Rajasthan. In the Comilla District of eastern Bangladesh '*M. musculus*' appears to breed year-round in farm households, with embryo counts ranging from 1–10 (modal values of 5–6).

POPULATION DYNAMICS: the highest capture rates of *M. musculus* in farm households in Joydebpur were obtained in October–January and May–July, corresponding to periods of changing weather followed by major rice harvests.

DAMAGE TO CROPS: at high population densities, house mice presumably cause significant damage to stored grain and other foods. They are also said to damage household items such as clothes and furniture.

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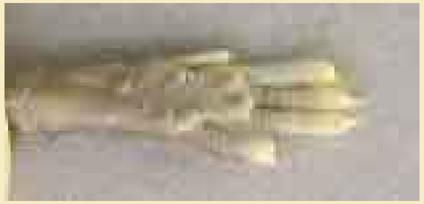
Adult *Mus musculus* from Bangladesh.



Adult from Bangladesh, lower surface of pes.

Adult from Australia.

Nesokia indica (Gray and Hardwicke, 1830)

Common names: mole rat, short-tailed mole rat

Nesokia indica is a highly fossorial species found in arid regions from South Asia to the Middle East and North Africa. It is a major pest species in north-western Bangladesh, where it causes extensive damage to wheat, rice and sugarcane. The burrow systems of this species are elaborate and it is reported to spend long periods below ground without emerging.

morphological features: a medium-size, stocky rat with a broad head, short snout, very wide incisors, short, rounded ears, and a very short, thinly-furred tail that in adults is ≥50 mm shorter than the head+body. Uniquely among the Asian murid rodents, the lower pair of incisors of *Nesokia* is wider than the upper pair. The fur is thick and shaggy, grey–brown on the back and flanks, but with an orange mantle across the shoulders. The guard hairs are short and inconspicuous, even on the lower back. The belly fur is pale grey. The claws are strongly developed on both the manus and pes. Unlike all *Bandicota* species, the inner and outer plantar tubercles are both rounded in shape and of approximately equal size (the inner tubercle is longer and elongated in *Bandicota* spp.).

mammae: 1+1+2.

other recently applied scientific names: numerous subspecies names; the population in Bangladesh may be typical *Nesokia indica indica*.

distribution: a large area of South Asia and Eurasia—from western Bangladesh and northern India to Israel, north-eastern Egypt and Tadzhikistan.

taxonomic issues: numerous regional populations have been assigned species or subspecies names. The genus is in need of revision using modern methods.

habitat use: in India, *N. indica* shows a preference for moist areas with relatively soft soil and some vegetation cover. Burrow systems are usually located in large field bunds and banks of major canals, and only rarely in flat fields.

This species appears to be entirely herbivorous. A significant proportion of feeding is done from below ground.

nesting behaviour: burrow systems are extensive and elaborate, with a pyramidal pile of soil

Adult measurements	Bangladesh
Weight (g)	170 ± 33
Head+body (mm)	to 194
Tail length (mm)	to 128
Pes length (mm)	to 37
Ear length (mm)	to 20

at each opening. Most have multiple entrances (up to 19) and a zigzagging internal arrangement. The longest recorded burrow was 34.5 m in total length, measured in India.

Breeding biology: litter size is relatively low, with estimates in wild populations in South Asia of 3.8 ± 0.25 and 4.1 ± 0.5. The highest recorded litter was eight pups. Vaginal perforation is recorded at body weights below 40 g but the smallest pregnant female weighed 63 g. First pregnancies are more typical in the weight range 100–119 g, corresponding to an estimated age of 120 ± 7 days. The gestation period in South Asia is variously reported as 24 and 30 days; the different estimates perhaps reflect delayed implantation in lactating females (see Chapter 6). Newborn pups have an average weight of 4.6 g for males and 4.1 g for females. The mean interval between births in outdoor pens is 36 ± 2.6 days.

The pregnancy rate of a wild population in the Punjab was 30%, averaged through the year. Wild populations in Pakistan show two peaks in breeding activity, corresponding to cooler months but avoiding periods of extreme cold. In a rice-growing area of Pakistan, the average female productivity was only 10.6 pups per female.

Population dynamics: nothing is reported.

Damage to crops: *N. indica* is reported to cause damage to a wide variety of crops, including cereals (rice, wheat, barley), potato, peanut, sugarcane, melons and tomato. In rice-growing areas of Pakistan, *N. indica* consumes only the ripening grain.

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Adult specimens of *Nesokia indica* from Bangladesh.

Adult, lower surface of pes.

Rattus argentiventer

(Robinson and Kloss, 1916)

Common name: rice-field rat

Rattus argentiventer is the major agricultural rodent pest across much of island and mainland Southeast Asia. Its apparent natural preference for waterlogged areas with dense grassy cover makes it ideally suited to life in rice fields. Moreover, an unusually high litter size allows the species to undergo rapid population increase at times when food is abundant.

MORPHOLOGICAL FEATURES: a medium-size rat with moderately spiny, orange–brown dorsal fur that is typically flecked with black. The belly fur can vary from silvery-white to a dull grey in colour, and there is often a darker streak along the midline of the belly. The snout is moderately long and the ears are large and lightly furred. A distinct orange fringe of fur is usually present just forward of the ear, although this may fade in older animals. The tail is usually just shorter than the head+body and is dark above and below. The pes is relatively long and narrow, and usually has a broad band of dark hairs on the upper surface, extending forward from the ankle.

MAMMAE: 1+2+3 (compared to 1+1+3 in all *R. losea* and in a variable but often high proportion of *R. rattus*).

This species is most often confused with *R. losea*, '*R. rattus*' and *R. tiomanicus*. The orange ear fringe is uniquely diagnostic for *R. argentiventer*, but absence of this fringe, especially in an old adult, is not informative. In comparison to *R. argentiventer*:

- *R. losea* is a smaller species with softer, grey–brown to orange–brown dorsal fur and a grey-based but cream or white-tipped belly fur. The pes of adult *R. losea* is shorter and narrower than that of an equivalent-size (but younger) *R. argentiventer*. The ears of *R. losea* are distinctly smaller and furrier than in *R. argentiventer* and the tail is relatively shorter and more finely scaled. *Rattus losea* and *R. argentiventer* are often found living together in Vietnam and Cambodia.
- *R. tiomanicus* usually has a longer tail and a slightly shorter, broader pes. The dorsal fur is

Adult measurements	Thailand	Northern Vietnam	Malaysia	Sumba Is, Indonesia
Weight (g)	to 212	52–239	–	–
Head+body (mm)	to 204	136–205	160–194	176–230
Tail length (mm)	to 187	149–195	165–210	172–201
Pes length (mm)	to 39	30–38	34–41	35–40
Ear length (mm)	to 22	16–22	20–24.5	20–24

a plainer brown colour and of sleeker texture, with less prominent guard hairs, especially on the lower back. The pure-white belly fur of *R. tiomanicus* contrasts with the grey or silvery belly of *R. argentiventer*

- the European 'black rat' form of '*R. rattus*' is easily distinguished from *R. argentiventer* by its dark belly fur, much longer tail and broader pes. However, many Asian populations of '*R. rattus*' have relatively short tails, a narrower pes and a high frequency of white-bellied individuals. These populations are much more similar to *R. argentiventer*, but can be distinguished by consulting the following suite of characteristics: the orange ear fringe (never present in '*R. rattus*') pes colour (generally less extensive dark fur in '*R. rattus*'), pes shape and pad morphology (pes slightly broader and pads more prominent and strongly striated in '*R. rattus*'), dorsal fur colour (usually less peppered with black in '*R. rattus*'), belly fur colour (either grey-based or pure creamy white in '*R. rattus*', rarely pure grey or silvery), tail length (not often shorter than head+body in '*R. rattus*'), tail scale size (slightly smaller scales in '*R. rattus*'), and ear furring (less densely furred in '*R. rattus*').

OTHER RECENTLY APPLIED SCIENTIFIC NAMES: *Rattus rattus argentiventer*, *Rattus rattus brevicaudatus*, *Rattus rattus bali*, *Rattus rattus umbriventer.*

DISTRIBUTION: lowland areas of southern Thailand, Cambodia and Vietnam, extending along the Mekong River into southern Laos, and along the length of the Malay Peninsula; all of the major islands of Indonesia, east to Sulawesi and Timor. Isolated populations are present in southern New Guinea and on the islands of Cebu, Luzon, Mindanao, Mindoro and Negros in the Philippines. On Timor, a population was found living in terraced rice fields in a narrow valley on the lower slopes of Gunung Mutis, in the central highland area.

The populations on Sulawesi, the Lesser Sunda Islands, the Philippine islands and New Guinea presumably were introduced by people in recent prehistoric or historic times.

TAXONOMIC ISSUES: some slight differences in body proportions are found between major island populations in Indonesia. These populations may represent different subspecies.

HABITAT USE: found in and around rice fields, gardens and orchards, and in adjacent areas of fallow grassland across its entire range; generally absent from village habitats, except as a vagrant. *Rattus argentiventer* is probably most abundant in areas that experience regular and extensive seasonal inundation—a condition that may favour this species over other, less water-tolerant rodent species.

Rattus argentiventer eats a wide variety of food items, including green foliage (e.g. grasses and paddy weeds), grass seeds including cereal grains, and invertebrates (e.g. crabs, molluscs and insects). In captivity, the species survives best when fed on cereal grains or other starchy foods.

Males and females both dig burrows but those dug by breeding females are more extensive. Burrows are often located in low bunds between fields, in the banks of irrigation canals, and in and around raised vegetable gardens or orchards.

Patterns of habitat use are best known from studies in West Java, Indonesia. In this area, during fallow periods and through early stages of crop growth, burrows are concentrated in refuge habitats, such as along canals and in upland garden areas. At this time, individual rats often travel considerable distances between burrows and feeding areas, generally moving along regular trails. At later stages of crop growth, when the rat population is increasing and the crop provides dense cover, more burrows can be found in the low bunds between fields and some rats also take shelter in the field through the day. After a field is harvested, many rats take shelter in piles of straw left in the fields, while others move to exploit nearby unharvested fields. Individual movements decrease during this period, perhaps due to increased predation risk in the more open, postharvest habitat.

Nesting behaviour: burrows dug by breeding females tend to be more extensive than those occupied by males or non-breeding females. Communal burrows have not been recorded, but one burrow can house two or more litters from a single female. The burrow is presumably enlarged to accommodate each successive litter.

Breeding biology: breeding activity is closely linked to the growth and maturation of rice crops, with first mating taking place just before maximum tillering. Many females produce their first litter as the rice reaches booting stage, their second litter during the ripening stage, and a third litter shortly after harvest. Members of the first litter usually do not get an opportunity to breed within a single cropping cycle. However, they may do so if adjacent crops are planted 2–3 weeks later, thereby extending the availability of abundant, high-quality food.

Females become perforate and begin ovulating at body weights of 31–40 g, or around 28 days of age. However, most females do not experience their first pregnancy until body weight reaches 60–120 g. Males appear to mature somewhat later, with full testicular descent only in males weighing more than 90 g (at an estimated 59 days old). The gestation period is 20–26 days, with a mean of 21 days. The interval between births in captive animals is usually 20–25 days.

Embryo counts as high as 18 have been recorded for *R. argentiventer*, but the average embryo count is around 7–8 for captive animals. Litter size in wild-caught samples was 5–7 (mode of 6) in Malaysia and 11–12 for West Java, Indonesia. An unusual aspect of reproductive behaviour in *R. argentiventer* is the frequent presence of multiple litter generations within a single breeding burrow. More typically among rodents, the birth of a new litter leads to the obligate dispersal of previous offspring. This behaviour in *R. argentiventer* may partly explain how this species is able to achieve such high local population densities.

Very high adult female pregnancy rates, close to 100%, have been recorded for *R. argentiventer* in West Java. This, together with the high litter size, may also explain the very high seasonal abundances of this species.

Population dynamics: the seasonal breeding activity generally mirrors the cycles of the rice-farming system, with one breeding season in areas with a single rice crop per year and two breeding seasons in areas that practise double cropping. Triple cropping, as practised increasingly in areas with reliable irrigation water, can lead to more-or-less continuous breeding, especially where the crops are grown asynchronously for reasons of water or labour management.

The close link between breeding and cropping cycles generally leads to pronounced seasonal changes in abundance, with a rapid increase in numbers during the crop-ripening stage and a dramatic collapse after harvest. Local population densities as high as 500–600 individuals/ha have been recorded at field sites in Indonesia where double cropping is practised. Local densities may be even higher in areas with triple cropping. Annual, deep flooding also seems to promote very large fluctuations in population size in *R. argentiventer*, presumably as a result of high mortality caused by the flooding itself and by the long period of enforced fallow.

Damage to crops: damage occurs at all stages of growth of the rice plant, but is perhaps most intense around the booting and milky stages. Crop losses in rice-growing areas where the rodent community is dominated by *R. argentiventer* are typically in the order of 10–20%. In areas with double cropping, losses are typically higher during the second crop.

Chronic losses in the order of 30–50% are reported for fields positioned close to refuge habitat such as major canals or extensive 'upland' areas. Very high chronic losses are also reported in areas where triple cropping is practised and rat densities are especially high.

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Adult *Rattus argentiventer* from Indonesia.

Adult tail; specimen from Vietnam.

Adult from Cambodia.

Juvenile *Rattus argentiventer* from Vietnam.

Pes of adult from Indonesia: upper surface (left) lower surface (right).

Adult from Vietnam.

Adult from Indonesia.

Rattus exulans (Peale, 1848)

Common names: Pacific rat, Polynesian rat, kiori

Rattus exulans is the major field and village rat in many parts of Melanesia, Micronesia and Polynesia. In Indonesia through to mainland Southeast Asia, it is usually restricted to village houses and gardens, and is less commonly found in the major cropping areas. In New Zealand and on some other islands, *R. exulans* has declined in abundance and geographical range following the introduction of *Rattus rattus* and *R. norvegicus*.

MORPHOLOGICAL FEATURES: a small, reddish-brown to grey–brown rat with spiny, reddish-brown dorsal fur and cream- or white-tipped belly fur with grey bases. The facial vibrissae are very long and typically reach beyond the ears when folded back. The tail is usually longer than the head+body and is uniformly dark above and below. The upper surface of the pes is white, but often with a strip of dark hairs along the outer edge. This species is much smaller than any other pest *Rattus* and is often misidentified as a mouse. The presence of an elongated inner metatarsal pad on the pes is one feature that distinguishes *R. exulans* (even juveniles) from all species of *Mus* (all with a rounded pad).

MAMMAE: 1+1+2.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES: *Rattus concolor*, *Rattus browni*.

DISTRIBUTION: mainland Asia from eastern Bangladesh to central Vietnam, the Malay Peninsula, Taiwan and the southern Ryukus; all major and most small islands of Indonesia and the Philippines; the island of New Guinea and its satellites, and beyond into Island Melanesia, Micronesia, Polynesia and New Zealand; Adele Island, off the north-western coast of Australia.

The exact place of origin of *R. exulans* is unknown, but the species is probably of mainland Southeast Asian origin. It was introduced into eastern Indonesia and the wider Pacific region with early seafarers, mostly within the last 2000–3000 years.

TAXONOMIC ISSUES: there appears to be no significant geographical variation, except that populations on small islands tend to be larger.

Adult measurements	Bangladesh	Southern Vietnam	Pacific Islands
Weight (g)	34–40	23–42	–
Head+body (mm)	105–120	91–130	75–165
Tail length (mm)	120–135	105–146	102–197
Pes length (mm)	22–28	21–26	23–30
Ear length (mm)	–	15–18	–

HABITAT USE: highly arboreal, often seen climbing around in tall grasses or low trees, and on the walls and roofs of houses. *Rattus exulans* is usually confined to villages and household gardens, but is also present in areas of disturbed forest and regrowth vegetation. In New Guinea, it is very common in tall grassland habitat, such as *Imperata* and canegrasses.

In lowland areas of Bangladesh, Laos, Cambodia and Vietnam, *R. exulans* coexists in village houses with various members of the *R. rattus* Complex, all of which are substantially larger-bodied. In the uplands of Laos, *R. rattus* is dominant in village habitat and the smaller species is rarely, if ever, present.

In areas that lack any surviving native rodent species, such as the mountains of Timor, Indonesia, *R. exulans* can be found in primary forest, far from human habitation.

NESTING BEHAVIOUR: usually constructs a leaf or grass nest, most often in dense grass and positioned 20 cm or more above the ground. Inside buildings, nests are usually located in roof thatch, less often in piles of straw or other material on the ground.

BREEDING BIOLOGY: studies in Malaysia and Papua New Guinea (PNG) suggest year-round breeding but with reduced output during the cooler months in PNG. In Hawaii, where the climate is more strongly seasonal, breeding is restricted to the wetter months. The reproductive life span of females in Hawaii is less than one year. The gestation period for non-lactating females is 23 days, but 3–7 days longer for a lactating female.

Litter size in PNG and Hawaii ranges from 1–7, with a modal value of 4 in both populations. In Malaysia, the maximum recorded litter size is 10, but with a mean of 3.8 and a mode of 4. In Hawaii, females develop a perforate vagina from 32–44 g, and males develop scrotal testes at 41–57 g. In Malaysia, females with a body weight above 30 g are commonly pregnant. Estimates of reproductive output (number of young per female per year; based on litter size and the average proportion of adult females pregnant) range from 9.8 on Ponape in Micronesia, to 17.2 in Hawaii and 25.7 in Malaysia.

POPULATION DYNAMICS: population density estimates are available for various Pacific islands, including 1–3/ha in coconut plantation on Guam; 7–12/ha in grassland and 11–24/ha in coconut plantation on Ponape; and 7–30/ha for various habitats on Tokelau.

DAMAGE TO CROPS: on mainland Southeast Asia and through Indonesia, this species is usually confined to village habitats, where it attacks household gardens and damages stored food. However, in New Guinea and on many of the smaller Pacific islands, *R. exulans* is the major agricultural pest rodent, causing damage to root crops, coconuts, fruits and vine vegetables such as beans. In some parts of Thailand, Malaysia and the Philippines (including Palawan), *R. exulans* is reported as a significant field pest of rice crops.

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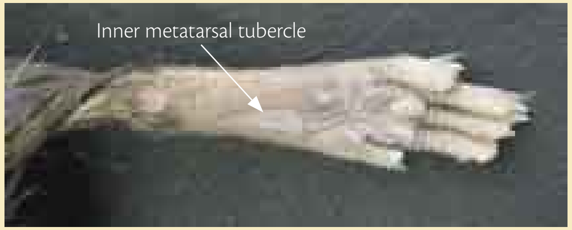
Adult *Rattus exulans* from highlands of Papua New Guinea.

Adult from Vietnam.



Lower surface of pes; adult from Vietnam.

Upper surface of pes; adult from Vietnam.

Rattus losea (Swinhoe, 1871)

Common name: lesser rice-field rat

Rattus losea appears to be discontinuously distributed across mainland Southeast Asia and East Asia north to Taiwan, and it displays regional variation in its morphology. Although it is often mentioned as an agricultural pest species, the role of *R. losea* in this regard is overshadowed by the fact that it often occurs together with larger-bodied species, such as *R. argentiventer* in Vietnam and Cambodia, and *R. rattus* in Thailand and Laos. Accordingly, little is known of its basic biology.

morphological features: there appear to be two major populations of *R. losea* that differ in morphology and genetics. All populations are distinguished from other Southeast Asian *Rattus* species by their smaller ears, softer dorsal fur that lacks any obvious spines, and shorter, more finely scaled tail.

Typical *R. losea* from Taiwan through to the north of Vietnam is a medium-size, terrestrial rat with dull, grey–brown dorsal fur and grey-based but white- or cream-tipped belly fur. The tail is usually 5–15 mm shorter than the head+body and is weakly 'bicoloured' (darker above than below), especially in younger animals. The pes is usually white, but sometimes with a narrow dark band of hairs down the outer side.

Populations currently referred to *R. losea* from the south of Vietnam, Cambodia, Thailand and lowland areas in Laos are smaller and more richly coloured, with brown to reddish-brown dorsal fur, darker grey but buff-tipped belly fur, a shorter tail that is dark above and below, and darker feet. Cambodian specimens are a rich, reddish-brown colour, contrasting with plainer, brown-coloured populations in surrounding areas.

mammae: 1+1+3 in all populations.

Adult measurements	Thailand	Northern Vietnam	Southern Vietnam	Taiwan
Weight (g)	to 77	22–90	38–92	–
Head+body (mm)	128–160	120–177	120–160	to 185
Tail length (mm)	75–163	128–165	113–140	to 170
Pes length (mm)	28–33	24–32	28–32	to 32
Ear length (mm)	15–20	16–20	15–18	to 21

other recently applied scientific names: *Rattus exiguus*, possibly *R. hoxaensis* (usually treated as a synonym of *R. argentiventer*).

distribution: found across much of lowland Southeast and East Asia. As indicated above, there appear to be two distinct forms of *R. losea*. True *R. losea* (described from Taiwan) appears to be distributed across southern China (including Hainan Island) through to northern and central Vietnam. The second form is found in the Mekong Delta region of southern Vietnam through to Cambodia and Thailand, and north to Vientiane Province in Laos. An apparently isolated population of *R. losea* occurs on the Malay Peninsula, just south of the Isthmus of Kra. The relationship of this population to the two groups mentioned above is currently unclear.

taxonomic issues: the populations of *R. losea* from northern and southern Vietnam to Cambodia are genetically distinct. To date, Thai samples have not been included in any genetic analysis and their affinities remain uncertain.

habitat use: reported from across its range as an inhabitant of rice fields and associated vegetable gardens and orchards. In most localities, *R. losea* appears to be less abundant than larger-bodied, co-occurring *Rattus* species (either *R. argentiventer* or '*R. rattus*', depending on location). In Vinh Phuc Province, northern Vietnam, the abundance of *R. losea* in any habitat appears to be inversely proportional to that of *R. argentiventer*, perhaps the result of active competition between these species. In the Mekong Delta, southern Vietnam, *R. losea* is most abundant in areas that experience heavy flooding but where there are significant areas of upland habitat. Conversely, it appears to be least abundant in areas that experience more widespread and uniform inundation.

Rattus losea is recorded as the dominant pest species (90% of captures) in Prachin Buri Province, Thailand, where deep-water ('floating') rice is grown once a year, from June to December. This population of *R. losea* shows a clear cyclical pattern, with numbers peaking just after harvest and then falling steadily through until the following planting season. The fact that animals were captured in floating live-traps indicates an ability to move about freely in the deep-water habitat.

In Chaiyaphum Province, Thailand, *R. losea* occurs in natural grassland beneath pine forest at an altitude of 850 m. While this may represent a natural habitat for the species, much caution is needed to distinguish genuinely natural from feral populations of any widespread pest species.

nesting behaviour: *R. losea* has been dug from burrows in rice-field bunds in both northern and southern Vietnam and in Thailand. In Prachin Buri Province, breeding takes place at a time when the fields are deeply inundated; unfortunately, it is not reported where *R. losea* builds its nests under such conditions.

breeding biology: in Prachin Buri Province, breeding of *R. losea* commences in September and lasts through until harvest of the deepwater rice in December. In the north of Vietnam, breeding activity is linked to rice cropping cycles, starting around maximum tillering and ending a few weeks after harvest. The average litter size is 7.5 in this population.

population dynamics: population cycles have been studied in both northern and southern Vietnam. In both areas, *R. losea* numbers fluctuate in response to the availability of field crops, especially rice. However, the amplitude of the fluctuations is not as high as for co-occurring populations of *R. argentiventer*.

damage to crops: damage caused by *R. losea* has not been distinguished from that caused by *R. argentiventer* or *R. rattus*.

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Adult specimens of *Rattus losea* (top) and *Rattus argentiventer* (below) from Cambodia showing differences in body size and relative tail length.

Adult *Rattus losea* from Cambodia.

Pes of adult *R. losea* from southern Vietnam; upper surface (left) and lower surface (right).

Rattus New Guinean species:

Rattus mordax (Thomas, 1904), *Rattus praetor* (Thomas, 1888) and *Rattus steini* Rümmler, 1935

Common names: **New Guinean spiny rats (*R. mordax* and *R. praetor*), Stein's rat (*R. steini*)**

Three native *Rattus* species (*R. mordax*, *R. praetor* and *R. steini*) cause significant crop damage in New Guinea and nearby islands, with impacts on both subsistence gardens and plantations. All are probably disturbance specialists that were advantaged by the development and spread of agricultural practices in Melanesia over the last few thousand years. One of the three species (*R. praetor*) was carried during prehistoric times into more remote parts of the Pacific.

Morphological features: all three species are medium-size, terrestrial rats with grizzled, reddish- to dark-brown dorsal fur and unicoloured tails that are 20–30 mm shorter than the head+body. In addition:

- *R. mordax* is a spiny-furred rat with few projecting guard hairs. The dorsal fur is rust-brown with yellowish-brown tipping, and the belly fur is a dull-cream colour. The pes is moderately broad and covered with short, brown hairs
- *R. praetor* also has coarse, spiny dorsal fur but with the addition of long, black guard hairs. The dorsal fur is brown, sometimes with reddish tipping, and the belly fur is pale-grey or ivory coloured, often with a pure-white chest patch. The pes is narrow and has a covering of light-brown hairs
- *R. steini* has soft dorsal fur with few, if any, spines but with fine, projecting guard hairs. The belly fur is grey with buff tipping, and the pes is narrow, with a covering of cream or light-buff hairs.

Adult measurements	*R. mordax*	*R. praetor*	*R. steini*
Weight (g)	–	164–228	110–220
Head+body (mm)	142–254	157–245	140–193
Tail length (mm)	115–203	144–181	136–155
Pes length (mm)	28–44	34–39	33–37
Ear length (mm)	–	18–20	16–21

MAMMAE: 0+1+2 or 0+2+2 in *R. steini*; 0+2+2 in *R. praetor* and *R. mordax*.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES:

- for *R. mordax*: *Rattus ringens mordax*, *Rattus leucopus mordax*, *Rattus ruber mordax*, *Rattus ruber*
- for *R. praetor*: *Rattus leucopus praetor*, *Rattus ringens praetor*, *Rattus ruber praetor*, *Rattus ruber*
- for *R. steini*: *Rattus ringens steini*, *Rattus ruber steini*, *Rattus ruber.*

DISTRIBUTION: *R. mordax* is confined to the Huon Peninsula and south-eastern 'tail' of New Guinea. Most records are from elevations below 600 m. A distinctly larger subspecies (*R. m. fergussoniensis*) is found on many of the islands of the D'Entrecasteaux group and the Louisade Archipelago, and on Woodlark Island of the Trobriand group. *Rattus praetor* occurs in the northern lowlands of New Guinea and on New Britain and the Solomon Islands to the east. The species is also recorded from recent fossil remains from Vanuatu and Fiji, far outside of its current range. All of the island populations probably resulted from prehistoric human introductions. *Rattus steini* is widely distributed at mid-altitudes (approximately 500–2500 m) along the central mountain chain of New Guinea, with isolated populations in the northern ranges and on the Huon Peninsula. Three subspecies of *R. steini* are distinguished on the basis of slight morphological differences and variation in mammary formulae.

TAXONOMIC ISSUES: each of the New Guinean pest species of *Rattus* was formerly included under the species *R. leucopus*, *R. ringens* and *R. ruber*. *Rattus leucopus* (with subspecies *ringens*) is a distinct, forest-dwelling species found in the lowlands of southern New Guinea and northern Australia. The name *Rattus ruber* was based on a New Guinean example of *R. nitidus*.

HABITAT USE: all three species occur in low numbers in primary rainforest but they are more abundant in subsistence gardens and plantation areas, where they are usually the most commonly caught species of rat. *Rattus steini* and *R. mordax* are also common in anthropogenic grasslands created by gardening and burning. None of these species is reported as a true resident of village habitat. Indeed, everywhere across New Guinea, this niche is occupied by the introduced species *R. exulans* and *R. rattus*. However, *R. mordax* will occasionally enter village houses to attack stored rice and sweet potato.

NESTING BEHAVIOUR: all three species are reported to dig burrow systems. Females of *R. steini* and *R. praetor* are known to raise litters in this context.

BREEDING BIOLOGY: breeding is recorded at all times of year in *R. steini* and *R. praetor*. Estimates of mean litter size are 4.5 (range 2–7) for *R. praetor*, 2.7–3.4 (range 2–5) for *R. steini*, and 2.3 (range 2–4) for *R. mordax*.

POPULATION DYNAMICS: in the Southern Highlands of Papua New Guinea, *R. steini* remains common in abandoned gardens for the first nine months of successional regeneration. After that, its numbers decline as a shrub layer develops and various forest-dwelling species of rodents become re-established.

DAMAGE TO CROPS: there are few specific reports of crop damage, but all three species are identified by subsistence farmers as significant pests. Damage commonly occurs to tuber crops, especially to sweet potato.

Damage to stored food by *R. mordax* was noted above.

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Adult *Rattus mordax.*

Adult *Rattus steini.*

Adult *Rattus praetor.*

Rattus nitidus (Hodgson, 1845)

COMMON NAME: Himalayan rat

Rattus nitidus is a major agricultural pest species in rice- and wheat-growing areas of Sichuan Province, southern China. In some of the more mountainous parts of Southeast Asia, it is said to be a common village pest. Although this species has been introduced in recent prehistoric or historic times to various Philippine and Indonesian islands, its pest status in these areas remains undocumented.

MORPHOLOGICAL FEATURES: a medium-size rat with soft, woolly fur that is brown dorsally, and cream but grey-based on the belly. The snout is long and broad, and the ears are large and lightly furred. The tail is approximately equal in length to the head+body and is weakly 'bicoloured' (dark above, paler below). The pes is relatively long and narrow, and clothed in pure white hairs. The manus and lower fore-limb are also pure white.

MAMMAE: 1+2+3.

Measurements from published sources suggest that more northerly populations (Sichuan and Gansu Provinces of China) grow to a considerably larger size than those from Southeast Asian localities, e.g. maximum body weights recorded for Sichuan are 273 g for males and 320 g for non-pregnant females, compared with 122 g for the Thai population.

OTHER RECENTLY APPLIED SCIENTIFIC NAME: *Rattus rattus nitidus*.

DISTRIBUTION: mountainous and hilly regions of northern India and Nepal, through northern Myanmar, northern and central Thailand, northern Laos and southern China to Hainan Island and Fukien Province; extending down the central mountain chain of Vietnam. *Rattus nitidus* is also found in four widely scattered localities in island Southeast Asia, presumably as a result of human introductions: Benguet Province, Luzon Island, in the Philippines; central Sulawesi, Indonesia; Seram in Maluku Province, Indonesia; and the Bird's Head Peninsula, Province of Papua, Indonesia. On Seram

Adult measurements	Thailand	Southern Vietnam	Sichuan, China (male)	Sichuan, China (female)
Weight (g)	to 122	–	135.9	114.4
Head+body (mm)	to 177	173–177	163.4	157.6
Tail length (mm)	to 168	168–191	170	166
Pes length (mm)	to 37	35–40	36.0	34.0
Ear length (mm)	to 21	20–24	21.3	21.0

and the Bird's Head Peninsula of Papua, *R. nitidus* has successfully invaded montane forest habitat.

HABITAT USE: abundant in all cropping systems in Sichuan Province, including rice, wheat, maize and potato fields and orchards, but uncommon in associated village habitat where '*R. rattus*' is dominant. Results of a mark–recapture study suggest that individuals regularly shift their exploitative focus between habitats, presumably following the availability of food.

In the uplands of Thailand, *R. nitidus* is said to occur exclusively in village houses, where it is trapped in about equal numbers with '*R. rattus*' and *R. exulans*. In a village near Luang Prabang in the uplands of northern Laos, small numbers of *R. nitidus* were trapped in irrigated rice fields situated between a village and regrowth forest. At this locality, *R. nitidus* is either rare or absent in the village habitat, which instead supports a high-density population of '*R. rattus*'.

NESTING BEHAVIOUR: nothing is reported. *Rattus nitidus* presumably nests in or around houses in upland villages in Thailand, but may dig burrows where it occurs as a field pest in southern China.

BREEDING BIOLOGY: breeding activity in Sichuan Province occurs in all months except December–February. Pregnancy rates peak at 50% in March–April, with a second, more variable peak (25–50%) in August–September. These peaks correspond to periods of crop growth and maturation for wheat and rice, respectively.

Litter size in Sichuan Province ranges from 4–15, with an overall average of 8.25. There is little variation in litter size through the course of the extended breeding season. Captive females can produce four litters per year with an interval between births of 34.7 ± 10.3 days. However, most wild-caught pregnant females have only one set of scars, indicating a lower reproductive output under natural conditions. Females in Gansu Province, China, produce 2–3 litters per year, with litter sizes of 2–7. A wild-caught female from Thailand was reported to have produced and raised a litter of 6.

Captive-born pups from the Chinese population are reported to weigh 7 g at birth, which is very large in comparison with other pest species (e.g. 4.3 –6.2 g in *R. norvegicus*; see Chapter 6, Table 6.1). The pups are weaned after 25–30 days. Males reach sexual maturity at 63–80 days; females considerably later at an average of 119 days. The average life span is estimated at around 12 months for males; slightly less for females.

POPULATION DYNAMICS: *R. nitidus* makes up 67% of rodent captures in Sichuan Province, with average densities through the year estimated at around 3–4 individuals/ha. Peak abundances (around 10/ha) are recorded in May–June (during the ripening phase of wheat) and September–October (just after the rice harvest), reflecting the two major periods of juvenile recruitment at those times.

DAMAGE TO CROPS: levels of damage to crops are not reported for Sichuan Province.

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Fore-limbs of adult *Rattus nitidus* from Laos.

Upper surface of pes; adult from Laos.

Lower surface of pes.

Rattus norvegicus (Berkenhout, 1769)

Common names: Norway rat, sewer rat, brown rat

Rattus norvegicus is a major urban pest worldwide and it has successfully invaded many Asian cities and towns. It is also reported as a field pest in scattered locations in Thailand, Vietnam and the Philippines, but generally with lower population densities than other local pest rodents.

morphological features: a large, terrestrial rat with short, grey–brown to plain-brown dorsal fur and a pale-brown or grey belly. Black (melanistic) individuals are moderately common in some populations. The snout is long and broad, and both the eyes and the ears are small. The tail is almost always shorter than the head+body. It is usually weakly 'bicoloured' (dark above, paler below) but sometimes appears mottled or blotched. The pes is proportionally longer and heavier than in other species of *Rattus* and is usually clothed in pure white hairs (but with dark hairs in melanistic individuals).

Rattus norvegicus is sometimes mistaken for species of *Bandicota*. However, the bandicoot rats have larger ears, a darker manus and pes, and broader incisors.

mammae: 1+2+3 (some eastern European populations have 1+1+3).

other recently applied scientific names: *Rattus rattus norvegicus, Rattus norvegicus socer.*

distribution: original distribution is thought to be south-eastern Siberia and northern China, but now found on all continents except Antarctica. In South and Southeast Asia and in the wider Pacific region, *R. norvegicus* is most commonly found around ports and the major towns. However, in several areas it appears to be established as an agricultural pest.

taxonomic issues: the name *norvegicus* was originally proposed for the population occupying Great Britain. East Asian populations, including those found in a presumed wild state, are generally referred to the subspecies *R. norvegicus socer*. Because this species is often found around wharves and ships, many local populations may be of mixed origin.

habitat use: a terrestrial, burrowing species with poor climbing skills and often found close to water, such as along rivers and major irrigation canals. It

Adult measurements	Russia	Thailand	Northern Vietnam
Weight (g)	–	to 300	230–510
Head+body (mm)	150–248	to 233	205–260
Tail length (mm)	100–220	to 201	190–250
Pes length (mm)	27–44	to 44	38–50
Ear length (mm)	17–22	to 21	19–26

occurs in many major cities and towns, where it lives in and around buildings and animal yards, feeding on refuse and stored food. Less commonly, it is found in cultivated areas removed from human habitation, including rice fields in Vietnam, Thailand and Luzon Island in the Philippines, and rice–wheat fields in Sichuan Province, southern China.

Rattus norvegicus lives communally and constructs large and complex burrow systems that may be occupied for many years. A typical burrow complex has multiple points of entry and exit, and numerous interconnected tunnels and chambers. Food storing or 'caching' behaviour is reported for this species in North America. Detailed behavioural studies of wild *R. norvegicus* have documented a strongly hierarchical social system in which high-ranked individuals (males and females) enjoy privileged access to food and other resources. This allows them to forage less often and for shorter periods each night, and for high-ranked females to breed at a younger age and with considerably greater success. Behavioural differences related to social rank become especially pronounced under high population densities.

NESTING BEHAVIOUR: nests lined with leaves or other soft material are constructed within the communal burrow complex. Food caches are often added immediately before the weaning of pups—presumably to allow the immature rats to remain longer in the safe, burrow environment.

BREEDING BIOLOGY: in Sichuan Province, breeding activity is restricted to the warmer months (May–October). Year-round breeding is likely in warmer regions, provided adequate food is available.

No litter size estimates are available from Southeast Asia. Elsewhere in the region, a mean litter size of 8.1 is reported for India and 10 (range 5–13) for central Asia. In North America, estimates of mean litter size range from 8.4–9.9, with similar estimates (8.7–9.3) for populations in Europe. Overall pregnancy rates for adult females are estimated at 15% for India, and in the range of 11–29% for North America and 17–31% for Europe. The pregnancy rate peaks at 30% in June in Sichuan Province, China. The gestation period in wild populations is reported as 22–24 days.

In one wild North American population in Baltimore, females entered oestrus for the first time at around 40 days of age, but first conception was often delayed by several months, especially in socially low-ranked females. Females continued to produce litters through to a maximum of 420 days of age, but with longer intervals between litters after the first year. Females generally outlived males, but few individuals lived longer than two years.

In wild European and North American populations, males generally develop scrotal testes at a head+body length of 93–190 mm. Females generally show vaginal perforation at 72–123 mm, but rarely produce their first litter below 180 mm.

POPULATION DYNAMICS: low population densities of 0.5–3 individuals/ha are reported from cropping areas in Sichuan Province. Slight fluctuations in abundance occur through the year, with minor peaks in June and in September–October. Experimental removal of *Rattus nitidus*, the major co-occurring pest species, led to an increase in the abundance of *R. norvegicus*.

The historical introduction of both *R. norvegicus* and *R. rattus* to many different parts of the world has had various outcomes. In Great Britain, *R. norvegicus* arrived later than *R. rattus* and led to the local decline, almost to extinction, of the latter species. The reverse has occurred in New Zealand where *R. norvegicus*, once common and widespread, has been largely displaced by *R. rattus*.

DAMAGE TO CROPS: the level of damage to crops caused specifically by *R. norvegicus* in South and Southeast Asia is not recorded. Elsewhere in the world, the species is responsible for extensive agricultural damage. It is also known to harm domestic fowl.

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Adult *Rattus norvegicus* from Vietnam.

Pes of adult from Vietnam: upper surface (left) and lower surface (right).

Adult specimen from Cambodia.

Adult from Vietnam.

Rattus rattus Complex

Common names: **house rat, black rat, roof rat**

This group or 'complex' includes a number of closely related species that presumably arose in discrete geographical areas but are now intermingled across at least part of their ranges. This has probably resulted in some local interbreeding and gene flow (hence the term 'complex'), and resulted in much confusion over the true number of species in the group. The group probably originated in Southeast Asia and still has its main diversity there. Today, the most widely distributed member of the group is the 'black rat' which spread initially to Europe and from there to many other parts of the world. In many countries, members of the *Rattus rattus* Complex are confined to village or urban habitats. However, in some parts of Southeast and South Asia, these animals are the dominant agricultural rodent pests, causing extreme damage in a wide range of crops, including cereals.

morphological features: medium-size rats that are equally at home on or off the ground. Most populations are highly variable in external appearance. In Asia, the dorsal fur is usually some shade of brown (greyish to reddish). Black individuals are rare in Asia, in contrast to Europe where the 'black rat' is the more typical form. The belly fur in Asian populations is equally variable, with some individuals having pure creamy-white belly fur and others having a grey-based fur with cream to buff tipping. A contrasting chest patch or mid-belly line is quite common, either white against a dark belly, or dark against a white belly. In adults, the dorsal fur is moderately spiny, especially on the flanks. Long, black guard hairs project through the dorsal fur; these are most conspicuous on the lower back. The snout is moderately long and narrow, and the ears are large and thinly furred. The tail is usually slightly longer than the head+body, but in some populations it is either slightly shorter or much longer than the head+body. The tail is always dark above and below, but very occasionally

Adult measurements	India (arid zone)	Bangladesh	Thailand	Northern Vietnam	Malaysia	Sumba Is, Indonesia
Weight (g)		to 213	–	to 219	–	–
Head+body (mm)	138–185	73–225	to 182	105–215	150–205	172–230
Tail length (mm)	163–216	55–234	to 188	120–213	175–231	176–237
Pes length (mm)	22–33	18–39	to 33	26–35	32–39	35–43
Ear length (mm)	19–22	–	to 23	17–23	19–25	22–28

ends in a short, all-white tip. The fur on the upper surface of the manus is dark over the wrist but white on the digits. The pes is moderately broad and has prominent plantar pads, usually with obvious striations. The upper surface of the pes is occasionally pure white, but is more often partially clothed in black or orange hairs. The fur on the toes is white.

MAMMAE: 1+1+3 or 1+2+3; some individuals have contrasting numbers of postaxillary teats on the left and right sides of the body.

Members of the *R. rattus* Complex can be difficult to distinguish from the similar-size pest species *R. tiomanicus*, *R. argentiventer* and *R. nitidus*, and from *R. sikkimensis*—a highly arboreal, forest-dwelling species. In comparison to *R. rattus*:

- *R. tiomanicus* is always white-bellied and adults have 'sleeker' fur with shorter guard hairs that barely project through the fur, even on the lower back
- *R. argentiventer* usually has a conspicuous fringe of orange hairs just forward of the ear, a slightly longer and relatively narrower pes that is more boldly marked with dark hairs, a relatively shorter tail with slightly larger tail scales, more densely furred ears, and a more 'peppered' (orange and black) appearance to the dorsal fur
- *R. nitidus* has darker, woollier fur, a pure-white manus (the white fur often extends partway up the fore-limb), and a relatively long and narrow, pure-white pes. The tail is often slightly darker above than below (weakly 'bicoloured')
- *R. sikkimensis* has larger plantar pads on the pes, longer and thicker facial vibrissae that extend past the ears when folded back, very prominent guard hairs along the entire length of the back, and a proportionally longer tail. This is a highly arboreal species.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES: *Rattus tanezumi*, *Rattus flavipectus*, *Rattus germaini*, *Rattus molliculus*; also various subspecies within *R. rattus* (e.g. *R. r. alexandrinus*, *R. r. arboreus*, *R. r. diardii*, *R. r. frugivorous*, *R. r. mindanensis*, *R. r. sumbae*).

DISTRIBUTION: members of the *R. rattus* complex are found throughout mainland Southeast and South Asia, including all large and most small islands. They also are widely distributed through the Pacific region, where they were introduced during prehistoric (Micronesia) and historic times (Melanesia and Polynesia).

TAXONOMIC ISSUES: members of the *R. rattus* Complex display a variety of chromosomal rearrangements, some of which result in reduced fertility between hybrids. In some recent works, the names *Rattus rattus* and *Rattus tanezumi* have been used to distinguish the European 'black rat' with 38 chromosomes (*R. rattus*, with possible wild populations in India) from the Asian 'house rats' with 42 chromosomes (*R. tanezumi*). However, genetic studies currently in progress show two major genetic groups among the Asian house rats, with partially overlapping ranges. Because we are not confident that *R. tanezumi* is the earliest available name for either of the two Asian lineages, we prefer to group them all as the *Rattus rattus* Complex pending completion of a comprehensive taxonomic study. In the following sections, they are referred to collectively as '*R. rattus*'.

HABITAT USE: most commonly found in and around human dwellings, livestock yards and storage facilities. However, in Asia and the Pacific region, '*R. rattus*' also commonly enter gardens and cropping areas, including rice fields. In Indonesia, Malaysia, Vietnam and Cambodia, '*R. rattus*' usually accounts for less than 10% of captures in these habitats, presumably as a consequence of competition with *R. argentiventer*. In areas where *R. argentiventer* is absent, such as in Bangladesh, Laos, parts of Thailand and on many of the Philippine islands, capture rates of '*R. rattus*' in field areas are typically much higher, and it sometimes assumes the role of dominant agricultural pest.

In the uplands of Laos, '*R. rattus*' is the dominant pest in both village and field habitats. The species is also abundant in adjacent forest-edge habitat. A recent radio-tracking study in Luang Prabang Province, undertaken immediately postharvest, found many individuals sheltering in piles of rice straw and cut Job's tear stalks. Others were using burrows and arboreal nests in trees, located both in field and fallow habitats, and in adjacent forest. Large-scale movements were observed between forest and field habitats, with rats using the forest–field interface for at least some of the more extensive movements. Females with pups were found occupying burrows in the field habitats.

In southern Laos, '*R. rattus*' is said by farmers to dislike entering water. This statement is supported by observations of rice tiller damage only around the edges of flooded fields, adjacent to the bunds. Dry fields in the same area had more extensive damage in patches throughout the crop. This observation is seemingly contradicted by a report from the Philippines of exceptionally high densities of '*R. rattus*' (800–2200 individuals/ha) in a large area of flooded marshland alongside rice paddy. These estimates are based on rats flushed from arboreal leaf nests in this habitat and are presumably reliable. One possible explanation is that the emergent marshland sedges were sufficiently robust for '*R. rattus*' to occupy this habitat without entering the water. Alternatively, the apparent aversion to swimming among Lao '*R. rattus*' may be a peculiarity of that population or member of the species complex.

NESTING BEHAVIOUR: nests are constructed in almost any convenient place. They usually consist of leaves or other dry, soft material drawn together in a bundle and placed in a confined space—in a burrow, among rocks, in a tree hollow or a fallen log, in the fork of a tree, in the foliage of tall grasses or dense shrubs, inside the stump of a cut banana leaf, in roof thatch, in a wall cavity or inside a mud-brick wall, in a pile of cut wood or brush, in a straw-pile in a harvested field, among stored sacks of grain or jute etc. Numerous different nesting sites are often used within a single population. For example, in one area of northern Laos, different individuals were found raising litters in burrows, in straw piles, in tree hollows, in large, arboreal leaf nests, and in a house roof. Only one litter was ever present in any burrow or nest, so any previous young may disperse upon or before the birth of a new litter; alternatively, the female may herself relocate to a new nest for each successive litter.

BREEDING BIOLOGY: breeding data are available from many parts of the world but most studies refer to urban populations of the European 'black rat'. In South and Southeast Asia, urban or village populations of '*R. rattus*' generally breed more-or-less year-round, probably feeding on refuse and stored food. However, populations living in field habitat generally show cycles of breeding activity and population abundance linked specifically to cropping cycles (see below). For example, in upland areas of Laos, breeding is probably continuous in village habitats but appears to cease altogether during the long dry season in adjacent field habitats.

Estimates of mean litter size fall mostly in the range of 4–8, with the highest mean litter sizes (up to 10) found in rice-producing regions in the Philippines. Both in the Philippines and in Sekong Province of southern Laos, individual females have been found with as many as 14 live embryos, but such high counts are unusual.

Pregnancy rates averaged across the entire year usually fall around 15–20% of adult females. Individual monthly values typically peak at around 25–30%, but monthly values up to 70% have been recorded in both field and village populations in upland Laos.

Vaginal perforation is reported in individuals as small as 25 g, but many females of 50 g body weight remain imperforate. Pregnancy is recorded in females with body weights as low as 50 g, but first pregnancies are more common above 80–100 g. The gestation period for European '*R. rattus*' is 20–22 days, longer in lactating females. Males typically develop scrotal testes at body weights of 60–100 g.

POPULATION DYNAMICS: in rice-growing areas of the Philippines, the abundance of '*R. rattus*' fluctuates in direct relation to cycles of crop maturation and harvest. A single peak in abundance was reported for Cotabato, Mindanao, with a single, rainfed rice season, but where double cropping is practised in Siniloan, Laguna, two distinct peaks in abundance were observed.

Refuge habitats probably play an important role in population cycles of 'R. rattus' as a field pest. In many agricultural areas, the most likely refugia are villages, where population levels may remain fairly constant through the year. Individuals from these areas presumably colonise the adjacent fields as food and cover for nesting become available.

Upland areas with extensive areas of remnant forest may also act as an important refuge and source of emigrants. Little is yet known about the ecology of '*R. rattus*' in such habitats in Asia. However, in various parts of the world including Madagascar, New Zealand and some parts of Indonesia, '*R. rattus*' is known to have successfully invaded primary or only minimally disturbed forests. In both Madagasar and in the Galapagos Islands, invasion by '*R. rattus*' has apparently precipitated the extinction of native species. In New Zealand, the earlier invader *R. exulans* has been largely displaced from all habitats by the larger and more aggressive '*R. rattus*'.

DAMAGE TO CROPS: '*R. rattus*' is responsible for major postharvest losses in many countries. Where '*R. rattus*' is the dominant field pest, it also causes extensive damage to a wide variety of cereal, vegetable and fruit crops, including coconuts. The rats cut whole tillers at all stages of growth but are also sufficiently agile to climb and directly attack the panicles of mature plants.

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Tamarin, R.H. and Malecha, S.R. 1972. Reproductive parameters in *Rattus rattus* and *Rattus exulans* of Hawaii, 1968 to 1970. Journal of Mammalogy, 53, 513–528.

Uhler, L.D. 1976. Seasonal abundance of *Rattus rattus mindanensis* at the International Rice Research Institute, College, Laguna, Philippines. The Philippine Agriculturalist, 51, 581–586.

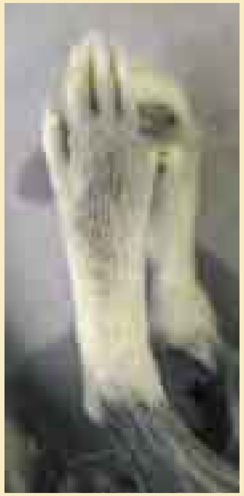
Adult *Rattus rattus* from the uplands of Laos.

Adult from Bangladesh.

Lower surface of pes: adult *Rattus rattus* from Bangladesh.

Lower surface of pes: adult from southern Vietnam.

Upper surface of pes; adult from Bangladesh.



Upper surface of pes; adult from southern Vietnam.

Adult from the uplands of Laos.

Adult from the uplands of Laos: note dark fur of fore-limb.

Juvenile from the uplands of Laos.

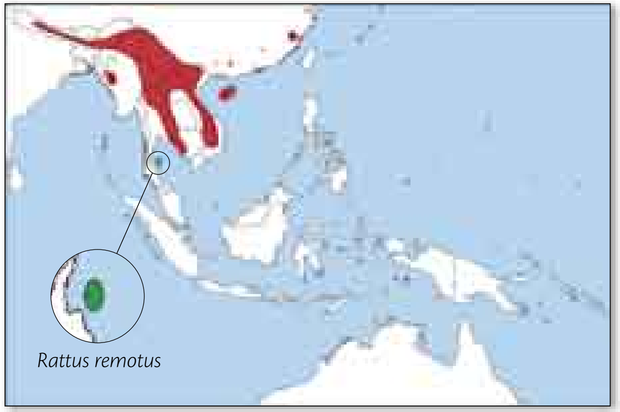
Adult from the uplands of Laos.

Incisors of adult from Bangladesh.

Lower surface of manus; adult from Bangladesh.

Rattus sikkimensis (Hinton, 1919)

Common name: Sikkim rat



Rattus sikkimensis is widespread in upland forest habitats of mainland Southeast Asia. It is a highly arboreal species and closely resembles *Rattus rattus* in appearance; indeed, the two are often confused. However, unlike the members of the house rat group, *R. sikkimensis* is not known either as a village or as an agricultural pest.

MORPHOLOGICAL FEATURES: a moderately large, arboreal rat, closely resembling white-bellied varieties of the house rat, *Rattus rattus*. It differs from these in a number of features including its larger and more prominent plantar pads, its proportionally longer tail (commonly 20–30 mm longer than the head+body), its larger ears and longer, more inflated snout, and its longer, thicker vibrissae and more prominent guard hairs. The dorsal fur is orange–brown and distinctly shaggy, with conspicuous, black guard hairs all the way down the centre of the back. The belly fur is either pure white or cream in colour, sometimes with a reddish-brown chest patch. The pes is densely furred with a mixture of white and black hairs—the dark hairs often extending to the base of the toes or beyond. The ears are relatively larger than in any other Southeast Asian *Rattus* species and the vibrissae are also exceptional both for their thickness and their length (extending well past the ears when folded back). A short, white tail-tip is reported in 20% of specimens from Hainan Island, southern China. One specimen from Hong Kong had an extensive white patch covering the snout and cheeks.

MAMMAE: always 1+2+3.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES: *Rattus rattus sladeni, Rattus rattus koratensis, Rattus koratensis, Rattus remotus.*

DISTRIBUTION: widely distributed across the upland regions of Southeast Asia, from Nepal in the west, through the Sikkim region of India and northern Myanmar and Laos, to the uplands of northern and central Vietnam in the east. It is recorded from various localities in southern China including Hainan and Hong Kong Islands, north to Fujian Province.

TAXONOMIC ISSUES: *R. sikkimensis* is sometimes treated as a geographical variant of *Rattus remotus*

Adult measurements	Thailand	Laos	Vietnam	Hong Kong
Weight (g)	to 129	–		105–50
Head+body (mm)	to 173	200	to 185	156–200
Tail length (mm)	to 209	212	to 204	185–240
Pes length (mm)	to 33.5	31	to 36	32–37
Ear length (mm)	to 22.5	–	–	23–25

(Robinson & Kloss, 1914), a morphologically similar species found on Koh Samui and some nearby islands in the Gulf of Thailand (see map on previous page). If this were proven correct, *remotus*, being the earlier name, would apply to the entire group.

HABITAT USE: in Thailand, *R. sikkimensis* is said by Marshall (1977) to be "common in evergreen forest of mountains". In Laos, we have trapped the species in upland gardens adjacent to forest, and in clumps of giant bamboo growing along a major river flowing alongside a large village. Despite this close proximity to human activity, no individuals of *R. sikkimensis* were trapped in village houses, perhaps on account of competition from *R. rattus*. In Vietnam, this species (as *R. remotus*) is said by Lunde and Son (2001) to be "often trapped in agricultural areas, scrub habitats and around houses". However, during our work in Vietnam, we have never encountered *R. sikkimensis* in densely settled, lowland agricultural habitat in either of the Mekong Delta in the south or the Red River Delta in the nort.

NESTING BEHAVIOUR: nothing reported.

BREEDING BIOLOGY: nothing reported.

POPULATION DYNAMICS: nothing reported.

DAMAGE TO CROPS: although there are no reports of crop damage, the potential for confusion with *R. rattus* should be kept in mind.

KEY REFERENCES:

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Lunde, D. and Son, N.T. 2001. An identification guide to the rodents of Vietnam. New York, Center for Biodiversity and Conservation, American Museum of Natural History, 80 p.

Marshall, J.T. 1977. Family Muridae. In: Lekagul, B. and McNeely, J.A., ed., Mammals of Thailand. Bangkok, Kurusapha Press, 397–487.

Musser, G.G. and Heaney, L.R. 1985. Philippine *Rattus*: a new species from the Sulu Archipelago. American Museum Novitates, No. 2818, 1–32.

Adult *Rattus sikkimensis* from Laos.

Subadult from Hong Kong.

Pes of adult from Laos; upper surface (left) and lower surface (right).

Rattus tiomanicus (Miller, 1900)

Common name: wood rat

This highly arboreal species is found in secondary forests and plantations of the Malay Peninsula and the surrounding islands of the Sunda Shelf. It is a minor pest in gardens and orchards but reaches high densities and causes significant damage in oil palm plantations. In some parts of Malaysia, *R. tiomanicus* is found in villages, but generally only where its close relative, *R. rattus* is absent.

Morphological features: a medium-size, arboreal rat with grizzled brown dorsal fur and a pure-white to off-white belly. The snout is short and broad, and the ears are large and thinly furred. The tail is usually slightly longer than the head+body and is dark above and below. Overall, *R. tiomanicus* is very similar in appearance to *R. rattus* but with shorter guard hairs that barely project through the fur. The fur is described as 'sleek' compared with 'coarse' or 'shaggy' in *R. rattus*.

Mammae: 1+1+3.

Other recently applied scientific names: *Rattus jalorensis*, *Rattus rattus jalorensis*.

Distribution: the Malay Peninsula and the surrounding Sunda Shelf islands (Sumatra, Borneo, Java, Palawan and many smaller islands). Off the Sunda Shelf, it is found on Bali, Enggano Island (south-west of Sumatra) and the islands of the Maratua Archipelago (east of Borneo).

Taxonomic issues: some morphologically distinct island populations are currently recognised as subspecies (e.g. *R. tiomanicus mara* of the Maratau Archipelago).

Habitat use: primarily arboreal and said to feed mainly on fruits. In oil palm plantations, *R. tiomanicus* often shelters in piles of cut fronds and, less frequently, in cut stumps or fallen logs. Very occasionally it is found in terrestrial burrows, but these are probably excavated by other species. Individuals generally have small home ranges, consisting of one or a few adjacent palms. Occasional, larger-scale movements are undertaken to establish new feeding areas.

Nesting behaviour: nests are said to be off the ground, presumably in crowns of palms and in hollow stumps and logs.

Adult measurements	Malaysia
Weight (g)	91 ± 34
Head+body (mm)	154–176
Tail length (mm)	155–198
Pes length (mm)	27–35
Ear length (mm)	16–22

BREEDING BIOLOGY: studies in a Malay oil palm plantation found year-round breeding. Litter size ranged from 2–7, with a mean of 4.4. The average female pregnancy rate, taken over several complete years, was 17.6%, or 27.9% if restricted to sexually mature individuals.

Males show rapid testicular enlargement at a body weight of around 60 g. Females show vaginal perforation from body weights below 30 g, but a few are still imperforate at 50 g. The smallest recorded pregnant female weighed 65 g.

POPULATION DYNAMICS: estimates of population density in unbaited oil palm plantations range from 183–539/ha, with an average of 306/ha.

DAMAGE TO CROPS: *R. tiomanicus* damages the maturing and ripe fruit of the oil palm, and can cause losses of up to 5% in oil production if uncontrolled.

KEY REFERENCES:

Harrison, J.L. 1952. Reproduction in rats of the subgenus *Rattus*. Proceedings of the Zoological Society of London, 121, 673–694.
Wood, B.J. 1984. A long-term study of *Rattus tiomanicus* populations in an oil palm plantation in Johore, Malaysia. Journal of Applied Ecology, 21, 445–464.
Wood, B.J. and Liau, S.S. 1984. A long term study of *Rattus tiomanicus* populations in an oil palm plantation in Johore, Malaysia. III. Bionomics and natural regulation. Journal of Applied Ecology, 21, 465–472.

Adult *Rattus tiomanicus* from peninsular Thailand (museum specimen).

Rattus turkestanicus (Satunin, 1903)

Common name: Turkestan rat

Rattus turkestanicus is an important field pest in parts of south-eastern China. In the western part of its range, it is known mainly as a forest rat.

MORPHOLOGICAL FEATURES: a medium-size, primarily terrestrial rat with reddish-brown dorsal fur and a tail that is approximately the same length as the combined length of the head+body. In the western part of its range, there are two colour 'forms' that may represent distinct subspecies or species. The 'typical' form of *R. turkestanicus* has a yellowish-white belly and a weakly 'bicoloured' (dark above, paler below) tail. The snout is short and broad, and the ears are relatively small and densely furred with a mixture of white and dark hairs. In the *vicerex* form, the belly fur is grey-based with cream tipping, the fur on the manus and pes is pure white, the ears are larger and the tail is strongly bicoloured. The eastern population most closely resembles typical *turkestanicus*.

MAMMAE: 1+2+3.

Overall, this species most closely resembles *Rattus norvegicus* but adults are smaller and have a relatively longer and more densely furred tail.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES: *Rattus rattoides*, *Rattus vicerex*.

DISTRIBUTION: highlands of the Middle East to Central Asia, extending along the southern flanks of the Himalayan massif, including parts of northern India, Nepal and south-western China (Yunnan Province). A possibly isolated population occurs in south-eastern China (Guandong, Xiamen and Fujian Provinces).

TAXONOMIC ISSUES: the south-eastern Chinese populations of this species are generally reported as *R. rattoides*. It is unclear whether these populations are continuous with typical *R. turkestanicus* of the Central Asian highlands. There is some variation in chromosome morphology among the western populations but it is unclear how this relates to the morphological variations noted above.

HABITAT USE: in the western part of its range, this species occupies natural forests at moderate to high altitudes. To the east, the species occupies the major

Adult measurements	Turkestan
Weight (g)	100–200
Head+body (mm)	168–215
Tail length (mm)	167–213
Pes length (mm)	31–38
Ear length (mm)	19–25

rice-producing area of the South China Plain, along the lower reaches of the Yangtze and Pearl Rivers. Here, *R. turkestanicus* is the dominant agricultural rodent pest, making up 62–84% of trap captures in rice-field habitat.

NESTING BEHAVIOUR: nests are located in burrows. Areas with dense groundcover are preferred as burrow sites, with burrow densities averaging almost 50 holes per 100 m transect through dense (>60%) groundcover. In rice fields, burrows are located in bunds and are most numerous along weedy bunds.

BREEDING BIOLOGY: in Guandong and Fujian Provinces, there are two peaks in breeding activity, in June and October—both linked to periods of rice maturation. The lowest pregnancy rate occurs during winter (December–January). Two peaks are also reported in Xiamen Province, but in March–May and August–October.

Mean litter size (from embryo counts) is 6.78 (range 2–11) in the Pearl River Delta and 7.0 (range 4–11) in Fujian Province. In both areas, litter size varies seasonally, with slightly higher litters in late winter–autumn (August–October) than in spring (March–May).

POPULATION DYNAMICS: in Fujian Province, high densities occur in November–December through to April, with a dramatic decline during May. In Xiamen Province, population densities remain fairly stable in the irrigated rice fields, but fluctuate markedly in vegetable and dry-land plots. Seasonal migration is reported in Guandong Province, with rats moving from the rice fields to nearby orange and banana plantations after each harvest.

DAMAGE TO CROPS: in southern China, the greatest damage is inflicted on early ripening rice crops, with reported yield losses of 5.3%. Damage is also reported to vegetables and fruits (oranges, bananas) but it is unclear whether damage is inflicted to fruiting bodies (which would imply some climbing ability) or to the plants themselves.

KEY REFERENCES:

Hong, C., Yan, G. and Zheng, B. 1989. The population dynamics and prediction to numbers of *Rattus rattoides*. Acta Theriologica Sinica, 9, 137–145.

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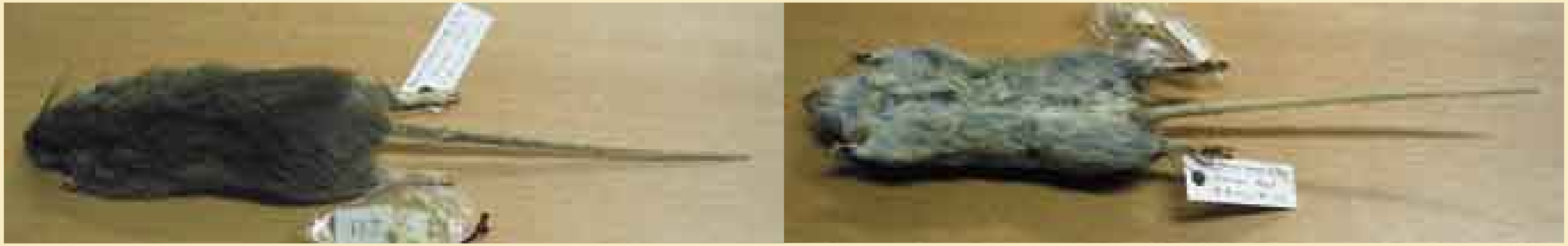
Zheng, Z. and Huang, Y. 1988. Studies on the seasonal population fluctuation in *Rattus rattoides*. Acta Theriologica Sinica, 8, 199-207.

Adult *Rattus turkestanicus* (*vicerex* form) from Nepal (museum specimen).

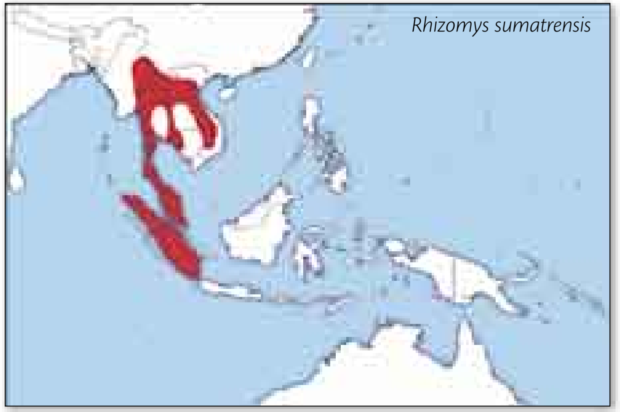


Adult *Rattus turkestanicus* (*vicerex* form) from Nepal: dorsal view (left) and ventral view (right) (museum specimen).

Adult ('typical' form) from Nepal: dorsal view (left) and ventral view (right) (museum specimen).

Rhizomys species

Common name: **bamboo rats**



Bamboo rats of the genus *Rhizomys* are widespread across the upland regions of northern Myanmar to southern China. They are moderately large to huge, stockily built animals with obvious adaptations to fossorial life and their diet of bamboo rhizomes and shoots. Although their burrows are sometimes located in slash-and-burn gardens, it is unclear how much damage they inflict on crops. There are some reports of bamboo rats damaging sugarcane and cassava.

Morphological features: all species share a common body form, with a massively broadened head, a plump body with short limbs, strong claws on both the pes and manus, small eyes and ears, and a short, sparsely haired tail that lacks scales (it is instead covered in soft, wrinkled skin).

Rhizomys species have grey–brown to dull orange–brown fur, rounded ears that just project through the fur, and granulated plantar pads on the manus and

Adult measurements	*R. pruinosus* Thailand	*R. pruinosus* Vietnam	*R. sinensis* China	*R. sumatrensis* Thailand
Weight	–	645–690 g	–	2–4 kg
Head+body (mm)	256–350	280–290	230–450	280–480
Tail length (mm)	100–124	108–120	50–90	102–200
Pes length (mm)	45–61	47–48	35–60	46–67
Ear length (mm)	18–26	18–21	11–20	18–36

pes (compared to smooth pads in *Cannomys badius*). *Rhizomys sumatrensis* (Raffles, 1821) grows to a much greater size than the other species, the tail is relatively longer, and the top of the head bears a distinctive, triangular patch of dark fur. The two posterior plantar pads on the pes of *R. sumatrensis* are united (compared to separate in other *Rhizomys* spp.). *Rhizomys pruinosus* Blyth, 1851 is a smaller species with a shorter tail and numerous white-tipped hairs that gives the fur a frosted appearance. *Rhizomys sinensis* Gray, 1831 is similar to *R. pruinosus* but has lush, pale-brown fur that lacks any frosting. The top and sides of the face in *R. sinensis* are darker than the back or flanks.

MAMMAE: 1+1+3 for all three species;
1+0+3 in some *R. pruinosus*.

OTHER RECENTLY APPLIED SCIENTIFIC NAMES:
of *Rhizomys pruinosus* = *Rhizomys pannosus*
of *Rhizomys sinensis* = *Rhizomys vestitus*, *Rhizomys senex*
of *Rhizomys sumatrensis* = *Nyctocleptes sumatrensis*.

DISTRIBUTION: *R. sumatrensis* is found in the uplands of eastern Myanmar, western, central and peninsular Thailand, south-western Cambodia, Laos and Vietnam. It occurs across a wider elevational range in peninsular Malaysia and on the island of Sumatra, Indonesia. *Rhizomys pruinosus* has a similar distribution to *R. sumatrensis* but it extends further west into Assam, India, and north to cover large parts of southern China. It is absent from Sumatra. *Rhizomys sinensis* occurs in the uplands of southern China and northern Vietnam, through to northern Myanmar. It has not yet been recorded in Laos but might be expected in the northern provinces.

TAXONOMIC ISSUES: each species shows geographical variation and subspecies are sometimes recognised. The bamboo rats as a whole are in urgent need of revision, especially on account of the heavy exploitation of these species in some areas as commercial food items.

HABITAT USE: bamboo rats are probably most abundant in the natural bamboo forests that still cover large areas of the uplands of Southeast Asia. Their presence in such areas is usually obvious from their large, poorly concealed burrow systems in which they shelter through the day. In Malaysia, *R. sumatrensis* emerges in the early evening and roams widely within the bamboo thickets, feeding on fallen fruit and other herbivorous matter. This species also has the habit of climbing bamboo culms to cut out sections of woody stem; these are carried back to the burrows for unknown purpose.

NESTING BEHAVIOUR: the burrow systems of *Rhizomys* spp. are possibly more complex than those of *Cannomys badius* but no details are available.

BREEDING BIOLOGY: litter size is reported as 3–5 in *R. sumatrensis*, which has a gestation period of "at least 22 days".

The young of *R. sumatrensis* grow hair at about 10–13 days, open their eyes at 24 days and are weaned over an extended period from 1–3 months after birth. Life span in captivity is about 4 years.

POPULATION DYNAMICS: nothing known.

DAMAGE TO CROPS: damage to sugarcane and cassava has been reported.

KEY REFERENCE:

Marshall, J.T. 1977. Family Muridae. In: Lekagul, B. and McNeely, J.A., ed., Mammals of Thailand. Bangkok, Kurusapha Press, 397–487.

Tail of adult *Rhizomys pruinosus* from northern Vietnam, showing absence of scales and very sparse fur.

Adult *Rhizomys pruinosus* from Laos.

Adult *Rhizomys sinensis* from China (museum specimen).

Adult *R. pruinosus* from northern Vietnam.

Pes of adult *R. pruinosus*; specimens from northern Vietnam (left) and Laos (right).

Adult *Rhizomys sumatrensis* from Malaysia (museum specimen).

Key to the pest rodents of South and Southeast Asia and the Pacific

1a. Tail covered with soft skin, lacking obvious scales **2**
1b. Tail covered with scales, arranged in rings **5**

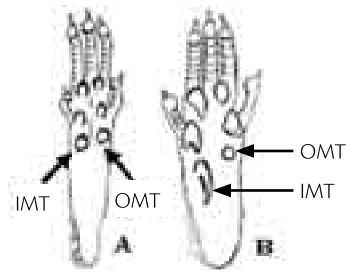
2a. Plantar pads on pes with smooth surfaces; ears completely hidden in fur . . . . ***Cannomys badius***
2b. Plantar pads on pes with granular surfaces; ears projecting through fur **3**

3a. Inner and outer metatarsal tubercles on pes fused; adult body size can exceed 1.5 kg . . . . ***Rhizomys sumatrensis***
3b. Inner and outer metatarsal tubercles on pes separate; adult body size not exceeding 1.5 kg **4**

4a. Fur on back and flanks plain gingery-brown, lacking projecting guard hairs . . . . ***Rhizomys sinensis***
4b. Fur on back and flanks grey with long, silvery tipped guard hairs . . . . ***Rhizomys pruinosus***

5a. Head+body length less than 110 mm **6**
5b. Head+body length more than 110 mm **12**

6a. Inner and outer metatarsal tubercles (IMT, OMT) on pes of nearly equal size (diagram A, below); females with mammae 1+2+2 . . . . **7**
6b. Inner metatarsal tubercle elongated, much larger than outer metatarsal tubercle (diagram B, below); specimen is juvenile (proceed with extreme caution!) **12**



7a. Inner metatarsal tubercle positioned close to outer metatarsal tubercle (as in diagram A, above) **8**
7b. Inner and outer metatarsal tubercles widely separated (gap between them far exceeds diameter of either pad) **11**

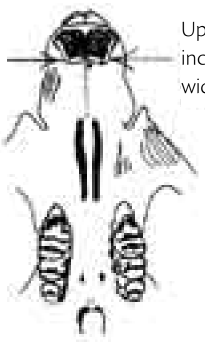
8a. Fur very stiff due to presence of numerous, broad spines; tail weakly bicoloured . . . . ***Mus cookii***
8b. Fur soft, without spines or with few, narrow spines; tail distinctly bicoloured **9**

9a. Plantar pads on pes distinctly raised; tail usually longer than head+body . . . . ***Mus caroli***
9b. Plantar pads on pes low; tail usually shorter than head+body **10**

10a. Belly fur pure white; tail usually 10 mm or more shorter than head+body .... ***Mus booduga***
10b. Belly fur grey-based with white or cream tipping; tail usually less than 10 mm shorter than head+body .... ***Mus terricolor***

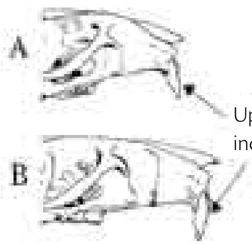
11a. Tail distinctly bicoloured and usually 10 mm shorter than head+body .... ***Mus cervicolor***
11b. Tail uniformly dark or weakly bicoloured and usually longer than head+body .... ***'Mus musculus'***

12a. Upper incisors in adult greater than 3.5 mm in combined width across tips; vibrissae on sides of snout short (barely reach ears when folded back) **13**
12b. Upper incisors in adult less than 3.5 mm in combined width; vibrissae on sides of snout long (overlapping ears when folded back) **16**



13a. Upper incisors wider than lower incisors; inner metatarsal tubercle elongated; tail with conspicuous hairs **14**
13b. Upper incisors narrower than lower incisors; inner metatarsal tubercle rounded; tail hairs indistinct .... ***Nesokia indica***

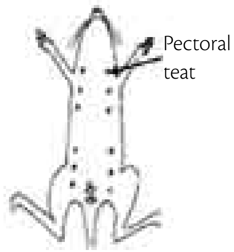
14a. Upper incisors projecting forward (diagram A, below); head+body usually 20 mm or more longer than tail; females with at least seven mammae on each side .... ***Bandicota bengalensis***
14b. Upper incisors curving backward (diagram B, below); head+body usually less than 20 mm longer than tail; females with six mammae on each side **15**



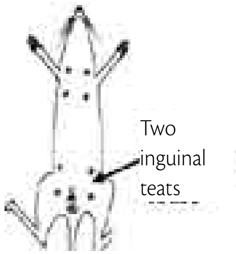
15a. Pes longer than 40 mm, even in juveniles; ear longer than 26 mm in adults; adult body weight commonly exceeding 350 g .... ***Bandicota indica***
15b. Pes usually shorter than 40 mm; ear not exceeding 26 mm; adult body weight usually less than 350 g .... ***Bandicota savilei***

16a. Specimen is adult female (able to accurately count mammae) **17**
16b. Specimen is male or young female (unable to count mammae) **33**

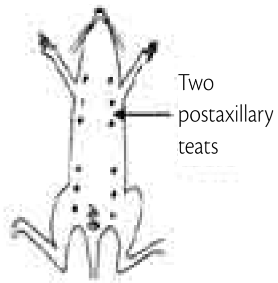
17a. Pectoral teat present **18**
17b. Pectoral teat absent **31**



18a. Two inguinal teats on each side **19**
18b. Three inguinal teats on each side **21**



19a. Two postaxillary teats on each side .... ***Berylmys berdmorei***
19b. One postaxillary teat on each side **20**



20a. Belly fur grey-based; pes shorter than 30 mm; incisors with orange or yellow enamel .... ***Rattus exulans***
20b. Belly fur pure white; pes longer than 30 mm; incisors with white or pale yellow enamel .... ***Berylmys bowersi***

21a. One postaxillary teat on each side **22**
21b. Two postaxillary teats on each side **24**

22a. Tail slightly shorter or longer than head+body; fur on back and flanks with obvious spines **23**
22b. Tail 15 mm or more shorter than head+body; fur on back and flanks soft, lacking obvious spines .... ***Rattus losea***

23a. Guard hairs conspicuous on lower back; belly fur pure white to cream or grey-based .... ***Rattus rattus***
23b. Guard hairs barely visible on lower back; belly fur always pure white or cream .... ***Rattus tiomanicus***

24a. Belly fur distinctly grey-based, with cream or buff tips **25**
24b. Belly fur pure white, cream or silvery grey **27**

25a. Large rat, adult body size commonly exceeding 250 g; pes length usually exceeding 40 mm, even in juveniles .... ***Rattus norvegicus***
25b. Smaller rat, adult body size rarely exceeding 250 g; pes length usually less than 40 mm **26**

26a. Fur very soft; manus and fore-limb covered in white fur; tail weakly bicoloured . . . . ***Rattus nitidus***
26b. Fur with obvious spines; fore-limb covered in dark fur, contrasting with manus; tail uniformly dark . . . . ***Rattus rattus***

27a. Tail bicoloured (darker above than below) **28**
27b. Tail uniformly dark above and below **29**

28a. Large rat, adult body size commonly exceeding 250 g; pes usually longer than 40 mm, even in juveniles . . . . ***Rattus norvegicus***
28b. Smaller rat, adult body size rarely exceeding 200 g; pes usually shorter than 40 mm . . . . ***Rattus turkestanicus***

29a. Fringe of orange fur just forward of ear; tail usually shorter than head+body . . . . ***Rattus argentiventer***
29b. No fringe of orange fur just forward of ear; tail usually longer than head+body **30**

30a. Vibrissae on sides of snout reach ears when folded back; all plantar pads on pes moderately large but well-separated . . . . ***Rattus rattus***
30b. Vibrissae on sides of snout extend beyond ears when folded back; all plantar pads on pes very large and close together . . . . ***Rattus sikkimensis***

31a. Fur on back and flanks with obvious broad spines **32**
31b. Fur on back and flanks lacking obvious spines . . . . ***Rattus steini***

32a. Fur on back with numerous projecting guard hairs; belly fur grey or ivory . . . . ***Rattus praetor***
32b. Fur on back without projecting guard hairs; belly fur cream . . . . ***Rattus mordax***

33a. Tail bicoloured (darker above than below) **34**
33b. Tail uniformly dark above and below **38**

34a. Large rat, adult body size commonly exceeding 250 g; pes usually longer than 40 mm, even in juveniles **35**
34b. Smaller rat, adult body size rarely exceeding 200 g; pes shorter than 40 mm **36**

35a. Tail shorter than head+ body; belly fur grey or brown; incisors with yellow or orange enamel . . . . ***Rattus norvegicus***
35b. Tail longer than head+body; belly fur cream or white; incisors with white or pale yellow enamel . . . . . . ***Berylmys bowersi***

36a. Belly fur pure cream or yellowish-white colour **37**
36b. Belly fur distinctly grey-based, with cream or buff tipping . . . . ***Rattus nitidus***

37a. Dorsal fur plain grey; incisor enamel cream or white . . . . ***Berylmys berdmorei***
37b. Dorsal fur brown or reddish brown; incisor enamel yellow or orange . . . . ***Rattus turkestanicus***

38a. Belly fur distinctly grey-based, with cream or buff tips **39**
38b. Belly fur pure white, cream or silvery grey **44**

39a. Large rat, adult body size commonly exceeding 250 g; pes usually longer than 40 mm, even in juveniles .... ***Rattus norvegicus***
39b. Smaller rat, adult body size rarely exceeding 250 g; pes shorter than 40 mm **40**

40a. Fur on back and flanks very soft, lacking obvious spines; tail equal in length or shorter than head+body **41**
40b. Fur on back and flanks with obvious spines; tail equal in length or longer than head+body **43**

41a. Manus and pes covered with pure white hairs; fur on lower fore-limb also pure white, forming long 'glove' .... ***Rattus nitidus***
41b. Manus and pes with a few to many dark hairs; fur on lower fore-limb dark **42**

42a. Dorsal fur reddish-brown; specimen from Melanesia .... ***Rattus steini***
42b. Dorsal fur grey–brown to reddish–brown; specimen from mainland Southeast Asia .... ***Rattus losea***

43a. Pes not longer than 30 mm, even in adult .... ***Rattus exulans***
43b. Pes usually longer than 30 mm, even in juveniles .... ***'Rattus rattus'***

44a. Large rat, adult body size commonly exceeding 250 g; pes usually longer than 40 mm, even in juveniles .... ***Rattus norvegicus***
44b. Smaller rat, adult body size rarely exceeding 250 g; pes shorter than 40 mm **45**

45a. Tail much shorter (at least 15 mm) than head+body **46**
45b. Tail slightly shorter than or longer than head+body **48**

46a. Fur on lower back and flanks soft, lacking obvious spines .... ***Rattus losea***
46b. Fur on lower back with obvious spines **47**

47a. Fur on lower back of adult with many long guard hairs .... ***Rattus praetor***
47b. Fur on lower back of adult with few projecting guard hairs .... ***Rattus mordax***

48a. Most vibrissae on sides of snout extending beyond ears when folded back; all plantar pads on pes very large and close together .... ***Rattus sikkimensis***
48b. Most vibrissae on sides of snout not extending beyond ears when folded back; all plantar pads on pes well-separated **49**

49a. Fringe of orange fur just forward of ear; tail usually 10 mm or so shorter than head+body .... ***Rattus argentiventer***
49b. No fringe of orange fur just forward of ear; tail usually equal in length or longer than head+body **50**

50a. Fur on lower back of adult with many long, projecting guard hairs .... ***Rattus rattus***
50b. Fur on lower back of adult with few projecting guard hairs .... ***Rattus tiomanicus***

APPENDIXES

Appendix 1: Trapping data sheet and coding system

TRAPPING DATA SHEET

Site Name:	Census No.:	District:	Date:	Name of Trapper & Data Recorder:	Entered by:	Verified by:	Page No:
							/

Crop Stage:	Water Depth:	Recent Farmer Control Activities:

CEN	YR	JUL	SITE	LINE	TRP	HAB	CS	RAT	SP	SX	V	T	P	TAIL LTH	EAR LTH	FOOT LTH	Total WGT	BAG	WGT	CL	CN	FA	Comments

Comments:

Codes for trapping data sheet

CEN **census number**

YR **year** (e.g. 2003 or 2004)

JUL **Julian date** (day of the year—see Appendix 3)

SITE **site number**

LINE **trap-line number**
1 = field
2 = channel/bank
3 = sugarcane
4 = village

TRP **trap number**

HAB **habitat code**
1 = local variety rice crop
2 = improved variety rice crop
3 = sugarcane
4 = groundnut
5 = sunflower
6 = mung bean
7 = black gram
8 = vegetable
9 = village (house)
10 = village (stores)
11 = village (garden)

CS **crop stage of rice**
1 = fallow
2 = tillering
3 = booting
4 = flowering
5 = harvesting
6 = stubble

RAT **rat number** (individual ear-tag number)

SP **species number***
1 = *Rattus argentiventer*
2 = *Rattus rattus* (European)
3 = *Rattus rattus* (Asian)
4 = *Rattus norvegicus*
5 = *Rattus exulans*
6 = *Bandicota indica*
7 = *Bandicota bengalensis*
8 = *Bandicota savilei*
9 = *Mus cervicolor*
10 = *Mus caroli*
11 = *Mus booduga*
12 = *Suncus murinus*
13 = other species (write species in comments)

* This is an example. A list such as this would need to be compiled for each country.

SX **sex**
1 = male
2 = female
−1 = not determined

V **vagina**
1 = not open (membrane intact)
2 = open (membrane broken)

T **teats**
1 = barely visible—never lactated before
2 = prominent but not currently lactating
3 = prominent and currently lactating

P **pregnancy** (by feeling)
1 = no or not sure
2 = pregnant

TAIL LTH **tail length**
length (mm) from middle of anus to tip of tail (−1 = tail with tip lost)

EAR LTH **ear length**
length (mm) from tip of ear to base of cartilage

FOOT LTH **pes (hind-foot) length**
length (mm) from tip of longest toe to heel

TOTAL WGT **weight (g) of bag + rat**

BAG **weight of the bag without the rat (g)**

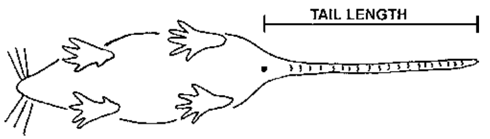
WGT **weight of the rat (g)**

CL **capture class**
1 = first capture
2 = recapture within current census
3 = recapture from previous census
4 = recapture but tag lost

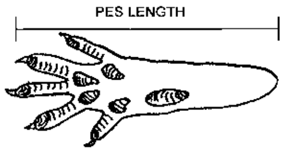
CN **capture number**
the number of times has the animal been caught over all censuses

FA **fate of the animal**
1 = released at site of capture
2 = died in trap
3 = escaped without tag
4 = taken to laboratory
5 = taken as voucher specimen
(write voucher number in comments)

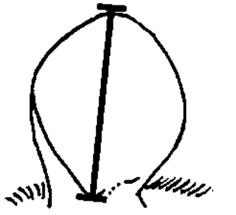
COMMENTS any observation about the rat, trap or change in normal procedure



Measure tail length from the middle of the anus to the tip of the tail.



Measure the pes length from the base of the heel to the end of the toe pad on the longest toe (not including the claw).



Measure the length of the ear from the bottom of the ear notch to the furthest point along the rim.

Appendix 2: Breeding data sheet and coding system

BREEDING DATA SHEET

Site Name:	Census No.:	District:	Date:	Name of Trapper & Data Recorder:	Entered by:	Verified by:	Page No.:
							/

CEN	YR	JUL	SITE	HAB	CS	RAT	SP	SX	V	T	P	TAIL LTH	EAR LTH	FOOT LTH	HB	WGT	EMB	E STAGE	SCAR	UT STAGE	VN	Comments

Codes for breeding data sheet

CEN **census number**

YR **year** (e.g. 2003 or 2004)

JUL **Julian date** (day of the year—see Appendix 3)

SITE **site number**

HAB **habitat code**

1 = local variety rice crop
2 = improved variety rice crop
3 = sugarcane
4 = groundnut
5 = sunflower
6 = mung bean
7 = black gram
8 = vegetable
9 = village (house)
10 = village (stores)
11 = village (garden)

CS **crop stage of rice**

1 = fallow
2 = tillering
3 = booting
4 = flowering
5 = harvesting
6 = stubble

RAT **rat number** (individual ear-tag number)

SP **species number***

1 = *Rattus argentiventer*
2 = *Rattus rattus* (European)
3 = *Rattus rattus* (Asian)
4 = *Rattus norvegicus*
5 = *Rattus exulans*
6 = *Bandicota indica*
7 = *Bandicota bengalensis*
8 = *Bandicota savilei*
9 = *Mus cervicolor*
10 = *Mus caroli*
11 = *Mus booduga*
12 = *Rattus losea*
13 = *Rattus tiomanicus*
14 = *Rattus nitidus*
15 = *Suncus murinus*
16 = other species

* This is an example. A list such as this would need to be compiled for each country.

SX **sex**

1 = male
2 = female
−1 = not determined

V **vagina**

1 = not open (membrane intact)
2 = open (membrane broken)

T **teats**

1 = barely visible—never lactated before
2 = visible but with fur at base—not currently lactating but has lactated previously
3 = visible and obvious, with no fur at base—currently lactating

P **pregnancy** (by feeling)

1 = no or not sure
2 = pregnant

TAIL LTH **tail length**
length (mm) from middle of anus to tip of tail (–1 = tail with tip lost)

EAR LTH **ear length**
length (mm) from tip of ear to base of cartilage

FOOT LTH **pes (hind-foot) length**
length (mm) from tip of longest toe to heel

HB **head+body length**
length (mm) from tip of nose to middle of anus measured with the animal of its back

WGT **weight of the rat (g)**

EMB **number of embryos in uterus**

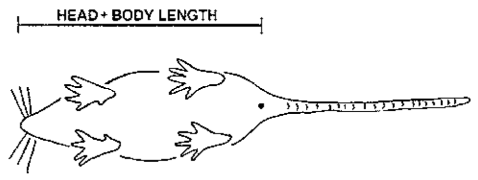
E STAGE **embryo stage**
1 = first trimester (early pregnancy)
2 = second trimester (mid pregnancy)
3 = third trimester (late pregnancy)

SCAR **number of SETS of scars in the uterus**
(if you can count the number of scars in any set, write the number in the comments column)

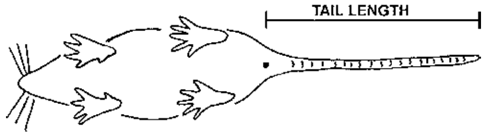
UT STAGE **condition of uterus**
1 = very thin (like a thread) and with indistinct blood supply
2 = thin (like a string) but with distinct blood supply
3 = thick but not pregnant
4 = with embryos

VN **voucher number**
number attached to voucher specimen

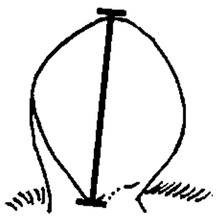
COMMENTS any observation about the rat, trap or change in normal procedure



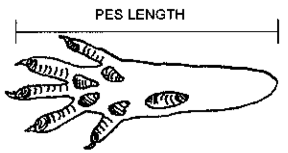
Measure the head+body length along the spine of the rodent from the tip of the nose to the middle of the anus.



Measure tail length from the middle of the anus to the tip of the tail.



Measure the length of the ear from the bottom of the ear notch to the furthest point along the rim.



Measure the pes length from the base of the heel to the end of the toe pad on the longest toe (not including the claw).

Appendix 3: Tables of Julian dates

Julian dates for non-leap years and leap years

NON-LEAP YEAR

	1	2	3	4	5	6	7	8	9	10	11	12
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	122	153	183	214	245	275	306	336
3	3	34	62	93	123	154	184	215	246	276	307	337
4	4	35	63	94	124	155	185	216	247	277	308	338
5	5	36	64	95	125	156	186	217	248	278	309	339
6	6	37	65	96	126	157	187	218	249	279	310	340
7	7	38	66	97	127	158	188	219	250	280	311	341
8	8	39	67	98	128	159	189	220	251	281	312	342
9	9	40	68	99	129	160	190	221	252	282	313	343
10	10	41	69	100	130	161	191	222	253	283	314	344
11	11	42	70	101	131	162	192	223	254	284	315	345
12	12	43	71	102	132	163	193	224	255	285	316	346
13	13	44	72	103	133	164	194	225	256	286	317	347
14	14	45	73	104	134	165	195	226	257	287	318	348
15	15	46	74	105	135	166	196	227	258	288	319	349
16	16	47	75	106	136	167	197	228	259	289	320	350
17	17	48	76	107	137	168	198	229	260	290	321	351
18	18	49	77	108	138	169	199	230	261	291	322	352
19	19	50	78	109	139	170	200	231	262	292	323	353
20	20	51	79	110	140	171	201	232	263	293	324	354
21	21	52	80	111	141	172	202	233	264	294	325	355
22	22	53	81	112	142	173	203	234	265	295	326	356
23	23	54	82	113	143	174	204	235	266	296	327	357
24	24	55	83	114	144	175	205	236	267	297	328	358
25	25	56	84	115	145	176	206	237	268	298	329	359
26	26	57	85	116	146	177	207	238	269	299	330	360
27	27	58	86	117	147	178	208	239	270	300	331	361
28	28	59	87	118	148	179	209	240	271	301	332	362
29	29		88	119	149	180	210	241	272	302	333	363
30	30		89	120	150	181	211	242	273	303	334	364
31	31		90		151		212	243		304		365

LEAP YEAR

	1	2	3	4	5	6	7	8	9	10	11	12
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	32	61	92	122	153	183	214	245	275	306	336
2	2	33	62	93	123	154	184	215	246	276	307	337
3	3	34	63	94	124	155	185	216	247	277	308	338
4	4	35	64	95	125	156	186	217	248	278	309	339
5	5	36	65	96	126	157	187	218	249	279	310	340
6	6	37	66	97	127	158	188	219	250	280	311	341
7	7	38	67	98	128	159	189	220	251	281	312	342
8	8	39	68	99	129	160	190	221	252	282	313	343
9	9	40	69	100	130	161	191	222	253	283	314	344
10	10	41	70	101	131	162	192	223	254	284	315	345
11	11	42	71	102	132	163	193	224	255	285	316	346
12	12	43	72	103	133	164	194	225	256	286	317	347
13	13	44	73	104	134	165	195	226	257	287	318	348
14	14	45	74	105	135	166	196	227	258	288	319	349
15	15	46	75	106	136	167	197	228	259	289	320	350
16	16	47	76	107	137	168	198	229	260	290	321	351
17	17	48	77	108	138	169	199	230	261	291	322	352
18	18	49	78	109	139	170	200	231	262	292	323	353
19	19	50	79	110	140	171	201	232	263	293	324	354
20	20	51	80	111	141	172	202	233	264	294	325	355
21	21	52	81	112	142	173	203	234	265	295	326	356
22	22	53	82	113	143	174	204	235	266	296	327	357
23	23	54	83	114	144	175	205	236	267	297	328	358
24	24	55	84	115	145	176	206	237	268	298	329	359
25	25	56	85	116	146	177	207	238	269	299	330	360
26	26	57	86	117	147	178	208	239	270	300	331	361
27	27	58	87	118	148	179	209	240	271	301	332	362
28	28	59	88	119	149	180	210	241	272	302	333	363
29	29	60	89	120	150	181	211	242	273	303	334	364
30	30		90	121	151	182	212	243	274	304	335	365
31	31		91		152		213	244		305		366

Appendix 4: Cereal crop damage data sheet and example of calculations

CEREAL CROP DAMAGE DATA SHEET

Crop type: ______________________

Transect No.	Site Name:	District:	Date:	Name of Data Recorder:	Entered by:	Verified by:	Page No: ……/……

Distance	Number of tillers	Hill Number										
		1	2	3	4	5	6	7	8	9	10	Total
Edge of field	Cut tillers (damaged)											
	With mature grain (undamaged)											
	With growth but not mature (short)											
	Total tillers											
20% in	Cut tillers (damaged)											
	With mature grain (undamaged)											
	With growth but not mature (short)											
	Total tillers											
30% in	Cut tillers (damaged)											
	With mature grain (undamaged)											
	With growth but not mature (short)											
	Total tillers											
40% in	Cut tillers (damaged)											
	With mature grain (undamaged)											
	With growth but not mature (short)											
	Total tillers											
Centre of field	Cut tillers (damaged)											
	With mature grain (undamaged)											
	With growth but not mature (short)											
	Total tillers											

Example of calculations

Example of rat damage to rice crop in Vietnam, where there were 72 rat damaged tillers out of 1569 tillers (from 200 plants):

Size of field in square metres (N) = 2000
Area of one set of transect samples (40 plants) in m² (size of stratum h (N_h)) = 0.50
Total area in units of samples = 2000/0.50 = 4000

Strata	Number of the sampled tillers damaged by rodents								Average proportion	Stratum size
	Transect 1		Transect 2		Transect 3		Transect 4			
	Damgd	Total	Damgd	Total	Damgd	Total	Damgd	Total	(Damgd/n_h=$\hat{p}_h$)	(N_h)
Edge of field	3	116	1	68	2	60	1	62	7/306 = 0.0229	800
20% in	5	97	2	83	4	85	5	62	16/327 = 0.0489	800
30% in	7	78	5	58	1	73	9	68	22/277 = 0.0794	800
40% in	3	86	2	49	5	98	1	84	11/317 = 0.0347	800
Centre of field	4	112	1	89	6	68	5	73	16/342 = 0.0468	800

Damgd = Number of damaged tillers.

Estimated mean proportion damaged averaged over all strata ($\hat{p}_{ST}$):
= sum of stratum size × average proportion

$$= \frac{(0.0229 \times 800) + (0.0489 \times 800) + (0.0794 \times 800) + (0.0347 \times 800) + (0.0468 \times 800)}{4000}$$

= 0.0465

The stratifed mean proportion damaged by rodents ($\hat{p}_{ST}$) is given by:

$$\hat{p}_{ST} = \frac{\sum N_h \hat{p}_h}{N}$$

where:
N_h = Size of stratum h (in number of sample units)
$\hat{p}_h$ = Estimated proportion damaged for stratum h
N = Total field size (in number of sample units)

Continued overleaf…

Calculation continued…

Calculation of the standard error of the stratified mean proportion, $SE(\hat{p}_{ST})$:

$$SE(\hat{p}_{ST}) = \frac{1}{4000}\sqrt{\sum\left[\begin{array}{l}\frac{800^2 \times (800-306) \times 0.0229 \times (1-0.0229)}{(800-1)\times(306-1)} + \\ \frac{800^2 \times (800-327) \times 0.0489 \times (1-0.0489)}{(800-1)\times(327-1)} + \\ \frac{800^2 \times (800-277) \times 0.0794 \times (1-0.0794)}{(800-1)\times(277-1)} + \\ \frac{800^2 \times (800-317) \times 0.0347 \times (1-0.0347)}{(800-1)\times(317-1)} + \\ \frac{800^2 \times (800-342) \times 0.0468 \times (1-0.0468)}{(800-1)\times(342-1)}\end{array}\right]}$$

$SE(\hat{p}_{ST}) = 0.0042$

In this example, the confidence limits for the stratified mean proportion were 0.038 to 0.055.

An EXCEL spreadsheet program (Stratified_Damage_Estimates.xls) to do these calculations from raw data is available on request from rodent-inquiries@csiro.au. Note that this spreadsheet will do the correct calculations even if there is only one transect.

The standard error of the stratified mean proportion damaged by rodents ($SE(\hat{p}_{ST})$) is given by:

$$SE(\hat{p}_{ST}) = \frac{1}{N}\sqrt{\sum\left[\frac{N_h^2(N_h - n_h)\hat{p}_h\hat{q}_h}{(N_h - 1)(n_h - 1)}\right]}$$

where:

N_h = Size of stratum h (in number of sample units)

n_h = Sample size in stratum h (= 4 in this case)

$\hat{p}_h$ = Estimated proportion damaged for stratum h

$\hat{q}_h$ = $1 - \hat{p}_h$

N = Total field size (in number of sample units)

Glossary

authority the author and date of publication of a species name

bicoloured (of the tail) the upper half of the tail differs in colour from the lower half

breeding season (of a population) starts with the first successful mating after a period of non-breeding, and ends when the last litter of pups is weaned

common property resource users share the 'rights' and 'benefits' of resource use, and also share the 'duties' of resource management

control (in an experiment) an experimental unit that has been given no treatment, or the baseline against which the other experimental outcomes are compared

dorsal/dorsum (anatomy) technical term for an animal's upper surface or back

effective trap-nights the total number of traps set, minus any traps that are sprung without making a capture

exclusion plot a representative area of crop that is protected against rodent damage by a rodent-proof fence or barrier

experimental unit the smallest division of the experimental material such that any two units may receive different treatments

gestation period the period from conception to delivery of offspring

guard hairs long, straight, thick hairs that project some distance beyond the general body hair

head+body the combined length of the head and body, measured from the tip of the nose to the centre of the anus

home range the area used by an individual animal in the course of its regular pattern of activities

hypothesis (plural: hypotheses) an explanation for one or more observations; can be tested by further observations or by an experiment to manipulate one or more factors

hybridisation interbreeding between members of two different species

imperforate (vagina) in juvenile rodents, the vagina is sealed off by a thin, shiny layer of skin, hence **imperforate**. As the animal reaches sexual maturity, the vaginal covering breaks down and the vagina is open or **perforate** from then on

intensity of infection (by a parasite) number of parasites per infected animal

interspersion (in an experiment) the planned placement of treatments and controls to obtain a good spatial mixture

Julian date the number of a day within a year from day 1 through to day 365 (366 in a leap year)

mammae teats of female rodents

manus technical term for the fore-foot (also known as the fore-paw or hand)

murid rodent of the Family Muridae

necropsy dissection and examination of a dead animal

neophobia fear of new objects in the environment

palpation a technique used to confirm whether a female is pregnant; it involves running a thumb and finger gently down the abdomen to feel the developing embryos

pes technical term for the hind-foot

population a group of individuals that occupy a single locality and among which all members of one sex could potentially interbreed with all members of the opposite sex

population density number of animals of a given species per unit area

prevalence of infection percentage of animals infected with a particular parasite or disease agent

radio-tracking method for observing the movements of animals using a radio-transmitter that is attached to an animal

randomisation (in experimental design) taking a random sample from the population or assigning treatments at random to experimental units

range overlap the proportion of a home range that is used by more than one individual of the same species

range span the largest distance across a home range

replication the repetition of a basic experiment (each repeated version is called a replicate)

reproductive potential the number of offspring that a typical female is likely to produce during her life

stratified random sampling sampling method whereby a population is first subdivided according to some criterion into non-overlapping subgroups called strata, and then sampled on a random basis within each stratum

transect a line of traps, set through an area of uniform habitat type

trap–barrier system (TBS) a combination of multiple-capture traps integrated with a drift fence which directs rodents to the traps

trap-line a series of traps, usually placed at set intervals along a transect

trap-nights calculated by multiplying the number of traps by the number of nights of trapping, e.g. 100 traps set for 4 consecutive nights equals 400 trap-nights

trapping effort total number of effective trap-nights over a particular trapping period

trapping grid	traps set in parallel lines that ensure an even density of traps per unit area
trap success	number of rodents caught, divided by the total number of effective trap nights—this value is usually multiplied by 100 to give percentage trap success
treatment	(in an experiment) an experimental unit that has been manipulated in some way (to be compared to control or untreated units)
triangulation	the process by which the location of a radio transmitter can be determined by measuring the direction of the received signal from two or three different points
trimester	a third of the gestation period (the gestation period is divided into first, second and third trimesters)
tubercle	a small knoblike prominence projecting from the plantar or under-surface of the foot (pes)
ventral/ventrum	(anatomy) technical term for an animal's belly or underside
vibrissae	(anatomy) technical term for sensory whiskers, found on the head and limbs
zoonoses	diseases that can be transmitted between animal hosts and humans; also known as zoonotic diseases

Index

Note: on many occasions through this index, readers are referred to 'species accounts'. Species accounts make up the bulk of Chapter 11. Each species account provides a summary of all the information available on the featured rodent species, and includes the scientific and common names for the pest rodent, distribution map, table of adult measurements, and information under the following headings—morphological features; mammae; other recently applied scientific names; distribution; taxonomic issues; habitat use; nesting behaviour; breeding biology; population dynamics; and damage to crops.

References to species accounts are given in **boldface** type.

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