Problems associated with the control of rodents in tropical Africa

N. G. GRATZ [1] & A. A. ARATA [1]

As elsewhere in the world, rodents are responsible for very considerable economic losses in tropical Africa because of their depredations on both growing crops and stored food products. Unfortunately, few accurate data are available on the extent of these losses but there is evidence that they are considerable. The public health importance of rodents, both as reservoirs and vectors of disease in tropical Africa, is also great; plague, leptospirosis, murine typhus, and Lassa fever are among the diseases associated with rodent hosts. Scientifically based rodent control programmes have been carried out in very few areas of Africa and there is urgent need for studies and demonstrations on rodent control in both urban and rural areas. The problems likely to be encountered are reviewed and methods of control proposed.

INTRODUCTION

Lassa fever virus has been isolated from a high percentage of specimens of *Mastomys natalensis* that were collected in houses in two villages of Sierra Leone where outbreaks of this disease had occurred (1). None of the other 3 rodent species present in the houses at the time of the epidemic, *Mus musculus*, *Rattus rattus* and, rarely, *Hylomyscus simus*, yielded virus. A total of 16 species of rodent were trapped both within the villages and in the surrounding fields and only *M. natalensis* was positive. It would therefore seem that this species may play an important role in the dissemination of the disease and that its control may serve to prevent transmission of the disease. That it can be possible to prevent such transmission from the rodent reservoir to a human host was demonstrated in the case of an epidemic of another arenavirus disease, Bolivian haemorrhagic fever (BHF), when control of the probable rodent host *Calomys callosus* in Bolivia apparently halted an outbreak of the disease. Extensive rodent control measures were carried out in the town of San Joaquin, one of the epidemic centres of BHF in Bolivia, by applications of a poisoned bait consisting of whole corn, vegetable oil, zinc phosphide, and tartar emetic. A total of 3020 rodents were known to have been destroyed, of which 2896 were *C. callosus*, the only species from which Machupo virus, the agent of BHF, had been isolated. The number of BHF cases among persons living in the area under control began dropping 2 weeks after the start of the rodent control activities, a period of time that corresponds with the estimated incubation period of the disease in man. Cases continued to appear in an uncontrolled area until rodent control activities were extended to it (2).

The present paper will therefore consider the public health and economic importance of *M. natalensis* and the possibility of carrying out effective, economic, and safe control of this species in tropical Africa. Inasmuch as it cannot be excluded that other species of rodent may also serve as reservoirs on the disease, the general problem of rodent control under tropical African conditions will also be considered.

THE DISTRIBUTION OF *M. NATALENSIS*

Mastomys natalensis in its various forms is the most widespread indigenous rodent in tropical Africa, being found from the southern and eastern edges of the Sahara to the Cape; infestation has also been reported in Morocco (3). Though it may be found at a distance from habitations it is usually associated with man, his houses, food stores, farms, and other clearings (4). It is not common in large towns and on the coast it seems to have been replaced by *Rattus rattus* and *R. norvegicus*.

Because of its widespread distribution, the fact that it is the most common rodent species over much

[1] Vector Biology and Control, World Health Organization, 1211 Geneva 27, Switzerland.

of its range, and its close association with man and his farms, *M. natalensis* has been one of the main targets of rodent control in those comparatively few areas of Africa where organized rodent control activities have been undertaken. In addition to its economic importance, *M. natalensis* is one of the most important reservoirs of plague in Africa, often serving as an intermediate between the primary wild rodent reservoirs, such as the gerbils (especially *Tatera* spp.), and man (5).

THE ECONOMIC IMPORTANCE OF RODENTS IN AFRICA

Accurate information on economic losses due to rodents is in general sparse, and particularly so from Africa; in part this is due to the pattern of African agriculture, with much of the food crops around villages being raised and stored on a small scale. Taylor (6) lists the most important rodent pest of major agricultural crops in Africa as *M. natalensis*, which attacks wheat, maize, and cotton among other crops. *Arvicanthis niloticus* attacks wheat and maize; *Rhabdomys pumilio*, wheat; *Funisciuris* spp., cocoa; *Heliosciurus* spp., cocoa; *Cricetomys gambianus*, cocoa, and *Thryonomys swinderianus*, rice. Bellier (7) described the rodent pests of West Africa and the crops they attack in rather greater detail and Table 1 is modified from his paper.

Taylor (8) investigated an invasion of rats in agricultural areas of Western Kenya in 1962. About 20% of the area under maize was damaged and had to be replanted. Damage to young wheat in some fields amounted to total loss and sampling of two fields with moderately high damage showed a loss of 34% for the wheat field and 23% for the barley field. Eight species of rodent were regarded as pests and the 3 most important of these were *M. natalensis*, *A. niloticus* and *R. pumilio*. Of the species involved, *Mastomys* was the only one responsible for damaging maize cobs on upright stems; it was also found to bark saplings up to a height of 2.5 m when other food was scarce. It is of special interest to note that these essentially grassland rodent species favoured areas of rank grass and dense ground vegetation and that clean crops of maize and wheat, although damaged at the field edges, were relatively free of rats towards the centre whereas unweeded crops were damaged throughout. Severe damage was also caused to bags of stored maize and wheat in the area.

Jackson (9) investigated the rodent problem in Ethiopia and found that very little accurate information on rodent damage was available. Rodents were plentiful and were reported as causing severe damage, mainly to maize as well as to other grains. It was noted that heavy rodent damage seemed to be reported frequently from areas newly opened to agriculture.

Everard (10) discussed the damage caused by rodents to cocoa in Nigeria and Ghana; in Nigeria it was estimated that 10% of the cocoa crop in 1957 was lost through rodent damage. In July and August 1963 it was reported that 1.69% of all sacks of stored cocoa showed rat damage.

In Zaire, Rwanda, and Burundi rats and squirrels cause varying degrees of damage to young rubber plantations, to cocoa, and to other crops, including groundnuts.

More information is available on rodent damage in Egypt and the Sudan, although these are not part of tropical Africa. Shuyler (11), in a general survey of rodent damage in Egypt, found that 5 species of rodent belonging to 4 genera were serious agricultural problems. In contrast to the findings in tropical Africa, however, most damage was ascribed to *R. rattus*. He also found that *A. niloticus* was not as serious as it was previously reported to be. Rodent densities ranged up to 2380 per hectare in outdoor stores, and individual field crop losses ranged up to 80%, though overall losses to agriculture and stored crop products were estimated at 4–5%. Schmutterer (12) reports that *M. natalensis* is a major pest in irrigated areas of the Central Sudan, preferring cereals but also attacking cotton.

The type of information presented above is of considerable importance in establishing a base for long-range rural rodent control programmes. While outbreaks of disease may provide the stimulus for brief, intense control programmes, it would seem unlikely, on the basis of past experience, that important rodent control programmes will be long maintained in and around villages unless both individual farmers and agricultural authorities are convinced that substantial economic losses are being sustained through rodent depredations and that these can be overcome by a control campaign that is relatively easy to carry out and relatively certain of success. One of the first tasks to be undertaken when initiating rodent control work in tropical areas will therefore be the gathering of sufficient data, not only on the public health importance of rodents but especially on the losses caused to standing crops and

Table 1. Damage to growing crops caused by rodents in West Africa [a]

Type of habitat	Crop	Species	Kind of damage
Forest	Rubber	*Thryonomys swinderianus*	Cuts down young plants
		Praomys tullbergi	Attacks germinating seeds
	Cocoa	*Funisciuris Heliosciurus*	These are selective feeders that may destroy a dozen pods before eating one
		Cricetomys gambianus	Freeds on pods within 2 m of the ground
Savanna	Rice	*T. swinderianus Rattus rattus Arvicanthis* spp.	Plant is eaten
	Sugar cane	*Arvicanthis* spp. *Mastomys natalensis*	
	Groundnuts	*Mastomys Arvicanthis* spp. Gerbils	Vegetation is eaten
	Root crops (cassava & yams)	*Xerus erythropus Cricetomys gambianus M. natalensis Arvicanthis* spp.	Cause malnutrition by destroying the gardens of the indigenous farmer
Plantations	Palm	*Dasymys inconitus*	Devours cover crops, but as the rodent population exhausts the food supply turns to the young palm. There are three kinds of damage. *Dasymys* may kill the palm by eating the heart or inflict only a superficial injury that is rapidly infected by fungi. Finally, insect larvae may penetrate the palm through the injured tissues
		Lemniscomys spp. *Oenomys* spp.	Cause occasional damage to the bunches
	Coconut (only)	*R. rattus*	Damage to nuts only. Given the damage this species does to other crops (rice, sugar cane) elsewhere in the tropics, it is to be feared that this could happen in West Africa in the future

[a] After Bellier (7).

stored agricultural products by rodent pests; such information can be used to assist administrators in deciding on the resources that should be allocated to rodent control.

RODENT CONTROL PRACTICES IN TROPICAL AFRICA

Urban areas

Where rodent control activities are carried out in urban areas of tropical Africa, the most effective programmes are generally those undertaken in ports in an effort to limit damage to stored food products and to ensure that the ports fulfil the requirements of the International Health Regulations (13). These require (article 16) that "The health authority for each port and airport shall: (*a*) take all practicable measures to keep port and airport installations free of rodents; (*b*) make every effort to extend rat-proofing to the port and airport installations." The problem species in such areas and the type of control required differ little from those in Europe and the Americas in that in most ports and port cities in tropical Africa, the dominant species is either *R. norvegicus* or *R. rattus*, which displace native species almost completely once they have been introduced by shipping. The black rat, *R. rattus*, was formerly believed to be better able to adapt, especially to conditions in West Africa, than the Norway rat and the latter is generally restricted to sea ports while *R. rattus* has spread inland, even to small towns and villages. Buxton (14) mentions that from February 1931 to December 1934 during a cleaning up operation to control plague transmission in Lagos, Nigeria, 139 528 *R. rattus* and 7426 *R. norvegicus* were examined, over 3100 rats a month being captured. While rat densities in Lagos have certainly declined since that period, they nevertheless are a serious problem in the city. However, Voelckel & Varieras

(15), in a survey conducted over several years, found that *R. norvegicus* appeared to be displacing *R. rattus* in Douala, Cameroons, a phenomenon that has been recorded in other areas where these species have been in competition, e.g., in the United Kingdom (16) and Israel (17).

As has been stated above, the problems of control of the 2 *Rattus* species in cities of tropical Africa would differ little from those encountered in dealing with similar infestations in cities elsewhere in the world, and the methods adopted would also be similar. There are some problems, however, that would certainly be more acute in the urban areas of tropical Africa, if not unique to them. One of the outstanding problems would be the difficulty of ensuring an adequate " take " of either solid or liquid baits since, although these might be acceptable to the rats from the taste viewpoint, they would have to compete with an abundance of other food sources in the form of solid wastes that had been poorly disposed of and standing water. In addition, stored food products in cities and towns are generally poorly protected and the " rat-proofing " of warehouses and granaries is only a recent and rather uncommon development. Thus, the improvement of municipal sanitation is an urgent first step towards rodent control in urban areas. A more severe problem is the almost total absence of well trained professional or semi-professional staff. While this is also a problem in many of the developed countries, it is an especially severe impediment in Africa.

Rural areas

Though several African cities have rodent control programmes of varying degrees of efficiency, organized rodent control in rural or agricultural areas of tropical Africa is not common. Probably the earliest organized rodent control work in rural areas was done as an anti-plague measure. As an example, Guggisberg (18) has translated and commented upon an article written in 1913 by R. Lurz, a medical officer in the German Army, describing an epidemic of plague in the Kilimanjaro area in 1912. In the original paper, the rodent which was determined as being the plague reservoir was identified as " *Pelomys fallax iredescens* "; however, from the description of it in the paper, Guggisberg concludes that it was actually *M. natalensis*. In the rodent control campaign that Lurz carried out, small groups of men dug up burrows in the immediate surroundings of the house and searched the roof thatch for rodents. Rats were found in the burrows and only rarely in the thatch; each rat catcher was paid 1 Heller for a young rat and 3 for an adult. By the end of nine weeks, 30 663 rodents had been handed over from the 3 plague-infested localities. While this number is impressive, the biotic potential of *M. natalensis* is such that the area was undoubtedly quickly reinfested.

Misonne (19) reviewed the rodent control activities carried out in the plague foci in the Congo (now Zaire) over a period of 40 years. In the Lake Edward focus more than 9 807 000 rodents were captured from 1929 to 1937 and starting in 1936, 8000–9000 huts were checked each month, with 4–10 rats being captured per hut. Over the whole period considered some 18 million rodents were captured in the Lake Albert focus and 11 million in the Lake Edward focus. While these figures may not be precise, they give an idea of the general magnitude of the rodent populations in the area. The control programme reduced the index of rats per hut from 10 to between 1.5 and 4.0. Impressive as these enormous numbers are, they are unlikely to have other than a temporary effect on a wild rodent population estimated as 20–30 million individuals in the Lake Albert focus alone, along with a domestic rat population that is about half a million during periods of rodent control and more than three million otherwise. The rate of *Mastomys* reproduction is such that in the absence of any rodent control measures or natural suppression, a population can more than double its numbers in a month and in 6 months population levels in villages regain their previously high levels. Faced with such a biotic potential, control hardly seems possible; if it remained based on the methods used in the past in many areas, such as the clubbing and trapping of rats and flooding of burrows, control would be extremely inefficient and ineffective. Nevertheless, by applying modern control methods based on adequate knowledge of the bionomics of the target rodents, it is possible to achieve effective and reasonably economic control of rodent populations in tropical Africa. Before proposing guidelines for future rodent control campaigns in this region, a few examples of past programmes will be cited.

Taylor (8) described control trials against *Arvicanthis* and *Mastomys* in a wheat and maize growing area near Kitale, Kenya; an effort was made to develop a rapid and effective method of control that would prevent further damage to the crops. The farmers themselves had used maize soaked in a cattle dip containing arsenic and toxaphene, but this gave only limited success. Large quantities of warfarin had also been used but control was again unsatisfactory. Besides carrying out further trials with warfarin, we studied the efficacy of zinc phosphide in a maize meal bait (30 g/kg) and of endrin as spray along the edges of rat-infested fields. Warfarin was distributed at a high density of baiting points (1 every 4.5 m) but rodent densities as measured by consumption of baits fell only slowly over the 10-day period of observation. The area baited—a single field—was probably too small to prevent reinvasion. The endrin spraying was also ineffective as measured by a census baiting with unpoisoned grain killing only a proportion of the *Mastomys* and *Arvicanthis* in the field. However, 3% zinc phosphide in maize gave an 80% to 83% reduction in the preliminary trials. It was therefore decided to use this rodenticide formulation for controlling rats on 71 farms covering nearly 100 000 acres (40 500 hectares). Results were evaluated by questioning the farmers; 80% of them claimed satisfactory results; 80–100% reduction in damage (though it is not clear how this was measured); and the remainder, less success. Unfortunately, in one area where only 4 lb (1.8 kg) of zinc phosphide had been used, the farmers reported collecting 14 dead porcupines, 12 crowned cranes, one aardvark, nine oribi and one cow, in addition to 800 rats. Such a heavy kill of non-target animals would probably exclude the routine use of the rodenticide in many areas of Africa in other than the most serious infestations of rodents.

Considerable effort and study have been expended in South Africa on the control of the gerbil, *Tatera* spp., and Davis & Thomas (20) recommended the placing of strychnine-impregnated wheat grains in the rodent burrows; while this method would be effective when there is a shortage of food for the rodent populations, it would probably quickly give rise to bait shyness when alternative food sources were readily available. In addition, the material is hazardous to man and to domestic animals and its widespread use would probably produce the same type of kill of non-target animals described above following the use of the somewhat less hazardous zinc phosphide. Calcium cyanide was also recommended, but since the rodents often block off part of their burrows with earth plugs, this method, in addition to being dangerous to the operators, is not always effective.

Tatera valida became a serious problem in the area of the Leopoldville (now Kinshasa) airport in 1956, its burrows being so numerous as to threaten undermining of the landing strip. Devers et al. (21) were able to control the populations very satisfactorily by using a commercially prepared anticoagulant tracking powder based upon coumachlor (10 g/kg), after having excluded the possibility of utilizing more hazardous compounds, such as arsenic, thallium sulfate, strychnine, zinc phosphide, calcium cyanide, and sodium monofluoroacetate, on the grounds of undue toxic hazard to non-target animals. It is relevant to the general problem of rodent control in Africa that Devers et al. also rejected the use of rodenticides formulated as poisoned baits because of the difficulty in finding a food readily acceptable to rodents. As has been seen, other workers have overcome this difficulty. It must be admitted, however, that in some areas of Africa, the procurement of large quantities of food otherwise suitable for human consumption for use as baits for rodents will undoubtedly give rise to difficulties and misunderstandings unless such use is clearly explained to the local population in advance. The tracking powder was placed around all active burrows and in a circle around bait stations in which a dozen palm nuts were placed to attract the rodents. While the reduction was extensive, reinfestation began to appear within 8 months, making another treatment necessary. The reinfestation was due, the authors emphasize, to the fact that the rodent-free area was not protected by a treated barrier zone.

In the Sudan, control of *M. natalensis* is carried out by poisoned baits using crushed dura as a carrier (12); both warfarin and zinc phosphide are used, the campaigns being concentrated in the villages when food in the fields is scarce. Only warfarin is used in the villages, while zinc phosphide is used in the field at a rate of 30 g of the toxicant to 1 kg of crushed dura, this mixture being applied only during the dry season and before cotton is sown.

Though *A. niloticus* is also a pest, it does not reach the densities that *M. natalensis* does.

THE PROSPECTS FOR EFFECTIVE RODENT CONTROL

Once adequate ecological information on the target species is available, the organization of rodent control programmes can be undertaken. Several approaches may be considered: chemical control, cultural or environmental control, and biological control. The prospects and guidelines for each approach will be considered below. However, whatever method or combination of methods is chosen, a reasonably trained and responsible field staff must be available to carry them out, professional supervision must be provided, at least on a part-time basis, and they must be preceded by an estimate of the size of the target population or, alternatively, by the establishment of a reliable index of the size. Control measures should be evaluated in terms of the reduction in the population or the reduction in the index or indices of that population. As has been seen above, the actual numbers of rodents in a given geographical area of tropical Africa (or Asia) may be immense and, unless rodent control measures are constantly employed, the killing of large numbers of rodents may have little more than a transitory effect on the population and may, in fact, result in sizeable if temporary increases beyond original density as numbers recover.

Biological control

Because of concern about contamination of the biotope by pesticides and about the effect of rodenticides on non-target animals, the biological control of rodents has been seen as a very attractive prospect. Unfortunately, there appears to be no predator, pathogen, or parasite that can be considered for operational use against rodent populations in Africa (or elsewhere) at present. The use of cultures of *Salmonella* has been strongly opposed by a Joint FAO/WHO Expert Committee on Zoonoses (22) and their use would be likely to be particularly undesirable in Africa where living conditions often permit an all too close association between man and rodents and the possibility of the contamination of man's food and drink by rodent faeces and urine—which indeed is the presumptive path of transmission of Lassa fever from rodent to man. A recent WHO Scientific Group on the Ecology and Control of Rodents of Public Health Importance (23) called attention to the effect of the myxoma virus in reducing the European rabbit populations in certain areas but also pointed out that rabbit strains resistant to the infection have appeared. While frequent mention is made in the literature of rodents being part of the prey of many species of carnivores in Africa, such predation probably does little more than keep a constant balance between predator and prey. Predation by all species of cats, by dogs, snakes, and predatory birds may be of assistance in keeping rodent populations from reaching excessive numbers, but such predation is not species specific and introduced predators may not only be successful in eliminating rodents but, as is well known, may also turn their attention to more easily sought prey, such as nesting birds.

Chemical control

Rodenticides may conveniently be grouped into anticoagulants (24) and single-dose toxicants (25).

Anticoagulants. All presently marketed anticoagulants are based upon either coumarin derivatives or indandiones. Their general mode of action is the prevention of blood clotting and death is caused by internal haemorrhages. The fact that death results only after multiple feedings considerably reduces the hazards to non-target animals. Bait shyness rarely develops to the compounds of this group and they may thus be used over long periods to maintain rodent populations at low levels. Their disadvantage, however, especially in campaigns that must cover large territories, is the necessity for laying down bait several times to replenish bait stations that have been emptied on initial feedings. It is impracticable to put down large enough quantities of anticoagulant baits to cover an entire period of a campaign in the wet tropics as they may rapidly mould and become unattractive to rodents before the populations are adequately suppressed by feeding on them for a sufficient period of time. Another drawback to their use in Africa is that virtually no base-line data are available on the susceptibility of tropical African rodent species to the various anticoagulant rodenticides commercially available. They can probably be used effectively against *Mastomys* and *Dasymys*, but unsupervised field trials against *Arvicanthis* failed (7).

The use of correct baits with anticoagulants is all-important, in some ways even more so than with the single-dose rodenticides, since one must ensure that the rodent will not only feed once but will continue to feed until it has acquired a lethal dose. There is a very urgent need for laboratory and field trials of different anticoagulants in different bait bases against the various pest rodents in Africa. Until these are carried out, it will be virtually impossible to make any general recommendations as to how and at what concentrations the anticoagulants should be utilized. Furthermore, bait acceptance will vary from area to area even for the same species; as an example, *R. rattus* living in fruit orchards will not readily accept a toxicant offered in a grain base, which is strange to them. Finally, the extensive use of the anticoagulants may well result in rodent resistance to this group of compounds—especially in populations of *R. norvegicus* and *R. rattus*, as has occurred in Europe and America (26). However, such resistance usually results from a long period of selection pressure following extensive use of the anticoagulants and is unlikely to be a serious problem for some time in African cities where only sporadic use has been made of this group.

The use of the anticoagulants, especially on a large scale, requires exacting supervision to ensure that baits are well placed in adequate quantities and that they are replenished as required. Without well-trained and supervised personnel, a large-scale campaign can be a costly failure.

Single-dose or " acute " rodenticides. The use of toxicants of this type is attractive to the planner since they are generally effective against several species of rodent and a single feeding on a well prepared bait will generally provide a quantity well above the toxic dose for virtually all rodent species. Their action is usually rapid and poisoned baits, such as impregnated seeds, vegetables or pieces of fruit, can be widely and rapidly broadcast—even by aircraft. However, the risk to non-target species, including man, is proportionately higher and can preclude the use of many of these compounds in areas where there is ready access to them by non-target animals. As examples, sodium monofluoroacetate, thallium sulfate, arsenic oxide, strychnine, and phosphorus must all be considered as much too hazardous to use in any large-scale rodent poisoning campaigns, not only in tropical Africa but in most other countries as well. On the other hand, antu and norbormide would be completely ineffective against species other than *Rattus*, owing to the extremely high species specificity of both compounds. Similarly, red squill is virtually limited to use against the Norway rat, despite its safety for most other animals. Practically the only one of the older single-dose rodenticides that can be considered for large-scale use is zinc phosphide, particularly if baits are prepared with the addition of tartar emetic (10 g/kg), which causes vomiting in man and domestic animals but not in rodents. As has been seen above, zinc phosphide has been used against *Arvicanthis* and *Mastomys* in Kenya with a considerable measure of success; it is possible that had tartar emetic been added, the kill of non-target animals other than fowl might well have been much lower than that reported.

The question of preferred bait still remains, but generally speaking corn (maize) would probably be as acceptable as any other grain bait likely to be considered, but if the whole cereal is used rodents tend to nibble only at the grain (27). Forest rodent species are likely to be attracted primarily by fruit baits since this group usually feeds on fruits (28), but the density of purely forest species rarely arrives at a level to be of economic importance.

A small number of newer single-dose rodenticides are now appearing on the market but even in temperate climates too little experience is available on which to base recommendations for use in tropical Africa.

Summing up the position of chemical control, it is certainly possible to achieve a reasonably high level of control over large rural or peridomestic areas using a single-dose rodenticide; if properly applied, anticoagulants may also give good control. It would be preferable to precede any large-scale control campaigns by small preliminary studies and trials of the toxicants and baits; further knowledge of the species distribution and ecology of the peridomestic and wild rodent species in Africa is also essential for successful rodent control. It should again be emphasized that the control activities must be carefully prepared and undertaken, accompanied by accurate evaluation of the results, and carefully supervised.

Environmental manipulation

Where adequate knowledge of the ecology and habits of the target species exists, advantage can be taken to utilize environmental measures as a means of control. Clean crops will tend to suffer less damage from grassland rodent species and have much lower infestations than those that are unweeded and provide protection for the rodents. Often destruction of weeds and undergrowth in uncultivated fields surrounding crops will considerably reduce invasion of food crops. Keeping the vicinity of dwellings and the circumference of villages free of plant debris and rank vegetation will also tend to lower rodent populations.

The use of mechanical means, such as barrier fences, is costly and must be excluded from consideration in the marginal farming areas of much of rural Africa. Rodent exclusion or " rat proofing " can certainly be effectively and profitably employed to protect stored food in villages, with a consequent reduction in rodent populations. Traps can, at best, catch only a small proportion of the rodents likely to be found in and around villages and would be useless in the face of the large populations of field rodents. In order to re-use a trap it is necessary to dispose of the rodent that has been caught and reset the trap; such handling of rodents is definitely to be discouraged in any area where Lassa fever—or plague—may be endemic in the rodent populations since it would obviously expose the person removing the rodents to the infectious agents.

CONCLUSIONS

Effective rodent control is possible and has been achieved economically in many parts of the world in cities, villages, and rural areas, in both developed and developing countries, and in temperate and tropical zones. Such control, especially in areas where little is known of the species distribution, population densities, and ecology of the target species must be based on careful preliminary studies of the ecology and interaction of the different species, including fundamental knowledge of the reproductive capacity, movements, and preferred foods of the rodents. When such information is available it should be possible to choose an effective method or combination of methods to use in suppressing rodent populations. Eradication of a species is most unlikely though both natural forces and man's control efforts can result in one species displacing another, e.g., the replacement of *M. natalensis* by *R. rattus*; however, the possible agricultural and public health consequences of such a replacement must also be carefully considered before undertaking a control campaign.

A first step might well be the establishment of a study and demonstration unit in one or more ecological zones to provide the type of information required, to study the economics, and to develop effective and economically acceptable methods of rodent control.

Essential as are the fundamental ecological studies, the training of professional and sub-professional personnel to carry out the studies, the trials, and the control measures is no less important to ensuring effective rodent control campaigns in tropical Africa.

RÉSUMÉ

PROBLÈMES LIÉS À LA LUTTE CONTRE LES RONGEURS EN AFRIQUE TROPICALE

Jusqu'ici, on n'a isolé le virus de Lassa qu'à partir d'un rongeur africain commun, *Mastomys natalensis*, qui est également le principal réservoir de la peste sylvatique dans le sud et l'est de l'Afrique. On le trouve un peu partout au sud du Sahara et au Maroc. Le plus souvent, il s'agit d'une espèce des prairies, gîtant dans les champs cultivés, qui envahit fréquemment les habitations. Ce rongeur cause aussi de graves dégâts aux récoltes.

La lutte contre cette espèce est difficile, en particulier contre les rongeurs qui occupent à la fois un habitat sylvestre et un habitat domestique et péridomestique. A l'heure actuelle, la lutte contre les rongeurs en Afrique tropicale souffre, d'une part, de l'insuffisance des connaissances concernant les espèces et l'action des rodenticides normalisés et, d'autre part, de l'organisation défectueuse des campagnes de lutte.

Nous avons résumé dans le présent document les connaissances et l'expérience acquises à ce jour dans le domaine de la lutte contre les rongeurs en Afrique et examiné les problèmes qui se posent. S'il est possible de lutter efficacement contre ces animaux — chose qui a pu être réalisée économiquement dans de nombreuses parties du monde — il n'est pas sûr en revanche que leur destruction puisse fournir la réponse au problème de la fièvre de Lassa. Il faudrait, dans un premier temps, créer une unité d'étude et de démonstration dans une ou plusieurs zones écologiques pour obtenir le type d'information nécessaire et étudier les facteurs économiques et la mise au point de moyens de lutte financièrement acceptables. En outre, la formation de personnels de niveaux universitaire et intermédiaire pour l'exécution des travaux de recherche, des essais et des mesures de lutte est d'une extrême importance si l'on veut réaliser un travail efficace en Afrique tropicale.

REFERENCES

1. MONATH, T. P. ET AL. Lassa virus isolation from *Mastomys natalensis* rodents during an epidemic in Sierra Leone. *Science*, **185**: 263-265 (1974)
2. KUNS, M. L. Epidemiology of Machupo virus infection. II. Ecological and control studies of hemorrhagic fever. *Amer. J. trop. Med. Hyg.*, **14**: 813-816 (1965)
3. DEYKEYSER, P. L. Les mammifères de l'Afrique noire française, Dakar, Institut français d'Afrique noire, 1955

4. ROSEVEAR, D. R. The rodents of West Africa. London, British Museum (Natural History), 1969 (Publication No. 677)
5. DAVIS, D. H. S. Plague in Africa from 1935 to 1949—a survey of wild rodents in African territories. *Bull. World Health Organ.*, **9**: 665-700 (1953).
6. TAYLOR, K. D. Rodent problems in tropical agriculture. *Pest articles and news summaries*, **13**: 81-88 (1972)
7. BELLIER, L. Rodent pests of West Africa. *Span*, **16**: 28-30 (1973)
8. TAYLOR, K. D. An outbreak of rats in agricultural areas of Kenya in 1962. *E. Afr. Agricult. Forestry J.*, **34** (1): 66-77 (1968)
9. JACKSON, W. B. An investigational framework to assist research and management of rodent populations in Ethiopia, Addis Ababa, Institute of Agricultural Research, 1973
10. EVERARD, C. O. R. Some aspects of vertebrate damage to cocoa in West Africa. *In :* Proceedings of a Conference on Cocoa Pests, Nigeria, West African Cocoa Research Institute, 1964, pp. 114-119
11. SHUYLER, H. R. Control of rodents and grain-eating birds. Report to the Government of United Arab Republic, Rome, Food and Agriculture Organization of the United Nations, 1970 (FAO report No. AGP: RP 7/70)
12. SCHMUTTERER, H. Pests of crops in Northeast and Central Africa, Stuttgart, Fisher, 1969
13. WORLD HEALTH ORGANIZATION. International Health Regulations (1969), Second annotated edition, Geneva, 1974
14. BUXTON, P. A. Breeding rate of domestic rats trapped in Lagos, Nigeria and certain other countries. *J. Anim. Ecol.*, **5**: 53-66 (1936)
15. VOELCKEL, J. & VARIERAS, G. La répartition des espèces *R. norvegicus* et *R. rattus* à Douala, *Med. Trop.*, **19**: 456-459 (1959)
16. BENTLEY, E. W. A further loss of ground by *Rattus rattus* L. in the United Kingdom during 1956-61. *J. Anim. Ecol.*, **33**: 371-373 (1964)
17. GRATZ, N. G. Urban rodent-borne disease and rodent distribution in Israel and neighboring countries. *Israel J. med. Sci.*, **9**: 969-989 (1973)
18. GUGGISBERG, C. A. W. Translation of " An epidemic of plague on Kilimanjaro in 1912 " by R. Lurz, *E. Afr. med. J.*, **44**: 215-220 (1967)
19. MISONNE, X. Quarante années de lutte antipesteuse au Congo, *Ann. Soc. belge Méd. trop.*, **49**: 1-16 (1969)
20. DAVIS, D. H. S. & THOMAS, A. D. Gerbil control. An aid to crop protection and plague prevention, Department of Agriculture & Forestry, Union of South Africa, 1941 (Bulletin No. 233)
21. DEVERS, R. ET AL. Une campagne de contrôle des gerbilles, *Tatera valida* Bocage, à la plaine de la Ndjili, Léopoldville, *Ann. Soc. belge Med. trop.*, **36**: 145-170 (1959)
22. JOINT FAO/WHO EXPERT COMMITTEE ON ZOONOSES. Third report, Geneva, World Health Organization, 1967 (*WHO Technical Report Series* No. 378)
23. WHO SCIENTIFIC GROUP ON ECOLOGY AND CONTROL OF RODENTS OF PUBLIC HEALTH IMPORTANCE. Report, Geneva, World Health Organization, 1974 (*WHO Technical Report Series* No. 553)
24. BENTLEY, E. W. A review of anticoagulant rodenticides in current use. *Bull. World Health Organ.*, **47**: 275-280 (1972)
25. GRATZ, N. G. A critical review of currently used single-dose rodenticides. *Bull. World Health Organ.*, **48**: 469-477 (1973)
26 LUND, M. Rodent resistance to the anticoagulant rodenticides, with particular reference to Denmark. *Bull. World Health Organ.*, **47**: 611-618 (1972)
27. CORNWALL, P. B. & BULL, J. O. Taste preferences in rodenticide development. *Pest Control*, **35**: 15, 16, 18, 20, 64, 66 (1967)
28. HARRISON, J. L. The natural food of some rats and other mammals. *Bull. Raffles Mus. Singapore*, **25**: 154-165 (1954)

DISCUSSION

MONATH: Could you comment on one possible means of biological control that you did not mention: a selective change in the population structure of rodent species within the endemic area. This could be effected, for example, by introducing the competitive species *Rattus*, which, according to Dr French's data, would eliminate over a period of time the less competitive vector species. A number of methods come to mind, for example, development of a rodenticide specific for *Mastomys* or even a live-trapping programme, with release of the competitive species.

GRATZ: This question could be debated at great length, because it implies so many different things. The short answer, I think, is " No, I do not think it is possible ". I do not even think that it would be desirable to attempt it because the outcome would be unpredictable. I would guess that the rodent problem in coastal African cities where *Rattus rattus* and *Rattus norvegicus* have replaced the indigenous species 50 or 100 years ago, is probably far more severe today than it would have been if *Mastomys natalensis* had stayed behind in the cities. I would also suspect that you would have to study many other factors. You might introduce a species that was not a reservoir of Lassa fever, but would it prove to be a better reservoir of plague, murine typhus, leptospirosis, or other rodent-borne diseases? The most likely candidate for a competitive species is going to be *Rattus rattus*, but then *Rattus rattus* itself is being replaced by *Rattus norvegicus*.