CHAPTER 12

Ecological Considerations for Management of Rodent Pests in Tanzania

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Introduction

More than 25 species of rodents have been recorded as pests in East Africa (Fiedler 1994, Hubbard 1972). They cause a wide range of damage in crops including cereals, legumes, vegetables, root crops, cotton and sugar cane; some species create problems in forestry and industry. They play an important role as reservoirs and carriers of zoonotic diseases (Gratz 1997). Some of the pest species are found in certain geographical and environmental conditions, while others are widely distributed (Kingdon 1974).

Rodents show a wide range of adaptation enabling them to successfully colonize and inhabit almost any type of habitat (De Graaf 1981). Among the pest species, the multimammate rat, *Mastomys natalensis* Smith 1834, the Nile rat, *Arvicanthis niloticus* Desmarest and the roof rat, *Rattus rattus*, are widely distributed in East Africa (Kingdon 1974). In Sub-Saharan Africa, the major rodent species causing severe damage to crops belong to the genus *Mastomys* (Muridae). The commonest and by far the most serious rodent pest in East Africa is *M. natalensis* (Smith 1834) (Fiedler 1988, 1994). *Mastomys natalensis* is a very serious pest in Tanzania (Makundi *et al*. 1999). In rural communities, crop damage in the field and during storage is undoubtedly high. Previous estimates indicated that losses were about 15% (Makundi *et al*. 1991), but much higher losses occur during rodent outbreaks, particularly at planting and seedling stage (Mwanjabe and Leirs 1997, Mulungu et al 2005). The need to control outbreaks becomes urgent taking into consideration the associated losses and the benefits which can be realized with successful rodent management. Studies conducted in China for example, showed that the benefit-cost ratio for rodent management was 71:1, which achieved good economic, social and ecological benefits (Zhuang *et al*. 1999).

Certain characteristics of *M. natalensis* such as high reproductive capacity and dispersal are thought to contribute to its success as a pest (Meester *et al*. 1979, Leirs *et al*. 1993). This species, in some seasons or in some years, erupt in large numbers. The outbreaks can reach high densities and are favoured by certain ecological conditions that were previously not well understood, but are now the subject of intensive research in Tanzania. Outbreaks of *M. natalensis* are a recurring problem in some areas of Tanzania, but this and other species of rodents are also a chronic problem in farmers field, which require some control measures.

The management of *M. natalensis* and other pest species in the past was on ad-hoc basis, with control strategies based on the use of rodenticides particularly during outbreaks (Myllymaki 1987). However, farmers have always considered as inevitable, certain levels of crop damage due to rodents (Makundi et al. 2005a). Thus, they consider chronic rodent damage as something beyond their control. The application of rodenticides however, unless it is carried out synchronously on a wide area, has little impact in reducing damage and losses of crops. This can be attributed to the fact that outbreaks are usually not localized and occur on a wide geographical area where enormous amounts of poisons would be required to contain them.

The dependence on chemical methods has several drawbacks. They include the risks of evolving resistance to the poison in the target population, high costs of the poison and its application, and the dangers of toxicity to non-target animals and humans. Although traditional rodent control measures have evolved in some areas, these are largely ineffective particularly for the management of rodent outbreaks. In many cases, farmers do not realize the importance of managing the pest when populations are low and after crops have been harvested.

The idea of ecological approach for management of rodent pests in Tanzania is not new (Leirs *et al.* 1996, Makundi *et al.* 1999). An ecological approach for management of rodents makes use of the knowledge on the biology and ecology of the pest species to reduce their impact on the crop. According to Singleton *et al*. (1999) there is a growing demand, particularly on developing countries, for rodent control strategies that either have less reliance on chemical rodenticides or can better target their use. For small-holder farmers with little knowledge on biology and ecology of rodents, it is difficult for them to appreciate the impact of environmental manipulations on rodent population size unless this is demonstrated in practical terms.

The major constraint in formulating ecologically sound rodent management in Tanzania is the inadequacy of our knowledge on the ecology of the pests and processes involved in rodent outbreaks. In the past 10-15 years however, a keen interest in the ecology of *M. natalensis,* the major pest species, has led to new findings which are instrumental for designing rodent management strategies which are ecologically based (Makundi 1999a)..

The purpose of this chapter is to review the advances made in studies of the ecology of rodents, particularly *M. natalensis,* in Tanzania and how these findings could be integrated into ecological approaches for management of rodent pests.

The ecology of rodents in Tanzania

Breeding pattern vs outbreaks

Studies on the population biology of *M. natalensis* in Tanzania clearly show that there is an association between rainfall and breeding (Leirs 1992, Leirs *et al*. 1989, Telford 1989). Seasonal variations in breeding and growth occur (Christensen 1993, Leirs 1992). Thus a previously established relationship between rainfall and reproduction of rodents in other parts of East Africa (Neal 1986, Delany 1972, Taylor, 1968, Taylor and Green 1976) was also confirmed in Tanzania (Telford 1989, Leirs 1992). Population fluctuations, reproduction and survival have been found to be strongly influenced by the rainfall patterns (Leirs 1992). The growth patterns and maturation rates are also strongly associated with rainfall (Leirs *et al*. 1990). We now understand that not only the timing of rainfall is important in breeding of *M. natalensis,* but also the abundance and duration of the rains in the previous short rains season (*vuli*) and the following wet (long rains) season. These conditions can create conditions favourable for the occurrence of rodent outbreaks later in the year (Mwanjabe and Leirs 1997)

Description of the breeding pattern

The main breeding season for *M. natalensis* starts after the major rains in March-May and continues until September (Telford 1989, Leirs 1992). A short breeding period occurs early in the following year if the short rains (vuli) are abundant (Leirs 1992, Leirs *et al*. 1989). Studies by Leirs *et al*. (1993) indicated the existence of three distinct generations of *M. natalensis* with different life histories. These variations in life history were also found to be related to the rainfall pattern and influence the productivity and population dynamics of *M. natalensis* (Leirs *et al*. 1993).

Productivity of M. natalensis

Productivity of rodents (number of offspring produced per female per given period) differs widely, and is characteristic of the species, geographical location, type of habitat and climatic conditions. Habitats created by land disturbance are particularly characterized by high productivity and turnover rate (Fleming 1975). In Tanzania, *M. natalensis* is found in large numbers in cultivated land and close to human habitations where its productivity and turnover rates are high. It has been reported that land preparation methods affect distribution of rodents in the field (Massawe et al. 2003)

The litter size of *M. natelensis* is usually 10 -13, but can range from 3- 20 (Chapman *et al*. 1959, Telford 1989, Leirs 1992, Delany 1972). The female has a gestation period of 30 days but can become pregnant again immediately after giving birth, with young becoming sexually mature at the age of 14 weeks (Kingdon 1974). When conditions are favourable, breeding can occur in a short interval of time resulting to large numbers at the end of the breeding season, usually at the beginning of the dry season in Tanzania (Chapman *et al*. 1959, Telford 1989, Leirs 1992).

Population fluctuations

A range of densities of *M. natalensis* have been reported in the field, some of which could be categorized as outbreaks. Telford (1989), Leirs (1992) and Christensen (1996) reported densities of 1125, 900 and 384 animals/ha, respectively, in Morogoro, Tanzania. This further illustrates that wide ranging population fluctuations between seasons and years occur. The nature of the outbreaks, involving large numbers of animals would most likely suggest that mass dispersal or migrations occur (Harris 1937). On the contrary, home range studies and other field observations (Christensen 1996, Leirs *et al*. 1996) have revealed that a large proportion of individuals in the population does not migrate far from their established home range.

Population size limitations

In general, rodent population size is limited by a number of factors including the food quantity and quality, availability of nesting sites, human activities such as land preparations and control activities (Leung *et al*. 1999, Massawe *et al*. 2003). Further, both density dependent and independent factors also affect population size ((Leirs *et al*. 1997a). For almost all pest species, large population size will be maintained if the survival rate is high. If other factors, particularly the density independent ones remain favourable, then the food supply can play a major role in rodent survival and numbers feeding on the crop. In Tanzania and other tropical areas, there are pronounced seasonal changes, which are also associated with changes in food availability for rodents. These play an important part in seasonal survival differences. Figures 1, 2 and 3 show population fluctuations in ecologically different localities in North East, Central and Southwest Tanzania. The magnitude of rodent population density fluctuations varies according species, season, years and ecological conditions in the area (Figs 1-3) (Makundi *et al*. 2005b).

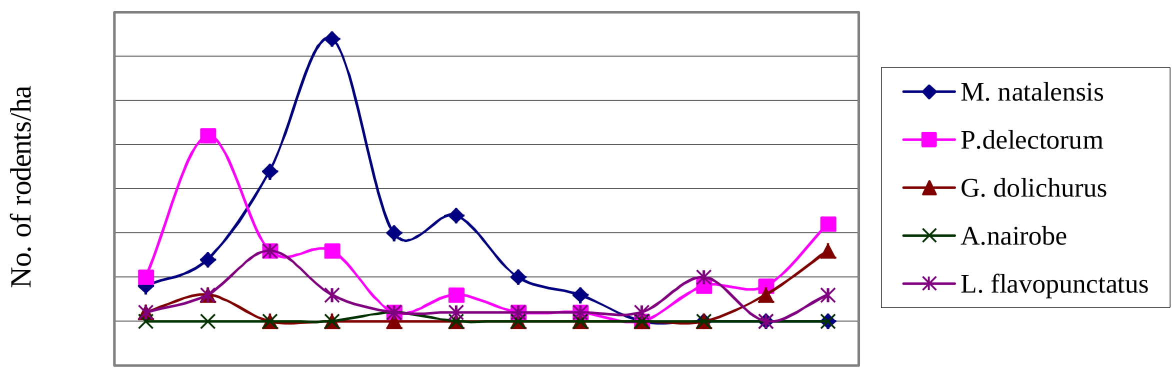

Fig 1: Rodent population fluctuations in Magamba Forest, Western Usambara Mountains in 2002-2003.

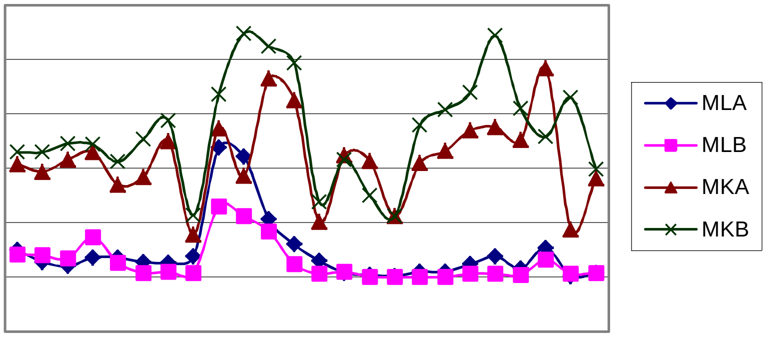

Fig 2: Fluctuations of the population density of *Mastomys natalensis* in Mvomero, Morogoro, Central Tanzania

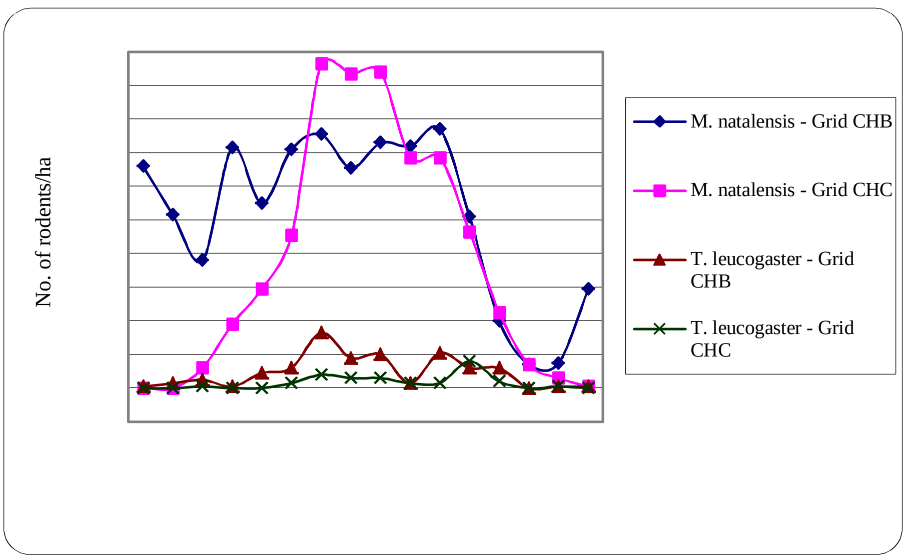

Fig. 3. Rodent population density fluctuations in Chunya, Lake Rukwa Valley, Southwest Tanzania

Population dynamics vs rainfall pattern

Both density dependent and density independent factors influence the population dynamics of *M. natalensis* (Leirs *et al*. 1997a). These factors affect the regulation of population size of *M. natalensisis* and that both effects occur simultaneously. It has been reported that the timing of reproduction is linked to rainfall and the effects of rainfall are density independent (Leirs *et al*. 1989, Leirs *et al*. 1994, Leirs *et al*. 1997a, Makundi et al. 2006). It has also been shown that, in

Tanzania, abnormal unseasonal rainfall is correlated with population outbreaks (Leirs *et al*. 1996).

Previous rainfall is an important factor in the population dynamics. Rainfall was found to have clear effects on sub adult survival of *M. natalensis*, but affected the maturation rate (Leirs *et al*. 1997b). Further, these studies indicated that adult survival was not affected by previous rainfall, but there was a clear tendency for decreased survival at higher densities.

Spatial patterns of rodents

An understanding of the spatial patterns of space use is important in developing ecological strategies for management of rodents. Results of studies carried out in Tanzania showed a negative correlation between rodent numbers and open space and a positive correlation between numbers and high dense grass (Leirs *et al*. 1996). We further know that there is a considerable overlap of home range between individuals and members of the same sex and between farms and fallow land. This knowledge is considered important in view of the farming practices in small-holder farmer's fields. The farming practices consist of small plots (0.5 - 1 ha), sometimes interspersed with variable sizes of fallow land, forming a mosaic of habitats particularly suitable for pest species like *M. natalensis*. Thus, it is reasonably viewed that alterations of these habitats could invariably affect the population dynamics of *M. natalensis*. Further, investigations into the ability of *M. natalensis* to colonize and get established in new habitats including agricultural land have indicated that recolonization occurs faster in mosaic fields in which rodents have previously been removed (Mercelis and Leirs 1999). These findings are consistent with earlier reports that fields which were initially depopulated through application of rodenticides were soon colonized (Myllymaki 1987). This is attributed to the high reproductive and dispersal capacity of the local population of *M. natalensis*.

Rodent management options

The range of rodent control strategies, and their limitations, applied in Tanzania have been described (Makundi *et al*. 1991, Makundi *et al*. 1999b). These include:

- Rodent barriers, particularly in storage structures
- Poisoning using both acute and chronic (anticoagulant) rodenticides
- Trapping
- Removal of refugia and other shelter (e.g. through burning)

Deliberate use of predators against rodents is uncommon, but has potential for rodent management in Tanzania. A routine use of rodenticides for regular rodent control is also uncommon in Tanzania. However, in outbreak situations in the past, the government, through the extension service, supplied the rodenticides and organized control campaigns (Makundi *et al*. 1999b). Rodenticides usage in agriculture is still low due to their high costs, problems of procurement and distribution to village level (Makundi *et al*. 1991). It is also possible that farmers feel that rodents are too difficult to control, and therefore, they do not take any drastic measures or are ignorant of the possible and potential strategies, which they can use to reduce population size and crop damage. It is common for farmers to replace seed that has been eaten by rodents, because of the inability to control them. When damage occurs later however, it becomes impossible to avoid losses if no action is taken to kill the rodents.

Integration of techniques in routine management of rodent pests in Tanzania
The reliance on a single technique to alleviate the damage and losses of crops due to rodent pests is both unwise and ineffective as a long-term strategy. Therefore there is need to integrate the practical management strategies, applicable for small-holder farmers. In management of rodents in Tanzania, the following techniques have potential for integration.

(i) Preventive and exclusion measures
Preventive methods aim at reducing the accessibility of the crop to rodents. These methods therefore, are more practical in crop storage than when the crops are in the field. The range of methods include:

- Using rodent proofed storage structures to store the crop. These structures must have tight fitting doors, no holes leading into the store, and where the "kihenge" type of structures are used, they must be raised at least a metre from the ground and the poles are also rodent proofed using galvanized conical flaps to prevent rodents climbing into the store.

- Clearing of the surroundings of the stores to remove spillage and other sources of food which attract rodent to the vicinity of the store.

- Removal of weeds, dense vegetation, bushes and tree branches to a distance of at least 5 m in order to discourage harbourage of rodents close to the store.

(ii) Deterrence of rodents
These techniques are particularly effective in the fields. They include the following techniques:

- Removal of fallow patches of land around the fields. These fallow patches encourage rodent harbourage close to the crop by providing shelter.

- Removal of garbage and other materials, which provide shelter and supplementary food resources.

  Burning the fields before and after harvest to displace the rodent population. Burning after harvest will also eliminate the crop residues and therefore deny the rodent population a potential source of food.

  Ploughing and regular weeding. Deep ploughing destroys the nests and therefore it displaces the rodent population (Massawe *et al*. 2003) whereas regular weeding removes an alternative source of food as well as harbourage (Mwanjabe and Sirima 1993).

(iii) ***Timing of the crop***
This is particularly important when the susceptible stage is not during the peak of the pest population. The timing of sowing and harvesting can be altered to avoid the peak pest population, but requires a good understanding of the population dynamics of the pest and how it relates to phenology of the crop.

(iv) Inter-cropping
The practice of growing several crops at the same time may disrupt the pest from the crop.

(v) Biological methods

Encouraging predators in farm land, particularly by providing nest boxes for owls and resting perches for raptors and birds of prey

(vi) Trapping

This may be effective for small rodent populations, particularly for sub-terranian species such as mole rats. It is not an affective strategy for outbreak species like *M. natalensis*.

(vii) Chemical control

Baiting using approved rodenticides is necessary, particularly during outbreaks. In Tanzania, Zinc phosphide is the most widely used acute rodenticide. Its widespread use is largely because it is relatively cheap and effective. It is made available in large quantities through government channels. The development of bait shyness where rodents associate the symptoms of poisoning with the intake of the bait is, however, the major disadvantage of continuing to use the rodenticide. The anticoagulants have the advantage of not causing bait shyness, but they are relatively more expensive than the acute rodenticides. The major disadvantage of anticoagulants is however, farmers do not see immediate results because of the delayed death of rodents and therefore do not easily accept them. However, anticoagulant rodenticides are the most desirable for routine control of recurring (chronic) rodent problems in Tanzania. The Rodent Control Center (RCC) has produced a local formulation of bait, the RCC Pellets, for rodent control in Tanzania. The formulation is based on bromadiolone as active component. And are highly palatable and acceptable to rodents. Other studies have proposed the use of seed protectants to reduce damage at the seedling stage of cereals (Ngowo et al. 2005; Ngowo et al. 2003)).

Ecological approach

♦ ***Limitations of past rodent management approaches in Tanzania***

One of the shortcomings of rodent control in Tanzania has been the lack of integration of control methods, and the fact that it has focussed on measures that reduce numbers at the most susceptible stage of the crop. For example, the use of rodenticides and trapping aim at reducing numbers when the crop is already suffering damage. The continued dependence on the use of rodenticides as a sole rodent management strategy in Tanzania is also contrary to our current knowledge on the response of rodent populations after reduction of numbers. Various studies show that the population density may be reduced immediately after applying the rodenticide, but the remaining population compensates with better survival and breeding performance (Singleton *et al*. 1999, Myllymaki 1987).

Additionally, some of the traditional methods of rodent control, such as burning of vegetation have not proved effective in reducing population size. We now understand that after a fire, the area becomes quickly recolonized, particularly when regeneration of new grass occurs (De Graaf 1981). Mwanjabe and Leirs (1997) also reported that in maize fields, the effects of a single control operation undertaken at the time of planting do not persist long enough to protect seedlings, due to quick re-invasion.

♦ *Ecological strategies*

Ecological approaches advocate the manipulation of the demographic processes which regulate population size. Singleton *et al*. (1999) have highlighted the aims of ecological approaches as:

- Minimizing the adverse effects on target organisms and the environment
- Developing an approach that is economical and sustainable for end users, particularly farmers.
- Establishing an approach that is durable

The basis for ecological approaches in rodent pest management lies in the understanding of the biology and ecology of the pest species. Knowledge of the pest biology and ecology can enable better targeting of the available control options, such as where and when to apply rodenticides, when to plant the crop, etc. In recent years several studies aimed at developing ecologically based rodent management have been carried out in East Africa (Odhiambo et al. 2005; Mulungu et al. 2005; Makundi et al. 2003; Makundi and Massawe 2003)

♦ *Biological and ecological considerations*

Population dynamics

A successful ecological approach requires long term population dynamics studies. An understanding of the various factors responsible for limiting population growth is mandatory for this management strategy to function. Therefore, good knowledge of the population dynamics of the problem species will provide information on their densities on farmland and prediction of damage levels to enable timing of control activities. Further, the response of the population after treatment needs to be compared with the pre-treatment population densities to determine whether further action is needed. This can also enable better targeting of the poisoning operations and better economic returns in the use of the poisons.

Spatial dynamics

An understanding of the determinants of space use in the population of the pest species could enable a better planning for implementation of the control options, placement of bait, etc. We know that dispersal is influenced by the age structure, sex ratio and social structure of the rodent population. Therefore, a control programme must consider how the rodent pests are distributed in the field and the conditions which determine the observed distribution. For example, we know that expansive monocultural practices in agriculture are less prone to infestation by rodents (Taylor 1968), where as small plots, typical of peasant farming in Tanzania, are much more seriously damaged particularly when these are interspersed with fallow patches of land (Mercelis and Leirs 1999). Rodents are attracted to dense grass and usually, populations are low in cleared open land. This trend has been confirmed in studies on *M. natalensis* in Tanzania where numbers of rodents were negatively correlated with open space and positively correlated with high dense grass (Leirs *et al*. 1996). Therefore, in planning control operations of rodents at farm level, we need to consider the influence of uncultivated pieces of land between cultivated plots on the ensuing damage. The fallow areas are considered to be a refugium from where recolonization of the cultivated land occurs. Removal of the fallow patches could invariably alter the spatial pattern of distribution. Where baiting has to be carried out, targeted positioning of the bait could be carried out. The fallow patches could be ideal areas to place bait in control operations particularly if an initial knockdown of the population is deemed necessary before it builds up to damaging levels.

Characteristics, forecasting and management of rodent outbreaks

The rodent species which are pests in Tanzania, particularly *M. natalensis*, show typical characteristics of r-selected species where the number of offspring is large, they mature fast and take opportunity of the short favourable period (seasonality) to maximize their reproductive efforts (Krebs 1978). These characteristics (fast breeding, taking advantage of favourable conditions) are particularly important when we want to develop a forecasting system for the problematic species in Tanzania. A forecasting system involves predictions on when the population size will be expected to reach a certain threshold in agricultural systems, warranting interventions to control them. The economic benefits of these predictions are outlined by Davis *et al*. (2004).

An essential consideration for the ecological approach, is the capability to forecast outbreaks of the target pest. Forecasting pest outbreaks is necessary because we need to know:

- When to anticipate the start and subsequent development of an outbreak
- The damage potential of an outbreak
- The timing of control operations
- To predict outbreaks, knowledge of the population dynamics and ecology of the pest is mandatory. Further, the environmental factors responsible for precipitation of such outbreaks need to be understood (Leirs *et al*. 1996). This information can then be used to develop models to predict outbreaks. Unfortunately, we know little of the ecology and population dynamics of some of the serious pests of crops. What is lacking is information on pest history and the factors that led to outbreaks in the past. For example, weather can contribute a lot in the control of pests because of its influence on the pest population size, rate of growth, migration, etc., particularly in arthropods. Therefore, in future, we need to understand better the mechanisms controlling the occurrence of outbreaks and how such information could enable building models that can be used to predict outbreaks.

The idea that population eruptions of *M. natalensis* in East Africa could be predicted is not new. Harris (1937), Neal (1977) and Taylor (1968) suggested that outbreaks were associated with wet years. It was further suggested that the wet years, due to prolonged rainfall, appeared to favour survival and breeding, particularly after a long dry spell (Fiedler 1988). However, after comparing several recorded outbreaks with the rainfall regime that preceded them, it was quite clear that before they occurred there was abundant rainfall early in the season (Leirs *et al*. 1996). The studies were extended to show whether rainfall at the end of the year could explain the occurrence of outbreaks thereafter. These studies showed that the outbreaks were not preceded by a long dry spell as stipulated by Fiedler (1988), but they occurred after a high rainfall at the end of the previous year (Leirs *et al*. 1996).

Leirs *et al*. (1997a) reported that there is an interaction between density dependent and density independent factors (i.e. rainfall) in the population dynamics of *M. natalensis*. This type of relationship has been very useful in developing a system for forecasting outbreaks of *M. natalensis* in Tanzania (Mwanjabe and Leirs 1997, Leirs *et al*. 1996, Davis *et al*. 2004).

Population structure

For an effective management of rodent populations, we need to know certain parameters associated with the pest species. Among the most important parameters include:

- Dispersion and space use by individuals in the population - this can help in determining the best positions for laying bait and how fast an area that has been depopulated is re-invaded by immigrants.

- The social behaviour- an understanding of how individuals of different sex or age interact. Social hierarchy could influence bait intake by the pest species.

- How fast new individuals recolonize depopulated areas (for example after killing the resident population by a rodenticide).

- Breeding and recruitment - this is particularly important for r-strategists like *M. natalensis* which have a quick population turnover. We need to understand the changes in population densities and when an economic threshold for controlling a particular pest population will be reached. If the population of the pest could be reduced before the threshold population density is reached, crop damage and losses could be prevented or reduced. There is a considerable variation in the breeding patterns of rodents and the timing of reproductive activities. In any particular area where rodent pests have to be controlled, this kind of knowledge is particularly important.

The carrying capacity of habitats

With the ecological approach, reducing the suitability of the potential habitats for the rodent species is of paramount importance. This includes many kinds of activities such as land preparation methods (Massawe et al. 2005), weeding practices, etc. Weeding, for example, could reduce cover and the potential sources of alternative food. When cover in surrounding fields is removed, fewer animals will attack the crop in cultivated land. Reducing potential food sources, particularly after harvests, will deny the pest species enough food required for breeding and reduce survival due to increased mortality rates. Improving the sanitary conditions can also reduce the interaction with rodents, particularly for the commensal species.

♦***Constraints of the ecological approach***

One of the major constraints to implementing ecological approaches for rodent management in Tanzania is the fragmented farming system, where the fields are a mosaic of cultivated land interspersed with fallow land. Implementing the rodent control activities involving ecological manipulations of individual plots could be very difficult. To be successful, the ecological practices must be practiced on large geographical areas and must involve the whole community. An area wide poisoning of rodents could prevent re-establishment by immigration.

♦***Planning, implementation and community participation***

The management of rodent outbreaks depends on the level of preparedness and the accuracy of the outbreak forecasts. Makundi *et al.* (1999) prepared a flow chart of activities to enable timely control of rodent outbreaks. Although control activities are primarily the responsibility of the farmers, in Tanzania, the government has organized and supplied the inputs. Management of outbreaks in Tanzania relies primarily on the use of rodenticides as a symptomatic measure when populations are already high and crop damage is unavoidable without poisoning. This is necessary to alleviate severe losses of the crop associated with large invading populations of rodents. However, there are several constraints associated with this strategy. The first is that with large numbers of rodents in the crop fields, there is no assurance that the crop will escape damage. Secondly, with anticoagulants, which do not kill the rodents immediately, the likelihood of damage occurring over a span of several days is not ruled out. Additionally, bait acceptance is not always assured if the crop is more attractive to the pest. When the control of outbreaks is being conducted by the whole community, it is likely to be most effective. According to Buckle (1999), application of rodenticides in agriculture is more cost effective, and the effectiveness of the chemical is more long lasting when large areas of the crop areas are treated simultaneously. Where the farmers are small holders with small plots, they must be mobilized to conduct the baiting campaigns together for the control to be effective.

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