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Chapter 4

RODENT PROBLEMS IN AFRICA

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I. INTRODUCTION

After several other major African agricultural pest problems such as locusts and armyworms were reduced, rodents received more attention and are now considered major pests.[183,244] A high degree of social tolerance by Africans to this problem and the tendency of several rodent species to irrupt or dramatically increase their number has resulted in major economic losses.[51] Despite these losses, very little investigation of agricultural rodent problem has occurred, nor is there currently any major existing or proposed effort to deal with rodent pests in Africa. While agricultural problems have received little attention, research on rodent-borne diseases affecting humans has received higher priority.

Taxonomic studies dominated the literature through the mid-1950s, when rodent ecology studies emerged, then expanded and continue to be a primary research topic.[51] Behavioral studies in the laboratory and field increased in the 1970s and have now become an important area of investigation.

Diversity in climate, weather, soil, topography, and vegetation has produced a wide variety of habitats occupied by an equally diverse rodent fauna. Most African countries have 24 to 36 rodent genera,[51] but the majority are not economically important. Rodents have been found at high altitudes and even observed in mines 610 m below the surface.[255] Deserts and semideserts contain mostly cricetids (*Gerbillus*, *Meriones*, and *Tatera*) and a dipodid (*Jaculus*) which are adapted to extremely arid conditions and frequently damage the dryland crops of subsistence farmers. Wet environments, such as marshes, harbor several rodents (*Dasymys*, *Otomys*, *Thryonomys*, and *Rhabdomys*)[144] capable of damaging crops. Grassland and woodland savannas contain *Tatera*, *Arvicanthis*, *Praomys*, and *Thryonomys*[51,144] which are responsible for agricultural losses that are normally chronic but can be periodically acute. When new agricultural areas are cultivated, most species increase in population and significant crop damage occurs.[51,81]

Rodent pest outbreaks or "irruptions" occurring at national or regional levels have been reported since at least 1905 (Table 1). The species involved most frequently are *Meriones shawi* in North Africa and *Praomys natalensis* and *Arvicanthis niloticus* in sub-Saharan Africa. These major rodent outbreaks have been somewhat predictable after periods of extended drought followed by normal rainfall. In other cases, excessive precipitation above the norm has sometimes been followed by increased pest rodent populations.[248] The fact that irruptions do not always occur after these unusual weather events indicates that the cause-and-effect relationships are complex and do not presently permit simple explanations.

Factors which may contribute to increased rodent reproduction and survival include diet, vegetative cover (both of which are influenced by rainfall), fewer predators, and decreased mammalian competition (both of which occur after extensive droughts). Seasonal rainfall patterns with distinct wet and dry periods occur in many areas and are associated with annual reproductive periods of many rodent species as well as migration of large mammals.[179,232] The relationship between increased rainfall and greater rodent numbers was first observed in Kenya[209,210] and later noted in *Praomys erythroleucus* in Sierra Leone.[26] Since then, more than 25 species have been reported to have reproductive periods related to rainfall patterns.

A number of agricultural crops are grown during wet seasons. They become susceptible to damage, particularly when rodent populations are increasing and/or establishing themselves within the sheltered environment provided by maturing crops. Major rodent pests prefer habitats of ripening grain.[245] After harvest, however, when conditions become arid and food and shelter are reduced, rodent populations generally decline due to reduced reproduction and increased mortality. The cycle repeats itself during the next wet season. Many areas experience two annual wet seasons — typically March-May (long rains) and September-November (short rains)[178] — resulting in a bimodal rodent reproductive and population pattern.

Table 1
REPORTED NATIONAL OR REGIONAL RODENT OUTBREAKS IN AFRICA

Year	Country	Species	Ref.
1905	Tunisia	*Meriones shawi*	187
1907—09	Tunisia	*Meriones shawi*	187
1920	Uganda	*Arvicanthis niloticus*	144
1925—26	Tanzania	*Praomys natalensis*	98
1929—30	Algeria	*Meriones shawi*	190
1929—31	Tunisia	*Meriones shawi*	187
1930—32	Tanzania	*Praomys natalensis*	98
1932	Morocco	*Meriones shawi*	82
1934	Morocco	*Meriones shawi*	82
1934—36	Algeria	*Meriones shawi*	82
1936	Tanzania	*Praomys natalensis*	144
1939—41	Morocco	*Meriones shawi*	82
1949—50	Morocco	*Meriones shawi*	21, 196
1951—52	Kenya, Tanzania	*Praomys natalensis, Arvicanthis niloticus*	106, 244, 248
1952—54	Morocco	*Meriones shawi*	82
1954	Tunisia	*Meriones shawi*	21
1955—56	Tanzania, Uganda	*Arvicanthis niloticus, Praomys natalensis*	36, 144
1961	South Africa	*Praomys* sp.	153
1962—63	Kenya, Sudan, Tanzania	*Praomys natalensis, Arvicanthis niloticus, Rhabdomys pumilio*	28, 242—244, 248
1963	South Africa	*Gerbillurus* sp.	108
1963—64	Morocco	*Meriones shawi*	82
1966—69	South Africa, Botswana	*Praomys natalensis, Tatera leucogaster*	233, 254
1966	Zambia	*Praomys natalensis*	226
1967	Zimbabwe	*Praomys natalensis*	37, 264
1968	Kenya	*Arvicanthis niloticus*	245, 248
1969	Sudan	*Praomys natalensis, Arvicanthis niloticus*	115
1971	Tanzania	*Praomys natalensis*	144
1970—72	Nigeria	*Praomys natalensis, Arvicanthis niloticus*	28
1975	Zimbabwe	*Praomys natalensis*	37, 70
1975—76[a]	Sudan	*Praomys natalensis, Arvicanthis niloticus*	28
1975—76[a]	Senegal, Mauritania, Mali	*Praomys huberti, Praomys erythroleucus, Arvicanthis niloticus, Taterillus* sp.	28, 66, 67, 118, 197—200
1975—76[a]	Senegal	*Praomys huberti, Arvicanthis niloticus*	66, 67, 198, 199
1975—76[a]	Senegal, Mauritania, Mali	*Praomys huberti, Praomys erythroleucus, Arvicanthis niloticus, Taterillus* sp.	28, 66, 67, 118, 197—200
1975—76[a]	Nigeria, Niger	*Praomys natalensis, Gerbillus*	28
1977—78	Kenya	*Arvicanthis niloticus Praomys natalensis*	4, 42
1978	Somalia	*Praomys natalensis*	14

[a] A major rodent outbreak occurred throughout the Sahel region during this time period.

Extreme population troughs and peaks are accentuated during and after prolonged drought. For example, a drought in Botswana from 1962 to 1965 resulted in reduced breeding by *Praomys natalensis*. After the drought, a massive rodent irruption took place.[233] Outbreaks occurring in Somalia (1978), Senegal (1975-76), and Kenya (1962) were also preceded by prolonged drought. The return of rains initiates a rapid growth of grasses[35,232] which provide food and protective cover for rodents. Since prolonged drought also affects grazing ungulates, which require longer periods to repopulate by reproduction, the rodent has little immediate competition. Raptors, carnivores, and other predators, reduced during drought, repopulate affected areas slowly, favoring rapid rodent population increases.

Seasonal increases in rodent-borne diseases would be expected at or following rodent population peaks. Human plague cases near the Kenyan border of Tanzania, an endemic plague focus area, normally increase in November-December, reaching a peak in January.[159,177] *Praomys natalensis*, a potential carrier of infected fleas, usually reach peak numbers at this time and are commonly found in households and adjacent farmland. Plague has been seasonal in most African countries[46] and a relationship to rodent population dynamics seems possible.

There are many taxonomic problems within several genera in Africa. Some are currently being addressed through a combination of morphometric, blood protein, and karyotyping studies. To some, this may seem more academic than practical, but important applications have been reported in epidemiological studies of an arenavirus[129] and plague. In the multimammate rat, *Praomys natalensis* species complex of southern Africa, the diploid chromosome number 2N = 36 is susceptible to plague, but the 2N = 32 is resistant.[124] Two distinct species were proposed naming the 2N = 36 chromosome number as *P. coucha* and 2N = 32 as *P. natalensis*.[89] Other rodent pest genera including *Praomys* of West Africa, *Arvicanthis, Aethomys, Gerbillus, Tatera*, and *Saccostomus* have been investigated to help resolve taxonomic questions.[85,130,134,206] Nomenclature and taxonomy in this text follow those of Honacki et al.[112]

II. AGRICULTURAL PROBLEMS

Despite decades of rodent research on biology, taxonomy, ecology, and disease, research on agricultural rodent pest problems in Africa has lagged. Periodic outbreaks involving *Praomys natalensis* or *Arvicanthis niloticus* and the resultant serious crop losses raise concerns, but during the interim years, insidious crop damage due to rodents receives very little attention. The emergency measures taken during these outbreaks are usually ineffective, temporary, acute actions which have not led to long-term solutions.[229]

Africa's climatic, geographic, and habitat diversity has resulted in 12 rodent families with about 240 species[53] of which 77 caused some economic damage (Table 2). Most countries (Figure 1), however, contain only about four to six species which are involved in significant damage to one or more agricultural crops.[71] The genera most frequently involved in field crop damage include *Praomys, Arvicanthis, Meriones, Tatera, Rhabdomys*, and *Thryonomys*, while primarily *Rattus, Praomys*, and *Mus* damage stored foods. Recognition of specific African rodents has been facilitated by an identification manual developed for field use.[162]

Agricultural damage ranges from traditional cereals to plantation, root, forestry, vegetable, and forage crops, as well as postharvest damage to stored foods. When available, cereals are preferred by major rodent pests possibly because of higher water, protein, and carbohydrate content.[171] Important cereal crops significantly damaged by African rodents include wheat, maize, sorghum, rice, millet, and barley. Root crops susceptible to severe damage include groundnut, cassava, and sweet potato, while plantation crops include oil palm, coconut, rubber trees, and cacao. Coniferous tree plantations (including cyprus) and other shrubs and trees receive locally severe damage from several rodent species. Cotton and sugar

Table 2
AFRICAN RODENTS REPORTED TO HAVE DAMAGED AGRICULTURAL CROPS

Family and Genus	Genus Ref.	Species	Ref.
Sciuridae			
Atlantoxerus		*getulus*	263
Funisciurus		*anerythrus*	18, 51, 185, 241, 246
Heliosciurus		*gambianus*	18, 51, 185, 246
		rufobrachium	61, 213
Protoxerus		*stangeri*	61
Sciurus		*carolinensis*	160, 235
Xerus		*erythropus*	18, 76, 78, 115
		inauris	270
		rutilus	70, 172, 173
Pedetidae			
Pedetes		*capensis*	31, 144
Cricetidae			
Cricetomys		*gambianus*	18, 25, 74, 97, 115, 144, 181, 235, 241, 246, 257
Gerbillurus	108	(probably *paeba*)	
Gerbillus	194	*campestris*	263
		gerbillus	5, 263,
		nanus	263
		pyramidum	5, 115, 263
Meriones	194, 247	*crassus*	5, 21
		libycus	21, 113
		shawi	20, 21, 183, 190
Otomys	188	*angoniensis*	70, 249
		denti	144
		irroratus	58, 100, 101, 115, 144
		laminatus	100, 144
		typus	40, 70
Psammomys		*obesus*	5, 194
Steatomys		*caurinus*	25
		pratensis	25, 257
Tatera	18, 38, 144, 247	*brantsii*	115
		robusta	70, 115, 215, 223
		valida	25, 57, 76, 115
Taterillus[a]	25, 28, 66, 67, 115, 118	*gracilis*	
		pygargus	
Spalacidae			
Spalax	260	*leucodon*, (= *ehrenbergi*)	5, 113, 194
Rhyzomyidae			
Tachyoryctes		*macrocephalus*	70
		splendens	70, 115, 127, 180, 238
Muridae			
Acomys	260	*cahirinus*	70, 115, 144, 194
		wilsoni	260
Aethomys		*chrysophilus*	234, 235
		kaiseri	70
Arvicanthis		*niloticus*	5, 6, 18, 66, 67, 70, 76, 115, 135, 144, 181, 182,

Table 2 (continued)
AFRICAN RODENTS REPORTED TO HAVE DAMAGED AGRICULTURAL CROPS

Family and Genus	Genus Ref.	Species	Ref.
			194, 198, 215, 242—244, 246, 247
Dasymys		*incomtus*	18, 76, 78, 115, 244
Grammomys (= *Thamnomys*)		*rutilans*	51
Lemniscomys	18	*barbarus*	263
		striatus	33, 70, 76, 81, 90, 115, 144
Lophuromys		*flavopunctatus*	70, 90, 115, 144
		sikapusi	64, 73, 115
Mus (Leggada)		*minutoides*	76, 235
		musculus	21, 70, 115, 182, 194
Nesokia		*indica*	5, 115, 194
Oenomys		*hypoxanthus*	18, 115, 144
Pelomys		*fallax*	81, 97, 144
Praomys		*albipes*	70
		erythroleucus	18, 118
		huberti	198
		morio	25
		natalensis	14, 18, 69, 70, 74, 75, 76, 78, 81, 87, 97, 98, 115, 181, 198, 215, 233, 234, 242—244, 246, 247
		tullbergi	18, 51
Rattus		*norvegicus*	144, 182, 194, 213, 235, 247
		rattus	14, 18, 70, 74, 75, 115, 182, 194, 228, 247
Rhabdomys		*pumilio*	70, 100, 101, 115, 144, 188, 244, 246, 247, 249
Stochomys		*longicaudatus*	51
Uranomys		*ruddi*	17, 76, 115
Gliridae			
Graphiurus	117	*hueti*	64, 74, 241
		murinus	235, 257
Dipodidae			
Allactaga		*tetradactyla*	5, 113, 184, 194
Jaculus		*orientalis*	5, 113, 184, 194
Hystricidae			
Atherurus		*africanus*	25, 52, 144, 213
Hystrix	115, 144, 172, 173, 246, 247	*africaeaustralis*	108, 115, 128, 235
		cristata	25, 52, 70, 213
Thryonomyidae			
Thryonomys		*gregorianus*	144
		swinderianus	10, 18, 25, 52, 65, 69, 70, 76, 78, 144, 150, 235, 246, 247, 252

Table 2 (continued)
AFRICAN RODENTS REPORTED TO HAVE DAMAGED AGRICULTURAL CROPS

Family and Genus	Genus Ref.	Species	Ref.
Bathyergidae			
Bathyergus		*suillus*	49, 50, 108, 207, 235
Cryptomys		*hottentotus*	49, 60, 230, 235
		ochraceocinereus	25, 260
Georychus		*capensis*	207, 235
Heliophobius		*argenteocinereus*	97
Heterocephalus		*glaber*	70, 110, 115, 238

* Since external appearance of *T. gracilis* and *T. pygargus* are similar, references to damage are listed by genus only.

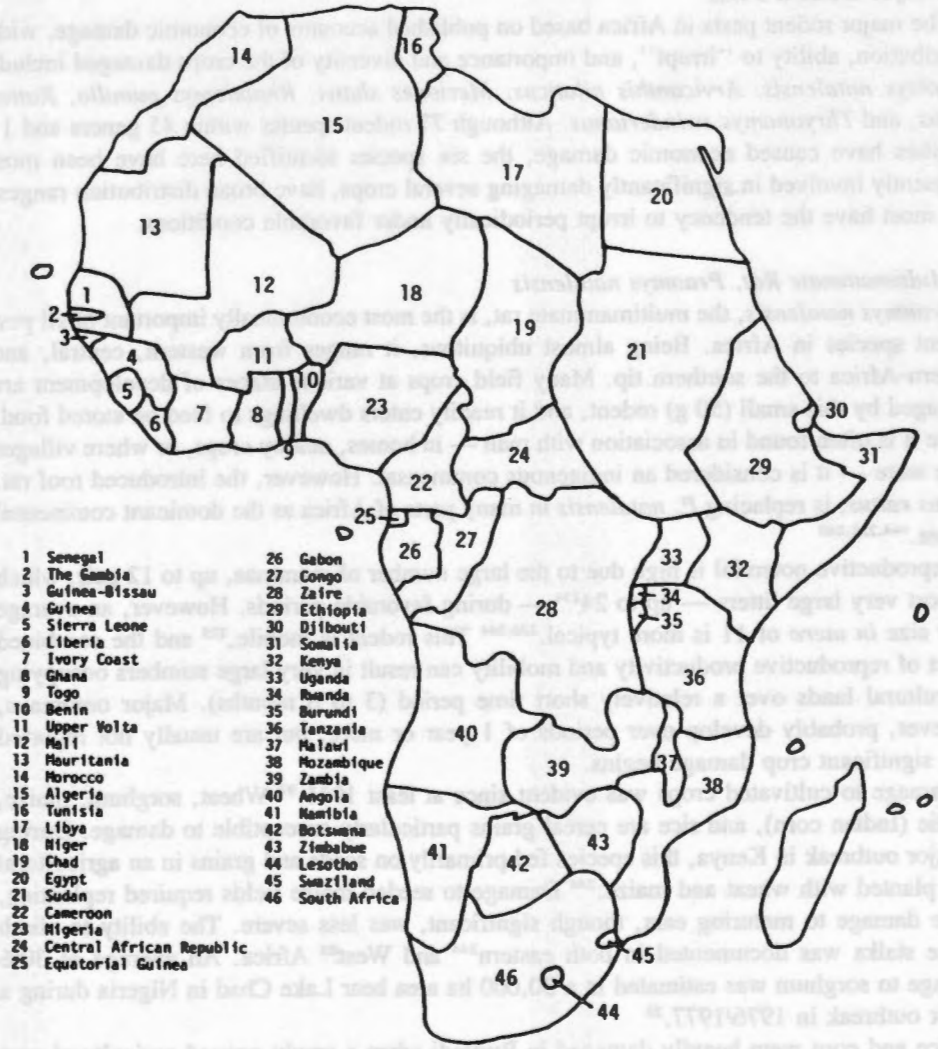

FIGURE 1. Continental African countries.

cane are particularly susceptible during rodent outbreaks. Vegetable and forage crops are not immune to rodent damage. Stored grain and other commodities along with processed food are consumed by several species that enter buildings in large urban areas as well as small village dwellings.[115,125] Estimates of these agricultural losses by rodents have, at best, been good guesses.[126]

Several ecological factors influence pest rodent populations and include climate, weather, soil, vegetation, and topography. When conditions become favorable and susceptible crops are present, agricultural crop damage may be great. Current rodent control measures are insufficient to deal with these periodic irruptions and the result is economic hardship to subsistence as well as cash crop farmers. When ecological factors become only moderately favorable, such as during or after seasonal rains, pest rodent populations usually increase during susceptible crop maturation often resulting in locally severe damage before harvest. The distinct dry and wet seasons result in somewhat predictable patterns of rodent population increases and crop damage,[199,248] but little applied field work has been done to confirm the feasibility of using this knowledge to reduce losses.

A. Major Rodent Pests

The major rodent pests in Africa based on published accounts of economic damage, wide distribution, ability to "irrupt", and importance and diversity of the crops damaged include *Praomys natalensis, Arvicanthis niloticus, Meriones shawi, Rhabdomys pumilio, Rattus rattus,* and *Thryonomys swinderianus*. Although 77 rodent species within 45 genera and 11 families have caused economic damage, the six species identified here have been most frequently involved in significantly damaging several crops, have broad distribution ranges, and most have the tendency to irrupt periodically under favorable conditions.

1. Multimammate Rat, Praomys natalensis

Praomys natalensis, the multimammate rat, is the most economically important of all pest rodent species in Africa. Being almost ubiquitous, it ranges from western, central, and eastern Africa to the southern tip. Many field crops at various stages of development are damaged by this small (50 g) rodent, and it readily enters dwellings to feed on stored food. Since it is often found in association with man — in homes, nearby crops, or where villages once were — it is considered an indigenous commensal. However, the introduced roof rat, *Rattus rattus*, is replacing *P. natalensis* in many parts of Africa as the dominant commensal rodent.[144,222,260]

Reproductive potential is high due to the large number of mammae, up to 12 pair, which support very large litters — up to 24[234] — during favorable periods. However, an average litter size *in utero* of 11 is more typical.[226,244] This rodent is mobile,[225] and the combined effect of reproductive productivity and mobility can result in very large numbers occupying agricultural lands over a relatively short time period (3 to 6 months). Major outbreaks, however, probably develop over periods of 1 year or more, but are usually not reported until significant crop damage begins.

Damage to cultivated crops was evident since at least 1931.[97] Wheat, sorghum, maize, mealie (Indian corn), and rice are cereal grains particularly susceptible to damage. During a major outbreak in Kenya, this species fed primarily on seeds and grains in an agricultural area planted with wheat and maize.[244] Damage to seeded maize fields required replanting, while damage to maturing ears, though significant, was less severe. The ability to climb maize stalks was documented in both eastern[244] and West[63] Africa. An average of 30% damage to sorghum was estimated in a 30,000 ha area hear Lake Chad in Nigeria during a major outbreak in 1976/1977.[28]

Rice and corn were heavily damaged in Burundi when a newly opened agricultural area was developed.[81] *Praomys* was primarily responsible, even in the flooded rice fields. Its

presence in and damage to maturing rice has also been recorded in Somalia,[14] Liberia,[213] and Nigeria where it was also responsible for significant damage to seeded rice fields.[76,78] In West Africa, *Praomys*, along with *Arvicanthis*, are present around flooded rice fields, but only *Praomys* within the rice field itself.[198] Damage, which occurred during a major outbreak, from both species was 80 to 100%.

Cotton damage by this species was "widely known" in the 1930s in Tanzania where all crop stages were susceptible.[98] *Praomys* continues to be a major vertebrate pest in cotton growing areas.[70,213,215,246]

Root crops, particularly groundnuts (peanut), including the vegetative portion, are heavily damaged.[14,18,50,215,233,247] Other root crops damaged include cassava and yams.[18]

Stored grains and foods are frequently consumed, contaminated, or damaged by this commensal rat.[74,87,115] During a major rat outbreak, a loss of more than 2300 bags of stored maize and wheat was claimed by 44 farmers at Kitale, Kenya; farmers also lost 6352 bags gnawed beyond repair.[244] Storage problems have increased after field crops were harvested[98] indicating that reduced food and shelter brought about by harvest influenced movement to village dwellings. Damage to stored rice occurred in Nigerian milling stations, stores, and domestic pantries; although *Rattus rattus* was considered the main storage pest, *P. natalensis* may also have been responsible for the gnawing of jute and polyethylene bags containing rice resulting in spillage losses of 2 to 5%.[78] Similar damage was reported in poultry houses in Nigeria.[75]

Sugar cane,[18,87] tree saplings,[244] sorghum,[14,98,215] millet,[215] sesame,[14] and mealies[234] have also been reported to be damaged by *P. natalensis*. Being a true omnivore, *Praomys* will also feed on vegetables, vegetation, bark, insects, or whatever may be available. This opportunistic species may even feed on adult chickens in Nigeria.[75] The list of agricultural crops damaged by this species will undoubtedly grow as research efforts better document field agricultural problems.

2. Unstriped Grass Rat, Arvicanthis niloticus

Where *Arvicanthis niloticus* is present, it is a serious field pest. Its dominant range is found in eastern Africa only, but the complete range includes Senegal to the west, Egypt to the north, and Zambia to the south.[112,144] In Senegal, it has been a major pest only during outbreaks.[118,198,200] This medium-sized (80 g) rodent is primarily herbivorous, feeding on grasses, and unlike the majority of rodents is diurnal.[54,186,221,257]

The preferred habitat is grassland[221,257] with sufficient cover to protect it from daytime raptors and other predators. In Sudan it was more frequently found near permanent water supplies.[215] Being gregarious, several individuals may be found in burrows which often are modified natural crevices.[144] It may cache food in these burrows[198,215,239] and will occasionally share its burrow with other species — *Lemniscomys striatus*, *Lophuromys flavopunctatus*,[161] and *Praomys natalensis*.[244] In Ethiopia, home ranges for adult males were 2750 m^2 in the wet season and 1400 m^2 in the dry season with adult females and juveniles occupying much smaller ranges.[170]

Field crops damaged include most cereals, cotton, sugar cane, groundnut, and several other root crops. Significant damage to wheat by *Arvicanthis* in Egypt,[194] Sudan,[215] Kenya,[244,246] and West Africa[18,198] has occurred. The potential exists for this rodent to completely destroy tillering wheat fields during outbreaks. Cereal crop damage in Kenya was concentrated around field edges, but in weedy crops, which most likely provided additional cover, damage was throughout fields.[244] Rice seedlings and young stems in Nigeria were damaged primarily by this species.[76] In Senegal, 80 to 100% of growing rice tillers were cut by *Arvicanthis* and *P. huberti*, and seeds 5 to 10 m from field edges were also eaten.[198] Maize in the earlier crop stages is susceptible,[215,244,246] but apparently the developing ears (cobs) are not damaged due to the poor climbing ability of *Arvicanthis*. Other grain crops damaged include millet,[215] barley,[18] sorghum,[67,215] and pennisetum (pearl millet).[215]

Root crops, primarily groundnut,[18,67,215] but also cassava and sweet potato,[18,144,260] are damaged. In some areas, sugar cane and cotton yields may be seriously affected.[18,194,247]

Although not normally a storage pest, *Arvicanthis* occasionally enters grass huts and grain stores.[144,244] Damage to stored food was noted in Egyptian agricultural settlements,[5,135] particularly when food was scarce in fields.[6] Elsewhere, damage to stored grain in eastern Africa[144,244] and at groundnut storage sites in Nigeria[1] indicates that this field pest should be considered at least a minor storage pest.

3. Shaws Jird, Meriones shawi

Meriones shawi, a medium-sized (130 to 200 mm) jird, found only in northern Africa, has been responsible for serious damage to cereals, primarily barley and millet, and forage crops.[21,190] Large, daily food requirements (45% of body weight),[21] continuous food caching, and a habitat preference for moist cultivated areas lend this pest very destructive potentials. Periodic population increases, similar to those of *P. natalensis*, have occurred in Morroco, Tunisia, and Algeria. Vegetable crops, as well as olive groves (low fruit and bark) and almond and pistachio nut orchards (fallen nuts and bark), are also affected. Burrow excavation, which may cover a 15 × 7 m area, has seriously reduced forage crop yields.[20] Two other species of *Meriones, M. libycus*, and *M. crassus*, also damaged cereals, typically in 2- to 3-m clumps in marginal or subsistence crops of North Africa,[5,113] and *M. libycus* has damaged dikes on terraced mountains.[21]

4. Four-striped Grass Mouse, Rhabdomys pumilio

Rhabdomys pumilio, primarily a nonburrowing, diurnally active, small rodent (35 g), was one of three major pests during a serious rodent outbreak in Kenya.[244] It is readily identified by four dorsal black stripes which account for its common name. The range of this species, though not wide, covers eastern and southern Africa from about Kenya south to Angola. Cereals, primarily wheat,[246,247,249] are seriously damaged during high population densities. Although common in maize fields, they are not known to climb stalks to damage maturing cobs.[50,234] In South Africa, 12 to 39% damage by *R. pumilio* and *Otomys* sp. to *Pinus patula* and *P. caribea* trees (many dead or dying) occurred, and 2- to 3-year-old trees were girdled at ground level.[188] A blue dye applied to bark was found in 16 of 76 trapped *Rhabdomys pumilio*, considered a primary pest in coniferous tree plantations in South Africa.[100]

5. Marsh Cane-Rat, Thryonomys swinderianus

Thryonomys swinderianus (in semiaquatic habitats) and *T. gregorianus* (in dryland habitats) are widely distributed and capable of localized severe damage. Commonly referred to as the grasscutter or marsh cane-rat, the larger (4.5 to 9.9 kg) *T. swinderianus* lives in swampy or moist valleys and along margins of rivers and lakes.[144] Its range includes much of western, central, eastern, and southern Africa.

A wide variety of crops are damaged by cane-rats. *T. swinderianus* is a principal mammalian pest of rice in West Africa[18,69,78] where tillering, reproductive, and maturing stages were routinely damaged.[76,150] Also, in West Africa, oil palm seedlings (23.3% damage) and young rubber plants,[18,252] as well as cassava and eggplant[10,150] were consumed by *T. swinderianus*, common in coastal areas. Elsewhere, damage to rice, maize, sweet potato, groundnut, elephant grass, and sugar cane,[52,65,246,247,260] consumption of nuts and fallen fruit, and debarking of young trees in orchards has occurred.[50,144] In southern Africa, cereals (including maize cobs, millet, sorghum, and wheat), sugar cane, pineapple, pumpkin, sweet potato, and groundnut were damaged.[50,233,235]

6. Roof Rat, Rattus rattus

The roof rat, *Rattus rattus*, introduced to many African shipping ports in the late 1800s,[59,213] has normally been a commensal pest damaging stored foods of towns, villages, and remote

farms. It was considered the main rodent pest in Egypt, accounting for at least 4 to 5% in total agricultural losses, including poultry operations.[228] It was a primary storage pest in Uganda,[260] Nigeria[78] (including poultry and rabbit houses),[74,75,77] and in villages of western Kenya.[147] With man's assistance, *R. rattus* continues to extend its African range.[213,222]

In some areas, however, it has entered fields and damaged several growing crops, such as irrigated citrus groves in Egypt[247] where it has also damaged rice, sugar cane, and possibly maize.[5,194] This pest has been found with *P. natalensis* in rice fields of Somalia[14] and was one of four rodents responsible for damage to seeded rice in Nigeria.[76] Coconuts growing in West[18] or eastern Africa[97] may also be damaged by the gnawing and penetration of green husks. Another introduced commensal, *R. norvegicus*, normally restricted to large port cities, has reportedly damaged irrigated cereal and vegetable crops in Egypt.[194,247]

B. Other Rodent Pests

In addition to the six primary rodent pests described above, there are at least 71 others that have damaged one or more crops. All 77 rodent pests are summarized and referenced in Table 2. A brief description of damage by most of the remaining species follows.

1. Sciuridae

Squirrels are frequently involved in damage problems such as in Ghana cacao plantations where, over 1 year, 5.2% of the pods were discarded due to damage.[185] *Funisciurus anerythrus* damages West African cacao and due to its selective feeding behavior may destroy a dozen pods before eating one.[18,51,246] This same selective feeding behavior was exhibited by *Heliosciurus gambianus*,[18,51] a serious pest in Ghana and Nigeria.[246] *F. anerythrus* has also consumed oil palm, fruits, and cassava.[52,241]

Xerus erythropus damages root crops including cassava, potato, and yam.[18,52] Beans, maize cobs, cotton bolls, groundnut, melon, and large fruits are also susceptible food items for this species.[52,78,260] Though not a major pest in Nigerian rice fields, it has consumed seedlings and cut a few stems.[76] Very low damage (0.04%) to maize seedlings and occasionally cobs along field edges by a related species, *X. inauris*, was estimated in South African agricultural lands;[270] in Kenya, *X. rutilus* has reportedly consumed planted seed in dry, marginal farming areas.[70]

One squirrel, *Sciurus carolinensis*, introduced to South Africa about 1900,[22,45,50] has damaged fruit (peaches and grapes), almond, and maize.[45,235] Almost 33,000 bounties were paid from 1918 to 1958 due to damage to fruit, grapes in particular, vegetables, and minimal damage to young trees.[22,160]

2. Pedetidae

The springhare, *Pedetes capensis*, found in sandy, open flats of eastern Africa and parts of southern Africa, occasionally damages sweet potato, pumpkin, planted maize seeds, and growing wheat, as well as barley, oats, maize, sorghum, bean, and groundnut.[31,50,144,180] This large (3 to 4 kg) kangaroo-like rodent, unique to Africa, is hunted both as a pest (10 to 15% estimated damage in Botswana field crops) and as an important food source for bushmen.[31,50,233]

3. Cricetidae

Cricetomys gambianus is widely distributed from Senegal to Sudan, south to Mozambique and the northern edges of South Africa. It damaged cacao in West Africa by feeding on pods within 2 m of the ground.[18,241] In 1934, damage to sprouting cereals was recorded in eastern Africa, and though its numbers were not large, it damaged almost any food crop.[97] Root crops, including cassava and yam,[18,246,257] bulbs, tubers, and groundnut;[50,144,235] fruit, including avocado, pear, and mango;[117,235,257] and vegetables, including beans, peas, and

pumpkin,[117,144,235,260] were damaged. Among cereals in southern Africa, sorghum and maize (cobs) are eaten.[50,235] It will climb trees, if necessary, and in gardens can be a problem.[117] In Harare, Zimbabwe, 42 animals were removed from a 0.5 ha area containing young peas, lettuce, and cabbage plants.[235] In urban areas of West Africa, it has even invaded sewers.[144]

Gerbillus spp. are potential pests in northern Africa where barley and millet farms are at risk.[194] *G. gerbillus*, in millet and groundnut fields of Niger and Nigeria, *G. pyramidum*, found in association with man and domestic animals in Egypt, *G. campestris*, and *G. nanus* have all been referred to as pests,[5,21,263] but documentation is apparently lacking.

Otomys spp. are particularly damaging to conifers (*Pinus patula* and *P. caribea*) in South Africa where (with *Rhabdomys pumilio*) they accounted for 11.9% (5.0% damaged, 6.9% slightly damaged) to 39.0% (17% dead or dying, 22% slightly damaged) damage by girdling 2- to 3-year-old trees at ground level.[188] In Kenya, small quantities of wheat and the bark of shrubs and trees were taken in dry periods by *O. angoniensis*, but otherwise no significant damage was found.[90,249] In high mountains of Kenya, a large number of *O. typus* was responsible for 30 to 40% removal of vegetation.[40] Both *O. irroratus* and *O. laminatus* were found as secondary contributors to coniferous (*P. patula* and *P. caribea*) forest plantation debarking in which *R. pumilio* was the primary pest.[100] *O. irroratus* damaged forest nurseries and plantations (up to 65% damage) in Zaire and South Africa,[50,58,143,174,191] while in Kenya and Uganda, *O. denti* removed bark and cambium from cyprus trees.[144]

Psammomys obesus, the colonial fat sand rat of North Africa, can be very destructive to grains such as barley and millet;[194] up to 500 barley heads were cached in a single burrow.[99] Adapted for arid environments, it is common near brackish water.[5]

Steatomys pratensis in Tanzania and Zambia brought groundnut and finger millet to their burrow to eat.[257] Commonly referred to as fat mice, they have the ability to form large fat deposits which facilitate estivation during unfavorable periods,[213] thus making them very desirable as food by some natives.[180]

Tatera robusta and *T. valida* have rarely been involved in severe damage[247] but are widely distributed in Africa and affect several crops. Cassava, groundnut, and groundnut vegetation were readily eaten in cultivated areas as well as planted seeds of several crops.[38,144,223,247] *T. valida*, however, was a significant pest on rice seeds and seedlings in Nigeria,[76] and in Zaire, it seriously undermined an airport facility by constructing elaborate burrow systems typical of this genus.[57] Cotton has been damaged by *T. robusta* in Sudan.[215]

Taterillus pygargus was implicated in damage to groundnut in Senegal during a major rodent outbreak.[66,67] Increased rainfall during that time resulted in a population density that rose from 2 to 6 individuals/ha up to 180/ha.[197] *T. gracilis*, differing from *T. pygargus* only in chromosome number,[181] also increased during this outbreak and may have contributed to losses in millet and groundnut in Senegal.[28,118]

4. *Spalacidae*

Spalax leucodon (= *ehrenbergi*) storage chambers sometimes contain barley.[113] This mole-rat chews on plant roots in the littoral semi-desert areas of Egypt, where it is usually less abundant than *Nesokia indica*, but nevertheless damages vegetables and tuberous plants.[5,194] Outside Africa, root crops and rhizomes of sorghum are consumed, and burrows with stored barley, wheat, potato, and sugar beet have been found.[99]

5. *Rhyzomyidae*

Tachyoryctes splendens, an eastern African mole-rat, was reported to be in such high numbers that it hampered grazing in Kenya.[127] With *Heterocephalus glaber* it damaged pyrethrum and other cultivated crops[238] that may include sweet potato, corn, beans, peas, and groundnut.[180] *T. macrocephalus*, found only in Ethiopia,[267] has affected grazing lands and root crops in the higher elevations.[70]

6. Muridae

Acomys spp., spiny mice with characteristic dorsal spines, damaged field crops in Egypt.[194] *A. cahirinus*, common throughout Egypt, has also been a commensal pest.[180,214] *A. wilsoni*, common around sorghum fields, was accused of damaging maize cobs in Uganda.[260]

Aethomys chrysophilus, the bush rat of eastern and southern Africa, damaged maize, sorghum, and legumes (peas and beans) and was a storage pest in southern Africa where it occasionally entered houses.[234,235] *A. kaiseri* has reportedly been a pest of fodder grasses in Kenya.[70]

Dasymys incomtus, the shaggy swamp rat, is found from Senegal to Ethiopia, south to South Africa. It damaged palm plantations in West Africa, more so when a cover crop was exhausted, by eating or injuring the palm heart.[18] Rice seeds, seedlings, or young stems were consumed by this species in Nigeria.[76,78]

Grammomys (=Thamnomys) rutilans, the thicket rat, damaged cacao in Ghana and Nigeria.[51] It ranges from portions of West Africa east to Uganda.

Lemniscomys striatus, the striped grass mouse, ranges from Sierra Leone and parts of eastern Africa south to Zambia and Malawi where it is more abundant.[144] It has damaged oil palm, sweet potato, cassava, groundnut, fallen maize cobs, sorghum, and cotton.[18,33,52,81,260] Though capable of affecting most cultivated crops,[144] only minor damage to Kenyan rice seeds occurs.[90] In the southern range, where it is more abundant, it may be a more significant pest.

Lophuromys flavopunctatus, a brush-furred mouse found primarily in eastern Africa, does not cause significant crop damage.[90] It has, however, been involved in conifer damage that may have been due to *Otomys* spp.,[144] and minor damage to wheat, barley, and sorghum in Ethiopia, and fodder grasses in Kenya.[70] *L. sikapusi*, the rufous-bellied rat, may be a minor pest in oil palm and some other crops in Nigeria.[64,73]

Mus (=Leggada) minutoides (=musculoides), widely distributed south of the Sahara, was a major pest to seeded rice in Nigeria.[76] This small (7 g) mouse may occasionally enter homes, and population irruptions have occurred.[235] *Mus musculus*, the introduced house mouse, has become an important commensal pest whose range includes much of Africa.

Nesokia indica, an Asian mole-rat whose range now includes the Suez Canal Zone and Nile delta of Egypt,[99,112] damaged tuber crops, sugar cane, and the roots of wheat and rice.[194] Corn, barley, and vegetables received enough damage that Egyptian farmers flooded burrows to limit losses;[113] the undermining of water channels also occurs.[5]

Oenomys hypoxanthus, a relatively good climber, damages palm bunches in West Africa[18] as well as millet and rice.[144] Commonly named the rufous-nosed rat, it ranges from Sierra Leone to Ethiopia and into much of central Africa.[112]

Pelomys fallax, the creek rat of eastern and southern Africa, was found in fallow fields, corn, sorghum, and cotton fields of eastern Africa but no damage was indicated.[81] Though not usually considered much of a pest, damage to ripening grain in the coastal plain area of Tanzania, consumption of sugar cane and elephant grass (a perennial grass resembling sugar cane grown for forage), and the ability to fell maize stems does occur.[97,144]

Praomys albipes has reportedly damaged maize and sorghum in Ethiopia[70] and *P. tullbergi* has been responsible for losses to cacao and young rubber plants in West Africa.[18,51] Sugar cane, groundnut vegetation, and root crops (cassava and yam) are eaten by *P. erythroleucus* in West Africa.[18]

Stochomys longicaudatus, the target rat, named for its long guard hairs resembling arrows in a target, has damaged cacao in Ghana and Nigeria.[51] This medium-sized (80 g) murid ranges eastward to Uganda and inhabits mostly forests and plantations.[180]

Uranomys ruddi (=foxi), the Rudd's brush-furred rat, was reported to eat planted rice seed in Nigeria[76] and readily colonizes oil palm plantations.[17] Though widely scattered from Senegal to Kenya south to Mozambique, and occasionally found in abundance, it is generally considered rare.[180]

7. Gliridae

Graphiurus murinus, a small (25 g) African dormouse found throughout the sub-Saharan region, was considered a minor domestic pest to stored food in houses of Tanzania and Zambia[257] and responsible for causing shorts in electrical circuits in southern Africa.[235] Another dormouse, *G. hueti*, damaged cacao pods and beans[74] in West Africa where 4.6%[241] and 2.2 to 11.8%[64] damage estimates were made. Dormice in Tanzania occupied beehives and were considered a nuisance by beekeepers.[117]

8. Dipodidae

Allactaga tetradactyla, the four-toed jerboa of Libya and Egypt, may be involved in damage to several arid zone crops including barley in valleys.[5,113,194] This species is expected to decline when coastal valleys are cultivated and its preferred habitat changes.[5,184]

Jaculus orientalis, another North African dipodid, damages sprouting barley and ripe grain, sometimes severely, in the drier areas of Egypt, especially on desert slopes near the Mediterranean Sea.[5,184,194] This large jerboa (130 g) was common in and around Bedouin fields where barley and dates were found stored in burrows.[113] Bedouins commonly capture and eat this rat.[184]

9. Hystricidae

Atherurus africanus, the African brush-tailed porcupine, is found in western and central Africa where this small porcupine fed on sweet potato and cassava near forest edges.[52,144,213] Fruits such as pawpaw, banana, and guava were consumed in Uganda.[52] Newly opened agricultural areas of forests are very susceptible to damage.

Hystrix spp., large porcupines of Africa, are capable of severe local damage to many crops including sugar cane,[246,247] root crops, groundnut, pumpkin, maize cobs (by severing the stalk), and young cotton.[144] *H. africaeaustralis* damaged maize, potato, and groundnut in Zimbabwe where they were controlled by attraction into baited, fenced enclosures.[128] In southern Africa, it may also affect beet, carrot, onion, maize cobs, pumpkin, melon, and plants of young cotton, beans, and peas.[50,233,235] Almost 360 bounties were paid by South Africa in 1956.[108] *H. cristata*, with a similar appearance and behavior, occurs within the northern half of Africa. It damaged potato and maize in Kenya[70] and cassava, maize cobs, sweet potato, and groundnut in Uganda.[52,260] In some areas, populations of *H. cristata* have declined rapidly from human depredation due to their pest status and tasty flesh.[213]

10. Thryonomyidae

The savanna cane-rat, *Thryonomys gregorianus*, coexists with the marsh cane-rat, *T. swinderianus*, in many areas, and due to a similar appearance, is not readily distinguished. *T. gregorianus* has been a pest of pumpkin, groundnut, sweet potato, and stems of cassava and maize.[50,144] Both species are commonly hunted for food,[50] and attempts at domestication were made in West Africa.[2,3]

11. Bathyergidae

Five species within the family Bathyergidae also two within Rhyzomyidae, one murid (*N. indica*), and one spalacid (*Spalax leucodon*), are commonly referred to as mole-rats. All have been economically important rodent pests in Africa. *Heliophobius argenteocinereus* (=*emini*), the silvery mole-rat, damaged potato and groundnut in Tanzania.[97] Another bathyergid, *Cryptomys hottentotus* damaged cassava in the northern half of Zambia[230] and potato and vegetable gardens of South Africa.[49,50] It also was a nuisance in irrigation schemes[60] and on lawns and golf courses by creating mounds while burrowing.[235] *C. ochraceocinereus* has dug up newly sprouted maize and has damaged sweet potato and groundnut.[25,260] *Georychus capensis*, the Cape mole-rat, also consumed or spoiled vegetable, root, and bulb

crops in South Africa.[50,207,235] *Bathyergus suillus*, a dune mole-rat of South Africa, excavated burrows which were a nuisance on golf courses, bowling greens, and tennis courts; damaged reaping machines in wheat fields; contributed to soil erosion in the sandy coastal belt; and undermined railway track beds.[49,50,108,207,235] *B. suillus* has also been a pest of vegetable gardens.[49,50] *Heterocephalus glaber*, the naked mole-rat of eastern Africa, was responsible for losses in pyrethrum and some other cultivated crops including gardens.[110,238] Irrigation dikes in Somalian orchards were apparently affected by *H. glaber*,[70] and Ethiopian citrus tree roots, field crops, and lawns have been damaged.[125]

III. DISEASE PROBLEMS

Tropical diseases abound in Africa, and rodents are responsible for several which affect man or livestock including plague, leptospirosis, murine typhus, and Lassa fever.[86,87] A number of arthropod-borne viruses, many bearing the African name of geographic discovery, are thought to involve rodents.[19,137,139,157,261] One such virus, Rift Valley fever, affecting lambs and calves as well as man, is transmitted by a mosquito, but the vertebrate host, rodent or otherwise, has been difficult to confirm.[43,262] Rodent variants of the rabies virus exist in Africa in several species including *Xerus inauris*.[7,19,138,144] They mimic rabies virus in diagnostic tests and clinical symptoms. Small mammal involvement may yet prove to be significant.[137] Diseases in which African rodents play a part are summarized in Table 3.

A. Bacterial

1. Plague

Plague has been a serious disease in northern Africa since an epidemic in Libya in 50 B.C.,[111] and other parts of Africa since the pandemics in 542 A.D.[86,169] and in the 14th Century.[195] Many epidemics followed known introductions of *R. rattus* and/or their infected fleas in the late 1800s. Some authors, however, have suggested that plague has been present in Africa long before written records indicate.[48,208]

In the early 1900s, plague was discovered in fleas of indigenous rodents — gerbils, *Tatera* spp., and the multimammate rat, *Praomys natalensis*.[234] In some areas of eastern Africa, sylvatic plague was present prior to the known arrival of *R. rattus* and involved *P. natalensis*, *A. niloticus*, *R. pumilio*, and *O. angoniensis*.[92,260] *P. natalensis*, being both commensal and a field pest, frequently contacts *R. rattus* in dwellings and *Tatera* spp. in the field, thereby serving as an intermediary to spread the disease.

Plague foci are found in four areas including one each in southern, eastern, western, and northern Africa.[7] These foci, as in many other plague areas of the world, harbor rodents which are resistant and periodically spread plague to susceptible species resulting in epidemics involving humans. For example, in southern Africa, *T. brantsii* has been a principal wild plague reservoir[44,47,122] spreading the disease to susceptible *P. natalensis* populations which transmit infected fleas directly to humans or indirectly by involving a third species, *R. rattus*. Research in southern Africa has demonstrated two "forms" of *P. natalensis*,[84,88,89,95,151] one being plague-resistant (*P. natalensis*, species A) and one susceptible (*P. coucha*, species B).[124] A similar resistant/susceptible cycle may be operating within this species complex influencing plague outbreaks.[250,251]

The urban phase introduced to South Africa in 1899[163] has not been prevalent there since 1938 nor in Mombassa (port of Kenya) since 1941.[44,189] Outbreaks are now confined to rural areas (sylvatic phase) where the conditions for man to become involved in the gerbil/multimammate rat/roof rat transmission cycle are greatest. A 5- to 6-year periodicity was common.[44]

Plague in North Africa is largely restricted to coastal areas, and the indigenous jerboas which are resistant have not readily spread the disease inland to susceptible commensal

Table 3
SOME AFRICAN RODENT-BORNE DISEASES AFFECTING MAN

Disease	Agent	Rodent reservoir[a]	Vector	Ref.
Bacterial				
Brucellosis	*Brucella suis*	*Arvicanthis niloticus*, Commensals, *Praomys natalensis*	Direct contact	19, 105
Leptospirosis	*Leptospira interrogans*	*Arvicanthis niloticus* *Cricetomys gambianus, Mus musculus, Rattus norvegicus, Rattus rattus*	Urine of infected rodents	12, 15, 16, 19, 50, 86, 156, 227, 247, 256
Plague	*Yersinia pestis*	*Acomys, Arvicanthis niloticus, Aethomys chrysophilus, Aethomys kaiseri, Lemniscomys striatus, Meriones, Mus, Otomys angoniensis, Otomys irrorattus, Otomys unisulcatus, Praomys natalensis, Rattus rattus, Rhabdomys pumilio, Tatera brantsii, Tatera leucogaster, Tatera robusta, Xerus inauris*	Fleas	4, 8, 44, 48, 50, 51, 84, 87, 88, 89, 92, 93, 104, 106, 117, 122, 123, 124, 163, 168, 189, 204, 210, 211, 234, 240, 247, 250, 251
Rat-bite fever	*Spirillum minor, Streptobacillus monoliformis*	Commensals *Meriones shawi, Paraxerus cepapi, Xerus erythropus*	Oral secretion from bite	19, 24, 86, 102, 116, 152, 261
Relapsing fever (tick-borne)	*Borrelia recurrentis*	*Praomys natalensis*	Ticks	19, 86, 139, 166, 224, 269
Salmonellosis	*Salmonella* spp.	Commensals	Contaminated food	19, 50, 86
Tularemia	*Francisella tularensis*	Commensals, Field rodents	Direct contact, blood-sucking arthropods	86
Rickettsial				
Boutonneuse fever (African tick typhus)	*Rickettsia conorii*	*Acomys cahirinus, Aethomys kaiseri, Arvicanthis niloticus, Lemniscomys striatus, Lophuromys, Lophuromys*	Ticks	19, 30, 41, 80, 86, 99, 104, 133, 155, 261

		flavopunctatus, Mus musculus, Otomys angoniensis, Otomys irroratus, Praomys natalensis, Rattus rattus, Rhabdomys pumilio		
Murine Typhus	*Rickettsia typhi*	*Acomys cahirinus, Arvicanthis niloticus, Cricetomys gambianus, Mus musculus, Otomys angoniensis, Rattus norvegicus, Rattus rattus Tatera nigricauda*	Fleas	19, 86, 99, 104, 131, 132, 253, 261
Q-fever	*Coxiella burnetii*	*Acomys cahirinus, Aethomys kaiseri, Apodemus sylvaticus, Arvicanthis niloticus,* Commensals, *Cricetomys gambianus, Lemniscomys barbarus, Lemniscomys striatus Lophuromys, Otomys angoniensis, Otomys irroratus, Praomys natalensis, Rhabdomys pumilio, Tatera nigricauda*	Airborne, direct contact	19, 23, 86, 99, 104, 131, 261
Viral				
Crimean-Congo hemorrhagic fever	Congo virus	*Praomys natalensis*	Ticks	261
Lassa fever	Machupo-like arenavirus	*Mus minutoides, Praomys natalensis, Rattus rattus*	Urine of infected rodents	7, 8, 62, 86, 88, 122, 136, 164, 165, 247, 265
Rift Valley fever	Rift Valley virus (sandfly fever group)	*Arvicanthis niloticus*	Mosquito	7, 19, 43, 86, 89, 144, 157, 220, 262
Protozoan				
African sleeping sickness (Trypanosomiasis)	*Trypanosoma spp.*	*Hystrix cristata, Xerus inauris*	Tsetse fly	9, 144, 201, 213
Babesiosis	*Babesia* spp.	Porcupines,	Ticks	19, 146
Leishmaniasis	*Lelshmania donovani L. tropica*	*Acomys cahirinus, Arvicanthis niloticus, Rattus rattus, Tatera nigricauda, Tatera robusta, Xerus rutilus*	Sandflies	11, 13, 19, 27, 34, 86, 91, 94, 103, 104, 107, 109, 114
Toxoplasmosis	*Toxoplasma gondii*	*Rattus norvegicus, Rattus rattus*	Direct contact, water	19, 56, 86, 203, 205

Table 3 (continued)
SOME AFRICAN RODENT-BORNE DISEASES AFFECTING MAN

Disease	Agent	Rodent reservoir[a]	Vector	Ref.
Helminthic				
Angiostrongyliasis	*Angiostrongylus cantonensis*	Several	Third-stage larvae in rat lung, mollusks	19
Hepatic capillariasis	*Capillaria hepatica*	*Otomys irroratus, Praomys albipes, Praomys natalensis, Rattus rattus*	Contaminated food, water, or soil	49, 68, 219
Schistosomiasis	*Schistosoma* spp.	*Arvicanthis niloticus, Dasymys incomtus, Gerbillus pyramidum, Lophuromys flavopunctatus, Oenomys hypoxanthus, Otomys, Pelomys fallax, Praomys jacksoni, Praomys natalensis, Rattus rattus, Tatera, Thallomys*	Water	51, 86, 96, 139, 149, 154, 167, 176, 192, 193, 216, 217, 218, 219, 237
Trichinosis	*Trichinella spiralis (T. nelsoni* proposed for tropics)	*Praomys natalensis, Rattus norvegicus*	Infected meat	19, 50, 268

[a] Includes both true reservoirs and potential reservoirs implicated by serological surveys or parasite presence.

species. In Egypt, rodent control on river boats was apparently successful in stopping the spread of plague from the Suez Canal and northern ports to lower Egypt.[120] Ports along the Mediterranean are particularly susceptible through introduction of infected fleas and/or rats from shipping operations. The fact that *A. niloticus* is now somewhat commensal in Egypt[204] could play a significant role in future plague outbreaks.

Since the first recorded outbreak in eastern Africa in 1697, the Kenya/Tanzania border has continued to be an endemic plague focus.[208,210,240] Through serological surveys, *A. niloticus, R. rattus,* and *P. natalensis* have been identified as important reservoir hosts.[48] Nomadic movements of people, periodic rodent irruptions, and the presence of susceptible rodent species have led to frequent epidemics.[168] It is quite possible that rodent control operations have contributed to plague outbreaks when fleas were not also controlled.

The relationships between rainfall, rodent breeding seasons, and flea indices in eastern Africa were examined early as causative parameters of plague.[209,210,240] Seasonal human case fluctuations have been related to rodent population peaks when high natural mortality begins, thereby increasing the chances for infected fleas of rodents to contact humans. Monitoring the rat/flea index in these endemic areas has helped to identify potential plague areas and time periods.[142] The identification of fleas and rodents has explained why some areas in South Africa have no plague while others do.[122]

Plague was in epidemic proportions in 1929, killing thousands of people in West African coastal areas such as Lagos, but is now relatively rare.[213] *R. rattus* has largely been replaced by *R. norvegicus* as the dominant commensal in much of the coastal area,[32,148,258] but away from the port areas *R. rattus* is "not uncommon in towns and villages throughout the forest belt."[213] The replacement of *R. rattus* by *R. norvegicus* occurred in Egypt also and was believed to be one of several factors responsible for a decline in plague severity.[120]

Certainly the use of drugs, when delivered in a timely manner, has limited the severity of plague outbreaks in Africa today. Within the endemic areas, however, plague remains serious. From 1971 to 1980, the World Health Organization (WHO) annually recorded about 22 deaths and many more cases.[86] Of 30 countries reporting plague from 1958 to 1979, 16 were in Africa.[4]

2. Salmonellosis

Another bacterial disease, salmonellosis, is transmitted to humans by food contaminated with rodent feces containing *Salmonella*, of which there are some 2000 serotypes known.[19] Although more commonly reported in temperate countries, the presence of several commensal rodents and unsanitary conditions suggests that salmonellosis may not be uncommon in Africa.

3. Leptospirosis

Leptospirosis, a spirochaete transmitted to man in urine of infected commensal and field rodents, occurs worldwide, including Africa.[19,247] Fatality rates are generally low but may increase with age or in the more susceptible human populations of Africa.

4. Others

Rat-bite fever, brucellosis, relapsing fever, and tularemia are bacterial diseases affecting Africans and involving reservoirs that include several rodents present in Africa. The causative agent, rodent reservoir, and vector or method of transmission are summarized in Table 3.

B. Rickettsial

Murine typhus, a rickettsial disease commonly transmitted from commensal rodents to man by the flea *Xenopsylla cheopis* has been hosted by several field and commensal rodents in Africa. Boutonneuse fever (African tick typhus), carried by *Arvicanthis niloticus* and

other rodents, is transmitted to man by ticks. A third rickettsial disease, Q-fever, spread by the airborne or direct contact route, has also been found in several commensal and field rodents in Africa.

C. Viral

1. Lassa Fever

The virus causing Lassa fever has become well known since its discovery in West Africa.[29,165,265] It is a fatal arenavirus infection related to machupo virus which causes Bolivian haemorrhagic fever in South America. The mode of transmission is not well understood, but the urine of infected rodents, *Praomy natalensis*, can transmit the virus through direct contact or contaminated food; person-to-person infections are also possible during acute stages of illness. A large number of ectoparasites have been found on *P. natalensis*, and involvement of one or more may yet be demonstrated.[122]

The epidemiology of Lassa fever was studied in households of an endemic site in Sierra Leone.[136] Rodent infection was focal with 39% viremic rodents found in human case houses compared to only 3.7% in control houses. Trapping removed an estimated 31 to 82% of the *Praomys* population but did not significantly reduce human seroconversion rates over a 4-week period. Preventing or interrupting epidemics of Lassa fever will require additional study and may prove to be very difficult.

The antibodies to a Lassa-related arenavirus named Mozambique were found in *P. natalensis* (20% seropositive) and *Aethomys chrysophilus* (7.7% seropositive) in Zimbabwe.[129] All of the positive *P. natalensis* were of the diploid number 2N = 32 while none were of the chromosomal type 2N = 36. If the Mozambique virus is a naturally attenuated form of Lassa fever, and if the immunity response of Mozambique-exposed Rhesus monkeys to Lassa fever[140] is present in humans, a vaccine against Lassa fever could be developed.[129] There is yet no evidence of human clinical symptoms from this virus although antibodies have been found. Other Lassa-related arenaviruses have been found and may continue to be found in the *Praomys* species complex[83,266] or possibly other rodents.[8]

2. Others

Crimean-Congo hemorrhagic fever and Rift Valley fever have been found in rodents, but their role as reservoirs needs further study.

D. Parasitic

1. Helminthic Infections

Parasitic diseases of humans involving rodents in Africa are present but epidemiologically not well described. *Shistosoma* spp., blood flukes whose larvae develop in freshwater snails, emerging to penetrate the skin of humans in freshwater bodies, have been found in several African rodents. Although irrigated agricultural lands have been associated with a high human incidence, the role of naturally infected rodents is debatable.[167] High parasite incidence rates have been recorded in those species that occupy moist environments, i.e., *Dasymys* sp., *Pelomys* sp., and *Lophuromys flavopunctatus*, which may be involved in maintaining the life cycle of shistosomiasis in Africa.[51,216,217,219] Other genera which have harbored the parasite but which may not be important agents in the life cycle due to drier habitat preferences include *Praomys*, *Rattus*, *Otomys*, and *Thallomys*. The fact that some rodents readily eat snails, i.e., *Lophuromys flavopunctatus*,[96] could influence favorably the prevalence of this disease.

Trichinosis, caused by an intestinal roundworm larvae, is found worldwide. When raw or undercooked infested meat is consumed, the encysted larvae mature in the intestine. Adults mate and female worms release larvae which pass through the intestinal wall and travel via the bloodstream to skeletal muscle throughout the host. It is usually mild, but

when large numbers of trichinae occur, it can be fatal. Fecal transmission by commensal rodents could result in human infection.[212] Since several rodent species are eaten by Africans, the incidence of human infection by this route could be significant. Trichinae have been found in several predators of rodents (serval, hyena, jackal),[175] and bushpigs, another rodent predator, have caused outbreaks of human trichinosis.

Capillaria hepatica, parasitic worms which principally infect rodents can fatally infect man. Though reported cases in Africa are few, the zoonotic involvement may be more than realized. The infected liver of rodents, when consumed by man or another predator, contain eggs of the adult nematode which develop in the gut and dropped feces. When a second host ingests these eggs, larvae are released, migrate to the liver, and mature as adults. During the first stage, "spurious infection" occurs with no clinical infection occurring until the second stage when larvae are produced. Infected *R. rattus* and *P. albipes* were found in commensal habitats of Ethiopia.[68] *P. natalensis* in South Africa had infection rates of 48%, and infected gerbils, mice, and humans were found.[39,145,231] In Zaire, characteristic egg spots were found by visually inspecting the liver in several rodent species.[219] Prevention would appear likely through eliminating human consumption of contaminated food, soil, and possibly water.

2. Protozoan Infections

Leishmaniasis (*Leishmania tropica*, cutaneous type) occurs in most of Africa with *L. donovani* (visceral type) found only in southern Sudan and Kenya.[19] It is transmitted to man by sandflies which have fed on infected rodents or other mammalian hosts. Untreated, it can be fatal. It is more common in rural areas (both types) and in children (visceral type). Dogs appear to be an important reservoir, but *Arvicanthis niloticus* hosted *Leishmania* in Senegal[202] and Ethiopia.[94] In Kenya, the parasite was found in a ground squirrel (*Xerus rutilus*) and gerbils (*Tatera* sp.).[94,107]

In Africa, other protozoan diseases with rodent reservoirs include African sleeping sickness (trypanosomiasis), babesiosis, and toxoplasmosis. These are summarized in Table 3. Malarial species occur in anomalurids (flying squirrels),[141] *Atherurus africanus* (a porcupine), and *Grammomys (= Thamnomys) rutilans*.[79,144,146,213] As in monkeys, however, which carry several malaria species potentially affecting man, natural transmission is probably uncommon.

IV. DISCUSSION

The Sahel region has once again suffered a drought, and when the rains do come again, a repeat of the 1975-76 rodent outbreak could very likely happen. Walsh[259] predicted that economic problems will continue even when rains return since human population increases have canceled modest gains in food production. A severe rodent outbreak now could have consequences worse than the 1975-76 occurrence.*

Monitoring of certain pest rodents to anticipate population increases in selected critical areas would be extremely helpful in Africa. Enough lead time necessary to alert farmers and mobilize control efforts would result in increased effectiveness of limited manpower and materials. Such forecasting tools using rodent activity indices or density estimators in agricultural areas have recently been proposed.[119,199,248]

Procedures have largely been (1) waiting for reported crop damage, (2) confirmation of these reports by on-site visitations, then (3) instituting control methods. Such emergency campaigns have proved costly and difficult to organize.[245] The time lag is too long for effectively stopping or reducing crop losses from short- or long-term rodent outbreaks; nor

* Such an outbreak did occur in 1986 to 1987.

does this approach prevent the chronic, insidious damage that is occurring each crop season resulting in significant losses.

Reducing crop losses due to rodents requires continual effort related more to annual chronic rat damage rather than emergency control efforts. A simulation model for tropical rodent populations was compared to actual field data from Sierra Leone to evaluate the effects of different population characteristics and environmental conditions on the rate of growth of a *Praomys huberti* population.[72] Such models increase the understanding of pest rodent population dynamics and within certain limitations[236] help in designing appropriate monitoring methods to forecast rodent problems in advance.[229]

Applied research on agricultural rodent problems in Africa should be increased. Sampling procedures for crop damage assessment, appropriate for African cropping systems affected by rodents, is lacking. Small-scale field trials are also needed for determining efficacy of current practices compared to new methods. Laboratory testing of candidate chemicals on major rodent pests and food preference tests are needed to develop better bait delivery systems. Nonchemical control methods need to be evaluated and incorporated into an integrated, cost-effective rodent pest management system unique for African rodent problems. Many African pest rodents are used for food[55] and this must be considered in any control program.

Africa contains 31 "crisis countries" designated for special attention by international agencies.[121] With so many economic problems needing attention, rodent control has been neglected short of a catastrophy. In fact, African agriculture, in general, has been biased by low government investments in research, training, and extension services.[158] Formally trained rodent pest management specialists are few, training and extension materials and programs for farmers are lacking, and outside donor support to assist in institutionalizing rodent control has been limited. At a time when increased food production is so vitally needed, research and development of cost-effective rodent control techniques specific for Africa need to be encouraged.

Africa is ripe for the development of cost-effective rodent pest management techniques to increase food production and reduce disease incidence. The problem is severe, while the potential gains are large. The passive acceptance by farmers and government officials of damage caused by rodents combined with the lack of a concerted effort by donor agencies supporting agricultural development has prolonged the rodent problem. Until efforts reach the magnitude of what has been done on other major African pests or on rodent damage pests in other parts of the world, rodent damage in Africa will continue to be a major problem.

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