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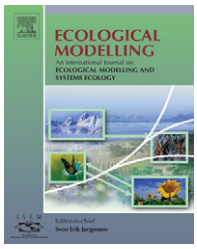

# Simulating the impacts of vegetation structure on the occurrence of a small mammalian carnivore in semi-arid savanna rangelands

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ARTICLE INFO

*Article history:*
Received 28 February 2007
Received in revised form 4 June 2007
Accepted 19 June 2007
Published on line 6 August 2007

*Keywords:*
Yellow mongoose
Rangeland
Individual-based model
Shrub encroachment
Spatial explicit
Structural diversity

ABSTRACT

In arid and semi-arid savannas, species diversity is strongly influenced by structural diversity, which in these systems is characteristically formed by woody vegetation. Shrub encroachment, associated with overgrazing by domestic livestock, changes the structural diversity and hence affects biodiversity. Many investigations have been carried out with focus on the structure building trees, but little is known about the importance of shrubs. Here, we present a spatially explicit and individual-based population model for analysing the influence of shrub encroachment on the occurrence of yellow mongooses (*Cynictis penicillata*) in the Southern Kalahari, South Africa. This analysis is based on field investigations in Southern Africa. The results of the modelling study are in line with the results of a field study, in which the same unimodal relationship between shrub cover and yellow mongoose abundance was found. The model could explain this relationship by the need of shrubs as protective structures on the one hand, and the need of foraging habitat in the grass matrix on the other hand. To evaluate the factors influencing the population dynamics at different levels of shrub encroachment we carried out an extensive sensitivity analysis. Finally, we determined a range of existence of the yellow mongoose for various shrub covers. Model results indicate a lower and an upper limit of critical shrub densities at 1% and 38%, respectively. These limits indicate the range in shrub cover allowing the persistence of the yellow mongoose in the Southern Kalahari.



## 1. Introduction

In arid and semi-arid savannas landscape structure typically consists of trees and shrubs sparsely scattered in a matrix of grass (Scholes and Walker, 1993; Van Rooyen, 2001). The structural diversity of the woody vegetation strongly influences species diversity (Tews et al., 2004a,b). It is widely recognised that large Acacia trees are important keystone structures used as assembling points for wild as well as domestic herbivores resting in their shade and offering services for sheltering, foraging and nesting (Milton and Dean, 1995; Dean et al., 1999; Wichmann et al., 2003). Knowing how shrub density affects species diversity is an important issue in conservation biology, because of the severe changes in shrub cover which have occurred in the past caused by overgrazing. However, little is known about the importance of the structure building shrubs for species diversity. Savanna vegetation structure is especially sensitive to anthropogenic grazing by cattle or other

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doi:10.1016/j.ecolmodel.2007.06.017

large herbivores: Overgrazing decreases the grass layer leading to lower competition and hence increased water availability for seedlings of woody plant species (O'Connor and Roux, 1995). At the same time, the fuel load of an overgrazed grass biomass leads to lower fire frequencies and consequently to improved conditions for the establishment of woody plants (Scholes and Walker, 1993; Jeltsch et al., 2000). As a result woody plants are favoured and in extreme situations the woody plants spread over extensive areas leading to a total loss in grass biomass (Tainton and Walker, 1992; Jeltsch et al., 2000; Weber and Jeltsch, 2000).

At present shrub encroachment is thought to have negative impacts on biodiversity (Dean et al., 1999; Cingolani et al., 2005), but studies are scarce. The negative effect is mostly explained as decreasing production of herbaceous plants connected to dense shrub covers affects the food availability of animal species that use the wide grass matrix of the savanna for foraging negatively (e.g. Hutchinson and King, 1980; Ernest et al., 2000; Torre and Diaz, 2004). However, shrubs can also have a positive effect on some species, as they provide food and protection against avian predators (Rasa et al., 1992).

The yellow mongoose (*Cynictis penicillata*), a ground dwelling carnivore endemic to the southern African subregion, is assumed to be both, negatively as well as positively affected by shrub encroachment (Blaum et al., 2007a,b,d). On the one hand, it digs its dens under shrubs where the offspring can be nurtured and which serve as protection (Taylor and Meester, 1993; Blaum et al., 2007b). Shrubs play therefore an important role as protection structures, and an increase in shrub density may have a positive effect on the yellow mongoose population. On the other hand, yellow mongooses mainly feed on insects in the grass biomass (Nel and Kok, 1998). This implies a negative effect of shrub encroachment, as it reduces the foraging habitat of the yellow mongoose.

Here, we developed a spatial explicit and individual-based model for the yellow mongoose to perform a case study on how changes in shrubby vegetation structures can affect performance and survival of a species, which depends on shrub structures in a more complex way. The model is based on literature data and on an extensive 3-year field study on habitat use of the yellow mongoose in the Southern Kalahari, South Africa (Blaum et al., 2007a,b,d). Aim of our study is (i) to evaluate the factors influencing the population dynamics and extinction risk, (ii) to display the effect of shrub cover and distribution on the population dynamics and (iii) to present a range of shrub cover that is suitable for the existence of the yellow mongoose. Finally, we compare our results with field data on yellow mongoose abundance in relation to shrub cover, to validate our model.

## 2. Materials and methods

### 2.1. Study area

Our study area, where most of the model parameters and assumptions refer to, is situated in the Southern Kalahari in the northwestern tip of the Republic of South Africa with mean annual precipitation of 200 mm. The area is fragmented by farm boarders which separate farms sized between 3500 and 12,000 ha. The vegetation is classified as Kalahari thornveld (Van Rooyen, 2001), with scattered Acacia trees and shrubs (mainly *Rhigozum trichotomum* and *Acacia mellifera*) within a grassy matrix. The herbaceous vegetation is dominated by annual grasses (*Schmidtia kalahariensis*), and perennial grasses (*Stipagrostis ciliata* and *Stipagrostis obtusa*). Shrubs frequently grow in clumps with interlocking and/or overlapping canopies.

### 2.2. Subject of the study

The yellow mongoose is endemic to the southern African subregion (Lynch, 1980; Skinner and Smithers, 1990). Yellow mongooses prefer open, sandy terrain and occur in areas of mean annual rainfall between 100 and 800 mm. Besides the open terrain, mongooses also need shrubs to set up temporary refuge dens and burrows for reproduction within a territory (Wenhold and Rasa, 1994; Blaum et al., 2007b). Studies concerning the food items of the yellow mongoose (Herzog-Straschill, 1977; Lynch, 1980; Earle, 1981; McDonald and Nel, 1986; Avenant and Nel, 1997) indicate that the yellow mongoose is an opportunistic feeder, mainly insectivorous—but also small vertebrates like mice, snakes and lizards regularly appear in its diet. Since many insects (Hutchinson and King, 1980; Milton and Dean, 1995; Seymour and Dean, 1999) and vertebrates (Bowland and Perrin, 1989), on which the yellow mongoose feeds, rely on grass, prey abundance decreases with increasing shrub cover. Yellow mongooses live together in stable social groups but they forage alone (Cavallini, 1993). In the Kalahari these groups consist of between two and eight animals, with a dominant pair, young offspring, and assorted subordinate adults (Wenhold and Rasa, 1994). They occupy territories, closely correlated with foraging ranges, of between 80 and 100 ha (Taylor and Meester, 1993) which are defended exclusively (Estes, 1991). Yellow mongoose's life centers around a group den, which may be at one of several suitable sites in the group's defended territory. Dens are useful for avoiding predators and extremes of temperature. A territory has to provide several refuge dens so that a group can change their residence in case of perturbation (Wenhold, 1990; Blaum et al., 2007b). In the Southern Kalahari, yellow mongooses set up their dens under the dominant shrub species *R. trichotomum* and *A. mellifera* (Blaum et al., 2007a,b). Nevertheless, not all shrubs of these species are utilized by the yellow mongoose, as a refuge den has to provide an open view in at least one direction so that a well-timed escape is granted (Blaum et al., 2007b).

Females are polyoestrous, in other words they have two estrus cycles in each breeding season, which gives each female the potential to produce two small litters of one to three offspring each. The second litter is environmentally suppressed if conditions are harsh and food is scarce (Rasa et al., 1992). Weaning occurs at 6–8 weeks, after which the young are guarded and provisioned at the den until they are ready to forage themselves (Rasa et al., 1992). Sex ratios of 1:1.2 favouring females (Lynch, 1980; Zumpt, 1976) and 1.2:1 favouring males (Earle, 1981) have been recorded. Large raptors are the most important natural predators. Furthermore, large snakes and lizards prey on young or immature yellow mongooses (Taylor