Les recherches et la lutte contre les Rongeurs

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1. BIOLOGY AND CHARACTERISTICS OF SAHELIAN RODENTS IN CHAD*

Nearly 1700 species of rodents are recognized in the world today. Fortunately, only a handful of these are known to be pest species. Pest rodents are generally rapid breeding, short-lived herbivores (eating plant foods) or omnivores (eating almost anything) competing with man for food crops, reducing the supply of his stored foods and other commodities, damaging his constructions, and harboring and transmitting harmful parasites and diseases.

In the Sahelian area of Africa, periodic outbreaks of rodent populations have been recorded during the past 30 years and for perhaps even longer than that historically. These outbreaks usually occur following good rains that end several years of drought. Just as the farmers are expecting good harvests, the rodents reach outbreak proportions and cause heavy losses to the crops before they can be harvested.

Rodents are one of the most diverse of the mammalian groups in terms of form. For example, rodents may have long, slim bodies or short, squat ones; the fur may be entirely soft, woolly, or silky and sleek, or it may appear as long, stiff bristles or quills; the pelage may be dense and long or there may be no fur at all; there may be large ears or external ears may be lacking. Tails, too., are extremely diverse: they can be more than twice as long as the head and body or there can be virtually no tail; tails can be almost naked and scaly, or densely clad with long hair forming a most striking and beautiful appendage to the body. Although most rodents get from place to place by running on all four legs, there are those that walk or hop on only two and, finally, there are those rodents that glide through the air from tree to tree by using special membranes stretched between the fore and hind legs.

1.1 How to recognize a rodent

What then, with all this diversity, constitutes a rodent? The answer lies in the teeth. The gross dental pattern of all rodents is the same. At the front of the mouth are two pairs, one pair in each jaw, of long, circularly curved, strongly built, incisor teeth. These incisors are separated from the molars by a large gap called the diastema (Fig. 1). The incisors in rodents grow continuously. The are kept sharpened by rubbing the teeth up and down against each other. The front surface of the incisors is composed of hard enamel and the back surface is made up of softer dentine.

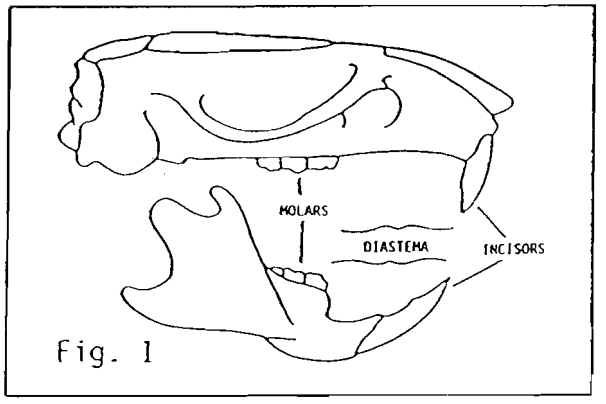


Fig. 1

* Drawings for figures 4-9, and 13-16 adapted from Kingdon (1974), *East African Mammals*, University of Chicago Press, used with permission.

instead, tend to have broad incisors and mill-like grinding teeth with appropriately stout skulls to support them. The omnivorous types tend to fall in between the two.

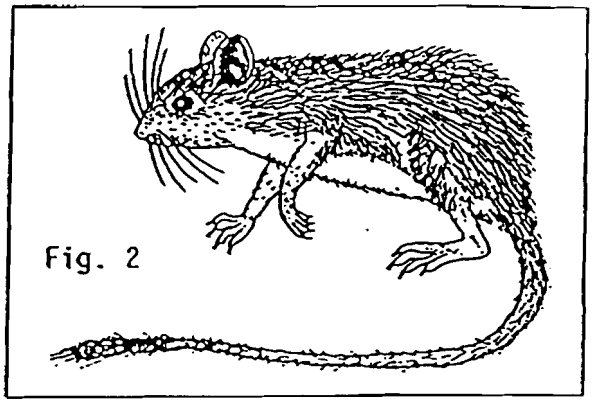


Fig. 2

The animals most similar to the rodents in this dental structure are rabbits, hares and pikas. But in contrast to the rodents, the latter have two incisors in each half of the upper jaw, the second one being peg-like and rather small. Most other small mammals lack a diastema, which can be seen in rodents when the lips are pulled back.

In most rodents the ears are fairly prominent and quite often naked, or not haired. The eyes are large for the size of the animal, an adaptation for seeing more easily at night. The head is usually tapered to the pointed snout which is covered with long whiskers, or vibrissae. The tail can be shorter than the head and body but in most species is equal to or longer than the head and body (Fig. 2).

Adult female rodents are recognized by the numerous mammaries or teats. These may be arranged in patterns in the pectoral (chest) area and in the inguinal (groin) area. They can number from as few as 6 (3 pairs) to as many as 24 (12 pairs), depending upon the species (Fig. 3). *Gerbillus* and *Tatera* are pattern 1; *Mus*, pattern 2; *Rattus rattus*, pattern 3; and *Praomys*, pattern 4; as shown in Figure 3.

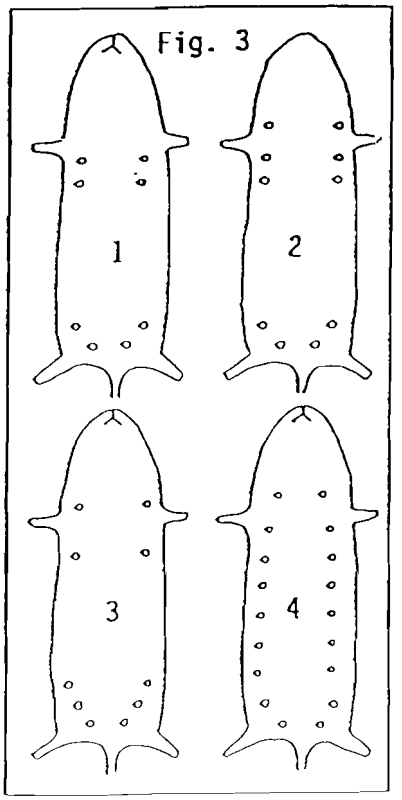


Fig. 3

For the field worker in West Africa, rodents will be met with as members of communities rather than as isolated species, and a line of traps set in any habitat will generally catch a variety of species of several different types. Each has its own adaptations to the difficult environment, based upon its feeding and living habits. Some never invade agricultural fields; others invade at every opportunity, causing widespread damage to cereal grains and vegetable crops.

Some are capable of causing human disease, such as plague, murine typhus, and Lassa fever. Others may carry parasites that could be transmitted to humans and domestic animals. For many West African rodents very little is known of their distribution, habitats, feeding habits, breeding habits, longevity, and the effects of climatic and vegetation growth factors on their population dynamics. A study of their habits and methods for their control will become

more important as food supplies for the human and domestic animal populations in the Sahel become even more scarce than at present. This training manual is designed to impart to the trainee what information is at present known about the more common of the Sahelain rodent species, some collection and preservation methods, toxicity and bait testing, and how to plan and implement control programs.

1.2 Biology of Some Chadian Pest Rodents

1.2.1 The Egyptian gerbil or sand rat, *Gerbillus andersoni*.

Egyptian gerbils are small (15 to 32 g), with sandy dorsal pelage, and a white ventral pelage. The eyes are large. The tail is long, sandy above, white below, with an elongated tuft of long hairs, often with blackish tips, at the end. The soles of the hindfeet are covered with short white hairs.

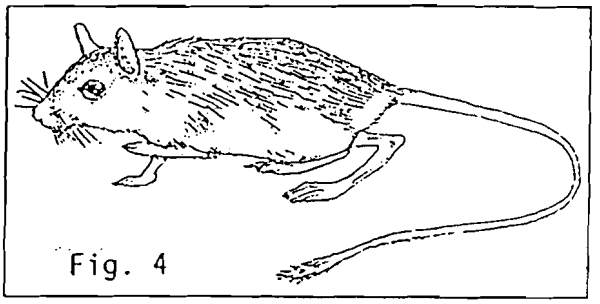


Fig. 4

Egyptian gerbils typically live on sandy dunes. The gerbils are distributed over all the drier parts of Africa and Arabia, Iran, and northern India. They construct burrows in the sand to escape the daytime high temperatures. They are entirely nocturnal (coming out only after dark). They feed mainly upon grass seeds, grass stems and roots, and insects. The litter size in *G. andersoni* observed in the area near Lake Chad and N'Gouri averages 5.0 and ranges from 2 to 9. They appear to essentially breed year-round but quite often respond to prolonged greening of the grasses and weeds with a heavy breeding effort and a large out-pouring of young animals.

Egyptian gerbils have hind feet which are somewhat longer than the forefeet; this allows them to hop around while searching for seeds during the night (Fig. 4). They can hop faster than they run on all four legs. Seeds are picked up with the small forelegs. Their burrow openings can be found on the sandy dunes sometimes near the desert shrubs, The openings are only about 2 to 3 cm in diameter.

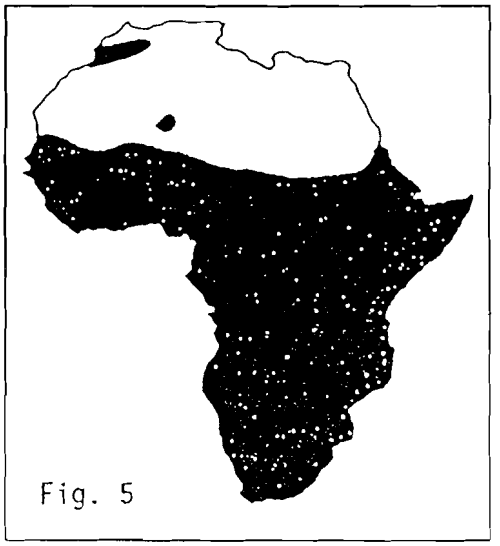


Fig. 5

1.2.2 The multimammate mice or rats, *Praomys (Mastomys) natalensis*

The multimammate mice or rats are a species complex widely distributed in Africa (Fig. 5), occurring from Morocco in the northwest to the tip of South Africa and from Senegal in the


Fig. 6

west to Somalia in the east. They are probably the most widely distributed small mammal in tropical Africa. There are some unsettled problems in the naming of this species, with both *Praomys* and *Mastomys* being used for the genus name. *Praomys* is a semi-commensal rodent, living both with and without man. Over the centuries they have accommodated themselves to the African village, but they are now being replaced where the true commensal rat, *Rattus rattus*, expands its range. The best identifying features are the particularly silky grey-based fur, the tail shorter than head and body (Fig. 6) and, in females, the presence of up to 12 pairs of mammae. These rats are extremely important because they are a principal host of human plague and in the past 20 years have been found to reservoir and vector the deadly Lassa fever virus.

Multimammate rats are typical unspecialized rats. Within their vast geographical range, they show a great ecological diversity and, besides living with man in villages, they live in grasslands, savannas, and agricultural fields. They can reach extremely high densities in all these habitats. Because of rapid reproductive capability and an ability to reach extremely high numbers at times, they are often are serious agricultural pests.

Breeding activities in many African countries are strongly correlated with rainfall. A few weeks after the onset of rains, breeding increases with peaks most commonly between the months of October and March, depending upon the geographical location. Multimammate rats have litter sizes ranging from 4 to 19 and averaging 11.0. They can respond to greening of vegetation by breeding in several generational cycles until they reach outbreak proportions. The litter size during these outbreaks can increase to an average of 12 to 13 per female. Young born in one breeding season are sexually mature (3½ months) and already capable of breeding in the next season following the rains. The gestation period is 23 days and young are weaned at about 21 days.

They are basically omnivorous in food habits and probably are opportunistic feeders like *Rattus*. In better habitats they tend to feed as much on animal matter, particularly insects, as they do on vegetable matter. When their diet is restricted, they may feed exclusively on a single item, such as cassava, maize, or rice. They are able to live in relatively dry habitats but do like to drink water, and they will expose themselves more than most other rodents in their search for food and water. This lack of caution makes them easy prey, for when they are numerous various predators, snakes, owls, and carnivores can glut themselves with ease on this species.

This nocturnal species lives in burrows. Their burrows are by preference modifications of natural cracks and crevices but they can dig their own burrows when forced to. Quite often their burrows have been dug and previously occupied by other rodents. The nest for the young is made in the burrow.

1.2.3 Nile rats, *Arvicanthis niloticus*

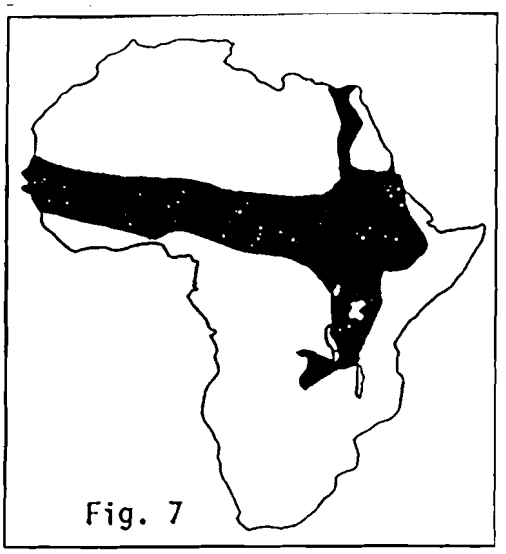


Fig. 7

Nile rats, also known as unstriped grass rats, occur in a broad belt across the Sahel region, extending north and south into the Nile valley and the Rift Valley (Fig. 7). They are common in the northern savannas where they feed mainly on the seeds, leaves, and shoots of grasses. They are basically diurnal (active during daylight hours) but, in response to intense heat, may also be nocturnal. In Chad, they can be found along grassy and weedy field borders and in thorny fencerows around cultivated areas, especially wadis. They are localized in their distribution because of their large water requirements. Nests are usually found in banks or rubbish heaps or at the base of bushes. Runways lead through tall grass away from them. Surface nests as well as burrows are located in thick bunches of grass. Underground nests, lined with fine grass and often found in numbers of four or five together are usually between 20 to 60 cm below the ground surface. These rodents are gregarious but the number of rats within each burrow system tends to be regulated to small groups, even in areas where large groups of well-established burrows have joined up over years of occupation to form a large colony.

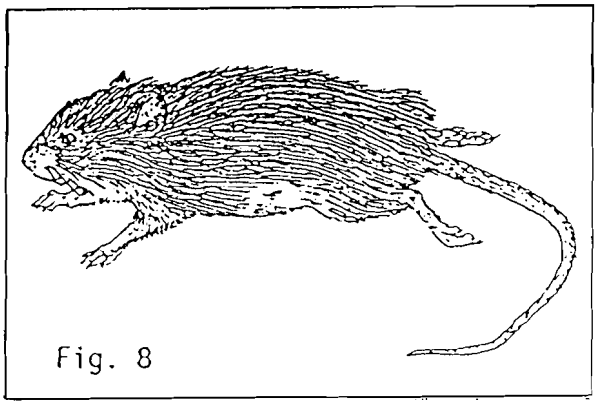


Fig. 8

Nile rats are heavily built, shaggy-coated rats, weighing 115 to 150 g (Fig 8). The dorsal pelage is greyish-brown to dark brown and 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, paler below. The mammae number 3 pairs, 1 pair pectorally, 2 pairs inguinally.

Nile rats can respond to greening vegetation by increased breeding. They are capable of breeding year-round; however during dry spells breeding drops to a minimum. One facet of *Arvicanthis'* success seems to lie in their ability to recoup their numbers after the annual dry season depletion. The gestation period is about 18 days with an average litter size of 5.3 and a range of 1 to 11. Heavier females tend to have larger litters.

Arvicanthis are primarily diurnal. They feed mainly in the afternoon when most predators are resting in the shade. They feed mainly on the seeds, leaves and shoots of grasses. They also attack crops, mainly stored grains, cassavas, sweet potatoes, tomatoes, and egg plant. They will enter grass huts and grain stores in search of food.

1.2.4 The fringe-tailed gerbil, *Tatera robusta*

This is a large, heavily built gerbil, weighing about 100 g (Fig. 9). The dorsal pelage is sandy-grey to sandy-brown. The tail is sparsely haired, dark above, white below, with a tuft of darkish hairs at the tip. It is longer than the head and body. The head is rounded in shape, the eyes rather large.

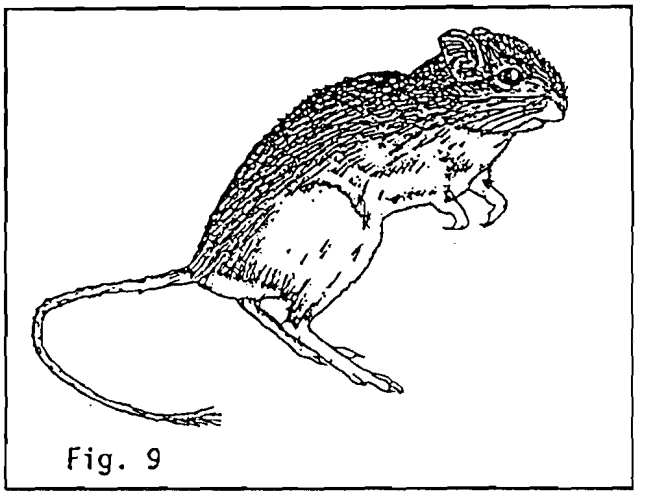


Fig. 9

These gerbils are found in many forms of savannah where there is good cover of grasses, or dense shrubs. They prefer dry, sandy soils although they occur in irrigated agricultural lands in wadis near N'Gouri. Like other gerbils, they dig deep burrows, often with many chambers and tunnels. These burrows are 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). Roots and bulbs are dug out and crops such as cassava and groundnuts are sometimes damaged in cultivated areas. In Chad, they may feed on local crops and cause some damage in wadi crop plots. When food is scarce they probably forage over many hundreds of meters each night.

Gestation is about 3 weeks and the 4 to 8 young are born in an undeveloped state and must remain in the nest for a month before accompanying the adults out to forage. Juveniles have been recorded in the dry season, from December to March but the extent of the breeding season is not known.

1.2.5 The roof rat, *Rattus rattus*

Roof rats are introduced rats which have spread northwards into Chad from the coast. Once established, they are able to live in mesic habitats surrounded by a generally arid environment. Despite their wide geographical range, roof rats live almost exclusively in houses, stores, and other human habitations. They are good climbers and are often found in the upper parts of houses. They do not invade croplands and therefore are not pests of growing crops. They apparently compete with and exclude *P. (M.) natalensis* from human habitations where they coexist.

Roof rats in Chad are only medium-sized as compared with their Asian cousins, averaging about 80 to 140 g when fully grown. They are dark, fairly slender rats (Fig. 10). The dorsal pelage is dark-grey to grey-brown and the ventral pelage is dull-grey. The ears are large and hairless. The tail is thin and very long, covered with small scales and small dark bristles.

Roof rats are extremely prolific, have 5 to 8 young in a litter and a female may have up to 3 litters in her lifetime. In human habitations they tend to breed throughout the year. Their breeding potential, however, as compared to *Praomys* is only about half, since their mean litter size is about 5 to 6, whereas multimammate rats average 11 to 12 per litter.

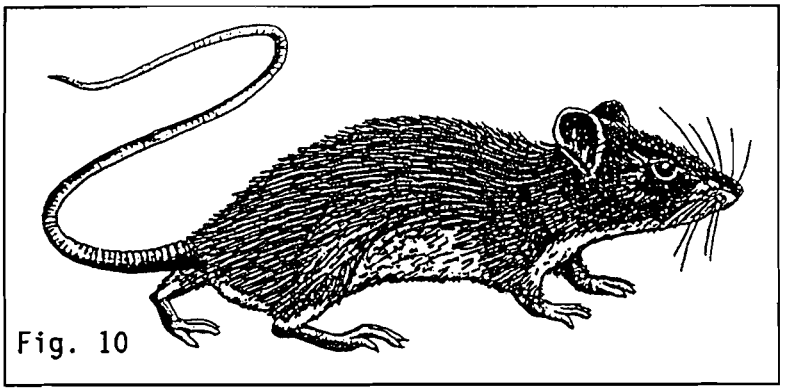


Fig. 10

1.2.6 House mice, *Mus musculus* and other *Mus* species.

The mice of the Sahel in Africa are a problematic group. It appears they have no obvious relationship with any other African group but are more closely related to some Eurasian and especially Indian mice species. It has been suggested that *Mus* migrated from Eurasia independently of the original parent stock of the other African Muridae, probably at a later date.

Trapping in the Karal area near Lake Chad has yielded two forms of *Mus*, one which is obviously *M. musculus* (Fig. 11). The other probably is *M. minutoides* or a related pygmy mouse, *M. haussa*. *Mus musculus* is an introduced species, adding to an already confused picture with the indigenous species.

House mice are generally thought to be close commensals of man, living in human habitations in arid areas. However, in the successional agricultural areas near Lake Chad, they can be found in the crop fields. They are small greyish-brown backed forms with light grey to greyish-white bellies. The tail is usually equal to or longer than the head and body. Adults may weigh from 13 to 20 g. In the Karal area they appear to breed essentially year-round, since immature animals have been seen in each quarter of the year.

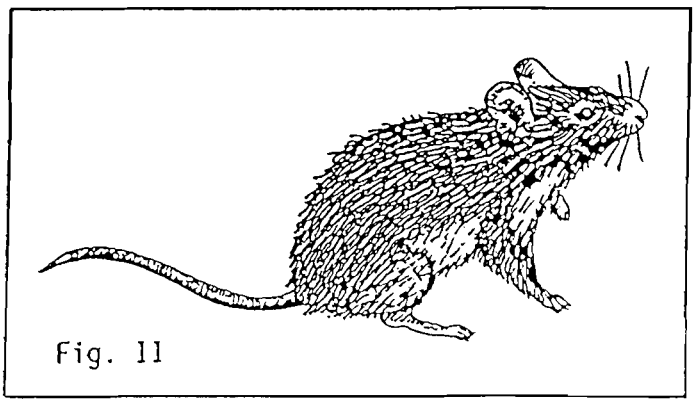


Fig. 11

The related *Mus* species, either *M. minutoides* or *M. haussa*, are apparently intermixed with, but do not interbreed with, *M. musculus* in the Karal area. The pygmy mouse, *M. minutoides* is a small mouse weighing only 4 to 11 g, and with a head and body length of 55 to 70 mm and a tail only 38 to 49 mm, or less than the head and body length. They are brownish-colored on the back, with a white belly. Pygmy mice excavate short burrows in sandy soil, quite often filling the mouth of the burrow with small stones when they hide inside.

The Hausa mouse is probably the northern equivalent of the pygmy mouse, found in the Sahel savanna zones from northern Guinea to the Sudan. They are very small mice, with a head and body length of only 48 to 55 mm, and a tail length of 35 to 41 mm. The back is sandy-colored, the belly is white. No data are available on their reproduction.

A key to the *Mus* species likely to found in the Chadian Sahel and especially around Lake Chad is given in Table 1.

Table 1. Key to *Mus* species in the Chadian Sahel (from Happold 1987).

1. Dorsal pelage light to dark brownish-gray; ventral pelage gray or grayish-white; HBL about 85 mm, weight 13-20 g; can be commensal with man in villages and towns but also occurs in croplands. *Mus musculus*

Dorsal pelage sandy to rufous-brown; ventral pelage pure white; HBL 50-70 mm; weight 6-10 g; Sahelian croplands..... 2

2. HBL 48-55 mm; skull length 15-17 mm; dorsal pelage sandy-brown or sandy; Sahel savanna zone ..... *Mus haussa*

HBL 55-70 mm; skull length at least 17 mm; dorsal pelage golden-brown to rufous-brown; Sahel savanna zone and adjoining more southerly areas ..... *Mus minutoides*

1.2.7 The lesser Egyptian Jerboa, *Jaculus jaculus*

Jerboas are adapted for living in hot, dry habitats, and are widely distributed throughout the arid and semiarid parts of northern Africa. Jerboas are adapted for leaping along on their hind legs; these legs are long, more than half as long as the rest of their head and body. The tail, used as a counterbalance and rudder when leaping, is extremely long (almost twice the length of the head and body). The short forelimbs are held close to the chest and are not used for medium and fast hopping.

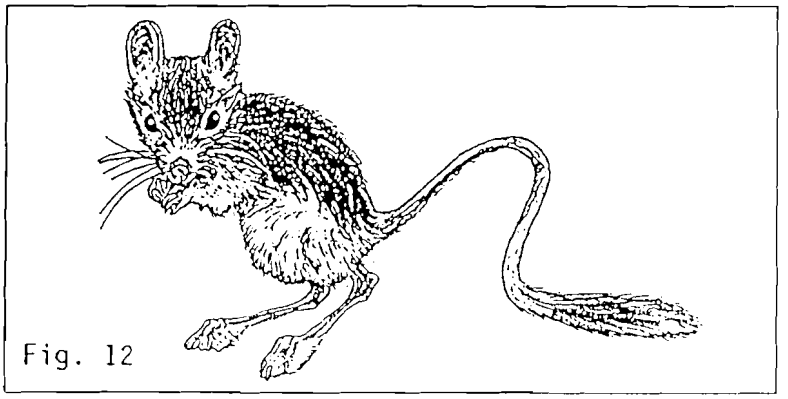


Fig. 12

This is a medium-sized rodent, averaging about 50 to 60 g in weight. The head and body measure from 92 to 119 mm, the tail from 166 to 195 mm. The head is large and rounded (Fig. 12). The dorsal fur is long and silky, pale sandy to sandy-rufous in color, while the belly fur is pure white. The tail is very long, with the basal two-thirds covered with short sandy hairs; the terminal third is covered with long hairs forming a brush.

Jerboas occur in sandy habitats which, for most of the year, have little ground cover except for scattered bushes. Jerboas are nocturnal, and during the day they live in burrows where they are sheltered from high daytime temperatures. The burrow entrance is "plugged" with sand when the jerboa leaves or enters the burrow. Jerboas walk, run, and hop on their hindlimbs, often very rapidly, using the long tail as a rudder and counterbalance. When standing, the body is supported on the hindfeet and the tail.

Jerboas are herbivorous and feed mainly on seeds, roots, and bulbs. Unlike most gerbils in similar habitats, they do not store food. Jerboas can survive without drinking because they obtain water from succulent foods and from metabolic processes. However, they need to conserve water in every possible way and accomplish this by producing very dry feces and very small amounts of concentrated urine, by living in humid burrows during the day and by specialized behavior.

Despite the arid conditions, jerboas can breed in many months of the year, provided adequate food is available. In most localities, breeding occurs after the irregular rainstorms when plant growth and seed production are good. There are two to five young in each litter.

1.2.8 Naked-soled gerbils, *Taterillus*

These gerbils appear to be a smaller type of *Tatera*. Nowak and Paradiso (1983) list seven species, all of them found south of the Sahara Desert in Africa:

- *T. gracilis*, Senegal to Nigeria, probably Cameroun
- *T. pygargus*, southern Mauritania, Senegal, Gambia, SW Mali
- *T. arenarius*, so. parts of Mauritania, Mali, and Chad
- *T. lacustris*, NE Nigeria, no. Cameroun, possibly Niger and Chad
- *T. congicus*, eastern Cameroun to Sudan
- *T. harringtoni*, central Sudan and eastern Central African Republic to southern Somalia and northeastern Tanzania
- *T. emini*, Chad and Central African Republic to northwestern Kenya
- *T. nigeriae*, known only from the Jos Plateau, is listed by Happold (1987).

Taterillus ranges over the Sudanic savannas and steppes south of the Sahara from Senegal to Ethiopia, Somalia, and Kenya (Fig. 13). They live in open, dry, and well-drained soils on plains, in savanna woodland or in thorn scrub. They have adapted to the secondary vegetation around villages and to cultivation. They are much less abundant than *Tatera*, but tend to be more common around savanna farmlands than in undisturbed woodland savannas, and small areas of a few hectares may support dense populations.

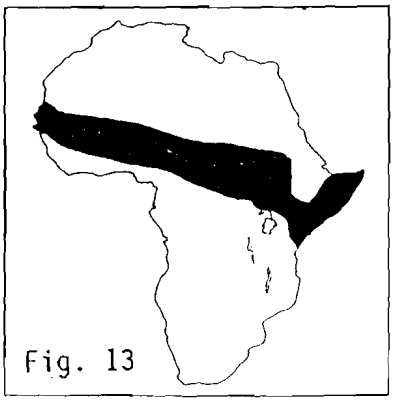


Fig. 13

The HBL varies from 100 to 144 mm; tail length is 140 to 194 mm; HF 29 mm (25-32); and the ear is 19 mm (17-22). *T. arenarius* weighs 42 to 52 g, *T. gracilis* weighs 30 to 68 g (Happold 1987), and *T. emini* weighs 51 g (♀) and 53 g (♂) according to Delany (1975). The coloration above ranges from pale yellow, through light buffy, clay color, light reddish brown, and tawny olive to dark tawny brown. The sides are paler and the underparts, including the hands and feet, are white or almost white. The head is slender with a slightly pointed nose as compared with *Tatera* (Fig. 14). A dark mark runs behind the eye to the base of the ear. The eyes are particularly large and the ear bullae somewhat smaller than in most other gerbils, suggesting a slightly different behavior pattern for this gerbil. The tail is usually well tufted and darkest toward the tip. Externally, this genus is similar to *Tatera*, but is usually smaller and the soles are sometimes partially haired, not completely naked. As in some *Tatera*, the upper incisors are grooved.

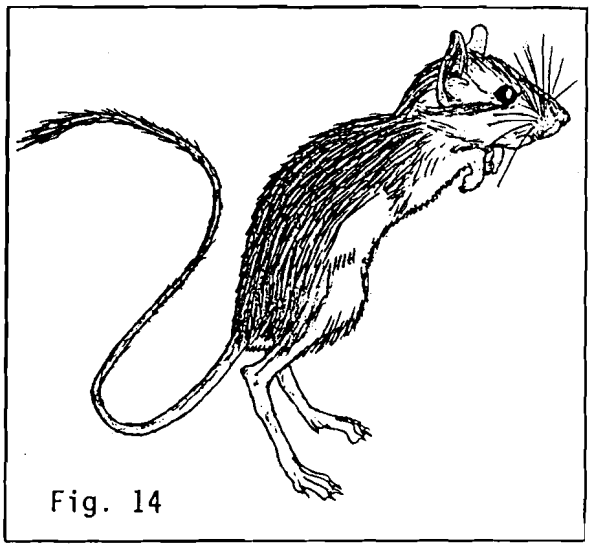


Fig. 14

This gerbil lives in underground burrows which resemble those of *Tatera* species, being about 50 cm deep and situated on bare, well-drained soils. Excavated soil is not piled up around the several entrances, which are kept closed with sand from within by the occupants. The animal is strictly nocturnal; if excavated in daylight it rushes for the nearest burrow and immediately blocks itself in with earth.

In studies on a dry thornbush savanna in northern Senegal, Poulet (1972, 1978) found *T. pygargus* to be nocturnal, granivorous, and insectivorous. Population density in this area was calculated to be about 2 to 6 animals/ha. Following heavy rainfall, however, density increased to as high as 180/ha. Adult home range averaged 1100 sq. meters for males and 300 sq. meters for females. The home range of an adult m,ale overlapped that of several females. Births occurred only after rains, in the period from September to march. A female could have a litter every six weeks and she would change her burrow each litter. The gestation period was 3 weeks and there were usually 4 young per litter. Juveniles were nomadic for a brief period and then settled onto permanent home ranges by the time they were 3 to 5 months old.

The distinguishing field characteristics of these several rodents are given in Table 2. For *Arvicanthis* these are the speckled pelage on the back and the tail being bicolored and shorter than the head and body. *Praomys* is recognized from *Rattus* by its tail being shorter than the head and body and the smaller hind feet and ears. *Gerbillus andersoni* is distinguished by its small size, haired soles on the hind feet, and a tail longer than head and body with a dark brush on its tip. *Jaculus* is easily recognized by its very long hind legs, a tail almost twice the head and body length, and the hairy hind feet with only 3 toes. *Tatera* is a fairly robust, medium-sized rodent with small ears and a naked, bicolored tail with a very small brush at its tip. *Taterillus* is a smaller, slender version of *Tatera*. Other rodents may be encountered that are not included in Table 2. To identify these, the field worker should use one of the mammal or rodent guides for the West African region listed in the References section.

Table 2. DISTINGUISHING CHARACTERISTICS OF SEVERAL SAHELIAN RODENTS

Character	*A. niloticus*	*P. natalensis*	*G.andersoni*	*J. jaculus*	*T. robusta*	*Taterillus sp.*
Color	back speckled yellow and black, belly gray to white	back grayish-brown, belly pale gray	back light sandy brown, belly white	back brownish-orange, belly white	back sandy-gray to sandy-orange, belly white	back sandy yellow to light reddish brown, belly white
Toes	5 hind, 4 fore	5 hind, 4 fore	5 hind, 4 fore	3 hind, 4 fore	5 hind, 4 fore	5 hind, 4 fore
Soles	naked	naked	haired	haired	naked	partially haired
Tail color	bicolored	not bicolored	not bicolored at base brush small and dark	not bicolored, large brushy sepia/white tip	bicolored, small dark brushy tip	bicolored, small dark brushy tip
Tail	shorter than the body (120-150 mm)	shorter than the body (115-135 mm)	longer than the body (105-135 mm)	longer than the body (166-195 mm)	longer than the body (140-187 mm)	longer than the body (140-194 mm)
HBL	145-180 mm	130-155 mm	75-110 mm	92-119 mm	110-160 mm	100-144 mm
HF	32- 37 mm	22- 24 mm	22- 26 mm	55- 60 mm	29-35 mm	25- 32 mm
Ear L	18- 22 mm	17 mm	13- 16.5 mm	18- 21 mm	15- 23 mm	17- 22 mm
BodyWGT	115-150 g	80-110 g	15- 32 g	45- 60 g	82-100 g	30- 68 g
Mammary formula	1 + 2 = 6	8-12 = 16-24	2 + 2 = 8	2 + 2 = 8	2 + 2 = 8	2 + 2 = 8

2. Other Small Mammals That Might Be Seen

2.1 Four-toed Hedgehog, *Erinaceus albiventris*

Hedgehogs are easily recognized by the spines (modified hairs) on the back and flanks, and by their ability to curl up into a ball when disturbed. The four-toed hedgehog ranges rather intermittently throughout the savanna and semi-arid zones of the northern half of Africa from Senegal to Somalia and Tanzania. A darker, five-toed species, *E. frontalis*, replaces it in southern Africa, and another slightly larger species, *E. algirus*, is distributed along the African shores of the Mediterranean.

Hedgehogs are rather large as compared to rats, weighing from 250 to 700 g. The head and body length is 170 to 230 mm and the tail measures only 20 to 50 mm. The back of the neck, back, and flanks are covered with dark spines with

pale tips. The face is pointed, with black eyes and dark, fairly large ears. White pelage occurs on the forehead and extends backward above each eye, across the cheeks below the ears, and on to the neck, lower flanks and the belly (Fig. 15). Hedgehogs curl into a ball when distrubed to protect the head and ventral surfaces.

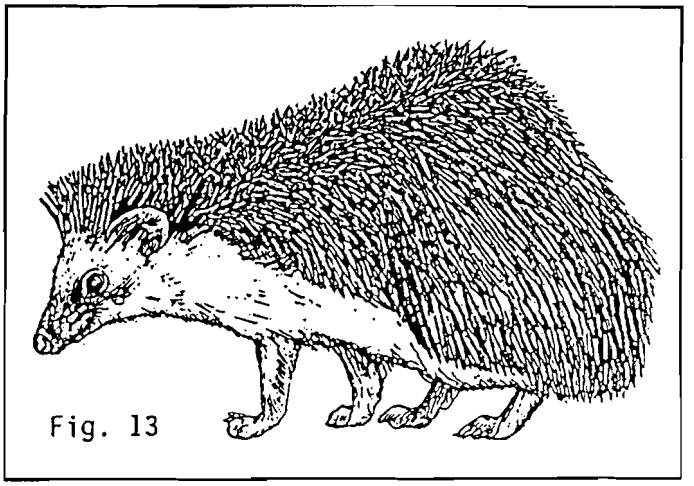


Fig. 13

Hedgehogs are nocturnal and solitary. They seem conservatively attached to a very small home range, provided it supplies them with an abundance of ground-dwelling insects and other invertebrates. They usually live in grassy areas and light undergrowth where they hunt for insects, earthworms, grubs, snails and slugs, and any other animal food, such as eggs and ground-nesting birds, small mammals, frogs, reptiles, and crabs, which can be obtained. Hedgehogs will eat one-third of their body weight in one night. Hedgehogs seem to need dry shelters and are not found in waterlogged country or forest. Two to four young are born in a litter and no set breeding season is seen. The gestation period is 30 to 40 days. The young are born in a nest.

2.2 African Giant Shrew, *Crocidura flavescens*

The African giant shrew is a medium-sized, rat-like animal in appearance but is not a rodent (Fig. 14). Shrews are insectivores, with a mouthful of sharp teeth made for chewing and grinding insects and other invertebrates into tiny pieces. The African giant shrew may be found living in and around houses. Shrews are active mammals, giving the impression they are always investigating their surroundings with their long mobile noses. They feed throughout the day and night, eating up to their own body weight in food every 24 hours. Shrews are rarely seen because of their secretive habits.

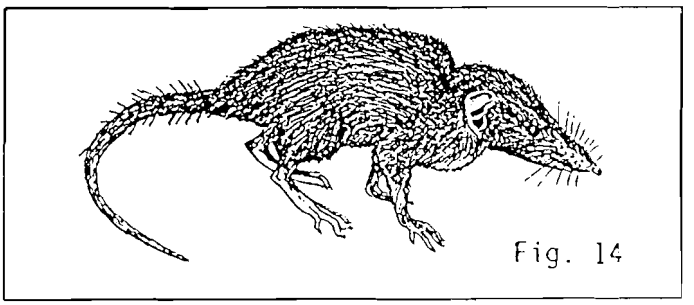


Fig. 14

African giant shrews are one of the largest shrews found in Africa; their head and body length averages 130 mm, the tail measures 85 to 100 mm. The body weight varies from 30 to 80 g, averaging about 50 g. The back and belly are covered with a find pale grey pelage. The tail is thick at its base, tapering towards the tip.

Very strong musky secretions give the shrew a distinctive and rather unpleasant smell. The head is large and heavy, flat in profile.

This shrew is a commensal of man and is found in many habitats including houses, food stores, banana plantations, and farmlands as well as riverine habitats. It is probable that their numbers and range have increased as more man-made habitats have become available. African giant shrews are probably very successful predators and scavengers, and are remarkably fierce for their size. Their diet includes small mammals, birds, molluscs, and millipedes. Young animals have been collected in most months of the year, indicating that there is no clearly defined breeding season.

3. Basic characteristics of Sahelian rodents

Happold (1987), in his "The Mammals of Nigeria", says "Mammals of the Sahel savanna experience a very severe environment characterized by high daytime temperatures, cool or cold nights, high insolation, low unpredictable rainfall, and low plant productivity. For all species, the problems of obtaining adequate water and food, and maintaining the body temperature at a constant level in spite of the widely fluctuating ambient temperature, determine all aspects of their ecology and behaviuor." He characterizes the small mammals of the Sahel as follows:

> "(1) Population numbers of small mammals fluctuate greatly from very low numbers during drought to high numbers after good rain and when food ius plentiful.
>
> "(2) All small mammals are nocturnal;" (except *A. niloticus*, which may come out during the cooler parts of the daytime) "during the heat of the day, they remain in burrows, hollow trees, caves, and other micro-habitats which are comparatively cool and moist."
>
> "(3) Efficient conservation of body fluids is essential for survival. All mammals combine a number of methods to ensure that the limited water in their food is not wasted. These include the production of dry faeces and very small volumes of concentrated urine, the selection of foods which contain relatively high amounts of water, the production of metabolic water, and the minimal use of water for evaporative cooling."
>
> "(4) Reproduction occurs only when food and water are plentiful. Consequently, several years of drought can mean the cessation of reproduction for several years, and therefore a dramatic fall in population numbers."

Hanney (1975) says of desert rodents: "The three main problems facing the desert-dweller concern shortage of water, lack of food and extremes of temperature." To avoid shortages of water he lists several characteristics of desert rodents: eating succulent vegetation for its stored reserves of water, living on metabolic water from the oxidation of carbohydrates, excreting very

concentrated urine, producing very dry feces, and avoiding high protein diets, since these cause an increase in urine excretion. Lack of food is circumvented by storing of food (seeds) in the burrows, having lowered metabolic rates, and sometimes aestivating (summer sleep or hibernation) during the food-short periods. Extremes of temperature are coped with by having fine silky fur for better insulation, by nocturnal activity, by retreating into the burrow during the heat of the day, by blocking the burrow opening to conserve humid conditions, and by having long tails for better heat exchange.

Praomys (Mastomys), *Arvicanthis*, and *Gerbillus* are both granivorous and insectivorous. In the Sahelian area, the herbaceous vegetation is "alive" only during the rainy season, and seeds are the only forms of plant life available during the long dry season. It is probable that large amounts of these are stored inside the burrows of the gerbils during the protracted dry seasons. Arthropods are also eaten by the rodents; caterpillars (during the rainy season); beetles and termites during the dry seasons. *Gerbillus* probably is more insectivorous than *Praomys*, which in turn is more insectivorous than *Arvicanthis*.

The main cause of mortality in all species of Sahelian rodents is predators, such as foxes, jackals, genets, owls, and other birds of prey. Annual mortality in *Arvicanthis* and *Praomys* is high; rarely would animals live for one year, and for most, the life span is 8 months or less. Mortality rates may run as high as 50% per month in these species at times of peak densities. At peak densities the main cause of deaths is disease and parasites. Mortality produced by predation is continual but its intensity may vary according to the density of the rodent populations; whereas mortality due to epizootics is connected with outbreaks and acts quickly but only temporarily.

Arvicanthis and *Praomys*, because of their ability to produce large numbers of young in each litter when plant foods are abundant and nutritious, have the capabilities of quickly reaching outbreak proportions. This occurs mainly in the absence of significant predation. Following several years of the rodent populations being very low, predators tend to move on, die from starvation, or resort to other types of prey (insects, lizards, etc.) to survive. Pest rodents can quickly breed and reach outbreak numbers before predators can respond, since predators generally breed much slower. What few predators are around when rodents become super-abundant have an easy time of catching rats and quickly glut themselves. Rodent populations are usually "crashing" (rapidly decreasing back to their previous low levels) long before predators can cause a significant impact on their numbers.

2. COLLECTION AND PRESERVATION OF RODENT SPECIMENS*

2.1 Methods of Collection

(1) Snap Traps

The most successful trap for catching small rodents and insectivores is the snap trap. These traps are generally sold commercially in mouse-trap and rat-trap sizes. The larger, more powerful rat-trap is designed for killing mammals the size of rats and small squirrels. Designed for mammals of shrew and mouse size, the smaller mouse-trap is more effective, but the spring bar of the trap frequently crushes the skull of the specimen.

Most collectors prefer the Museum Special trap (Fig 1). This trap is intermediate in size between the mouse- and rat-trap and it is designed to kill mammals weighing up to 50 g. Advantages of this trap are an extremely sensitive trigger mechanism and a spring bar designed to break the specimen's back rather than crush the skull. Equipped with a weak spring, this trap can be used to catch small mammals such as shrews without seriously damaging the specimen. Snap traps should be checked at least once each day, preferably in the early morning. Dead animals decompose rapidly, especially in the warm climate of Sahel Africa. In tropical areas you may have to check traps more frequently as ants may quickly eat specimens.

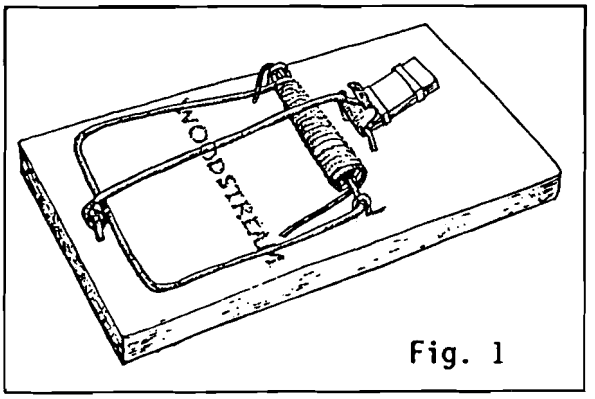


Fig. 1

(2) Live Traps

Live traps are used to obtain live mammals for special studies in the field and laboratory. Also, live traps permit the collector to select only those mammals required for specimens and release others unharmed. As some animals (e.g. shrews) may be reluctant to enter, live traps are generally not as effective as snap traps. To sample the small mammal population of an area accurately, both live capture traps and some snap traps should be used.

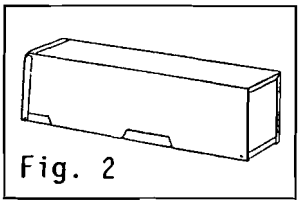


Fig. 2

The most popular traps for small rodents are the Sherman trap (Fig. 2) and the National or Tomahawk trap. The Sherman trap is a rectangular box made from aluminum or galvanized metal, has a spring-loaded treadle which releases the door when depressed. An assortment of sizes and models, including folding and non-folding models are available. To prevent deaths in live traps, check them several times daily, preferably early in the morning, mid-day, and late afternoon. The traps can be covered with a piece of cardboard, tree branches or grass leaves. Anything that will provide shade will help.

* Adapted from D. W. Nagorsen and R. L. Peterson, Mammal Collectors' Manual, Royal Ontario Museum, Toronto, Canada, 1980.

(3) Bait

An effective bait for small mammals that can be used in snap traps or live traps is a mixture of peanut butter and rolled oats. Chopped nuts, seeds, or raisins can be added to this mixture. In the dry heat of Chad an effective bait has been the use of small squares of cardboard dipped into maize or peanut oil. Plastic containers with screw-top lids are useful for carrying baits when checking traps.

(4) Operating a Trapline

To sample the small mammals of an area thoroughly, traps should be set in a variety of habitats (wadis, dunes, open savanna, etc.). The recommended procedure is to set the traps in a "trap line" at regular intervals and roughly in a straight line. Trap sites are marked by tying a piece of colored, plastic flagging tape or strip of cloth to a tree branch, shrub, or clump of vegetation. The total number of traps in a line (usually 25 to 50), the number of traps at each site, and the spacing of traps is determined by experience. To be certain that no traps are missed when checking a trap line, many collectors number their traps in sequence. Permanent numbers can be painted on live traps and numbers can be written with a pencil or indelible marking pen on wooden-based snap traps.

2.2 Collection of Data

2.2.1 Weights and Measurements

Mammalogists rely on weights and body measurements for aid in identifying specimens, determining the age of specimens, and for studying variation between different populations. It is essential that the collector record accurate measurements and weights before the specimen is prepared as a study skin or preserved in fluid. Study skins shrink during their preparation and reliable measurements cannot be made from the finished skin. Fluid-preserved specimens become stiff and inflexible once they have set in the fixative and are difficult to measure accurately. Measurements are always given in metric units. Linear measurements should be in millimetres and weights in grams or kilograms. Note any aberrant measurements resulting from damaged specimens (tail broken, ear torn).

The following are the standard measurements taken by most small mammal collectors (Fig. 3):

Head and Body Length (HBL): straight line distance from the tip of the nose to the beginning of the first tail vertebra. Lay the animal on its back on the ruler and measure by extending the specimen, pressing the body flat. Pull the body to its full length, measuring to the first tail bone.

Tail (T): distance from the base of the tail to the tip of the last vertebra, exclusive of the hairs. With the animal on its back, place the ruler at the point where the tail joins the body, pull the tail downward and measure to the end of the last bone.

Hind foot (HF): distance from the end of the heel bone to the end of the claw on the longest toe. Stretch the toes and measure from the heel to the longest length of the claws.

Ear length (E): distance from the base of the notch of the lowest part of the ear to the uppermost margin of the ear.

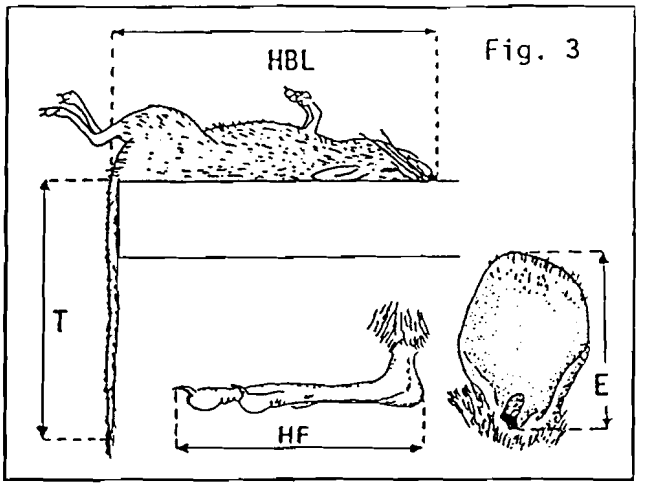


Fig. 3

Specimens should be weighed promptly and before preparing. A high quality spring balance for weighing small mammals is the Pesola scale. These come in a variety of sizes for weighing small mammals all the way from 25 g up to 30 kg. For most small mammals, the 100 to 500 g sizes are best.

2.2.2 Determining the Sex of Small Mammals

The external genitalia of the male usually can be distinguished from those of the female by larger size and their position relative to the anus. Most males have a prominent penis (Fig. 4), but some small mammals, particularly shrews, have the penis retracted into a sheath or tubular fold of skin during the intervals between the breeding seasons. With a fine, pointed forceps, it is usually possible to protrude the penis from its sheath.

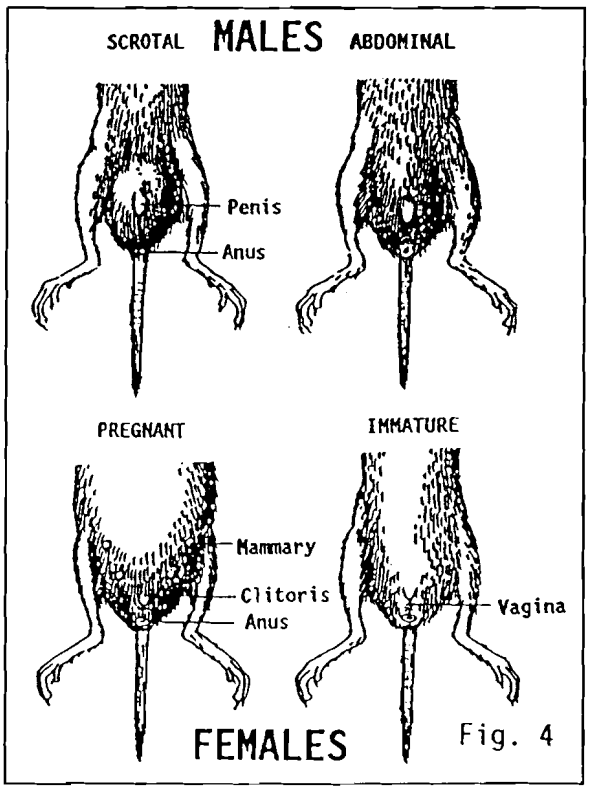


Fig. 4

In most adult males, the testes occur outside the abdominal cavity. When the testes occur outside the abdomen, they are usually situated in a scrotum. Testes may remain permanently in the scrotum (as in primates, dogs) or they may be intra-abdominal during the non-breeding season (as in most rodents). In shrews the testes are not in a scrotum, and although they are outside the abdominal cavity, they remain under the skin in the inguinal region.

The external genitalia of females consists of a vaginal opening and teats or nipples, which during the breeding season may be enlarged. The number and position of the teats vary greatly in different species. Rodents have the teats usually situated in parallel rows along the ventral surface of the chest and abdomen.

Internal Reproductive Organs

The animal should be necropsied after the skin has been removed, if the specimen is to be prepared as a study skin. Testes appear as whitish or creamy yellow-colored oval organs (Fig. 5). Females can be distinguished by the presence of a uterus and ovaries (Fig. 6).

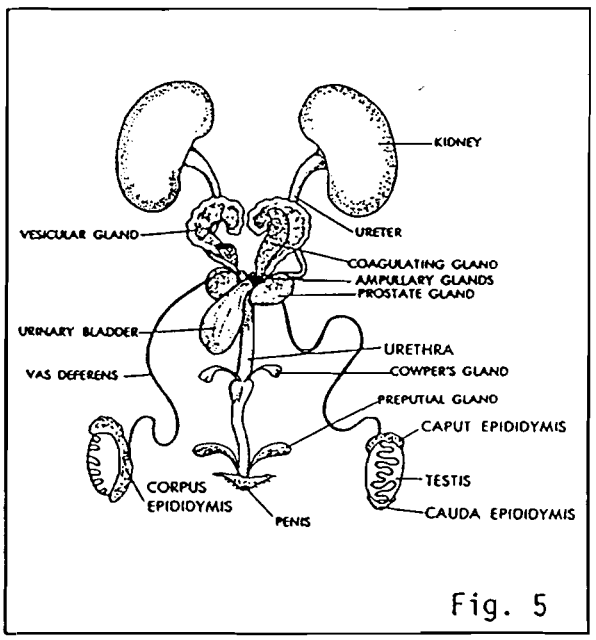


Fig. 5

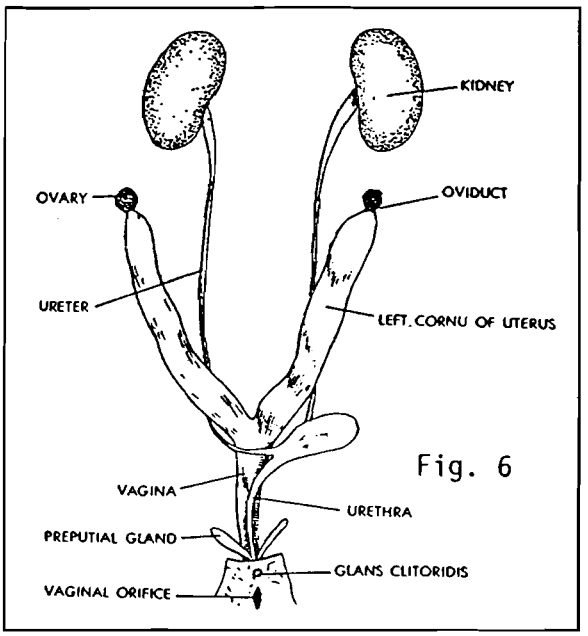


Fig. 6

Notes on the condition of the reproductive organs provide important biological data. The length and time of the year of the breeding season, litter size, numbers of litters per year, and the age at sexual maturity can be determined for a particular species from these data.

Males: Criteria used to distinguish breeding males are the size of the testes and the size of the tubules in the cauda epididymis. Measure the length and width of the testes in mm. See if the tubules of the cauda epididymis are visible to the naked eye; if they are, they appear swollen and usually contain sperm. However, if they are not visible, they are probably void of sperm.

Females: Breeding females may be pregnant, lactating, or both. Criteria used to diagnose the breeding condition of females are the condition of the vagina, presence or absence of visible embryos, presence or absence of placental scars, and the condition of the mammary glands.

Vagina: The vagina of the females is usually sealed (imperforate) by a membrane until puberty, which in most small rodents occurs anywhere from 42 to 70 days after birth. At the time of puberty, the vaginal orifice opens and in most rodents remains open, described as perforate.

Lactation: Lactation is defined as the secretion of milk. The following are used as evidence that a female is lactating: (1) female is observed nursing

young, (2) milk can be squeezed from the teats, (3) heavy deposits of mammary tissue that contain milk are present and can be seen only at necropsy.

Pregnancy: Pregnancy is defined as the condition of having a developing fetus or embryo. Females in late pregnancy may have a swollen abdomen and at this stage it may be possible to detect embryos by palpating the uterus. In necropsied animals, carefully examine the uterus. When examining the uterus, it may be helpful to dissect it out and stretch it on a piece of white board or paper. The presence of embryos is positive evidence of pregnancy (Fig. 7). Count and measure the crown-rump length (CR) of all embryos. This measurement is from the top of the head to the end of the rump, with the embryos not straightened. If more than one embryo is present, measure all and give an approximation of their size (e.g. 5 embryos, CR = 16 mm). In small mammals, some embryos may die and be resorbed into the uterus. Resorbed embryos appear conspicuously smaller and underdeveloped when compared to the normal ones. Be careful to distinguish any resorbed embryos when recording embryo counts (e. g. 5 normal embryos, CR = 15 mm; 2 resorbed embryos, CR = 3 mm).

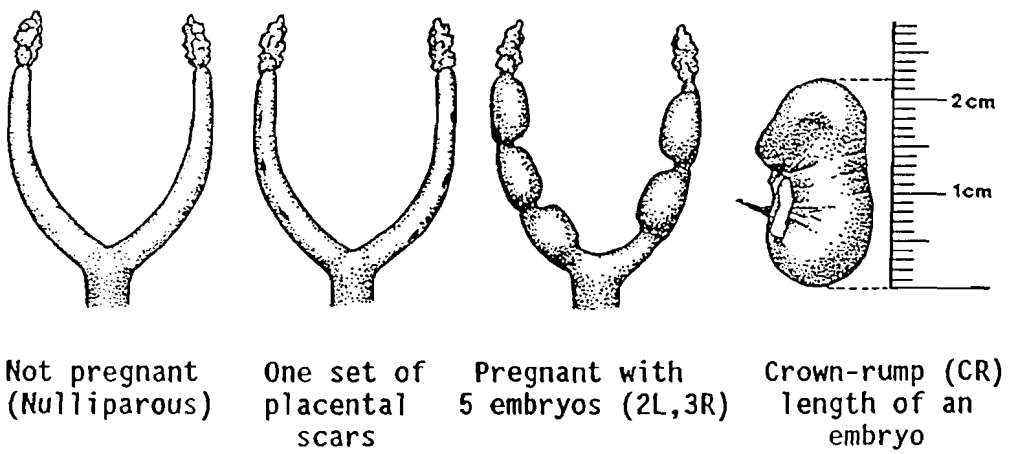


Fig. 7

The uterus should also be examined for the presence of placental scars. In some mammals (shrews, rodents, carnivores), after a female gives birth, placental scars form at sites in the uterine wall where embryos were implanted. These scars appear as yellow to black pigmented spots on the inside of the uterus. Although the scars become increasingly paler with age, they may persist for one year in mice and rats. Generally the number of scars corresponds to the number of embryos. However, embryos that die during pregnancy will also leave scars and because scars from several litters may be present, the number of scars is not always a reliable indication of litter size. The presence or absence of placental scars is important in determining the reproductive history of the animal. When scars are badly faded, scars from several litters are present, or when scars are obscured by embryos, it may not be possible to count them accurately. If two (or more) sets of scars representing two (or more) different pregnancies are present, one set of scars will appear larger than the other. Although it may be impossible to count all

scars, it is important to indicate that two (or more) sets of scars were observed.

With the data obtained from examining the uterus, females can be classified as: nulliparous - no embryos or placental scars; primiparous - embryos or one set of placental scars; multiparous - embryos and one (or more) sets of scars present, or two (or more) sets of placental scars present.

2.3 Methods for Preparing Specimens

Three kinds of specimens are usually prepared from mammals: skins with accompanying skulls and/or partial skeletons, complete skeletons, and entire mammals preserved in fluid. Each has advantages and disadvantages and the kind of specimen prepared depends upon the objectives of the collector and the local circumstances. The condition of the specimen will often determine the kind of specimen that should be prepared. Live-captured animals make the best specimens for fluid preservation, after appropriate humane killing. Mammals from snap traps can usually be prepared as study skins. Decomposed specimens in which the internal organs have deteriorated and the fur is slipping are best prepared as skeletons. A "skull only" should be salvaged if the remaining carcass is badly damaged.

2.3.1 Fluid Preservation

Because changes in tissues occur shortly after death, specimens should be preserved immediately after killing. To effectively kill small mammals without damaging the skin and skull, use an airtight jar, can, or plastic bag with a wad of cotton containing a few drops of chloroform or ether. Avoid inhaling these chemicals as they are toxic to humans. Ether and chloroform are also highly inflammable.

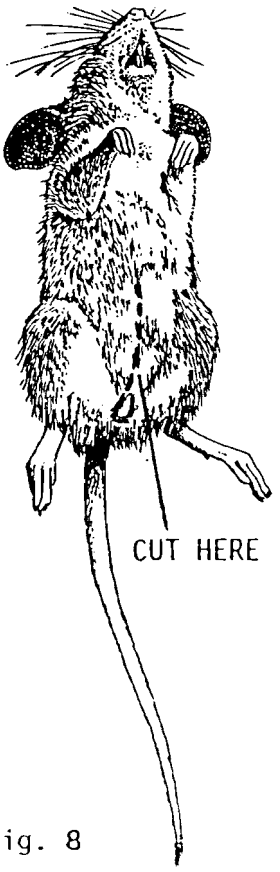


Fig. 8

The preparation of entire mammals in fluid involves two steps: fixing the tissues with a solution such as 10% formalin, Bouin's solution, or sodium acetate and transferring the specimen for permanent storage to a preserving fluid, for example, 65 to 70% ethanol or 45 to 60% isopropyl alcohol. "Fixing" halts enzyme processes in tissues and hardens or "sets" the specimen. Preservatives prevent the growth of microorganisms and also prevent gradual chemical or physical changes in the specimen's structure.

After specimens have been killed, weighed, measured, and given a number, a field tag should be tied securely to each. If paper labels are used, be certain they will not disintegrate in the preserving fluid. Using waterproof ink or a pencil, write the number and sex symbol (♀ for female and ♂ for male) on both sides of the label.

With the specimen on its back, and with the syringe full of formalin, insert the needle into the abdomen and slowly fill the body cavity until it becomes turgid. Do not inject too much fluid, but be sure that the body cavity is full and firm. After injection, the specimen is fixed by placing it in a jar, pan, or pail containing 10% buffered neutral formalin. Care should be taken to keep the specimen in a normal, relaxed position, for it will retain this shape permanently once it has been fixed. After 12 to 48 hours specimens are fixed and they may be packed more tightly in containers for storage. If specimens are to be stored for a long period before shipment, they should first be washed thoroughly in fresh water and then placed in 65 to 70% ethanol or 45 to 60% isopropyl alcohol.

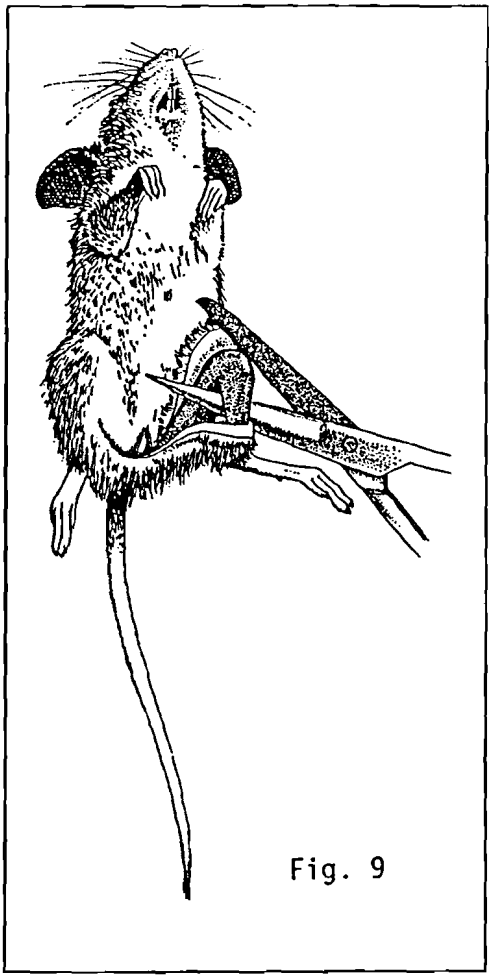


Fig. 9

2.3.2 Preparing Study Skins

Three types of skins can be prepared for museum specimens: (1) Traditional study skins that are filled with cotton or a similar material to approximate the natural shape of the mammal. As the leg bones are normally left in the skin, a complete skeleton cannot be obtained and usually only the skull is kept. (2) Flat skins, which consist of the skin stretched over a cardboard outline. For a flat skin, it is possible to obtain a skull and much of the skeleton. (3) Tanned skins, which are first dried and later tanned for permanent preservation. A skull and skeleton can be obtained from a mammal prepared as a tanned skin with only the terminal digits left on the skin. However, as tanning requires special chemicals and methods, this method will not be covered here.

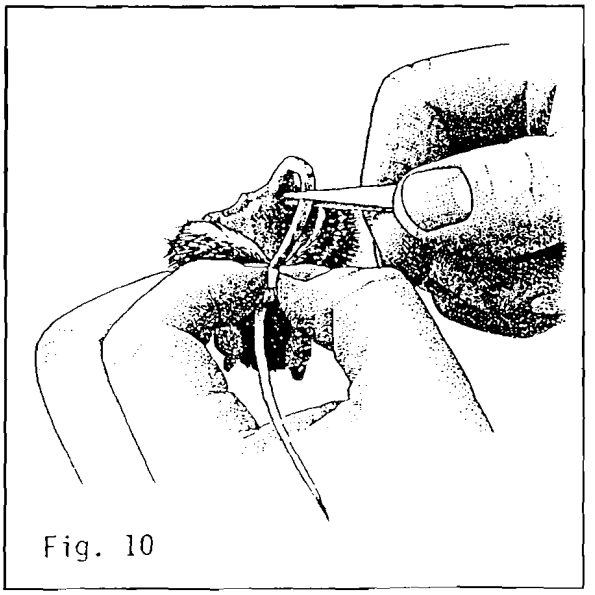


Fig. 10

Begin with a midventral incision from the level of the last rib to near the anus (Fig. 8). Always cut to one side of the penis so that the external genitalia remain attached to the skin. To keep the skin clean and dry, cornmeal, borax, magnesium carbonate powder, or sawdust may be sprinkled on the skin or placed in a skinning tray or pan to absorb blood and body fluids. Another skinning technique is to make an incision that extends across the lower

abdomen and down the inside of the leg to the heels. Leave the external genitalia on the skin by cutting between the anus and genitalia. For males that have a baculum in the penis, be careful not to cut or damage this structure for it may be an important aid in identification. With mammals such as mice, the baculum may be left intact in the penis to dry on the skin. If bacula studies are anticipated, remove the entire penis and store it in 100% glycerine, 10% formalin, or 70% alcohol. For larger mammals, the baculum should be extracted from the penis, tagged and dried with the skull and any skeletal material. With fingertips, a scalpel handle, or blunt forceps, work the skin free of the body wall in the vicinity of the incision. Try not to cut into the body cavity. Holding the hind foot, push the knee joint upward towards the midline of the body. Peel the skin off the leg to the ankle, then sever the leg at the hip or knee joint with scissors or a scalpel (Fig. 9). When the hind legs are free, work the skin to the base of the tail. Use care while skinning around the anus.

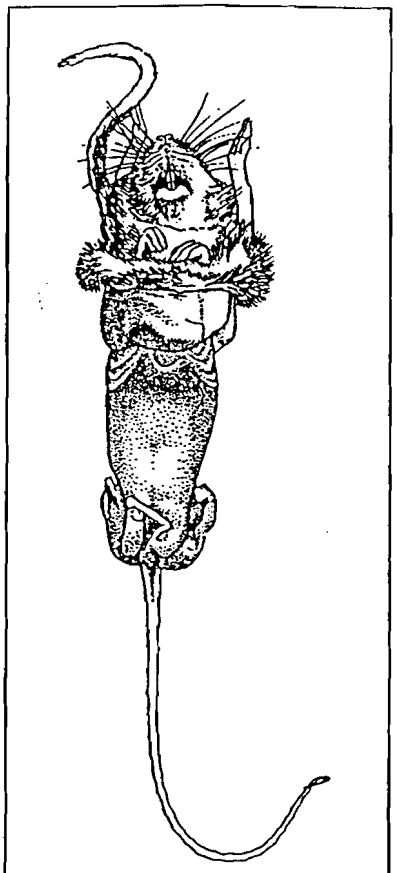


Fig. 11

If a fleshy tail is present, slip it out of the skin and later replace it with a wrapped wire. Rolling the tail on a table top or skinning board will help loosen the connective tissue that attaches the tail vertebrae to the tail sheath. For shrews, mice, and other small specimens grasp the tail at the base of the sheath with the thumb and index finger (Fig. 10) of one hand. Press the thumb- and finger-nails firmly against the tail vertebrae. Then with the other hand, slowly pull the tail vertebrae until they are free of the skin. If the tail vertebrae break off in the tail sheath, you must split the skin of the tail and remove the vertebrae. After inserting a tail wire, the incision should be sewn with a fine needle and thread. For mammals larger than a squirrel, it is usually necessary to split the tail by longitudinal incision in order to remove the vertebrae.

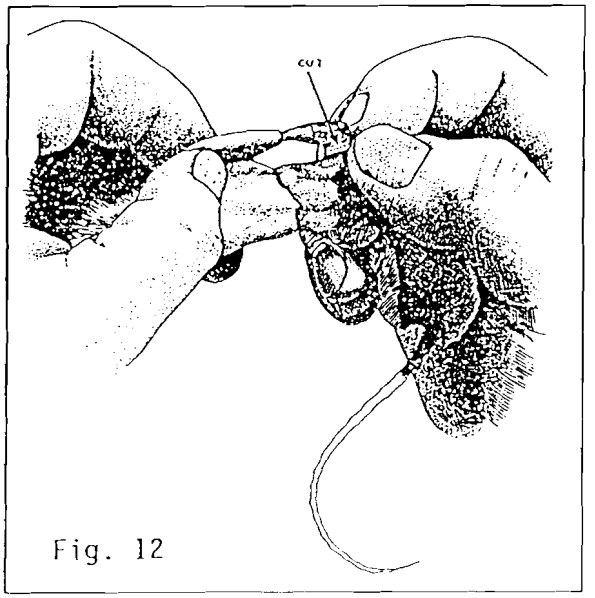


Fig. 12

With the tail free, the skin can now be peeled back to the region of the front legs (Fig. 11). Do not pull the skin off the body, as this will result in an overstretched study skin. A recommended method is to use one hand to gently push the skin off the body and with the scalpel held in the other hand, sever any connective tissue holding the skin

to the carcass. Remove the skin from the front legs down to the ankle. With scissors or scalpel, cut the front legs at the shoulder joint (Fig. 12). Peel the skin over the chest area to the base of the skull.

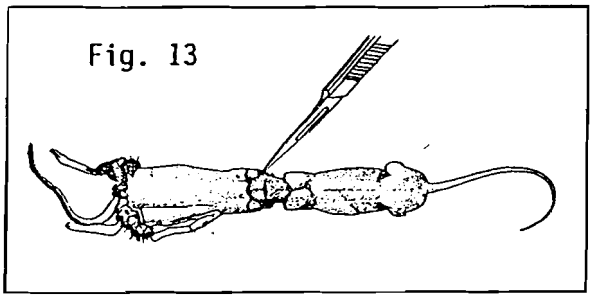


Fig. 13

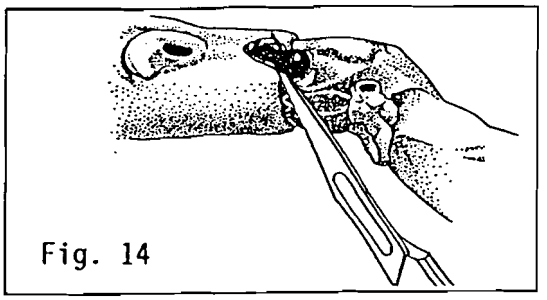


Fig. 14

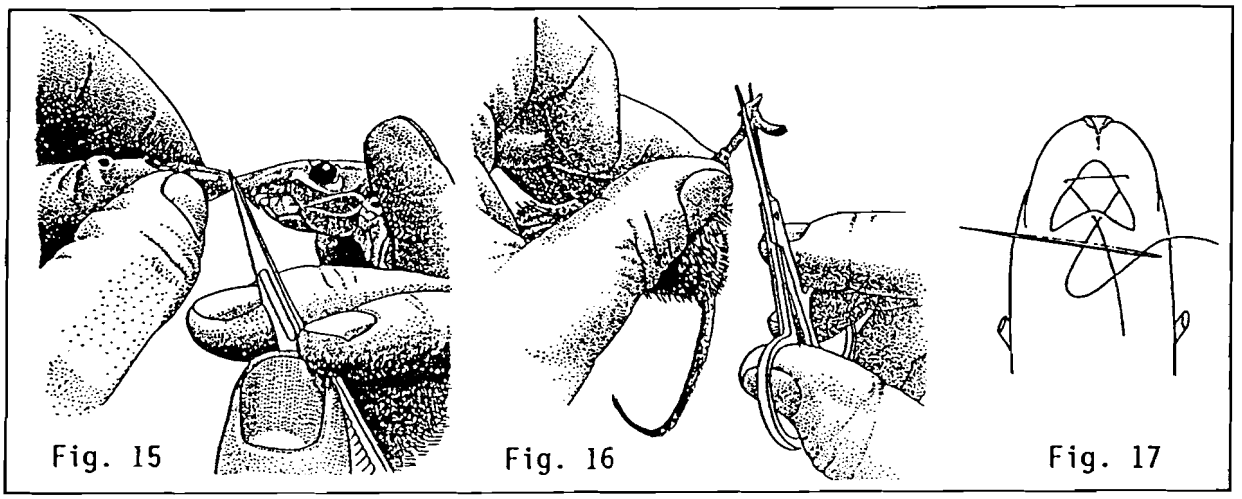


Fig. 15

Fig. 16

Fig. 17

Probably the most difficult stage of the skinning operation is to remove the skin from the head region without damaging the ears, eyelids, lips, and skull. Use a sharp scalpel for skinning the head region. Carefully work the skin over the head until you reach the cartilaginous bases of the ears (Fig. 13). Pick away any fatty tissue that may obscure the ear cartilage and sever the cartilage at the base of the ear. Continue to peel the skin over the head until the eyes are exposed. With the skin held away from the head, cut the membrane that covers the eyes (Fig. 14). The skin should be still attached in the eye region at the front corner of the eyelid. Carefully cut this attachment with your scalpel but avoid cutting into the eyelid, as the skin of the eye region will tear when the skin is stuffed. Work the skin to the lips and sever the connective tissue that attaches the lips to the skull. Finally, peel the skin forward until it is attached to the body only at the tip of the nose. Cut the nasal cartilage being careful not to cut into the nasal bones of the skull (Fig. 15).

Once the skin is removed, dissect the carcass for reproductive data, then direct your attention to the skin. Remove all fat and excess flesh from the skin. To accelerate drying and inhibit insect damage, rub a drying agent into the flesh side of the skin. Magnesium carbonate is recommended for study skins and flat skins. Borax can also be used as a drying agent-preservative.

For smaller mammals, fat and flesh can be picked off the skin with the fingers; however, it may be necessary to use a dull knife to remove this material from larger mammals.

Remove the muscle tissue from the leg bones with scissors, scalpel, or forceps (Fig. 16) and rub the bones in magnesium carbonate. Restore the legs to their approximate original shape by wrapping the bones with cotton to replace the muscles. With the skin still reversed, sew the lips together (Fig. 17).

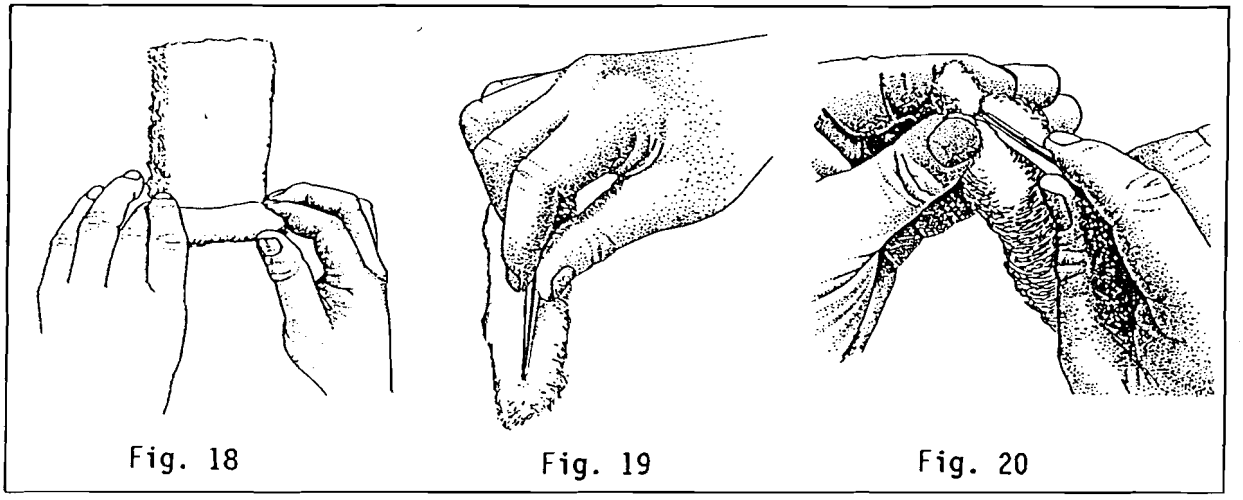


Fig. 18 Fig. 19 Fig. 20

Now the skin is ready to fill with a body and head made from a single piece of cotton. Roll the cotton into a smooth cylindrical bundle that is slightly longer and thicker than the body of the mammal (Fig. 18). Form the head region of the cotton filler with a pair of forceps by pressing in the center at the end of the roll (Fig. 19). Grasp the two corners on either side of the forceps, fold together, and take a new hold of the pointed end and shape as a smooth cone (Fig. 20).

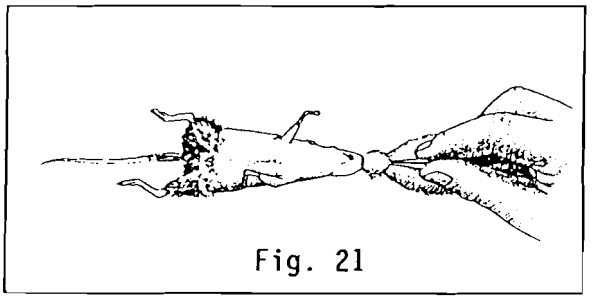


Fig. 21

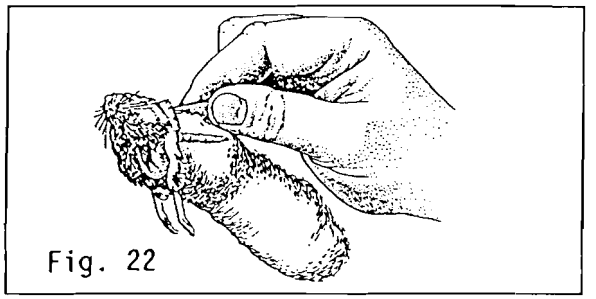


Fig. 22

Place the cone into the head of the skin and reverse the skin over the points of the forceps (Fig. 21, 22). Adjust the eyes, ears, and mouth, then continue to reverse the skin slowly over the cotton until the specimen is completely filled. The length of the cotton body can be trimmed with scissors to fill the skin properly (Fig. 23).

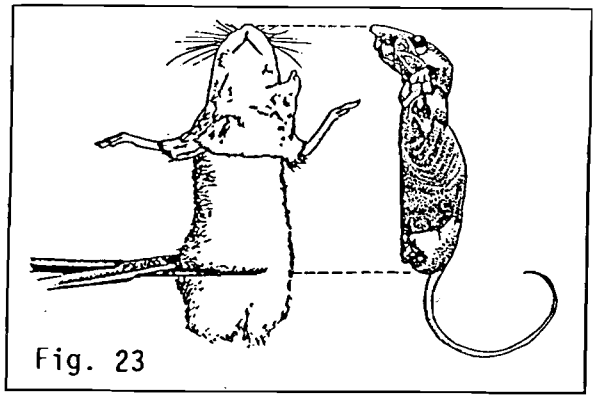


Fig. 23

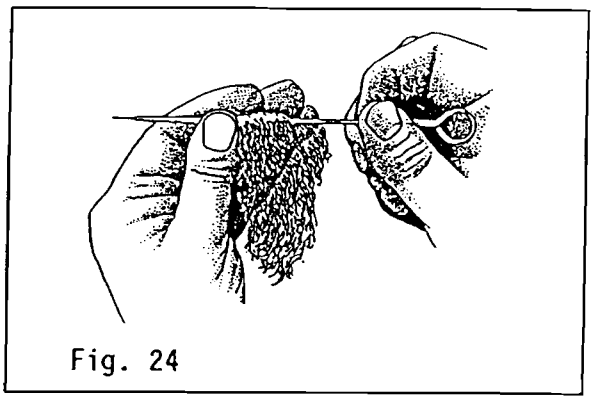


Fig. 24

If the tail vertebrae were removed, then an appropriately sized wire wrapped with cotton must be inserted into the tail for support (Fig 24). If available, use Monel wire, as it will not corrode. Cut the wire to a length that extend from the tip of the tail to midway into the body. A loop at the body end of the wire provides added strength and stability to the finished specimen. Wrap thin wisps of cotton to form a shape similar to that of the original tail vertebrae (Fig. 25). It may be necessary to moisten the tail wire with saliva to make the cotton adhere. Pad the portion of the looped tail wire that extends beyond the tail into the body cavity with a thin piece of cotton then stitch the midventral incision with a fine needle and thread (Fig. 26) and tie a field tag to the hind foot of the skin.

The next step is to anchor the study skin to a skinning board (cardboard or corkboard) for drying. Careful pinning is the key to a well-prepared skin. For most mammals the front and hind feet are positioned parallel to the body and held in place with pins through each foot and a pair of pins at the outer side of each hind foot near the heel (Fig. 27). Anchor the tail by a pair of pins angled across its base and by one pair angled across the tip. To shape the ears and head, use pins placed against the sides of the skin.

Check to be sure the head is symmetrical and, if necessary, a thin (insect) pin may be used to anchor it in place. The eyelids may be held open by pulling through a small bit of cotton from the head. A final check of the specimen should be followed by cleaning the fur with a small brush (a toothbrush) to remove dirt or dust (Fig. 28).

The pinned specimen should be allowed to dry thoroughly. Drying time will vary considerably with local conditions. In hot, dry climates, stuffed skins may dry in one day. A shaded area with good air circulation provides the best conditions. Do not place skins in direct sunlight as this fades the hair and intense heat may cause excessive shrinking of skins. When skins are dried, remove the pins and store the skins in cabinets or shipping boxes.

Flat Skins

Flat skins mounted on cardboard can be prepared for such species as shrews, mice, squirrels, and small carnivores. A method is recommended that will allow a flat skin and an almost complete skeleton.

Rather than make a cut along the midline of the abdomen, begin the cut at one heel, cutting through the skin at the back and inner side of the leg, across the base of the tail between the anus and external genitalia, and then extend the incision to the opposite heel (Fig. 29). Leave the external genitalia on the skin. Detach the skin from the legs and cut through the leg bone at the ankle of only one leg; leave that foot on the skin. On the opposite leg, detach the skin to the ankle and then cut the skin there. This foot is left attached to the body of the mammal as part of the skeleton. Now remove the skin from the tail and pull it towards the front legs. Do the same for front legs as the hind leg - leave one foot on the body of the mammal and detach the other foot with the skin. Remove the skin from the head region being careful not to damage the ears or lips. Dissect the carcass for reproductive data. Clean all fat and excess flesh from the skin and, to hasten drying, rub a drying agent (borax, magnesium carbonate) into the flesh side of the skin.

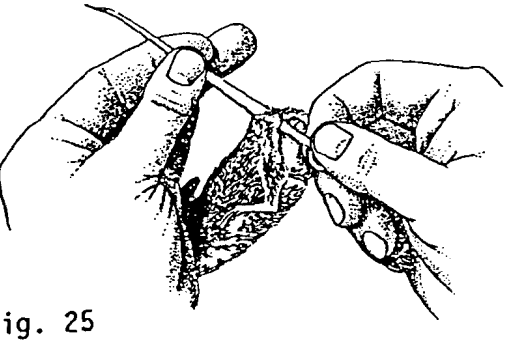


Fig. 25

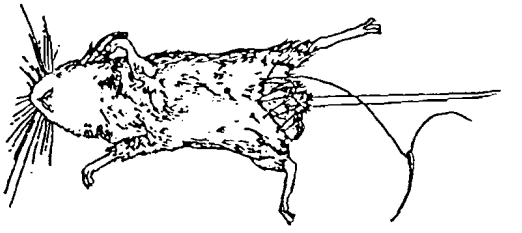


Fig. 26

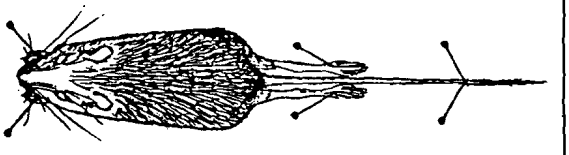


Fig. 27

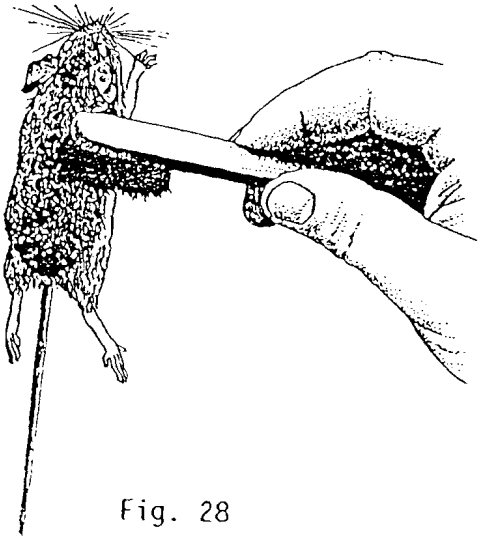


Fig. 28

Unlike the conventional study skin, the flat skin is stretched on a piece of cardboard or corrugated pasteboard. To prepare the stretcher, lay the skin flat on the board and trace its outline. Shape the card with scissors, leaving a sufficient amount of the card behind the shaped outline to support the tail and to permit writing of field data (Fig. 30). Use a board sufficiently thick to support the body fully. Pull the skin over the stretcher board, being careful not to overstretch. For small mammals, the skin is put on the board, fur side out.

Insert a wrapped tail wire for support as with conventional study skins and tie the hind foot and base of the tail to the board with thread (Fig. 31). Heavy needles are required for piercing the cardboard. Small pins are used for holding the front foot in position for drying and for shaping the lips if necessary. use a toothbrush for a final cleaning of the fur. Tie the field number to the stretcher card and write the field number on the card in case the tag is lost.

Flat skins dry quickly and under optimal conditions they may be sufficiently dried in one day. Follow the precautions for drying study skins, that is, keep flat skins out of direct sunlight and protect them from insect pests. After they have been dried, flat skins can be packed compactly into boxes for shipping.

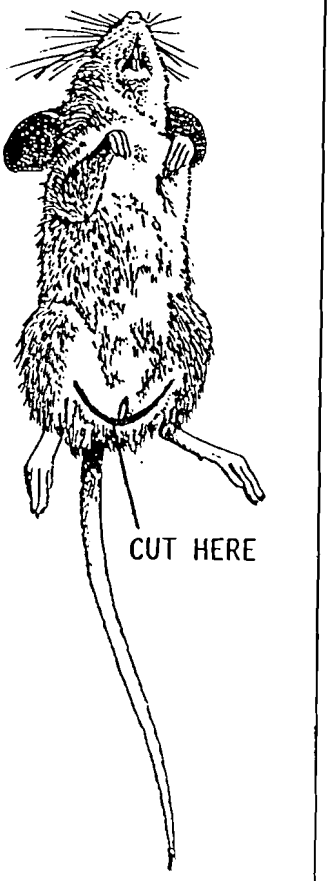


Fig. 29

2.3.3 Preparing Skulls

After the study skin in finished, start work on the skull. Care should be taken to prevent damage to any part of the skull. Separate the skull from the carcass by severing at the joint of the skull and the first vertebra. Fragile skulls from mice and shrews are dried without any cleaning. However, the brain, eyes, tongue, and heavy muscle layers should be removed from skulls about the size of squirrels or larger. A piece of wire with a small hook on the end can be used to pick the brain tissue out of the cranium, or the brain tissue can be flushed out of the skull with a syringe. Cut the muscles attaching the eyes and tongue with scissors and then pull these organs from the skull using forceps. Heavy muscle tissue can be removed using a scalpel or scissors, but be extremely careful not to damage the thin processes on the skull.

Thoroughly dry skulls in the field. An efficient method of drying skulls is to place them in cloth bags. Make the bags from cheesecloth or other

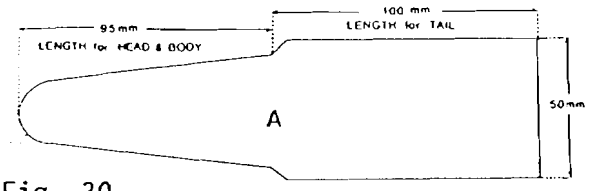
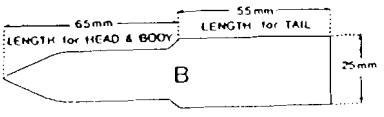


Fig. 30



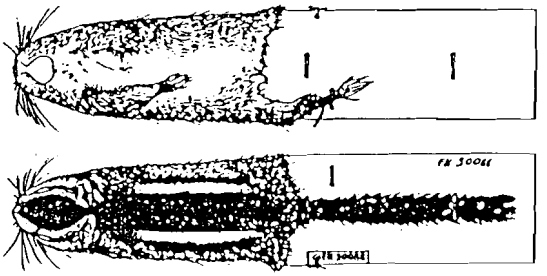


Fig. 31

porous materials. Write the field number in pencil on a heavy paper or cardboard tag and tie it to the skull. The same number can be attached to the outside of the bag (Fig. 32). Skull bags can be strung on a wire and put out in a ventilated place to dry. Ensure that skulls cannot be reached by animals that might be attracted to them. After skulls have completely dried, they can be compactly packed for shipping.

Skulls may be stored in 10% buffered neutral formalin, after thorough cleaning of excess flesh and after washing out the brain tissue. Another option is to put the cleaned skull into "weak" (1-2%) formalin and then clean the flesh from it after it fixes for a week or 10 days. Always ensure that a skull tag with the animal's field number on it is tied to the skull.

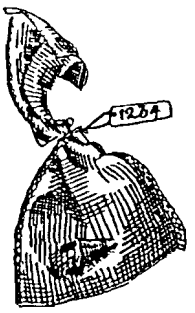


Fig. 32

The usual method of cleaning skulls after they have dried is to place them into a colony of dermestid beetles. These carnivorous beetles will remove every bit of meat, whether dried or not, within a matter of days.

Fixing and Preserving Fluids

Formulas for preparing several of the fixatives and preserving fluids mentioned in this chapter are given below.

Alcohol, ethyl 70%:	95% ethanol	70 ml
	Water	25 ml
Bouin's fluid:	Picric acid, saturated aqueous soln.	750 ml
	Formalin (40% formaldehyde)	250 ml
	Acetic acid, glacial	50 ml
Embalming fluid:	Formalin (40% formaldehyde)	1 part
	Glycerin	1 part
	Phenol	1 part
	Water	85 parts
Formalin, 10% neutral buffered:	Formalin, (40% formaldehyde)	100 ml
	Distilled water	900 ml
	Sodium acid phosphate ($NaH_2PO_4.H_2O$)	4.0 g
	Anhydrous disodium phosphate (Na_2HPO_4)	6.5 g

3. RODENTICIDES AND BAITS

3.1 Characteristics and Toxicity

Most programs to control rodents, besides using environmental management options, depend upon the application of poisons, called rodenticides, incorporated in either food baits, powder, or water. These rodenticides are classified either as *chronic* (multiple dose, slow-acting) or *acute* (single dose, fast-acting) compounds. Of particular importance are the anticoagulant rodenticides since these slow-acting compounds are now regarded as first-choice rodenticides against rodents. Acute rodenticides still have a part to play but they are principally and most effectively used in situations demanding a rapid reduction of high-density rodent populations.

3.1.1 Chronic rodenticides

The various anticoagulant (chronic) rodenticides have a similar physiological action in that they disrupt the mechanism that controls blood-clotting and cause fatal internal hemorrhages to develop. Their action is cumulative and all of them need to be ingested over a period of several days to be effective. Anticoagulants possess two main advantages over acute rodenticides. First, they are readily accepted by rodents when they are included in bait at low concentrations so that sublethal dosing and bait-shyness problems do not normally arise. Second, primary and secondary poisoning hazards to non-target species are reduced and if accidental poisoning of man or animals does occur, an effective antidote, vitamin K_1 is available. Even so, the utmost care must be taken in their application.

There are about 12 or so anticoagulants in current use in various countries throughout the world. Since their distribution is so limited in Chad, we will discuss only three: warfarin, chlorophacinone, and brodifacoum.

Warfarin

Warfarin was the first anticoagulant to be developed as a rodenticide and it has had the most widespread use. Warfarin requires multiple doses (usually a daily dose for 5 days) in which to be effective. Against most rodents it is used at a concentration in baits of 0.025%. Since it is supplied as a concentrate of 0.5% warfarin mixed with inert ingredients, it is used as one part concentrate to 19 parts bait ingredients to give the correct field concentration. At this concentration, each gram of bait contains 0.25 mg of warfarin. The usual amount of warfarin that kills rodents is 1 mg/kg per day for 5 days. This means that if a 250 g rat ate 1 g of bait per day for 5 days, the poison should kill it, whereas if it ate 5 g of bait in one day it probably would not be lethal.

Warfarin, even though called a "first generation" anticoagulant, remains an excellent rodenticide to use in many situations involving pest rodents. If baiting sites are checked several times a week and fresh warfarin baits laid where needed, then usually only two weeks of baiting are needed to bring a rodent population to its low point.

Chlorophacinone

Chlorophacinone is available as a 0.28% concentrate in mineral oil, which is diluted to 0.005% in the final bait mix. Chlorophacinone is more toxic to most African pest rodents than is warfarin. Since each gram of bait contains only 0.05 mg of poison, it still requires that rodents eat the baits for 5 days before dying. All anticoagulants act by their cumulative action against certain enzymes produced in the liver. In practice, anticoagulants are often put out and left in place for up to 2 weeks for the best results. Part of the reason for this is that certain rodents in a population will find the baits first and will feed heavily at the bait stations and sometimes keep other rodents from feeding. Those animals excluded must quite often wait until the more dominant animals start dying before they can feed. This may take up to 2 weeks for all animals to have access to the baits.

Brodifacoum

Brodifacoum is the most toxic of all the anticoagulants. Quite often only one dose will kill up to 50 to 60% of the rodents feeding on it. Death does not take place any more quickly than with warfarin or chlorophacinone (usually 4 to 8 days after feeding on the poison bait begins). Since so little is required, about 0.4 mg/kg for one to 2 days will prove lethal, the poison has been used as a once-per-week bait for 3 weeks. Only small baits (5 to 15 g) are placed out but they are put at many locations. The idea is that each time the bait is used, it kills a proportion of the population, say 60%. Again the following week, another 60% of the survivors are killed (60% of the 40% survivors = leaving only 16% of the original population alive). In the third week, 60% of the 16% survivors are killed, leaving only 6% of the original population alive. A final baiting would in all likelihood finish off these 6% survivors.

3.1.2 Acute rodenticides

Among the acute rodenticides, only zinc phosphide has received world-wide acceptance. This dirty-grey powder is easily mixed with broken grain baits by using a small amount of vegetable oil (maize, groundnut, cotton-seed, etc.) to coat the grain first. The oil also acts somewhat as an attractant to the rodents. Zinc phosphide currently is registered with the Environmental Protection Agency in the United States for many different field rodent situations. It has a good safety record as far as a lack of accidental primary or secondary poisoning of non-target animals and humans over the years. It gives off a faint odor of phosphorous (a garlic-like smell) that is unattractive to most animals and humans but does not repel rodents. This coupled with its dirty-grey color on baits generally precludes humans from eating the baits. Zinc phosphide breaks down rapidly when in contact with the acids in the rodents' stomach, releasing phosphine gas. This gas is quickly absorbed through the wall of the stomach into the blood, affecting respiration and cardiovascular functions.

Zinc phosphide generally is used in a 2% concentration when mixed with food baits. Information of its toxicity to the Sahelian rodent species indicate it should provide excellent kills when used against *Arvicanthis, Praomys, Gerbillus* and *Tatera.* One potential problem with zinc phosphide, however, is that it may induce bait-shyness (subsequent refusal to eat poison baits containing zinc phosphide after surviving poisoning with sublethal doses of the material) in some of the rodent species. Another problem is that the onset of poisoning symptoms make take place too soon for the rodent to have consumed a lethal dose. This leads to kills of only 60 to 80% when the material is used in the field. Generally, zinc phosphide is used in the field to give a quick knock-down of the rodent population. This application is followed with another one using one of the slow-acting anticoagulants in a different bait, since there may be bait-shyness to the previously used zinc phosphide bait in the surviving rodents.

3.2 Toxicity Testing

3.2.1 LD50 determinations

Toxicity is a relative term used to compare the poisoning power of one chemical with another. There is *acute* toxicity, where a chemical is effective in a single dose, usually, but not necessarily, in a short time following administration. In *chronic* toxicity several doses are usually required for the chemical to be effective and death may not occur for several days or weeks. *High toxicity* means that only a small dose (1mg/kg body weight) is effective; *low toxicity* means that high doses (>100mg/kg body weight) are needed for effectiveness. Certain factors can affect toxicity: the route of administration, whether intramuscular, intravenous, intraperitoneal, inhalation, dermal, or oral; the age of the animal; the sex; whether sick or injured; what type of carrier is used; the time of day; whether fasted or non-fasted, the ambient temperature; and the amount of dose given. The LD_{50} is a statistical measure of the toxicity of a poison. LD_{50} means the amount of poison that will kill 50% of a test group of animals when the dose is adjusted for body weight.

LD_{50} determinations usually are made by giving the material by gavage (by syringe and needle or by stomach tube) to a group of test animals. Animals generally are in a fasting condition (for 4 to 24 hours) since food in the stomach can cause highly variable results. Animals are assigned to dose groups by using animals of roughly equivalent weights and by using random numbers.

Test Requirements

Animal Type. Animals used will be mature and not obviously pregnant. They will not have previously been exposed to any toxicant and will have been recently trapped or freshly caught from a holding colony. Extremes in animal weights should be avoided. Animals should be allocated at

random to treatment and control (without toxicant but with carrier) groups.

Carrier and volume. Unless otherwise specified, all compounds will be dissolved or suspended in maize oil. For each of the animals used, a minimum and maximum volume range will be established and no animal will be given a total volume outside of these limits. For animals < 75 grams, use 0.3 to 1.0 ml; for animals between 75 and 300 grams, use 0.5 to 1.5 ml; for animals from 300 to 1000 grams, use 1.0 to 3.0 ml.

Fasting. All animals will be fasted a minimum of 4 hours and up to 24 hours to avoid administration of toxicant to animals with a full stomach.

Observation period. Animals will be observed for 14 days after treatment or longer if necessary.

Dosage progression. Graduated mg/kg (milligrams of toxicant per kilograms of body weight) steps are used. They are, for example, 2.0, 4.0, 8.0, 16.0 (a 2.0 progression factor); or 1.0, 1.6, 2.4, 3.7, 5.5, 8.0, 12.0, 18.0 (a 1.5 progression factor)

Number of dosage levels and animals. Four dosage levels will be used with a minimum of 2 animals per level; however, the number of animals used at each level must be constant and equal.

The material to be tested is dissolved or suspended in a vegetable oil, such as maize oil. Dissolve or suspend an amount necessary to provide 5, 10, 20 and 40mg/kg body weight of the material, or 1.0, 2.0, 4.0, and 8.0 mg/kg, when administered as a 0.5 to 1 ml dose. When dosing the first groups, use the 10 or 20mg/kg, or the 2.0 and 4.0mg/kg levels, and based upon mortality results, adjust the other dosings either up or down.

The dissolved or suspended material is gavaged by using a 1 to 5 ml syringe, with a ball-tipped feeding needle. Depending upon body weight, determine the amount to be given (for example, 1.5 ml of 10mg/kg solution for an animal weighing 150 grams). Each rat is held with it's back against the experimenter's hand, and it's neck between the experimenter's index and middle fingers. The neck is gently extended and the mouth is gently opened. The gavaging needle is gently inserted down the dorsal surface of the rat's esophagus to a point below the trachea. Care must be taken to avoid lung or liver damage or to perforate the intestine. After the gavaging needle is in the appropriate position, the dose of the chemical is administered, the gavaging needle withdrawn, and the rat returned to it's cage.

Animals are checked for any symptoms of intoxication in 1, 2, 3, 4, 8, and 24 hours following dosing. These symptoms could be labored breathing, slumping and sluggish posture, lying on it's side, convulsions, paralysis, and death.

After 24 hours, the animals should be checked daily for up to 14 days for death. Any other symptoms should be noted on the toxicity record. Mortality results, the number dead out of the number dosed at each dose level, are treated statistically using the method of Thompson and Weil. This is a very simplified version of a complex standard analysis with probits. When using this method, it is very important to keep the number of animals at each dose level equal. A minimum of 2 animals at each level can be used. This method, with its 95% confidence levels, provides a rough approximation of the LD_{50}, but this estimation is quite useful in calculating the concentration of the active ingredient required in the finished bait formulation. The estimation is done by using the following procedure:

Suppose the number of animals was 2 at each of 4 dosage levels, 5.0, 10.0, 20.0, and 40.0 mg/kg. Mortality was 0, 1, 1, 2.

Enter the following data notations onto the worksheet: the correct values are given in ( ).

n = the number of animals treated per dosage level; this may be 2, 3, 4, 5, 6, or 10. (2).

R = the geometric progression factor between dosages. For the example described here, it is (2.0).
K = the number of dosage levels minus one (4 - 1 = 3).
d = log constant between dosages, i e., the logarithm of R (.3010 in our example).
r = a set of mortality data. (0,1,1,2).
log Da = the logarithm of the lowest dosage level. (.3162).
f = a function from Table I. (0.5).
$^{\sigma}f$ = a function from Table I. (0.70711).
log m = logarithm of the LD_{50}.
The general formula for the LD_{50} is log m = log Da + [d x (f + 1)]

log m = .3162 + [.3010 x (0.5 + 1)] = .3162 + .4515 = .7677

LD_{50} = antilog of .7677 = 8.85 mg/kg.

Calculate the 95% confidence limits for the example from the formula, log m ± 2 (d x $^{\sigma}f$):

log m = .7677
d = .3010
$^{\sigma}f$ = from Table I (n = 2)(K = 3) = .70711
.7677 ± 2 (.3010)(.70711) = 2 x .213 = .426
.7677 ± .426 =
1.194 _____ .342, logarithms of the upper and lower limits

Upper limit = 13.2 mg/kg = the antilogarithm of 1.194 from the table of common antilogarithms

Lower limit = 2.2 mg/kg = the antilogarithm of .342 from the table of common antilogarithms

Thus, the LD_{50} of the example above is 8.85 mg/kg with 95% confidence limits from 2.2 to 13.2 mg/kg.

All tables and worksheets necessary for these calculations are given as appendices to this chapter.

3.2.2 Caged Animal Trials

Following the LD_{50} determinations, trials of the test material should be carried out on individually caged animals. Based upon the LD_{50}, the approximate concentration needed to provide 0.5 to 10 x LD_{50} doses in 1 gram of finished bait are calculated and prepared as test baits. The test material is mixed into a bait formulation that is preferred by the test animals. This may be maize meal, wheat meal, millet meal, etc., with the addition of a small amount of sugar and/or oil. The several concentrations of the test material, ranging from 0.1% to 2% concentrations in the finished baits, are offered to groups of 10 individually caged animals, 5 of each sex, for periods ranging from 1 to 4 nights, depending upon whether acute or chronic toxicants. The materials can be given to the animals without any other choice of baits, or the same baits, with and without toxicant, can be offered. If paired cup trials are carried out, the position of the cups should be reversed each night.

Before the trial, all animals are weighed to the nearest 0.1 gram. The day the trial is started, papers are placed beneath each cage to catch any spillage from the cups. The amounts spilled are weighed back each morning. The amounts of bait eaten are calculated and the amount of intake of active ingredient are calculated from the intake and the animals body weight. All animals are observed for signs of intoxication and for mortality for 14 days after starting the trials. All animals dying are necropsied for signs of poisoning; i. e., congested lungs, internal hemorrhage, or pale or bleached liver.

Based upon the mortality at each concentration and the intake of the active ingredient, a concentration that provides 100% mortality and good intake of the finished bait is usually found. Sometimes several concentrations are found that give equal results; select the lowest concentration that will give the desired mortality.

3.3 Baits and Bait Preference Testing

In order to use a bait with the best chance of getting rodents to feed on it, tests to determine the bait preferences of local rodent species should be carried out. All commercially-available bait materials should be tested. Usually the cereal grains provide the best bait materials. They are easily

mixed into formulated baits and are preferred by rodents. They also have excellent keeping qualities when made into formulated baits.

One method to determine rodent preferences for baits is to conduct paired preference trials. In paired preference trials one bait material is tested against another. Usually at least 6 (10 would be better) individually-caged animals, 3 males and 3 females, are used for the test. These animals should have been trapped alive from suitable habitat and brought into the laboratory promptly from the field to prevent any injury or stress, or they could have been maintained in a colony in the laboratory. The freshly-captured animals are run from the live-capture traps into plastic or cloth bags and weighed and sexed. They are then caged and held for 3 weeks before any testing is done to exclude any pregnant females. All tested animals should preferably be adults. Make certain that all animals to be tested are feeding normally before the test.

On the day of the test, all animals are run into plastic or cloth bags and weighed. Measured amounts (15 to 20 g) of each food to be tested are put into food cups and the cups secured side by side at the front of the cage. Papers are placed below each cage to catch any spilled foods. The following morning the food cups are removed and weighed. Any spilled foods are put back into the proper cups. The difference between the previous weight and the weight the next day equals the amount consumed. On the second day of the test, the positions of the cups in the cages are reversed. The test is generally run for 4 nights. The differences between mean daily consumption of the two foods are checked statistically using the "t" test, the Chi-square test, or Fisher's Exact test can be used to see if one food was selected statically more times than the other. The preference testing should be repeated several more times using different individuals of the same species.

Paired preference tests can be run against all commercially-available foods using all permutations of choice. Or conversely, all foods can be tested against what the investigator suspects may be one of the more preferred foods, using it as the standard. The first kind of test gives results of the kind food A > food B > food C > food D. The second gives a relative ranking of each food compared to the standard; foods A, B, and C > standard while food E, F, and G < standard. Finally, from the test results, the investigator should be able to pick a preferred food with confidence; perhaps several foods are good choices.

3.3 Bait Formulation

The rodenticidal materials are usually supplied by the manufacturers as concentrates; the exception is zinc phosphide, which is supplied as the technical material (80 to 96% pure, depending upon manufacturer). Concentrates are less hazardous for the person formulating the baits than are the technically pure materials. Anticoagulants are usually used in a 1 part concentrate to 19 parts ratio with the bait ingredients. If using zinc

phosphide at 2% it would be used at a ratio of 1 part to 49 parts bait, or if only 80% pure would be used at 1 part to 39 parts bait. The bait ingredients should be of a medium ground meal or at least the cracked or broken form of the grain. This is done to get more surfaces for the poison to adhere to. A vegetable oil is added to help the poison stick to the grain. The best are maize and groundnut oils. Mix the oil with the grain first to minimize dust from the mixing operation, then add the poison concentrate mixed with a little oil. Mix the ingredients thoroughly for at least 15 minutes. Mixing of small amounts of bait can be done in a bucket, but if larger quantities are needed a bait mixer is required. The design of a simple mixer is shown in Fig. 1. This mixer is made of materials that should be easily at hand and require only some simple welding and woodworking skills. The mixing is best done under an exhaust hood to carry away any dusts but if a hood is not available, mix the ingredients outdoors in a spot protected from the wind. The person mixing the bait should wear a protective dust mask, disposable gloves, and coveralls over their regular clothes.

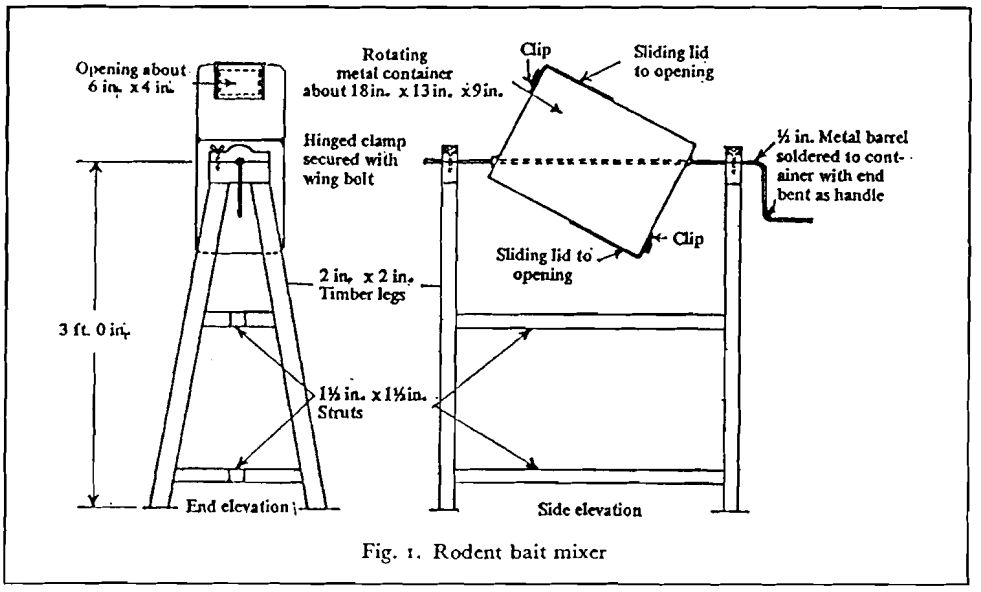


Fig. 1. Rodent bait mixer

After mixing, the formulated baits are packaged into units best used in the field. For anticoagulants this may be as 1 kg amounts packed into polyethylene bags and sealed. For zinc phosphide, it may mean 50 kg amounts packed into jute bags. All rodenticidal baits should be labelled with the name and concentration of the active ingredient.

Another formulation of the baits used successfully in south Asia is the "bait cake." This bait is made from equal amounts of wheat flour and either broken rice or ground maize. A vegetable oil is added at 2% concentration. The formula is 24 parts wheat flour, 24 parts rice or maize, 1 part oil, and 1 part zinc phosphide. All ingredients are mixed until the grey color of the zinc phosphide is thoroughly blended in the mix. Then add water slowly to the mixture until a stiff dough can be made. The dough is thoroughly mixed and put on a firm surface and rolled out until approximately 2 to 3 mm thick. Sometimes adding small amounts of flour to the dough will keep it from

sticking to the surface. After rolling into a thin cake, cut it into squares approximately 2 cm in size. Break these apart carefully and place the mixture out into the sunlight for a day or two to sun-dry. The cakes can then be packaged as either 100 g or 1 kg amounts into plastic bags, adding an appropriate label of active ingredients and concentration. If an anticoagulant bait is desired, change the formula to 47 parts wheat flour, 47 parts broken rice or maize meal, 1 part oil, and 5 parts anticoagulant concentrate. Mix, cut, and package as above.

Zinc phosphide can be recognized by its dirty grey color. Anticoagulant concentrates usually come with a warning color mixed into them. If for some reason the concentrate comes without any warning dye, add a small amount of methylene blue or any blue, green, or red food colorings that are at hand. If no dyes are available, add lampblack or finely ground charcoal to the bait mixture as a warning color to keep humans from eating the baits.

3.4 Safety Precautions

When formulating baits for rodent control, always observe these safety precautions:

(1) Mix baits under an exhaust hood or in the open air in a place protected from the wind.

(2) Wear a dust mask and disposable gloves. Do not eat, smoke, or drink without first washing the hands thoroughly. If non-disposable gloves are used, wash them with soap and water after use. If coveralls are available, wear them over the regular clothes.

(3) Clearly label all poisons (pure chemicals, concentrates, and formulated baits) should be POISON and held in a locked cabinet in a room which is also locked when not in use.

(4) Clearly label all containers with poisonous contents with the name of the active ingredient, its concentration, etc. Thoroughly wash empty containers before re-use or disposal.

(5) Use bait containers, if necessary, to prevent animals other than rodents from reaching the baits. Bait containers need to be weighted down where livestock could otherwise move them.

(6) When poison baits are laid, tell the occupier of the land or premises of their locations - so that children, livestock, and pets can be kept away.

(7) Do not lay poison bait where the excess cannot be picked up in order to prevent any later danger. Keep a record of the number and location of baiting points. After treatment, pick up all uneaten baits and bury in the ground or burn any rat or mouse bodies found. Check to see that all baiting points have been accounted for.

3.6 Field evaluation of rodenticidal baits

After selecting the best bait materials and finding the correct concentration of the candidate rodenticide, the investigator will wish to test it in the field. To do this locate at least two good infestations of the pest rodents to be treated; the infested areas each should cover several hectares in extent. One of the areas will serve as the treated area; the other will serve as the reference area in which any unusual changes in rodent numbers during the trial will be accounted for. Efficacy of a rodenticide is measured by a change in rodent numbers or rodent activity. These measures are taken before the treatments are done and after they are completed, usually called the pre-treatment and post-treatment periods. Rodent numbers are difficult to measure in the field. Generally, indirect measures of rodent population size are used; such things as activity at tracking tiles, amounts of food consumed over several days, a change in the number of active burrows, a reduction in rodent damage to a field crop, etc. Any one method, or a combination of them, or all may be used in evaluating the efficacy of rodenticidal field trials.

3.6.1 Estimating Rodent Activity

Rodent activity measures before treatment are useful because they can be compared with the same measures taken after treatment to estimate the success of the treatment. Activity measures are made using (1) inked tracking tiles, (2) food consumption at a number of baiting sites, (3) counts of active burrows in the area to be treated, (4) the numbers of rodents captured alive and released back into the population, and (5) the reduction in damage to a crop to be protected.

(1) Inked tracking tiles are vinyl floor tiles, measuring 30 by 30 cm. These may be cut into quarters, giving tiles 15 cm on a side. Ordinary mimeograph ink is applied to one-half the tile, the other half left clean. Tiles are placed along transects in the area to be treated and spaced about 10 m apart to try to cover the area. The tiles are placed out in both the area to be treated and the reference area. They are set in late afternoon and picked up and scored early the next morning. Rodent footprints are easily seen on the clean area of the tile; quite often other animals' footprints will be seen, such as beetles or birds. The tiles are scored as positive if a single rodent footprint is seen, negative if none are detected. The proportion positive out of the total number of tiles set is the measure of rodent activity. The ink can be cleaned from the tiles by wiping with a cloth soaked in acetone. Repeat the above given procedure in the same areas in a week after the end of the treatments.

(2) Food consumption to measure rodent activity is used in two ways; one is to place a weighed amount of excess food out in several baiting containers for several nights. The amounts remaining in each container are weighed the following morning. This is repeated for several days (5 to 10 days), or until food consumption reaches a peak. This peak amount equals the rodent activity at that time. If the rodents consumed 550 g overnight, this

level of consumption would be assumed to equal 100% of the rodent population.

The other way to measure rodent activity using food is to put out small measured or counted amounts of foods at many places within the treated and reference areas. For example, 3 peanuts or 10 millet seeds could be set out at marked sites at intervals of every 10 meters throughout the two areas. Do this for several nights to allow all rodents time to locate the sites. Score activity by the proportion of peanuts or seeds picked up out of the total number set. Be aware that other animals may be picking up these foods and, if so, try to eliminate these observations from the data. It might be desirable to put the foods into small containers to protect them from other animals. Repeat the above described procedure in a week after the completion of the treatment.

(3) Counting active burrows within the treated and reference areas is another method of determining activity of burrowing rodent species. It may be impossible to cover the entire areas so sampling transects are taken instead. The transect is usually at least 250 meters in length and may be 4 to 6 meters wide. The observer walks the transect and locates and records all active burrow openings for up to 3 meters distance on both sides. The same transects can be used for the post-treatment evaluations. All active burrows are counted on each area. A week after completing the treatment, the same transects are run again and all active burrows counted. Active burrows generally have fresh sand or soil at their entrances and the entrances are clean without cobwebs or other debris. If there is doubt about whether burrows are active, they can be closed and the next day only those that were opened can be counted. The percent reduction in the number of active burrows before and after treatment is used as the measure of efficacy.

(4) Capturing rodents alive, and then releasing them back into the population, on both areas, is another way of estimating rodent populations. Either the actual number of rodents caught or the trapping success are used as measures of the population. It is important to return the captured rodents back to the population otherwise the trapping will influence the treatment results. Appropriate live-capture traps are baited with a suitable bait and set in transects throughout the two areas, reference and treatment, before and after treatments are done. It is best to carry out the trapping for 3 nights. This is done because some animals are wary of traps for the first few nights after they are set. The total number captured in the 3 nights and the overall trapping success (the number of rodents captured divided by the number of effective traps set are used as the measures of rodent activity. A week after the treatment is completed this procedure is repeated. The difference in captures and in capture success are used as the measures of efficacy.

(5) Measuring the reduction in damage to a field crop after treatment for rodent control is yet another way of evaluating efficacy. Damage estimates are taken in field crops during the growing season, using both treated fields and untreated reference fields, as nearly alike as possible. Damage estimates should be taken before rodent control measures are applied

and then again several times following the control treatments. Crop-clipped samples can be taken in randomly chosen sites in the treated and untreated fields to estimate how much the yield was increased due to the rodent control measures.

Appendix 3.7.1. **TOXICITY RECORD**

Denver Wildlife Research Center

CHEMICAL _____ DRC _____ TEST MAMMAL _____

FORMULATION DATE _____ TEST DATE _____ OBSERVATION PERIOD _____ DAYS

TYPE OF ADMINISTRATION _____ APPROXIMATE LD = _____ /kg.

FORMULATION: _____

_____

COMMENTS: _____

Animal No.	Sex and Weight	Dosage λor mg/kg	Actual Dosage (ml)	Time of Admin.	TIME OF DEATH

thod employed as described by Wm. Deichman and T. LeBlanc in the Journal of ustrial Hygiene and Toxicology, Vol. 25, No. 9, pp. 415-417.

Investigator _____

GPO 835-723

LD_{50} DATA ANALYSIS WORKSHEET

(Thompson and Weil)

Notations

n = _____

R = _____

K = _____

d = _____

r = _____

Log Da = _____

f = _____

$^{\sigma}f$ = _____

LD_{50}

Log m = Log Da + [d x (f + 1)]

= _____ + [_____]

Anti Log m = LD_{50} = _____

Confidence limits (95% level)

Log m ± 2d x $^{\sigma}f$ = _____ x _____

Upper limit = Log m + _____

Lower limit = Log m - _____

LD_{50} _____(_____ - _____) 95% confidence limits

Table for Estimation of Median-Effective Dose by Moving-Average Interpolation.***

r-values	f	σ_f
(n = 2, K = 4)		
0 0 0 2 2	1.0	(0)
0 0 1 1 2	1.0	0.70711
0 0 1 2 2	0.5	0.5
0 0 2 2 2	0.0	(0)
0 1 1 1 2	0.5	0.86603
0 1 1 2 2	0.0	0.70711
1 0 0 2 2	1.0	(0)
1 0 1 1 2	1.0	1.41421
1 0 1 2 2	0.0	1.41421
1 1 1 1 2	0.0	2.0
0 0 1 2 1	1.0	1.41421
0 0 2 2 1	0.0	(0)
0 1 1 1 1	1.0	2.0
0 1 1 2 1	0.0	1.41421
(n = 2, K = 3)		
0 0 1 2	1.0	0.5
0 0 2 2	0.5	(0)
0 1 1 2	0.5	0.70711
0 1 2 2	0.0	0.5
1 0 1 2	1.0	1.0
1 0 2 2	0.0	1.0
1 1 1 2	0.0	1.73205
0 0 2 1	1.0	1.0
0 1 1 1	1.0	1.73205
0 1 2 1	0.0	1.0
(n = 2, K = 2)		
0 0 2	1.0	(0)
0 1 2	0.5	0.5
0 2 2	0.0	(0)
1 0 2	1.0	(0)
1 1 2	0.0	1.41421
0 1 1	1.0	1.41421
0 2 1	0.0	(0)
(n = 2, K = 1)		
0 2	0.5	(0)
1 2	0.0	1.0
0 1	1.0	1.0

Appendix 3.7.3

r-values	f	σ_f
(n = 3, K = 4)		
0 0 0 3 3	1.0	(0)
0 0 1 2 3	1.0	0.47140
0 0 1 3 3	0.66667	0.33333
0 0 2 2 3	0.66667	0.47140
0 0 2 3 3	0.33333	0.33333
0 0 3 3 3	0.0	(0)
0 1 1 1 3	1.0	0.57735
0 1 1 2 3	0.66667	0.57735
0 1 1 3 3	0.33333	0.47140
0 1 2 2 3	0.33333	0.57735
0 1 2 3 3	0.0	0.47140
0 2 2 2 3	0.0	0.57735
1 0 0 3 3	1.0	(0)
1 0 1 2 3	1.0	0.70711
1 0 1 3 3	0.5	0.55902
1 0 2 2 3	0.5	0.75
1 0 2 3 3	0.0	0.70711
1 1 1 1 3	1.0	0.86603
1 1 1 2 3	0.5	0.90139
1 1 1 3 3	0.0	0.86603
1 1 2 2 3	0.0	1.0
2 0 0 3 3	1.0	(0)
2 0 1 2 3	1.0	1.41421
2 0 1 3 3	0.0	1.41421
2 0 2 2 3	0.0	1.73205
2 1 1 1 3	1.0	1.73205
2 1 1 2 3	0.0	2.0
0 0 1 3 2	1.0	0.70711
0 0 2 2 2	1.0	0.86603
0 0 2 3 2	0.5	0.55902
0 0 3 3 2	0.0	(0)
0 1 1 2 2	1.0	1.0
0 1 1 3 2	0.5	0.75
0 1 2 2 2	0.5	0.90139
0 1 2 3 2	0.0	0.70711
0 2 2 2 2	0.0	0.86603
1 0 1 3 2	1.0	1.41421
1 0 2 2 2	1.0	1.73205
1 0 2 3 2	0.0	1.41421
1 1 1 2 2	1.0	2.0
1 1 1 3 2	0.0	1.73205
1 1 2 2 2	0.0	2.0
0 0 2 3 1	1.0	1.41421
0 0 3 3 1	0.0	(0)
0 1 1 3 1	1.0	1.73205
0 1 2 2 1	1.0	2.0
0 1 2 3 1	0.0	1.41421
0 2 2 2 1	0.0	1.73205

r-values	f	σ_f
(n = 3, K = 3)		
0 0 2 3	0.83333	0.33333*
0 0 3 3	0.5	(0)
0 1 1 3	0.83333	0.47140*
0 1 2 3	0.5	0.47140*
0 1 3 3	0.16667	0.33333*
0 2 2 3	0.16667	0.47140*
1 0 2 3	0.75	0.51539
1 0 3 3	0.25	0.375
1 1 1 3	0.75	0.71807
1 1 2 3	0.25	0.80039
2 0 2 3	0.5	1.11803
2 1 1 3	0.5	1.5 **
0 0 3 2	0.75	0.375
0 1 2 2	0.75	0.80039
0 1 3 2	0.25	0.51539
0 2 2 2	0.25	0.71807
1 0 3 2	0.5	0.70711**
1 1 2 2	0.5	1.58114**
0 1 3 1	0.5	1.11803
0 2 2 1	0.5	1.5 **
(n = 3, K = 2)		
0 0 3	1.0	(0)
0 1 3	0.66667	0.33333
0 2 3	0.33333	0.33333
0 3 3	0.0	(0)
1 0 3	1.0	(0)
1 1 3	0.5	0.55902
1 2 3	0.0	0.70711
2 0 3	1.0	(0)
2 1 3	0.0	1.41421
0 1 2	1.0	0.70711
0 2 2	0.5	0.55902
0 3 2	0.0	(0)
1 1 2	1.0	1.41421
1 2 2	0.0	1.41421
0 2 1	1.0	1.41421
0 3 1	0.0	(0)
(n = 3, K = 1)		
0 3	0.5	(0)
1 3	0.25	0.375
0 2	0.75	0.375
1 2	0.5	0.70711

Corrected values of σ_f where Weil's table (Biometrics, 1952, 8, page 253) is in error.

* Line-items inadvertently omitted from Weil's table (ibid.).

** In accord with original definitions (Thompson, Bact.Rev., 1947, 12, 115-45) and given plan (Thompson and Weil, Biometrics, 1952, 8, 51-4), Weil (ibid., 249-63) gave tables covering K = 3, n = 2,3,4,5,6 and 10; Thompson (oxalided, 18 + 3 pp) covered remaining cases for K = 1,2,3 and n = 4 to 10, and K = 4, n = 5. Values given above are for comparison and use, if needed; but not to encourage such use of n < 4.

FOUR-PLACE LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7965	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4
N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9

ANTILOGARITHMS

	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5	6	7	8	9
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	3	3	3
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	3	4
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
.34	2189	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9

ANTILOGARITHMS

	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5	6	7	8	9
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9

Logarithms

DEFINITION OF TERMS

The logarithm of a positive number is the exponent, or power, of a given base that is required to produce that number. For example, since $1000 = 10^3$, $100 = 10^2$, $10 = 10^1$, $1 = 10^0$, then the logarithms of 1000, 100, 10, 1, to the base 10 are respectively 3, 2, 1, 0.

The system of logarithms whose base is 10 (called the common or Briggsian system) may be used in all numerical computations.

It is obvious that $10^{1.5377}$ will give some number greater than 10 (which is 10^1) but smaller than 100 (10^2). Actually, $10^{1.5377} = 34.49$; hence $\log 34.49 = 1.5377$. The digit before the decimal point is the *characteristic* of the log, and the decimal fraction part is the *mantissa* of the log. In the above example, the characteristic is 1 and the mantissa is .5377.

The mantissa of the log of a number is found in tables, printed without the decimal point. Each mantissa in the tables is understood to have a decimal point preceding it, and the mantissa is always considered positive.

THE CHARACTERISTIC

The characteristic is determined by inspection from the number itself according to the following rules.

(*1*) For a number greater than 1, the characteristic is positive and is one *less* than the number of digits before the decimal point. For example:

Number	5297	348	900	34.8	60	4.764	3
Characteristic	3	2	2	1	1	0	0

(*2*) For a positive number less than 1, the characteristic is negative and is one *more* than the number of zeros immediately following the decimal point. The negative sign of the characteristic is written in either of these two ways: (*a*) above the characteristic, as $\bar{1}$, $\bar{2}$, and so on; (*b*) as 9. − 10, 8. − 10, and so on. Thus the characteristic of the logarithm of 0.3485 is $\bar{1}$, or 9. − 10; of the logarithm of 0.0513 is $\bar{2}$, or 8. − 10.

(*3*) Negative numbers do not have logarithms.

TO FIND THE LOGARITHM OF A NUMBER BY USE OF TABLES OF LOGARITHMS IN THE APPENDIX

Suppose it is required to find the complete log of the number 728. In the table of logarithms in the Appendix glance down the N column to 72, then horizontally to the right to column 8 and note the entry 8621 which is the required mantissa. Since the characteristic is 2, $\log 728 = 2.8621$. (This means that $728 = 10^{2.8621}$).

The mantissa for log 72.8, for log 7.28, for log 0.728, for log 0.0728, etc., is .8621, but the characteristics differ. Thus:

$\log 728 = 2.8621$	$\log 0.728 = \bar{1}.8621$ or $9.8621 - 10$
$\log 72.8 = 1.8621$	$\log 0.0728 = \bar{2}.8621$ or $8.8621 - 10$
$\log 7.28 = 0.8621$	$\log 0.00728 = \bar{3}.8621$ or $7.8621 - 10$

To find log 46.38. Glance down the N column to 46, then horizontally to column 3 and note the mantissa 6656. Moving farther to the right along the same line, the figure 7 is found under column 8 of Proportional Parts. The required mantissa is .6656 + .0007 = .6663. Since the characteristic is 1, $\log 46.38 = 1.6663$

LOGARITHMS

The mantissa for log 4638, for log 463.8, for log 46.38, etc., is .6663, but the characteristics differ. Thus:

log 4638	= 3.6663	log 0.4638	= $\bar{1}$.6663 or 9.6663 − 10
log 463.8	= 2.6663	log 0.04638	= $\bar{2}$.6663 or 8.6663 − 10
log 46.38	= 1.6663	log 0.004638	= $\bar{3}$.6663 or 7.6663 − 10
log 4.638	= 0.6663	log 0.0004638	= $\bar{4}$.6663 or 6.6663 − 10

Exercises. Find the logarithms of the following numbers.

(1) 464	(6) 0.621	*Ans.* (1) 2.6571	(6) $\bar{1}$.7931 or 9.7931 − 10
(2) 5280	(7) 0.9463	(2) 3.7226	(7) $\bar{1}$.9760 or 9.9760 − 10
(3) 96,500	(8) 0.0353	(3) 4.9845	(8) $\bar{2}$.5478 or 8.5478 − 10
(4) 30.48	(9) 0.0022	(4) 1.4840	(9) $\bar{3}$.3424 or 7.3424 − 10
(5) 1.057	(10) 0.0002645	(5) 0.0241	(10) $\bar{4}$.4224 or 6.4224 − 10

Sometimes the log of a number must be used in an algebraic equation, such as $y = 7.5 \log x$, or in graphs. If x is greater than 1, $\log x$ is positive and there is no special problem. If x is less than 1, however, $\log x$ is negative. This negative log, according to the above rules, is written as the sum of a positive mantissa and a negative characteristic. For algebraic manipulations it is preferable to treat $\log x$ as a single number with a definite sign, either positive or negative. For such a purpose, $\bar{2}$.7486 would be written as −1.2514, obtained by adding −2 and +.7486 algebraically.

Exercises. Write the logarithms of the following numbers as quantities suitable for insertion in an algebraic equation.

(1) 0.275 (2) 0.000394 (3) 0.0149 *Ans.* (1) −0.5607 (2) −3.4045 (3) −1.8268

ANTILOGARITHMS

The antilogarithm is the number corresponding to a given logarithm. "The antilog of 3" means "the number whose log is 3"; that number is obviously 1000.

Suppose it is required to find the antilog of 2.6747, i.e. the number whose log is 2.6747. The characteristic is 2 and the mantissa is .6747. Using the table of Antilogarithms in the Appendix, locate 67 in the first column, then move horizontally to column 4 and note the digits 4721. Moving farther to the right along the same line, the entry 8 is found under column 7 of Proportional Parts. Adding 8 to 4721 gives 4729. Since the characteristic is 2, there are three digits to the left of the decimal point. Hence 472.9 is the required number.

It should be understood that the antilog of 1.6747 is 47.29; the antilog of 0.6747 is 4.729; the antilog of 9.6747 − 10 is 0.4729; etc. On the other hand, the antilog of −1.6747 must be rewritten as antilog of $\bar{2}$.3253, or 8.3253 − 10, before the tables may be used, because only positive mantissas are found in the tables.

Exercises. Find the numbers corresponding to the following logarithms.

(1) 3.1568	(7) 0.0008	*Ans.* (1) 1435	(7) 1.002
(2) 1.6934	(8) 9.7507 − 10 or $\bar{1}$.7507	(2) 49.37	(8) 0.5632
(3) 5.6934	(9) 8.0034 − 10 or $\bar{2}$.0034	(3) 493,700	(9) 0.01008
(4) 2.5000	(10) 7.2006 − 10 or $\bar{3}$.2006	(4) 316.2	(10) 0.001587
(5) 2.0436	(11) −0.2436	(5) 110.6	(11) 0.5707
(6) 0.9142	(12) −3.7629	(6) 8.208	(12) 0.0001726

BASIC PRINCIPLES OF LOGARITHMS

Since logarithms are exponents, all properties of exponents are also properties of logarithms.

A. The logarithm of the product of two numbers is the sum of their logarithms.

$\log ab = \log a + \log b$ $\log (5280 \times 48) = \log 5280 + \log 48$

4. MONITORING RODENT POPULATIONS

4.1 Periodic Monitoring

If rodents are monitored from selected sites on a periodic basis and the monitoring methods are standardized, then any abrupt changes in the numbers of the rodents should be easily detected. If immature animals suddenly appear as a large proportion of a trapped population, then the investigator can assume that breeding has been good and may be able to predict that the up-coming breeding of this new generation may even lead to an outbreak of rodent populations in the area. Monitoring methods should be adequate to detect a 50% change in the population, either an increase or decrease. Several methods will be outlined here. In general, these methods will measure the relative abundance of rodent populations, or a relative change in rodent activity. It would be well to use several methods simultaneously, rather than relying on only one method.

4.1.1 Selection of monitoring sites

The sites to be periodically monitored should be selected on the basis that they are representative of the general area, whether sandy dunes grown with millet and sorghum or wadis with hand-irrigated small crop plots. Several sites of each crop type should be selected to account for local variations in food and cover available to rodents and to allow for variations in the distribution of rodent speciés. The sites should encompass a minimum of 100 hectares in area so that several transects or traplines can be selected within the site area. Transects or lines should be permanently marked and numbered. Then one or more transects or traplines are selected at random each monitoring trip. The sites should be scheduled for periodic monitoring, say every month, every other month, or quarterly.

4.1.2 Trapping

For simple purposes of merely estimating a rodent population, a line of traps may be useful. Snap traps should be placed in a reasonably straight line with 25 stations at 10 meter intervals (Fig. 1). The trapline should pass mainly through habitat typical of the site. Thus, in wadis, the transects should sample the crop plots as well as the thorny, brushy fencerows alongside the fields. If desired, two traps approximately a meter apart, can be set at each station. This will increase the efficiency of the trapline. Depending upon time available, the traps can be set for one to three days. Traps are set in the late afternoon, checked the next morning early and then left until afternoon in order to catch any day-time active *Arvicanthis*.

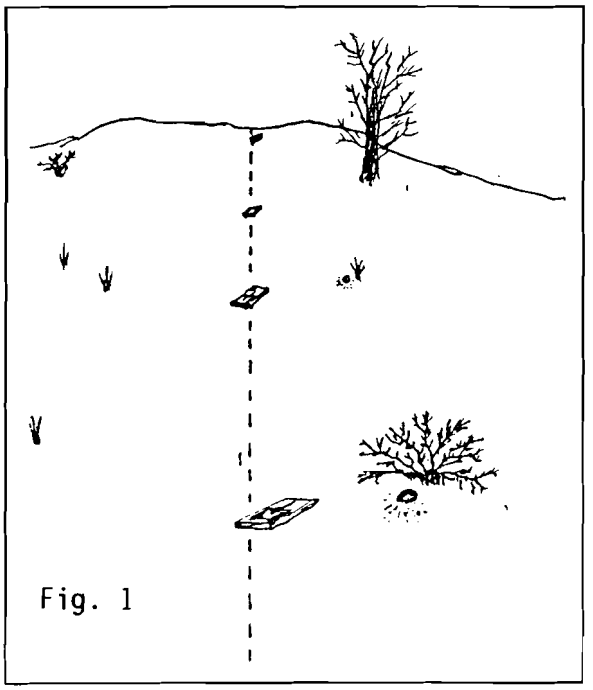
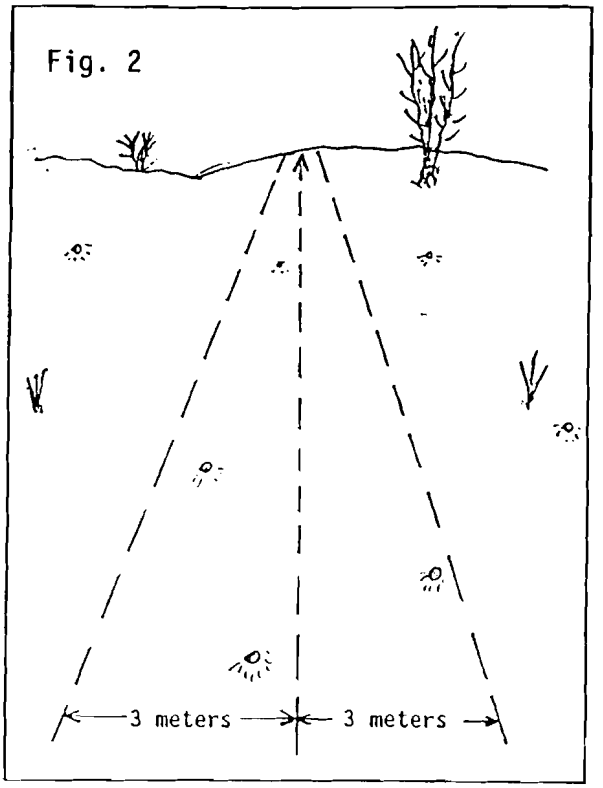


Fig. 1

Each captured rodent should be identified to species, sexed, weighed to the nearest gram, the head and body length, tail, hind foot, and ear measured; and assigned to a category of either adult or immature based upon body weight and development of sexual characters. All adult females should be necropsied to determine if visibly pregnant or not and the number of fetuses counted. The number of sprung traps without captures, divided by 2 since sprung traps are assumed to be effective for at least half the night, should be deducted from the number of traps set to determine the number of effective traps. The formula is: Total traps set minus (number of traps sprung/2), times number of nights trapped = effective trap nights (ETN). The number of rodents captured per effective trap night (or 100 ETN's) is calculated to give the relative abundance of the population. For example: 50 traps set for 2 nights, minus 5 (10 traps sprung divided by 2 = 5), equals 95 ETN. Twenty rodents captured, divided by 95 ETN = 0.21 rodents/ETN.

4.1.3 Burrow counts



Taking counts of active burrows along selected transects is another way of determining rodent activity. Permanent transects should be selected in representative habitats and run periodically just as suggested for trapping. The transects should cover a line 250 meters in length and should be about 6 meters in width (Fig. 2), 3 meters on each side of the observer. While walking along the transect, the observer would count every open, closed and fresh burrow within the transect. Do not include obviously old, abandoned burrows in the count. These counts are assumed to show some correlation of activity with the size and density of the rodent populations. For a valid statistical estimate of the population by this method, the lines or transects should be chosen at random and several replicates made to allow for the calculation of a mean and a standard deviation. The analysis of variance is applicable to this type of count.

4.1.4 Road counts

Counting rodents spotted at night while driving roads is another method of assessing rodent activity. Roads, selected at random, are driven in a vehicle moving at a given speed, say 20 to 25 km/hour, from just after sunset until about midnight. It is best to have two observers, one to drive and spot on one side of the road, the other to spot on the other side of the road. All

rodents picked up in the headlights of the vehicle are counted. These counts are taken periodically and the road patterns are driven in the same way and at approximately the same times each trip. Some allowance must be made for changes in the time of sunset and for the weather; cloudy nights may bring out rodents while bright moonlight may inhibit their activity. These occurrences should be recorded on the monitoring records. The results can be analyzed by the method described above for burrow counts.

4.1.5 Tracking tiles

Tracking tiles are inked (mimeograph ink) vinyl tiles, about 15 cm square. The ink is applied to one-half of each tile with a brush or rubber roller (Fig. 3). As rodents walk across the tile, they walk through the inked half and leave tracks of their footprints on the un-inked half. Tracking tiles are put out in transects much like traps would be, setting one every 10 meters or 10 steps, using a total of 25 tiles per line. They are usually set for only one night; if time is available, they could be run for 2 nights and the results averaged. Each tile is scored as positive or negative the following morning when they are examined. If they are to be immediately reused, the rodent footprints can be wiped clean with a light rubbing of acetone. Sometimes the ink must be reapplied. One major disadvantage is that if heavy dust or sand comes up during the night, the ink could become coated and gummy and some tracks may not be recorded. If several replicates are run, then a mean and standard deviation can be calculated and the data analyzed by ANOVA.

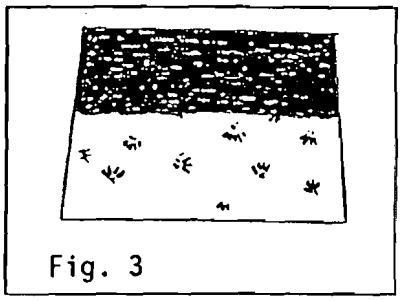


Fig. 3

4.1.6 Food removal

The removal of peanuts or seeds placed in small piles can be used to measure rodent activity. A counted amount of peanuts or millet seeds, say 3 to 10 per pile, are placed on the ground along the transect at measured intervals, every 10 meters. Take care to make sure that ants or other insects are not removing the food items. The number of food items removed along each transect each night is used as a measure of rodent activity. Again, as above, note the occurrence of cloudy nights or bright moonlight nights on the survey sheets. If replicated transects are run, selected at random, the mean and standard deviation can be calculated, allowing the analysis of variance to be applied.

4.2 Using the monitoring data

When each months' data, or whatever sampling period is used, are recorded, enter the information onto graph paper at the proper interval. Plot the data and note any changes from previous collection periods. If a sudden change is seen, say a doubling or tripling of the activity or numbers of rodents captured, look at the age structure of the trapped sample and at the pregnancy rate in the adult females. These could indicate that another breeding cycle is imminent and serve as the trigger for action. It is suspected that at

times of rodent outbreaks, the numbers increase 10 to 100-fold over those seenat times of rodent lows. What is desired in the monitoring process is to be able to predict when the rodent populations are about to become irruptive.

Before this can be done, other data should be collected. This would include monthly rainfall data for the current and preceding 3 years, the vegetation greening index, and the cereal grain crop yields for the current and preceding 3 years. A model for predicting plagues of house mice in Australia showed that the probability of a plague occurring in the following autumn is raised if: (1) grain yield in the current season is high but was low 2 years previously; (2) autumn rainfall in the current year is high; and (3) November rainfall (beginning of the harvest) is high and October rainfall is low in the current year. It is doubtful that there is any relationship between this predictive model and conditions in the Sahel.

Another predictive model was presented by French investigators working in Senegal. They hypothesized that the quality and quantity of available food - which, in turn, is correlated with rainfall - seems to be one of the most important factors regulating reproduction and survival in Sahelian rodents. In the absence of predation, parasites, and disease, abundant high-quality food may induce a rodent population outbreak. This is particularly true of *Praomys (Mastomys)* and *Arvicanthis* populations because of their high reproductive potentials. Their investigations in Senegal indicate that outbreaks seem to occur after a period with low rodent population densities (disappearance of predators?) and when there are two or more favorable rainy seasons. The first season allows the population to reach a "pre-outbreak" level, and then, if the following year is also favorable, the outbreak will finally take place. Rainfall is easily measured; this is not the case with the available food resources. Factors inherent in the rodent populations can be measured by regular trapping surveys.

In the Chadian Sahel, it appears that several factors may lead to a raised probability of high rodent numbers: (1) several years of drought, followed by 2 years of normal or above normal rainfall; (2) an absence of predators due to very low rodent populations; (3) a greening of the savanna vegetation, with subsequent production of high-quality grass and weed seeds; (4) a successful harvest of the millet and/or sorghum crop; (5) a good breeding effort by the residual pest rodent populations; (6) excellent survival of the immature rodents produced by the breeding; and (7) several additional breeding cycles by the newly-produced rodent generations. Thus, within a year of the increased rainfall, the greening of the savanna vegetation, and a harvestable-yield of grains, there could be an increased probability of a rodent outbreak.

5. DAMAGE ASSESSMENT METHODS

5.1 Introduction

Purpose: Assessment of the damage caused by rodents to growing crops and stored foods is done in order to establish the economic importance of the pest species in the country or in a local situation. This information is needed for planning purposes and for setting priorities for control programs. Sampling on a national scale is done to establish the extent of crop losses throughout the crop-growing areas. At other times, sampling may be done only in local areas, say a district or prefecture. Quite often limited damage assessments are done for research purposes to determine if certain control methods are effective or not; at other times damage assessments may be done over fairly large-scale areas for demonstration purposes. Damage assessment research on small plots requires more time and samples per plot while country-wide damage assessments require less time and numbers of samples per sampled plot but would need many more plots. If there is considerable variation between sampled areas in the amounts of damage, then this will require more samples or more sampled units.

5.2 Selection of Sampling Areas.

The selection of sampling units, fields, subplots, acres, or hectares, is an important element in starting any crop damage assessment procedure. It is usually impractical to sample all fields or subplots in an area, unless it is quite small, so samples must be chosen from the larger areas. For most purposes a sample of 100 to 200 units (fields, acres, hectares) taken randomly from an area is sufficient for statistical confidence. Sometimes the area should be broken down into similar types, or strata, based upon natural features or political boundaries (unions, districts, regions). This is known as stratified random sampling.

Having maps of the sampled areas simplifies the procedure, but detailed maps often are not available. In these cases recognizable boundaries, such as roads, streams, or boundaries between vegetation types, are needed. Sampling schemes based on kilometer blocks established along both sides of a given length of road have been useful in unmapped remote areas. Blocks are randomly selected and, within each block, random hectares or other area units are sampled for damage.

For example, suppose millet fields along several roads in a district need to be sampled for rodent damage. A starting point is selected and, using the odometer in the vehicle, each kilometer along both sides of the road are marked off. A piece of brightly-colored plastic engineering tape is tied to a shrub of clump of grass to mark each kilometer. Say 20 kilometers of road are marked, giving 40 kilometer square blocks available to sample (Fig. 1). Ten kilometer square blocks are selected at random, using a table of random numbers or simply drawing 10 numbers from 40 numbered slips. Then 10 sampling units within each square kilometer block (measuring a kilometer in distance perpendicular to the road) are also selected randomly. Each sampling unit could be a hectare, in which case there are 100 to each square kilometer.

Measuring 100 meters each along the edge of the square kilometer, these are easily paced off and located, even those distant from the road. Say the unit to be sampled is hectare 7 along the road by hectare 8 distant from the road. Measure 700 meters off along the road and then proceed 800 meters (Fig. 1) perpendicular to the road to locate the selected hectare.

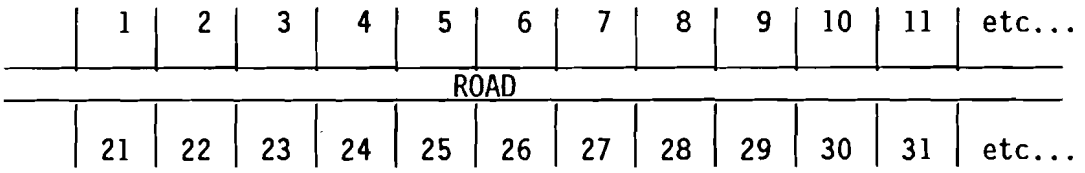
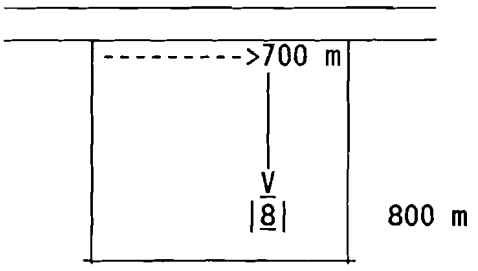


Fig. 1. Use of a road to mark off km^2 blocks to be sampled.



Another method to select the sampling units uses maps, marked off with grid lines which serve as coordinates to locate the 100 to 200 sampling units from which to randomly select. Other methods use political boundaries to first subdivide the area into randomly selected subdivisions within districts. The districts first were randomly selected from a larger sample. Within each district subdivision, sample units would be chosen at random.

The important issue is to select sampled units as randomly as possible so that the data will be statistically meaningful. Quite often the degree of statistical confidence can be estimated and its limits calculated.

5.2.1 Damage Assessment in Small Irrigated Plots

Small irrigated plots of vegetables in wadis are frequently divided by the farmers into small squares, each about 1 square meter in size. Proceed by selecting approximately a 10% sample of the 1 square meter subplots. If the plot contains 66 individual subplots, number these from 1 to 66. Then, using a table of random numbers, select 7 subplots for damage assessment. In each subplot, examine all plants for rodent damage, counting the number of damaged and undamaged plants or fruits. Each is entered on the data sheet, adding the two together to get a total of all plants on the subplot. In the wadis selected, examine the required number of fields according to their random selection previous. This could be 10 fields per wadi and a total of 10 actively farmed wadis. Or the sampling scheme could be stratified to sample for tomatoes, okra, and millet, using 4 or 5 fields of each per wadi.

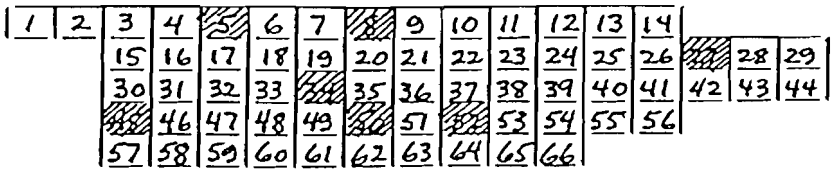


Fig. 2. Sampling scheme for vegetable and grain crops in wadis.

Calculate rodent damage as the number of damaged plants (or fruits) divided by the total number of damaged and undamaged plants found in each plot (as in the example, the 7 square meter subplots examined), times 100 (to give a percentage). If doing a number of fields, add up the damage for all the fields, divided by the number of fields, to get the mean percent damage for the crop type.

Example:

Subplot	Damaged	Undamaged	Total
1	3	22	25
2	0	19	19
3	1	21	22
4	5	18	23
5	0	27	27
6	2	19	21
7	1	17	18
Totals	12	143	155

$$\text{Damage} = \frac{12}{155} \times 100 = 7.74\%$$

Damage for a number of fields: 7.74%, 2.30%, 4.97%, 3.56%, 8.02%, 3.26%, 5.87%, 2.45% = 38.17/8 = 4.77%.

5.1.3 Damage Assessment in Recessional Crops

Recessional crops often cover much larger areas than the small plots in wadis. These should be sampled using line transects. Select a starting corner by using the numbers 1 through 4, picked at random, to indicate the side of the field to start from. Let 1 represent the north side, 2 the east, 3 the south, and 4 the west side. Once a starting corner has been selected, then select 25 random steps (a step is each time a foot falls) from a total of 150 (the approximate number of steps on the diagonal of a square hectare) along the line transect. Arrange the numbers from lowest to highest (Fig 3). For example, the numbers 2, 4, 7, 10, 16, 23, 24, 25, 31, 35, etc. might be selected. Starting at the chosen corner, take 2 steps into the field on the

diagonal and select the plant nearest the foot for damage assessment (Fig. 4). Examine the plant carefully for rodent damage (eaten fruit, burrow underneath, cut stems, eaten grains, etc.). After examining the plant at step 2, proceed on to step 4 and repeat the process. Record the number of damaged and undamaged plants at each randomly selected footfall on the transect. If the edge of the field is reached before all the samples have been taken, select another transect based upon the two sides of the field not used for starting points (if the transect ran N to S, select either the E or W, at random, for the second transect).

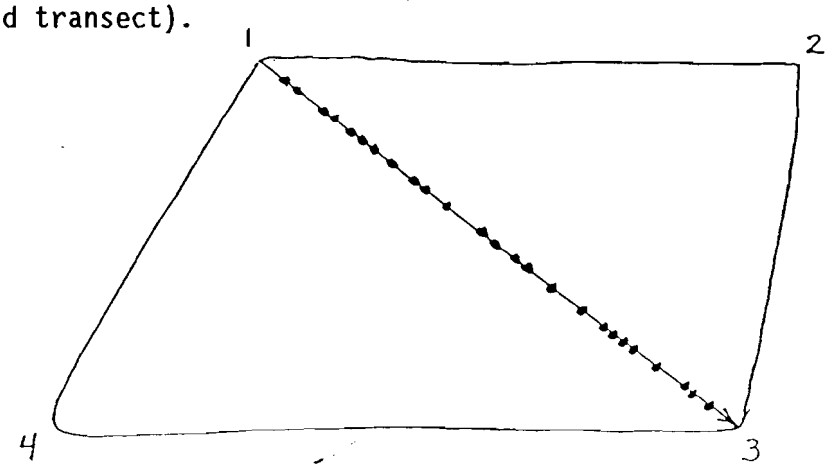


Fig. 3. Sampling on the field diagonal.

Damage calculations are: total plants (or fruits) damaged, divided by the total of damaged and undamaged plants, times 100, to give percent damage. This method should be suitable for sweet potato, tomato, okra, cow peas, and peanut. Peanut can be a problem in that damage occurs below ground, but if burrows are seen at the base of plants, assume the plants have been damaged.

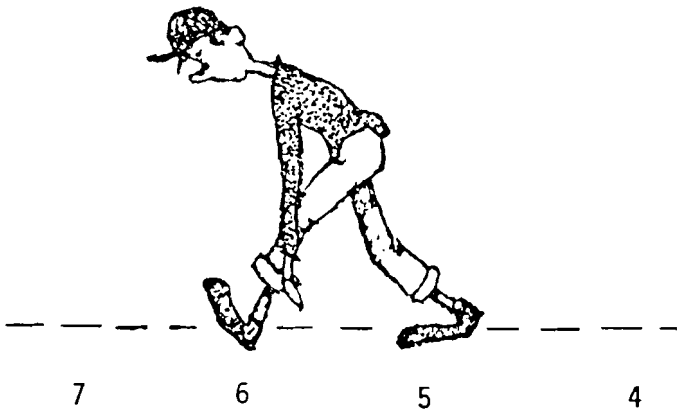


Fig. 4. Take the required number of steps into the field along the field diagonal and select the plant nearest the foot for damage assessment.

5.1.4 Damage Assessment in Dune Crops

Dune plantings of millet and sorghum can be sampled by the line transect method. Select the side to start from by choosing a number from 1 to 4, letting the numbers represent the compass directions. Then select 25 numbers between 1 and 150, using a table of random numbers. Arrange these from lowest to highest. Take the required number of steps into the field along the transect, and sample the plant nearest the foot. Or, if a quadrat is to be used (a wooden sampling frame 50 by 50 cm), place this over the plants at the point where the foot came down. Count all the plants as damaged that have been cut by rodents and from which the seed head, or panicle, has been removed. Count and record all undamaged plants also. Damage is calculated as given above.

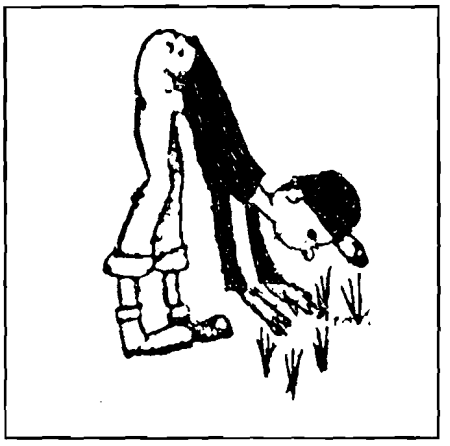


Fig. 5. Examine the plant nearest the foot for damage.

5.1.5 Sampling Frame

The sampling frame could be of any size but for ease of handling, a 50 cm by 50 cm size is convenient. This allows for easy conversion to metric since the frame is exactly 1/4 of a square meter. One side should be open for ease of placing the frame into the vegetation (Fig. 6).

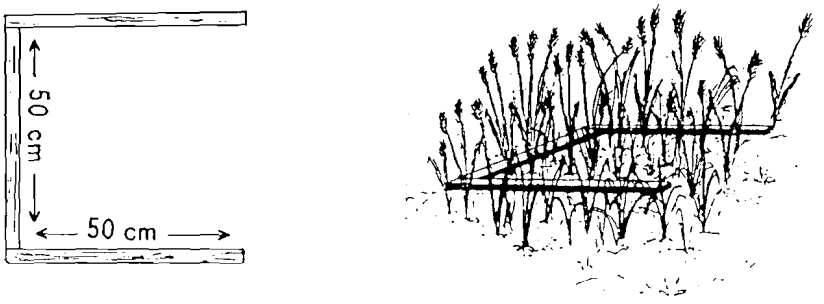


Fig. 6. Sampling frame and placement in crop to be damage assessed.

6. PLANNING, MONITORING, AND OPERATING RODENT CONTROL PROGRAMS*

6.1 The treatment of rodent infestations ideally involves 4 quite separate activities. First, a survey is made of the infested area to discover the extent and nature of the problem (***Problem Definition***). Second, the information gathered during the survey is used to develop a plan of action (***Action Plan***). Third, the plan is put into operation (***Rodent Control Operations***). Fourth, while the plan is being carried out, it is monitored to check that the treatments are going according to plan and permits the plan to be changed where necessary in order to ensure its successful outcome (***Program Monitoring***). In practice in simple situations, an experienced person can merge some of these activities together (i.e. survey and planning together with initiating action and monitoring together with continuing action) for the sake of speed and efficiency.

When a large area is to be treated, it is generally called a rodent control program. Such a program of treatments requires exactly the same 4 activities as the individual treatments, but because the success of the program will depend on understanding the role of a large number of interacting and often complex factors, it is essential to keep the 4 activities as separate as possible. Most rodent control programs are involved with preventing rodent damage to a growing crop, such as millet or wheat. In this case, the co-ordination of treatments is essential for success. Areas for treatment must be scheduled and the needed manpower, supplies, and equipment must be on hand.

In order to develop a plan for action for a rodent control program, the planner needs two main types of information. He or she needs to know the nature and extent of the problem, including what methods and resources are already being used to tackle it. He or she needs to know what other methods and resources could be used to improve the situation. In deciding how the situation can be improved, the planner should know what actions in similar situations others have taken, so that he or she can avoid their mistakes and seek to emulate their successes.

6.1.1 Problem Definition

6.1.1.1. Taking a sample

It is rarely possible or desirable to carry out a complete survey of an area to obtain planning data, unless the area is very small. For normal purposes a sample of about 200 units (a field or a hectare) should be selected at random from the total population of units in the area. If however, it is thought desirable to make comparisons of different types of unit, say grain fields on dunes versus vegetable fields in wadis (an Arabic word meaning oasis), it may be necessary to take a larger sample, perhaps stratified at the start into unit types (dune fields, wadi fields, etc.). Even with apparently simple surveys, it is best to seek the advice of a statistician at the outset so that the survey can be undertaken as efficiently as possible and the correct degree of confidence can be placed in the results.

* Adapted in part from David C. Drummond, Rodent Pests and Their Control, 1981, GTZ, Eschborn, West Germany, N. Weis, editor.

The best way to pick fields at random is to obtain a large map of the area with the fields marked in. If this is not possible, then take a map of the area and divide it into a grid of approximately 100 hectares each square kilometer and at least 10 kilometers on each side. Take 200 samples from the 100 km^2 area by using a table of random numbers. Take a random number from 0 to 99 to select the fields on the west to east axis; then take another random number from 0 to 99 to select the field on the north - south axis. Where the two numbers intersect, is the field to be sampled. Fig. 1 illustrates the method.

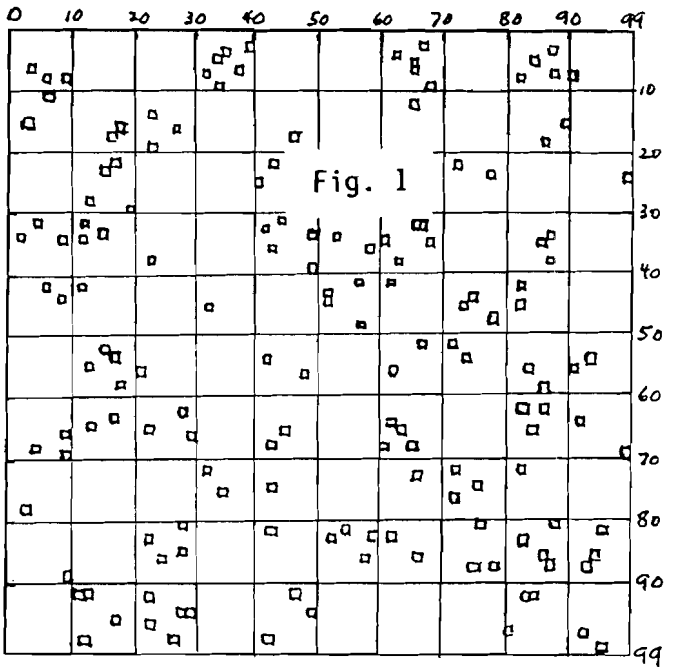


Fig. 1

6.1.1.2 Observations in each sample unit

(a) Measurements of damage and infestation: One of the most important bits of information that the planner needs is some idea of the economic cost of the damage so that he can decide what level of resources should be used to reduce it. Methods are available for measuring damage to growing crops by selecting a random point for survey and then counting the number of rodent-cut tillers or stems and those not cut. The number cut is then expressed as a percent of the total tillers. This method sometimes under-estimates the actual yield loss and improved methods are needed. Information on rodent infestation is also recorded, such as number of active burrows seen, active runways, etc. The selection of the sampling points can be done by first selecting the field corner at random from numbers 1 through 4. Let one of the numbers stand for the corner nearest the north side of the field. After the corner is selected, then use the field diagonal as the transect along which to take the survey samples. Using a table of random numbers, take 25 samples along the transect, selecting numbers from 1 to 150 (the usual number of steps across an acre, or 0.4 hectare). Each number equals one step (see Fig. 2 for example).

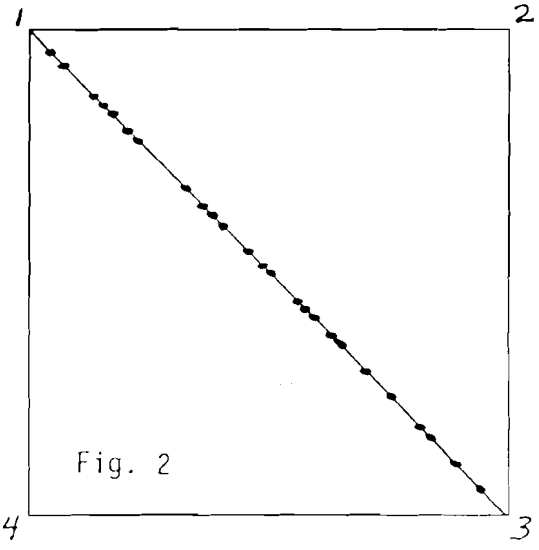


Fig. 2

(b) Other observations: As well as knowing what levels of damage and infestation exist, the planner will also need to know as much as possible about what factors have given rise to the problem, especially those factors which can be most readily changed to reduce it. Thus, for example, in each sampling unit observations may be made on what growth stage is the crop in at the time of the survey;

what poisons are being used and where and how often they are distributed; what removable rodent food and shelter is present; how many people have done rodent control work.

6.1.2 Making the Action Plan

6.1.2.1 Objectives and Priorities

It is desirable to have an ideal long term objective (e.g. a reduction of rodent damage to growing crops to such a low level that everywhere it ceases to be of any economic importance) towards which a program can strive. On the other hand, for the purposes of good planning, there also needs to be practical short term objectives, attainable within a reasonable period of time (say 2 to 5 years) and definable in measurable terms, so that progress towards them can be monitored and so that their attainment can be recognized.

It will almost always be the case that resources are limited and the planner must decide or priorities. For example, the objectives of an agricultural rodent control program might be defined as follows:

(a) To reduce rodent damage to cereal crops below 2% in the defined rodent control area. The objective might give a certain size area to be protected, say 100,000 ha.

(b) To reduce rodent damage to less than 10% in vegetable and other irrigated crops in wadis. Again, the size of the area to be protected could be defined as number of wadis or number of hectares.

(c) To reduce rodent numbers to a minimum (no more than three burrow openings per hectare) in all remaining areas so that re-invasion of crop fields will be minimized. It will be readily appreciated that by introducing priorities into the objectives, a plan of action has already begun to emerge.

The decisions needed to initiate the action to reach the program's objectives can perhaps best be made by considering the planning information already collected in relation to a series of questions as follows:

6.1.2.2 Detection of need for control
- (a) What methods are currently being used to detect the need for control and as a trigger for action (e.g. monthly rodent population monitoring, night counts along roads, burrow counts)?
- (b) What detection methods should be used?
- (c) What action is needed to improve the existing methods and to introduce new methods?

6.1.2.3 Control methods to Use
- (a) What control methods (including both killing and environmental manipulation techniques) are currently being used?
- (b) What control methods should be used?
- (c) What action is needed to introduce new and improved techniques?

6.1.2.4 Who should do control
- (a) Who is currently doing rodent control - Government or farmers?
- (b) Who should do the control under the circumstances - outbreak or local abundance?
- (c) What action is needed to get the proper authority to do the control?

6.1.2.4 Resources on Hand and Required
- (a) What resources, in terms of numbers and different types of personnel, equipment, materials, and money are currently being used?
- (b) What resources are needed?
- (c) What action is needed to modify old resources and obtain new resources?

6.1.2.5 Human social values
- (a) What social attitudes of man are currently affecting rodent control for the good or bad?
- (b) What attitudes are needed?
- (c) What action is needed either to adjust the available technology to existing attitudes or to modify attitudes beneficially?

As well as using the type of planning information already indicated to answer the above questions, it may of course also be necessary to take into account the policies of the Government of the day. For example, the small farmer may be required to be self-supporting and take action for himself even though planning information may indicate that central or local government action taken on his behalf might be more cost effective from the viewpoint of national food production. In addition, some of the planning information may be too imprecise, particularly that concerned with human attitudes and cooperation. In such circumstances, it may be very desirable to carry out a pilot control scheme in order to forecast how much funds will be needed to carry out a large scale program. The resources needed for such things as training for agricultural plant protection agents, general publicity, transport, and local storage facilities are frequently under-estimated through lack of the sort of experience that a pilot scheme would be able to provide.

In section 6.1.2.4 above, a decision was made as to who will carry out the rodent control program. Will the Government undertake the large-scale program needed to bring rodent control to the farms and villages in the affected regions? If so, this will require a major long-term effort with extensive subsidy and even may need external donors to assist in the funding. Or should the rodent control program be farmer-based, with the assistance of the Government in providing the needed resources? A farmer-based program might be much less expensive to implement.

6.1.3 Farmer-Based Rodent Control

A farmer-based approach would "integrate" rodent control as one of the essential activities necessary for farmers to produce and store a successful harvest - just as the use of quality seeds, fertilizers, and weed control are part of a successful effort to produce the crop. This approach would require that the Government crop protection services and the agricultural extension

services see that the necessary rodent control materials (baits, toxicants, fumigants, traps) and information about rodent control methods (brochures, posters, radio, audio cassettes, videotapes) are available to farm families. The crop protection services would be responsible for overseeing the availability of formulated baits, fumigants, and inexpensive traps at village and major market town level in the affected regions of the country. These materials, in all probability, would have to be subsidized by the Government.

The agricultural extension services would be responsible for developing and disseminating information on rodent control methods. For the literate farmer, brochures, posters, picture comics, and handbills, liberally illustrated, could be utilized. These could be distributed through village markets, at subprefectural offices, at voluntary agency offices, and through school children at schools. For the illiterate farmers, there is a need for audio cassettes, videotapes, and radio messages conveying information on rodent control in a variety of entertaining ways in local languages and dialects. These materials could be presented to farmers at planned training sessions, perhaps at markets on market day,

6.1.3.1 Surveillance and Monitoring

Even before the crops are planted, the farmer, or his family members, should survey the crop fields, adjacent fallow or waste areas, and areas around the farm buildings for signs of rodents (burrows, runways, fecal droppings). Any pockets of rodent infestation found should be eliminated with poison baits, traps, and fumigants to prevent the animals from invading the planted crops. Much care should be taken by the farmer when using poison baits around livestock and children in the farm buildings.

The farmer should continue surveillance for rodent infestation and plant damage after the crops are planted. A routine, once-per-week survey of the crop fields, adjacent waste areas and around the farm buildings should be done. If signs of rodents are found, the infestations should be dealt with at once. This routine should be maintained until the crops are harvested and either put in storage or taken to the local market to be sold.

Waste areas should be cleared of grasses, weeds, and shrubs, or at least the undergrowth should be cleared out. Fences should be kept neat, with a minimum of thorny brush used and the areas underneath kept clean to discourage rats from living there. All waste foods found around livestock feeding areas should be cleaned up and buried or burned. Foods stored indoors should be kept in earthenware or metal containers to prevent rodent damage.

The farmer should monitor the success of his efforts by noting if rodent signs have decreased or disappeared. Burrow openings should be closed and re-checked to see if they are re-opened. Along with surveillance, monitoring should be continuous until the crops are harvested. Conditions in the crops change as the crop grows and begins to mature. Weeds may become important and contribute to the rodent infestation by providing additional cover. Weeding at this time would benefit not only increased cereal grain plant growth, but

would make the rodents more vulnerable to control methods and predators. Cereal grain crops are most vulnerable to rodent attack in the newly-planted stage, when rodents may dig up the seeds before sprouting and, again, at the stages just as the grains start to fill with starch, such as the "milk" stage and soft dough stage. Damage inflicted on the cereal grain plants during the stages before panicle formation generally are compensated for by the plants and little change in yield is seen. After panicle formation, however, increasing losses of yields are seen if damage continues as the crop matures. For these reasons, the farmer needs to monitor the condition of his fields on a weekly basis to detect rodent infestations and plant damage before they become serious.

6.1.3.2 Feed-back and Evaluation

Feed-back from the monitoring of the control efforts on the rodent population allows the farmer to re-adjust his strategy. Sometimes the poison baits prove ineffective because the crop itself is more attractive as food. Bait-shyness may have developed in the rodent survivors because of several applications of the same acute poison. A change in control methods is needed. Where poisons fail, traps may catch the survivors of previous poisonings.

In addition to farmer-feedback, the rodent control effort should be evaluated by teams of crop protection personnel. These teams should evaluate the availability of rodent control materials and information for the farmers and their acceptance by them. The proportion of farmers adopting rodent control methods should be determined through farmer interviews. The evaluation teams should find if there were any restraints on the use of the control methods and if the information provided was appropriate and useful. Attempts should be made to determine if the farmer-based rodent control was effective in reducing crop losses and in increasing crop yields. Some of this could be done by damage assessments in crop fields during the growing season; other information could be gathered from interviews with farmers. The evaluation should point out areas in need of improvement or changes in strategy.

6.1.4 Government Rodent Control Operations

The alternative approach to rodent control is to have government agencies undertake the work. This approach may have to be done in case of widespread outbreaks of rodent populations. In times of normal levels of rodents in the fields, a farmer-based program, backed by Government help, as described above, would seem the better approach. A typical government-based rodent control program is described below.

6.1.4.1 Staffing the Program

Local conditions, particularly those affecting the availability of funds and manpower, can influence the organization and staffing of rodent control programs. In conducting long-term rodent control programs it is preferable to recruit and train permanent staff. The overall supervisor of the program should be a professional or semi-professional biologist or rodent control

specialist having a good knowledge of rodent control techniques and how best to use them in the local situation. Good organizational and administrative abilities are needed and the person concerned must be able to deal effectively with other departments and agencies in the area.

A team leader is essential to direct and supervise the work of field staff, to arrange the daily schedule of activities, and to handle reports and records. A store with a storekeeper to oversee the safe-keeping and supply of rodenticides, traps, weighing and other equipment, is also necessary and room should be set aside for the mixing and packaging of bait. Field workers are needed to conduct surveys and carry out control operations. Pick-up trucks or vans are required to transport field teams together with their equipment.

Field staff should be organized into teams; ideally one field leader and a small number of plant protection operators (2-5) would make up one team. Each team should be assigned to a specified district within the area selected for comprehensive control. Flexibility is important, however, and a team assigned to cover a certain area should be available to move to another one if necessary. As far as possible the areas selected for treatment should lie adjacent to each other so as to reduce the likelihood of re-invasion occurring from untreated areas. It is stressed that good record keeping is essential to ensure the best direction of activities.

All staff should be thoroughly trained in the biology and behavior of rodents, in the characteristics and hazards of toxic materials, in methods of rodent control to be used, and in ways in which to evaluate the success of the control operations. This can be done through a series of workshops and training courses. In addition, in-service training should be offered in an on-going basis and periodic refresher courses should be given. A standard operation procedures manual and technical manuals should be prepared and distributed to all operational personnel. Attempts should be made to recruit the best caliber personnel.

6.1.4.2 Supplies and Equipment

Rodenticidal concentrates, technical materials, and fumigants should be stocked in depots in the areas where rodent control operations are expected. The reason for stocking concentrates or technical materials is that these keep quite well for long periods, whereas stockpiling of formulated baits runs the risk that these may become insect-infested or spoiled by excessive heat or humidity over a period of time. With concentrates or technical materials on hand, fresh baits can quickly be formulated at the sites when needed. The concentrates, technical materials, and fumigants should be stored in locked cabinets in a secure structure. Adequate stocks should be kept so that even a large rodent outbreak could be dealt with. Each depot should have bait mixing equipment and a supply of plastic bags for bagging the finished baits. If the baits are to be applied by plant protection personnel, it would be best to have cloth or canvas bags with shoulder straps for carrying baits into the field. If the baits are to be supplied to farmers for them to apply in their fields, then the baits should be bagged in 100 gram to 1 kilogram amounts in

sturdy plastic bags. The active ingredient and its concentration should be given on a label in each bag, along with safety precautions and instructions for use of the baits in the local language.

A good supply of bait boxes, fumigation equipment, and traps should be maintained at each depot. Rat-sized and mouse-sized snap traps should be available in numbers of several hundred each. Bait boxes, if used in the field control, should be stored in a knocked-down condition, ready to be set-up when needed. These also should be available in numbers of several hundred. Rodent control posters and handbills for farmers explaining in the local language the purpose of the rodent control program should be on hand ready for distribution in the field.

Ideally, each rodent control team should have a vehicle capable of carrying 4 to 5 persons along with their baits and other rodent control equipment, such as bait boxes, fumigation equipment, traps, etc. For this purpose, a 4-wheel drive pickup truck with covered back is best. The double seated pickup would be ideal. If vehicles are unavailable, then alternatives, such as motorcycles or even bicycles, should be considered.

6.1.4.3 Rodent Control Program Strategy

When dealing with rodent populations that are capable of outbreaks and of reaching peak densities of 100 times more than those seen at population lows, the best strategy is to do the control in a *preventive* manner instead of a *reactive* manner. Reacting to high rodent numbers, trying to deal with peak rodent populations, is not effective. The damage to field crops and stored foods has already been done and efforts at rodent control in the field will simply be a waste of time, money, and effort. What is needed is to head off the peak populations before they develop. As monitoring data comes in indicating that the rodents are breeding in response to greening vegetation and adequate rainfall, steps should immediately be taken to implement the control program in the areas most at risk, i. e. those with crops in the field and those village situations where foods are stored. The idea is to cut the rodent densities before they can begin to build up and to keep them low until the crops are harvested or until the normal rodent peaks would have passed.

6.1.4.4 Bait Application Methods

(1) Burrow Baiting

Placing baits into the burrow openings of rodents is an often used method of laying baits. This works because many of the pest rodents live in burrow systems and the openings to the burrows are frequently left open during the day or are opened at night when the rodents come out to feed. The rodents encounter the baits when they attempt to leave the burrow. This is an ideal time since they are usually leaving to go search for food. Another advantage to placing the baits in burrows is that they are provided some protection from birds and other animals.

(2) Broadcast Baiting

Broadcast baiting is done infrequently because there are some hazards with it of poisoning non-target animals. The bait is spread by hand, machine, or aircraft over the area to be treated. This type of baiting is sometimes done in crops in which hand-baiting is difficult, such as sugarcane. The application rate of the baiting is determined by the toxicity of the rodenticide used, its concentration in the bait, and the type of bait used (whole grain, cracked grain, pelleted baits, etc.). In general, this kind of baiting operation is not recommended unless there are no alternatives.

(3) Container Baiting

In order to protect baits from non-target animals and to provide a secure place for rodents to feed, baits are sometimes placed into containers into which only rodents have access. These containers consist of bamboo tubes, PVC pipe tubes, wooden boxes, tinned cans, and plasticized cardboard milk cartons. The container usually has one or two openings large enough to admit a mouse or rat (3 to 10 cm in diameter) and a place inside where the bait is secured. Bait containers are usually used in urban situations, less frequently in field crops since they are bulky and large numbers are needed for field situations. They have been used in rice and wheat crops with success, however. They are usually put out about 10 to the acre, or 25 to the hectare, which allows field rodents the spacing in which to locate them after several nights.

6.1.4.5 Trapping Methods

Traps are used only in special circumstances. Since house mice are much easier to trap then are rats, mouse traps can be used with fair success against mice infestations. Mice inside structures, such as food storage warehouses, can be dealt with using traps. But the number of traps to use must be determined by the degree of infestation. If the infestation is severe, then probably several hundred traps should initially be laid. Multiple-catch traps, such as the "Tin Cat" can be used to reduce the trapping effort over that required with snap traps, but even with these, adequate numbers must be used to cover the area. Since mice have limited ranges of movement, usually only several meters in diameter, traps should be placed every 3 meters or so to provide adequate coverage. If using snap traps, bait them with dried fish, nut meats, pieces of bread, etc. for house mice.

Traps, placed out in quantity, may have a place in controlling rodent populations around wadis. Snap traps placed along rodent runways in the thorny fencerows around wadis may be very effective in taking out *Arvicanthis*. Pit traps, made by burying tinned cans or earthen jars up to their lips in the sand, can be quite effective in catching small rodents, who fall into the can or jar and are unable to escape. This is a method that farmers could use around their fields to prevent the build-up of rodent populations. The traps need very little maintenance once they are installed.

6.1.4.6 Other Methods

(1) Fumigation is sometimes used against burrowing rodents. However, where the rodents are burrowed into sandy soil, the fumigants would be ineffective because the soil would not hold the gasses. If the soils are of loam or clay, then fumigants could be used. Commonly used field fumigants are aluminum phosphide tablets and calcium cyanide powder. Aluminum phosphide tablets need no equipment other than a long-handled spoon for inserting the tablets into the burrow and a shovel for covering the burrow opening. Usually one tablet per burrow opening is used. The burrow opening is closed after inserting the tablet and rechecked a day or so later to see if it was reopened. Any burrows reopened should be retreated.

Calcium cyanide is applied with a dusting applicator. This is a hand pump with hose and a container for holding the cyanide powder. The operator's foot holds the pump in place. The hose is put into the burrow opening and soil is packed around it to make a tight fit. A few strokes of the pump handle forces the cyanide powder down the hose and into the burrow. A lever is flipped and a few more strokes forces air into the burrow, effectively pushing the cyanide powder deeper into the burrow. After the hose is withdrawn, the burrow is closed. Persons doing burrow fumigation with cyanide should always work in pairs and be properly trained in safety and first-aid precautions, just in case one of the pair becomes overcome by cyanide gas. If one member is overcome by the cyanide fumes, he should be treated immediately with an ampoule of amyl-nitrate, breaking it and holding it under the nose for 30 seconds out of every 2 minutes.

(2) Habitat manipulation

Sometimes certain aspects of the habitat can be changed to reduce the rodent population. Removing some of the factors supporting rodent life lowers the capability of the habitat to maintain rodent densities. For example, the thorny fencerows built around the wadis to keep out the livestock make excellent habitat for *Arvicanthis*. However, it is unlikely that Chadian farmers will remove the fencerows since they are easy and cheap to make and serve to keep the sheep and goats out of the crop fields. Unless there is an inexpensive substitute, farmers will continue to use the fencerows. There are things that can be done, however. Any little waste areas around cultivated areas should be cleaned up and eliminated since these may provide living conditions for rodents. Throwing rotten vegetables and fruits out of the fields provides extra food for rodents. Rotting produce should be buried or burned instead.

(3) Good housekeeping

Good household sanitation is needed to keep indoor rodents from stored food supplies. Leaving waste foods lying around will maintain mice and rat populations indoors. Stored foods should be kept in rodent-proof containers (metal or earthen) instead of in jute bags or open containers. The house should be swept daily to remove any traces of foodstuffs lying around. Any waste foods should be fed to livestock or buried in the ground a short

distance from the house. Animal foods should be stored in rodent-proof containers (metal or earthen containers) and spilled foods cleaned up promptly to avoid attracting rodents. If rodents are living in the household, they should be trapped out with the use of rat or mouse traps.

6.1.5 Communication Strategies

There is a need for imparting information to the target groups (farmers and villagers) in order to increase the acceptance and effectiveness of control programs. The information should create awareness of the problems and of their solutions and motivate the target groups to participate in the control program. The information, awareness, and motivation can be transferred through a variety of means, including the political leaders, the plant protection service, the agricultural extension service, the schools, and the mass media, using radio, television, newspapers, posters, handbills, and brochures. A one-on-one with farmers extension system approach has been found to be the preferred method in other places.

6.1.5.1 Mass Media

The mass media can be utilized where they play an active role in the life of the community. If the newspapers, magazines, radio, and television are active in the country and reach a large segment of the target groups, in this case farmers and villagers, they can very effectively be used to create and transfer information, awareness, and motivation about the rodent problem and ways of solving the problems. However, in many countries, the mass media seldom reaches the target groups because of a lack of persons able to read and because many persons lack the means to purchase radios or televisions. There may be no electricity in the villages, hence no way radio or television communication could be used.

6.1.5.2 Role of Plant Protection

The plant protection service should provide the resources needed for the communication campaign. They should develop the training materials required for the agricultural extension service, which would include a short training manual for extension workers on rodent control programs and materials for extension workers to convey to villagers and farmers, such as posters, handbills, brochures, and comic strips. The plant protection service would offer a series of one-week workshops to agricultural extension workers throughout the areas where rodent control operations are expected.

6.1.5.3 Role of Agricultural Extension

If the agricultural extension service is active in the country, they can be used to communicate much of the information and awareness materials. The desired rodent control information can be conveyed to the extension workers in a series of one-week workshops, including a half day in the field. The plant protection service could hold a series of workshops in the parts of the

country where rodent outbreaks are expected to be most severe. The workshops should be carried out with good demonstration materials and with developed materials that the extension workers could transfer to farmers and villagers. These would include posters, handbills, brochures, and comic strips, for those that can read. For those unable to read, each extension worker should be provided with an audio cassette player and audio cassettes which convey the information through songs, music, dialogue, and narratives. Demonstration materials, such as traps and bait packets, should also be available to the extension workers.

The extension workers should visit each village prior to the beginning of the control operations in that area and provide training to the villagers and the local farmers. Posters should be hung at prominent places in each village and handbills, brochures, and comic strips liberally distributed to the public. The local headman should be involved in the training.

6.1.5.4 Role of Decision Makers and Other Leaders

It is very important to include different decision makers in the process of creating awareness for the need for rodent control. These persons need not necessarily be limited to people in the agricultural sector. They would include politicians, village headmen, union council leaders, journalists, radio and television reporters, and heads of schools. Once these individuals are motivated, they lend support to rodent control activities within their areas of responsibility. It is critical that the support of the lead governmental agency is at hand, that of the Ministry of Agriculture. It also is of primary importance that adequate resources, in staff, equipment, supplies, and funding, are available.

6.1.6 Integrated Pest Management Strategies

Integrated pest management (IPM) strategies are used to bring to bear all the various methods of rodent control against the rodent populations. Integrated pest management does not mean the elimination of rodenticides; these materials still have a role to play, but IPM tries to use the minimum amount necessary to do the job. IPM starts with surveillance; of the crops, of the stored foods, of the burrows in the fields, etc. There is a certain threshold of rodent populations or rodent damage to growing crops that calls for the need for IPM. Farmers should be aware of the rodent populations around or in their fields; if crop damage is visible to the farmer while walking through his field, then it is time to take action. All previously mentioned methods of control are then brought to bear on the problem. Any habitat changes that will reduce rodent populations are initiated; stored foods are provided protection from rodents by using rodent-proof containers; traps are used extensively; predators are encouraged instead of being killed; poison baits and fumigants are used in the least amounts needed to do the job. The progress of the control operations is continually monitored and evaluated, by farmer feed-back and by surveys by program staff.

6.1.7 Monitoring the Operations

It is quite common that what the planner plans even in simple operations is often not what actually happens in practice. For this reason the operations actually being undertaken to implement the plan need to be monitored and adjusted where necessary to conform with the original plan. Or the monitoring may show that the planned action was not practical and that it is the plan that needs changing to conform with reality. Another possibility may be that monitoring the operations reveals that the plan is operating perfectly but monitoring the success indicates that the objectives are not being reached. This situation requires a change in the original plan.

6.1.7.1 Post-treatment Surveys

In essence monitoring the program's success should simply be a repeat of the preliminary survey so that new and, it is hoped, lower levels of damage and infestation can be compared with the results of the earlier survey and with the program's objectives. In this way it will be seen how far success has been achieved and how much further there still remains to go. Also this monitoring survey needs to use the exact same observations on factors affecting damage and infestation as were made on the earlier survey, so that any changes in damage can be correctly attributed to appropriate actions, which in turn can be expected to lead to a better understanding of the situation and better program management.

Ideally a new random sample should be used for each monitoring survey and the survey team should be independent of the team carrying out the planned operations. In the cases of field crops, surveys will have to be carried out during those periods of the year when losses due to rodents can be most easily measured.

6.1.7.2 Pilot Schemes

As already stated, the planner may feel that he has too little information, to predict whether his plan will work. In these circumstances he is wise to put his plan to the test on a small scale first and run a pilot rodent control scheme. The pilot scheme should be carried out in an area large enough to contain within it all the problems likely to be encountered in a full scale operation. Preliminary damage and infestation surveys and monitoring surveys should be run just as they would in a full scale program. If possible, take random surveys from the larger potential program area. Comparing the samples from the two areas will make it easier to see what problems need to be overcome in the smaller area and to provide some solutions to the whole program.

Pilot schemes also provide an ideal opportunity for rodent control research and extension workers to get together. The research biologist should be brought in at an early stage in the planning to ensure that the control technology and monitoring systems are appropriate and that any modifications that bare needed are in line with current knowledge of rodent biology and behavior. The practical experience of helping to run a pilot scheme will also serve to improve his ability to direct research to practical ends.

6.1.7.3 Evaluation of Control Efficacy

The efficacy of the control treatment should be evaluated within days of its completion. This is done by comparing some measure of rodent activity taken before treatment with the same measure taken after treatment. Activity measures include (a) the amount of unpoisoned baits eaten from containers, (b) the scoring of inked tracking tiles as positive or negative for rodent footprints, (c) the counts of active and inactive burrows, (d) the numbers of rodents taken in traps, and (e) the reduction in rodent damage to treated field crops. When food consumption if measured, it should be done for periods of 3 to 10 days before and after treatment. The amounts placed each night are carefully weighed and again weighed the following morning to determine consumption. Inked tracking tiles are often placed out for one night only but can be run for two nights and the results averaged. Burrow activity should be assessed by closing each burrow with soil and rechecking to record how many are opened the next morning. The number of rodents trapped should be done with live-capture traps and the rodents released alive, otherwise the trapping will influence the results. Results are expressed as the percent reduction in food consumption, in tile activity, burrow counts, or number of rodents trapped before and after. All results and their interpretation should be conveyed to the persons having done the rodent control, whether farmers or operational program personnel and supervisors.

7. REFERENCES

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8. SOURCES OF EQUIPMENT AND SUPPLIES

Snap Traps: Mouse-sized Rat-sized	Woodstream/Ekco Housewares 9234 W. Belmont Ave. Franklin Park, Illinois 60131 USA
Live Traps: Tomahawk	Tomahawk Trap Company P. O. Box 323 Tomahawk, Wisconsin 54487 USA
Live Trap: Sherman Snap Trap: Museum Special Pesola Scales Dissecting Kits Dust masks	Forestry Suppliers Inc. 205 W. Rankin St. P. O. Box 8397 Jackson, Mississippi 39284 USA
Gavage needles Disposable syringes Disposable needles Forceps Rulers, mm and cm Scalpels Scissors	Baxter Scientific 1118 Clay Street North Kansas City, Missouri 64116 USA
Bait mixing equipment:	Hobart Corporation Troy, Ohio 45374 USA
Balances:	Ohaus Corporation 29 Hanover Road Florham Park, New Jersey 07932 USA
Water bottles Stoppers Drinking tubes Food cups	Ancare Corporation P. O. Box 661 North Bellmore, New York 11710 USA
Rodenticides:	Pest control Supplies Kansas City, Missouri USA