Belg. J. Zool., 135 (supplement) : 83-89 December 2005

# Movements and spatial patterns of *Mastomys erythroleucus* in maize cropping systems in the Kenyan Rift Valley

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ABSTRACT. We studied movements and spatial patterns of *Mastomys erythroleucus* in four permanent capture-mark-recapture grids in maize cropping systems in the Kenyan Rift Valley. Mean daily movements were affected by maize crop phenology. There was also a significant interaction effect between sex and crop phenology on daily movements. Ranging distances varied by sex with males ranging further than females between successive captures. The majority of marked individuals remained within 20 m of their point of first capture for the three consecutive days in each trapping period. Rodent captures were highly clustered around the grid center or the periphery in three grids but were distributed randomly in the fourth grid. The clustered dispersions could suggest habitat preferences by *M. erythroleucus* within these fields and such areas could provide targets for ecologically based management. Changes in movement patterns in response to environmental factors allow for colonization and use of available resources in cultivated areas. Rodent control measures may focus on, among other approaches, limiting dispersal in farms.

KEY WORDS : Movements; spatial patterns; *Mastomys erythroleucus*; maize cropping systems.

## INTRODUCTION

In Kenya, maize is a subsistence crop grown in smallholdings of 0.5 to 20 hectares under partial mechanization (GOVERNMENT OF KENYA, 1997). Such land tenure systems are often under different management practices that lead to the formation of habitat patches across agricultural landscapes (MAKUNDI et al., 1999). In these patches, the qualities of resources including levels of their productivity are frequently ephemeral and follow an annual crop cycle. Species respond to these changes in resource levels over space and time by adopting different life history strategies, especially in their choice of diet, preferred habitat and mating systems (FLEMING, 1979).

Habitat heterogeneity created from resource patches has profound influence on the intensity of the effects of density-dependent factors (such as competition, diseases and predation) on various demographic parameters (GOLDWASSER et al., 1994). Rodents in African fields are highly motile animals (LEIRS et al., 1997) and through dispersal, may connect between patches to reduce the levels of competition for limited resources (STENSETH & LIDICKER, 1992; LAMBIN, 1994; MANSON et al., 1999). Such movements are reflected in their demographic traits such as mortality, recruitment (LARSEN & BOUTIN, 1994), densities, distribution, persistence, extinctions and colonisations (DIFFENDORFER et al., 1995; FERRERAS 2001; THOMAS et al., 2001; BRITO & FERNANDEZ, 2002; JOHNSON et al., 2002; KIE et al., 2002). This may ultimately influence community structure and its biological diversity (HOLT, 1997).

*Mastomys erythroleucus* (Temminck, 1853), a multimammate mouse, is an important murid pest of maize crops in the Kenyan Rift Valley (ODHIAMBO & OGUGE, 2003). Earlier reports from the area mentioned it as *M. natalensis* (TAYLOR, 1968; TAYLOR & GREEN, 1978), but that species has a different chromosome number. Although documentation of current rodent damages is not available, earlier reports have indicated 20% loss of maize and 34-100% loss of wheat and barley during the 1951 and 1962 rodent outbreaks in western Kenya (TAYLOR, 1968). In the eastern Africa region, the economic importance of this species has been reported from the farmlands in Ethiopia (BEKELE & LEIRS, 1997) while the congeneric *M. natalensis* is the most important pest of maize in Tanzania (MWANJABE et al., 2002). Different strategies for success of pest populations have implications for control. One of the fundamental goals in ecology is to understand the distribution and abundance of organisms and to use this knowledge for the management of populations in a variety of natural and managed ecosystems (GUTIERREZ, 1994). Our study assessed for (i) effects of crop phenology on movement patterns of *M. erythroleucus*; and (ii) its distribution patterns in maize crop fields. We tested the following hypotheses; first, that movement patterns in this species remain unaffected under changing crop phenology in cultivated areas. Secondly, that individuals in this population as in the majority of species are distributed at random.

## MATERIAL AND METHODS

### *Study site*

The study was conducted in Rongai Division, Nakuru District, in the Kenyan Rift Valley (35° 28' - 35° 36' E and 0° 13' - 1° 10' S), at altitudes of between 1520-2400m above sea level (Fig. 1). The climate in this area falls between semi-arid (annual rainfall less than 760 mm) in the lower areas and dry sub-humid (annual rainfall of 1270mm) regions in the higher altitudes. Mid-day temperature ranges between approx. 24°-30°C. The area is important for maize production mainly for subsistence but also as a cash crop. The region contributes substantially to the country's production of maize, beans and potatoes (Government of Kenya, 1997).

In this study area, the original vegetation of moist forest has been replaced largely by a mosaic of cropped and fallow areas with exotic tree species *Grevillea robusta* and *Cyprus* spp. on the high slopes. In the sub-humid region, the current vegetation has resulted from repeated burning, grazing and cultivation except along moist ravines. The most common ravine tree species were *Podocarpus latifolius*, *Syzygium guineense*, *Ficus stuhlmannii*, *Albizia coriaria* and *Acacia nilotica*. In the intermediate zone, vegetation is dominated by species of *Acacia xanthophloea, Acacia seyal*, *Acacia nubica* and *Acacia senegal*. The common grasses are *Themeda triandra* and *Themeda diplandra*. In the driest part of the Division, the study was carried out near the River Rongai, where the riverine vegetation is dominated by shrubs of *Lantana camara*. Other common species included scattered *Acacia* species, succulents such as *Euphorbia candelabrum*, *Euphorbia tirucalli* and *Aloe ballyi*. The dominant grasses in fallow areas there were *Panicum maximum*, *Cynodon dactylon* and *Themeda triandra*.

### *Sampling methods*

Rodents were live-trapped using Sherman's LFA traps (Sherman Traps Inc., Tallahassee, Florida, USA) on four permanent one-hectare grids coded (i) Mugo, (ii) Beth, (iii) Kurt, and (iv) Moto. The grids were established in April 2000 along an altitudinal gradient from a sub-humid (Mugo grid), over intermediate ares (Beth and Kurt grids) to semi arid (Moto grid) conditions (Fig. 1). Each grid consisted of trapping stations laid at 10 m within and between rows giving a total of 100 stations and marked using white painted bricks. One trap was placed at each station with traps being opened for three consecutive days and nights every 28 days between May 2000 and December 2001. Trapping in Kurt grid commenced in April 2001. Fried coconut cubes mixed with peanut butter and corn oil were used as bait.

Animals were sampled using the Capture-Mark-Recapture (CMR) technique. Captured animals were identified to species level, weighed, sexed and their trapping station and other general remarks were recorded. Each animal was individually marked by toe clipping. The animals were then released at the point of capture and traps re-baited.

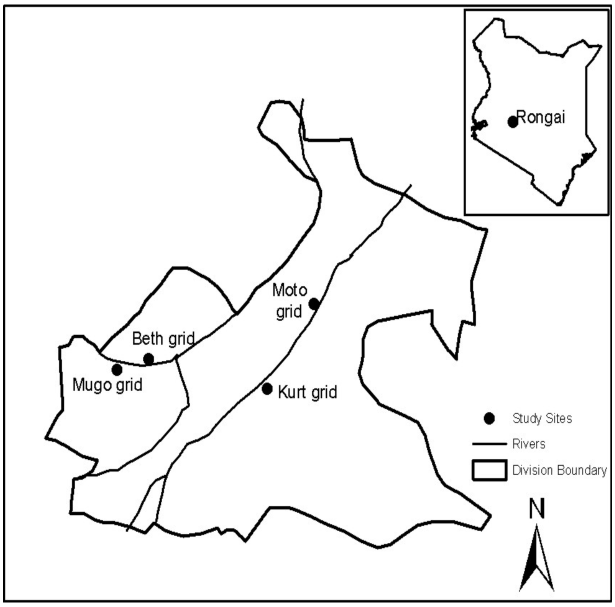


Fig. 1. – A map of Kenya showing the location of Rongai Division and the study grids.

### *Data analyses*

Movements during the trapping periods were determined from the secondary capture histories. The XY reduced capture histories were used in the data input file of the program CAPTURE (Rexstad & Burnham, 2002). Range lengths were determined by calculating the linear maximum distance between capture stations in consecutive months (Delany & Monro, 1985), using the formula;

$$d= \sqrt{}(x_2-x_1)^2 + (y_1 -y_1)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where d = linear maximum distance estimate (m)
$x_1$= X-co-ordinate of the initial trap station
$x_2$= X-co-ordinate of the final trap station
$y_1$ = Y-co-ordinate of the initial trap station
$y_2$ = Y- co-ordinate of the final trap station

Daily movement and range length data were first standardized using log (x + 1) transformation (Rohlf & Sokal, 1984); then General Linear Model (GLM) analysis of variance in program SYSTAT Version 9.0 was used to test the effects of sex, maize crop phenology and grid location on net movements during the trapping period. We did not make appreciable rodent recaptures in year 2000; therefore, these estimates and analysis were based on data obtained between January and December 2001.

Distribution of individuals within maize fields was mapped out using frequency of primary captures in the 100 trapping stations per grid. Only the first capture of each individual in a month was used as the point of reference to eliminate biases. To enable further analysis, the 100 trapping locations were divided into three distinct concentric zones : an outer periphery with 36 trapping stations, middle zone with 28, and a central one with 36 for use in analysis of spatial patterns. Thereafter, a coefficient of dispersion (CD) was calculated for each of the three zones (Krebs, 1989). The significance of the departure from randomness was assessed statistically by computing :

$$t = \frac{\left| s^2/\bar{X} - 1.0 \right|}{\sqrt{2/(n-1)}} \quad \ldots\ldots(2)$$

where $s^2$ is the sample variance, $\bar{X}$ is the sample mean capture frequencies and $n$ is the sample size, respectively (Clapham, 1936). The calculated $t$ was compared to the critical values on mathematical tables for $n$-1 degrees of freedom (Rohlf & Sokal, 1984).

## RESULTS

### *Movements and range lengths*

Daily movement in *M. erythroleucus* was similar ($F$ = 1.39, $P$ = 0.24, $n$ = 204) between sexes across the four grids (mean ± SEM : males= 19.54 ± 1.87 m; females= 17.76 ± 1.41 m) (Fig. 2). Maize phenology affected movements ($F$ = 2.42, $P$ = 0.016, $n$ = 204) as ranging distances varied between planting/seedling (23.6 ± 3.1 m), harvesting (20.1 ± 1.8 m), vegetative (17.6 ± 2.3m), ripening (16.5 ± 4.7 m) and fallow (14.2 ± 2.1 m) stages, respectively. There was also a significant interaction effect ($F$ = 2.76, $P$ = 0.012, $n$ = 204) between sex and crop phenology on these movements during the capture periods. A high proportion (Mugo grid 60.43%, Beth 79.27%, Kurt grid 54.72% and Moto grid 60.00%) of animals moved shorter distances (<20m) between successive capture sessions (Fig. 3).

Range length was significant between sexes ($F$ = 18.972, P < 0.001, $n$ = 136), with males (44.19 ± 3.8 m) ranging further than females (27.54 ± 2.4 m) (Fig. 4). Ranging distances were similar across the grids ($F$ = 1.302, $P$ = 0.276, $n$ = 136). No interactive effect was detected between sex and grids ($F$ = 1.231, $P$ = 0.301, $n$ = 136).

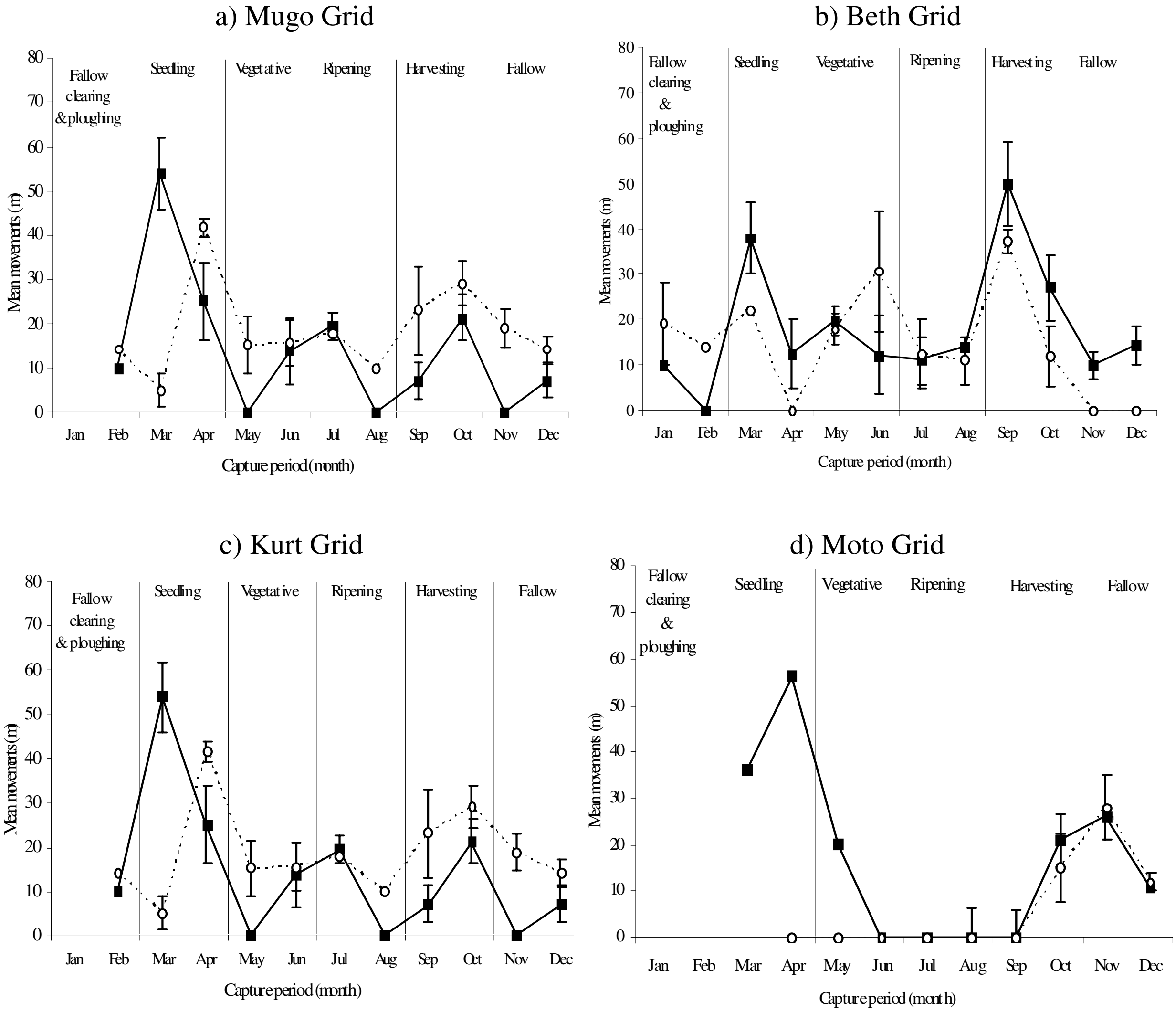


Fig. 2. – Mean (± SEM) daily movement patterns of male (black squares, full lines) and female (open circles, dashed lines) *M. erythroleucus* under different maize crop phenology in; a) Mugo, b) Beth, c) Kurt and d) Moto grids as estimated at 95% confidence interval from XY reduced secondary Capture histories using the program CAPTURE. Data collected from January to December 2001. The different stages of the maize crop fields are indicated.

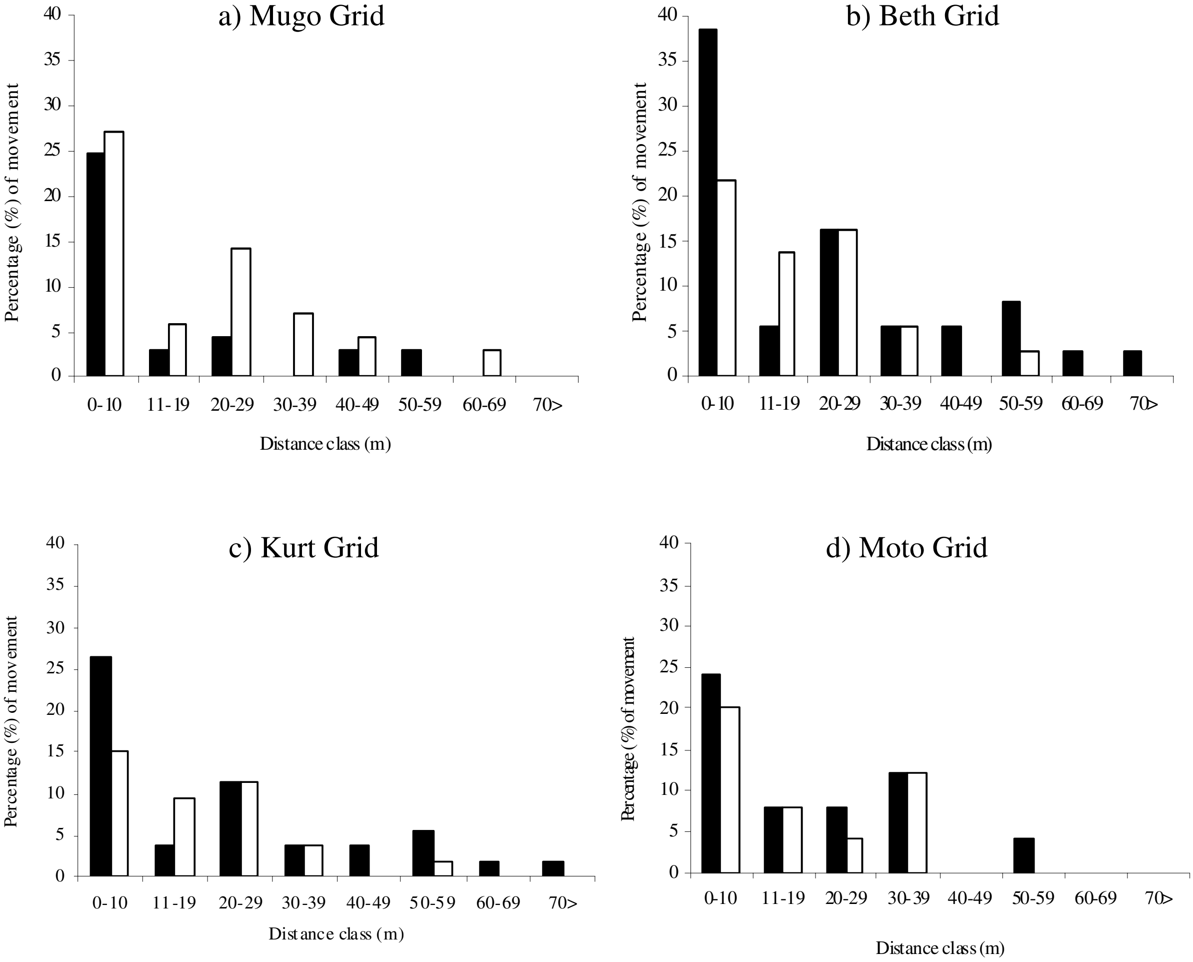


Fig. 3. – Class frequencies of daily movements by adult male (dark) and female (light) *M. erythroleucus* in a) Mugo, b) Beth, c) Kurt and d) Moto grids between successive capture positions following release. Only animals caught within the three sampling sessions are included.

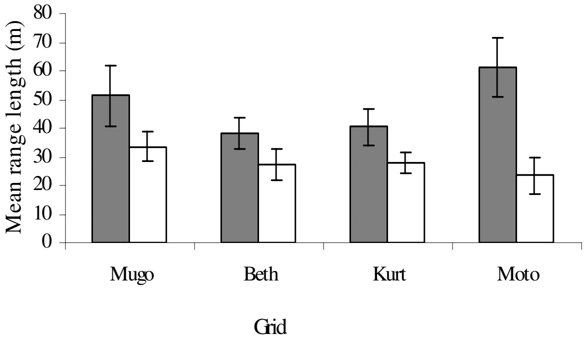


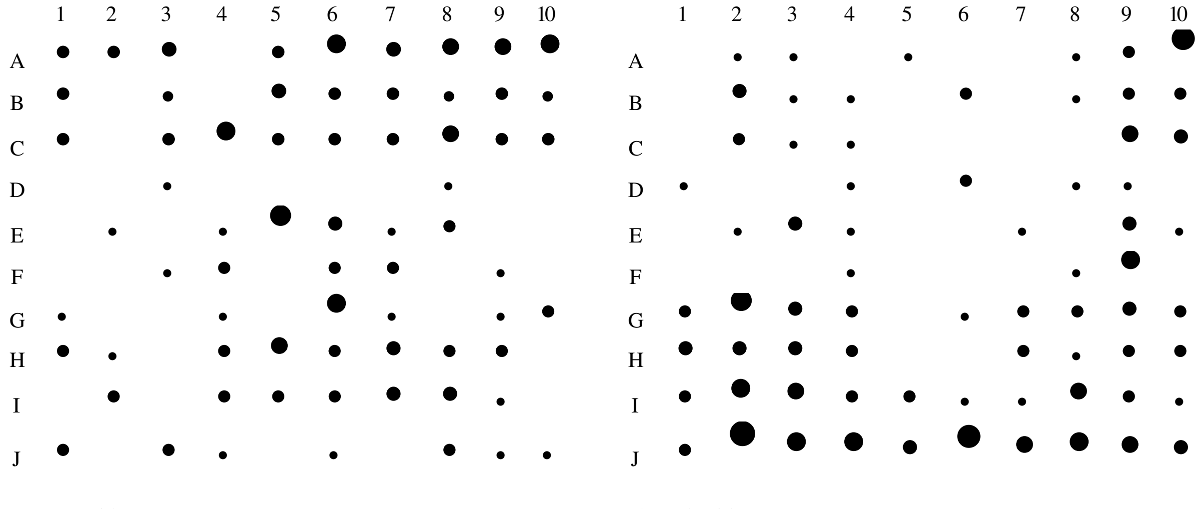
Fig. 4. – Mean range lengths for adult male (dark) and female (light) *M. erythroleucus* between successive capture positions following release.

### *Distribution of captures within grids*

Patterns in rodent distribution were not entirely consistent within the maize fields (Fig. 5). Rodent captures exhibited both peripheral (CD = 1.7, $t = 3.1$, $P < 0.01$, $n = 36$) and central (CD = 1.8, $t = 3.6$, $P < 0.01$, $n = 36$) clustering at Mugo grid. Similar peripheral (CD = 2.5, $t = 6.5$, $P < 0.01$) and central (CD = 1.7, $t = 3.1$, $P < 0.01$) clustering were noted at Beth grid. Distribution in Kurt grid was only clustered peripherally (CD = 2.3, $t = 5.3$, $P < 0.01$, $n = 36$) while it was random at Moto. In Mugo grid, 68.1% of the captures were made from the whole of A-line and along the 5th, 6th, 7th and 8th vertical lines. In the Beth grid, 75.1% of captures were made from the edges of the farm on the J-line and along the 2nd, 3rd, 9th and 10th vertical lines. In Kurt grid captures were mainly from one edge of the farm thus on line-1 and constituting 43.6% of the captures. In Moto grid, no particular trapping stations could be associated with significant proportions of captures.

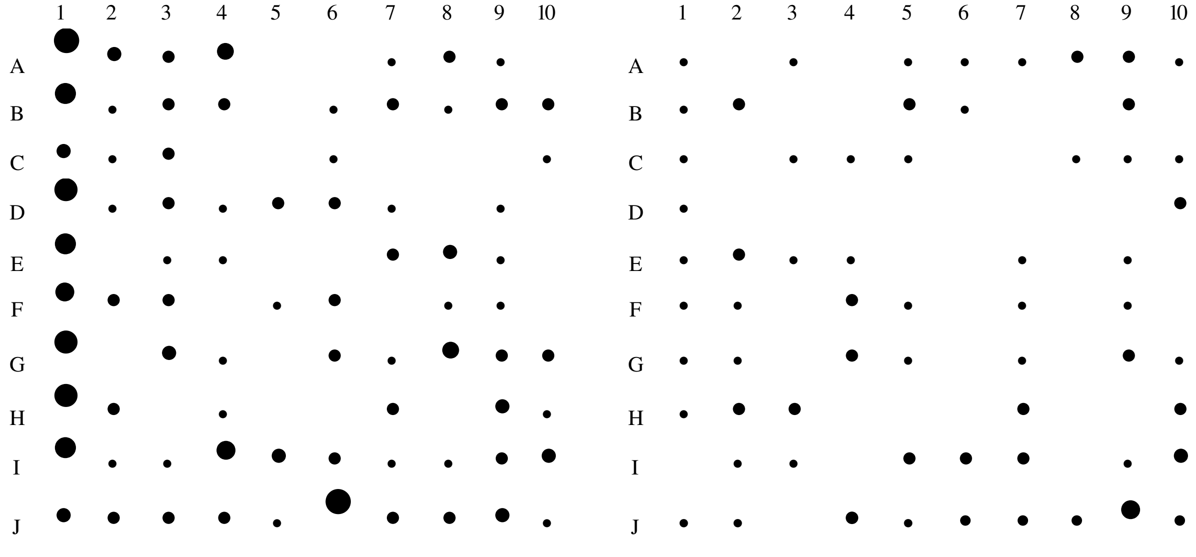
## DISCUSSION

Our study shows that male and female *Mastomys erythroleucus* cover similar distances in their daily activities, i.e. 19. 5 (± 1.9 m) and 17.8 (± 1.4 m), respectively (Fig. 2). However, the long daily movements made during seedling and harvesting stages of maize crop may be due to habitat alterations caused by weeding and trampling on vegetation, respectively, which could have led to reduced ground cover forcing rodents to seek new habitat patches. Manual harvesting could have further reduced food resources in the farms. The short movements during the vegetative, ripening and fallow stages of the crop (Fig. 2), coupled with the majority of captures (60.43%, 79.27%, 54.72% and 60.00% in Mugo, Beth, Kurt and Moto grids, respectively) less than 20m from point of original capture (Fig. 3) suggests that *M. erythroleucus* settled temporarily within the perimeter of the resource rich habitat patches of the maize farms. Earlier experimental work has shown an inverse relationship between food and rodent movements. Increases in food supplies lead to small home ranges, declined space use and immigration into the area, while the reverse is observed when food supplies are reduced (Boutin, 1984). The reasons for the interaction effect between sex and crop phenology, however, remain unclear in this study.



(a) Mugo grid

(b) Beth grid



(c) Kurt grid

(d) Moto grid

Fig. 5. – Distributions of total capture frequencies per trapping station for *M. erythroleucus* in a) Mugo, b) Beth, c) Kurt and d) Moto grids between January and December 2001.

Although ranging distances were similar between grids, males ranged longer distances than females (44.2 ± 3.8 m and 27.5 ± 2.4 m), respectively (Fig. 4). This would suggest larger home range in males whose larger body size (Odhiambo, 2003) suggests a polygynous social system (Ostfeld, 1986). Similarly, a study by Martin et al. (1989) in Kitale area in western Kenya captured *M. erthroleucus* up to 50 m from the edges of newly sown vegetation-bare maize fields. The clustering of rodent captures at certain trapping positions (Fig. 5), suggests that some parts of the habitat were utilised more or a possibility of some social attraction that enhanced presence of other individuals. Crops in these loci, for example, at the peripheral and central zones of the farm are likely to suffer increased risk to depredation from rodents leading to the patchy nature of damage. Similar results indicating site fidelity and edge effects have also been reported from the studies of *Arvicanthis niloticus* in Kenyan grassland (DELANY & MONRO, 1985), and for other small rodents in forest and adjoining farmland habitats (MANSON et al., 1999). Conversely, random distribution of captures in Moto may be attributed to pure and uniform stands of fodder grass surrounding the trapping stations. Other studies have reported the influence of microhabitat on food, abundance and distribution of *Mastomys* in Kenyan grasslands (MARTIN & DICKINSON, 1986; OGUGE, 1995).

From our study, we can conclude that the crop phenology strongly influenced movements of *M. erythroleucus*. Males generally made wider field excursions than females, but once settled most rodents in the farm preferred to temporarily stay near their home ranges. Changes in movement patterns in response to environmental factors allow for colonisation and use of emerging resources in cultivated areas. Control measures may focus on, among other approaches, limiting dispersal during periods of high precipitation. The clustered dispersions would suggest habitat preferences by *M. erythroleucus* in these fields and this may provide targets for ecologically-based rodent management.

## ACKNOWLEDGEMENTS

We would like to thank the Officers in the Ministry of Agriculture especially Mr. Mbuba, Mr. Korir, Mr. Kimwele and Mr. Mugo for their cooperation and provision of logistic support. We are also grateful to local farmers who allowed us to use their farms for sampling our rodent data. This study was fully funded by the Rockefeller Foundation's Forum on Agricultural Resource Husbandry programme.

## REFERENCES

BEKELE, A. & H. LEIRS (1997). Population ecology of rodents in maize fields and grasslands in central Ethiopia. *Belgian Journal of Zoology*, 127 (Suppl.) : 39-48.

BRITO, D. & F.A.S. FERNANDEZ (2002). Patch relative importance to metapopulation viability : the neotropical marsupial *Micoureus demerarae* as a case study. *Animal Conservation*, 5 : 45-51.

BOUTIN, S. (1984). Effect of late winter and food addition on numbers and movement of Snowshoe hare. *Oecologia*, 62 : 393-400.

CLAPHAM, A.R. (1936). Over dispersion in grassland communities and the use of statistical methods in plant ecology. *Journal of Ecology*, 24 : 232-251.

DELANY, M.J. & R.H. MONRO (1985). Movement and spatial distribution of the Nile rat (*Arvicanthis niloticus*) in Kenya. *Journal of Tropical Ecology*, 1 : 111-130.

DIFFENDORFER, E.J., M.S. GAINES & R.D. HOLT (1995). Habitat fragmentation and movements of three species of small mammals (*Sigmodon, Microtus* and *Peromyscus*). *Ecology,* 76(3) : 827-839.

FERRERAS, P. (2001). Landscape structure and asymmetrical inter-patch connectivity in metapopulation of endangered Iberian lynx. *Biological Conservation*, 100 : 125-136.

FLEMING, H.T. (1979). Life-history strategies. In : STODDART D.M. (ed). *Ecology of small mammals*. Chapman and Hall, London : 1-52.

GOLDWASSER, L., J. COOK & E.D. SILVERMAN (1994). The effects of variability on Metapopulation dynamics and rates of invasion. *Ecology*, 75(1) : 40-47.

GOVERNMENT OF KENYA (1997). *Economic Review*. Government Press. Nairobi. Kenya.

GUTIERREZ, P.A. (1994). A Physiological Based Tritrophic Perspective in Bottom-Up down regulation. *Ecology*, 75 : 2227-2242.

HOLT, R.D. (1997). From meta-population dynamics to community structure : some consequences of spatial heterogeneity. In : HANSKI I. and M. E. GILPIN (eds). *Metapopulation biology : ecology, genetics and evolution*. Academic Press, San Diego, California, USA : 149-164.

JOHNSON, R., J.W.H. FERGUSON, A.S. VAN JAARSVELD, G.N. BRONNER & C.T. CHIMIMBA (2002). Delayed responses of small mammal assemblages subject to afforestation-induced grassland fragmentation. *Journal of Mammalogy,* 83 (1) : 290-300.

KIE, G.J., R.T. BOWYER, M.C. NICHOLSON, B.B. BOROSKI & E.R. LOFT (2002). Landscape heterogeneity at differing scales : effects on spatial distribution of Mule Deer. *Ecology*, 83(2) : 530-544.

KREBS, C.J. (1989). Ecological Methodology. Hapre & Row, Publishers, Inc, New York, NY (664 pp).

LAMBIN, X. (1994). Natal philopatry, competition for resources and inbreeding avoidance in Townsends' voles (*Microtus townsendii*). *Ecology*, 75(1) : 224-235.

LARSEN, K.W. & S. BOUTIN (1994). Movement, survival and settlement of young red squirrels. *Ecology,* 75(1) : 214-223.

LEIRS, H., R.VERHAGEN, C.A. SABUNI, P.S. MWANJABE & W.N. VERHEYEN (1997). Spatial dynamics of *Mastomys natalensis* in a field-fallow mosaic in Tanzania. *Belgian Journal of Zoology*, 127 : (Suppl.) : 29-38.

MANSON, H.R., R.S. OSTFELD & C.D. CANHAM (1999). Responses of a small mammal community to heterogeneity along forest-old-field edges. *Landscape Ecology*, 14 : 355-367.

MAKUNDI, R., N. OGUGE & P. MWANJABE (1999). Rodent Pest Management in East Africa - an ecological approach. In : SINGLETON, G., H. LEIRS, Z. ZHANG, and L. HINDS (eds). *Ecologically-based Rodent Management*. ACIAR Publications, Canberra : 460-476.

MARTIN, G.H.G. & N.M. DICKINSON (1986). Small mammal abundance in relation to microhabitat in a dry sub-humid grassland in Kenya. *African Journal of Ecology*, 23 : 223-234.

MARTIN, G.H.G., N.O. OGUGE & J.M. GATIMU (1989). *Technical Report for the Development of Rodent Control Program in the Crop Protection Branch, Ministry of Agriculture, Kenya*. FAO/UNDP Project Ken/85/009.

MWANJABE, P.S., F.B. SIRIMA & J. LUSINGU (2002). Crop losses due to outbreaks of *Mastomys natalensis* (Smith, 1834) Muridae, Rodentia, in the Lindi region of Tanzania. *International Journal of Biodeterioration and Biodegradation*, 49 : 133-137.

ODHIAMBO, C. (2003). Population dynamics and habitat use by murid rodents in Maize cropping systems in Rongai Division, Nakuru District, Kenya. M.Sc Thesis, Kenyatta University, Nairobi.

ODHIAMBO, C. & N.O. OGUGE (2003). Patterns in rodent pest distribution in a maize cropping system in the Kenyan Rift Valley. In : SINGLETON, G., L.A. HINDS, C.J. KREBS & D.M. SPRATT (eds). *Ecologically-Based Rodent Management*. ACIAR Publications, Canberra : 217-219.

OGUGE, N.O. (1995). Diet, seasonal abundance and microhabitats of *Praomys (Mastomys) natalensis* (Rodentia : Muridae) and other small rodents in a Kenyan sub-humid grassland community. *African Journal of Ecology,* 33 : 211-223.

OSTFELD, R.S. (1986). Territoriality and mating systems of California voles. *Journal of Animal Ecology*, 38 : 341-359.

REXSTAD, E. & K. BURNHAM (2002). Users' guide for interactive program CAPTURE. Abundance Estimation of Closed Animal Populations. Internet : *ftp ://pwrcftpr.er.usgs.gov/research/software/capture.zip.*

ROHLF, F.J. & R.R. SOKAL (1984). Statistical tables. 2nd ed. W. H. Freeman and Co., San Franscisco.

STENSETH, N.C. & W.Z. LIDICKER JR. (1992). Pre-saturation and saturation dispersal 15 years later : some theoretical considerations. In : STENSETH and W. Z. LIDICKER JR. (eds). *Animal dispersal* : *Small mammals as a model.* Chapman and Hall, London : 199-220.

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

TAYLOR, K.D. & G. M. GREEN (1978). The influence of rainfall on diet and reproduction in four African rodent species. *London Journal of Zoology*, 174 : 453-471

THOMAS, J.A., N.A.D. BOURN, R.T. CLARKE, K.E. STEWART, D.J. SIMCOX, G.S. PEARMAN, R. CURTIS & B. GOODGER (2001). The quality and isolation of habitat patches both determine where butterflies persist in fragmented landscapes. *Proceedings of the Royal Society of London*, 268 : 1791-1796.