Seed dispersal by vervet monkeys in rehabilitating coastal dune forests at Richards Bay

S.H. Foord, R.J. van Aarde and S.M. Ferreira*
Mammal Research Institute, Department of Zoology, University of Pretoria, Pretoria,0002 Republic of South Africa

Received 10 March 1994; accepted 17 June 1994

The role of vervet monkeys, *Cercopithecus aethiops,* in the dispersal of seed from unmined to mined areas was studied to extend our knowledge of the structure and function of rehabilitating coastal dune forest communities. Vervet monkeys feed on a great variety of fruits of dune forest plants and move into the rehabilitating stands where they defecate. An analysis of the faeces showed that seeds of a variety of broad-leaved forest trees were present and viable. Through their dispersal of seed, vervet monkeys could conceivably influence succession in rehabilitating forests.

Die rol van blou-ape, *Cercopithecus aethiops,* in die verspreiding van sade van ongemynde na gemynde areas is bestudeer om ons kennis van struktuur en funksie van rehabiliterende kuswoud-gemeenskappe uit te brei. Blou-ape eet vrugte van 'n verskeidenheid plante wat in kuswoude voorkom. Die ape se bewegingspatrone sluit dele van rehabiliterende areas in waar hulle ontlas. Faeces-analiese dui op die teenwoordigheid en lewensvatbaarheid van 'n hele aantal sade van breëblaar plantspesies. Blou-ape kan dus 'n invloed hê op suksessie in rehabiliterende woude deur verspreiding van sade.

Keywords: *Cercopithecus aethiops*, vervet monkeys, rehabilitation, succession, seed dispersal

*To whom correspondence should be addressed

Introduction

Post-mining rehabilitation of coastal sand dunes north of Richards Bay, KwaZulu/Natal is initiated through spreading topsoil, collected before dredge mining, on reshaped sand dunes. Subsequent sowing of a seed mixture consisting of *Acacia karroo* and a variety of annuals results in dense *A. karroo* shrubland with a thick grass cover within 18 months following the initiation of rehabilitation (Camp 1990). The rehabilitation programme has resulted in the development of a series of known-age communities abutting an unmined strip of forest characterized by patches of mature forest vegetation. The oldest rehabilitating area (14 years at the time of the study) is dominated by *A. karroo* with secondary forest species colonizing the stand specifically where gaps have formed (P.J. van Dyk, pers. comm.). Gap formation plays an important role in the successful recruitment of new plants (Estrada & Fleming 1986) and may be an important factor during secondary plant succession.

A study by van Aarde, Ferreira, Kritzinger, MacMahon, Miller & Leumann (1993) indicated that seeds of secondary forest species do not occur in the seedbank of the oldest rehabilitating area. In spite of this, studies by Mentis & Ellery (1994) on the woody vegetation of the rehabilitating and surrounding areas disturbed through cattle grazing and burning, and by P.J. van Dyk (pers. comm.) on plant community changes during seral stages of rehabilitation, suggest that ecological succession typical of coastal dune forests in KwaZulu/Natal is evidenced in rehabilitating areas.

Vervet monkeys (*Cercopithecus aethiops)* were recorded foraging in rehabilitating areas as well as the adjacent unmined areas, and may be of potential significance during plant succession in these dunes. The size of fruits of tree species characterizing later stages of seral succession tends to be larger than those typical of earlier stages (see Davidson 1993). Vervet monkeys, which feed on species characterizing later stages of succession (see Pooley 1968), may be one of the most important dispersers of such seeds.

Material and Methods

Free-ranging vervet monkeys were kept under close observation for 310 h during January, April, May and June 1993. Three troops (A, B & C) were identified consisting of 20, 23 and 37 individuals respectively. Scan sampling was conducted at 10 min intervals while following the monkeys on foot. The following data were collected: location, activity, food type and species eaten. Activity and food eaten at each sampling time were ranked from 1 to 4 depending on the number of individuals in sight performing a specific action or feeding on specific food items. No observations included more than four activities or food items at the time of sampling. The activity or food eaten by most individuals received the highest rank. When individuals performed a specific action or fed on a specific food item in equal numbers, these activities or food items received equal ranking.

Food eaten in the unmined strip and rehabilitating area was examined separately. The ranking for each species or food item eaten was summed and monthly totals expressed as a percentage of all items consumed. The mean percentage for each item over the four months of observation was considered an index of the extent of use.

Faeces were collected and examined for the presence of seeds. Seeds were identified to species level and the number of seeds in each sample was counted. Germination trials were conducted on the seeds of five of these species and seeds collected from plants in the study area were used as controls. The five species selected for germination trials were the only seed available at the time. Seeds were placed in 90 mm diameter petri dishes on Schleicher & Schuell (0860) filter paper and 10 ml distilled water added. The experiment continued for 35 days at 25°C at constant light in a germination cabinet. Distilled water (≈7 ml) was added once a week to each petri dish.

Home range size and patterns of spatial utilization were determined using the harmonic mean (Dixon & Chapman 1980) and core convex polygon methods and were estimated using an adaptation of Kenward's (1987) 'Program 1' and 'Program 2'.

Results

Home range sizes ranged from 20,8 to 80,9 ha and are presented in Figure 1. Troop B moved into rehabilitating areas on 20 mornings during 29 mornings of observation and 7 out of 17 afternoons, spending 40 ± 33 min (n = 43) at a time within these areas. Troop B passed most of their time (85,5%) in the unmined strip and only 13,3% of their time was spent in rehabilitating areas. Twenty-five percent of Troop B's home range consisted of rehabilitating areas. Troop B moved a mean distance of 433,9 ± 102,8 m (n = 29) during a morning and 208,9 ± 77,3 m (n = 18) during afternoons. The mean distances moved in rehabilitating areas during mornings and afternoons were significantly (t_{45} = 7,818; p < 0,05) shorter than those recorded while moving in the umined strip.

Troop A occupied an area to the south-west of Troop B and was never recorded in rehabilitating areas. Troop C was to the north-east of Troop B, spending 50,8% of their time (35 h) in rehabilitating areas. Fifty-nine percent of Troop C's home range included rehabilitating areas. The mean distance travelled during the mornings was 450 ± 81 m (n = 4).

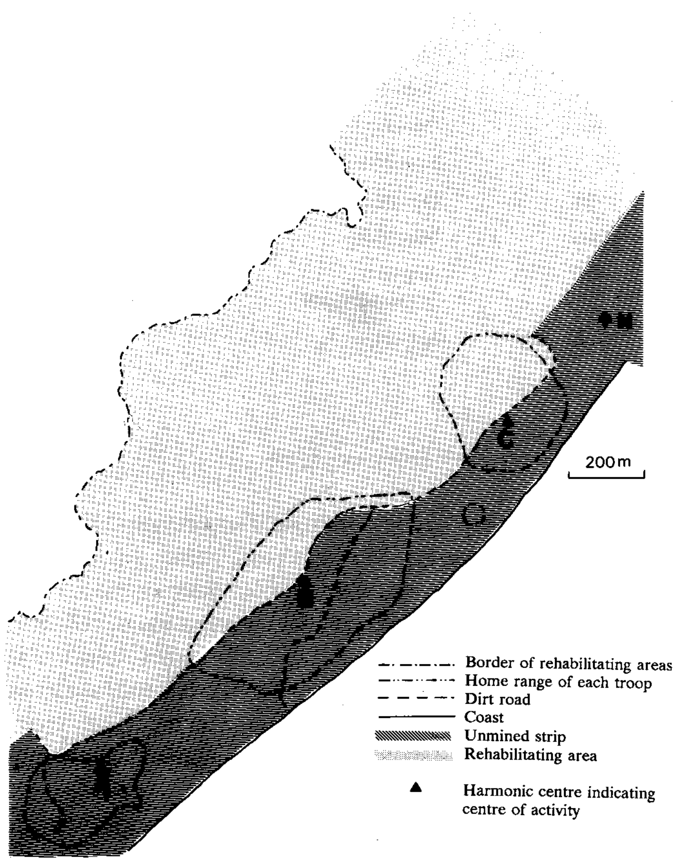

Figure 1 Location of the home ranges of three troops of vervet monkeys (*Cercopithecus aethiops*) that were followed during the months of January, April, May and June 1993 near Richards Bay. The home ranges indicate the extent to which they overlap with the rehabilitating areas and are represented by a 90% probability contour and harmonic centre (▲). The home range sizes were as follows: troop A = 20,8 ha; troop B = 80,9 ha and troop C = 37,5 ha.

Table 1 Number of times (10 min intervals) that the three troops of vervet monkeys were observed in the unmined strip and rehabilitating areas near Richards Bay, KwaZulu / Natal. The χ^2 values (df = 1) and p values are also given

Troop	Unmined strip	Rehabilitated area	χ^2	p
A	186	0	93	< 0,05
B	1111	167	697	< 0,05
C	103	113	0,46	> 0,05

Habitat utilization differed significantly between the troops, with Troop C being recorded more frequently in rehabilitating areas than Troops A and B (see Table 1). Chi square-values for habitat use of Troops A and B indicate a significant deviation from the expected frequencies (expected = no preference for any area) showing a marked preference for the unmined strip.

Vervet monkeys consumed various parts of 29 species of trees and vines. These tree species belonged to 15 families and the fruit, flowers or seed of 23 of these species were eaten (Table 2). The monkeys destroyed the seed of *A. karroo* and *Strelitzia nicolai* while eating them by chewing the seed.

All faecal stools contained seeds, with 26% of the 31 stools collected coming from rehabilitating areas. The number of species that occurred per stool ranged from 1 to 6 ($\bar{x} \pm SD$ = 2,42 ± 1,31), while the number of seeds per sample varied from two to thousands and seed size varied from 1 mm (*Ficus* spp.) to 20 mm (*Phoenix reclinata*). Seeds of 17 plant species were found in the faeces of which 12 were from trees (Table 3).

Germination trials on the seeds of *Rhus nebulosa, Carissa macrocarpa, Scutia myrtina,* and *Chrysanthemoides monilifera* revealed that seeds were not destroyed in the digestive tract. None of *Trema orientalis* seeds germinated which could be a result of the experimental layout. Mean germination success for seeds ingested by the monkeys was 47,6% (n = 276) and that of control seeds 42,2% (n = 177). Only the germination rate of *R. nebulosa* was significantly higher (χ^2 = 7,6; df = 1; p < 0,01) for seeds ingested than for those collected from trees.

Discussion

Seed dispersal is a function of both the number of faeces containing seeds and the pattern of spatial distribution of faeces (Pigozzi 1992). In the present study, seeds occurred in all faecal stools. Vervet monkeys defaecate throughout their home range, making them very good potential agents for seed dispersal. Furthermore, the results show that seeds of at least four species are not destroyed in the digestive tract of vervet monkeys. Dispersal distances are increased while clumping in time and space is diminished for seeds of these species. The fate of dispersed seeds is complicated by spatial and temporal unpredictability of favourable germination sites and pressures exerted by non-disperser organisms e.g. dung beetles and rodents (Estrada & Coates-Estrada 1986).

The rehabilitating areas used by vervet monkeys in the present study were 14 years old and already colonized by a

Table 2 The percentage preference, parts eaten and fruiting periods of trees and vines fed upon by vervet monkeys inhabiting rehabilitating areas and the unmined strip bordering rehabilitating areas near Richards Bay. Data were collected through direct observations during January, April, May and June 1993. Fruit descriptions follow Palgrave (1988). * = Vines

	Preference %			
Species	Unmined strip	Rehabilitating areas	Plant parts eaten	Fruit period
Trema orientalis	19,0	6,1	fruit	Jan–Jun
Strelitzia nicolai	17,2	2,7	flowers, seed, leaves	
Phoenix reclinata	11,0		fruit	Feb–Apr
Tricalysia sonderana	8,5	5,0	fruit	Dec–Apr
Acacia karroo	8,5	58,3	flowers, gum, seed	
Rhoicissus digitata	5,1	1,4	fruit	Jan–Feb
Scutia myrtina	5,1	0,4	fruit	Feb–Apr
Trichilia emetica	2,7		fruit	Dec–Mar
Carissa macrocarpa	1,8	2,0	fruit	Sep–Jan
Rhus nebulosa	1,7	2,5	fruit	Apr–Jul
Ficus natalensis	1,2		fruit	Jul–Jan
Canthium inerme	0,6		fruit	Nov–Mar
Chrysanthemoides monilifera	0,4	0,4	fruit	Oct onwards
Sclerocarya birrea	0,4		fruit	Apr–Jun
Vepris undulata	0,1		fruit	May–Jul
Apodytes dimidiata	0,1		fruit	Dec–Jun
Syzigium cordatum	0,1		fruit	Nov–Mar
Celtis africana	0,1		fruit	Oct–Dec
Dodonaea viscosa		0,1	fruit	May–Oct
Albizia adianthifolia	<0,1		seed	Aug–Oct following year
Antidesma venosum	<0,1		fruit	Mar–May
*Smilex kraussiana**	1,5		fruit	
Carpobrotus edulis	0,5		fruit, leaves	

variety of secondary species (see Lubke, Moll & Avis 1993 for list of species). Several of the species which have not been recorded in the seedbank (i.e. *T. orientalis, R. nebulosa, P. reclinata)* of this area (see van Aarde *et al.* 1993) were recorded in the faeces of these monkeys. The occurrence of these plants in rehabilitating areas may be facilitated by their seeds being dispersed by vervet monkeys as suggested by the germination trials. Some seeds which have not been destroyed while eating, pass through the digestive tracts of vervet monkeys without loss of viability. It should be noted that some of the species occurring in rehabilitating areas (i.e. *T. orientalis, Carissa macrocarpa*), may also have been dispersed by fruit and seed-eating birds and ants (see Handel & Beattie 1990).

Following Ewel's (1990) criteria for the success of rehabilitation (sustainability, productivity, nutrient retention, invasiability and biotic interaction) Lubke *et al.* (1993) and van Aarde *et al.* (1993) concluded that rehabilitation of mined areas is taking place through ecological succession. The interactions between vervet monkeys and their environment recorded during the present study reflect three of these criteria. Invasiability, which refers to the colonization of rehabilitating areas by new species as habitat becomes suitable, is conceivably affected by these monkeys, thus reflecting on their potential role in the rehabilitation process. Biotic interaction, which is the ultimate goal of rehabilitation since it represents the restored state of an affected area, is reflected by seed dispersal through feeding and movement behaviour of vervet monkeys. Although only two of the troops studied spent some of their time in the oldest stands of rehabilitating areas, other troops were recorded feeding and moving through 4–10-year- old rehabilitating stands in the vicinity of the study area. However, no troops live exclusively in the rehabilitating areas and not even the oldest rehabilitating stand has as yet reached the stage where it can exclusively provide the food requirements of vervet monkeys. This is not

Table 3 The number of seeds (broken and unbroken) and proportional occurrence in all faecal samples collected in the rehabilitating dune forest of Richards Bay from January to June 1993

Species	Number of intact seeds	Number of broken seeds	Percentage occurrence in faecal stools (n=31)
Scutia myrtina	133	10	48
Ficus species	46700	0	39
Trema orientalis	54	0	29
Chrysanthemoides monolifera	21	2	26
Rhus nebulosa	552	13	23
Rhoicissus digitata	12	0	19
Carissa macrocarpa	24	0	19
Phoenix reclinata	20	0	10
Vepris undulata	8	0	6,0
Canthium inerme	7	0	6,0
Tricalysia sondorana	2	0	6,0
Solanum species	0	0	6,0
Unknown 1	3	0	3,0
Unknown 2	4	0	3,0
Unknown 3	1	0	3,0
Unknown 4	7	0	3,0
Total	47548		

surprising when considering the habitat preferences of vervet monkeys in general and given the relatively early stage of seral succession represented by these rehabilitating areas. Sustainability of rehabilitating areas may result from the presence of nuclei of unmined forests which provide seed sources and dispersal agents to move seed to rehabilitating areas.

Acknowledgements

Financial and logistical support were provided by Richards Bay Minerals and the University of Pretoria. We wish to thank Paul Camp, Clive MacMahon, Henk Moen, Johan Kritzinger, Ronwyn Stander and Sonja Rass for their help in various ways.

References

CAMP, P.D. 1990. Rehabilitation after dune mining at Richards Bay Minerals. *S.A. Mining World*, Oct 1990.

DAVIDSON, DIANA, W. 1993. The effects of herbivory and granivory on terrestrial plant succession. *Oikos* 68: 23–35.

DIXON, K.R. & CHAPMAN, J.A. 1980. Harmonic mean measure of animal activity areas. *Ecology* 61: 1040–1044.

ESTRADA, A. & COATES-ESTRADA, R. 1986. Frugivory by howling monkeys (*Aluoatta palliata*) at Los Tuxtlas, Mexico: dispersal and fate of seeds. In: Frugivory and seed dispersal. (Eds) Estrada, A. & Fleming, T.H. Dr W. Junk Publishers, Dordrecht.

ESTRADA, A. & FLEMING, T.H. 1986. General introduction. In: Frugivory and seed dispersal. (Eds) Estrada, A. & Fleming, T.H. Dr W. Junk Publishers, Dordrecht.

EWEL, J.J. 1990. Restoration is the ultimate test of ecological theory. In: Restoration ecology, a synthetic approach to ecological research. W. R. Jordan III, M. E . Gilpin & J. D. Aber. Cambridge University Press, Cambridge.

HANDEL, S.N. & BEATTIE, A.J. 1990. Seed dispersal by ants. *Sci. Am.* 263: 58–64.

KENWARD, R. 1987. Some analysis techniques. Ch. 8 In: Wildlife Radio Tagging: Equipment, Field techniques and Data Analyses. Academic Press, London.

LUBKE, R. A., MOLL, J. B. & AVIS, A. M. 1993. Rehabilitation ecology. In: Environmental impact assessment: Eastern Shores of Lake St Lucia. (Kingsa/Tojan Lease Area) Specialist Reports. Coastal and Environmental Services. Roslin McComb & Paula Macfarlane, Rhodes University.

MENTIS, M.T. & ELLERY, W.N. 1994. Post-mining rehabilitation of dunes on the north-east coast of South Africa. *S. Afr. J. Sci.* 90: 69–74.

PALGRAVE, K.C. 1988. Trees of Southern Africa. Struik Publishers, Cape Town.

PIGOZZI, G. 1992. Frugivory and seed dispersal by the European badger in a Mediterranean habitat. *J. Mamm.* 73: 630–639.

POOLEY, A.C. 1968. A short note on the diet of the vervet monkey in Zululand. *Lammergeyer* 9:29–31.

VAN AARDE, R.J., FERREIRA, S., KRITZINGER, J., MACMAHON, C., MILLER, M., & LEUMANN, L. 1993. Report on special study programme on rehabilitated coastal dune woodland north of Richards Bay. Report to Richards Bay Minerals, P.O. Box 401, Richards Bay. 47pp.