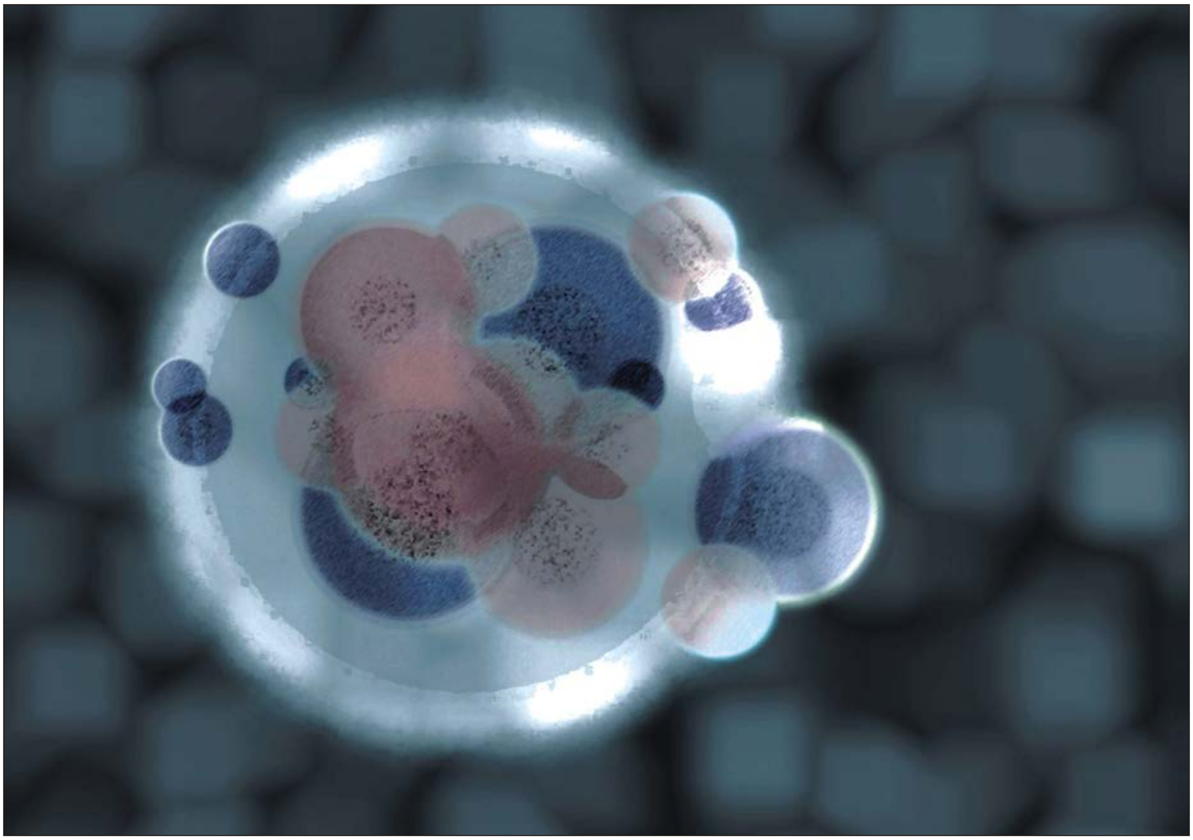

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The Type of Farming Practice may Affect the Movement and Reproduction Pattern of Rodents in Crop Fields: A Case Study of *Mastomys natalensis*

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Abstract: A Capture-Mark-Release study was carried out in crop fields in Morogoro, Tanzania, to investigate how the movement and reproduction of multimammate field rats, *Mastomys natalensis*, was influenced by farming practices. Two land preparation methods and two cropping systems were investigated in a Complete Randomized Design (CDR) experiment with 2×2 factors. The results showed that females and males differed significantly in their movements in the different land management practices (Wald Stat =16.27; df = 1 and p = 0.001). It was also observed that land preparation methods and cropping systems had no significant effect on the proportion of females and males in the population. However, significant changes in the proportions of both sexes occurred with time and these were influenced by cropping systems for females (F(29,120) = 1.612; p = 0.039) and land preparation methods for males in the population (F(29,120) = 2.1352; p<0.001). The distribution of females with perforated vagina was significantly influenced by the land preparation methods (p≤ 0.05) and was higher in the slash and burn fields than in the tractor ploughed fields (Tukey LSD test; F (1, 32) = 11.199; p<0.001). An interaction between land preparation methods and cropping system on the distribution of sexually active females in the population was found (F (1, 12) = 5.279, p = 0.040). Therefore one could generalize that the slash and burn fields were more conducive for breeding and consequently higher increase in the population of *M. natalensis* due to better food conditions

Key words: Agricultural practices, Capture-mark-recapture, rodents, crop fields, *Mastomys natalensis*

INTRODUCTION

Rodent population outbreaks have dramatic consequences in agriculture and human health in developing countries. In East Africa, they are considered a major problem and they cause considerable economic losses to staple crops especially cereals.

Mastomys natalensis, is one of the most notorious rodent pest species in sub Saharan Africa and is found distributed in different kinds of habitats, including savannahs, woodland, secondary growth, forest clearings, houses and cultivated fields (Kingdom 1997). The species has a broad habitat tolerance which makes it a pioneer species in the colonization of disturbed (e.g., by agriculture) habitats. It is an opportunistic species, characteristically conforming to an r-selected strategist when conditions are favourable (Leirs *et al*., 1997). Outbreaks of large numbers of this species have been reported in many localities in sub-Saharan Africa (Leirs 2003; Taylor 1968; Harris 1937; Leirs *et al*., 1996). Recent studies in Tanzania and elsewhere in Eastern Africa suggest that large litter size (average 11-13 young/litter), several litters in a season, increased survival and quick maturation, favourable rainfall (both amount and duration which promote abundant primary productivity of particularly nutritious seeds and vegetation cover) are some of the principal factors responsible for maintaining high populations of *M. natalensis* (Cheeseman and Delany 1979; Delany 1972, 1974; Telford 1989). Therefore, it is now hypothesized that populations of *M. natalensis* are strongly influenced by food availability with rainfall playing an indirect role by determining when, where and the amount of food that will be available.

In Tanzania, farming practices are characterized by mosaic of small plots of various crops, surrounded by patches of fallow lands and permanent grass-land. Small scale farmers use slash and burning method of land preparation. This type of farming practices affects the nature of the habitat, shelter and population density and thus creates favourable conditions for rodent pests and results in high degree of damage (Taylor, 1968; Mwanjabe, 1993; Myllymaki, 1989).

An understanding of the factors that influence the population dynamics of rodent pests and the way in which cropping systems differ from natural ecosystems, can provide an indication of the type of strategy that should be employed in the management of the pest.

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Some attempts have so far been made to determine interactions of rodents with the various cropping systems found in many agricultural areas under different land management practices (Makundi *et al*., 2007; Massawe *et al*., 2003, 2005, 2007). One of these interactions, for example, is the influence of agricultural practices on certain ecological characteristics of rodent populations.

The current study was carried out to investigate the influence of land management practices on rodent population characteristics. In this manuscript the influence on reproduction and movement are reported. Influence on other population parameters were reported elsewhere (Massawe *et al*., 2003, 2005, 2007, 2008).

MATERIALS AND METHODS

The study was carried out at Solomon Mahlangu Campus (6°46'S37°37'E), Sokoine University of Agriculture, Morogoro, Tanzania from April 1999 to August 2001. The area has a bimodal rainfall pattern. The short rains occur between October and January and the long rains between March and May. The short rains were generally low and intermittent. The mean radiation was generally higher during the short rains than the long rains. A Capture-Mark-Recapture (CMR) study was conducted during the 1999-2001 cropping seasons. Eight 70×70 m grids were prepared, consisting of 7 parallel lines, 10 m apart and 7 trapping stations per line, also 10 m apart (total of 49 trapping stations/grid). One Sherman LFA live trap (H.B.Sherman Traps Inc., Tallahassee, FL, USA) was placed on each trapping station. A 200-300 m wide zone of fallow land separated the grids from each other. The grids were subjected to two types of cropping systems (mono-cropping and inter-cropping) and two land preparation methods (tractor ploughing; slash and burning). The mono-cropping system consisted of a monoculture of maize and the inter-crop consisted of a mixture of maize and beans. The choice of these treatments was based on common farming practices in Tanzania. The experiment was a Completely Randomized Design (CRD) with 2×2 factors replicated twice. The grids were ploughed in November and February during the short and long rain seasons, respectively. Tractor ploughing was done using a disc plough at a depth of 30 cm, a normal rooting depth for most annual crops. Harrowing was not done in these fields, since in most small scale farming practices, farmers do not harrow their fields. In the slash and burn fields, slashing was done by hand hoe and the weeds were left to dry for one or two days depending on the weather conditions and thereafter burnt within the fields. Maize sowing followed a standard procedure (planting lines 90 cm apart, plant holes 60 cm apart and three seeds per planting hole (variety Staha). The bean crop was sown 3 weeks after the maize, at a spacing of 50×10 cm (Variety Kablanket). All necessary agronomic practices such as fertilizer application and weeding were carried out equally in all the plots. Triple Super Phosphate (20 kg ha^{-1}) and Nitrogen (40 kg N ha^{-1}) were applied before sowing and 3-4 weeks after sowing, respectively.

Trapping was conducted in each grid for three consecutive nights at intervals of four weeks. Additionally, trapping was conducted for three consecutive nights before land preparation (ploughing or slashing/burning), after land preparation and after seed emergence. Traps were baited in the afternoon with peanut butter mixed with maize bran and were inspected early in the morning. Toe clipping using specific number coding was used to recognize individual animals. The trapping station, sex, weight and reproductive status of captured animals were recorded. Animals were later released at the station of capture.

In this study, sex ratio is defined as the proportion of females to males in the whole population. It was hypothesized that the proportion of females to males was equal in the different treatments (ratio 1:1). The total number of captures was used in the analysis. To determine the sex ratio the following formula was adopted:

$$\text{Proportion of females/males} = \frac{\text{No. of captured}}{\text{Total No. of animals captured}} \times 100$$

The Factorial ANOVA was used to establish the effect of the different treatments on males and females in the population.

In each treatment combination, the timing of reproduction was analyzed by plotting the proportion of adult females and males in reproductive condition in the population over time. Statistical analysis was performed to determine the effect of land preparation methods and cropping systems on the sexually active individuals in the population.

In this study, age structure is defined as the number of individuals of each age group that are represented in the population. The idea was to see if the different land management and cropping systems affect age structure in the population. Therefore, weight was used to classify the captured animals into three weight classes irrespective of sex, with an assumption that nutrition status was the same. Animals with less than 25 g were considered as juveniles, those with between 25 to 40 g were considered as sub adults and animals with more than 40 g were considered as adults irrespective of reproductive conditions. Statistical analysis was carried out using Factorial ANOVA in the Visual GLM model of the program STATISTICA, to compare the effect of the different treatments on the age structure of the population. In the current study, very few juveniles were captured and thus they were not included in the analysis.

The movement between captures in each treatment combination was measured. The idea was to establish how rodent movements were affected by land preparation and cropping systems. To perform this analysis, the distance between the trapping points was taken and only individuals captured two or more times in each season (i.e., non-cropping season, short rain season and long rain season) were included. For individuals captured two times only, the distance between the points was taken but for more than two captures, the maximum distance was taken. Since the distances obtained were not continuous variables (i.e., it can be 0, 10, 14.4, 20, 22.4, 28.3, 30, 31.6, 36.1 and 42.4 m) the analysis was not done as a normal comparison of a continuous variable. This is because the traps were at fixed distances of 10 m from each other and a distance of less than 10 m between traps was not expected. Therefore, the different distances were ranked into four levels as indicated below:

- Score 1: 0-10 m; Score 2: 11-20 m; Score3: 21-30 m; Score 4: >30 m

The data for movements were modeled in STATISTICA (VGLZ- Visual generalized linear models) using the ordinal multinomial distribution and the cumulative logit as link function. The outcome is the cumulative probability expected in each level ordered in their natural order: in level 1 the analysis calculates the expected proportion in level 1. In level 2 the expected proportion in level 2+expected proportion in level 1, in level 3 the expected proportion in level 3+expected proportion in level 2+expected proportion in level 1. The outcome presents intercepts (baseline probabilities) for each level (except for the last level which always will be 100%).

RESULTS

The results showed that females and males differed significantly in their movements in the different land management practices. In general, males were more mobile than females in all the fields. Land preparation methods, cropping system and season had no major effects on movements of rodents ($p \leq 0.05$) but there were interactions between different seasons and sex and between land preparation methods and sex of individuals (Wald Stat = 0.06; df = 1 and p = 0.800) (Table 1).

Table 1: Analysis of variance showing the effect of the two land preparation methods and cropping systems on home range

Effect	Df	Wald stat	p-value
Intercept	3	211.80	<0.001
Sex	1	18.00	<0.001
Land preparation	1	57.03	<0.001
Cropping system	1	4.93	0.026
Sex×Land preparation	1	0.06	0.800
Sex×cropping system	1	0.07	0.798
Land preparation×cropping system.	1	6.60	0.010
Sex×land preparation×cropping system	1	0.12	0.725

Significant at $p \leq 0.05$

Figure 1 shows the seasonal frequency distribution of movement of rodent on a 4-point scale. There was a seasonal effect on movement between sexes during the study period. During the non- cropping and long rains males moved further than females. Very few females moved more than 20 m from their centre of activity. Although the frequency distribution seems to be normal for both males and females during the short rain season, males were more mobile than females. Females were less mobile than males in the tractor ploughed fields (Fig. 2), while in the slash and burning fields movements were similar for males and females.

From this study land preparation methods and cropping systems had no significant effect on the proportion of females and males in the population. However, significant changes in the proportions of both sexes occurred with time and these were influenced by cropping systems for females ($F (29, 120) = 1.612$; $p = 0.039$) (Table 2) and land preparation methods for males in the population ($F (29, 120) = 2.1352$; $p<0.001$) (Table 3).

The proportions of sexually active individuals (males with scrotal testis, females with perforated vigina) are presented in Fig. 3 a and b. The highest proportion of sexually active males occurred between November and March. The analysis showed that there was an interaction between land preparation methods and trapping time on the distribution of sexually active males during the months with highest percentage of males with scrotal testis ($F (8,36) = 3.73$; $p \leq 0.004$). From August to early November 1999, land preparation methods had a significant effect on the distribution of males with scrotal testis in the population ($p \leq 0.05$) with more sexually active males occurring in the tractor ploughed fields (Tukey HSD test: $F(1,16) = 5.15$; $p<0.037$). Trapping after ploughing and after seed emergence indicated that more males with scrotal testis occurred in the tractor ploughed fields. When the maize crop was at the vegetative stage and beans were already established in the fields, the proportion of males with scrotal testis was higher in the slash and burn fields. However, when there was no crop in the field more sexually active males were found in the

Table 2: Analysis of variance showing the effect of the different treatments on the proportion (%) of females in the population

Effect	SS	Df	MS	F	p-level
Time	71091.2	29	2451.4	4.06	0.000**
Plough	621.5	1	621.5	1.03	0.312
System	115.9	1	115.9	0.1921	0.662
Time×plough	10788.6	29	372.0	0.6168	0.9336
Time×system	28197.8	29	972.3	1.6121	0.039*
Plough×system	1329.0	1	1329.0	2.2035	0.1403
Time×plough×system	17844.8	29	615.3	1.0202	0.449
Error	72375.9	120	603.1		

**Significant at p = 0.000. *Significant at p≤0.05

Table 3: Analysis of variance showing the effect of the different treatments on the proportion (%) of males in the population

Effect	SS	Df	MS	F	p-level
Time	106871.8	29	3685.2	6.975	0.000**
Plough	4.2	1	4.2	0.008	0.928
System	0.9	1	0.9	0.001	0.9661
Time×plough	32715.2	29	1128.1	2.1352	0.0023*
Time×system	8573.8	29	295.6	0.5596	0.9639
Plough×system	1550.5	1	1550.5	2.9345	0.0892
Time×plough×system	22300.5	29	769.0	1.4554	0.0830
Error	63401.8	120	528.3		

**Significant at p = 0.000. *Significant at p≤0.01

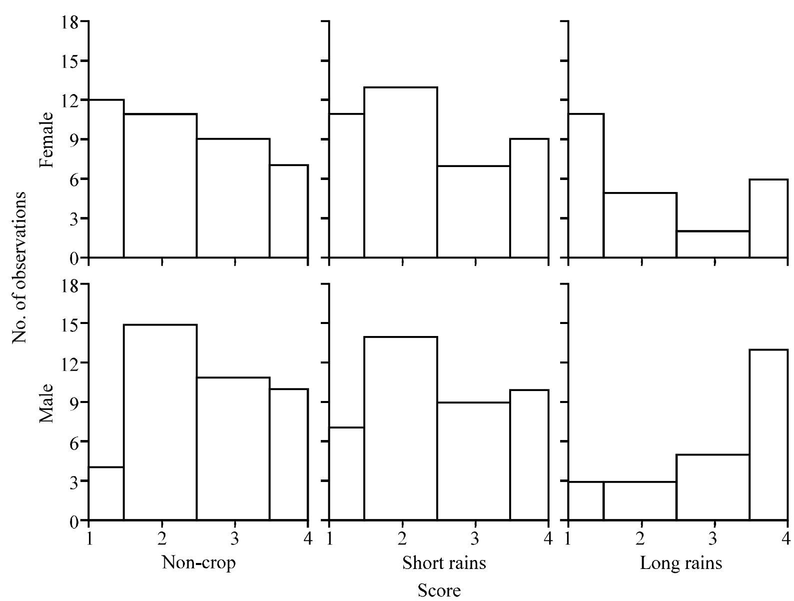

Fig. 1: Frequency distribution of movement of rodents showing interaction between seasons and sex of individuals (Scores 1-4 indicate increasing distances, where 1 is the shortest and 4 the longest)

tractor ploughed fields. At the onset of the long rainy season, (February), more sexually active males with scrotal testis were found in the slash and burn fields than in the tractor ploughed fields.

The distribution of females with perforated vagina was also significantly influenced by the land preparation methods ($p \leq 0.05$) and was higher in the slash and burn fields than in the tractor ploughed fields (Tukey LSD test; $F(1,32) = 11.199$; $p<0.001$). Land preparation methods also affected the distribution of reproductively active females with time (Tukey LSD test: $F(8,36) = 2.93$; $p = 0.017$). During the short rainy season, the proportion of females with perforated vagina was higher in the slash and burn fields, particularly when the bean crop was established and maize was at its vegetative stage. An interaction between land preparation methods and cropping system on the distribution of sexually active females in the population was found ($F (1,12) = 5.279$, $p = 0.040$).

The distribution of adults in the population differed significantly between intercropped and monocropped fields ($F (1,124) = 4.3498$, $p = 0.039$), with more adults in the mono-crop than in the inter-crop fields (Tukey LSD

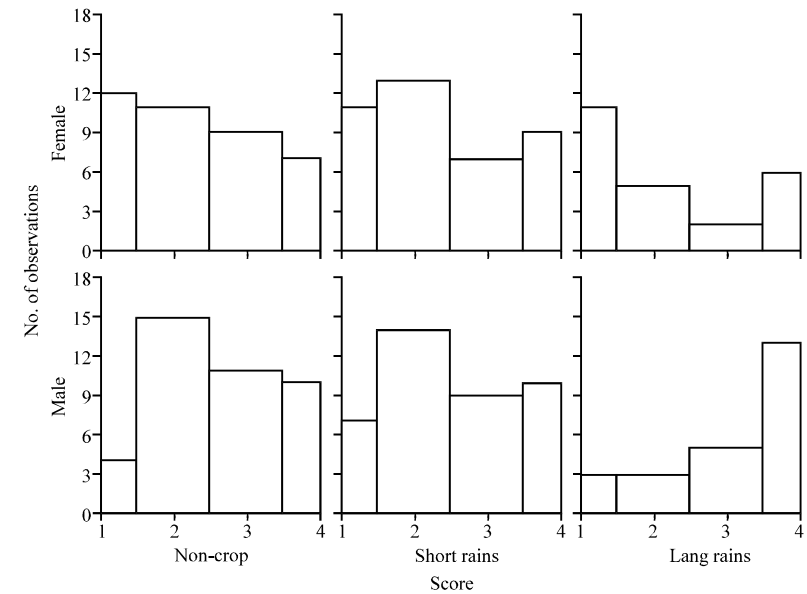

Fig. 2: Frequency distribution of movement of rodents showing the interaction between land preparation methods and sex of individuals (Scores 1-4 indicate increasing distances, where 1 is the shortest and 4 the longest)

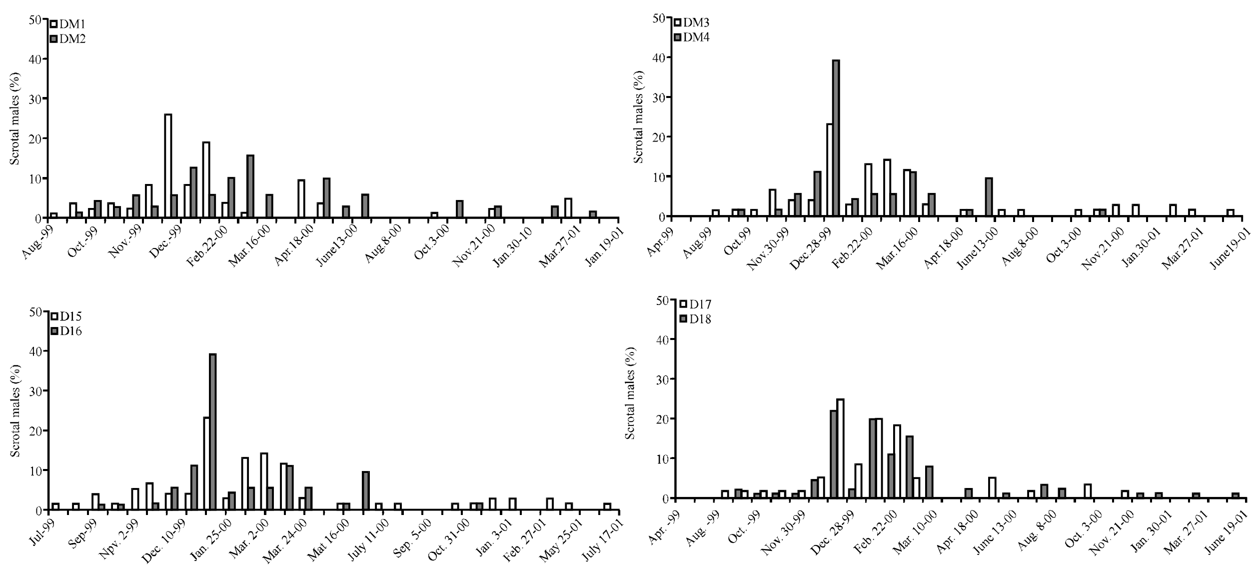

Fig. 3a: Distribution of sexually active males of *M. natalensis* in fields subjected to different treatments

test). Slash and burn and tractor ploughing didn't have significant effect on the proportion of adults in the population. However, land preparation methods significantly affected the age structure with time ($F (30,124) = 2.0840$, $p<0.001$). In October 1999, more adults were found in the tractor ploughed fields than in the slash and burn fields but immediately after land preparation (November 30, 1999) more adults occurred in the slash and burn fields (Fig. 4). After seed emergence (December 10, 1999) adults were fewer in the tractor ploughed than in the slash and burn fields but the differences were not significant. However, later in the season, (January 2000 to March 2000) there were significantly more adults in the slash and burn fields than in the tractor ploughed fields. During the long rainy season (2000), the mean number of adults was significantly higher in the tractor ploughed fields immediately after seed emergence (March) and remained

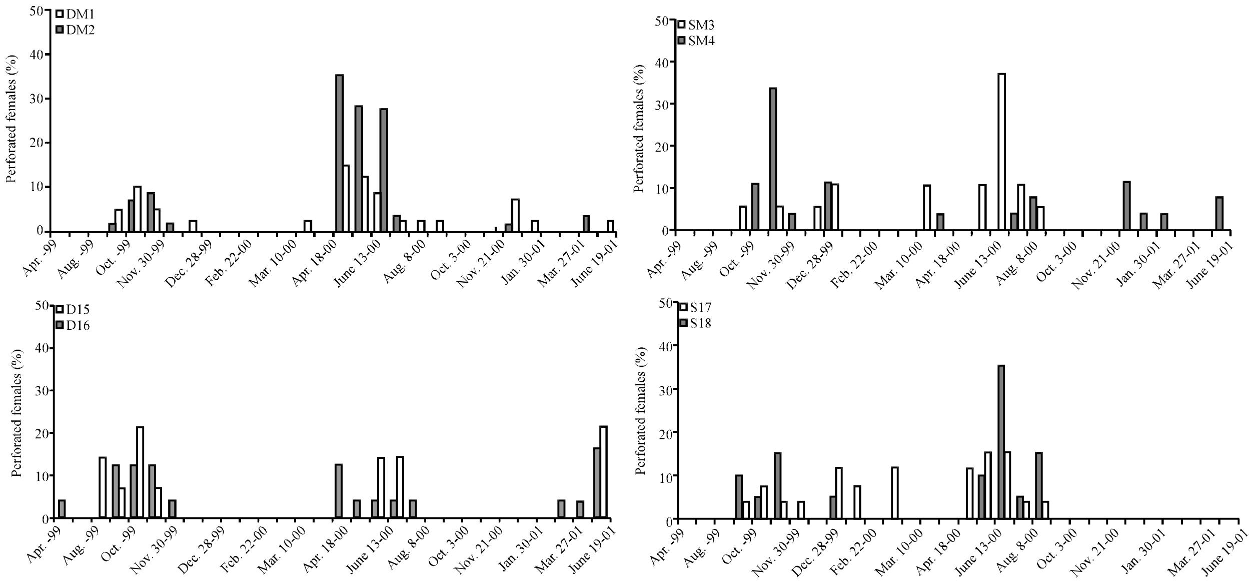

Fig. 3b: Distribution of females with perforated vagina in fields subjected to different treatments

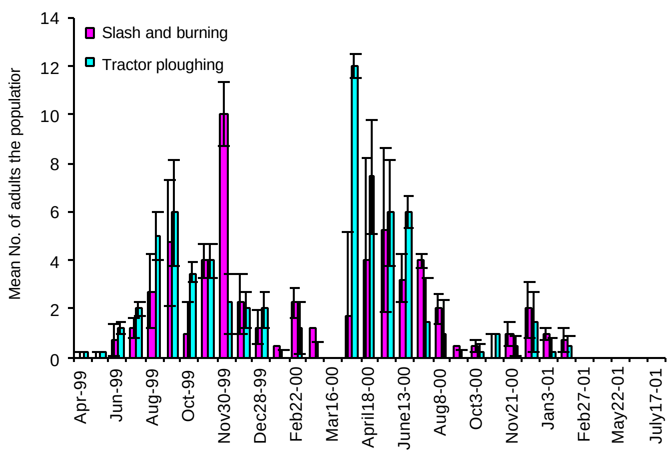

Fig. 4: Mean number of adults in the slash and burn and tractor ploughed fields

significantly higher in these fields for the rest of the season (June 2000). After harvest (July 2000 to September 2000), there were no significant variations in the distribution of adults between the tractor ploughed and slash and burn fields. The higher number of adults in the population in the slash and burn fields than in the tractor ploughed fields suggests that more adults were attracted to these fields after the fire. Probably more weed seeds become available for rodents as a result of the slash and burn.

There were significant differences in the distribution of sub-adults between tractor ploughed and slash and burn fields and mono and inter-crop systems ($F(1,124) = 13.167$, $p<0.001$ and $F(1,124) = 8.3734$, $p<0.001$, respectively). Interaction occurred between land preparation methods and cropping systems ($F(30,124) = 3.9081$, $p = 0.001$). Land preparation methods affected distribution of sub-adults with time (Fig. 5). The distribution of sub-adults in the population differed significantly during June-October 1999. After seed emergence (December, 10) sub-adults numbers were significantly higher in the tractor ploughed fields than in the slash and burn fields. During the vegetative stage of the maize crop (December, 1999-March, 2000) significant differences occurred with more sub-adults in the slash and burn fields than in the tractor ploughed fields. During

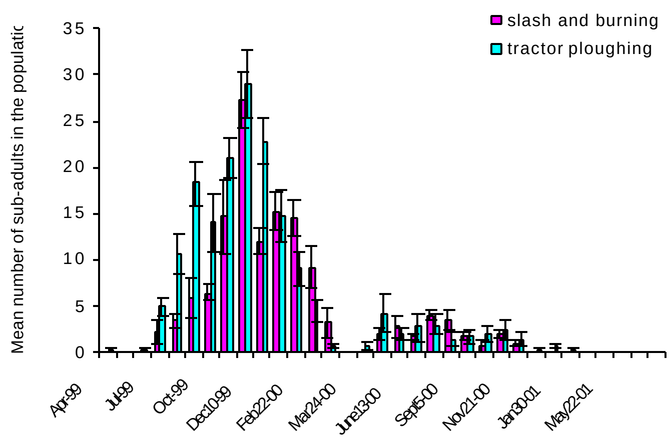

Fig. 5: Mean number of sub-adults in the slash and burn and tractor ploughed fields

the onset of the dry season (July-August), the sub-adults population was high in the slash and burn fields.

DISCUSSION

These findings suggest that tractor ploughing limited rodent movement and areas for foraging but were also affected by cropping system depending on the method used for land preparation. The movement of females was reduced in the tractor ploughed fields, with implications that the total area for foraging was reduced. The reasons for reduced movements in the tractor ploughed fields were not quite clear but it could be presumed that the deep ploughing disrupts movement of the animals due to formation of big soil clods after ploughing. These probably discourage the animals from moving up and down and consequently reduce their home range.

Theoretically, animals will forage far from the established home range when there is food scarcity and closer to home when food resources are abundant. Studies by Taitt *et al*. (1981), Ostfeld (1986) and Ims (1987) showed that access to additional food resulted in significantly smaller home ranges in adult males or reproductive females. This was not the case in this study since there was probably more food in the slash and burn fields than in the tractor ploughed fields and yet the movement was not affected in these areas. Although males moved further than females between capture intervals, movement for females was more affected in the tractor ploughed fields. When both home range and movements are restricted to a small area it could result into reduced survival, particularly when the population is high. Smith (1996) reported that the irregularities in distribution of food and cover produce corresponding irregularities in home range and in frequency of animal visits. It is most likely that interaction between distribution of food and vegetation cover affects the home range of *M. natalensis*. It is also likely that when the food distribution is patchy in an area with minimal cover, foraging will be limited as a result of risks of exposure to predation. For example, Mohr (2001) showed that there were more visits to feeding sites when cover was provided for *M. natalensis*. Although rodent dispersal was not investigated in this study, the observations from this study suggest that regular field disturbance like ploughing by tractor may force some individuals to leave their established home range.

The influence of land preparation and cropping systems on the distribution of the different sexes (sex ratio) and reproduction of *M. natalensis* is not quite clear. In some months during the study period there were significantly more reproductive individuals present in the slash and burn than in tractor ploughed grids. There are two plausible explanations. One is that individuals in breeding condition were attracted to these fields and secondly the conditions within these fields were more conducive for breeding probably as a result of more food availability when maize was at its vegetative stage. In the slash and burn fields weed regeneration was faster than in the tractor ploughed fields. The weed seeds were probably an important food source for the onset and continuation of breeding.

The high number of sub-adults in the population during vegetative stage of maize crop in the slash and burn fields suggest that breeding was occurring in these fields. These observations are supported by the high number of sexually active females observed in these fields during this period. Probably the slash and burn fields provided a better environment for breeding, in particular, the availability food resources. In general, weed regeneration was faster in the slash and burn fields. These weeds provide supplementary food resources for rodents in the field. Other studies have shown that the onset of breeding in other species of rodents coincides with changes in the availability and type of food eaten and suggested that food quality rather than quantity was a major factor influencing breeding (Bomford, 1987a and b). There is also strong evidence that nutritional factors such as green forage stimulate reproduction in small mammalian herbivores (Batzli, 1985; Bomford, 1987c).

In studies carried out in Australia (Bomford and Redhead, 1987), it was hypothesized that the quality of food in the diet of mice was an important factor in the formation of mouse plagues. For *M. natalensis*, an opportunistic species that highly dependent on favourable conditions for breeding, induced changes which affect the food source may determine the duration and where and when breeding takes place. Therefore one could generalize that the slash and burn fields were more conducive for breeding and consequently higher increase in the population of *M. natalensis* due to better food conditions.

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