Table 3.
Composition of rat species (%) from nine different provinces in the Mekong Delta (1995–1997). Rats were collected by live-t rapping and digging of burrows in rice crops and along channel banks. In each province, fifty rats were collected (except in March 1996 when 100 rats were collected) from six sampling occasions from November 1995 to July 1997.

Species	Ben Tre	Tien Giang	Long An	Can Tho	Dong Thap	Kien Giang	Minh Hai	An Giang	Vinh Long
Rattus argentiventer	50.2	72.0	63.4	67.8	69.7	28.4	57.3	68.6	75.4
Rattus losea	9.8	5.3	8.9	10.5	11.0	45.9	18.7	12.8	8.9
Rattus koratensis	17.3	1.3	8.3	4.3	5.5	6.7	9.0	4.0	8.5
Rattus germaini	8.5	2.0	3.0	1.0	2.7	2.0	2.7	2.4	2.8
Rattus rattus	1.8	4.2	2.1	3.3	1.0	0.2	2.3	2.8	1.2
Rattus flavipectus	1.3	1.3	2.3	2.3	1.8	0.7	0.2	0.4	0.0
Rattus nitidus	2.0	1.7	1.5	2.7	1.3	2.3	3.3	1.6	0.8
Rattus exulans	1.8	3.3	2.5	1.3	0.7	1.8	0.3	2.4	0.8
Rattus norvegicus	2.5	2.7	1.3	1.5	2.3	3.4	3.8	1.2	1.2
Bandicota indica	3.0	4.3	4.5	4.5	4.0	2.6	0.2	0.6	0.4
Bandicota bengalensis	0.0	0.3	2.2	0.7	0.0	0.2	1.2	1.6	0.0
Mus sp.	1.7	1.5	0.0	0.0	0.0	5.9	1.0	1.6	0.0

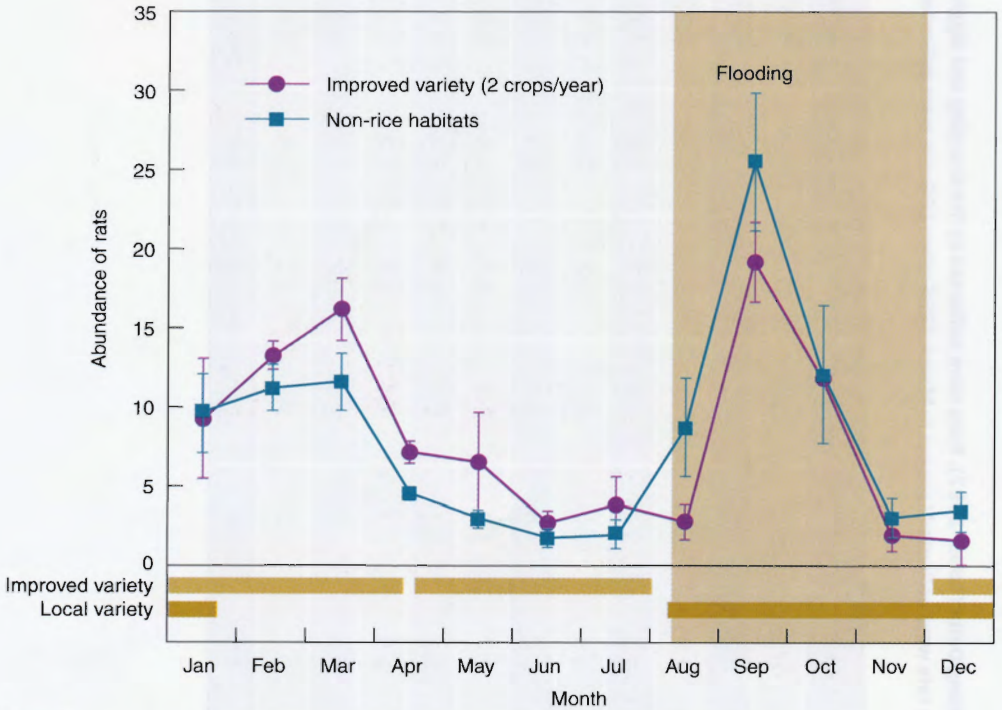

Figure 2.
Mean abundance of rats (per 100 trap nights; ± standard error) per month in improved variety rice (two crops per year) and all other habitats combined, Long An, 1994–1997.

The average weight of adult breeding females for *R. argentiventer* was 114.6 g (±3.2 standard error [SE]; range = 62–200 g; $n = 63$) and for *R. losea* it was 111.0 g (±3.4 SE; range = 60–200 g; $n = 69$).

The proportion of adult females in breeding condition was similar in improved variety rice habitat and other habitats ($\chi^2 = 0.69$, degrees of freedom [d.f.] = 1, $P > 0.05$; $\chi^2 = 1.09$, d.f. = 1, $P > 0.05$ for *R. argentiventer* and *R. losea*, respectively). The rate of recapture of tagged rats was very low both within trips (0.7%) and between trips (0.2%).

Population dynamics at Tra Vinh

Four species of rodents were identified from 384 captures. The most common species trapped was *R. argentiventer* (61.7%). *R. losea* (20.3%). *R. koratensis* (10.2%) and *R. germaini* (4.2%) made up the other species captured, with 3.6% of captures not identified to species.

Both *R. argentiventer* and *R. losea* were more abundant in the rice habitat than in other habitats (coconut, banana and channel bank combined) (Figure 4). No rats were caught in the rice habitat from November 1997 to May 1998, but some rats were caught in other habitats in February, March and May (≤0.3% trap success).

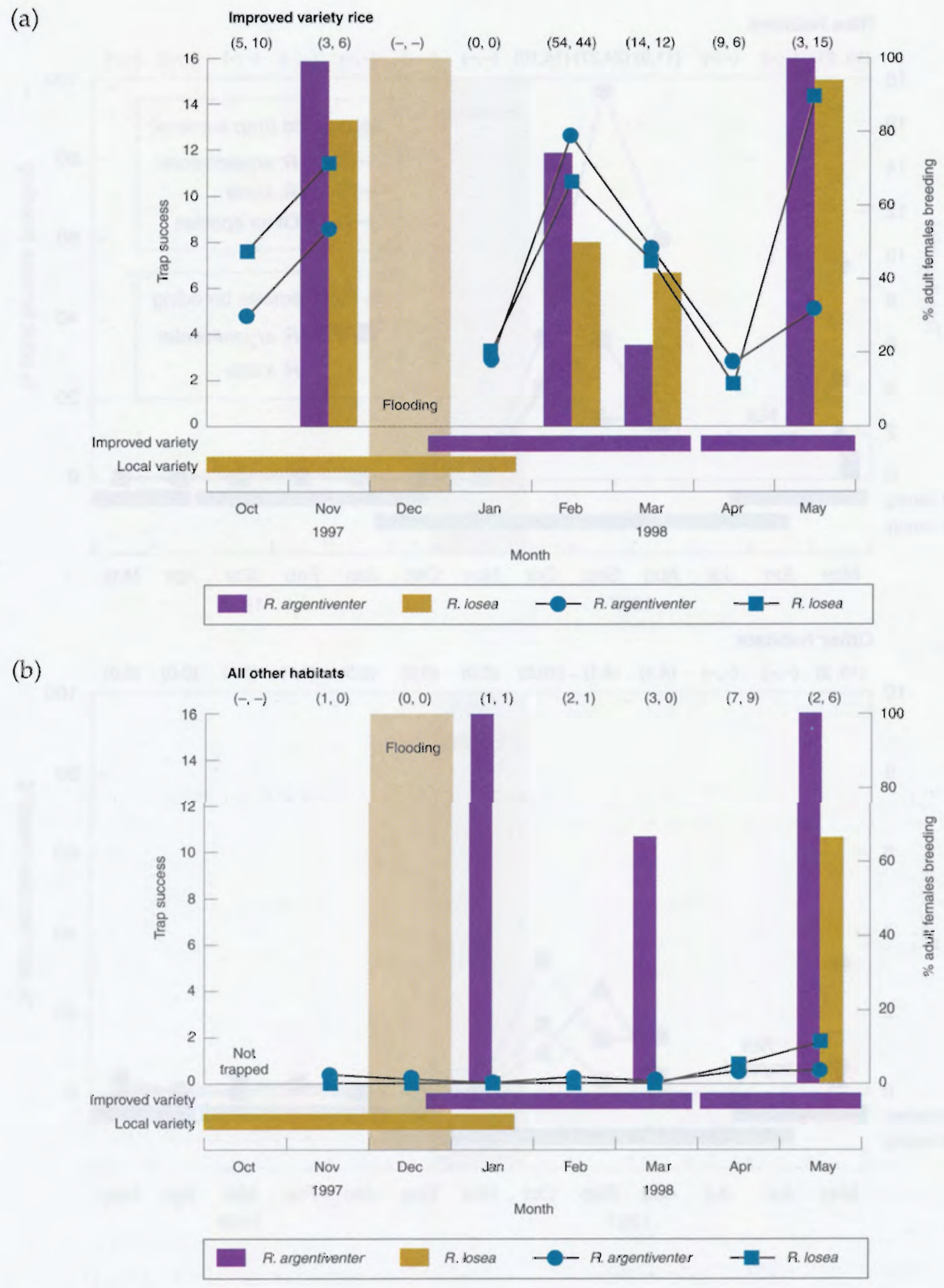

Figure 3.
Abundance of *Rattus argentiventer* and *Rattus losea* (number caught per 100 trap nights) and proportion of adult females breeding (lactating or pregnant) in (a) improved variety rice and (b) other habitats in Ha Tien, Kien Giang, October 1997 to May 1998. Numbers in brackets refer to the number of adult female rats caught for each species *R. argentiventer, R. losea*). No trapping occurred in December 1997 in improved variety rice or in October 1997 in other habitats. (Unpublished data G.R. Singleton and N.Q. Hung)

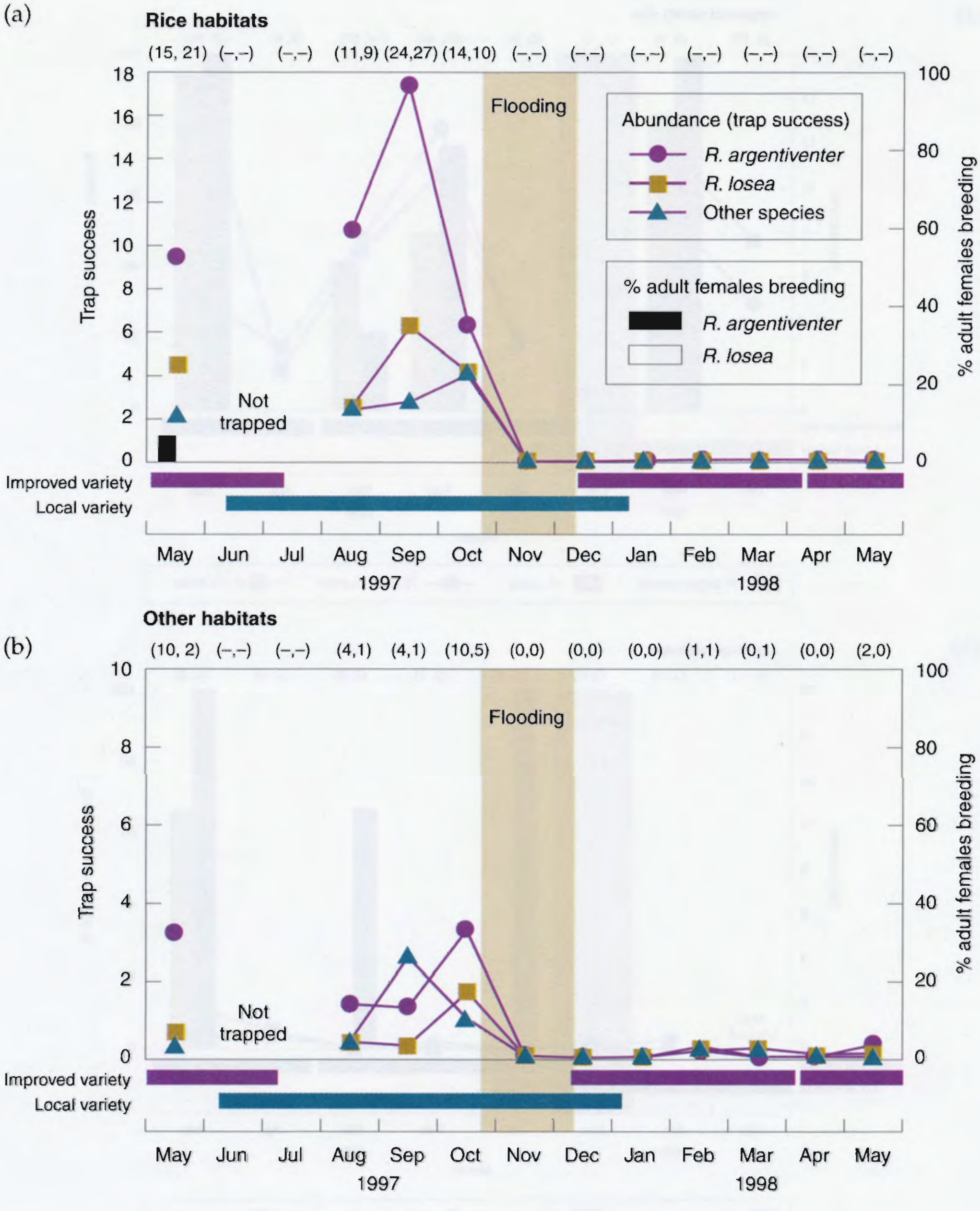

Figure 4.
Abundance of *Rattus argentiventer*, *Rattus losea* and other species (number caught per 100 trap nights) and proportion of adult females breeding (lactating or pregnant) in (a) rice habitats and (b) other habitats in Tra Vinh, May 1997 to May 1998. Numbers in brackets refer to the number of adult *R. argentiventer* and *R. losea* females caught, respectively. No trapping occurred in June or July 1997.

Only one adult female *R. argentiventer* was found pregnant (by palpation) during May 1998 in the rice habitat (6.7% of adult females) (weight = 174 g). No other adult females were in breeding condition for any other period or habitat. No rats were recaught within or between trips.

Population ecology of rats in Mekong River Delta

The dynamics of rat populations were different for Long An, Kien Giang and Tra Vinh. In Long An and Tra Vinh, the abundance of rats was highest during flooding, whereas in Kien Giang, the highest abundance was during the early stages of the reproductive phase of the crop. In Kien Giang, the abundance of rats in March 1998 (milky/harvesting stage) was lower than expected considering the breeding that occurred in February (assuming the young were trappable). Unfortunately, no trapping was conducted there during the period of flooding.

Few rats were caught in non-rice habitats in either Tra Vinh or Kien Giang. This suggested that rat populations were building up within the rice fields rather than in adjacent non-crop habitats. Breeding occurred during the reproductive phase of the crop in Kien Giang, but a comparison cannot be made with Tra Vinh where only one rat in breeding condition was caught.

In Tra Vinh, the population abundance of rats remained very low after flooding. These low numbers could be attributed directly to the floodwaters (a) drowning rats, (b) making food scarce, and/or (c) making it difficult for rats to find shelter. Furthermore, low numbers could be indirectly attributed to the waters driving rats to patches of high ground where farmers focused their control campaigns. When floodwaters subsided and new crops were planted, rat populations were at such low densities that they could not recover. For three months after the floodwaters had subsided, the only rats present in Tra Vinh were found in a banana plantation. How long does it take for rats to recolonise the rice habitats after such a flooding event? From our data, it seems that the effect of flooding on rat populations in Long An or Kien Giang are not as severe as found in Tra Vinh. Tra Vinh is situated toward the edge of the delta, and the area is more prone to flooding events than the other provinces that have a higher elevation and where floodwaters can subside more rapidly. We would not expect the effect of flooding on rat populations to be the same each year because the severity and duration of flooding differs between years.

A radio-telemetry study is required to gain an understanding of the habitat use of rats during flooding, and to determine if rats breed when the local traditional variety rice is in the reproductive phase of growth. Furthermore, when flooding occurs it is important that farmers know where they can concentrate their rat control activities.

In Kien Giang, there were few rats caught in April (from transplanting to maximum tillering). We would expect that populations would increase during April as new rats enter the trappable population from births in February and March. Are the low numbers attributable to low survival rates and poor recruitment of young in March and April 1998, or had these rats emigrated to other areas? Another factor that complicates our interpretation is that the catchability of rats is low, or the animals are very trap shy.

The population dynamics of rats in Indonesia follows a general pattern of increasing abundance during the fallow period after harvesting as young enter the trappable population (Murakami et al. 1990; Leung et al., Chapter 14). The difference in Vietnam is that there is no fallow period between crops. Subsequent crops are sown within a few days of harvest. Leung et al. (Chapter 14) found that the factors limiting rat populations in Indonesia were food quality, availability of nesting sites and human activities such as land preparation and rodent control activities. If rice is planted soon after harvest, then high quality food is available to the rats sooner. We therefore expect that rat populations in Vietnam would have a higher survival rate in the period between breeding seasons.

The low recapture rates of rats found in the Mekong River Delta are a problem for live-trapping studies. Wood (1971) obtained recapture rates in Indonesia of 14% within a trapping period and 6% between trapping periods for *R. argentiventer*. Our estimates were both <1%. Population parameters are more difficult to estimate when recapture rates are low (Krebs et al. 1994). It is not known whether *R. argentiventer* or *R. losea* in Vietnam are trap-shy or are transient animals moving through a trapping area. To improve population parameters, the recapture rate of rats needs to be enhanced. Research is required to examine better methods for trapping rats and to compare results with other areas such as Indonesia (L.K.-P. Leung and Sudarmaji, unpublished data).

One critical population parameter that we have not been able to gain sufficient information on is the survival rates of rats (we have been restricted by low recapture rates). How is survival influenced by crop stage and flooding? Survival rates of rats could be estimated using static life tables rather than by following individuals over time. This approach requires a comprehensive set of data to follow cohorts through time and an accurate method for ageing rats using eye lens weight (Murakami et al. 1992).

Breeding at Kien Giang

The only breeding (embryos in the uterus) evident from kill trapping was in February and March 1998, where 100% of adult female *R. argentiventer* were pregnant. The mean number of embryos was 11.4 (± 0.4 SE, range = 6–18, n = 65). The mean weight of pregnant females was 91.1 g (± 5.1 SE, range = 29–183, n = 65). These rats were significantly smaller than live-captured pregnant or lactating *R. argentiventer* ($t = 3.87$, d.f. = 126, $P < 0.001$). The minimum weight of pregnant females by kill-trapping was half that from live-trapping. This difference is interesting, because it suggests there could be a bias in the collection methods (rats caught in burrows versus rats caught in live-capture traps). Therefore, more work is required to understand this bias and to look at improvements to trap design and trapping procedures.

At harvest in October 1997, many adult females had uterine scars. The mean number of scars for *R. argentiventer* was 10.8 (± 0.5 SE, range = 6–17, n = 39), which was not significantly different to the mean number of embryos ($t = 0.93$, d.f. = 102, $P > 0.05$). The litter size was significantly higher for rats with more sets of uterine scars (one-way analysis of variance—ANOVA; $F = 28.4$, d.f. = 2,36, $P < 0.001$). The mean number of scars for rats with one set was 8.0 (± 0.4 SE, n = 16), two sets was 12.1 (± 0.7 SE, n = 15) and for three sets was 14.0 (± 0.6 SE, $n = 8$). This is evidence to show that *R. argentiventer* can have up to three litters during a single breeding season and that the size of the litter increases with each litter.

The proportion of rats in breeding condition collected by kill-trapping in March 1998 was higher than that found by live-capture trapping ($\chi^2_1 = 4.42$, $P < 0.05$), whereas there was no difference in February ($\chi^2_1 = 0.64$, $P > 0.05$).

Breeding was evident only during the reproductive stage of the rice crop. The relative percentages of *R. argentiventer* adult females in breeding condition during the different crop stages were: the vegetative growth stage, 0% (0/22 rats); tillering stage, 9% (1/11 rats); flowering stage, 100% (5/5 rats); and at harvest, 76% (57/76 rats).

Breeding of rats in Kien Giang was linked to the development of the improved variety rice crop. No breeding occurred in the vegetative stage of growth, but breeding was initiated at some point prior to maximum tillering stage to take advantage of high quality food during the reproductive and ripening stages of rice development. This is generally the case with *R. argentiventer* in other regions such as Indonesia (Murakami et al. 1990; L.K.-P. Leung and Sudarmaji, unpublished data) and Malaysia (Wood 1971; Lam 1980, 1983; Buckle 1990). The discovery that breeding by rats commenced prior to maximum tillering of rice crops led to an important re-evaluation of what triggers breeding by rats (Leung and Sudarmaji, unpublished data). Although we have limited data, we hypothesise that breeding is linked with the rice crop stage, and that if there are three rice crops grown per year (2 × improved variety and 1 × local traditional variety), then there will be three distinct breeding seasons per year. Furthermore, if the crops are not grown in synchrony (planting over a period of >2 weeks in an area), then the duration of time in which high quality food is available is prolonged. Therefore, we would expect that the breeding season would be prolonged, resulting in a higher numbers of rats.

Ecologically-based population management practices for rats in the Mekong River Delta

Rats have always been part of the rice-cropping ecosystem in Southeast Asia; *R. argentiventer* in particular is believed to have evolved from a grassland existence (Lekagul and McNeely 1977). The reason why rats have become a major pest of rice crops in the Mekong River Delta is thought to be due to the increased amount of cropping occurring (three crops per year instead of one or two; Singleton and Petch 1994). Other factors may include the increased awareness of the problem of rats and the mosaic of favourable habitats for rats.

We have applied our knowledge of the ecology of rodents in the Mekong River Delta reviewed in this chapter, to develop an ecologically-based appraisal of the appropriateness of different management actions (Table 4). These actions were developed by the Institute of Agricultural Sciences in Ho Chi Minh City, and were discussed by rodent scientists at an annual meeting of the Australian Centre for International Agricultural Research (ACIAR) funded project on the management of rodent pests in Southeast Asia in April 1998 at the International Rice Research Institute (IRRI, Los Baños, the Philippines).

Table 4.

Decision analysis of recommended best practices for managing *Rattus argentiventer* and *Rattus losea* in rice agro-ecosystems of the Mekong River Delta, Vietnam. (Timing: lp = land preparation; sb = seed bed; tp = transplanting; b = booting; Suitability of actions: ✓ = yes; X = no; ? = unknown).

Management actions	Parameters for ecologically-based pest management								
	Timing	Feasible	Economic	Socially acceptable	Environmentally friendly	Sustainable	Scale of adoption	Ecosystem focus	Priority
Routine actions									
Field sanitation and dyke management	lp›b	✓	✓	✓	✓	✓	village	?	high
Synchronous seeding and planting	sb, tp	?	? labour	✓?	✓	?	village	✓	medium
Reduce bund size within rice fields	lp	✓	✓	?	✓	✓	village	✓	high
Keep water level high in the field	Dry crop	?	✓	✓	✓	✓	village	n/a	high
Encourage natural enemies of rats in rice ecosystems	all	?	?	✓	✓	?	district	✓	high
Linear TBS[a] to halt movement into paddies	< sb, tp	?	?	✓	? ✓	✓	?	✓	medium
Management of rats on high ground	Flood	✓	✓	✓	✓	✓	village	✓	high
Locate and destroy rat burrows by fumigating and digging	< sb, tp	✓	✓	✓	✓	✓	village	?	high
Establish TBS[a] with trap crops	Each crop	?	✓	✓	? ✓	✓	?	✓	medium
Actions if high numbers forecast									
Rat drive using nylon nets	Flood	✓	✓	✓	✓	✓	village	✓	high
Apply chemical bait in fields and villages	< sb, tp	✓	?	✓	X	X	village	X	low
Burn rice straw after harvest	Dry crop	✓	✓	✓	X	X	village	X	low
Drive tractor through fallow fields (high terrain)[b]	Flood	?	?	✓	?	X	village	X	low

[a]TBS = trap plus barrier system

[b]Plant Protection Departments perform this activity.

There are two types of actions; routine actions that can be conducted all the time and actions that can be conducted if high rat numbers are forecast. For each action, eight parameters were considered: the timing of implementation, the feasibility, whether it is economical, socially acceptable, environmentally friendly, ecologically sustainable, the scale of adoption and whether it has an ecosystem focus. We also considered priority for implementation of each practice.

Ecologically-based pest management is a new paradigm for pest management (National Research Council 1996). It promotes the use of information on the biology and ecology of the pest species to formulate management actions. This approach has been used for house mice in Australia (Singleton 1997; Singleton and Brown 1999) and for *R. argentiventer* in Indonesia (Leung et al., Chapter 14). Our current knowledge of the biology and ecology of rats in southern Vietnam has allowed Table 4 to be formulated. Manipulative field experiments are now required to examine the effectiveness of these actions. Until these actions have been critically tested, they remain a 'best guess' of what limits rodent populations in the rice agro-ecosystem of southern Vietnam.

These actions were designed for the rice-growing areas of southern Vietnam. Some of the actions could be appropriate for other areas of Southeast Asia, particularly northern Vietnam, where many of the farming practices are similar, although major flooding events are rare.

A major hurdle to the success of these actions is being able to forecast when rat numbers are likely to cause damage. These monitoring systems could be operated by farmers themselves or by government officers. The amount of time farmers require to implement these actions also needs to be investigated.

WHERE TO FROM HERE?

The challenge ahead is whether these actions will be readily adopted at the village and/or district level. This is an essential requirement for mobile animals such as rodents, which can readily reinvade small areas following a reduction in rodent densities. In Vietnam, the level of interaction between researchers (Institute for Agricultural Sciences) and provincial extension staff (Plant Protection Departments) is very good, which bodes well for the success of implementation of actions by farmers.

Given our current understanding of the ecology of rodent species in the Mekong River Delta, we are able to determine the likelihood of success of a range of management practices on rodent populations even though we do not currently have sufficient scientific evidence (Table 5). We identify where we have sufficient data and which actions have a low, medium or high chance of success in reducing rat populations. We lack experimental data for many recommended actions, however, we can draw upon knowledge gained from studies conducted in Indonesia (Leung et al., Chapter 14). As our understanding improves, the likelihood for success will also change. This is an area for further research.

Table 5.
Strength of ecologically-based knowledge for the management of rats in the Mekong River Delta. If we have sufficient data on the ecology and population biology of rats, then 'Yes' appears in the table, if we lack sufficient data, then 'No' appears in the table. The likely level of success in reducing rat populations using each recommended action is based on our current knowledge (low, medium or high).

Recommended action	Sufficient data	Likelihood of sucess
Routine actions		
Field sanitation and dyke management	No	High
Synchronous seeding and planting	No	High
Reduce bund size within rice fields	Yes	High
Keep water level high in paddies	No	High
Encourage natural enemies of rats in rice ecosystems	No	Low
Linear TBS[a] to halt movement into paddies	No	Low
Management of rats on high ground during flooding	No	Medium
Locate and destroy rat burrows by fumigating and digging	No	Medium
Establish TBS[a] with trap crops	Yes	High
Actions if high numbers are forecast		
Rat drive using nylon nets	No	Low/Medium
Apply chemical bait in fields and villages	No	Medium
Burn rice straw after harvest	No	Medium
Drive tractor through fallow fields (high terrain)	No	Low

[a]TBS = trap–barrier system

An important output from a decision analysis process is clearer identification of the key gaps in our scientific knowledge for developing effective management of a particular rodent pest. To further our understanding of the ecology of the major rodent species, we have listed a series of ecological parameters and indicated the amount of information that is known about each in Table 6 (following Singleton and Petch 1994). We have a good understanding of the abundance, habitat use and breeding characteristics of *R. argentiventer* and *R. losea*, but we lack specific information for a range of other ecological parameters.

The ecological approach used here to critically examine management practices has allowed us to develop an integrated management strategy. Developing field projects to evaluate these recommendations in close association with farmers at the village or district level (as pointed out by Leung et al., Chapter 14) will provide the necessary feedback for developing an effective management strategy.

Table 6.
Summary of the extent of information available on various ecological parameters of the major rodent pest species in southern Vietnam (– = no information; * = anecdotal reports; ** = restricted to a single sample or survey; * = restricted to one or two growing seasons or a long-term data set not calibrated against other measures).**

Parameter	*Rattus argentiventer*	*Rattus losea*	Other species
Abundance	***	***	*
Habitat use	***	***	*
Dispersal	–	–	–
Breeding	**	**	–
Survival	–	–	–
Age structure	–	–	–
Diet	–	–	–
Predator/prey	–	–	–
Disease	–	–	–
Taxonomic status	**	**	**
Species interaction	*	*	–
Crop damage	*	–	–
Post-harvest damage	–	–	–

CONCLUSIONS

Although we have collected data for a limited period of time, we have been able to formulate proposals for the management of rodent pests in southern Vietnam. Current evidence suggests that *R. argentiventer* in Vietnam behaves in a similar fashion to *R. argentiventer* in other Southeast Asian countries. However, the interaction with *R. losea* requires further study. We suggest specific hypotheses about the likely population ecology of *R. argentiventer* and *R. losea* in the Mekong River Delta. These hypotheses need to be tested when at least two years data, but preferably three or more years of data, have been collected.

Suggested areas for further research include:

- Conduct a radio-telemetry study to examine the habitat use of rats during flooding periods.
- Conduct a trap catchability study to examine the best trapping method available and to test it over different crop stages and breeding and non-breeding stages.
- Estimate survival rates of rats over different crop stages and during flooding.
- Conduct manipulative field experiments to examine the effectiveness of actions to limit rat damage.

- Develop a monitoring system to enable forecasting of high rat numbers.

The information gained from this research will help establish a better understanding of the population ecology and habitat use of rodent pests.

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16. Rodent Management in Thailand

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Abstract

Thailand is an agricultural country where rice and other agricultural products contribute a substantial part to the gross domestic product. Rodents cause problems both in agriculture and as reservoirs of human diseases. Some basic data on the agricultural situation in Thailand and the damage inflicted by rodents as well as an overview of past and present efforts in rodent control are presented. The Ministry of Agriculture and Cooperatives is responsible for rodent problems in agriculture. In the Department of Agriculture, the Agricultural Zoology Research Group conducts research on rodent problems. It devises methods for rodent control and is responsible for the transfer of technical know-how to extension programs. Some aspects of the group's research are highlighted, including the use of the endemic parasitic protozoan *Sarcocystis singaporensis* as a potential biocontrol agent. As the Thai government aims to substantially reduce the use of pesticides, integrated pest management concepts, including new strategies in rodent control, are being pursued in pilot areas.

Keywords

Thailand, rodent management, rodent research, integrated pest management, rodent borne diseases, biological control, *Sarcocystis singaporensis*, ecology

Introduction

THAILAND IS A tropical country located in Southeast Asia surrounded by Cambodia, Lao People's Democratic Republic, Myanmar and Malaysia. The peninsula runs down to the Indian Ocean, and receives the south-west monsoon from mid-May to October. It covers a land area of 513,178 square kilometres and extends about 1,620 kilometres from north to south and 775 kilometres from east to west. There are three seasons: cool from November to February, summer from March to May and rainy season from June–October. The average minimum temperature is 20°C and average maximum temperature is 37°C. Annual rainfall averages from 1,000–2,000 mm, varying greatly from place to place and year to year.

Thailand is divided into four regions. The *northern region* is mostly mountain highlands where many rivers originate and run down to the central plain. In the north, agriculture is mostly limited to the fertile valleys of the Chao Phraya River tributaries. Fruit trees, forest trees and vegetable crops are the main sources of income in the region. The *north-eastern region* has a flat rolling terrain called the Khorat Plateau. Much of the land has poor soil fertility and little water. Large areas are flooded during the rainy season but are very dry during the rest of the year. Provinces along the Mae Kong River use this water for agriculture with rice being cultivated mainly for home consumption. Fruit trees and rubber are being promoted to help green the area. The *central plain* is regarded as the rice bowl of Thailand. Corn, fruit crops and vegetables are also of economic significance in the region. The *southern region* has several sizeable coastal plains and a mountain chain running along its western coast. This region has mostly sandy loam soil suitable for fruit trees and tree crops, especially rubber and oil palm.

Main Crops, Areas Involved and Contribution to the Economy

Thailand cultivates about 26,523,836 ha or 51.7% of its total land area (Anonymous 1996). Irrigated land comprises about 15.3% of the agricultural area. Of this area, rice comprises about 52%, field crops 25%, fruit trees and tree crops 16% and idle land 2.5%. The remaining land is grassland, housing and other areas. Rice has a farm value of nearly US$3 billion. Other major field crops are cassava, corn, sugarcane, oil crops, perennial trees such as rubber, and fruit trees (Table 1).

The importance of agriculture to the Thai economy can be measured by its contribution to the gross domestic product (GDP). Agriculture comprises 16% of the GDP, industry 24%, and commerce and service sectors the remaining 60%. Apart from its contribution to the GDP, agriculture boosts the national economy through wealth distribution and provides gainful employment for approximately 64% of the Thai population.

Crop Damage by Rodents

Major pest species

Although there are about 33 murid species in the southeastern end of the Asian continent (Corbet and Hill 1992), less than half of these are considered pests in Thailand. The two main ecotypes of rodents found in temperate zones, those occurring in grassland and woodland (Wood 1994), also largely apply to the situation in Thailand. There are pests of field crops and those of forestry and orchards. Additionally, cosmopolitan species like *Rattus norvegicus* are also prevalent. Table 2 lists the key pest species of various crops as observed by the Agricultural Zoology Research Group (AZRG) of the Department of Agriculture during field surveys (Ratanaworabhan 1971; Suasa-ard et al. 1987; Khoprasert et al. 1990; Hongnark et al. 1994).

Damage in lowland

Rodent problems in lowland occur mostly in rice and field crops in the central regions of Thailand. Because the Chao Phaya River and Tha Chin River run through the area and 70% of the region is irrigated, farmers can cultivate throughout the year. In Suphan Buri, Nakhon Pathom and Pathum Thani, rice varieties are cultivated which allow five harvests every two years; alternatively, field crops (soybean, mungbean, baby corn etc.) are grown after harvesting the major rice crop. When food is available all year, rodents can breed throughout the whole period (Boonsong et al. 1984a).

The importance of the problem of damage to rice by rodents in Thailand previously led to the introduction of a nationwide control scheme by the Thai–German Rodent Control Project (see below). At that time (1976–77), damage assessment in rice was performed in central, southern, northern, and north-eastern Thailand according to established methods (Weis 1981).

Table 1.
Area planted and estimated farm value of principal crops in 1995/96 in Thailand (rate of exchange 1 US$ = 40 baht).

Crop	Area (million ha)	Farm value (US$ million)
Rice	10.14	2622.1
Rubber	1.82	1064.0
Fruits	0.60	659.1
Vegetables	0.30	527.1
Coconut	0.38	78.0
Oil palm	0.10	115.6
Soy bean	0.30	83.5
Sugar cane	1.00	559.4
Maize	1.33	420.7
Cassava	1.26	426.0
Mungbean	0.35	69.5

Source:
Agricultural Statistics of Thailand, Crop year 1995/1996. Office of Agricultural Economics, Ministry of Agriculture and Cooperatives

In each of the four regions, three provinces were randomly selected and three districts in each province inspected. In each district, percentage damage was measured on eight plots (30 m × 30 m each) two weeks before harvest of the wet-season rice. Figure 1 shows that, on average, about 18% of the rice was damaged in the central plains which translates to losses of approximately US$300 million. A more recent survey (1990–93) by the AZRG, employing the same methods in the same areas, showed that the situation in rice had improved (Figure 1) (Hongnark et al. 1993) although an average of 1.5% damage still equates to losses of about US$35 million. Whether this reduction of the problem in rice can be entirely attributed to the control scheme (see below) or is in part due to other factors such as natural fluctuations in rodent populations is not known. Certainly, awareness of control measures among farmers has increased substantially. Currently, problems with rodents in rice appear to be moderate. It should be noted that *Rattus argentiventer* which is considered the most serious rice field pest besides *Bandicota indica* in Thailand (Wood 1994) was observed rarely during recent surveys of AZRG. Instead, *Rattus losea* seemed to be more abundant.

In oil palm plantations, losses caused by rats vary considerably both between years and between plantations. Damage to mature palms generally ranged from 6–36% (Boonsong et al. 1987). Rodents infesting older plantations are climbing species which prefer ripe oil palm fruits. Younger oil palms are attacked by ground-dwelling species (Table 2). Although conspicuous damage was patchy, trapping showed that rats are well spread (Wood 1987). The density of *Rattus tiomanicus* was reported to range from about 125–625 rats/ha in Malaysia (Wood and Liau 1984), and the situation appears to be similar in Thailand (Wood 1987).

Table 2.
Major rodent pest species in Thailand and the crops/areas they affect.

Species	Rice fields and field crops	Oil palms	Fruit trees (mango, longan, macadamia etc.)	Storage and houses
Bandicota indica	✓	✓ (young palms, < 3 years)		
Bandicota savilei	✓			
Rattus argentiventer	✓	✓ (young palms, < 3 years)		
Rattus bowersi		✓ (young palms, < 3 years)		
Rattus exulans				✓
Rattus losea	✓		✓	
Rattus norvegicus				✓
Rattus rattus	✓	✓	✓	✓
Rattus tiomanicus		✓		
Mus caroli	✓		✓	
Mus cervicolor	✓		✓	
Mus musculus				✓