

Comparative Study of Population Dynamics and Breeding Patterns of *Mastomys natalensis* in System Rice Intensification (SRI) and Conventional Rice Production in Irrigated Rice Ecosystems in Tanzania

Loth Mulungu S^{1*}, Happy Lopa² and Mashaka Mdangi E^{3,4}

¹Pest Management Centre, Sokoine University of Agriculture, PO Box 3110 Morogoro, Tanzania

²Rodent Control Centre, Ministry of Agriculture, Food Security and Cooperatives, P.O. Box 3047 Morogoro, Tanzania

³MATI-Ilonga, P.O. Box 66, Kilosa, Tanzania

⁴Crop Science and Production, Sokoine University of Agriculture, P.O. Box 3005, Morogoro, Tanzania

Abstract

Mastomys natalensis is among the most important rodent pests in Sub-Saharan Africa. This study investigated the population dynamics and breeding patterns of this mouse in system rice intensification (SRI) and in conventional cropping systems in irrigated rice ecosystem in eastern Tanzania. The *Mastomys natalensis* population varied with years and season, but not with either SRI or conventional cropping system which would be expected as the all fields are in the same area. The highest population peak was observed during the dry season i.e., August to September. Breeding patterns of this rodent pest was not influenced by the cropping system or season, indicating that *M. natalensis* is sexually active throughout the year and does not be affected by the rice production systems. Regular control and sustainable operations, such as the use trap barrier system (TBS), are therefore essential if the populations are to be kept within tolerable limits.

Keywords: *Mastomys natalensis*; Population dynamics; Breeding patterns; SRI; Conventional cropping system

Introduction

Tanzania ranks, second to Madagascar, as a major rice producer in Africa [1]. However, in several areas of Tanzania, rice has been grown in the conventional way, where farmers flood the field with water, followed by planting several seedlings per hole [2]. Farmers in some of the irrigated scheme in Tanzania, such as Mkindo, have started practicing System Rice Intensification (SRI) for rice crop production [3]. The SRI is an agro-ecological method of growing rice that enhances crop yields which is resilient to the adverse effects of climate change. It is being recognized for its impact on the availability, affordability, accessibility and adequacy of food. The main factors that explain the impacts of SRI management are: high vigor of plant, more effective root systems and the promotion of greater abundance and diversity of beneficial soil organisms, which are factors outside the Green Revolution paradigm [4,5]. In areas where farmers are not growing the rice crop using SRI, they can get paddy rice yields of an average of 2 tons ha⁻¹ from their very poor soils with conventional methods as compared to an average of 8 tons ha⁻² in SRI [3]. Therefore, SRI methods have been shown to increase crop yields by 20 to 50% with significant reductions in water and seed requirements [6].

SRI is a package of practices especially developed to improve the productivity of rice grown in paddies. Unlike the conventional method of continuous flooding of paddy fields, SRI involves intermittent wetting and drying of paddies as well as specific soil and agronomic management practices. Therefore, the advantages of SRI are that it gives higher rice yields compared to continuously flooded paddies; requires less water (e.g. it can save 25-50% water used in irrigation); uses less seeds. Moreover, the SRI, rice has a harder grain, thus less breakage during milling, fetches higher price. Nearly all rice varieties give higher yield with SRI, but some high-yielding varieties respond better than others [7,8].

Despite these advantages of rice production using SRI, rodents could be the major threat to crop. Mulungu et al. [9] reported that crop losses caused by rodents in rice crop are largely attributed to *Mastomys natalensis*, which is the most widespread rodent pest across sub-Saharan [10]. However, it is not known whether the SRI has any effect on rodent population dynamics due to availability of more food in the field for *M. natalensis*.

Mulungu et al. [9] reported that the population of *M. natalensis* in rice fields produced under the conventional cropping systems varied seasonally with the population being higher during the dry season. The rodents are sexually active throughout the year, although the population reaches the highest level when rice is at the maturity stage. This suggests that breeding is highly influenced by the presence of a rice crop in the field. Furthermore, Mulungu et al. [11] reported that continuously rodent breeding in rice grown under conventional cropping systems is attributed to the availability of vegetative plant materials and seeds largely consumed but also by the fact that the rodent are highly specialized herbivorous/grainivorous in nature.

This study aimed at investigating the population dynamics and breeding patterns of the rodent pest species in system rice intensification (SRI) in irrigated rice cropping systems in eastern Tanzania.

***Corresponding author:** Loth Mulungu S, Pest Management Centre, Sokoine University of Agriculture, PO Box 3110 Morogoro, Tanzania Tel: 255 752 119341; E-mail: lothmulungu@yahoo.co.uk

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Materials and Methods

Study area

This study was conducted at Mkindo village (6° 16' S, 37° 36'E; altitude 365 m a.s.l.) in Mvomero District, Morogoro, Tanzania. The study area has a bimodal rainfall pattern in which short rains fall from October to December while long rains fall from March to June. The soil is clayey loam with infiltration rate of 12 cm/day. Soils have a pH of 6.2, K 12.75 mg/kg, P 0.532 mg/kg and N (%) 1.00. Farmers in the study area produce the rice crop twice per year. The first cropping calendar is in the wet season from February to July, while the second is in the dry season, from September to January. The latter purely depends on irrigation. Land preparation and rice transplanting are done in February and September during the wet and dry seasons, respectively. The rice crops reaches physiological maturity in July and January, and farmers harvest in July and January, for the wet and the dry cropping seasons, respectively. For the remaining months, the crop is at a vegetative stage.

Trapping rodents

A capture-mark-recapture study was carried out from August 2012 to July 2014. Three 70 × 70 m permanent trapping grid in each three cropping systems (SRI, Farmer Field School with SRI, and conversional rice cropping systems) of the rice crop were established. Each cropping system consisted of seven parallel lines, 10 m apart, and seven trapping stations per line, also 10 m apart (a total of 49 trapping stations field⁻¹). One Sherman LFA live trap (8 × 9 × 23 cm; H.B Sherman Traps Inc., Tallahassee, FL) was placed at each trapping station, for three consecutive nights at intervals of 4 weeks. The traps were baited with peanut butter, mixed with maize bran/maize flour and were placed in the afternoon and inspected in the morning of the following day. During flooding, the traps were placed above dried grasses within the rice field.

Captured animals

All the captured animals were taken to the field laboratory and identified to species level [12]. On the first day of capture, the animals were marked by toe clipping using specific number coding. Their weights, trapping stations, sex and reproductive status were recorded. The sex and reproductive conditions considered either a perforated or closed vagina, in females, and scrotal or non-scrotal testes, in males. The animals were then released at the same station of capture. The recorded data were then entered into a CMR data input program for analysis. New animals captured on subsequent days and during subsequent rounds of trapping were similarly marked, recorded and released.

Data collection

Species composition: The percentages of each species relative to others were calculated by dividing the number of captured individuals of each species by the total number of captured animals in a particular habitat, and multiplied by 100.

Population dynamics: The population size was estimated monthly for each three day trapping session using the M(h) estimator of the program CAPTURE for a closed population, which allows for individual heterogeneity in a trapping probability [13].

Breeding patterns: Sexual activity and breeding patterns were determined by establishing the proportion of active and non-active individuals of female mice in both habitats and month. In females, the definition of sexual activity followed that of [14], who defined sexual

activity in females as a physiological condition and not as a typical behavior. Thus, females were considered to be sexually active when the vagina was perforated, when their nipples were swollen on account of lactation, and when they were pregnant.

Data analysis

To analyze factors that influence abundance and percentage of breeding animals, we used a generalized linear model with logit-link function. A correction for over dispersion was done as the residual deviation was always higher than the degrees of freedom of the models. We used the simultaneous test for general linear hypothesis with Tukey contrast (multcomp package in R) to investigate which years differed significantly from other years.

Results

Species composition

A total of 1882 individual animals belonging to three species of rodents and one species of shrew (*Crocidura* sp.), were captured from a total of 11025 trap nights (17.1% trap success). The rodent species comprised *Mastomys natalensis*, *Rattus rattus*, and *Mus species*. *Mastomys natalensis* comprised more than 96% of the total captures in the study area. The SRI had more individuals trapped than other rice cropping systems (Table 1).

Population dynamics

Mastomys natalensis was the predominant species in the study site. This observation justified analysis of population dynamics and breeding patterns for this species. Generally, the trend of this species was similar in both cropping systems. The abundances in the study area were significantly influenced by year (GLM, log link, df=1, p<0.001), with significant differences between the years 2013 - 2014 (p=0.004) and 2012 - 2013 (p=0.003). Similarly, the abundances were significantly influenced by season (GLM, log link, df=1, p<0.001), with a higher overall abundance during the dry season and a significant interaction effect between season and year (GLM, log link, df=2, p=0.002). However, no significant effect of cropping system on abundance (GLM, log link, df=1, p=0.054) was observed in the current study (Figure 1).

Breeding patterns

Results show that the percentage of breeding females was only significantly influenced by year (GLM, logit link, df=1, p<0.001), with significant differences between the years 2014-2013 (p=0.016), 2012-2013 (p<0.001) and 2014-2012 (p<0.001). However, no significant effect of season (GLM, logit link, df=1, p=0.618) and field rice cropping system (GLM, logit link, df=2, p=0.414) interactions, between the tested factors on the percentage of breeding females was observed. This indicated that the proportion of active and non-active female individuals were the same throughout the year and cropping systems. Generally, sexually active females were observed in all months during the entire study period in both rice cropping systems (Figure 2).

	Species	SRI	Farmer Field School	Conventional
1	<i>Mastomys natalensis</i>	746 (96.76)	567 (97.09)	511 (96.96)
2	<i>Crocidura</i> spp	25 (3.24)	15 (2.57)	15 (2.85)
3	<i>Rattus rattus</i>	-	2 (0.34)	-
4	<i>Mus</i> spp	-	-	1 (0.19)
	Total	771 (100)	584 (100)	527 (100)

Table 1: Species composition of different rodent species and shrew in SRI, Farmers Field School and Conversional rice production in Irrigated Rice production scheme.

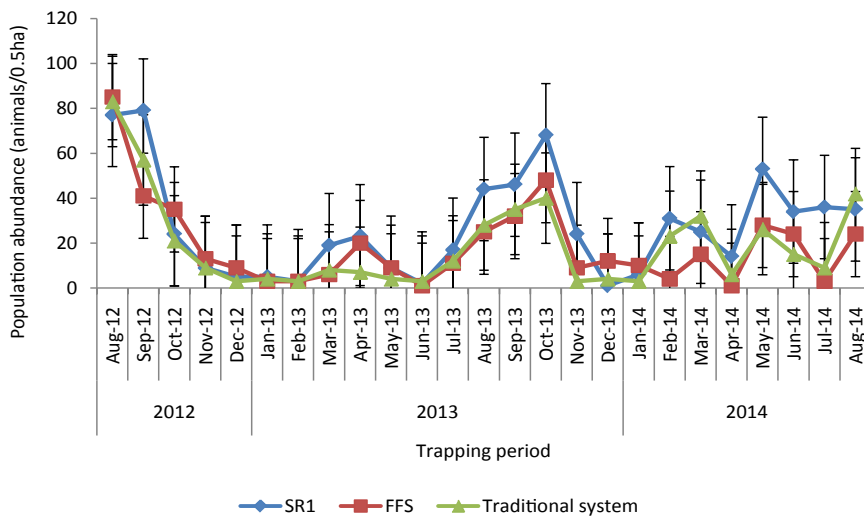


Figure 1: Population dynamics of *M. natalensis* in different cropping systems in Mkindo village.

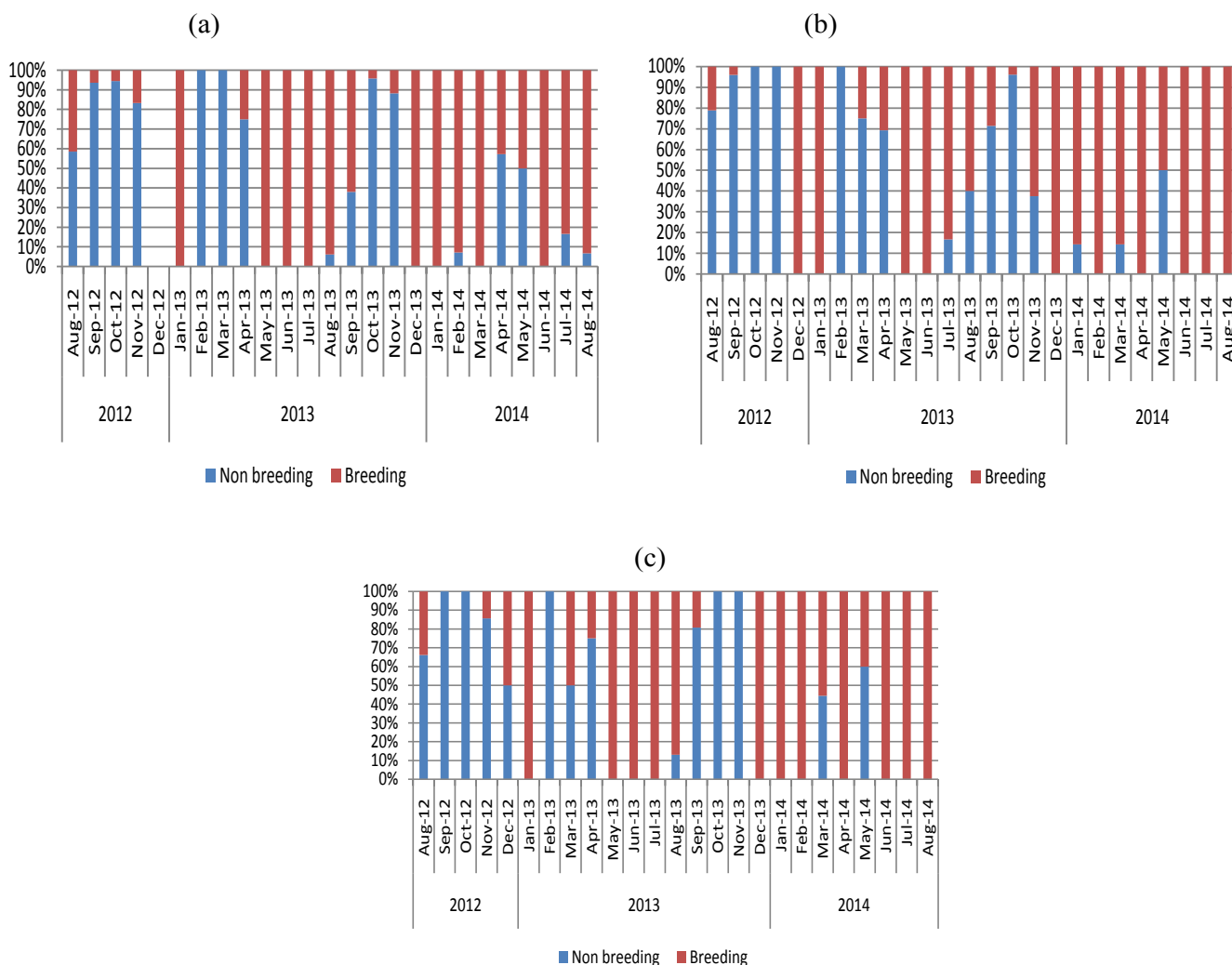


Figure 2: Breeding patterns of female *M. natalensis* in (a) SRI Fields, (b) Farmer field school, and (c) conventional rice production system.

Discussion

Rodent and shrew species were captured in the study area across the study period. *Mastomys natalensis* was the most abundant rodent species captured in the study area. This agrees with the findings reported by Mulungu et al. [9] who observed that >95% of individuals captured in irrigated rice were *M. natalensis*. These observations are consistent with those reported for areas where *M. natalensis* was most common in sites with many bushes or tall grasses [15,16].

Many small mammal species including rodents, show large spatial and temporal fluctuations in numbers. The abundances of *M. natalensis* in this study fluctuated over years and season in rice agro-ecosystem. This could be attributed to food availability in a particular year and season. Habitat quality for rodent pest species will likely vary according to food availability changes between years and seasons. Therefore, it is expected that the population dynamics of resident animals will exhibit abundance differences [17]. It was observed that in both years rodent abundance was higher in August and September, which corresponds with the dry season. The current findings are consistent with other findings [9,14,18,19].

It has been reported that in mosaic habitats, *M. natalensis* breeds during the long rains, and normally starts one month after the usual peak rainfall (March and April), lasting until the dry season [20,21]. This kind of breeding is related to variations in rainfall, peaking towards the end of the rainy season when food resources are plenty [18,22]. Their breeding therefore decreases during the drier months [23] where the population is higher [14,24]. However, in the current study, breeding of *M. natalensis* was observed to have no differences between season and rice cropping systems, indicating that both rice cropping systems had the equally adequate resources to support individuals which would be expected as the three cropping fields are in the same area, and hence breeding was continuous. Similar findings were reported by Mulungu et al. [9] in a conventional rice production in irrigated agro-system. Mulungu et al. [11] pointed out that continuous breeding in a conventional rice cropping system is attributed by vegetative plant material and seeds consumed. Vegetative productivity in the study area was influenced by continuous irrigation in rice fields which trigger sprouting of new green grasses. It has been reported that large amount of the chemical, 6-methoxy-2-benzoxazolinone, which is found to be present in large quantities in sprouting grass and it acts as a trigger for reproduction and influences growth in several rodents [25,26]. Similarly, Leirs and Verheyen [20] and Field [27] reported that seeds are an important food item during the breeding season and are required to meet the high energy needs of a reproducing organism.

Conclusion

Mastomys natalensis is the most abundant pest species in the study area and its population varies with years and season but not with the cropping systems. The highest population peak was observed during the dry season from August to September. The breeding patterns of this rodent pest species was also influenced by years and not by cropping systems and cropping seasons, indicating that *M. natalensis* is sexually active throughout the year in all cropping systems. Therefore, regular and sustainable control operations such as general field hygiene are necessary in order to keep the rodent pest population within tolerable limits in the study area.

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