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Rodent population fluctuations in three ecologically heterogeneous locations in northeast, central and southwest Tanzania

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ABSTRACT. Rodent population fluctuations and breeding patterns were investigated at localities in South-west, Central and North-east Tanzania. The three localities are ecologically heterogeneous in vegetation types, rodent species diversity, rainfall pattern and altitude. Capture-Mark-Release studies were conducted in 2001-2003 to compare rodent species composition and population trends. In North-eastern Tanzania, species composition is diverse and includes *Mastomys natalensis*, *Lophuromys flavopunctatus*, *Grammomys dolichurus*, *Arvicanthis nairobae*, *Praomys delectorum* and *Mus* sp.. Five species were recorded in South-western Tanzania namely, *M. natalensis*, *Graphiurus murinus*, *Saccostomus elegans*, *Tatera leucogaster* and *Steatomys pratensis*. In Central Tanzania *M. natalensis* was dominant, but a few *Lemniscomys griselda* were captured. Rodent abundance fluctuations were distinctively seasonal, especially for *M. natalensis* in the three localities and *T. leucogaster* in South-west Tanzania. In North-eastern Tanzania, *L. flavopunctatus*, *G. dolichurus*, *A. nairobae and P. delectorum* had low, but relatively stable populations throughout the year. In South-west Tanzania, population peaks of *M. natalensis* and *T. leucogaster* were reached in the dry season (June-September). In Central Tanzania, breeding of *M. natalensis* was seasonal, with highest population abundance during July-November. Female *M. natalensis* were reproductively active in January-May and males had scrotal testes in December-June. No males were sexually active during July-November. Female *T. leucogaster* in South-western Tanzania were reproductively active during November-April/May whereas sexually active males appeared in the population during November-March. In view of the observed rodent population fluctuations and breeding patterns, recommendations are given for pragmatic rodent control in South-west and Central Tanzania and for plague in North-eastern Tanzania.

KEY WORDS : *Mastomys natalensis*, *Tatera leucogaster*, *Grammomys dolichurus*, *Lophuromys flavopunctatus* sp., *Praomys delectorum*, *Saccostomus elegans*, *Graphiurus*, *Mus*, *Arvicanthis nairobae*, Tanzania, population fluctuation, crop damage, plague.

INTRODUCTION

In Tanzania, rodent populations exhibit a range of densities within and between seasons and years. Temporal variations in rodent density have been reported for various species, including the most common pest, *Mastomys natalensis*. TELFORD (1989), LEIRS (1992) and CHRISTENSEN (1996) reported densities of 1125, 900 and 384 animals/ha, respectively, in Morogoro, Tanzania. For a species whose breeding characteristics are strongly dependent on rainfall patterns, such fluctuations are expected to be the rule rather than the exception (MAKUNDI & MASSAWE, 2003). Population fluctuations of *M. natalensis* are influenced by density dependent and density independent factors occurring simultaneously, which regulate population size (LEIRS et al., 1997). Although much emphasis has been directed towards understanding the effect of weather on rodent population dynamics in Tanzania (TELFORD, 1989; LEIRS, 1992; MWANJABE & LEIRS, 1997; etc), the intrinsic characteristics of the species and nature of habitats have received much less attention. For example, it is more common for certain species populations to fluctuate more widely in certain types of habitats than in others, but the mechanisms underlying such fluctuations are little known. For this reason, ecologically heterogeneous areas may be expected to exert different influences on resident rodent species leading to varying levels of population fluctuations. Changes in population density of rodents, particularly the occurrence of high numbers at the most susceptible stage of crop growth, may have severe consequences on crop damage and losses. In plague outbreak foci, these changes could also influence the severity of disease outbreak and dissemination. We therefore investigated population fluctuations of different species of rodents in three ecologically heterogeneous localities in Tanzania in view of providing a pragmatic approach for effecting control measures to reduce rodent damage to maize crop at sowing and seedling stage and for plague control.

MATERIALS AND METHODS

Study sites

The study was conducted in northeast, central and southwest Tanzania. In Northeast Tanzania (NET), the study was carried out at two locations, Manolo and Magamba, in Shume Ward, Lushoto District, in the western Usambara Mountains. Shume ward is located north of

Lushoto town (04º 42' 16"S, 38º 12'16'E). The area has a single, but asymmetrical rainy season, extending from October to May. November/December and March/April are the wettest months (Fig. 2). The dry season is from July to September. There were two permanent trapping sites in the western Usambara Mountains. At the Magamba locality, a grid was set adjacent to the montane rain forest in an area reserved for agro-forestry at an altitude of 1730 m above sea level (a.s.l.). The grid was located on a steep slope and was planted with trees including *Gravillea robusta* and evergreen bushes. The Manolo study area was at an altitude of 1826 m a.s.l. The grid was set in permanent fallow land and bushes, surrounded by fields of maize, fruit trees and *Gravillea robusta*. Much of the grid had bushes whose vegetation was dominated by *Rumex usambarensis*. The Manolo and Magamba study sites are about 15 km apart.

In Chunya District, South-west Tanzania (SWT), the climate is characterized by a long dry season from April to November (Fig. 5). There is a single rainy season from December to March, but the amount of rainfall varies considerably between years. Chunya District has a hilly landscape, with vegetation characterised by miombo woodlands, scattered acacia trees and bush thickets. However, the study area was in the flat low lands in the Lake Rukwa basin within the Rukwa Rift Valley. It is characterised by miombo woodlands opened for agriculture, although the soils are of low fertility. Wooded savannah grasslands of *Acacia commiphora* bushlands and *Brachystegia julbernadia* woodlands dominate the uncultivated areas. Crops in cultivated fields included sorghum, sunflower, maize and cassava. The farms are generally small in size and fallow patches between fields are common, which increases the heterogeneity of the habitats. Overgrazing, particularly in the long dry season, leaves most of the landscape virtually bare of vegetation. The study sites consisted of two grids, located in Chang'ombe village (08º 46'S 33º 18'E), at an altitude of 600 m a.s.l. The two grids, coded CHB and CHC, were about 4 km apart and are within the Lake Rukwa basin. Grid CHB was under maize cultivation for several years before the study, but was maintained fallow throughout the study period. Grid CHC was communal land that had been maintained fallow, with many acacia trees and bushes before and during the study. In the dry season, it was subjected to grazing by cattle and goats. The grids were dominated by grass species, particularly the guinea fowl grass, *Rotthboelia cochinchinensis* and the bobbin weed, *Leucas martinnicensis.*

In Central Tanzania (CTZ), the study was conducted at two sites in Mvomero District. Each of the localities (Makuyu and Milama) (06º 22'S 37º 38'E) had two grids (MKA and MKB for Makuyu; MLA and MLB for Milama). The two localities were about 5 km apart and grids were approximately 300-400 m apart. The grids in Makuyu were fields under maize cultivation before the study but were maintained fallow throughout the study period. Fields under maize cultivation surrounded the grids. The grids in Milama were located in a large land block (>25 ha) owned by a local Catholic Mission. The land, which had not previously been under crop cultivation, was fallow and had several tree species dominated by kapok, but was also occasionally used for grazing cattle and goats by the neighbouring villagers. The study site in Makuyu (MKA and MKB) had several species of grasses, dominated by *Pennisetum* spp., *R. cochinchinensis* and *Cymbopogon* spp. These study sites were more uniform in vegetation type, and therefore were less heterogeneous. The rain patterns shows two rainy seasons; the short rainy season is from November to end of December, sometimes extending to January (Fig. 3b). In some years, no rains, or very little rains are received in this season. The long rains season (March-May) is characterized by heavy downpour except in some years when it is marginal.

Although the three study sites in NET, CTZ and SWT are ecologically heterogeneous, there is a strong human impact on vegetation and climate. The study sites in NET were part of the tropical moist forest covering most of the Usambara Mountains. However, a large proportion of the natural montane forest has been cleared for agriculture and pine plantations. The extended wet season, supplemented by irrigation, allows intensive cultivation of various crops including cereals, beans, various vegetables, and fruits. Temperatures are on average 18-22^{0}C and frost is regularly experienced on the ground when the temperature falls below 10^{0}C at night, particularly in July and August.

In CTZ, the area is extensively cultivated, but bushes and fallow patches of land intersperse between individual small fields, creating a vegetation mosaic. Flourishing opportunistic weeds in and around crop fields are common during the rainy season, but these are ploughed into the soil or burned during land preparation in the following season. When the short rains are adequate, the fields are cultivated with maize and sorghum, but the main cropping season is during the long rains. In SWT, cultivated fields and grasslands for grazing dominate the landscape, but large patches of woodland are scattered in the Lake Rukwa Valley.

Rodent trapping

Two 100 x 100 m grids were set in each locality, except in CTZ where there were a total of four grids (coded MKA, MKB, MLA and MLB). In each grid there were one hundred trapping stations at 10 m apart, with a single Sherman trap set per station. Trapping of rodents was conducted for three consecutive nights every month from May 2002 and April 2003 in NET, January 2001 to April 2003 in SWT and January 2001 to May 2003 in CTZ. Captured animals were identified, marked by toe clipping, weighed and the breeding conditions were recorded. In males, the breeding condition was determined by the position of the testes, whether scrotal or abdominal. In females, the breeding condition was determined either by signs of pregnancy by palpation, lactation, and/or perforate vagina. Animals were released at the point of capture soon after the data were recorded. Population density estimates were determined in the programme CAPTURE.

RESULTS

Table 1 shows the principal habitat type and species richness in the three study localities. Species richness was higher in the forest/agro-forestry habitats in NET and the savannah grassland, woodland and cultivated fields in SWT, than in the extensively cultivated fields in CTZ.

TABLE 1

Location of study sites, principal habitat type and rodent species richness.

Species captured	Western Usambara Mountains (NET)	South west Tanzania (SWT)	Central Tanzania (CTZ)
	Forest and agro-forestry habitats	Savanna grasslands, wood-lands and cultivated fields	Cultivated fields, crop-fal-low mosaics
Mastomys natalensis	X	X	X
Mus sp.	X		
Grammomys dolichurus	X		
Arvicanthis nairobae	X		
Lophuromys flavopunctatus	X		
Praomys delectorum	X		
Graphiurus sp.		X	
Tatera leucogaster		X	
Saccostomus elegans		X	
Steatomys sp.		X	

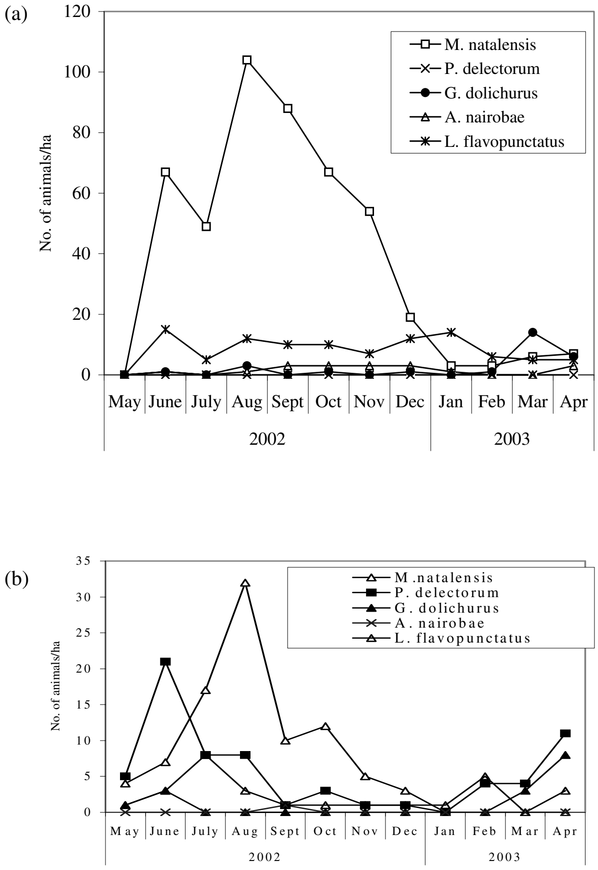

Fig. 1. – Rodent population density fluctuations at Manolo (a) and Magamba (b) in the Western Usambara Mountains, northeast Tanzania.

Fig. 1 shows the rodent population trends for different species in NET. In both study sites, the population density of *M. natalensis* was higher than for the other rodent species. Populations of *M. natalensis* reached 100 animals/ha and 33 animals/ha in Manolo (Fig. 1a) and Magamba (Fig. 1b) study sites, respectively, in August. The lowest population density was in January, with less than 5 animals/ha in both sites. *Praomys delectorum*, *Grammomys dolichurus*, *Arvicanthis nairobae* and *Lophuromys flavopunctatus* showed less marked fluctuations with less than 10 animals/ha. In NET, *A. nairobae*, a savannah species, was relatively abundant in February-May compared to other months. It is also obvious that more *P. delectorum* were captured in Magamba, where the grid was adjacent to the natural forest than in the Manolo site. *L. flavopunctatus* was found more abundantly in the secondary bush/forest fallow land inter-phase. Fig. 2 shows the rainfall pattern in the western Usambara Mountains. July-September were the driest months. Populations of *M. natalensis* peaked in August during the dry season and gradually declined towards January. Breeding individuals of *M. natalensis* occurred in the population in higher proportions during March-August and March-June for males and females, respectively (Figs 3a and 3b).

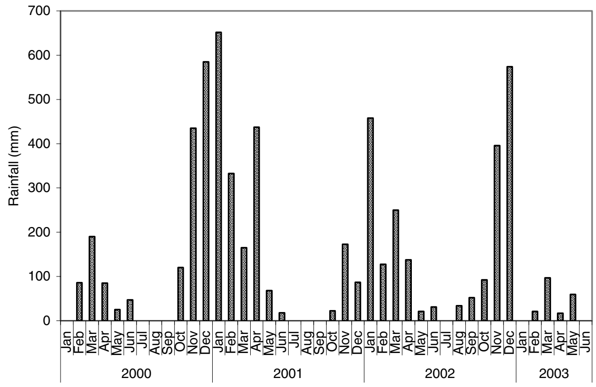

Fig. 2. – Rainfall pattern in Lushoto, Western Usambara Mountains, northeast Tanzania.

Fig. 4 shows the rodent population fluctuations in the Rukwa Valley (SWT). High populations of *M. natalensis* occurred, particularly between July and September, when densities were close to 200 animals/ha. The population density of *Tatera leucogaster* in SWT remained below 40 animals/ha throughout the year. The abundance and population densities of *Graphiurus murinus, Saccostomus elegans* and *Steatomys* sp. were relatively low. Fig. 5 shows the rainfall pattern in SWT, with a long dry season from May to October. Figs 6a and 6b show the population trends of female and male *M. natalensis* and the proportions of individuals in breeding condition. Sexual activity in females extended from February to May, with peak activity in March/April. Breeding activity was associated with the onset of the rains and population peaks were reached in the dry season. For males, reproductively active individuals appeared in the population in January until end of April. *T. leucogaster* also showed a seasonal activity in breeding, which was concentrated in the wet season (November-April). Females with perforated vagina, in lactating or in pregnant condition were found in the population from November to April (Fig. 7). Reproductive activity for males followed a similar pattern, with sexually active individuals appearing in the population from November to March (Fig. 8).

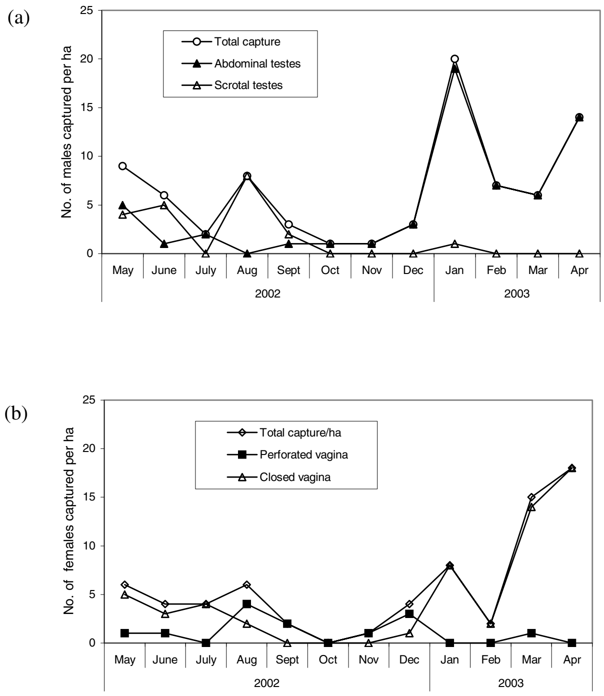

Fig. 3. – Reproductive conditions of male (a) and female (b) *Mastomys natalensis* at Manolo, Western Usambara Mountains, northeast Tanzania.

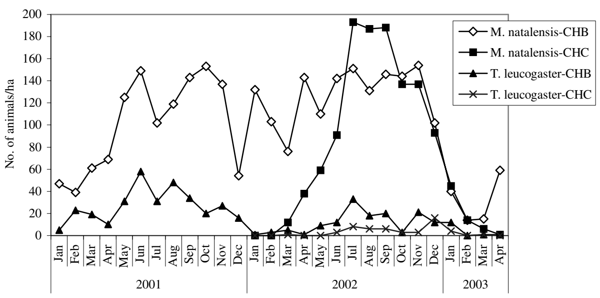

Fig. 4. – Rodent population density fluctuations in Chunya, Lake Rukwa Valley, southwest Tanzania.

Fig. 9 shows rodent population density fluctuations in CTZ. In this locality, only *M. natalensis* were captured in large numbers, and showed dramatic fluctuations with highest peaks of population density in July- November. This coincided with the beginning of the dry season and the onset of the short rain season (Fig. 10). Breeding activity reached peak between September and February for females (Fig. 11a) and December-March for males (Fig. 11b).

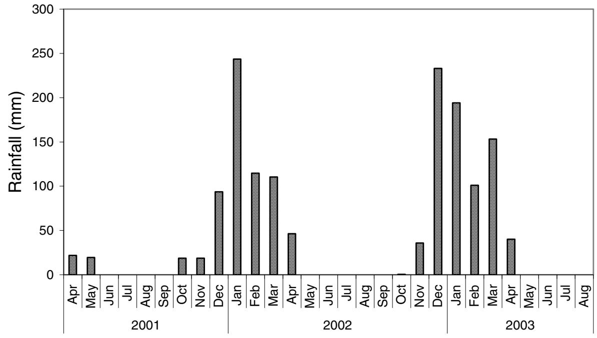

Fig. 5. – Rainfall pattern in Chunya, Lake Rukwa Valley, southwest Tanzania.

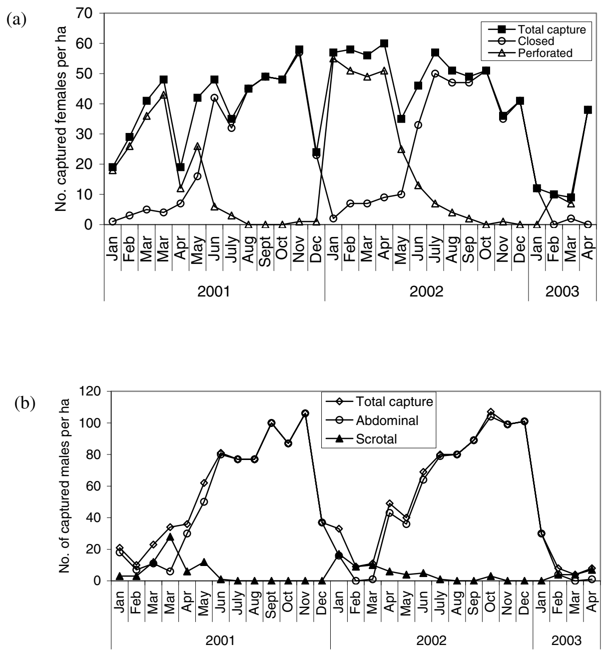

Fig. 6. – Breeding condition of female (a) and male (b) *Mastomys natalensis* in Chunya, Lake Rukwa Valley, southwest Tanzania.

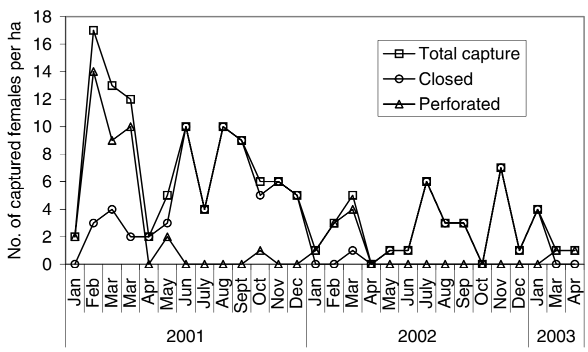

Fig. 7. – Breeding condition in female *Tatera leucogaster* in Chunya, Lake Rukwa Valley, southwest Tanzania.

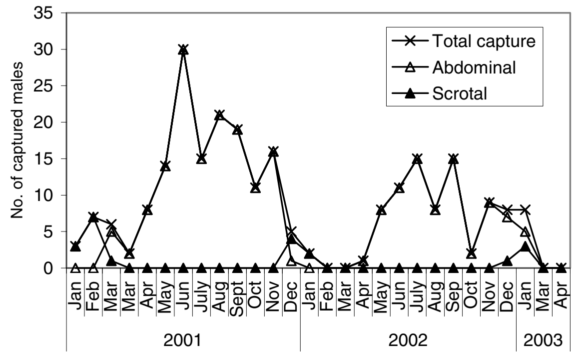

Fig. 8. – Breeding condition in male *Tatera leucogaster* in Chunya, Lake Rukwa Valley, south-west Tanzania.

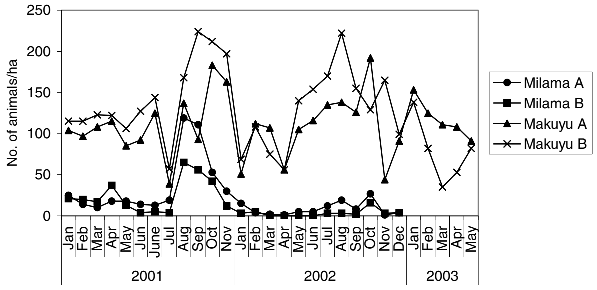

Fig. 9. – Rodent population density fluctuations in Mvomero, Morogoro, central Tanzania.

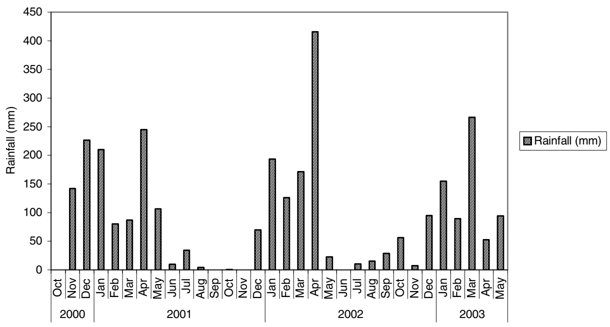

Fig. 10. – Rainfall pattern in Mvomero, Morogoro, central Tanzania.

DISCUSSION

Populations of *M. natalensis* underwent drastic increases and declines in numbers, particularly in SWT and CTZ. In SWT, *M. natalensis* and *T. leucogaster* were relatively abundant, but *T. leucogaster* maintained a consistently low population density. The fluctuations of the population of *M. natalensis* in CTZ followed a trend reported by LEIRS (1992). Tropical rodent species populations are generally influenced by many factors, but rainfall is considered as a principal factor determining the onset of breeding activity and reproduction (DELANY, 1986; LEIRS, 1992 and references therein). Temporal eruptions and extinctions of populations of *M. natalensis* were observed in the three localities in primarily fallow and agricultural land. It is apparent that land subjected to agriculture is a more variable habitat for *M. natalensis* and populations may fluctuate greatly as resources change in quality and quantity. The ecological changes that have occurred (including vegetation and climate) as a result of human activity, including opening of the woodlands and wooded grasslands in SWT and clearing of the natural forest in NET for agricultural development, have affected the spatial distribution and temporal fluctuations in density of rodent species. In NET, colonization by savannah species of rodents, mainly *M. natalensis* and *A. nairobae*, is probably due to habitat changes brought about by agriculture (MAKUNDI et al., 1999). In all the three localities, a much more detailed study is required to elucidate the species specific habitat requirements, which not only determines the species distribution, but also temporal fluctuations.

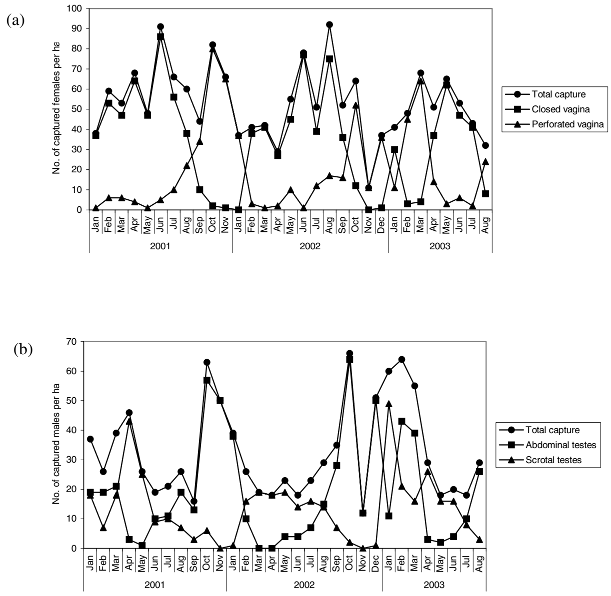

Fig. 11. – Breeding conditions of female (a) and male (b) *Mastomys natalensis* in Mvomero, Morogoro, central Tanzania.

The relationship between rainfall, breeding activity and fluctuations in numbers is obvious in the three localities. Breeding occurred during and after the rains in all the localities. The population peaks were reached in the dry season. The influence of rainfall on breeding of *M. natalensis* has been widely reported (e.g. LEIRS, 1992; DELANY, 1974; TELFORD, 1989). In the three study sites, food resources probably influenced to a great extent the fluctuations in rodent population density, but with greater influence in SWT and CTZ than in NET. It is also noticeable that there were some local effects on breeding of rodents, probably mediated through food resources in the three localities. Similar observations were made by SWANEPOEL (1978) who reported that in an agricultural area, *P. natalensis* were breeding during winter in irrigated wheat fields, but not in the natural vegetation. It has also been suggested that abundant high quality food in the absence of predation can induce population fluctuations to outbreaks proportions (HUBERT & ADAM, 1985), probably due to among the factors, the effects on breeding. In most Muridae in Africa breeding occurs during the most favourable time when resources are most abundant (DELANY, 1972; CHEESEMAN & DELANY, 1979). The abundance and quality of these resources most certainly increases survival and recruitment of young leading to increases in population density.

The study sites in SWT and NET supported more species of rodents than in CTZ. Apart from the variations in rainfall patterns in the three localities, differences in habitat types were very pronounced. Habitat heterogeneity in terms of vegetation structure was more pronounced in SWT and NET than in CTZ, where extensive cultivation was practised. The wooded savannah grasslands of *Acacia commiphora* bushlands and *Brachystegia julbernadia* woodlands and cultivated fields with fallow patches in the uncultivated areas were prominent habitats in SWT. This probably accounted for the higher species richness than in CTZ. In NET the agro-forest fields adjacent to the natural moist forest and the forest itself, were the dominant habitats for rodent species. These two habitats were more complex in vegetation structure and microhabitats, and therefore could also explain the higher number of species recorded.

It is known that environmental factors can influence populations of the same species at different locations (Krebs, 1999). The more heterogeneous habitat complexes in NET supported fewer individuals and had much lower fluctuations of population density. The forest dwelling species in NET showed less dramatic density fluctuations indicating occupation of a much more predictable and stable habitat. In general, species that inhabit relatively stable habitats show less dramatic changes in numbers compared to those inhabiting unstable habitats (Odum, 1966). These species have probably reached a stable equilibrium in which fluctuations only occur within limits set by the available resources, which do not show marked seasonal variations. *M. natalensis* appeared to respond to increased food resources in the aftermath of the rains by fast breeding and greater recruitment of young than the other species in SWT and NET. *Mastomys natalensis* was found predominantly in the cultivated land and in fallow land, which are much more unstable habitats compared to forest and woodlands. In NET, the intensive cultivation throughout the year, sometimes with low or little ground cover and few fallow patches between individual fields is probably not favourable for a large build-up of rodent populations, including *M. natalensis*.

In SWT, *T. leucogaster* generally maintained a consistently low population with no major fluctuations in density. This species occupied the same habitat as *M. natalensis* and experienced similar environmental conditions and yet the fluctuations were low. This could probably be attributed to competition for seeds and other resources with the numerically dominant *M. natalensis*. The same speculation could have accounted for the low numbers of *A. nairobae* in NET where *M. natalensis* was relatively dominant numerically.

Implications on rodent control

In SWT and CTZ, rodents are associated with severe crop losses, particularly maize at sowing and seedling stages. At the onset of the long rains in CTZ and SWT, rodent populations are still high for maize crop damage to occur at sowing and seedling stage. Therefore, it is important to control rodents in both CTZ and SWT to prevent maize crop damage. The observed population density fluctuation patterns suggest that rodent management will be more effective in reducing seed depredation and seedling damage if carried out before and during planting and early during the seedling stage of the maize crop. Telford (1989) suggested that rodent control should be concentrated between January and the onset of the long rains in CTZ, a duration of 2-3 months. However, this is not practical for poor resource farmers, with only about 0.5-1.0 ha of maize fields. Since maize is most susceptible to rodent damage in the first 2 weeks after planting (Makundi et al., 1999), a single treatment with bromadiolone or zinc phosphide, as currently practised in Tanzania may not be effective enough as fields are soon invaded by rodents 1-2 weeks after saturation baiting. A more pragmatic approach arising from observations from this study, and a general recommendation for all parts of Tanzania experiencing similar problems, will be to carry out saturation baiting with either broamadiolone or zinc phosphide or other recommended rodenticide three times; the first a week before planting, the second during planting and the third at the beginning of the second week after planting. This recommendation assumes that most or all farmers shall carry out control activities simultaneously.

In NET, human plague outbreaks occur in October-March when populations of rodents are low (Fig. 1a). This can be attributed to presence of "free" fleas, seeking for alternative hosts at low rodent densities (Makundi & Massawe, 2003; Makundi et al., 2003). A different approach for plague control in this locality is recommended. To avoid increasing mortality pressure on already declining populations of rodents and also not to increase the population of 'free' fleas without a host in the environment, the most practical approach will be to intensify control of fleas with insecticides and applying rodent control only in houses where *Rattus rattus* is dominant. This kind of approach is different from current practices in which rodent control is intensified during plague outbreaks within and outside houses.

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