Integrative Zoology 2007; 2: 233-238 doi: 10.1111/j.1749-4877.2007.00063.x

ORIGINAL ARTICLE

Reproduction and population dynamics of *Mastomys natalensis* Smith, 1834 in an agricultural landscape in the Western Usambara Mountains, Tanzania

Rhodes H. MAKUNDI, Apia W. MASSAWE and Loth S. MULUNGU

Pest Management Center, Sokoine University of Agriculture, Morogoro, Tanzania

Abstract

The multimammate rat, *Mastomys natalensis* Smith 1834, is a dominant species in agro-ecosystems in Sub-Saharan Africa, but adapts quickly to changes in non-agricultural landscape, particularly woodlands and forests. In this study we report on reproduction and population dynamics of *M. natalensis* in deforested high elevation localities in the Usambara Mountains, north-east Tanzania. We conducted Capture-Mark-Recapture studies in 2002-2004, and established that reproduction of *M. natalensis* takes place in the extended wet season between February and June, and the population density peaks in June-August. Reproduction cease in July to January and population density drops from July onwards. Reproduction and population density fluctuations are linked to the duration and amount of rainfall. In years when rainfall was below average and the wet season was short, the population density was significantly lower (below 10 animals/ha and 60 animals/ha in 2003 and 2004 respectively, compared to >100 animals/ha in 2002 when rainfall was above the seasonal average) ($F_{df\ 2,\ 13}$= 9.092, $p<0.01$ for in between years variations and $F_{df\ 12,\ 15}$ = 5.389, $p<0.01$ for effect of cumulative annual rainfall on population density). These densities were much lower than in the lowland savannah habitats in central and southwest Tanzania. A comparison between the farmland/fallow mosaic fields and agro-forestry areas showed higher population densities in the former, which have similarities to the preferred habitats in the lowland savannahs. The increasing abundance of *M. natalensis* in the Usambara could have some consequences: *M. natalensis* is major pest and is involved in the plague cycle in the western Usambara Mountains. *Mastomys natalensis* is also a strong competitor and the impact on endemic rodent species, e.g. *Lophuromys flavopunctatus* and *Praomys delectorum* is unknown.

Key words: *Mastomys*, population dynamics, reproduction, Tanzania.

INTRODUCTION

Mastomys natalensis Smith 1834, is the most serious rodent pest species in sub-Saharan Africa, found distributed in different kinds of habitats, including savannahs, woodland, secondary growth, forest clearings, houses and cultivated fields (Kingdon, 1997). The distribution indicates a broad habitat tolerance and makes it a pioneer species in the colonization of disturbed (e.g. by agriculture) habitats. In South Africa for example, it is the first species to colonize areas which have been rehabilitated

Correspondence: Rhodes H. Makundi, Pest Management Center, Sokoine University of Agriculture, P.O. Box 3110, Morogoro, Tanzania. Email: rmakundi@yahoo.com, rmakundi@suanet.ac.tz

from mining operations (Ferreira & Van Aarde 1996). It has been described as an opportunistic species, characteristically conforming to an r-selected strategist when conditions are favourable (Leirs *et al.*, 1997). Studies have indicated that there is a strong climatic influence, particularly rainfall, on population dynamics and breeding of this species (Leirs 1992; Leirs *et al*. 1989; Leirs *et al.* 1996; Taylor & Green 1976; Delany 1971, etc). Outbreaks of large numbers of this species have been reported in many localities in sub-Saharan Africa (Leirs 1994; Leirs *et al.* 1996; Leirs 2003; Taylor 1968; Harris 1937), which can be attributed to the intrinsic biological characteristics of the species and prevailing environmental factors. Studies in Tanzania and elsewhere in Eastern Africa suggest that large litter size (average 11-13 young/litter), several litters per season, increased survival and quick maturation are some of the demographic factors that favour high population turnover of *M. natalensis* within a short period (Cheeseman and Delany 1979; Delany 1972; Delany 1974; Leirs 1992; Telford 1989, etc). Favourable rainfall (both amount and duration) promote abundant primary productivity of particularly nutritious seeds and vegetation cover, which enable natural habitats to maintain large numbers of the species (Leirs 1992, Delany 1972). Therefore, rainfall plays an indirect role in the ecology of *M. natalensis* by determining when, where and how much food will be available.

The East African Highlands (e.g. Mt Kilimanjaro, Mt Kenya, Mt Elgon, Eastern Arc Mts, etc.) are home to various native rodent species. These highlands have undergone degradation and are still under high human pressure due to encroachment (i.e. deforestation, agriculture and various other activities e.g. collection of firewood and medicinal plants) into the remaining forest patches. The changing habitat structure in these highlands has often led to invasion by the opportunistic rodent species *M. natalensis*. Intensification of agriculture (multiple cropping, irrigation, and rain-fed agriculture) increases the resources available to *M. natalensis* and alters the carrying capacity of habitats, presumably maintaining higher population densities. It is not unexpected that several generations of this species are able to survive in these newly established agricultural systems. Also by altering the landscape, barriers to the distribution of *M. natalensis* in these highlands are removed thus enabling the species to increase its range.

In the current study, we investigated reproduction and population dynamics of *M. natalensis* in an area that was recently a natural forest, but was cleared for agriculture in the western Usambara Mountains. The study further compared the population dynamics of *M. natalensis* in these highlands with that of the lowland savannah habitats preferred by rats in two localities in central and south-western Tanzania and the potential consequences of its increasing abundance in the Usambara Mountains.

MATERIALS AND METHODS

Location of study

The study was carried out in the western Usambara, Mountains, which are the north-eastern wing of the Eastern Arc Mountains in Tanzania. The locations of the study were in Manolo and Magamba villages in Lushoto District. The two study locations are approximately 15 km apart, but share the same rainfall pattern. Whereas in Manolo (04^0 42’ 16”S, 38^0 12’16’E) the trapping grid was in an established fallow field, in Magamba (04^0 70’ S and 38^0 29’ E) it was primarily an agro-forestry field close to the natural forest. The grid in Manolo was at an altitude of 1,826 m above sea level, whereas in Magamba altitude was 1,920 m. The rainfall pattern is a single, but asymmetrical rainy season, extending from October to May. November/December and March/April are the wettest months. The dry season is from July to September. The western Usambara Mountains were previously covered by a montane rain forest that was opened for agriculture about 50 years ago, and currently has only a small proportion of forests intact. Cultivated fields are sometimes adjacent or not far from the remaining natural forest. At the time of trapping in the western Usambara Mountains, similar studies were conducted elsewhere in lowland savannah habitats in central and south-western Tanzania (see Makundi *et al*., 2005, for details). The data from these studies are used for comparison with the data from the Western Usambara Mountains collected in our study.

Trapping procedure

Capture–Mark–Recapture studies were conducted in 2002-2004 in 100 x 100 m grids with 100 trap stations and a single Sherman live trap per station. The grid in Manolo was set in permanent fallow land and bushes, surrounded by maize fields. The grid in Magamba was set in an agro-forestry farm which had been left fallow for several years. The vegetation included fruit trees, scattered *Gravillea robusta* trees, and *Rumex usambarensis* Dammer which was dominant among the shrubs. Trapping of rodents in both grids was conducted for three consecutive nights every month. 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 (scrotal, abdominal). In females, the breeding conditions were either signs of pregnancy by palpation, and/or perforated vagina. Animals were released at the point of capture.

Analysis of data

The density of animals per ha was estimated for each 3-day trapping session using the M(h) Estimator of the Programme CAPTURE for a closed population, which allows for individual variations in trapping probability (White *et al*. 1982). An analysis of variance was carried out for significant variations in population density between years.

RESULTS AND DISCUSSION

Figs. 1 (A and B) shows the breeding patterns of female and male *M. natalensis* in the western Usambara Mountains. In both sexes, individuals in breeding condition occur in the population during the extended wet season of the year. During June-August, a large number of reproductively inactive females and males, (largely sub-adults) were recruited in the population,

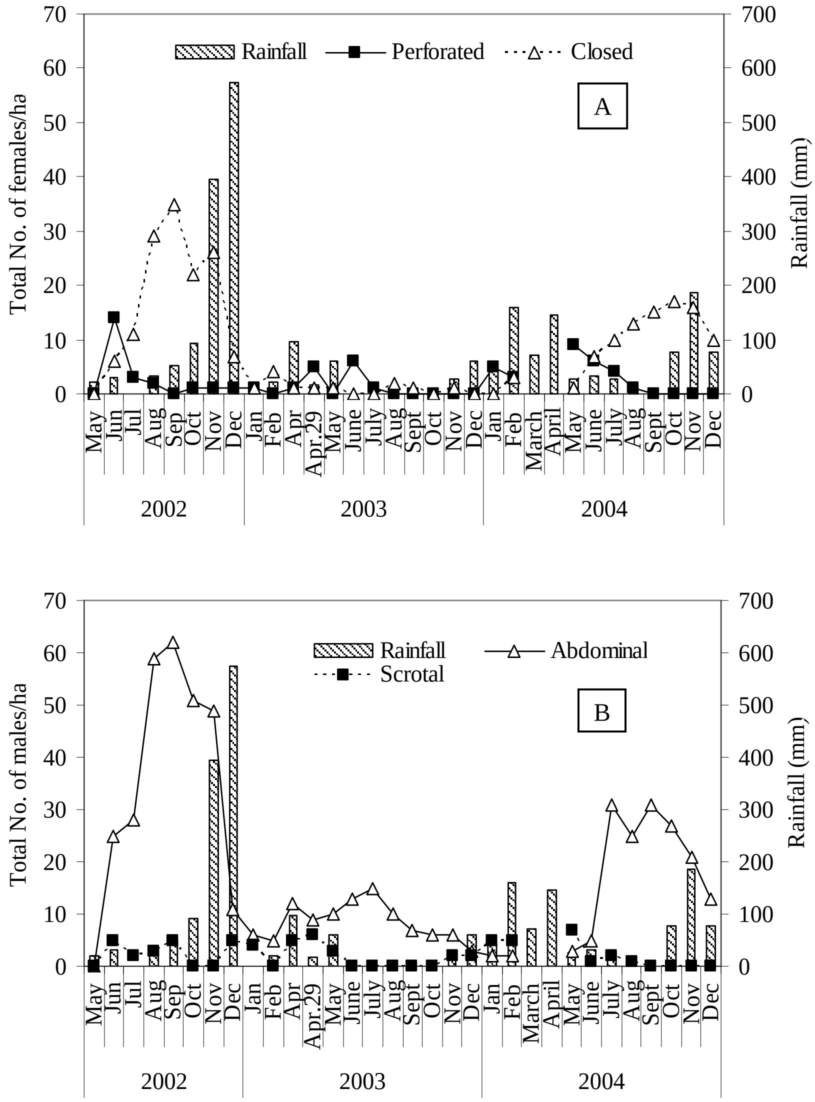

Figure 1 Seasonal and annual changes in reproductive conditions of female and male *Mastomys natalensis* in the Western Usambara Mountains.

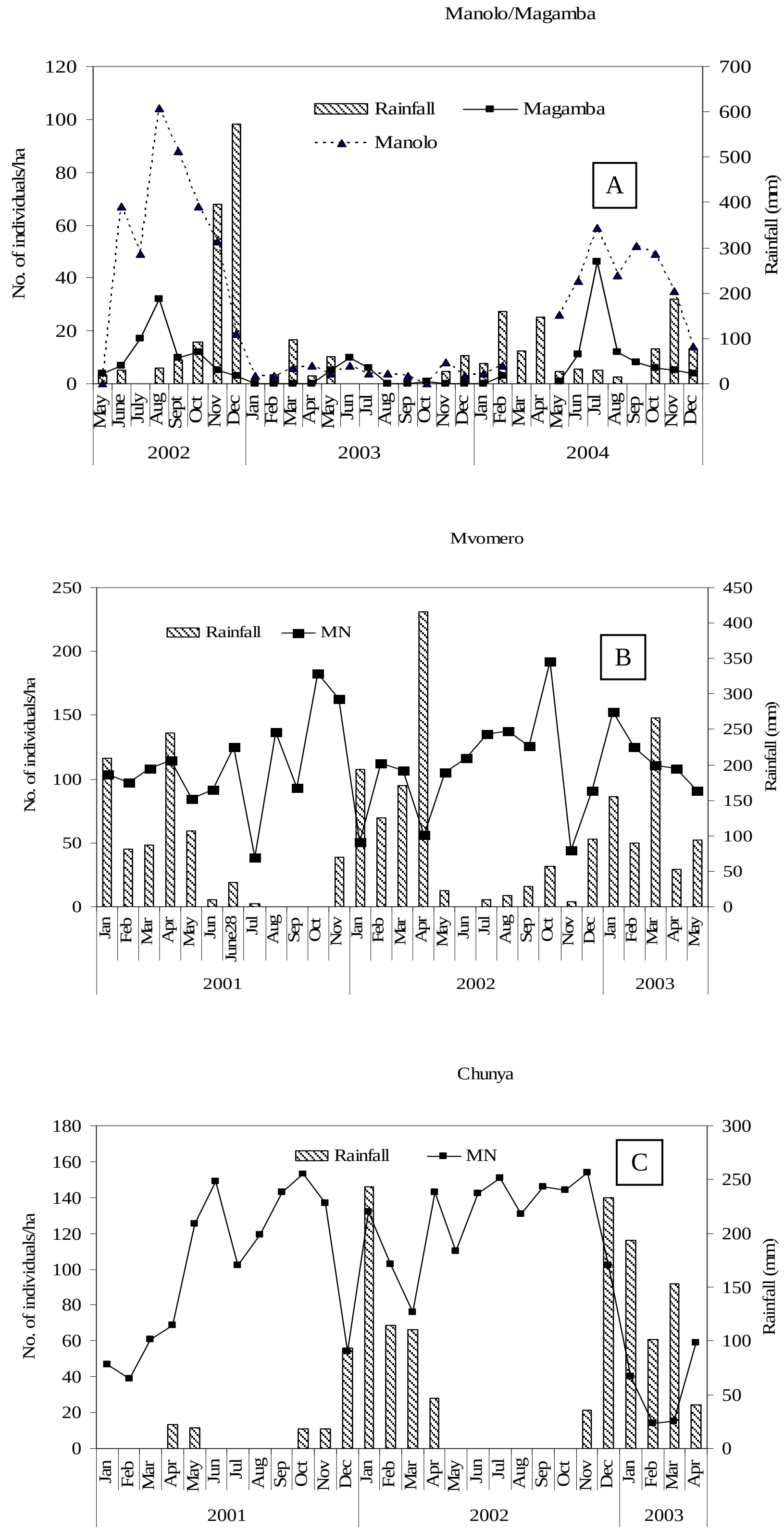

Figure 2 Population dynamics of *Mastomys natalensis* in fallow land at Manolo and in agro-forestry habitat in Magamba, Western Usambara Mountains (A), farm-fallow mosaic fields in Mvomero, central Tanzania (B) and Chunya, south-west Tanzania (C).

suggesting that these were born during the season and entered the trappable population later in the season.

Fig. 2 (A) shows the population dynamics of *M. natalensis* in the study localities in the western Usambara Mountains. Population densities were higher at Manolo in the permanent fallow field than in the agro-forestry habitat in Magamba. These density changes follow the seasonal patterns of rainfall. Population densities were highest at the end of the rain season to the middle of the dry season, but rapid decline in population density occurred towards the end of the dry season in September. Although October – January are also wet months, reproduction and recruitment did not occur in this species in the Usamabara Mountains. In years when rainfall was below average and the wet season was short, the population density was significantly lower (below 10 animals/ha and 60 animals/ha in 2003 and 2004 respectively, compared to >100 animals/ha in 2002 when rainfall was above the seasonal average) ($F_{df\ 2,\ 13}$= 9.092, p<0.01 for in between years variations and $F_{df\ 12,\ 15}$ = 5.389, p<0.01 for effect of cumulative annual rainfall on population density).

The rodent population dynamics models of the Usambara Mountains show striking similarities to the lowland savannah habitats in Mvomero, central Tanzania (Fig. 2B) and Chunya, south-western Tanzania (Fig. 2C) , but at much lower densities (Makundi *et al.* 2005).

Breeding, abundance and population dynamics of *M. natalensis* in the Usambara Mountains were strongly influenced by rainfall. Studies elsewhere in Tanzania have highlighted the importance of rainfall on breeding of this species (Leirs 1992; Leirs *et al*. 1989). Evidence of resource limitations to breeding and growth of *Mastomys* spp. has been reported in Tanzania and other localities in sub-Saharan Africa (Leirs 1992, Cheeseman and Delany 1979, Delany 1972, Neal, 1977, Hubert and Adam 1985; Makundi *et al*. 2005). In the Usambara Mountains, as the wet season ends and the dry season starts, reproduction of *M. natalensis* ceases. The decline of the population at this time indicates that survival is low and /or dispersal is high.

Deforestation and intensification of agriculture in the Usambara Mountains have created savanna-like habitats suitable for colonization by *M. natalensis*. These newly created habitats are similar to the preferred habitats in the low land savannahs. Kingdon (1974) reported that in tropical East Africa, *M. natalensis* could be found in forested areas and woodland where clearings have been made up to an altitude of 2,100 m., The densities supported by these habitat patches are however low, but when wide areas are cleared for agriculture at even much higher elevation as in the study localities in the Usambara Mountains, there is an increasing abundance and altitudinal range in the distribution of *M. natalensis*. The population densities of *M. natalensis* in fallow and agro-forestry fields clearly show some striking differences, despite the fact that the two habitats are within the same ecological zone and share the same rainfall pattern. In the lowland savannah habitats in central and southwest Tanzania, population densities of *M. natalensis* are high and show drastic changes associated with the seasons. In the Usambara Mountains, the seasonal nature of habitats is an important factor in breeding, development and recruitment of *M. natalensis*. Increasing abundance of *M. natalensis* in agricultural fields and their close proximity to human habitation in the Usambara Mountains have several consequences. The pest status of this species is being elevated because of widespread depredation of crops in the fields. *Mastomys natalensis* is also involved in the plague cycle in the Western Usambara Mountains (Makundi *et al.* 1999). The presence of anti-plague immunoglobulin antibodies in this species was demonstrated by Kilonzo *et al*. (2000). Therefore, increasing densities of *M. natalensis* in the Usambara Mountains could also increase the risk of plague outbreaks. *Mastomys natalensis* is also a strong competitor (Kingdon 1974) and its impact on other native species like *Lophuromys flavopunctatus* Thomas 1888 and *Praomys delectorum* Thomas 1910 which are weaker competitors and occur in much lower densities and yet their populations interact with that of *M. natalensis* in the same habitats (Makundi *et al*. 2003; 2006) is not known.

ACKNOWLEDGMENTS

We wish to sincerely thank the SUA-VLIR Programme (Inter University Council – Belgium and Sokoine University of Agriculture – Tanzania) for financial support that enabled the study to be carried out in the Western Usambara Mountains. The SUA Pest Management Centre provided both logistical and field assistance for the work. Various technical staff was involved in field excursions and they are all thanked.

REFERENCES

Cheeseman CL, Delany MJ (1979). The population dynamics of small rodents in a tropical African grassland. *Journal of Zoology London*. **188**, 451-475

Delany MJ (1971). The biology of small rodents in

Mayanja Forest, Uganda. *Journal of Zoology London*, **165**, 85-129.

Delany MJ (1972). The ecology of small rodents in tropical Africa. *Mammal Review* **2**, 1-42.

Delany MJ (1974). *The ecology of small mammals*. Edward Arnold, London

Ferrera SM, Van Aarde RJ (1996). Changes in community characteristics of small mammals rehabilitating coastal dune forests in northern KwaZulu/Natal. *African Journal of Ecology* **34**, 113-130.

Harris WV (1937). The grey field mouse. *East African Agricultural Journal* **2**, 315 - 318.

Hubert B, Adam F (1985). Outbreaks of *Mastomys erythroleucus* and *Taterillus gracilis* in the Sahelo-Sudanian zone in Senegal. *Acta Zoology Fennica*. **173**,113-117

Kilonzo BS, Makundi RH, Machang'u RS, Fadda C, Arntzen L (2000). Demonstration of *Yersinia pestis* DNA and antibodies in humans and animals in Lushoto District: need to improve diagnostic services. *Proceedings of the 19th Annual Scientific Conference of the Tanzania Public Health Association, Moshi, Tanzania, November, 2000.* pp 172 - 176.

Kingdon J (1997). *The Kingdon field guide to African Mammals*. Academic Press, Harcourt Brace and Company Publishers. London. 464 p.

Kingdon J (1974*). East African Mammals – an atlas of evolution in Africa* – Volume IIB (Hares and Rodents). Academic Press, London & New York.

Leirs H (1992). Population ecology of *Mastomys natalensis* (Smith 1834): Implication for rodent control in Africa. PhD Thesis, University of Antwerp, Antwerpen, Belgium

Leirs, H (1994). *Population ecology of Mastomys natalensis* (Smith 1934). *Implications for rodent control in Africa*. Belgian Administration for Development Cooperation. Agricultural Ed. N^{o}. 35, Brussels.

Leirs H (2003). Management of rodents in crops: the Pied Piper and his orchestra. In: Singleton GR, Hinds LA, Krebs CJ, Spratt DM (Eds.). *Rats, Mice and People: Rodent Biology and Management.* ACIAR Monograph no.96. 183-190pp.

Leirs H, Verheyen W, Michiels M, Verhagen R, Stuyck J (1989). The relation between rainfall and breeding season of *Mastomys natalensis* (Smith 1834) in Morogoro, Tanzania. *Annales Societe Royale Zoologie Belgique* **119**, 59 - 64.

Leirs H, Verhagen R, Verheyen W, Mwanjabe PS, Mbise T (1996). Forecasting rodent outbreaks in Africa. An ecological basis for *Mastomys* control in Tanzania. *Journal of Applied Ecology* **33**, 937 -943.

Leirs H, Stenseth N, Nichols JD, Hines JE, Verhagen R, Verheyen W (1997). Stochastic seasonality and non-linear dependent factors regulate population size in an African rodent. *Nature* **389**, 176 - 180.

Makundi RH, Oguge NO, Mwanjabe PS (1999). Rodent Pest Management in East Africa – An Ecological Approach. In: Singleton G, Hinds L, Leirs H, Zhang Z (eds) 1999. *Ecologically-based Rodent Management*. Australian Center For International Agricultural Research, Canberra, Australia, pp. 460 – 476.

Makundi, RH, Kilonzo BS, Massawe AW, (2003). Interaction between rodent species in agro-forestry habitats in the western Usambara mountains, northeast Tanzania, and its potential for plague transmission to humans. In: Singleton GR, Hinds LA, Krebs CJ, Spratt DM (Eds.). *Rats, Mice and People: Rodent Biology and Management.* ACIAR Monograph no.96. 20-24 pp.

Makundi, RH, Massawe AW, Mulungu LS (2005). Rodent populations fluctuations in three ecologically heterogeneous locations in north-east, central and south-west Tanzania. *Belgian Journal of Zoology* (Supplement) **135**, 159-165.

Makundi RH, Massawe AW, Mulungu LS (2006). Breeding seasonality and population dynamics of three rodent species in the Magamba Forest Reserve in the Western Usambara Mountains, north-east Tanzania. *African Journal of Ecology* **44**, 1-6

Neal BR (1977). Reproduction of the multimammate rat, *Praomys (Mastomys) natalensis* (Smith). *Zeitschrift für Säugetierkunde* **42**, 221-231.

Taylor KD (1968). An outbreak of rats in agricultural areas in Kenya in 1962. *East African Agricultural and Forestry Journal* **34**, 66-77.

Taylor KD, Green MG (1976). The influence of rainfall on diet and reproduction in four African rodent species. *Journal of Zoology London* **180**, 367-389.

Telford SR (1989). Population biology of the multimammate rat, *Praomys (Mastomys) natalensis* at Morogoro, Tanzania 1981 – 1985. *Bulletin Florida State Museum Biological Series* **34**, 249-287.

White GC, Anderson DR, Burnham KP, Otis DC (1982). *Capture-Recapture and Removal Methods for Sampling Closed Populations*. Los Alamos National Laboratory, Los Alamos, New Mexico, USA.