Chapter 6

Landscape use by elephants in the Tembe Elephant Park

Introduction

The quantity and quality of resources such as food, water and shelter are unevenly distributed across landscapes (Johst & Schoeps 2003; Koops & Abrahams 2003; Silver *et al*. 2000). Animals that depend on these resources should therefore be distributed unevenly (Verlinden & Gavor 1998). Consequently natural selection may favour individuals that have access to superior resources (Boyce 1979; Basolo 1998). Individuals may opt, therefore, to use those landscapes within their range that will enable them to optimize resource extraction. Under favourable and unrestricted conditions it is expected that individuals will select for landscapes that are superior in providing resource requirements and will avoid sub-optimal or marginal landscapes.

Landscapes incorporated into fenced-off protected conservation areas, such as the Tembe Elephant Park (TEP), some 300km^2, may not contain all landscape types or landscapes at the ratios, or of the quality, typical of unconfined ranges. Elephants fenced into TEP since 1989, may, therefore, be restricted in the landscapes they can select compared to those individuals that roamed over a much larger area (see Chapters 1 & 3). From studies elsewhere (e.g. Hall-Martin 1992; Armbruster & Lande 1993; Seydack, Vermeulen & Huisamen 2000; Whitehouse & Harley 2001; Whyte 2001; Osborn & Parker 2003) it is apparent that confinement prevents traditional movement patterns, thus supporting the notion that elephants living in the TEP may have limited opportunities to exercise landscape selection. The elephant population of TEP has been increasing in size over a number of years (see Chapter 3), and at current densities elephants may have less opportunity to select landscape types than when densities were lower. High local densities may also challenge opportunities for landscape selection. Here I aim to define the distribution of elephants across the TEP, and to determine if their distribution can be ascribed to them no longer having the opportunity to selectively use certain landscapes. This study is based on individual sightings made during repetitive surveys over a nine month period across all landscapes within TEP. It assumes that sightings (and therefore occurrence) proportional to the area of each of the landscapes signifies a lack of selection. Such a lack of selection may then be considered as a response to restrictions imposed upon individuals, either through social factors or through spatial limitations, or both.

Elephants occur across a wide range of landscapes in southern African savannas (Blanc *et al*. 2003). They are, however, unevenly distributed across these landscapes and when they are not confined prefer certain landscapes above others (see Caughley & Goddard 1975; Jachmann 1983; Viljoen 1989; Lindeque & Lindeque 1991; Dublin 1996; de Villiers & Kok 1997; Thouless 1998; Verlinden & Gavor 1998; Seydack *et al*. 2000; Stokke & du Toit 2002; Leggett *et al*. 2003; Osborn & Parker 2003). During the dry season elephants browse on woody species and use landscapes where water and other resources are available (Jachmann 1983; Ruggiero & Fay 1994; Dublin 1996; Thouless 1996; de Villiers & Kok 1997; Whyte 2001; Stokke & du Toit 2002; Osborn & Parker 2003).

Landscape selection is usually modelled under the assumption that a species will select and use habitats best suited to their life requirements. Consequently higher-quality habitat will be used more often than other habitats (Schamberger & O'Neil 1986). The use of habitat will then be directly proportional to its availability (Mysterud & Ims 1998). Landscape has been defined as 'a mosaic of habitat patches across which organisms move, settle, reproduce, and eventually die' (Forman &

Godron 1986). Habitats are those elements of a landscape in which a species is spatially and temporally distributed. I simplified landscape categories to address ambiguities in determining specific vegetation types (see Fairall & van Aarde 2004a).

Materials & Methods

Study Design

Data on elephant locations were collected from March to December 2001 during a mark-resight programme (see Chapter 4). Sampling took place from an existing road network divided into fixed non-overlapping transects which traversed all the landscape types of the Park (Fig. 6.1). I surveyed these transects on 14 occasions and recorded the position of all elephant sightings. Positions were plotted onto a landscape map of the Park on which transects (the road network) were superimposed (see Fig. 6.1).

I determined the proportion of each landscape type available to elephants from the proportional transect length in each landscape type. A landscape map constructed using Idrisi software and a LANDSAT 5 TM satellite image (ID 167-79 of 30 August 1999) purchased from the CSIR Satellite Applications Centre (PO Box 395, Pretoria, South Africa) was used to distinguish and outline open woodland, closed woodland, sand forest, reedbed and hygrophilous grassland as landscape types (Fairall & van Aarde 2004a). Hygrophilous grassland covers <1% of the Park and was therefore combined with the reedbed category (see Fairall & van Aarde 2004b).

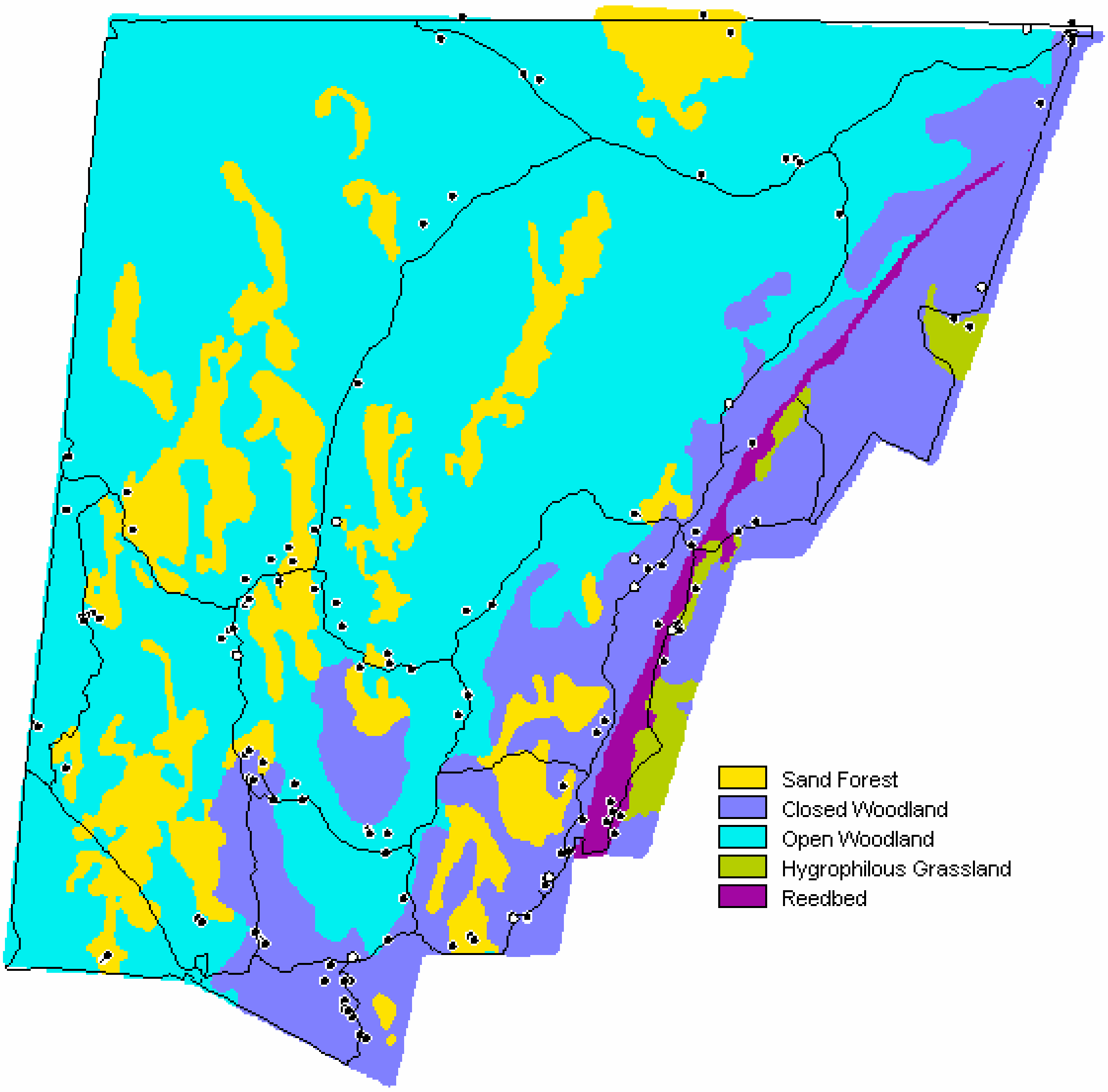

Figure 6.1. The landscape types of Tembe Elephant Park and elephant distribution. Black points indicate sightings of males and white points indicate sightings of breeding herds. The reedbed coloured purple represents the Muzi swamp. The black lines represent the survey routes.

Observations of elephants

Between March and December 2001 I observed elephants on 136 occasions in all available landscape types, during transect surveys. The sightings comprised 123 observations of bulls and 13 observations of breeding herds. The observations were used to calculate expected levels of use and actual use (Table 6.1). The potential consequences of landscape type for sightability have not been incorporated in the present study[17].

Data analysis

Landscape use at the population level

I used a Design I approach (Thomas & Taylor 1990) to evaluate landscape selection at the population level. Here the availability and use of landscape types is considered in terms of the entire study area and collectively for all individuals. The Design I protocol used a selection index following Neu, Byers & Peek (1974), and assumed that observations were independent within and between animals, and that all habitat types were equally available to all animals (McClean *et al*. 1998). The design II approach (Thomas & Taylor 1990) I used differed from the design I as individuals were recognised as separate entities.

[17] A more recent landscape study based on satilite tracking of elephants in Tembe (R.A.R. Guldemond PhD thesis 2005 in review) suggests that elephants in the park avoided reedbeds in the dry season but did not show landscape preference in the wet season. It is therefore unlikely that my observations were biased by sightability.

Table 6.1. Utilisation-availability data for landscape types in the Tembe Elephant Park. Utilisation is based on 123 observations of males and 13 observations of breeding herds. Proportion of available habitat type indicates availability. Proportion of observations in a landscape type indicates utilisation.

Landscape Type	**Proportion of available landscape** ***(p_i)***	**Number of observations in landscape** ***(u_i)***			**Proportion of observations in landscape** ***(o_i)***		
		Bulls	Breeding herds	Bulls & Breeding herds	Bulls	Breeding herds	Bulls & Breeding herds
Open Woodland	0.52	54	5	59	0.439	0.382	0.434
Closed Woodland	0.32	44	6	50	0.358	0.458	0.368
Sand Forest	0.09	15	0	15	0.122	0.008	0.110
Reedbed	0.07	10	2	12	0.081	0.153	0.088
Total	1.00	123	13	136	1.00	1.00	1.00

Observations were considered independent as they were logged along systematic sighting routes and an elephant could not be sighted twice in a single day. TEP is relatively small (300 km^2, Matthews *et al.* 2001) and elephants have the ability to use the entire area, so all landscape types were assumed equally available to all elephants.

To obtain a simple measure of selection I used the forage ratio (Savage 1931 and Williams & Marshall 1938 cited in Krebs 1999), now commonly referred to as the selection index (Manly, MacDonald & Thomas 1993), and calculated as:

$$\hat{w}_i = \frac{o_i}{p_i},$$

where $\hat{w}_i$ is the forage ratio for species i, o_i the proportion or percentage of habitat used and p_i the proportion or percentage of habitat available. To allow comparison of ratios between sexes and for the combined observations I calculated standardised selection indices as standardised ratios (Manly *et al.* 1993) that sum to 1.0 for all resource types:

$$B_i = \frac{\hat{w}_i}{\sum_{i-1}^{n} \hat{w}_i},$$

where B_i is the standardised selection index for habitat i and $\hat{w}_i$ the forage ratio for habitat i. I used a G-test goodness-of-fit to test the null hypothesis that elephants use habitats in proportion to their availability (Manly *et al.* 1993):

$$G = 2\sum_{i=1}^{n} \left[u_i \ln\left(\frac{u_i}{Up_i} \right) \right],$$

where u_i is the number of observations using habitat i, U the total number of observations of use equals $\sum u_i$,G is the G value with (n – 1) degrees of freedom (H_o: random selection) and n is the number of habitat categories.

Landscape use at the individual level

To determine if landscape use differed from random for individual elephants I used a Design II protocol, compositional analysis (Aebischer, Robertson & Kenward 1993). Aebischer *et al.* (1993) identify four problems in analysing data of habitat use. Problem 1 is an inappropriate level of sampling and sample size, problem 2 is non-independence of proportions where the proportions that describe habitat composition sum to 1 over all habitat types, (unit-sum constraint), problem 3 is differential habitat use by groups of individuals and problem 4 is the arbitrary definition of habitat availability. To overcome these problems Aebischer *et al.* (1993) recommend a compositional analysis method which is statistically robust and handles the unit sum constraint for habitat use and availability using individuals as sample points (Aebischer *et al*. 1993; McClean *et al*. 1998). This analysis assumes independence between animals but not within the observations of each animal (McClean *et al*. 1998). The assumption of independence of observations and availability of habitats was met as shown for the Neu *et al*. (1974) method. I pooled data using sightings of individual animals as sample units (see Aebischer *et al*. 1993). All observations of bulls (n=123) were pooled. I then made "packages" of observations, using a table of random numbers to select individual sightings randomly and without replacement, and used these packages to represent 17 individual bulls. Breeding herds were observed on too few occasions to allow Design II (landscape use by individuals) protocols to be applied (see Aebischer *et al*. 1993; Arthur *et al*. 1996).

For the simple measure of preference in the selection index comparing use and availability (Krebs 1999) values above 1.0 indicate preference, while values below 1.0 indicate avoidance. Selection indices are awkward to interpret as values cannot be directly compared between bulls and breeding herds. I therefore standardised the selection indices as ratios (Manly *et al*. 1993). I simplified the ranking matrices for the 17 bulls (Table 6.5) by replacing elements in the matrix with + where the selection value is >0 and – where selection value is <0 and triple signs indicate significant difference from random at $p = 0.05$. I used the number of positive signs to assign rank habitat preference from 0 (lowest) to 3 (highest) following Aebischer *et al*. (1993).

Results

Landscape use at the population level

In relation to availability all elephants avoided open woodland and all preferred closed woodland and reedbed (Table 6.2). Bulls show preference for sand forest in relation to its availability while no breeding herds were encountered in this landscape type (Table 6.2). From the standardised indices, where values greater than 0.25 indicate preference and values below 0.25 indicate avoidance, it is apparent that both bulls and breeding herds avoid open woodland in relation to its availability (Table 6.3). For closed woodlands bulls use this habitat in relation to its abundance, not preferring or avoiding it, but breeding herds highly prefer these woodlands. Sand forest appears to be favoured by bulls but no breeding herds were recorded in sand forest suggesting that they avoid this landscape type. The reedbed landscape is not preferred or avoided by bulls, but is preferred by breeding herds (Table 6.3). Based on this analysis the most preferred habitat for bulls is sand forest, while breeding herds preferred reedbeds. When analysed with G-test's, however, the landscape preferences of male elephants are not statistically significant (G_3=3.633, P=0.304) (Table 6.2). Breeding herds also did not select significantly for landscape type (G_3=3.836, P=0.208).

Table 6.2. Selection indices for landscapes for elephants in Tembe Elephant Park. Values above 1.0 indicate preference, values below 1.0 indicate avoidance. Values are not directly comparable between bulls and breeding herds.

Landscape type	**Bulls n = 123**	**Breeding herds n = 13**
Open Woodland	0.844	0.735
Closed Woodland	1.118	1.431
Sand Forest	1.355	0.000
Reedbed	1.161	2.186

Table 6.3. Standardised selection indices for landscape selection of elephants in Tembe Elephant Park. Values above 0.25 indicate preference, values below 0.25 indicate avoidance. Values are comparable between bulls and breeding herds.

Landscape type	**Bulls n = 123**	**Breeding herds n = 13**
Open Woodland	0.189	0.169
Closed Woodland	0.250	0.328
Sand Forest	0.303	0.00
Reedbed	0.259	0.502
Total	1.00	1.00

Landscape use at the individual level

I constructed a ranking matrix of landscape use by calculating the log-ratio mean values (±95% CI) of landscape use for 17 bulls (Table 6.4) derived from the randomly created packages of observations. To determine if the landscape use values are significant I added and subtracted the 95% confidence limit values and if the resultant value included a zero value it was not considered significant (see Aebischer *et al.* 1993). For individuals the between-rank differences in landscape use are not significant. Landscapes are, therefore, used at random and use did not differ significantly from their occurrence. When landscape preference is ranked for individuals, closed woodland was the landscape most selected for, followed by open woodland and then sand forest. The least selected for landscape was reedbed.

Table 6.4. Ranking matrix values (mean±SE) based on a comparison of proportional landscape use and proportional landscape availability for 17 bulls in Tembe Elephant Park.

Landscape type	Open Woodland	Closed Woodland	Sand Forest	Reedbed
Open Woodland	0	-0.185 ± 0.308	0.169 ± 0.403	0.338 ± 0.368
Closed Woodland	0.185 ± 0.308	0	0.354 ± 0.520	0.563 ± 0.466
Sand Forest	-0.169± 0.403	-0.354± 0.520	0	0.209 ± 0.552
Reedbed	-0.338± 0.369	-0.562± 0.466	-0.209± 0.552	0

Table 6.5. Simplified ranking matrix in descending order of landscape preference based on comparing proportional habitat use with proportional habitat availability for 17 bulls in Tembe Elephant Park.

Landscape type	Open Woodland	Closed Woodland	Sand Forest	Reedbed	Rank*
Closed Woodland	+		+	+	3
Open Woodland		-	+	+	2
Sand Forest	-	-		+	1
Reedbed	-	-	-		0

*Results for Aebischer's (1993) model ranks are not significant

Discussion

The TEP was established to conserve elephants and protect the endemic sand forest vegetation type (Sandwith 1997). There is concern that these two conservation goals are mutually exclusive as elephants may threaten this forest type (Matthews *et al.* 2001). I have attempted to ascertain if elephants showed preference for landscape types as any preference for sand forest may influence future management decisions.

At the population level a Design I (Manly *et al.* 1993) approach yielded an outcome that suggests that there are inter-sexual differences in landscape selection. In proportion to availability sand forest was the most preferred landscape for bulls but for breeding herds it was the least preferred landscape type (Table 6.3). Bulls neither avoided nor preferred closed woodlands while for breeding herds it was a preferred landscape type. For breeding herds reedbed was the most preferred landscape type while bulls used this landscape type in proportion to its availability. This implies that the conditions prevailing in TEP at the time of the study were still permitting elephants to selectively use certain landscapes.

In TEP bulls use all available landscape types while breeding herds may be more selective. Stokke & du Toit (2002) found that, in the dry season in northern Botswana, elephant bulls use all habitat types with the exception of one (used less than expected), in proportion to their occurrence. In their study females used five out of seven habitat types in proportion to availability. An earlier study, however, showed significant selection for three vegetation types (from 20 identified) for elephants in the same region (Verlinden & Gavor 1998), when using a simple method of frequency of observations in vegetation type *i* divided by the percentage elephant range covered by vegetation type *i*. Their vegetation types were, however, based on species compositions that may not reflect actual habitat types, and used fewer animals (18 collared elephants) than vegetation types.

Using different landscape classifications and more landscape types and monitoring four females elephants and one male, Ntumi (2002) determined that, at least during the wet season, elephants preferred the Futi floodplains and hygrophilous grasslands. These landscape types are the ones that most closely conform to the reedbed classification for TEP indicating that both sub-populations prefer the same landscape types. The elephant sub-population of Maputo Elephant Reserve (MER) appears to shows a higher affinity for forested landscapes than the TEP sub-population and this may be attributed to human disturbance in the MER (de Boer *et al*. 2000; Ntumi 2002).

When landscape preference is ranked for individuals the Design II approach of Thomas & Taylor (1990), based on the compositional analysis method of Aebischer *et al*. (1993), suggests that landscape preferences exercised by bulls differ from that of the Design I approach of landscape preferences at the population level. At the population level closed woodland is the most preferred landscape type followed by open woodland, then sand forest, with reedbed the least preferred. The ranks assigned to the landscape types in simplified ranking matrix indicate preference but are not statistically significant (Table 6.5). At this level I was, therefore, unable to reject the hypothesis of equal use of landscape types in proportion to their occurrence. That the two different approaches (Design I & Design II) give different results is not unusual even when the null hypothesis of equal use is rejected (Johnson 1980; Alldredge & Ratti 1986, 1992; Manly *et al.* 1993; McClean 1998), and may not represent real differences in landscape use (Bender, Roloff & Haufler 1996).

In northern Botswana, during the dry season, elephants concentrate in woodland habitats that are close to permanent water (Ben-Shahar 1996; Verlinden & Gavor 1998; Stokke & du Toit 2002). The preference shown by breeding herds for reedbeds in TEP may reflect the close association of this landscape with permanent water (Matthews *et al*. 2001). The reedbeds are situated in, or adjacent to, the Muzi drainage line (see Fig. 6.1) and the three females in the Park fitted with radio collars showed spatial affinity with the Muzi drainage line (Fairall & van Aarde 2004b). The sand forests of the TEP are dominated by large trees (Matthews *et al*. 2001). Elsewhere elephant bulls use woody vegetation types that are less available to elephants in breeding herds due to stem size, height or tolerance of variation in diet quality (Stokke & du Toit 2000). In addition sand forests are further from permanent water than reedbed or closed woodland forest types and selection may, therefore, favour the use of closed woodlands by breeding herds. In Tembe all landscapes are within 10 kilometres from water and so available to bulls, which can range further from perennial water than breeding herds (Knight, Hitchins & Erb 1994; Stokke & du Toit 2002). Based on dung counts de Boer *et al*. (2000) reported that elephants in the nearby MER in southern Mozambique preferred sand forest and other forest types over more open habitat types in the mid-1990s but previously preferred open habitats. They postulated that this was a behavioural change due to human persecution.

Elephants are generalists and bulk feeders (Owen-Smith 1988) it is, therefore, likely that they use resources such as habitats in proportion to occurrence. In the wet season when grasses are abundant and of high forage quality elephants are predominantly grazers, in the dry season elephants browse woody vegetation when it provides higher quality forage than grasses (Field 1971; Field & Ross 1976; Guy 1976; Barnes 1982).

Although I was unable to show that individual bulls significantly select for sand forest environments, at the population level this was the landscape type most favoured by bulls in the TEP. Elephants may modify landscapes (e.g. Laws 1970; Barnes 1983; Owen-Smith 1988; Dublin 1995; Cumming *et al*. 1997) and with further increases in population density and the high ratio of bulls to breeding herd members (see Chapter 4), elephants in TEP may have an impact on this landscape type. This will have conservation implications (see Sandwith 1997; Matthews *et al*. 2001). If elephants are using landscape types in proportion to their availability, and elephant density is high, additional habitat availability should alleviate pressure on habitats of conservation concern. Proposals for the development of a transfrontier reserve that will link the TEP and the MER through the Futi Corridor would add habitat types suitable for elephants and increase the area of each landscape type available to the TEP elephant population. While the MER and the Futi Corridor currently support elephants population density there is much lower than for the TEP (see Chapter 3). The successful establishment of a Transfrontier Conservation Area including the TEP, Futi Corridor and Maputo Elephant Reserve would reunite the Maputaland elephant population and may negate the impact of elephants on local stands of sand forests in the TEP.