14. Ecologically-Based Population Management of the Rice-Field Rat in Indonesia

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Abstract

The rice-field rat, *Rattus argentiventer*, occurs throughout most of Southeast Asia and is one of the most economically important pre-harvest pests in rice crops. Based on a capture–recapture study in an irrigated lowland rice agro-ecosystem, populations are limited by the availability of nest sites and food. We recommend the following management strategies: (1) minimise the number of banks to reduce the availability of nest sites; (2) maintain/retain fallow to limit populations; (3) synchronise crops to minimise breeding period; and (4) time the application of mortality control at the early to mid-tillering stage when population density is low, individuals are generally in poor condition and not breeding, and thus populations are least able to compensate for the imposed mortality. Active burrow counts are recommended for assessing population size for management purposes. Live-trapping is recommended for demographic studies. Decision analysis identified strengths in current management practices in West Java, as well as key gaps in our scientific knowledge for developing effective management. Future research priorities are as follows: (1) evaluate the impact of secondary food sources on rat populations; (2) identify cues used by rats to trigger mating; (3) examine the spatial dynamics of crop asynchrony and its effect on the movements of rats; (4) determine age-specific survival for targeting control; (5) develop standardised methods for assessment of yield loss caused by rats; and (6) develop appropriate decision models for use by growers.

Keywords

Rattus argentiventer, rice-field rat, population dynamics, pest management, rice

INTRODUCTION

THE RICE-FIELD rat, *Rattus argentiventer*, is one of the most economically important pre-harvest pests in rice agro-ecosystems in Southeast Asia (Buckle et al. 1985; Geddes 1992; Singleton and Petch 1994). It occurs throughout most of Southeast Asia, including parts of Burma, Cambodia, Vietnam, Thailand, Malaysia, Indonesia and the Philippines (Corbet and Hill 1992). It is the predominant rodent species in most rice agro-ecosystems. Other rodent species (e.g. *Rattus tanezumi*) become dominant only on islands where the rice-field rat is absent (Wood 1994).

The island of Java has long been Indonesia's rice bowl. In 1996, it produced 28 million tonnes, accounting for about 56% of national production. Over half of the rice grown in Java is in irrigated lowland fields (about 3 million ha), a quarter in rainfed lowland fields and the rest in dry, upland fields. The lowland systems produced 96% of rice production in Java in 1996 (Bureau of Statistics, Indonesia).

Rice agro-ecosystems have expanded to increase production. Raffles (1817) estimated that only one-eighth (12%) of Java was cultivated. This had increased to about 18% by 1870, to 50% by 1920 (Booth 1988), and to 64% by 1997. Further expansion is limited by the availability of suitable land (RePPProT 1989). Recent increases in rice production have been achieved mainly through the use of varieties with short growing seasons, increased cropping intensity, and improved water supply. Further increases in rice production may be achieved through reducing pre-harvest losses to rodents (Singleton and Petch 1994). This underpins the purpose of reviewing ecologically-based management of the rice-field rat in this chapter.

Tropical rice agro-ecosystems are one of the most complex and stable agro-ecosystems in the world. Despite its economic significance, the ecology of rice agro-ecosystems is under-studied (Anwar et al. 1984). We conducted a bibliographic search (August 1998) on this topic and found that studies have focused primarily on rice and insect pests.

Rice is the staple food in Asia. By 2025 Asia's production of rice will have to increase by 70% to meet the needs of four billion people (Lampe 1993). Although many methods are used to control rodent pests in Indonesia, pre-harvest damage levels have not been reduced in recent times (see below). Tolerance of rodent damage to rice crops will diminish under the intense pressure to increase production. This chapter aims to provide an ecologically-based approach to integrating rodent control methods. We begin by reviewing the economic significance of the rice-field rat and describing the rice agro-ecosystem of West Java. We then review what is known about the likely key factors that limit the population size of the rice-field rat in rice agro-ecosystems, drawing heavily on the findings of a study by L.K.-P. Leung and Sudarmaji (unpublished data) on the population ecology and habitat use of the rice-field rat in rice fields in West Java. In the final section, we discuss decision-support models for the management of the rice-field rat.

Economic Significance

In Indonesia, the rice-field rat has been ranked as the most important pest (non-weed) in Indonesia since 1983 (Table 1). Data collected by the forecasting centres of the Directorate of Food Crop Protection in Indonesia indicate that rats cause pre-harvest losses of around 17% per year to rice crops in Indonesia (Geddes 1992).

Rodent damage to rice crops is a chronic problem in Indonesia, although some years experience higher damage than others (Table 2). In West Java, rodent damage varies greatly among villages and sub-districts, and even among farms within a village—possibly because of the small size of average holdings (<2 ha) and different levels of rodent control effort among growers. Rodent control also lacks coordination. The patchy distribution of rodent damage has a significant impact on individual farmers and villages (Singleton and Petch 1994). On occasions, parts of some provinces suffer total crop loss to rats (Table 3).

Irrigated Lowland Rice Agro-ecosystem

This chapter draws heavily on research conducted in lowland irrigated rice fields of West Java. The main rice producing area in Java is located on the north coast of West Java, and consists of the neighbouring districts of Karawang, Subang and Indramayu. The irrigated area in these districts is 271,000 ha (Kartaatmadja et al. 1997).

Climate

Each year, the Southeast Asian region has distinct dry and wet seasons. In West Java, the dry season is from May to October and the wet from November to April. Around 75% of the annual rainfall occurs in the wet season. In general, two crops of rice are grown each year in the irrigated lowland rice agro-ecosystem: a wet season crop (first crop) from mid-October to February; and a dry season crop (second crop) from April to July/August. The field is fallow over the later part of the dry season when irrigation water is in short supply. Vegetables and a third crop of rice may be grown in some fields where water is still available. A brief fallow may occur between the wet and dry season crops because of a limited supply of labour for land-preparation and transplanting. The timing of crops varies among years because the planting of the first crop is dependent upon the onset of the wet season.

Phenology of rice

The main growth stages of rice, based on a 120-day variety of rice (IR 64) are: tillering (55 days long); reproductive (35 days); milky ripe grain (10 days; abbreviated as milky); and ripening (30 days) (after Reissig et al. 1986). The reproductive and ripening stages are collectively termed the generative stage. There are often different crop stages in a given area, because crops are planted over a period of time depending on the availability of irrigation water and labour for planting. Planting of the first crop (wet season) is usually more synchronised than the second crop.

Table 1.
Ranking of economically important, non-weed pests in rice crops in Indonesia.

Pest	Ranking of decreasing order of economic significance			
	1983–1985	1986–1990	1991–1994	1995–1997
Rice-field rat	1	1	1	1
Brown plant hopper	2	4	2	3
Rice stem-borer	4	2	3	2
Rice leaf folder	3	3	Not ranked	Not ranked

Source: Forecasting Center for Pest and Diseases, Jatisari, West Java.

Table 2.
Incidence of rat damage and damage intensity of rice in Indonesia during the period 1980–1996.

Year	Incidence of rodent damage to rice crops	
	Area damaged (ha)	Damage intensity (%)
1981	198 546	14.5
1982	194 144	17.6
1983	186 989	20.1
1984	186 036	15.9
1985	179 765	17.5
1986	119 602	15.6
1987	80 865	13.6
1988	100 171	15.7
1989	95 175	17.7
1990	76 140	17.2
1991	77 114	18.7
1992	85 512	19.5
1993	No data	No data
1994	86 694	21.9
1995	103 109	20.8
1996	103 109	20.8
Average	**119 819**	**17.8**

Source:
Bureau of Statistics, Government of Indonesia.

Table 3.
Rodent damage and crop loss to rats for lowland rice in 1995.

Province	Damage area (ha)	Mean damage intensity (%)	Area of total crop loss (ha)
DKI Jakarta	35	10.37	0
Jawa Barat	29 006	16.08	241
Jawa Tengah	11 282	14.32	662
D.I. Yogyakarta	2 138	11.28	0
Jawa Timur	4 493	22.18	485
D.I. Aceh	5 755	17.90	0
Sumatera Utara	878	16.00	10
Sumatera Barat	1 073	20.20	25
Riau	700	20.50	12
Jambi	597	24.10	105
Sumatera Selatan	2 380	22.50	217
Bengkulu	949	12.70	0
Lampung	1 473	18.60	70
Bali	212	25.40	0
NTB	550	15.90	0
NTT	45	5.30	0
Kalimantan Barat	1 476	32.40	337
Kalimantan Tengah	2 781	23.70	446
Kalimantan Selatan	140	20.20	0
Kalimantan Timur	1 385	23.10	19
Sulawesi Utara	612	28.80	110
Sulawesi Tengah	9 815	14.60	158
Sulawesi Selatan	23 362	32.40	2 179
Sulawesi Tenggara	1 972	24.80	149

Source: Bureau of Statistics, Government of Indonesia.

Sympatric species

As well as domestic species, seven other vertebrate species are commonly found in the lowland irrigated rice agro-ecosystem in West Java: the house shrew (*Suncus murinus*), the large bandicoot rat (*Bandicota indica*), a skink—*Mabuia multifasciata*, a frog —*Rana crytrala*, and two snakes — *Ptyas korros*, and *Coluber radiatus*. Based on our trapping data, the large bandicoot rat occurs at relatively low densities compared to the rice-field rat.

Avian predators are rare in the lowland rice agro-ecosystem in Java. Other predators are sighted occasionally such as the Javan mongoose (*Herpestes javanicus*), the fishing cat (*Felis viverrina*), the small Indian civet (*Viverricula malaccensis*), and many unidentified species of snakes also occur (L.K.-P. Leung, personal observation).

The native house rat (*Rattus rattus diardii*) is a commensal species and is occasionally found in the rice fields. The Polynesian rat (*Rattus exulans*) and the rice mouse (*Mus caroli*) occur in other rice agro-ecosystems.

Food

Very little is known of the diet of the rice-field rat. Stomach content analysis reveals that they consume crabs, snails, insects, rice and other plant material, which commonly occur in the rice ago-ecosystem (Rahmini, unpublished data). Rice at the ripening stage is the most important food; fragments of rice grains were found in 100% of stomachs examined ($n = 50$) and constituted more than 50% of the stomach content by volume (L.K-P. Leung, unpublished data).

Goot (1951) observed that rats in captivity survived for only four or five days when fed exclusively on weeds, rice plants at the tillering stage, crabs, snails, or insects; whereas rats survived for several months when fed on starch food such as rice grains, maize, soya beans, peanuts, and sweet potatoes. Murakami (1990) found that captive rats survived for more than two weeks when fed exclusively on rice plants at the ripening stage. In contrast, survival was poor when they were fed rice plants at the tillering and reproductive stages. The results of these experiments need to be interpreted cautiously because rats in the field have a choice of food. Nevertheless, these two studies indicate that rice at the ripening stage is the most nutritious food for the rice-field rat in a rice agro-ecosystem.

In mixed-crop systems in West Java, relative damage to crops by the rice-field rat indicates it prefers rice to maize, peanut, and, soya bean (S. Suriapermana, personal communication). For this group of crops, litter size is highest in rats living in rice (Goot 1951).

Habitat

The original habitat of the rice-field rat is grassland, where its breeding is seasonal (Harrison 1951, 1955). In West Java, the irrigated lowland rice agro-ecosystem consists of a continuous tract of rice fields and a network of roads, streams, irrigation channels and drainage lines. 'Islands' of villages (*kampongs*) are scattered across the landscape. Sugarcane, peanuts and other crops are grown on 'islands' of elevated ground. Populations of the rice-field rat are present in villages and elevated croplands only when rice crops are not at the ripening stage (Goot 1951).

Earth banks along margins of paddies are an important habitat for the rice-field rat in this ecosystem because when the paddies are flooded, burrows in earth banks are the primary source of shelter. Banks are important also for breeding females because young are born and reared almost exclusively in burrows (L.K.-P. Leung and Sudarmaji, unpublished data). Rat burrows are found in the substrate of paddy fields only after harvest when the fields are drained and not waterlogged. After harvest, rats also construct nests underneath piles of rice straw left in the fields.

Breeding

Lam (1980, 1983) conducted detailed and extensive studies of the reproduction of the rice-field rat in Malaysia and has shown that a single breeding season occurs where one crop is grown per year, and that two breeding seasons occur if two crops are grown per year. He also has shown that the breeding seasons correspond closely with the reproductive and ripening stages of the rice crop, and suggests that nutritional factors, particularly the presence of rice at the reproductive stage, trigger reproduction in the rice-field rat. Tristiani et al. (1998) obtained similar findings in populations of the rice-field rat in West Java.

L.K.-P. Leung and Sudarmaji (unpublished data) have determined from autopsy of females that mating begins just prior to maximum tillering. At this stage, the testes are at their largest in nearly all males, indicating peak breeding condition. The first litters of young are born during the booting stage. Post-partum mating occurs (Lam 1983) and a second litter can be born during the ripening stage and a third shortly after harvest (L.K.-P. Leung and Sudarmaji, unpublished data).

The onset of mating at the maximum tiller number stage allows females to make full use of the ripening crop for meeting the high energy demands of raising young. The ability of the rice-field rat to synchronise reproduction with the phenology of the rice crop is possibly the key to its success in the rice agro-ecosystem. This ability was possibly selected in its original grassland habitat. Thus the rice-field rat may be evolutionarily pre-adapted to invade rice agro-ecosystem because of the similar phenology of rice and other species of the Graminaceae.

Female rice-field rats can conceive at the age of 45 days (Lam 1983), and can potentially produce up to three litters per cropping season. The first litter of the season generally does not breed because of the rapid decline in quality of the food supply within two weeks of harvest. However, the availability of high quality food only needs to be extended by 3–4 weeks for these females to breed and successfully rear young. Asynchronous crops will therefore extend the breeding season of rats and allow the first litters of the cropping season to breed and successfully raise young. Therefore the number of breeding females would increase exponentially. This contention is supported by studies of the breeding status of different age classes of female rats collected in an asynchronous cropping area in West Java in 1996: from a sample of 410 adult females caught immediately post-harvest, 56% of those pregnant were less than two months of age (Rahmini, unpublished data).

Asynchronous cropping is typical of fast-growing varieties of rice. Traditional varieties in Southeast Asia are photosensitive and mature at a particular time of the year, even when crops are planted over a period of weeks (Grist 1975). Synchronous maturation was possibly selected as a defensive mechanism against rodents or other pests.

Monitoring pest populations

Accurate assessment of rodent population density assists the grower to properly schedule control efforts. Also, reliable estimation of population density is a prerequisite for research into factors determining distribution and abundance of the pest. Management decisions are only as accurate as the sampling methods employed.

The reliability of a relative abundance index is based on its linear relationship with the population size (Caughley 1977). Two relative indices (active burrow counts and catch index) have been developed and calibrated against directly enumerated population sizes of the rice-field rat in lowland rice agro-ecosystem (L.K.-P. Leung and Sudarmaji, unpublished data). We are aware of only two other studies that have achieved this (Parer and Wood 1986; Moller et al. 1997).

L.K.-P. Leung and Sudarmaji (unpublished data) recommend active burrow counts for assessing population size of the rice-field rat for management purposes because this method is simple and reliable, and is not affected by the growth stage of rice crops. The catch index, although less accurate than active burrow counts, is recommended for population studies because animals caught in live traps can be measured to estimate other demographic characteristics such as sex ratio, survival and age structure.

Likely Key Factors Limiting Population Size

In West Java, there appear to be three principal factors limiting the population size of the rice-field rat. However, there is a dearth of long-term studies and an absence of manipulative studies, so these conclusions are preliminary.

Farm management practices

Agricultural ecosystems undergo major fluctuations in biomass and disturbance. In West Java, the major disturbances occur during land preparation and at harvest. For example, land preparation for each rice crop involves concurrent, widespread cultivation of fields and substantial reformation of banks. These actions have major impacts on the distribution and abundance of the rice-field rat. Added to this is the rapid switching of rice crops from sub-optimal to optimal rat habitats associated with the growing and ripening phases of the crop.

Farm management practices by growers therefore have major impacts on rat populations. They influence the temporal and spatial availability to rats of shelter, nesting sites, and the quality and quantity of food. They also impose direct mortality on rats through physical actions such as hunting, trapping, fumigating etc.(see Singleton et al., Chapter 8).

Availability of nest sites

In the irrigated lowland rice agro-ecosystem, the availability of nest sites is a key limiting factor for populations of the rice-field rat (L.K.-P. Leung and Sudarmaji, unpublished data). The abundance of rats is lower in the middle than along the margin of crops, where nest sites are available in adjacent banks.

In West Java, earth banks of primary and secondary irrigation channels form a major network in lowland rice fields. These are prime nesting sites for rats and as a consequence large populations of rats are associated with these structures (L.K.-P. Leung and Sudarmaji, unpublished data).

Rat burrows are occasionally found in bunds (small banks) in paddies. Farmers, however, usually construct bunds to a dimension that is too small for rats to build a burrow system.

Food supply

Population size and body condition decline during the dry season fallow and both are at their minimum shortly after fallow, around the early to mid-tillering stage. This is possibly due to diminished availability of food during the later part of the dry season fallow when both the abundance of invertebrates (Wolda 1978) and plant growth are reduced.

After fallow, the rice-field rat persists in low numbers in rice fields during the tillering stage of the first crop. Goot (1951) observed that a small number of rats remained in the field when their burrows were not disturbed by land preparation. Population growth is closely associated with the ripening of the crop when quality food is abundant. The process of population growth at the local level consists of breeding and subsequent recruitment of juveniles into the population as well as immigration of rats attracted to the ripening crops (Lam et al. 1990; L.K.-P. Leung and Sudarmaji, unpublished data). Maximum densities of population are reached shortly after harvest. Direct enumeration of rats from fumigating burrows and disturbing straw piles indicates that densities range from 120 to 240 rats per hectare (L.K.-P. Leung and Sudarmaji, unpublished data). Similar densities have been obtained by counting all rats caught in large areas during an eradication campaign (Table 4).

Table 4.
Total counts of rats present in irrigated lowland rice fields in West Java after harvest of the dry season crops, August–September, 1998.

Site	Area (ha)	Number of rats	Number of rats per ha
Pabuaran	230	51 000	222
Patokbeust	130	17 157	131
Binong	516	64 844	125
Pagaden	911	30 644	34

Source: S. Suriapermana, unpublished data.

Ecologically-based Population Management Practices for the Rice-field Rat

Population ecologists often remark that their studies and theories 'provide insight' into pest management. To be useful, however, these ideas must be part of a decision-theory framework. The challenge is to combine the current scientific knowledge on the biology and management of the rodent species we wish to control with the social, economic and political factors that influence the adoption of management actions by farmers. The simple restrictions that cultural and religious beliefs place on some management actions for agricultural pests (see Norton and Heong 1988) emphasises the importance of determining how farmers are likely to perceive and react to a rodent pest problem and to recommended management actions. Frameworks for developing a 'decision analysis/systems analysis' approach to vertebrate pest management have been developed (Norton and Pech 1988; Braysher 1993) and have been applied to rodent pest problems in agricultural systems (Brown et al. 1998).

We have applied our knowledge of the ecology of the rice-field rat, reviewed in this chapter, to develop an ecologically-based appraisal of the appropriateness of different management actions (Table 5). This appraisal was developed through consultation with scientists and agricultural extension staff. In some cases the scientific knowledge was too weak to critically evaluate the likely efficacy or economics of a particular management practice. Therefore, the decision-analysis presented in Table 5 includes a number of 'best guesses' and simply provides a working model. Among the 15 practices examined, seven practices are not supported by any scientific evidence and will need to be critically tested by field trials.

Based on this decision analysis approach, we recommend an integration of four management strategies for appraisal in replicated field trials prior to their implementation.

- First, the number of banks in rice fields should be kept to the minimum to limit the availability of nest sites. The flooding of rice fields serves to deter not only rats but also weeds and other pests. Banks are the only nesting sites in irrigated rice fields, and cannot all be eliminated because they are used as roads and for managing water levels for irrigation. Better planning and technology may reduce the number of banks. On the experimental farm of the International Rice Research Institute (IRRI), the number of banks was minimised by converting open drain lines to underground pipes, and rodent damage was reduced as a consequence (Mark Bell, IRRI, personal communication). Also, concreting the surface of banks will prevent rats from building burrows. However, both underground pipes and concreting are costly and are rarely appropriate for developing countries.

- Second, planting of crops and harvesting should be synchronised over a large area so as to shorten the period that ripening rice is available to rats and hence reduce their breeding season. In West Java the main constraints to synchronised planting are water and labour supply. However, it appears that water supply schedules can be modified to reduce asynchrony of planting of crops (S. Suriapermana, personal communication).

- Third, fallow over the dry season should be maintained to reduce rat population size. This also reduces numbers of some insect pests (Grist 1975). In some regions in Southeast Asia there is pressure to boost crop production by growing three crops per year. This is already being practiced in the Mekong Delta in Vietnam, and rodent damage appears to have increased as a consequence (Singleton and Petch 1994). In 1998, massive rodent control campaigns were necessary for protecting a third rice crop trialled in parts of Java and Bali (S. Suriapermana, personal communication).

- Fourth, if mortality control is used, it is best applied at the early to mid-tillering stage after the dry season fallow when populations densities are low and animals are weak. If rat densities are significantly reduced over a large area at this time, populations would have little immediate capacity to compensate for their reduction in numbers. This timing of action is

Table 5.

Decision analysis of practices for managing populations of the rice-field rat in West Java, Indonesia. Eight parameters were considered. The table also includes scientific basis and priority given to each practice. No analysis was conducted for empty matrix cells. The analysis took place during a workshop at the International Rice Research Institute in 1998. (Timing: lp = land preparation; sb = seed bed; tp = transplanting; b = booting; m = milky; r = ripening; h = harvest; f = fallow. Suitability of practices: ✓ = yes; X =no; ? = unknown; N/A = not applicable.)

Management practice	Timing	Feasible	Economic	Socially acceptable	Environmentally friendly	Sustainable	Scale of adoption	Ecosystem focus	Scientific basis	Priority
Routine										
Field sanitation	lp to b	✓	✓	✓	✓	✓	village	✓	?	high
Synchronous seeding and planting	sb,tp	✓	✓	✓	✓	✓	village	✓	for	high
TBS[a] by farmer group	crop	✓	✓	?	✓	✓	village	✓	for	high
Reduce bund size within rice fields	lp	✓	✓	✓	✓	✓	village	✓	for	high
Encourage natural enemies of rats	all	?	?	✓	✓	?	district	✓	?	high
Plastic barrier for nurseries	sb	✓	✓	✓	?	✓	village	N/A	for	high
Fumigation	lp,b,m,r	✓	✓	✓	X	✓	village	?	against	moderate
Digging burrows	lp,sb,r	✓	?	✓	X	X	village	X	?	moderate
Hunting at night	lp,sb	✓	X	✓	✓	X	village		?	low
Trapping with net	>h	✓	X	✓	✓	?	village		?	low
Apply if high densities are forecast										
Do not plant rice as the third crop		✓	✓	✓	✓	✓	farmer	N/A	for	high
Remove rice straw after harvest	f	✓	✓	✓	X	X	village	✓	for	high
Monitor abundance of rats in field	lp to m	✓	✓	✓	✓	✓	village	?	for	?[b]
Apply rodenticide	f, tp	✓	?	✓	X	X	village	?	?	moderate
Pump water down burrow entrance	>dry f	✓	?	✓	✓	?	village	X	?	moderate

[a]Trap–barrier system
[b]Need economic threshold data.

consistent with the recommended use of chemical rodenticides. After the rice crop reaches the booting stage, rodenticides become less efficacious because the baits are less attractive to rats (Buckle et al. 1979).

How Our Ecological Knowledge Can Influence Current Management Practices

The previous section highlighted management strategies that need to be implemented or maintained (e.g. fallow) for successful rat management. Our ecological knowledge of rodent populations can also be used to modify existing actions so that they are more efficient and effective.

In West Java, much energy and effort is applied each year in digging and fumigating rat burrows. This is the most common form of pre-harvest control of rodents in rice fields because it requires little capital compared to rodenticides. However, these actions generally are conducted during the ripening stage of the crop—about five weeks too late for maximal effect. In many parts of Java, 'gropyokan' is a tradition, with people joining together just after the harvest to kill rats by digging and fumigating burrows in rice fields. Mortality control at this stage is not an efficient use of resources and labour because many of the rats they kill would have died anyway during the fallow period. Indeed, removing high numbers of rats early in the fallow period may result in better survival of remaining rats than if no control was implemented because of reduced competition for food and shelter. If more rats were to survive through until the commencement of the next breeding season, then post-harvest control activities may be counter-productive.

In West Java, the one exception to applying mortality control at early to mid-tillering would be when the fallow period is short and rat densities are high. In this situation there is a high risk of significant rat damage when the next rice crop is transplanted.

Where To From Here?

An important output from a decision analysis process is clear identification of the key gaps in our scientific knowledge for developing effective management of a particular rodent pest. Table 6 summarises the gaps in our knowledge of the ecology and biology of the rice-field rat and the priority for obtaining this information to strengthen our management of the species. Our major shortcomings include a lack of understanding of factors that influence age-specific survival and inter-year fluctuations in the amplitude of populations, and knowing little of where rats live and what they survive upon during the fallow periods.

Our understanding of the ecology of the rice-field rat in West Java has enabled identification of optimal timing, location and scale of actions and whether they are consistent with goals of sustainable agriculture, minimal environmental impact and humaneness. Through knowledge of the socioeconomic status of the farming communities in the region we have assessed also the likely impact and practicalities of the recommended management actions. An important next step is to closely liaise with growers to determine which management actions they are willing to adopt, what modifications they would require before an action would be adopted, and to ascertain whether there are other actions they would like to include in an integrated management program. Once the management practices have been modified and approved by the growers we will need to assess the impact of integrating these management actions on populations of the rice-field rat. This would require a village-level study involving close cooperation with growers and a replicated, controlled, experimental design. The assessment of the success of the study will not be measured by the number of rats caught or killed, but by the reduction in damage caused by the rice-field rat, compared to the cost of implementing the management practices. For this approach to be successful and to be sustained by farmers, the management actions need to be reviewed at least annually in consultation with growers.

In summary, an ecological approach has provided the tools and building blocks for developing an integrated management approach. Developing field projects to evaluate the approach in close liaison with growers at the village or district level provides the necessary furnishings and quality control for developing an effective and operational management approach.

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References

Anwar, J., Damanik, S.J., Hisyam, N. and Whitten, A.J. 1984. Ekologi ekasistem Sumatera. Yogyakarta, Gadjah Mada University Press.

Booth, A. 1988. Agricultural development in Indonesia. Sydney, Allen and Unwin.

Braysher, M. 1993. Managing vertebrate pests: principles and strategies. Canberra, Australian Government Publishing Service, 58p.

Brown, P.R., Singleton, G.R., Dunn, S.C. and Jones, D.A. 1998. The management of house mice in agricultural landscapes using farm management practices: an Australian perspective. In: Baker, R.O. and Crabb, A.C., ed., Proceedings of the 18th Vertebrate Pest Conference Santa Clara, California, USA, 2–5 March 1998. Davis, University of California, 156–159.

Buckle, A.P., Rowe, F.P. and Yong, Y.C. 1979. Field trials of two warfarin baiting methods against the rice field rat (*Rattus argentiventer*) in Peninsular Malaysia. Malaysian Agricultural Journal, 52, 78–95.

Buckle, A.P., Yong, Y.C. and Rahman, A. 1985. Damage by rats to rice in South-east Asia with special reference to an integrated management scheme proposed for Peninsular Malaysia. Acta Zoologica Fennica, 173, 139–144.

Caughley, G. 1977. Analysis of vertebrate populations. London, John Wiley and Sons.

Corbet, G.B. and Hill, J.E. 1992. The mammals of the Indomalayan region. Oxford, Oxford University Press, 488p.

Geddes, A.M.W. 1992. The relative importance of pre-harvest crop pests in Indonesia. Kent, UK, Natural Resources Institute, 70p.

Goot, P. van Der 1951. Over levenswijze en bestrijding van sawah ratten in het laagland van Java. Landbouw, 23, 123–275.

Grist, D.H. 1975. Rice. Tropical Agriculture Series, Fifth Edition.New York, Longman, 548p.

Harrison, J.L. 1951. Reproduction in rats of the subgenus *Rattus*. Zoological Society of London Proceedings, 121, 673–694.

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

Kartaatmadja, S., Soejitno, J. and Wardana, I.P. 1997. Pest management practices of rice farmers in West Java, Indonesia. In: Heong, K.L. and Escalada, M.M., ed., Pest management of rice farmers in Asia. Manila, Philippines, International Rice Research Institute, 87–98.

Lam, Y.M. 1980. Reproductive behavior of the rice field rat, *Rattus argentiventer* and implications for its control . Proceedings National Rice Conference, 243–257.

Lam, Y.M. 1983. Reproduction in the rice field rat, *Rattus argentiventer*. Malaysian Nature Journal, 36, 249–282.

Lam, Y.M., Supaad, M.A., Chang, P.M., Mohamed, M.S., Goh, C.S. and Radzi, H. 1990. An innovative approach for protecting rice against severe rat depredation. Proceedings of the 3rd International Conference on Plant Protection in the Tropics, 1–23.

Lampe, K. 1993. Will Asia starve? In: Food comes first for Asia. Parkville, Australia, Crawford Fund for International Agricultural Research, 59–71.

Moller, H., Clapperton, B.K. and Fletcher, D.J. 1997. Density of rabbits (*Oryctolagus cuniculus* L.) in the Mackenzie Basin, South Island, New Zealand. New Zealand Journal of Ecology, 21, 161–167.

Murakami, O., Priyono, J. and Triastiani, H. 1990. Population management of the ricefield rat in Indonesia. In: Quick, G.R., ed., Rodents and rice. Manila, Philippines, International Rice Research Institute, 49–60.

Norton, G.A. and Heong, K.L. 1988. An approach to improving pest management: rice in Malaysia. Crop Protection, 7, 84–90.

Norton, G.A. and Pech. R.P. 1988. Vertebrate pest management. In: Australia: decision analysis/systems analysis approach. CSIRO (Commonwealth Scientific and Industrial Research Organisation) Division of Wildlife and Ecology, Project Report No. 5. Melbourne, CSIRO Publications, 67p.

Parer, I. and Wood, D.H. 1986. Further observations of the use of warren entrances as an index of the number of rabbits, *Oryctologus cuniculus*. Australian Wildlife Research, 13, 331–332.

Raffles, T.S. 1817. The history of Java. Oxford, Oxford University Press.

Reissig, W.H., Heinrichs, E.A., Litsinger, J.A., Moody, K., Fiedler, L., Mew, T.W. and Barrion, A.T. 1986. Illustrated guide to integrated pest management in rice in tropical Asia. Los Baños, Philippines, International Rice Research Institute, 411p.

RePPProT 1989. Regional physical planning programme for Indonesia, review of phase 1 results: Java and Bali. Jakarta, Directorate General of Settlement Preparation, Ministry of Transmigration (Jakarta) and Natural Resources Institute Overseas Development Adminstration (London).

Singleton, G.R. and Petch, D.A. 1994. A review of the biology and management of rodent pests in Southeast Asia. Canberra, Australian Centre for International Agricultural Research, Technical Report No. 30, 65p.

Tristiani, H. Priyono, J. and Murakami, O. 1998. Seasonal changes in the population density and reproduction of the ricefield rat, *Rattus argentiventer* (Rodentia: Muridae), in West Java. Mammalia, 62, 227–239.

Wolda, H. 1978. Fluctuation in abundance of tropical insects. American Naturalist, 112, 1017–1045.

Wood, B.J. 1994. Rodents in agriculture and forestry. In: Buckle, A.P. and Smith, R.H., ed., Rodent pests and their control. Wallingford, UK, CAB International, 45–83.

15. Population Ecology and Management of Rodent Pests in the Mekong River Delta, Vietnam

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Abstract

Rodent pests are a growing problem in rice agro-ecosystems of Vietnam. However, little is known about which rodent species are responsible for losses to crop production, let alone how best to manage their impact. A survey of rat species in nine provinces in the Mekong River Delta found that the dominant rodent species found in rice ecosystems were the rice-field rat, *Rattus argentiventer* (60%) and the lesser rice field rat, *Rattus losea* (15%). Ten other species accounted for the remaining 25% of the population, and were unlikely to cause significant damage to pre-harvest rice. The breeding patterns of the two main rodent species and the relative population dynamics of rodents in different habitats were obtained from live-trapping studies (capture–mark–release) in a range of representative habitats based in and around the rice growing regions of Long An, Kien Giang and Tra Vinh provinces. Traps were set in rice crops (one and two rice crops per year), channel banks, melaleuca forest, undisturbed grassland, and coconut and banana plantations. Supplementary kill trapping was conducted to determine the breeding status (percentage of adult females breeding, litter size and embryo development) of the rats and to confirm their taxonomy.

Our focus on the ecology of the key rodent pest species has helped to define a range of potential management practices that are considered to be environmentally sustainable, economically feasible and socially acceptable. These practices are divided into routine actions that can be conducted all the time and preventative actions if high rat numbers are forecast.

Keywords

Species composition, habitat use, breeding, rice crops, ecology, *Rattus argentiventer*, *Rattus losea*

INTRODUCTION

RATS ARE THE number one pre-harvest pest of rice in many countries in Southeast Asia (Geddes 1992; Singleton and Petch 1994). In Vietnam, rodents are one of the three most important problems faced by the agricultural sector (Huynh 1987) and the level and intensity of damage has increased since about 1992 (Table 1). In the Mekong River Delta, there were 10,125 ha of damaged rice recorded in Long An, Dong Thap and Kien Giang provinces in the 1991/92 winter–spring season. In the winter–spring season of 1992/93, the area damaged increased to 44,000 ha over ten provinces. Crop losses were estimated at 300,000–400,000 tonnes of rough rice. Damage was recorded in Long An Province to over 10,000 ha with 10–30% losses, and 4,000 ha with 50–100% losses; in Ha Tien (Kien Giang Province), 800 ha were damaged with 80% losses. In 1996, the area damaged by rats increased to 130,000 ha over most provinces of the Mekong Delta. Rats also cause damage to other crops such as corn and potato in the suburbs of Ho Chi Minh City, in coastal regions (Binh Thuan Province) and in highland regions (Dong Nai Province). The factors that have lead to increased losses include more intensive farming and a general increase from two to three crops planted per year (Singleton and Petch 1994).

The factors that lead to increases in rat numbers and the importance of various habitats for breeding and shelter have not been addressed in Vietnam. The principal pest species is thought to be *Rattus argentiventer*, however little is known about the taxonomy or the population ecology of the species of rodents which inhabit rice ecosystems in Vietnam. In contrast, rodent species that are hosts for human plague in Vietnam have been studied extensively (Gratz 1988; Suntsov et al. 1997). Population studies of *R. argentiventer* have been conducted in Malaysia (Wood 1971; Lam 1980, 1983; Buckle 1990), Indonesia (Murakami et al. 1990; Leung et al., Chapter 14) and the Philippines (Fall 1977), but these results may not be appropriate for the Mekong River Delta which experiences annual floods. Furthermore, the mosaic pattern of habitats that exist in the Mekong Delta may be favourable or unfavourable for rats.

Table 1.
Area damaged by rats (ha) in the Mekong River Delta and other parts of Vietnam, 1992–1997 (adapted from Hung et al. 1998).

Year	Mekong River Delta	Other areas	Total area damaged in Vietnam
1992	18 640	–	18 640
1993	107 481	–	107 481
1994	134 616	–	134 616
1995	74 408	18 849	93 257
1996	130 777	130 723	261 500
1997	129 512	245 488	375 000

This chapter aims to provide an ecologically-based approach to the management of rodent pests in the Mekong River Delta of Vietnam. With a good understanding of the species composition, biology and behaviour of pest species it should be possible to devise management actions that are sustainable (environmentally and culturally) and could be combined with integrated pest management programs that are in place for insects, weeds and plant diseases (Singleton 1997). To provide some initial insight into the ecology of rodent pests in rice agro-ecosystems in the Mekong River Delta, data were collected from 1994 to 1998 on (i) the composition of rat species and (ii) the population dynamics, habitat use and breeding of the main rodent species, the rice-field rat (*R. argentiventer*) and the lesser rice-field rat (*Rattus losea*). Because none of this work has been published, we will begin by considering the methods adopted. We will then present the results of this study and suggest some preliminary management recommendations. As the data are limited, further studies are necessary to refine these strategies. Also highlighted are areas where critical information is lacking and further research is required.

Methods

Study sites

The provinces of Long An, Kien Giang and Tra Vinh are situated in the Mekong River Delta of Southern Vietnam (Figure 1).

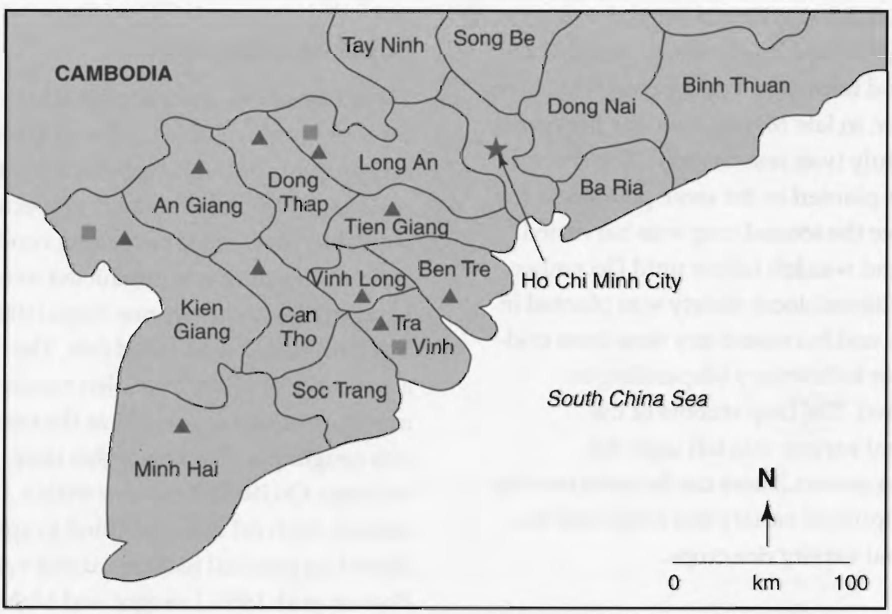

Figure 1.
Provinces of the Mekong River Delta of southern Vietnam. Shown are locations where the composition of rat species was determined (▲) and where the population dynamics of rats were assessed (■).

The annual rainfall in the region is 2,000–2,500 mm, which falls predominantly in the wet season (April to November). The topography is generally flat and some areas are regularly flooded during October and November, when the river systems overflow. The average temperatures range from 22–32°C in the dry season and 25–30°C in the wet season. There is an extensive network of channels and canals running through the delta delivering water for irrigation of rice crops. The width of the channels ranges in size from 1 m (tertiary channel), 2–5 m (secondary channel) and >5 m (primary channel).

The main rice crops grown at each study site were improved variety rice crops (90 day duration such as IR-54404, OM-1490 and OM-1037) and traditional, local variety rice (160–180 days duration). The first crop of improved variety rice was sown when flood waters subsided in December and was harvested in March (dry season crop), then the second improved variety crop was sown soon after, in late March, and was harvested in early July (wet season crop). The second crop was planted in the same paddies as the first. Once the second crop was harvested, the ground was left fallow until December. The traditional, local variety was planted in mid-July and harvested any time from mid-December to February (depending on conditions). The crop stubble of the traditional variety was left until the following season. There can be some overlap of the improved variety rice crops and the traditional variety rice crops.

Rat species composition

The composition of rat species from nine provinces was determined from six sampling occasions from November 1995 to July 1997. Fifty rats were collected at each sampling occasion (except in March 1996 when 100 rats were caught) from rice fields and from a 100 m length of a channel bank. Rats were collected by live-capture wire traps (200 × 100 × 100 mm) and from digging burrows until the required number of rats were obtained. It is not known whether this sampling procedure may cause bias towards some species. There have been no published studies that consider this bias for rodents in Southeast Asia. On subsequent visits to the sites, rats were collected from the same general area or within approximately 100 m of the area used previously. Rats were identified to species following van Peenen et al. (1969), Lekagul and McNeely (1977) and Tien (1985a,b) using external features and skeletal dimensions. Data are presented as percentages.

Population dynamics

Table 2 describes the trapping schedules for capture–mark–release studies and for breeding studies. At Long An, the rats collected were not identified to species, nor were they assessed for breeding condition.

Live-trapping was conducted using hand-made, single-capture traps (100 × 100 × 200 mm) baited with dried fish. The abundance of rats was pooled for each month, and was expressed as the number of rats caught per 100 trap-nights (trap success). On its first capture within a trap session, each rat was identified to species (based on external features, using van Peenen et al. 1969, Lekagul and McNeely 1977, and Tien 1985a,b; it was not possible to identify some animals because of taxonomical problems) and was marked using a numbered brass ear tag (Hauptner, Germany). Each rat was sexed and assessed for breeding condition, weighed (± 1 g), and tail length (if intact), hind foot length, ear length and head-body length were measured (± 1 mm). Each rat was released at the point of capture.

The minimum weight for an adult female classification was based on the lowest weight at which a rat was pregnant (determined by palpation) or lactating. Any rat lighter than this was considered juvenile or sub-adult. Palpation generally detects embryos from the second trimester, and so will underestimate breeding performance.

Breeding

At Kien Giang, kill samples were taken of rats from various habitats from captures in trap–barrier systems (see Singleton et al. 1998 and Chapter 8 for description), from live-capture traps, digging burrows and catching by hand with nets. Females were dissected to determine the condition of the uterus, number of embryos, size of embryos (± 1 mm) and number of uterine scars. Rats were considered pregnant if the uterus contained visible embryos.

Results and Discussion

Species composition

Twelve species of rodents were recorded from nine provinces (Table 3). Overall, the most common species was *R. argentiventer* (61%) followed by *R. losea* (15%) and *Rattus koratensis* (7.2%). *R. losea* was the most common species in Kien Giang. The *Mus* genus was likely to include *M. caroli* and *M. musculus.*

Table 2.
Summary of trapping conducted at Long An, Kien Giang and Tra Vinh provinces for capture–mark–release and breeding studies.

Study site	Trapping regime schedule (No. traps per trap line)	Duration	Habitats and number of trap lines
	Capture–Mark–Release		
Long An	50 traps, 1 night per week	Aug 94–Dec 96	Improved variety rice (1) Grassland (1) Cassava field (1) Melaleuca forest (1)
Kien Giang	35 traps, 2 nights per 2 weeks	Oct 97–May 98	Traditional variety rice (3) Improved variety rice (3) Melaleuca forest (3) Grassland (3) Secondary channel (3)
Tra Vinh	35 traps, 3 nights per 4 weeks	May 97–May 98	Improved variety rice (5) Primary channel bank (1) Banana plantation (1) Coconut plantation (1)
	Breeding		
Kien Giang	50 rats each month	Aug 97–May 98	Various

According to Sung (1999), there are 64 species of rodents belonging to 27 genera and 7 families in Vietnam. The species identified by Sung (1999) are generally similar to those that were found in our samples. In the agricultural fields of the Mekong River Delta, Sung (1999) lists *R. argentiventer* and *M. caroli* as common species with *Rattus flavipectus*, *Rattus exulans*, *Rattus nitidus*, *Mus musculus*, *R. koratensis*, *R. losea* and *Bandicota indica* found primarily around settlements. Other species of rodents identified by Sung from the zoographical zone of the Mekong River Delta were *Bandicota bengalensis*, *Rattus germaini* and *Rattus norvegicus*, but *Rattus rattus* was not listed. We did not capture *Mus cervicolor* which was a species identified by Sung (1999) as being present in the Mekong River Delta. Rodent species can be morphometrically similar but genetically distinct species (e.g. *Mastomys* spp., Granjon et al. 1997). Because of the diversity of species present, it can be easy to misidentify animals, particularly juveniles. Therefore, more work needs to be done to understand the taxonomy of these species in the Mekong River Delta.

Population dynamics at Long An

The highest abundance of rats occurred in September, when the local variety of rice was in the vegetative growth stage (Figure 2). The lowest abundance of rats occurred in June—when the second improved variety crop was at the maximum tillering stage, and in November and December—at the end of the flooding period. The proportion of rats caught in improved variety rice crop habitats compared to other habitats was similar throughout the year. There were no data on breeding from Long An, so we cannot determine whether increases in rat numbers were due to immigration or reproduction.

Population dynamics at Kien Giang

Eight species of rodents were identified from 449 captures. The capture rates of *R. argentiventer* (43.7%) and *R. losea* (45.2%) were similar. The next highest capture rate was *R. flavipectus* (5.1%). Seven captures were not identified to species (1.6%), with the six other species accounting for 4.4% of captures.

Both *R. argentiventer* and *R. losea* were more abundant in the improved rice variety habitat than in other habitats (Figure 3). The relative proportion of each species was similar within these habitats, except *R. losea* was more abundant in improved variety rice in May 1998.

Breeding of adult female *R. argentiventer* and *R. losea* was intermittent, although both species tended to be in breeding condition in similar proportions over time (Figure 3) (November: $\chi^2_1 = 0.11$, $P > 0.05$; February: $\chi^2_1 = 1.03$, $P > 0.05$; March: $\chi^2_1 = 0.16$, $P > 0.05$; May: $\chi^2_1 = 0.14$, $P > 0.05$). No breeding was evident in October 1997, December 1997 (very little trapping occurred because of flooding) or April 1998. The only breeding that occurred in January 1998 was in the melaleuca forest ($n = 1$). Breeding did not occur in the vegetative growth stage of the improved variety rice crop, but tended to occur in the latter two-thirds of crop growth from late tillering to harvest (a period of two months). Therefore breeding appeared to be linked to the presence of high quality food.