Belg. J. Zool. - Volume 127 (1997) - supplement 1 - pages 49-58 - Brussels 1997

AN EARLY WARNING SYSTEM FOR IPM-BASED RODENT CONTROL IN SMALLHOLDER FARMING SYSTEMS IN TANZANIA

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Abstract. We conducted a four-year study in Tanzania to test a method for predicting outbreaks of *Mastomys natalensis* rats and verify whether such method, based on rainfall variability, could be used in an Integrated Pest Management strategy for rodent control. Temporal fluctuations in rodent numbers and breeding activity were monitored at four localities with different rainfall regimes. Breeding peaked towards the end of the main rainy season and continued into the dry period. When the short rains of October-January were unusually abundant and well distributed, reproduction started earlier and rodent numbers increased faster. Where abundant short rains were a normal condition returning every year, such effect was not clear. A method to assess rodent damage to germinating seedlings was found to be robust and can be used for monitoring rodent problems. Using this assessment technique, we showed that the effects of a single control action undertaken at planting time do not persist long enough to protect seedlings, probably due to quick reinvasion of the treated fields by rodents from the surroundings. These observations are formulated into a rodent control package whose steps are to predict rodent outbreaks, to warn farmers and the government of the outbreaks, and to organise control measures in advance.

Key words : IPM, *Mastomys natalensis*, crop damage, rodent outbreaks, forecasting, early warning, Tanzania.

INTRODUCTION

Field rodents belonging to species of the genus *Mastomys* are among the major pests that affect production of food cereals in many sub-Saharan countries. The multimammate rat *Mastomys natalensis* (Smith, 1834) is the most important rodent pest in Tanzania. At planting time this rat digs out planted seeds and germinated seedlings. Populations of *M. natalensis* undergo irregular population explosions with densities as high as 1000 rats per hectare; the outbreaks occur during the dry season and last through the planting period of October-February (TELFORD, 1989; MWANJABE & SIRIMA, 1993). Rodent control on fields then becomes a necessity. The majority of farmers in Tanzania are smallholders, owning 0.5-2 ha of fields per household. The fields are usually isolated plots surrounded by bushes and fallow fields (MWANJABE, 1993). At a low rodent infestation, crop protection by individual farmers is quite feasible. In times of outbreaks, however, rodent control measures have to be on a large scale and organised, or at least facilitated, by the government. In order to enable the government to plan effective control operations far in advance of the outbreaks, an alert system should be implemented (TAYLOR, 1968; SHUYLER, 1977; MWANJABE, 1990).

TELFORD (1989) and LEIRS *et al.* (1989) reported that reproduction in a population of *M.natalensis* in Morogoro, Tanzania, was strongly linked to rainfall and suggested that unusual rainfall may initiate aseasonal breeding resulting in higher densities. This idea, and the underlying life history particulars, were further investigated and this resulted in an outbreak forecasting model, based on the occurrence of unusually high rainfall during the first part of the rainy season (LEIRS *et al.*, 1996). In the present study we investigate to what extent this forecasting model would be applicable in other localities in Tanzania with different rainfall regimes and how it can be incorporated into an integrated pest management (IPM) package.

MATERIAL AND METHODS

Rodent population studies

Four study sites were selected (Table 1). Site 1 is the same site where the forecasting model to be tested was developed (LEIRS *et al.*, 1996). Sites 1, 2 and 4 have a bimodal rainy season with so-called short rains (in Swahili «*vuli*») at the end of the year and long rains (in Swahili *«masika»*) between February and May. Although rainfall is variable between years, the long rains are predictably abundant at these three sites, while the short rains are in most years, but not always, rather poor in sites 1 and 2; site 3 has reliably good short rains allowing a *vuli* planting season every year. Site 4 has a unimodal rainy season between November and April, peaking early in the year.

TABLE 1

Information on the four study sites

	Site 1 *Morogoro*	*Site 2* *Makuyu*	*Site 3* *Chunya*	*Site 4* *Kibwaya*
	06° 51¢S, 37° 38¢E	06° 22¢S , 37° 38¢E	08° 46¢S, 33° 18¢E	06° 57¢S, 37° 49¢E
Trapping				
Study period	Jan'93-Sep'86	Apr'93-Aug'96	Jun'94-Dec'96	Jul'94-Aug'96
No. of sessions	33	24	12	12
Trap nights	18976	13500	8388	7484
Rainfall				
Short rains	Nov-Jan	Nov-Jan	-	Nov-Jan
Long rains	Feb-May	Feb-May	Dec-Apr	Feb-May
Farming activities				
Planting:				
short rains	-	Nov.	-	Nov
long rains	Feb-Mar	Feb	Dec-Jan	Feb
Harvesting	Jul-Sep	Aug	Jul-Sep	Jul-Sep

In each site, we selected maize field areas where we collected animals by removal trapping using metal snap traps, following the small quadrat method (MYLLYMÄKI *et al.*, 1971). In each trapping session, 15-20 small quadrats (15 m x 15 m) were set with 12 traps each, depending on the number of available traps. Total number of trap nights set for each site are shown in Table 1. Traps were baited with dry sardine fish and coconut and left overnight for three consecutive nights per sampling session. Sampling sessions were organised monthly at sites 1 and 2 but rather irregularly at the other, less accessible, sites (Table 1). Where trapping was undertaken every month, the actual trapping fields were changed monthly.

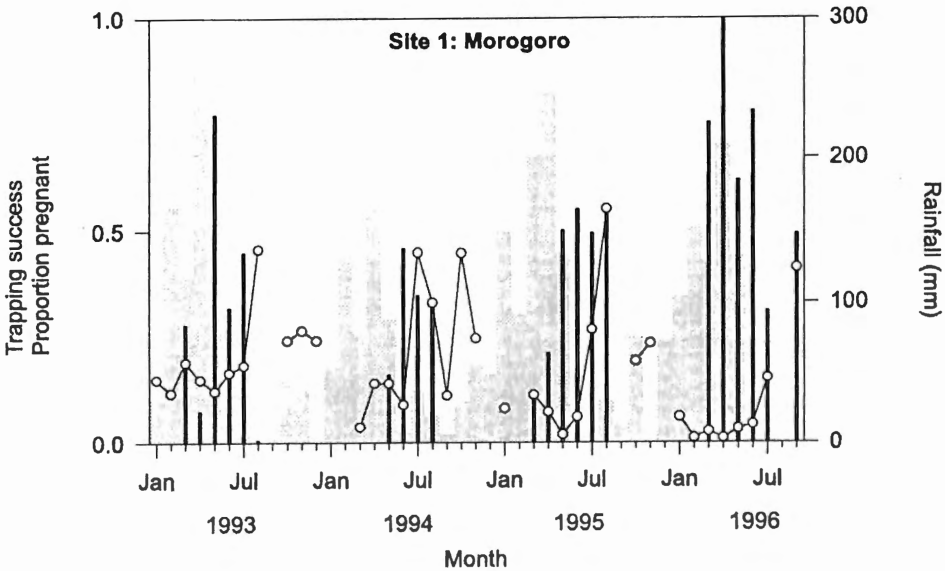
For each captured animal we recorded body weight, head and body length, testis length, and pregnancy (presence of embryos at autopsy). Population size was expressed as trap success index, *i.e.* number of captured animals per trap nights, adjusted for trap saturation (CAUGHLEY, 1977). A breeding index (percentage of pregnant females) was used to recognize reproductive periods. Rainfall data were obtained from national meteorological stations and from rain gauges installed in the research sites.

Crop damage assessment

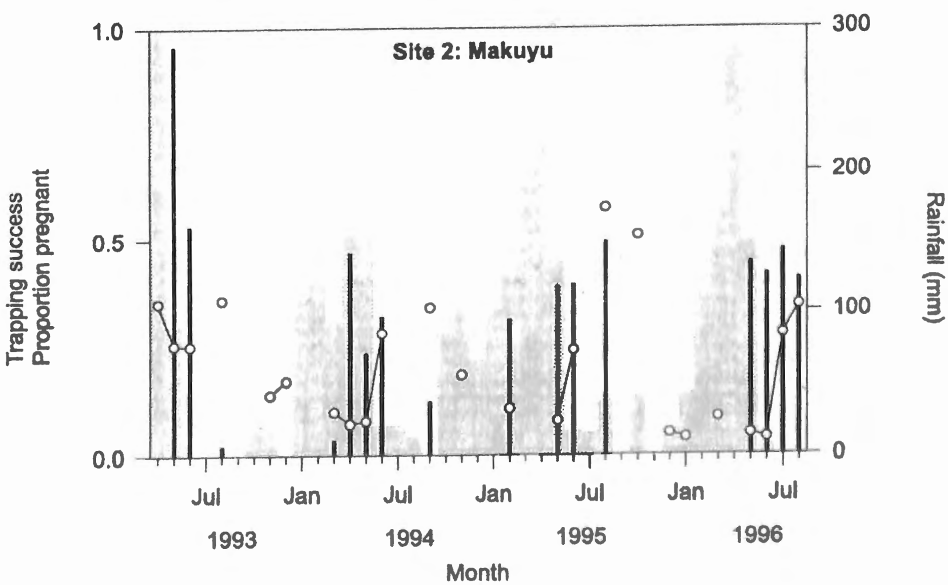
At planting time, we carried out damage assessment surveys in farmers' fields at different sites. The method at planting time was based on the one used in South East Asia where rat-cut tillers of paddy are counted at each hill (BUCKLE, 1994). In Tanzania, however, rats start retrieving cereal seeds immediately after sowing. In such a situation it would be difficult to count seeds removed by rats before emergence. Therefore, we counted missing (= unemerged) seedlings plus those actually found cut by rats after emergence. Before planting, we made arrangements with the farmers to plant a fixed number of three seeds per planting hole. The sampling units were maize rows, five rows apart, leaving out two edge rows all round the field. We sampled ten rows in fields of less than 1ha and twenty rows in larger fields. The assessor walked along maize rows across the field, counting missing seedlings at each hole or stand. Damage (D%) was calculated as $D=100d/(u+d)$, with d being the total number of missing seedlings in the whole sample; and u the number of undamaged seedlings. Before the harvest at site 2, we also assessed damage on gnawed maize ears. A maize plant in a stand was considered damaged if 25% of its ear was found gnawed by rats. Estimation of crop loss was calculated using the same formula as above.

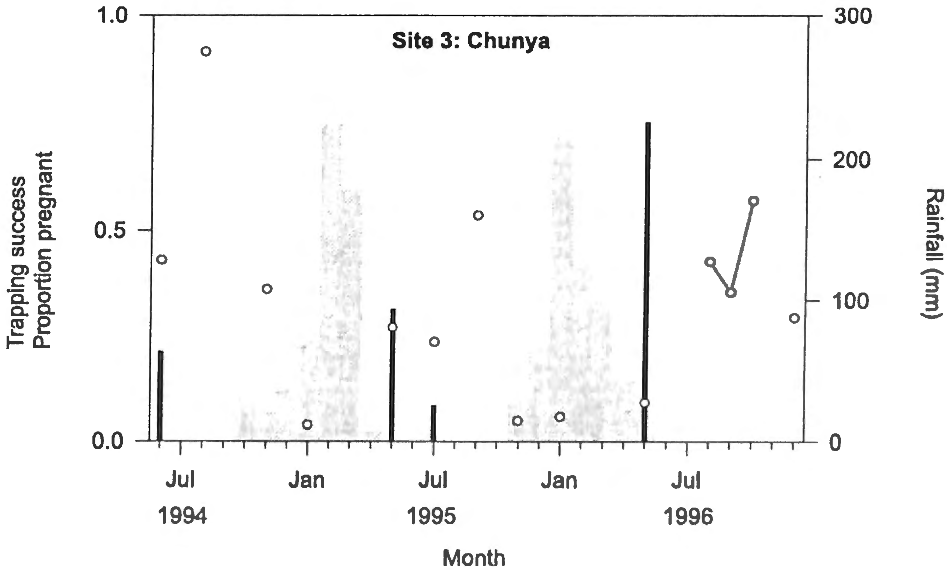
Recolonisation of treated fields

In order to investigate to what extent quick recolonisation of vacant fields would minimise the effects of rodenticide application at the time of planting, we set up an experiment at site 1. Four 0.5 ha maize field plots were selected, each one surrounded by fallow land; a rodent control action was undertaken in two of the plots, at the same day the seeds were planted. We applied a rodenticide bait with 1.5% zincphosphide, laid out in the field in small heaps of approx. 20 g, 10 m apart. A 10 m-wide margin around each treated plot was also baited. Dead animals found the next morning and autopsied confirmed the efficacy of the poisoned bait. Damage assessments were carried out for each plot as described above one and two weeks after planting; later on, young maize plants are no longer at risk from rodent damage. The changing abundance of rodents during this experiment is presented elsewhere (LEIRS *et al.*, 1997).

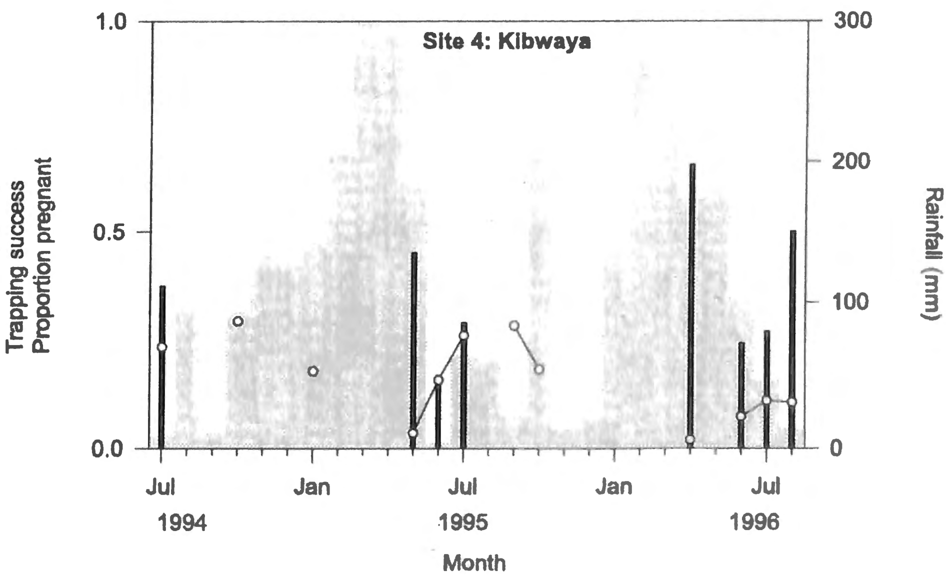


Figs. 1-2. – Monthly rainfall (grey columns), trapping success index (circles) and proportion of pregnant females (narrow black columns) at the four study sites. There were no captures in months for which no trapping success index is indicated.





Figs. 3-4. – Monthly rainfall (grey columns), trapping success index (circles) and proportion of pregnant females (narrow black columns) at the four study sites. There were no captures in months for which no trapping success index is indicated.



RESULTS

Data of rodent abundance and breeding activity were plotted together with monthly rainfall for each of the four study sites (Figs. 1-4). Rainfall during the study period was typical for each of the sites with short unimodal rainy seasons at site 3 and longer seasons at the other sites. Sites 1 and 2 had poor *vuli*-rains at the end of 1993 and 1995 but more rain at the end of 1994-start of 1995. At site 4, rainfall was also abundant and evenly spread in late 1994 but in late 1995 it was concentrated in October and November and December were dry. No rodent population outbreaks occurred during the study, but trapping success was high at site 3 in mid 1994. Trapping success varied considerably seasonally with, at all sites, low values during the rainy seasons, increasing towards the end of the rains and peaking well into the dry season. Breeding was also strictly seasonal with pregnant females appearing in the population about 1-2 months after heavy rains had occurred. When there was more rain in the first part of the rainy season, breeding started earlier (Figs. 1 & 2). At site 4, this could not be observed directly since there were no data for the first months of each year (Fig.4). However, in May 1995 there were many young and subadults in the population (10/23 animals weighed less than 30 g) while in the same month in 1996, there were only adults (0/14 animals <30g), suggesting earlier breeding in 1995, following the wet end of 1994. At site 3 rainfall was not very different between years and we have no indications for different breeding patterns neither (Fig. 4).

TABLE 2

Damage estimates at sites 2 and 4 shortly after planting and before harvest. All estimates are replicated for several plots at each site

Site	*Plot size*	*Post-planting*		*Pre-harvest*	
		Date	*Damage %*	*Date*	*Damage %*
2	0.8	20 Dec. 1993	70.4	4 July 1994	8.1
	0.4	”	77.2	”	6.6
	0.4	”	76.9	”	8.8
	0.4	”	74.9	”	9.3
	0.8	”	88.6	”	13.3
	0.8	”	82.3	”	10.6
4	0.5	4 Jan. 1994	49.21		
	0.5	6 Jan. 1994	38.51		
	0.5	26 Jan. 1994	43.43		
	0.5	1 Feb. 1994	39.58		

Damage assessments were easily performed with the chosen method. Damage figures were high, up to more than 80 % of the seedlings were damaged at one site. We obtained similar estimates in different plots at a same site but important differences between sites (Tables 2, 3).

TABLE 3

Damage assessment in maize seedlings in Zn_2P_3-treated and untreated control plots at Site 1. Planting and treatment were done simultaneously on 6 March 1995. Damage assessments were made one week and two weeks after planting

Field	*after 1 week*	*after 2 weeks*
Treated 1	42.51 %	43.85 %
Treated 2	40.78 %	39.12 %
Control 1	38.51 %	48.68 %
Control 2	47.03 %	58.05 %

In the recolonization experiment, seedling damage estimates were high in both treated and untreated fields (Table 3). After one week, there was no difference in damage between both field types (t-test, p=0.82), but after two weeks, the damage had increased in the control fields (paired t-test, p=0.03) but not in the treated fields (p=0.93); the difference between fields, however, remained small and non-significant (t-test, p=0.15)

DISCUSSION

The observed patterns of rainfall and breeding confirm what has been documented before for populations of *M. natalensis* in Tanzania (CHAPMAN *et al.*,1959; TELFORD, 1989; LEIRS *et al.*, 1989). Breeding starts soon after heavy rains and continues into the dry season. This is the case regardless of whether the rainy season is unimodal or bimodal. However, at site 4, where the short rains were very abundant in late 1994, there was not yet evidence of reproduction three months after the start of the rains, although we have indirect indications from the weight distributions in May for that site that breeding in 1995 did effectively start earlier than in 1996. This means that the basic biological mechanism of the forecasting model suggested by LEIRS *et al.* (1996), i.e. the relation between rainfall and breeding season, holds as a general rule in Tanzania. Such was also clear in many other studies elsewhere in Africa (reviewed in LEIRS, 1995). The present study is less conclusive on the importance of the short rains in determing population dynamics but this is due to unfortunate gaps in the trapping series and the absence of aseasonal rainfall during our study period at site 3. At least in the areas with bimodal rainy seasons and usually poor short rains, the hypothesis holds.The early breeding, if any, in the area with usually abundant short rains (site 4), was slower and this means that the population dynamics effects due to the quick succession of generations (LEIRS *et al.*, 1993) will be smaller. It is worth noting that FRENCH (1975) already concluded from a simple mathematical model that conditions with two clearly distinct rainfall peaks cause larger populations of *Mastomys* sp. than a single extended rainy season. Under the latter conditions, the validity of the forecasting model proposed by LEIRS *et al.* (1996) is not obvious.

The damage assessment technique that we used shortly after planting can be considered to be robust, judging from the very similar results obtained in different plots at the same site. Since the technique is also easy to apply, it can be used as a monitoring tool for

IPM-strategies. The absolute accuracy of this method relies on the assumptions that the seed has high germinating viability, and that there is enough soil moisture in the soil to allow germination. Under complete dry soil conditions, seeds remain in the ground intact until the rain comes but in partially moist soil, germination may be impaired due to seed moulding. Another assumption is that no pests other than rodents attack the seed. Insect or disease damage is of no big concern for the technique since there are many typical characteristics of rodent damage (digging activity, gnawing traces). Birds are probably incapable of retrieving seeds that are sown deep enough and well covered with soil (ANONYMOUS, 1987). These assumptions make that the damage assessments obtained in different years and at different sites cannot easily be compared. Clearly, estimates obtained after planting are of a different nature than those obtained before harvest and therefore they cannot be combined.

The observed damages after planting were high. During a study conducted in Chunya (Site 3 in our study) and other parts of Tanzania, a 10% damage of maize seedlings resulted in a 9.9% crop loss at harvest (MYLLYMÄKI, 1989). The damage levels of 40% to 80% that we observed in sites 1, 2 and 4 could thus be expected to cause serious losses of food crop. Farmers use informal damage assessments after planting to decide whether and how much they should replant. A more formal recording of damage assessments could be used to follow up and adjust predictive models and if they can be linked by future studies to rodent abundances, they can also be used as input for such models.

The used technique of damage assessment after planting seems also valuable to assess the effects of pest control applications. This was obvious in our recolonization experiment, where damage assessment showed rodent problems both in the treated and untreated fields. This corresponds to the observations that were made on rodent abundance during this same experiments (LEIRS *et al.*, 1997). Briefly, they found a quick decrease of rodent abundance immediately after the ploughing and planting, intensified of course by the rodenticide application in the treated fields: after a few days, densities increased again sharply and became even higher than before the planting, both in the treated and untreated fields. Clearly, our experimental fields were too small for the control effect to persist during a longer period. In terms of IPM strategies, these observations imply that rodent control operations should be started shortly before planting starts, and continued until at least one week after emergence of the crops (i.e. when the crops are no longer at risk from rats). At pre-harvest, use of rodenticides would be less effective because by then bait would be competing with rich food sources in the crop fields themselves. The most effective way to prevent crop loss at this time is to harvest the crop as soon as it is ready for harvest.

Our study showed that the presumed predictors of rodent outbreaks, abundant short rains and off-season breeding, may be of more general importance than proven until now. The predictive accuracy of a system based on this relation will depend on the number and distribution of monitoring sites in the country. A network of meteorological stations is present in Tanzania so that reliable rainfall data can be used. Surveys of rodent breeding and populations require specialist staff and equipment but are only needed for actual research; the monitoring of rodent problems can be based on simple damage assessments. The governments at different levels should be prepared to act accordingly when an outbreak forecast is issued and allow easy access to rodent control means. After the abundant short rains in late 1994, we issued a rodent outbreak warning to the Ministry of Agriculture but no action was undertaken; in 1995, farmers in southern Tanzania complained about unusually high rodent damage but unfortunately, extension services were not prepared for the situation.

ACKNOWLEDGEMENTS

This study was funded by the European Union (DG XII) through the STD project No. TS3*-CT93-0206 and partly by the Swedish International Development Agency (SIDA) through the Plant Protection Improvement Programme (PPIP). The project was executed by the Rodent Control Centre of the Ministry of Agriculture of Tanzania. The senior author is grateful to the staff of the Centre, particularly to the field technicians for their commendable job of data collection.

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