VERTEBRATE PESTS

Post-harvest Operations

INPhO - Post-harvest Compendium

Food and Agriculture Organization
of the United Nations

Vertebrate Pests: Damage on stored foods

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1. Introduction

General information on stored food losses at the farm and village level in developing countries is sparse and poorly documented. While it is known that millions of people throughout developing countries share their meagre households and foods with rats, mice, and pest birds, these problems mainly have escaped documentation by scientists and agriculturists. Farm families, living in or near poverty and nutritional catastrophe, suffer a double loss - a portion of their crop both before as well as after harvest.

While field crops are usually vulnerable to vertebrate pest damage during a short portion of the growing season, stored foods are vulnerable for as long as they are held in storage, sometimes for 6-12 months. Most storage of harvested crops occurs in farm household structures; these structures in the tropics and subtropics invariably are infested by one or more species of commensal and/or indigenous rodents and possibly depredatious birds. Stored foods are regularly lost due to the consumption, contamination, wastage, and spoilage by vertebrate pests. Most serious of all is the loss of seed for the next crop.

This chapter will attempt to show the extent of the problem, describe the vertebrate pest species responsible for stored food damage, and suggest some methods of managing and preventing damage by rodent and bird pests.

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1.1. Magnitude of the Problem

The first attempt to document the world-wide problems of stored food losses due to rodents was the mail survey by Hopf et al. (1976). The responses from a questionnaire about stored food losses included estimates made by stored food managers and agriculturists (Table 1). Almost all responses were guesses as to the actual amounts of stored foods lost due to rodents. The authors state: "The one single fact which emerges from the survey is the widespread ignorance of the magnitude of the rodent problem, and of means to control it." The following year, Jackson (1977) reviewed stored food losses due to rodents on a world-wide scale, using published sources; however, he was faced with the same lack of precise data. Subsequently, the US National Academy of Sciences (1978) published its review of post-harvest food losses throughout the food pipeline in developing countries. It concluded "Although the methods of loss estimation are frequently suspect and the supporting data rough, there are, as we have noted, sufficient data to show that substantial amounts of food are being lost annually in the post-harvest system."

During the ensuing two decades since these reports were issued, very little new information on stored food losses at the farm and village level was added. Several conferences and books on rodents since 1980 have only touched on the subject of stored food losses (Dubock,ed., 1982; Meehan, 1984; and Richards and Ku, 1986). Rodent Pest Management (1988), Prakash's book, didn't include a separate chapter on post-harvest problems; however, stored food losses are mentioned briefly in three chapters summarising rodent problems in South America, Asia, and Africa. Similarly, Buckle and Smith (1994) included a chapter on rodent control in food stores, but new information was absent.

Table 1. Stored food losses at farm and village level as reported on the mail survey of Hopf et al. (1976).

Area	Type of storage	Commodities	Percent damage or loss
Asia:			
Bangladesh	Bamboo bins	Rice, wheat	5
India	Village stores	Rice, wheat	1.7
India	Village, bags	Rice, wheat, millet, sorghum	3.5-5
India	bins, bags	Mud and bamboo Rice, wheat, pulses, sorghum	2-5
Korea	Sacks	Rice, barley	20
Laos	Cribs, mud and bamboo bins	Rice	3
Malaysia	Cribs in roof	Rice	2-5
Nepal	Sacks	Maize	3-5
Philippines	Cribs, sacks	Rice, maize	2-3
Thailand	Sacks in roof, maize in cribs	Maize, rice	5
Turkey	Farm houses, underground pits	Wheat, rice, maize	5
Africa:			
Egypt	Houses and stores	Maize, wheat, rice, cottonseed	50
Ethiopia	Huts on stilts, underground, bags	Grains	5-15
Ghana		Grains, maize, rice	2-3
Malawi	Woven cane bins, grass baskets	Maize, groundnuts, sorghum, millet	0.5-1.5
Malawi	Cribs	Cob maize	15
Sierra Leone	Cane baskets	Rice	1-10
Sierra Leone	Sacks	Rice	10-100
Sierra Leone	Roof and cribs	Rice, maize	2-3
Zaire	Bags in roof	Rice, maize	3
Zambia	Farm cribs	Cob maize, sorghum, millet	10
Latin America:			
Mexico	Cribs, sacks in roofs	Rice, maize	5-10
Brazil	Stacks, sacks, cribs	Rice, maize, beans	4-8

1.2. Losses by Crop Type due to Rodents

Losses occur due to various causes along the entire post-harvest pipeline. In this review, however, we are concerned mainly with losses caused by rodents and birds occurring in farm and village storage. Further, we will focus on cereal grains and legumes, since these two food groups together account for more than half of the world's food production.

1.2.1. Rice:

The data for rice losses from several causes in Asia probably approach the level of accuracy with which it is possible to assess losses on a large, nonexperimental scale. These are summarised for the Philippines by De Padua (1974), for Bangladesh by Greeley (1982), and forIndonesia by Winaro (1984). The losses in storage are primarily due to insects, rodents, and fungi. These range from 2-6 percentage in the three studies.

Table 2. Rice losses from harvest to milling in Asain countries (% weight loss)

	Philippines	Bangladesh	Indonesia (season)	
			Wet	Dry
Harvesting	1-3	1.45	0.89	0.63
Handling	2-7	1.03	--	--
Threshing	2-6	1.79	0.99	0.99
Drying	1-5	--	3.16	2.65
Storing	2-6	2.60	2.25	2.45
Milling	2-10	--	4.50	2.46

Post-harvest rice losses in developing countries are summarised in Table 3. The loss criteria were not given in the NAS (1978) report. In general, reported storage losses in rice are least in Asia, more in Africa, and most severe in Latin America. This may be because where research and documentation are done thoroughly, the loss estimates tend to be lower.

1.2.2. Maize:

Maize losses appear to be moderately serious in African countries and severe in the Latin American region (Table 4). There are few reports from Asia; consequently no conclusions can be drawn on losses from this region. FAO (1977) reported the losses in maize as averaging from 9.6 to 20.2 percent, mainly in storage and due primarily to insect damage, followed by fungus and rodent damage. However, the data are markedly inadequate. Maize presents considerable problems of loss estimation because it can be stored either on the cob or shelled. In South America the ears are bent down on the stalk and are left in the field to dry. This may lead to some rodent and bird damage before harvest.

Table 3. Reported post-harvest losses of rice world-wide (US NAS, 1978, based upon FAO data, 1977 unless otherwise indicated).

Region/Country	Total Percent Weight Loss	Remarks
Africa:		
Sierra Leone	10	
Uganda	11	
Rwanda	9	
Egypt	2.5	(Quoted in NAS, 1978)
Asia:		
Bangladesh	7	
India	3-5.5	Improved traditional storage Boxall and Greeley,1978)
Indonesia	2-5	
Malaysia	5	On-farm storage (Quoted in NAS, 1978)
Nepal	3-4	On farm storage
Sri Lanka	2-6	On-farm storage (Quoted in NAS, 1978)
Thailand	1.5-3.5	On-farm storage
		On-farm storage (Quoted in NAS, 1978)
Latin America:		
Belize	20-30	On-farm storage (Quoted in NAS, 1978)
Bolivia	16	On-farm storage
Dominican Republic	6.5	On-farm storage

Table 4. Reported post-harvest losses of maize world-wide (US NAS, 1978, based upon FAO, 1977 data unless otherwise indicated).

Region/Country	Total Percent Weight Loss	Remarks
Africa:		
Benin	8-9	Traditional on-farm storage (Harris and Lindblad, 1978)
Malawi	8	On-farm storage (TPI, 1977; Schulten, 1975)
Nigeria	1-5	On-farm storage
Rwanda	10-20	On-farm storage
Zambia	9-21	On-farm storage (Adams and Harman, 1977)
Asia:		
Pakistan	2-7	
Latin America:		

Region/Country	Total Percent Weight Loss	Remarks
Belize	10-20	On-farm storage (Quoted in NAS, 1978)
Brazil	15-40	
Dominican Republic	19	Farm storage
Honduras	20-50	Traditional storage, poor facilities (Quoted in NAS, 1978)
Mexico	10-25	
Nicaragua	15-30	
Paraguay	25	(Quoted in NAS, 1978)
Venezuela	10-25	

1.2.3. Wheat:

Farm losses of wheat reported from several countries indicate that this crop is lost in about the same percentage as rice (Table 5). The loss reports for wheat average 10 percentage, with the combined major causes being insects, rodents, and mould during storage. Rodents are a major problem of stored wheat in India, but are only partly responsible for the estimated 10 percentage losses there.

1.2.4. Millets and Sorghums:

Millets and sorghums are the main staple in drier regions of Africa, the Middle East, India, Pakistan, and China. Post-harvest technology is relatively unimproved for millets and sorghums as compared to that for the major cereal grains. Sorghum commonly stands in the field, or in piles, in Africa. This results in serious losses due to field rodents. The few reports on post-harvest losses in farm storage available are given in Table 5; these are relatively severe.

Table 5. Reported world-wide post-harvest losses from all causes of wheat, millets, and sorghum (US NAS, 1978, based on FAO, 1977 data unless otherwise indicated).

Region/Country	Total Percent Weight Loss	Remarks
Wheat:		
Pakistan	5-10	On-farm storage (Quoted in NAS,
India	8-25	(Quoted in NAS, 1978)
Rhodesia	10	On-farm storage (Quoted in NAS, 1978)
Sudan	10	
Bolivia	7	Stores
Brazil	1-4	Storage
Millets:		
India	5	Farm storage (Quoted in NAS, 1978)
Mali	2-4	On-farm storage (Guggenheim, 977)
Nigeria	0.1-0,2	On-farm storage
Zambia	10	On-farm storage
Zimbabwe	10-15	On-farm storage (Quoted in NAS, 1978)
Sorghum:		

Region/Country	Total Percent Weight Loss	Remarks
Nigeria	0-37	On-farm over 26 months (Hall, 1970
Senegal	1-5	On-farm storage (Spencer et al. 1975)
Zimbabwe	25	On-farm storage (Quoted in NAS, 1978)

1.2.5. Grain Legumes:

Rodent damage to grain legumes (beans, peas, lentils, cowpeas, groundnuts) is minimal. Legumes are not preferred foods of rats and mice except for groundnuts. Damage in farm-level storage is given in Table 6. Most damage is due to insects and fungi, not rodents. Experienced observers agree that legume post-harvest losses most often exceed those of cereal grains.

Table 6. Post-harvest losses at farm-level of grain legumes due to all causes (NAS 1978).

Country	Total Percent Weight Loss	Remarks
Kenya	30	On-farm storage (De Lima, 1973)
Zimbabwe	5	On-farm storage (NAS, 1978) (Groundnuts)
Thailand	12-15	Farm stores (NAS, 1978)
Honduras	20-50	On-farm storage (NAS, 1978) (Dry beans)

1.3. Stored Food Losses at Farm Level

There are several studies of stored food losses at farm level carried out since 1980. The losses of stored paddy (rice) from open woven bamboo storage baskets at Bangladesh farm households was indirectly measured by trapping small mammals in farm structures and estimating their populations before and after removal trapping by inked tracking tiles (Mian et al. 1987; Ahmad et al. 1994). These two studies estimated stored food losses based upon the numbers of small mammals found in farm structures and the amounts of stored paddy they potentially could consume, contaminate, or hoard. It was found that this approximated 50 kg of paddy/farm family/year. This amount of paddy represents about 5 percentage of the average 1,000 kg stored by the farm families over a crop season.

1.3.1. Other Losses.

Much grain on smallholder farms is stored in various containers, including woven baskets, earthen jars, metal cans, and in jute bags. Jute bags are frequently damaged by rodents. Often the monetary loss of bag or basket damage is greater than the loss of stored grains.
Rodents also contaminate stored foods with their faeces, urine, and hairs. This contamination often is more serious than the actual food losses because of the public health aspects and the possibility of disease transmission. The foods must be cleaned before being prepared for human consumption.

1.4. Disease Implications

The rodents that frequent food stores and live in close association with humans (commensal) in many parts of the tropics and subtropics in developing countries are also known to be the reservoirs and vectors of several human diseases. Among these are plague, murine typhus, Lassa fever, leptospirosis, several types of haemorrhage fevers , including hantavirus, and

salmonella infections. Roof rats, Norway rats, Polynesian rats, multimammate rats, and lesser bandicoot rats spread plague and murine typhus through their fleas. Lassa fever is known to be spread by the urine and faeces of the multimammate rat in parts of west Africa. Leptospires are bacteria present in the urine of roof rats and Norway rats. Hantavirus is spread in the droppings and urine of Norway rats and other rodents (Peromyscus, Sigmodon, Microtus, Oligorzyomys species). Argentine/Bolivian haemorrhage fevers are spread by the Calomys species in parts of
Bolivia and Argentina. Salmonella organisms are spread through the droppings of all the commensal rodents, house mice and rats alike. Prevention, reduction, or elimination of rodents from farm and village structures where these diseases are prevalent can reduce food losses as well as increase human health.

2. Major vertebrate pests of stored foods

2.1. Rodents

The rodent species that infest stored foods in farm and village structures differ in the several regions of the world. The primary rodent pests are the cosmopolitan, commensal rodents, of which the roof rat (*Rattus rattus*), also known as the black or ship rat, is the major rat species found in food storage facilities world-wide, followed closely by the abundant and ubiquitous house mouse (*Mus musculus).* Since the mouse consumes far less food daily, it may be of lesser importance than the rat species in terms of overall amounts of food lost. The Norway rat (*Rattus norvegicus*), also known as the sewer, barn, or brown rat, is not as common and widely distributed as the roof rat, but is a formidable pest of food stores in many temperate areas of the world.

Table 7. Regional commensal and peri-domestic rodents of stored foods.

Area	Scientific name	Common name	Remarks
Latin America:	*Calomys laucha*	Vesper mouse	Commensal
	C. musculinus	" "	"
	C. callosus	" "	"
	Akodon azarae	Grass mouse	
	Sigmodon hispidus	Cotton rat	Peri-domestic
	Oryzomys longicaudus	Rice rat	"
Africa:	*Mastomys natalensis*	Multimammate rat	Commensal
	Acomys caharinus	Spiny mouse	"
	Arvicanthis niloticus	Unstriped grass rat	Peri-domestic
	Tatera species	Gerbils	"
Asia:	*Bandicota bengalensis*	Lesser bandicoot rat	Commensal
	Rattus exulans	Little house rat	"

There are several rodent species that are important regionally (Table 7). Some are true commensals and live in human structures and others are occasional invaders, living mainly in field situations but entering structures in certain seasons (peri-domestic).

It is important to know about how much stored foods the several rodent species may consume daily, and, sometimes, the amounts eaten in a year, so this can be related to the amounts of stored foods at risk. In large central food stores, the amounts of grain in storage may be 500 to 5,000 metric tons (500,000-5,000,000 kg). Obviously, the estimated 5 to 9 kg of grain eaten yearly by one adult Norway rat represents an immensely small percentage of this stored mass. But when 5 roof rats (3-4 kg/year/rat), 3 bandicoots (6-9 kg/year/rat), and 10 house mice (1 kg/year/mouse) eat into a farmer's stored 1,000 kg of rice, the aggregate amount consumed equals 43 to 57 kg/year, a 4-6 percentage loss. These daily and yearly values are given for each rodent species in Table 8.

Table 8. Amount of food consumed daily and yearly by rodents infesting stored foods.

Rodent Species	Amount of food consumed daily (g)	Amount of food eaten yearly (kg)
Norway rat, *Rattus norvegicus*	15-25	6-9
Roof rat, *R. rattus*	8-12	3-4
Polynesian rat, *R. exulans*	5-8	2-3
Bandicoot rat, *Bandicota bengalensis*	15-25	6-9
Unstriped grass rat, Arvicanthis niloticus	5-8	2-3
Multimammate rat, *Mastomys natalensis*	5-8	2-3
Spiny mouse, *Acomys cahirinus*	3-6	1-2
House mouse, *Mus musculus*	2-3	0.7-1
Vesper mouse, *Calomys laucha*	3-5	1-2
Grass mouse, *Akodon azarae*	3-5	1-2

2.1.1. Biology and Behaviour

***Mus musculus* (House mouse)**

Description: Head and body 75-100 mm, tail 65-90 mm. Body weight about 15-20 g. The dorsum is dark brownish-grey, the venter light grey to creamy white. The tail is uncoloured, dark, sparsely-haired. The body is small and slender, the eyes and ears are prominent (Figure 1).

Range and Habitats: House mice have now spread around the world, occurring from the sub-Antarctic to the near Arctic, from temperate, tropical, steppe, and semi-desert regions. They habitually infest food stores and other premises in both urban and rural surroundings. They are found occupying such diverse habitats as cold stores; rice, sugarcane, and cereal grain fields; garbage dumps, salt marshes, and coal mines. In Alaska they have been captured in open tundra, far distant from human dwellings.

Natural history: House mice are terrestrial/arboreal. They are nocturnal. They make burrows in field situations, but also frequent the upper parts of rural farm structures in the tropics, nesting in the roofs and attic lofts. They make and use runways in fields and structures. Their range of movement is limited; usually an area of no more than 1-3 m2 suffices. Their food requirements are 2-3 g of food daily. In feeding, they nibble on foods, sampling the several types in the living area. They quite often consume only the kernel of the grain, discarding the rest, thus ruining the grain far in extent of what they actually consume. They are capable of

breeding year-round. The gestation period is 19-20 days; litter size averages 5.8 young, the young are weaned at 21 days, and sexual maturity is reached at 42 days.

***Rattus rattus* (Roof rat)**

Description:

Head and body 140-220 mm, tail 160-250 mm uncoloured. The body is slender, the muzzle sharp, the ears prominent and mostly bare of hair (Figure 2). The body weight is 120-260 g. The dorsum is brownish-grey, the venter varies from light grey to creamy white to lemon yellow.

Range and Habitats:

Roof rats are found throughout the world due to use of manmade transport and colonising efforts. They inhabit a wide range of buildings in temperate areas, including houses, flats, shops, large food stores, warehouses, poultry houses, barns, markets, restaurants, and grain elevators. They also live in close association with humans in many cities, farms and villages in the tropics. They are still the most common rat found on sea vessels, from which they derive their name, "ship rat". They are found in sugarcane fields, and are orchard pests in many areas, causing damage to citrus fruits, macadamia nuts, cocoa, coconut, date palms, carob, and avocado fruits. In the Pacific Coast of North America, they occupy riparian habitat covered with the dense growths of the introduced blackberry, Rubus species.

Natural History:

Roof rats are arboreal and nocturnal. When living in structures, because of their agile climbing abilities, they prefer the upper parts; the attics, lofts, and open beams. They are the common rat in food stores, markets, grain elevators, poultry houses, and rural farm houses in the tropics and subtropics. They quite often nest outdoors in trees and tall shrubs. They feed on cereal grains, seeds, fruits, and nuts. They freely change their dietary needs, however, taking insects and herbivorous foods if necessary. They eat about 8-12 g of cereal grains daily. They live in close association with humans in many parts of Asia and even in interior parts of Africa, where they have invaded during the last half century. They are the common rat in food storage facilities throughout the tropic and subtropic world, from Latin America,. Africa, and Asia. Only in the temperate pats of their range are they replaced by Norway rats. They have a definite social structure. A single dominant male was always present in a colony in Ghana. There were usually two or more females which were subordinate to the most dominant male but were themselves dominant over all other members of the group. A group territory around the feeding area was defended by the resident rats against strangers.

Roof rats have a gestation period of 20-22 days, average 6.2 young per litter, young are weaned at 28 days, and the young reach sexual maturity in 68-70 days. Breeding is usually bimodal, with peak production in the spring and fall months, but may be essentially continuous when climate, food, and shelter are optimum.

***Rattus norvegicus* (Norway rat)**

Description: Head and body length 180-260 mm; tail 150-210 mm. The tail is bare, lighter coloured below than above. Body weight varies from 250-600 g depending on age. The ears are sparsely haired and set closer to the head than in the roof rat. The dorsum is brownish-grey, the venter is light to dark grey (Figure 3).

Range and Habitats: Norway rats are now found throughout the world. In the tropics they are essentially restricted to the seaports and along rivers. They infest food storage centres in coastal areas, but rarely are found inland. They occur indoors and outdoors. Inside buildings they prefer living in spaces between walls and floors, beneath piles of rubbish and waste foods. Outdoors they frequently are found near water, by drains, along ditches, streams, rivers, marshes, and distributed from northern South America southward to Argentina.

C. laucha occurs from southern Bolivia and southern Brazil to central Argentina and Uruguay, C. musculinus occurs in Argentina; and C. callosus ranges from Bolivia and southern Brazil to northern Argentina. Vesper mice occur in a variety of habitats, including montain grasslands, brushy areas, and forest fringes. They may find shelter in bunch grass, in holes in the ground, in rotting tree stumps, or among rocks. They are active mainly at night and possibly in the evening and early morning. They are found in open grasslands, on rocky hillsides, and in edges situations but occasionally are captured in the vicinity of marshes and swamps. They also frequent human dwellings and outbuildings.

Natural History: Vesper mice are terrestrial/arboreal and nocturnal. They do not make runways and rarely use those of other species. Nests have been found under boards and rocks, in crevices in the ground, and even high above ground in trees. They climb well and on the ground they often hop on the hind legs in the manner of Dipodomys. The diet is predominately vegetative but insects also are taken. They may eat about 3-5 g of food daily. The breeding season apparently extends from October until the following April and two litters may be produced. The gestation period is about 25 days in C. laucha. The data from a captive colony of C. musculinus showed the following: gestation, 24.5 days; litter size, 5.4 young; female sexual maturity, 72.5 days; male sexual maturity, 82 days. Calomys is a vector of the viral disease, Argentine haemorrhage fever.

***Akodon azarae* (Grass mice)**

Description:

Head and body 90-140 mm, tail 55-100 mm. Akodon azarae range from 10-45 g body weight. The short tail and neck suggest the body form of voles (Figure 5). The dorsum is dark brown; the venter is greyish. Mice of the genus Akodon have been described as heavy-bodied, short-limbed, short-tailed, vole-like mice. The pelage is soft and full.

Range and Habitat:

Members of the genus range over all of South America; A. azarae occurs from extreme southern Bolivia, Paraguay, northern Argentina, southern Brazil, and Uruguay. South American grass mice occur in a variety of habitats, including relatively open country, grasslands, humid forests, and mountain meadows. They tolerate second-growth forests and man-made clearings. They range from near sea level to about 5,000 m. Some species are found frequently in human houses.

Natural History:

Although terrestrial, burrowing is not very important, but nests have been found 12-15 cm below ground. Various species of Akodon have been reported to be diurnal, nocturnal, and crepuscular, or active any time of day. The diet of A. azarae has been found to be herbivorous with a substantial amount of insects and other invertebrates. Considering the body weight, they probably eat about 3-5 g of food daily. The data on breeding are: gestation period, 23 days; litter size, 4.6 young; the young are weaned at 14-15 days; sexual maturity at about 60 days. The breeding season extends from August to May and there are probably two litters per year. Peak densities of 200/ha have been recorded from north-eastern Argentine pampas, decreasing to about 50/ha by late winter. At a semi-arid site in north-central Chile, the density of A. olivaceus was 30/ha in August and increased to 97/ha by November.

***Rattus exulans* (Polynesian rat)**

Description:

This is a small, slender rat (Figure 6). The head and body measure about 120 mm, the tail is about the same length. Adults rarely weigh more than 110 g in the wild, usually much less (30-60 g) when living in houses. Their ears are relatively large and thin. The dorsum is brownish-grey, the venter a pale grey.

Range and Habitats:
Polynesian rats, sometimes also called little Burmese house rats, range from eastern Bangladesh, through Myanmar, Thailand, Malaysia, Cambodia, Laos, and into Vietnam. They also occur on islands in the South Pacific and the Hawaiian Islands. They were thought to have been carried to the islands by the Polynesians, hence their name. They are a common house rat in Indonesia and in south-eastern Asia, assuming the role of a house mouse in this environment. They live indoors in human dwellings, preferring the upper parts of the structures like roof rats. They also live outdoors in some island habitats, preferring jungle edge and tall grassy areas. They do not burrow or live in ground burrows or crevices.
Natural History:
Polynesian rats are arboreal and diurnal/nocturnal. They are herbivorous and, to a small extent, insectivorous. They feed on berries, seeds, coconuts, sugarcane, grass stalks, and insects. They consume 5-8 g of cereal grains daily. Home range is limited: 70-85 percent of recaptures were within 20-25 m of the original point of capture on Ponape, Guam, and Hawaii. The gestation period is 19-21 days, average litter size is 4.0-4.1 young, young are weaned by 20-28 days, and sexual maturity is attained at 90 days in both sexes. Polynesian rats coexist with other rat species; they were trapped from the same houses in Rangoon, Myanmar from which roof rats and lesser bandicoot rats were captured. In Indonesia they are reservoirs of plague and are a threat to humans when cohabiting in rural households.

***Bandicota bengalensis* (Lesser bandicoot rat)**

Description: Lesser bandicoot rats are Asian versions of Norway rats. They measure 160-270 mm in head and body, the tail is 130-220 mm, dark in colour. Body weight is 250-600 g. The fur is coarse and rough-looking and the longer guard hairs are prominent (Figure 7). Animals range from brownish-grey to almost blackish-grey on the dorsum, the venter is light grey. Mammaries range from 12-20, averaging 16.
Range and Habitats:
Lesser bandicoot rats range from north-western Pakistan, India, and Nepal eastwards to the east coast of Vietnam, and southward through India, into Sri Lanka, Sumatra, and Java. They are primarily field rodents and pests of cultivated crops, but in many parts of India, Bangladesh, Myanmar, and Thailand, they have invaded cities, towns, and villages and become the main urban commensal rats in Bombay, Madras, Dhaka, Yangun (Rangoon), and Bangkok. In small towns and villages, they frequently occur inside and outside houses and food stores. In cultivated fields they occur in rice, wheat, and sorghum fields, and in waste areas between fields. They are peerless burrowing rodents, making extensive burrow mounds and easily-seen runways connecting burrows with feeding areas. Some burrow systems cover 10 m or more across and are up to 60 cm deep. They are good swimmers but weak climbers, since they are too heavy-bodied.
Natural History:
Lesser bandicoot rats breed throughout the year in Southeast Asia, but appear to have a bimodal cycle, with a peak in the dry winter months and a lesser peak during the monsoon months. The gestation period is 21-23 days, litter size averages 7-8 young, weaning takes 28 days, and the young become sexually mature in 60-75 days. They eat about 25 g of grain a day, but are notorious for hoarding 3-4 times more food a day than they eat. Their range of movement is limited to 30-50 m in diameter in fields and in urban environments they may move up to 150 m from shelter to food stores. They are gregarious, nesting in colonies under households in Myanmar towns and cities, yet are extremely aggressive when first approached by humans when in traps. They respond similar to Norway rats when exposed to baits and show almost the same tolerance to the several poisons so far tested for.

***Mastomys natalensis* (Multimammate rat)**

Description:

Small rats, measuring 100-150 mm head and body length, with a tail about the same length (Figure 8). Body weight is 60-120 g. The dorsum is grey to brownish-grey, brown, or reddish-buff, the venter is lighter coloured. Females are distinguished by having 8-12 pairs of mammaries, continuously distributed from the pectoral to the inguinal regions.

Range and Habitats:

Multimammate rats occur as field and house rats over parts of Africa south of the Sahara Desert. They are regarded as peri-domestic rats in most parts of Africa where they occur, living in close association with humans. They occur in central food stores, in towns, markets, and in rural households. They are found in fields of maize, rice, groundnuts, millet, sorghum and also live in grasslands, and savannahs. They are typical unspecialised rats, showing a great ecological diversity in their extensive range.

Natural History: While omnivorous and having cannibalistic tendencies, they are mainly granivorous, living on seeds of wild grasses, millet, maize, and rice. They will also eat grass stems and rhizomes, and insects may comprise a large part of the diet. They are responsible for considerable damage to food stuffs in stores and houses, consuming 5-8 g of food daily. They are important from a public health standpoint because they are involved in the transmission of plague and Lassa fever. They can be prolific breeders: the gestation period is 23 days, litter size averages 10-12 but can be as much as 19 young, young are weaned at about 21 days, sexual maturity occurs after 90-100 days, and breeding appears to be strongly correlated with rainfall. Breeding increases most commonly a few weeks after the onset of the seasonal rains.

***Acomys cahirinus* (Spiny mouse)**

Description:

Head and body measures 93-130 mm, tail measures 85-135 mm and is bicoloured. The dorsum ranges from brownish cinnamon to a uniform grey brown, the venter may be pure white to an overall slate grey. The hairs from behind the shoulder onto the rump are spiny; the sides are not (Figure 9). The ears are naked, greyish-black in colour. The weight varies from 20 to 64 g.

Range and Habitats:

Spiny mice range all across the drier parts of north Africa and into the Nile Valley, south as far as central Uganda and Kenya, the Middle East including the Arabian Peninsula, eastward across southern Iran and into western Sind, Pakistan. They are common in houses, stores, gardens, date groves, and rocky hills and cliffs bordering the Nile Delta and Valley. They are numerous in tombs and temples in Egypt. Desert specimens usually inhabit rocky hillsides, cliffs, and boulder-strewn canyons but can be found in settlements and native huts.

Natural History: Spiny mice are nocturnal and crepuscular; they are terrestrial but some have been trapped in trees. They are opportunistic feeders. Food consists of a variety of plants, grass seeds, leaves, dropped grain, nuts, flowers, and various animal matter; dates are a staple in some areas. They could eat 3-6 g of food daily. They are relatively generalised mice resembling the genus Mus. The gestation period is prolonged, 35-42 days; litter size averages 3; the young are semiprecocial and are weaned at 14 days; sexual maturity is reached at 2-3 months. They may breed over the greater part of the year.

***Arvicanthis niloticus* (Unstriped grass rats)**

Description:

Head and body are 106-204 mm, tail 100-152 mm. They are heavily-built, shaggy-coated rats, weighing 115 to 150 g (Figure 10). The dorsal pelage is greyish-brown to dark brown,

the ventral pelage is light-brown to medium-brown with white tips. The head is rounded with a blunt nasal region. The tail is covered with small hairs, dark above and light below. The mammae number 3 pairs.

Range and Habitats:

Unstriped grass rats range in a broad belt across the Sahel region of Africa, from Senegal to Ethiopia and extending north into the Nile valley through Egypt and south into the Rift valley as far as mid-Tanzania. The genus-species-complex may consist of as many as five species: A. niloticus found in the Nile Valley of Egypt and the south-western tip of the Arabian Peninsula and from Senegal to Ethiopia, Kenya, Tanzania, and Zambia; A. abyssinicus, from Ethiopia, a high altitude form endemic to Ethiopia; A. blicki in central Ethiopia, a form found in Afro-Alpine moorlands only in Ethiopia; A. nairobae, from east of the Rift Valley in Kenya and Tanzania; and A. somalicus, from east-central Ethiopia, Somalia, and Kenya. They frequent grassy savannahs, riverine habitats, into irrigated agricultural fields, and occur around human habitations. They are localised in their distribution because of their water requirements, preferring irrigated croplands and other rather moist habitats.

Natural History:

Unstriped grass rats feed mainly on the seeds, leaves, and shoots of grasses; they are polyphagous, however, eating insects, the bark of certain woody plants, agricultural crops (millet, sorghum, vegetables), and stored foods. They consume from 5-8 g of food daily. They are basically diurnal (active during daylight hours) but, in response to intense heat, may also be nocturnal. They are capable of breeding year-round but usually breed during the dry season. The gestation period is 21-23 days, the litter size averages 5-6 per litter but can run as many as 12 young. They are gregarious, living in colonies and sharing groups of burrows. Densities vary greatly and may increase greatly under favourable conditions, ranging from 12/ha in normal years to 100/ha during an outbreak in Senegal in February 1976 and from 65-250/ha in the Semien Mountains National Park of Ethiopia.

***Tatera species* (Gerbils)**

Description:

Head and body length is about 90-200 mm, depending on species; tail is 120-240 mm, some with short hairs and others with long hairs in the tail, and some with either a white or dark tail tip. Body weight varies from 50-220 g. The pelage is soft to medium. Colour ranges from pale sandy grey to dark brown mixed with grey above; the underparts are white. The body form is heavy and rat-like (Figure. 11). The head is rounded; the eyes rather large.

Range and Habitat:

The genus is mainly African except for T. indica, which ranges from Syria to India and Sri Lanka. Other members of the genus are found throughout the drier areas of Africa: T. robusta from Senegal to Somalia and central Tanzania; T. leucogaster from Angola and south-western Tanzania to South Africa; T. valida in savannah zones from Senegal to western Ethiopia and south to Angola and Zambia. They inhabit sandy plains, grasslands, savannahs, woodlands, and cultivated areas.

Natural History:

Gerbils are nocturnal and terrestrial. They usually walk on all four limbs but when alarmed they flee by means of running bounds of up to 1.5 meters in height and more than 3 meters in length. They are able to do this because of their powerful, well-developed hindlimbs. They are burrowing animals, with deeper burrows with many chambers and tunnels, used for resting during the day, rearing the young, and for food storage. They are mainly granivorous but will eat fruits, some leaves and roots, and insects (especially in the dry season). Gestation varies from 22 to 30 days; overall litter size for the genus is 1-13, with averages of 4.5 in T. leucogaster, 5 in T. indica, and 6 in T. robusta. Young are born in an undeveloped state and

remain in the nest for a month before accompanying the adults out to forage. Some species breed during the rainy season (*T. leucogaster*), all-year in *T. indica*, and during the dry season following the rains in *T. robusta*.

2.2. Pest birds

Birds, not prone to living inside the farm or village structures as rodents are, rarely have the opportunity to damage or consume stored foods. It is only in those outdoor situations where grains or seeds are exposed during drying or threshing that birds have the chance to eat them, or they may get into stored grains where they are stored in open cribs. Consequently, the losses of stored foods due to bird activities are small as compared to those caused by rodents. The several species of pest birds that are found in post-harvest situations in South and Southeast Asia are house and tree sparrows, *Passer domesticus* , *P. montanus* (Figure 12), common pigeons (*Columba livia*) (Figure 13), doves (*Streptopelia species*) (Figure 14), Asiatic house crows (*Corvus splendens*), and common mynas (*Acridotheres tristis*) (Figure 15). These are mainly pests in threshing and grain drying yards in farm household situations. The amounts of grain they consume are small as compared to that taken by rodents in farm stores. Birds rarely infest structures as rodents do; instead they rely on their mobility to quickly seek out places to feed.

Post-harvest losses of cereal grains due to birds are seen at threshing and drying stages. When grains are threshed in the field, or in clearings at the farm households, birds are attracted by the abundant grain. When grains are spread on the ground for drying in the tropic sun, birds are similarly attracted. Unless birds feed in large flocks, the amounts of grain they consume are negligible as compared to rodents. Garg et al. (1966) found that sparrows, mynas, crows, and pigeons visited and fed on wheat at threshing yards and estimated the losses caused mainly by the birds (a few yards had small numbers of rats) at 244 g/day/yard or about 7.3 kg/yard for the 30-day threshing season at Harpur, India. In Pakistan, mynas, crows, and pigeons were seen frequently at grain storage centres and at farm yards but they mainly fed on waste or spilled grain at these sites.

Libay et al. (1983) reported on losses of feed for ducks on farms in the Philippines due to European tree sparrows, *Passer montanus*. Losses at 4 farms where bird counts averaged 149-177 over the 14-month study were estimated at 4.5-5.0 kg/day of rice. This was equivalent to US $0.40-0.45/day for the 4 farms or $146-164/year. At the largest farm the loss represented 4 percentage of the total amount of duck feed used.

The common pest birds in food storage situations in Africa are sparrows (genus Passer) and weavers (genus *Ploceus*). Maize and sorghum are sometimes stored in open crib-type structures and in these situations these birds may cause damage.

The easiest method of control is to keep birds from access to stored foods. This is done by using wire mesh as screening, or using local-made netting, where foods are to be stored in open crib-type structures. The inside of the structure is lined with the wire mesh or netting before the grains are placed inside. Where birds are pests at threshing and drying yards, the use of bird-scaring devices or human bird scarers will help to keep birds from feeding.

The nests of house sparrows in the eaves or crevices around farm structures may be destroyed by pulling the nest contents out with a hooked stick or a wire bent to form a hook.

3 Indicators of pest infestation

3.1 Rodents

As rats and mice move around in their living environment, moving from food sources to their nests and shelter, they leave behind characteristic traces that betray their presence; these are called rodent signs and are useful in determining the presence and degree of rodent

infestation inside structures. Since rats and mice are secretive and come out after darkness, we rarely see them directly. However, family members of farm households should be aware of rodents in the farm structures, since in their daily activities they should see signs of rodents. Especially at night, they should be aware of the foraging activities of rodents in the household, sighting them in the structures or hearing their squeaks, gnawings, and rustlings. Some of the evidence observers should look for are detailed below.

3.1.1 Droppings.

Faecal droppings are found wherever rodents are active - along their pathways, near walls, and near food and shelter. If the droppings are of several sizes it may indicate animals of different ages or it could indicate an infestation of several species of rodents. Rat droppings are usually 10-15 mm in length, while those of mice are only 3-6 mm long. Numbers of droppings are not very useful in estimating the size of the infestation, since they may have accumulated over a considerable period of time. However, if the area is swept clean and examined the next day, some idea of numbers may be estimated. In general, roof rats make 37-60 droppings daily, house mice drop about 50 or so. Rodent droppings are one of the main contaminants of food stuffs, especially grains.

3.1.2 Runways

Runways are frequently travelled routes. Rodents leave greasy fur marks where they repeatedly use the same paths to and from food. These greasy smears persist as marks on beams, pipes, vertical boards where they climb into the lofts of houses, and around gnawed holes they use to go through walls.

3.1.3 Tracks

Rat and mouse tracks indicate past or present rodent infestation. In dust or mud, the trail of the tail and the 4-toed front feet and the 5-toed rear feet can be seen. Sometimes a fine dust of talc or wheat flour can be laid where rodent presence is suspected.

3.1.4 Burrows

Burrows are readily seen when terrestrial or fossorial rodents infest a premises. These are usually, but not necessarily, on the outside of the structure.
Burrows are made by Norway rats, bandicoot rats, and sometimes, house mice. In general roof rats, Polynesian rats, multimammate rats, and vesper mice will not make burrows. Burrows are indicated by the soil mounds at their entrances, by the burrow opening itself, and by runways connecting burrows.

3.1.5 Gnawings

All rodents gnaw and gnawed materials in certain instances reveal their presence. The gnaw marks may be seen as actual tooth-marks, as small particles resulting from gnawing, or as round holes around pipes, under doors, through walls, into jute bags, clothing, books, and cardboard boxes.

3.1.6 Nests

Nests are found indoors and outdoors in areas offering concealment and access to food sources. They may be found in attics, lofts, between walls, under wooden floors, and in burrows in or near the farm structures. Nests are usually globular or cup-shaped, constructed of soft grasses, leaves, and stems, and sometimes, of cloth or jute fibres from the farm household.

3.1.7 Damage

Damage to jute bags, woven bamboo baskets, and other food storage containers is evidence of rodent presence. The damage to bags consists of frayed-looking holes in the sides, bottom, or top of the bagged grain. Grains are usually spilled out and trail away from the bag towards the rodents' burrows or nests. Gnawed holes in the side of the grain basket indicates the

presence of rodents in the farm household. Likewise, clothing items, paper materials (books, newspapers, etc.), and bars of soap may be gnawed upon by rodents in the household.

3.1.8 Sightings

The members of the farm household may sight rodents during the day or night in the farm structures. Sometimes, rodents are disturbed during the daytime. The finding of dead rodents in the farm structures is not conclusive evidence of a current infestation since domestic predators like cats or dogs may have brought them in from outside. Trapping is another means of determining if rodents are present.

3.1.9 Sounds

The sounds that rodents make will confirm their presence. These sounds are generally made at night when the rodents are foraging for food.

4 Management of rodent populations

The prevention of losses of stored foods due to rodents by subsistence and small-holding farmers comes down to relatively inexpensive methods that the farm family can afford. These consist mainly of three things: 1) sanitation and good housekeeping, 2) denying rodents access to stored foods, and 3) elimination or reduction of rodents in the farm structures.

4.1 Sanitation and good housekeeping

Sanitation and good housekeeping in small-holding farmers housing structures means keeping all spilled grains swept up daily, not allowing food scraps to accumulate, and keeping the cooking area and cooking utensils and pots clean every day. It means sweeping the floors of the living quarters and the cooking area daily; keeping grains, vegetables, fruits, spices, and herbs used in daily food preparation in tins, jars, or earthenware containers when not in use, to prevent rodents from eating them.

All vegetation near the farm structures should be keep cut away from the buildings, especially any fruit trees or vines. Vegetable gardens should be planted away from the living quarters. Nearby grassy and weedy areas should be kept cleared.

Whenever grains are put outside for drying or winnowing to remove seeds, stems, stones and dirt, the area should be thoroughly swept after these tasks are finished. f grains are threshed in the farm compound, the area should be swept to recover all grains.

If livestock are kept in the farm structures, such as goats, sheep, or cattle, the family members should keep the animals' area clean and especially to keep any uneaten food swept up and disposed of by burying or burning.

4.2 Denying rodents access to foods

Keeping rodents out of stored grains may be difficult, especially if the amounts to be stored for even a month or two approximates 1,000 kg, the harvest from a half to one hectare of land. Much of the grain is stored in jute bags, woven baskets, or open cribs. None of these will keep rodents from the foods. Wire mesh, metal and ceramic containers, or brick and concrete bins are needed to keep rodents out. These items, unfortunately, are expensive and usually beyond the reach and pockets of subsistence and small-holding farmers. A collective or co-operative venture, whereby several farmers pool their resources and store their grains collectively in a structure especially made for that purpose, may be tried. This venture would require an unusual degree of Cupertino among neighbours, however, and could easily be subject to dispute as to amounts placed and withdrawn from storage. Some co-operatively agreed authority would have to record carefully the amounts of grain stored and to control and account for withdrawals.

Metal-covered wooden bins may be made to hold grains, using the metal from old kerosene tins to cover the exterior. Or discarded metal food tins may be flattened and used to rodent-proof a wooden bin. If wire mesh is available, this may be used instead of metal tins.
Care must be taken to cover all surfaces and not leave any gaps between overlapping pieces of mesh or metal. Rust is an ever-present possibility and so galvanised or tinned metal should be used if available. Otherwise, several coats of paint may retard rusting in the tropics.
The average farm family needs to protect the seed grain for the next planting very carefully. This can be done by storing it in small ceramic or metal containers with tight- fitting lids.
If the farm family keeps chickens, ducks, or pigeons, these should be maintained where rodents would not have access to their foods or food scraps, nor to their chicks or eggs. The birds should be penned at night in cages made with wire mesh too small for rodents to climb through. All excess uneaten foods or food scraps should be cleaned daily after the birds have been fed and buried or burned.

4.3 Eliminating or reducing rodent numbers

Rodents living in farm structures may be killed or their numbers reduced by destroying their nesting places in the roof or upper beams of the buildings. These areas, where accessible, should be sought out and the nests actually physically removed. This will not drive the animals out of the structure, however; the rodents may be killed with sticks when disturbed or dislodged from their harbouring places. If burrowing rodents are present in or around the farm structures, their burrows should be dug up and destroyed and the rodents killed when disturbed. If the farm family can afford even one trap, this can be set nightly for a number of weeks and should eliminate most rodents from the structures. Another form of trapping is the use of glue boards. These are squares of heavy cardboard that is covered on the upper surface with a vert sticky adhesive that entangles the feet and fur of any rodent venturing onto its surface. The rodent then is killed with a stick and disposed of and the glue board set again. Rain, dust, and dirt on the glue board will make it ineffective.
Medium-income farm families may be able to afford the use of poison baits around the farm structures, in addition to all of the steps given above. The use of poisons around the household will have to done very carefully, however, to prevent the poisoning of children and household pets and domestic livestock. Baits should only be used in covered containers into which a child, chicken, pigeon, cat, or dog cannot gain access to the poison. All baits should be placed out of sight, and on the ground or floor level. All poison baits should be used only in a manner consistent with the label directions.
The few rodenticides that can be used by farm householders are the anticoagulants and zinc phosphide. The several anticoagulants that may be available in developed countries consist of baits incorporating warfarin, coumatetralyl, diphacinone, chlorophacinone, brodifacoum, difenacoum, bromadiolone, flocoumafen, or difethialone at several concentrations.
Anticoagulants: Anticoagulants are mixed with baits in very small amounts, varying from 0.0375 percentage to 0.005 percentage concentrations. These baits do not kill quickly; instead they must be eaten by the rodents for several days and then the clotting ability of the blood is reduced, causing death by haemorrhage. In general, the spiny mice are very little affected by anticoagulants, so these are not recommended for their control. Also, the earlier anticoagulants (warfarin, coumatetralyl, diphacinone, and chlorophacinone) are relatively slow to kill roof rats and house mice; up to 21 days may be required to kill off most mice. To eliminate these species, the "second-generation" anticoagulants (brodifacoum, difenacoum, bromadiolone, flocoumafen, difethialone) should be used. Baits for household rodents should preferably be placed in bait containers or under cover where children and domestic animals will not have access to them. A surplus of bait should be maintained at the baiting sites for up to 10 days. Then all uneaten baits should collected and disposed of by deep burial. Zinc

phosphide: Zinc phosphide is mixed with bait materials at usually a 2 percentage concentration. This material is hazardous to humans and all domestic animals, including chickens, so should be used with extreme care by the householder. Baits should preferably be used in bait containers or at least placed under cover where children and domestic animals do not have access to them. Zinc phosphide kills rodents quickly; most animals that eat enough of the bait will die within 8 to 24 hours; some may die on or after the second day of baiting. After placing baits out for a few days, all uneaten baits should be retrieved and buried several feet in the ground. Generally after two or three days, all baits that weren't eaten in the first few days will be rejected by any surviving rodents. Zinc phosphide should be effective against all pest rodent species previously mentioned in this chapter.

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6. Annex

Table 1. Stored food losses at farm and village level as reported on the mail survey of Hopfet (1976)

Area	Type of storage	Commodities	Percent damage or loss
Asia:			
Bangladesh	Bamboo bins	Rice, wheat	5
India	Village stores	Rice, wheat	1.7
	Village, bags	Rice, wheat, millet, sorghum	3.5-5
	Mud and bamboo bins, bags	Rice, wheat, pulses, Sorghum	2-5
Korea	Sacks	Rice, barley	20
Laos	Cribs, mud and bamboo bins	Rice	3
Malaysia	Cribs in roof	Rice	2-5
Nepal	Sacks	Maize	3-5
Philippines	Cribs, sacks	Rice, maize	2-3
Thailand	Sacks in roof, maize in cribs	Maize, rice	5
Turkey	Farm houses, underground pits	Wheat, rice, maize	5
Africa:			
Egypt	Houses and stores	Maize, wheat, rice, cottonseed	50
Ethiopia	Huts on stilts, underground, bags	Grains	5-15
Ghana		Grains, maize, rice	2-3
Malawi	Woven cane bins, grass baskets	Maize, groundnuts, sorghum, millet	0.5-1.5
	Cribs Cob	maize	15
Sierra Leone	Cane baskets	Rice	1-10
	Sacks	Rice	10-100
	Roof and cribs	Rice, maize	2-3
Zaire	Bags in roof	Rice, maize	3
Zambia	Farm cribs	Cob maize, sorghum, millet	10
Latin America:			
Mexico	Cribs, sacks in roofs	Rice, maize	5-10
Brazil	Stacks, sacks, cribs	Rice, maize, beans	4-8

Table 3. Reported post-harvest losses of rice world-wide (US NAS, 1978, based upon FAO data, 1977 unless otherwise indicated).

Region/Country	Weight Loss(Total Percent)	Remarks
Africa:		
Sierra Leone	10	
Uganda	11	
Rwanda	9	
Egypt	2.5	(Quoted in NAS, 1978)
Asia;		
Bangladesh	7	
India	3-5.5	Improved traditional storage (Boxall and Greeley, 1978)
Indonesia	2-5	
Malaysia	5	On-farm storage (Quoted in NAS, 1978)
Nepal	3-4	On farm storage
Sri Lanka	2-6	On-farm storage (Quoted in NAS, 1978)
Thailand	1.5-3.5	On-farm storage
	2-15	On-farm storage (Quoted in NAS, 1978)
Latin America;		
Belize	20-30	On-farm storage (Quoted in NAS, 1978)
Bolivia	16	On-farm storage
Dominican Republic	6.5	On-farm storage

Table 4. Reported post-harvest losses of maize world-wide (US NAS, 1978, based upon FAO, 1977 data unless otherwise indicated).

Region/Country	Weight Loss (Total Percent)	Remarks
Africa:		
Benin	8-9	Traditional on-farm storage (Harris and Lindblad, 1978)
Malawi	8	On-farm storage (TPI, 1977; Schulten, 1975)
Nigeria	1-5	On-farm storage
Rwanda	10-20	On-farm storage
Zambia	9-21	On-farm storage (Adams and Harman, 1977)
Asia:		
Pakistan	2-7	
Latin America:		
Belize	10-20	On-farm storage (Quoted in NAS, 1978)
Brazil	15-40	Farm storage
Dominican Republic	19	Farm storage
Honduras	20-50	Traditional storage, poor facilities (Quoted in NAS, 1978)
Mexico	10-25	
Nicaragua	15-30	
Paraguay	25	(Quoted in NAS, 1978)
Venezuela	10-25	

Table 5. Reported world-wide post-harvest losses from all causes of wheat, millets, and sorghum(US NAS, 1978, based on FAO, 1977 data unless otherwise indicated).

Region/Country	Weight Loss (Total Percent)	Remarks
Wheat:		
Pakistan	5-10	On-farm storage (Quoted in NAS, 1978)
India	8-25	(Quoted in NAS, 1978)
Rhodesia	10	On-farm storage (Quoted in NAS, 1978)
Sudan	10	
Bolivia	7	Stores
Brazil	1-4	Storage
Millets:		
India	5	Farm storage (Quoted in NAS, 1978)
Mali	2-4	On-farm storage (Guggenheim, 1977)
Nigeria	0.1-0,2	On-farm storage
Zambia	10	On-farm storage
Zimbabwe	10-15	On-farm storage (Quoted in NAS, 1978)
Sorghum:		
Nigeria	0-37	On-farm over 26 months (Hall, 1970)
Pakistan	5	
Zimbabwe	25	On-farm storage (Quoted in NAS, 1978)

Table 6. Post-harvest losses at farm-level of grain legumes due to all causes (NAS 1978).

Region/Country	Weight Loss (Total Percent)	Remarks
Kenya	30	On-farm storage (De Lima, 1973)
Zimbabwe	5	On-farm storage (NAS, 1978) (Groundnuts)
Thailand	12-15	Farm stores (NAS, 1978)
Honduras	20-50	On-farm storage (NAS, 1978) (Dry beans)

Table 8. Amount of food consumed daily and yearly by rodents infesting stored foods.

Rodent Species	Amount of food consumed daily (g)	Amount of food eaten yearly (kg)
Norway rat, *Rattus norvegicus*	15-25	5.5-9.1
Roof rat, *R. rattus*	8-12	2.9-4.1
Polynesian rat, *R. exulans*	5-8 1	8-2.9
Bandicoot rat, *Bandicota bengalensis*	15-25	5.5-9.1
Unstriped grass rat, Arvicanthis niloticus	5-8 1	8-2.9
Multimammate rat, *Mastomys natalensis*	5-8 1.	8-2.9
Spiny mouse, *Acomys cahirinus*	3-6 1	1-2.2
House mouse, *Mus musculus*	2-3 0	7-1.1
Vesper mouse, *Calomys laucha*	3-5 1	1-1.8
Grass mouse, Akodon azarae	3-5 1.	1-1.8

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Table 20. Descriptions of commensal and indigeneous rodents of stored foods.

Common name	Scientific name		Head & Tail (cm)	body (cm)	Weight (gm)	Food consumed Daily (gm)
Norway rat	Rattus norvegicus	stocky bicolored	16-25	12-20	250-550	15-25
Roof rat	R. rattus	slender unicolored	14-22	16-25	120-260	10-15
Polynesian rat	R. exulans	slender unicolored	8-12	8-12	50-110	4-7
House mouse	Mus musculus	slender unicolored	7-10	8-11	15-21	2-3
Bandicoot rat	Bandicota bengalensis	stocky bicolored	17-27	12-20	300-600	15-25 (hoards 3X)
Multimammate rat	Mastomys natalensis	slender unicolored	10-15	10-15	80-140	5-8
Unstriped grass rat	Arvicanthis niloticus	stocky bicolored	11-20	10-15	115-150	5-8
Spiny mouse	Acomys cahirinus	slender bicolored	9-13	8-13	20-64	3-6
Vesper mouse	Calomys laucha	slender bicolored	6-8	3-5.5	10-18	3-5
Grass mouse	Akodon azarae	stocky bicolored	9-14	5.5-10	10-45	3-4

Zygodontomys (Cane mice)

Description: Head and body length is 130-145 mm and tail length is 93-100 mm. The tail is usually shorter than the head and body. The body weight is 45-70 g. The dorsal pelage is grayish to agouti brown and the the venter is grayish white to buffy gray. The tail is bicolored; whitish below and gray brown above; the ears are brown. Zygodontomys resembles Oryzomys but may be distinguished by their relatively shorter tail and shorter hind feet.

Range and Habitat: Z. brevicauda occurs from southern Costa Rica to western Ecuador and across most of northern South America, usually below 500 m elevation. They are broadly tolerant of a variety of habitat types; living in open country and in areas of low bushes and thick ground cover, including croplands, pasture, and clearings in evergreen forest. They are attracted to cultivated fields and may become agricultural pests.

Natural History: Cane mice are terrestrial and have habits much like meadow voles (Microtus). They make runways through dense grass and are active at night. Nests are made of grass and are built at the ends of short burrows in banks or under tree roots. The diet includes seeds, grasses, corn, rice, and fruit. They probably eat about 4-7 g of food daily. The gestation period is 25 days, litter size averaged 4.6 young, and birth weight 3.5 g. The young

opened their eyes after about 7 days and were weaned at 9-11 days. Females reached sexual maturity at about 26 days and males at 42 days. Reproduction can occur throughout the year but the timing is frequently controlled by rainfall.

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