CHAPTER 2

SPACE USE

Methods

Aerial survey

The distribution and population size of elephants in the MER and the Futi Corridor were assessed by a helicopter survey carried out over a five–day period from 13-18 October 1999. During the helicopter survey, we conducted a total count along non-overlapping transects as described by Norton-Griffiths (1975) and Douglas-Hamilton (1996). Thirty hours of flying was enough to cover the entire surveying area (800 km^2 of the MER and the Futi Corridor (470 km^2). The area was divided into six counting sections, delineated by features such as roads, cut-lines, protected area boundaries or rivers. The crew consisted of a pilot, a Front Seat Observer (FSO) and two Rear Seat Observers (RSO) (see Douglas-Hamilton 1996 for more details).

The survey was planned as a total count, covering 100% of the area (instead of random transects and data extrapolation techniques). Total counting has been adopted as the best alternative as elephants are large animals and relatively easy to spot and count (Douglas-Hamilton 1996). The survey comprised east-west orientated strip-transects. The road between Salamanga and Ponta de Ouro and the Futi River were used to cut the transects in shorter parts, which enhanced observer concentration. We initially planned that the strip transects would be measured during the survey and fixed. During this survey no elephants were noted within the strip transects but several elephants were noted beyond these strips. As a result we counted these elephants by changing the flight plan to enable closer scrutiny, thereafter returning and continuing the survey along to the original transects. The population size could only be estimated by summing the observations of elephants recorded outside the strip transects and correcting these for resightings. All observations were recorded and mapped on a detailed 1:50.000 vegetation map of the study area. As elephants are difficult to detect in the forests (personal observations during previous surveys) we decided to reduce flying height over these forests so as to enhance the likelihood of spotting elephants by flushing them from their hide outs. The flying height over forests was 60m and

92m while surveying woodlands and grasslands. The flight speed was 100km/h with 200m strip width.

The GPS (Geographical Positioning System) in the helicopter was used to assist in navigation and for recording waypoints (observation points) as recommended by Douglas-Hamilton (1996). For each group or individual elephant sighted we recorded the location as waypoints with GPS co-ordinates, the group size, the number of individuals is each age classes (adult or calves), the number of individuals of each sex (for adults only) and the vegetation type where the individual or the group was located. In some cases, photographs were taken to enable a more detailed count and check at a later stage.

Satellite tracking

Satellite tracking data denoting the locations of four young elephant cows and a bull between February 1998 and August 1999, were obtained using the techniques described by Lindeque & Lindeque (1991), Thouless (1996), Tchamba (1996) and Ntumi (1997). Five collars were used in this study, both fitted with a ST-14 Platform Transmitter Terminal (PTT) for satellite transmission and a MOD-600 VHF beacon transmitter (Telonics Inc. 932 Impala Ave, Mesa, Arizona 85204-6699, USA). All PTT's had different identification numbers and identifier signals and the VHF transmitters were transmitting on different frequencies. The PTT's used a frequency of 401.650 MHz with a 24/48 hour on/off duty schedule to extend battery life to about 2 years. The VHF transmitters were continually transmitting a 60 ms pulse per minute on the 177.200 MHz; 177.300 MHz; 177.400 MHz; 177.500 MHz and 177.600 MHz frequencies, respectively. For ground reception and location we used a a Telonics TR-2 receiver and a three element Yagi RA-14K hand-held antenna

The five collars were placed onto elephants during February 1998. We selected four young elephant cows from different groups for collaring, as they are known to rarely leave their natal herds (Moss 1996). The young bull that we selected for collaring was known to be a member of a separate group than the four cows. The selected elephants were immobilized with the anaesthetic M99 (Etorphine hydrochloride) delivered through a dart following the procedures as described by Kruger-Med Pharmaceuticals (Pty.) Ltd.(Whyte 2001). Various body measurements (see Appendix 2) were taken during about 10 minutes while the collars were attached.

Due to the difficulty of receiving a signal and the decrease in accessibility of the MER, VHF-radio telemetry was not used to obtain the data on elephant locations during this study. VHF telemetry was used only to locate the PTTs for retrieval.

Service Argos, in Toulouse, France calculated the locations of the PTT's, when receiving identifier signals. A successfully received identifier signal is called an uplink and information from several uplinks are combined to calculate a location based on the angle of reception. From Toulouse, France the data were sent to Maputo, Mozambique by e-mail at three-day intervals.

Data Analysis

Due to the resources shortages, no beacons (PTT's placed at known locations in the study area for future corrections on acquired elephant satellite locations) were used in the study. To avoid the inaccuracy of the locations, those with a quality of class 1 and class 0 (where accuracy was ≤ 1000 m and > 1000 m, respectly) were excluded from calculations on home ranges. Only class 2 and 3 data were analyzed (for more details see ARGOS 2000; Tchamba 1996). Class 3 data comprise locations in which accuracy was ≤ 150 m. Class 2 data have an accuracy of ≤ 350 m.

The local time in Mozambique was calculated by adding two hours to the GMT location hour. The UTM distances between successive locations (x_i,y_i) and x_{i+1}, y_{i+1}) was determined from the equation given by White & Garrot (1990):

$$\text{Distance} = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$$

where, x is the latitude and y is the longitude.

The minimum speed an elephant moved was calculated by taking the straight line distances between two subsequent locations per time that have elapsed between locations using the equation $speed = distance/t_{i+1} - t_i$, where, t is the time and **i** is the location (White & Garrot 1990).

Locations obtained between 06:00 am and 18:00 pm. were categorized as daytime observations and those from 18:01 pm. to 05:59 am as nighttime observations.

The time spent by the elephant in a particular habitat was assessed calculating the time that elapsed between locations within a given habitat. The assessment of the influence of season on movement and habitat use was based on distinguishing the wet season data (those collected from November to April) from the dry season data (those collected from May to October). Due to individual differences in the period of data collection only data collected over the first six months of the study were used to assess the individual identity on movement patterns. The Adaptive Kernel (AK) and the Minimum Convex Polygon (MCP) routines of the Calhome program (Kie *et al.* 1996) were used to calculate home range variables such as the core areas. Geographic coordinate data were converted to UTM using the MADTRAN program, also part of Calhome. Comparisons with other studies (Leuthold 1977a; Lindeque & Lindeque 1991; Tchamba 1996) are based on the Minimum Convex Polygon areas as described by White & Garrot (1990), Harris *et al.* (1990). However, due to the disadvantages of the Minimum Convex Polygon method (White & Garrot 1990 and Harris *et al.* 1990), the Adaptive Kernel method was used in this study to quantify home ranges and for comparisons between animals. It produces an area with very little bias and gives surface estimates with the lowest error (Seaman & Powell 1996).

The ARCVIEW GIS query package (ESRI 2000) was used to determine and illustrate the locations and the extent of home ranges of individual elephants during the seasons and the time of day. The Calhome program also calculated distances between successive locations. The proportional overlap of the home ranges of individual elephants was calculated by dividing the home range size of each elephant by that of the others with which it overlapped.

Mean monthly rainfall and climate records for the periods 1970 to 1974 and 1995 to 1999 for Bela Vista Meteorological station (4km from MER) were obtained from the National Meteorological Institute of Mozambique[2].

Seasonal differences in home range areas were tested using the paired T-test (Conover 1980, Zar 1984). The daytime/night distances between successive locations were tested using the Wilcoxon Matched Pairs Test (Motulsky 1995). A Mann-Whitney U-Test (Motulsky 1995) was used to test the distance between successive locations when the male was in or outside the MER.

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RESULTS

Helicopter Survey

Most (97%) of the 311 elephants sighted during the October 1999 aerial survey occurred within the MER. A few (2%) were noted outside the MER (western boundary) and only 2 bulls were recorded along the Futi Corridor. During the survey 36.7% of elephants were noted in woodlands, 34.7% in forests and 28.6% in grasslands. By excluding resightings the minimum size of the population has been estimated at 205 individuals.

Satellite tracking

Five elephants (four females and a male) were fitted with satellite tracking collars. Two of them, a female and a male were tracked for less than a year, as their collars were broken at the end of the 1998. The other three cows were followed for periods ranging from sixteen months to twenty-three months (Table 2). In total, 3997 locations were successfully obtained from the satellites (see Table 2).

Most (83.5%) of the locations fell within classes 2 and 3 (≤ 350 m). Excluding these locations and repetitive locations, the locations available for analyses for the first six months of tracking were dramatically less than that reflected in Table 2 (see Table 3).

Since the number of locations may affect calculated estimates of home range size, the minimum number of the locations considered as the optimum for the analysis in this study was 20 locations (Adaptive Kernel method) (Harris *et al.* 1990, Powell 2000) (see Fig. 3). However, estimates for individual home ranges reached asymptotes at different values and followed different trends (Fig. 3).

Seasonal Movements

The patterns of movement were uniform during the study considering the seasonality of use of space available for elephants in the MER. Both rainy and dry seasons elephant movements were restricted to the vicinity of the Futi River (Figs 4 & 5). The male, moved into the Massuane, Salamanga and Maputo floodplain areas outside the MER (see Fig. 6).

During this study the elephants did not move more than 5km to the south of the MER along the Futi River (Fig. 7).

Space use

Home range polygon sizes calculated with the Adaptive Kernel (95%) are shown in Table 4 and Figs 4 & 5. The Minimum Convex Polygon (MCP)(90%) and 50 and 70 % core areas determined by the Kernel method for all elephants are also presented in Table 4.

The information in Table 4 and in Figs 4, 5 & 7 and Appendix 1 reveal that although the MER extends over an area of 800 km^2 the range of the elephants tracked during this study covered only 33.0% of the total surface area. The core area for all elephants collectively calculated as 50% Adaptive Kernel extend over less than 6% of total surface area of the MER. The differences between the areas of elephant home ranges during the dry and rainy seasons were not statistically significant (Paired T=-1.33, df=4, p>0.05). However, values for the females for the rainy season were greater than those for the dry season (Table 4). The dry season range covered 22% of the total surface area of the Reserve whilst the wet season range covered 26% thereof.

The male had a larger home range than the females (Table 4 and Figs 4 & 5). The home ranges of individual elephants in the MER overlapped considerably (see Table 5). The area of these ranges was at the lower end of those recorded for other areas (Table 6).

The distances between successive locations moved by these elephants during the night (mean = 2.91 km, S.E. = 0.12; N = 786) and during the day (mean =3.78 km, S.E. = 0.14; N=727) were not similar (Wilcoxon Matched Pairs Test, T =1; N=10; $p < 0.05$) (Fig. 8). Distances between successive locations for the dry season (mean = 2.92 km, S.E. = 0.12; N = 737) differed significantly (Wilcoxon Matched Pairs Test, T =2; N=10; $p < 0.05$) from those for the rainy season (mean = 3.73 km, S.E. = 0.13; df = 776) (Fig. 9).

In areas outside the MER where humans have settled (Salamanga and Massuane) the mean distance between successive locations for the bull (mean = 3.33, S.E. = 0.45 and N = 97) was greater but not significantly (Mann-Whitney U-Test, $U_{36/97}$ = 1562; $p > 0.05$) than those within the MER (mean = 3.16, S.E. = 0. 31 and N = 36).

Table 2: The number of successful locations for the different elephants as a function of accuracy class and the period over which the movements of each individual was tracked.

		Accuracy Class				Period in months
Elephant	**ID - Code**	**1[a]**	**2[b]**	**3[c]**	**Total (1+2+3)**	
Female 1	6454	211	396	553	1160	23
Female 2	6455	223	224	517	964	20
Female 3	6456	118	214	268	600	11
Female 4	6457	24	176	758	958	16
Male 1	6458	84	125	106	315	11
Total		660	1135	2202	3997	

[a] locations where Argos estimates $\sigma \leq 1000$ m

[b] locations where Argos estimates $\sigma \leq 350$ m

[c] locations where Argos estimates $\sigma \leq 150$ m

Table 3: The number of class 3 locations for each of the five elephants collected over a six-month period of satellite tracking as a function of season. Here the dry season includes locations collected between May and October, while the rainy season include those collected between November and April.

Elephant	ID – Code	Dry season	Wet season	Total
Female 1	6454	79	63	142
Female 2	6455	43	24	67
Female 3	6456	64	38	102
Female 4	6457	88	36	124
Male 1	6458	60	55	115

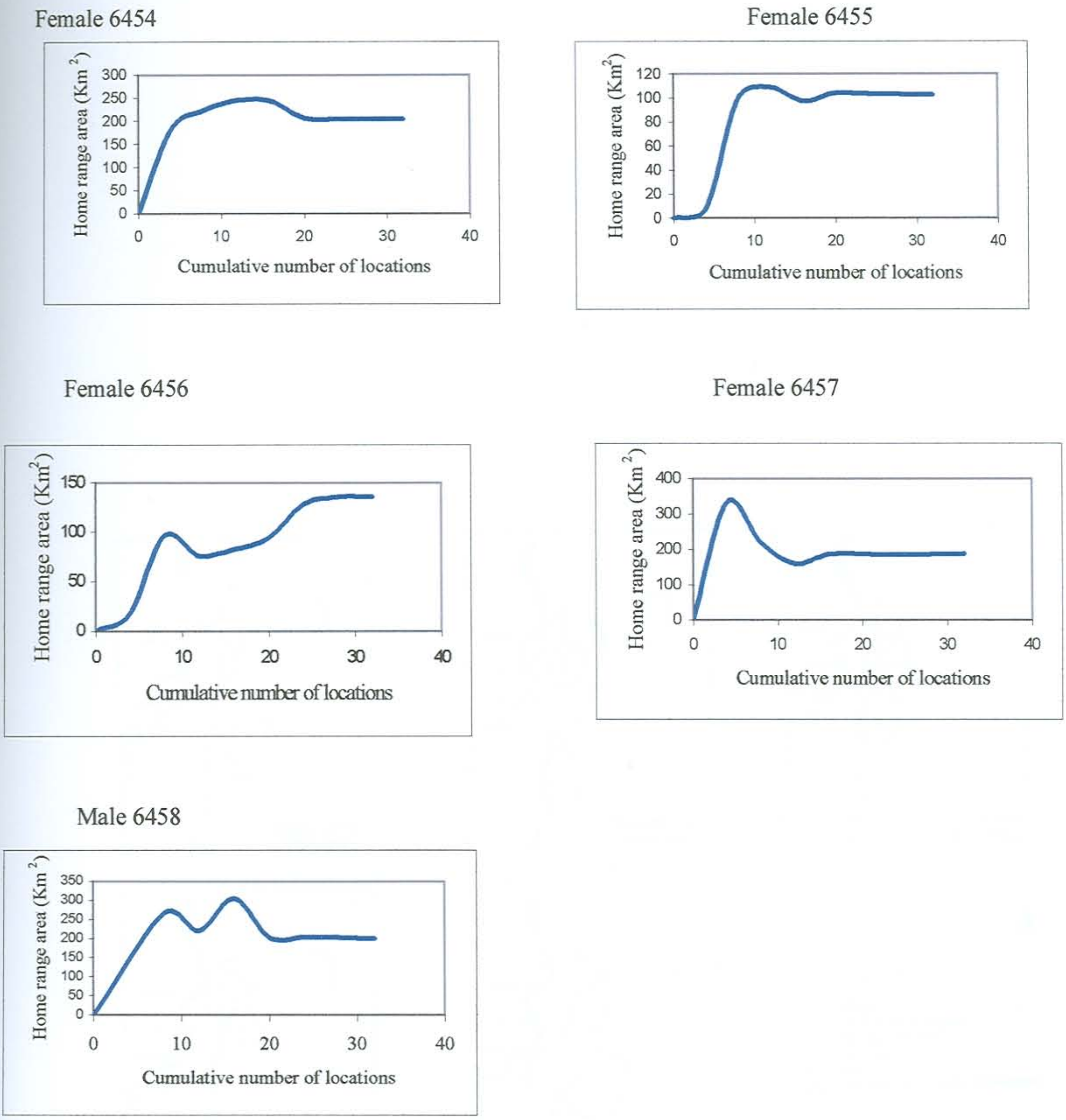

Figure 3: Home range area as a function of the cumulative number of locations included in the estimate using the Adaptive Kernel method for five individual elephants.

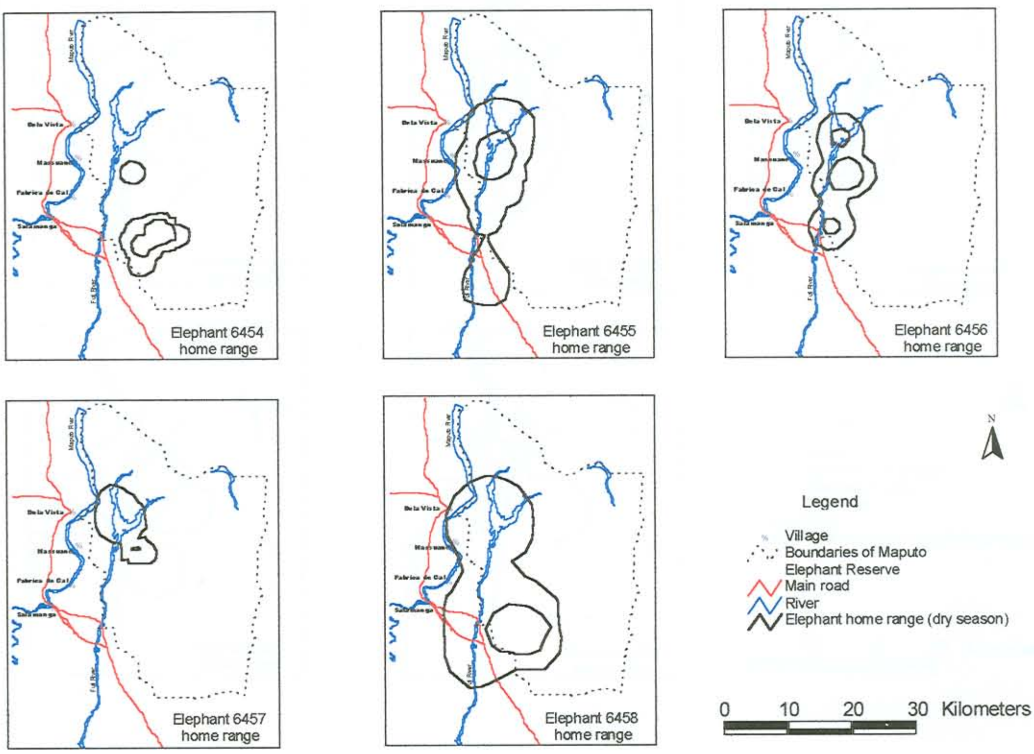

Figure 4: Home range locations and shapes of the tracked elephants during the dry season from February 1998 to August 1999. Here the dry season includes locations collected between May and October of each year.

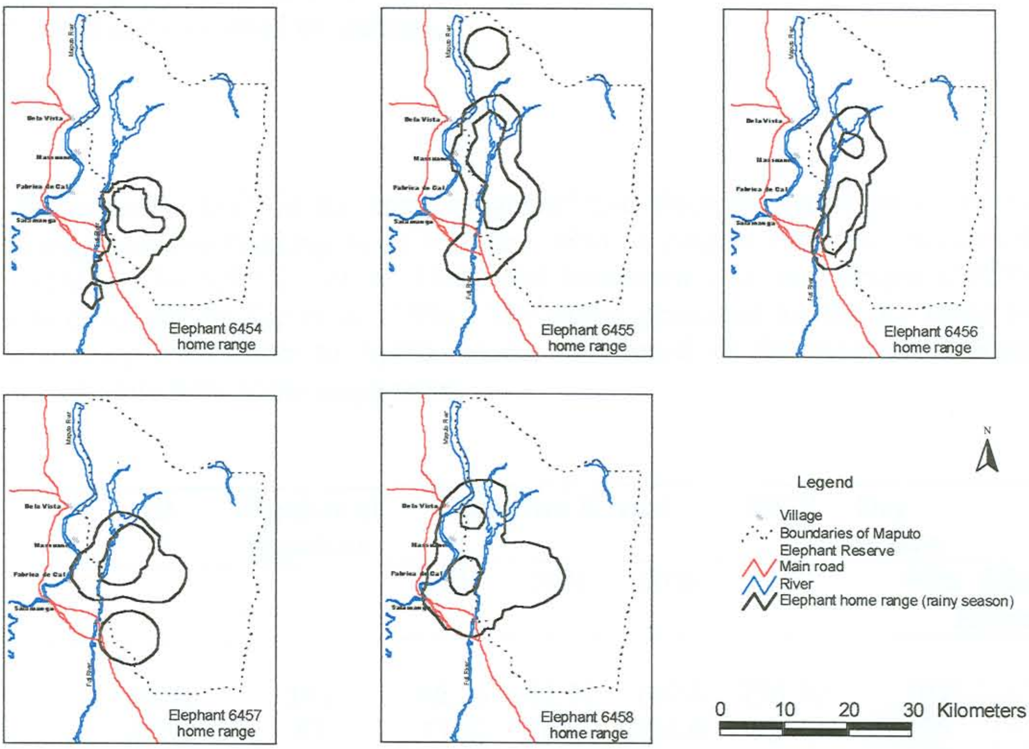

Figure 5: Home range locations and shapes of the tracked elephants during the rainy season from February 1998 to August 1999. Here the rainy season includes locations collected between November and April of each year.

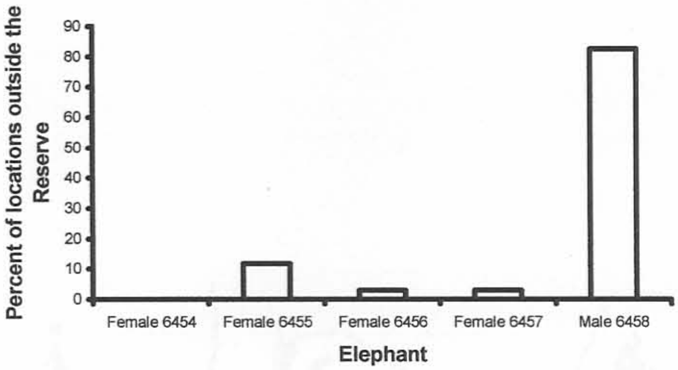

Figure 6: The frequency of locations for individual elephants beyond the boundaries of the Maputo Elephant Reserve during the study period (February 1998 to August 1999). The male spent most of his time on the Salamanga, Massoane and Madjajane floodplains that are inhabited and cultivated by humans.

Table 4: The areas (in km^2) of the home ranges of five elephants based on locations obtained through satellite tracking from February 1998 to August 1999 and calculated using the Adaptive Kernel (Kie *et al.* 1996) and Minimum Convex Polygon (MCP) techniques as described by Kie *et al.* (1996). The values presented for the dry (May to October) and rainy (November to April) seasons are based on the Adaptive Kernel technique to calculate 90% home range areas.

Elephant	**ID**	**Number of locations**	**Adaptive Kernel**			**MCP**	**Dry season**	**Rainy season**
			50%	70%	90%		90% Adaptive Kernel	
Female 1	6454	142	46.56	81.11	169.4	156.30	105	130.4
Female 2	6455	67	73.82	103.3	266.6	121.6	195	208.6
Female 3	6456	102	42.36	73.66	218.8	102.6	125	196.7
Female 4	6457	124	0.52	28.26	218.1	95.37	64.43	206.2
Male 1	6458	115	66.06	140.7	452.9	206.8	381.2	286.8
Mean for females			40.81	71.58	218.23	118.97	122.36	185.48
S.E for females			30.27	31.51	39.68	27.24	54.59	37.07

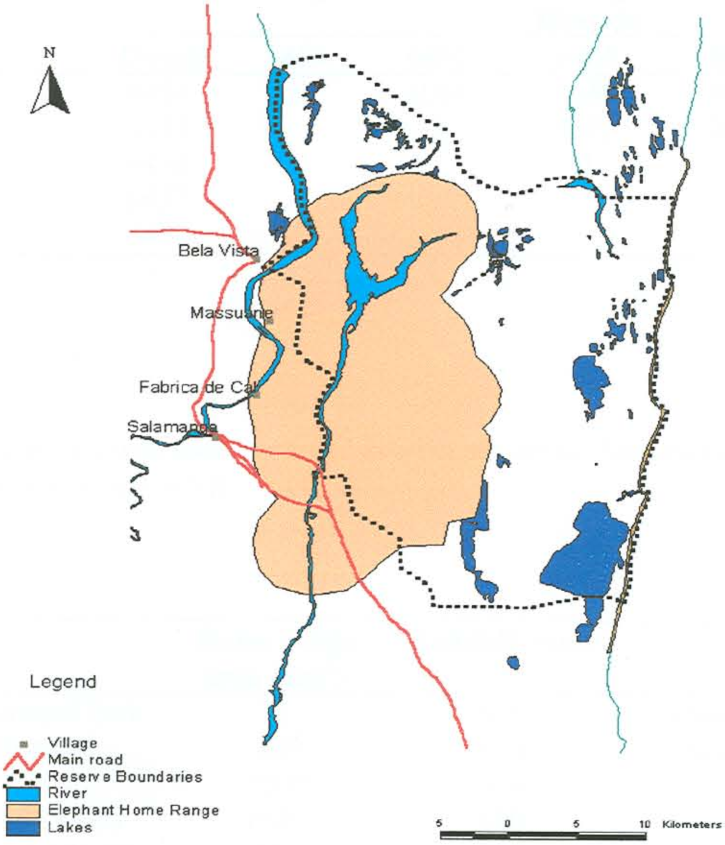

Figure 7: The collective home range (90% Adaptive Kernel) of five elephants based on satellite locations collected from February 1998 to August 1999.

Table 5: The proportional overlap of the home ranges of individual elephants based on data obtained through satellite tracking from February 1998 to August 1999.

		ID-code				
Elephant	**ID-code**	**6454**	**6455**	**6456**	**6457**	**6458**
Female 1	6454	1	0.64	0.46	0.77	0.39
Female 2	6455		1	0.72	0.84	0.6
Female 3	6456			1	0.6	0.84
Female 4	6457				1	0.51
Male 1	6458					1

Table 6: Elephant home range areas recorded in other studies on African elephants. All these estimates are based on the MCP method.

Area	**Home range area (km^2)**	**Rainfall (mm)**	**Reference**
Lake Manyara National Park	33	825	Douglas-Hamilton (1972)
Tarangire Game Reserve	330	650	Douglas-Hamilton (1972)
Sabi Sand Reserve	<200	619	Fairall (1979)
Tsavo National Park (East)	1620	550	Leuthold & Sale (1973)
Tsavo National Park (West)	746	260	Leuthold & Sale (1973)
Kruger National Park	436	590	Hall-Martin (1984)
Kruger National Park	523	590	Whyte (2001)
Northern Namib Desert	2172	64	Viljoen (1988)
Etosha National Park	7250	171	Lindeque & Lindeque (1991)
Waza National Park	1660	700	Tchamba (1996)
Gola Forest Reserve	250	3000	Meiz (1986)
Middle Zambezi Valley	179 (cows)	793	Dunham (1986)
MaputoElephant Reserve	129	845	Ntumi (1997)
Maputo Elephant Reserve	311	845	This study

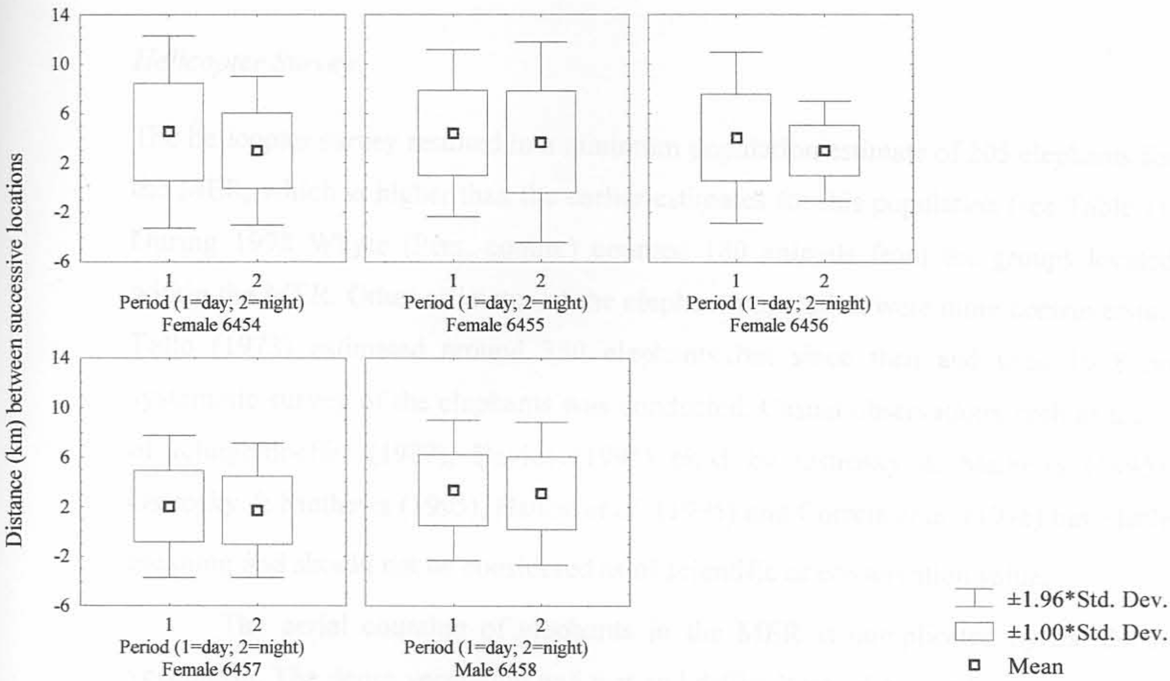

Figure 8: Mean distance (km) between successive locations as a function of the period of time that elephants have been tracked in the Maputo Elephant Reserve.

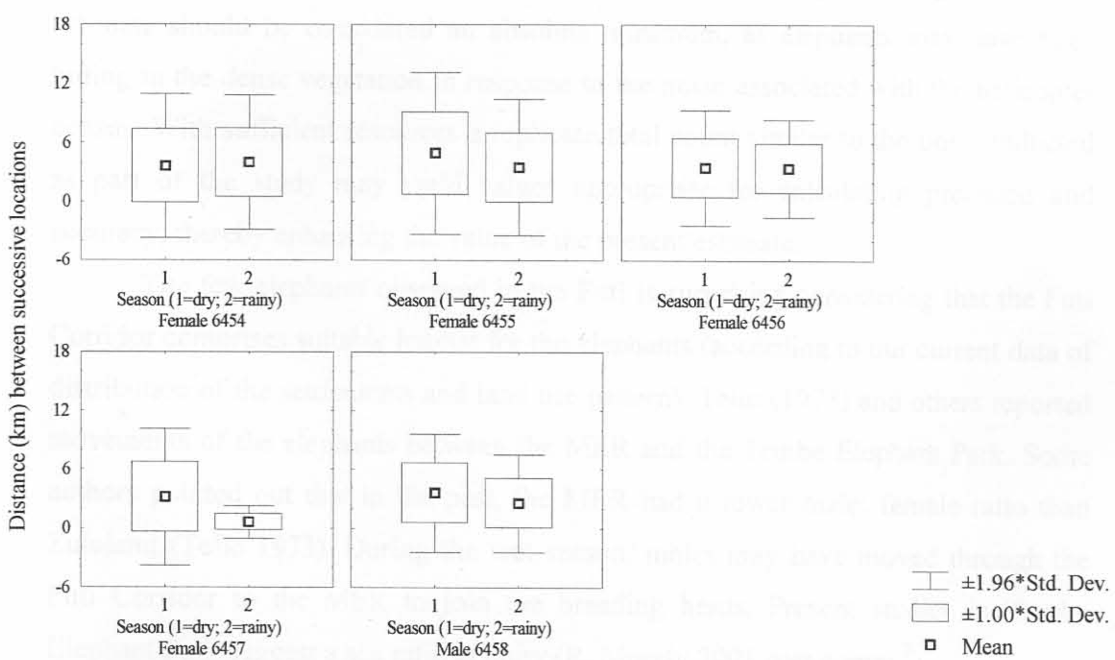

Figure 9: Mean distance (km) between successive locations as a function of the season that elephants have been tracked in the Maputo Elephant Reserve.

Discussion

Helicopter Survey

The helicopter survey resulted in a minimum population estimate of 205 elephants for the MER, which is higher than the earlier estimates for this population (see Table 1). During 1998 Whyte (Pers. comm.) counted 180 animals from the groups located within the MER. Other estimates of the elephant population were more controversial. Tello (1973) estimated around 350 elephants but since then and until 1998 no systematic survey of the elephants was conducted. Casual observations such as those of Klingelhoeffer (1987), Davies (1995) cited by Ostrosky & Mathews (1995), Ostrosky & Mathews (1995), Hatton *et al.* (1995) and Correia *et al.* (1996) have little meaning and should not be considered as of scientific or conservation value.

The aerial counting of elephants in the MER is complicated by the dense vegetation. The dense vegetation and wet and difficult traveling conditions prevailing in the MER also rendered ground counts nearly impossible with the limited logistical support that was available during the present study. Elephants living here are also rarely seen from the ground, except when they are out on the grasslands. Due to the conditions within the MER and the nature of the present helicopter survey, the present estimate should be considered an absolute minimum, as elephants may have been hiding in the dense vegetation in response to the noise associated with the helicopter census. With sufficient resources a replicate total count similar to the one conducted as part of the study may yield values appropriate for calculating precision and accuracy, thereby enhancing the value of the present estimate.

The few elephants observed in the Futi is surprising considering that the Futi Corridor comprises suitable habitat for the elephants (according to our current data of distribution of the settlements and land use pattern). Tello (1973) and others reported movements of the elephants between the MER and the Tembe Elephant Park. Some authors pointed out that in the past, the MER had a lower male: female ratio than Zululand (Tello 1973). During the wet season, males may have moved through the Futi Corridor to the MER to join the breeding herds. Present studies in Tembe Elephant Park suggest a sex ratio at unity (R. Morely 2001 pers.comm.[3]).

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At the mid dry season in Mozambique (October), the temperatures rise (see Appendix 3) and herbaceous biomass becomes less available (personal observation). In the Ruaha National Park, Tanzania, rising temperatures during the mid-dry season (September-October) were associated with low food availability (Barnes 1983). Under these circumstances elephants experienced a much greater heat load and as a consequence spend more time resting. As they may be resting in the shade provided by the dense forests they may not have been noted during the helicopter survey.

The few elephants noted during the survey of the present study also contrasts with more recent observations based on satellite tracking. A study from September 2000 to December 2001 showed that elephants do move all along the Corridor and those individuals can be encountered throughout the Futi Corridor (van Aarde & Fairall 2001). The few elephants noted in the Futi Corridor during both the October 1999 (present study) and April 2001 (van Aarde & Fairall 2001) helicopter surveys may be the result of poor visibility in the dense vegetattion or elephants being seasonally elsewhere.

Satellite tracking

Conventional radio tracking locations are only estimates and not exact locations (Harris *et al.* 1990, Garrot & White 1990). Factors that increase the size of the error include the distance away from the animal, the nature of the terrain and the atmospheric conditions. Satellite tracking locations are also estimates (ARGOS 2000). Tchamba (1996) placed beacons in various habitats in Cameroon. He used information from them to correct satellite locations. No beacon was used in the present study and it was not possible to correct for the inaccuracy of the satellite locations through a similar method. However, System Argos does give figures which allow an estimate of the accuracy of the locations given by the platform transmitters (ARGOS 2000). According to this all locations used in the present study should be within 350 m of the actual position, with most being within 150 m. Given the elephants movement capabilities a 350 m radius can be considered very accurate and only locations on the edges of habitat units could present measurement difficulty. This distance is also likely to be within the accuracy of measurement of the vegetation map used to interpret habitat use (see Chapter 3).

Estimates for individual home ranges reach asymptotes at different values (Figure 3). Previous studies on elephants argued that a hundred locations are sufficient for home range analysis using the Minimum Convex Polygon (MCP) (Leuthold 1977a) and 20 locations for kernel analysis methods (Powell2000). For the current study 20 locations may thus be considered the minimum number of fixes needed. The irregular distribution of preferred vegetation types and water might influence the number of fixes required (White & Garrot 1990), while the period over which the study was done (only one annual cycle in this case) and the accuracy of locations would also affect the number of fixes required (N. Fairall 2001 pers comm.[4]).

The actual number of locations in the present study are constrained by the time that the various collars were functional. In most cases this was in any event more than 100 with 67 being the lowest number, this conforms with the minimum requirements as stated in the literature and as can be seen in Figure 3 provides an asymptotic value.

Movements pattern

Very few mammal species use the space within their home ranges randomly (Harris *et al.* 1990) and elephants are no exception. Elephants select certain preferred areas, considered *core* areas (see Appendix 1) and, although home ranges of all collared elephants during the study have shown some overlap (Table 5) they showed mutually exclusive *core areas.* This means that these individuals probably belong to different elephant groups (Leuthold 1977a, Moss 1988).

Whyte (1996) correlated elephant movement in the Kruger National Park with rainfall. He observed increased distances between successive locations during the rainy season just after heavy rains. It is not clear what governs elephant movement in the MER. The north-south and east-west movements observed during the dry and rainy seasons, were also observed by Ostrosky (1987) in the Tembe Elephant Park. A monitoring program of elephant movements across the international border between South Africa and Mozambique in the Tembe Elephant Park before the electric fence was erected (Ostrosky 1987, 1988 and 1989) revealed peaks of elephant movements from Tembe to Mozambique during the wet season. These groups comprised breeding herds, lone bulls and bachelor groups. During the dry season, a reduction of movements was observed and were limited to bulls. Game scouts of the Tembe

Elephant Park (mentioned by Ostrosky 1987) recorded that elephants crossing into Mozambique returned to the Tembe Park in the same night or after a few days.

Scientific data regarding the Maputaland (Tongaland)[4] elephant ecology are scarce. Thomson (1974) cited by Klingelhoeffer (1987) mentioned that the elephant population at Muzi-Sihangwana area (Zululand) was in excess of 20 with a possible maximum of 50. He suggested that there were three to four small mixed groups (i. e. with cows and calves) permanently resident in the thickly wooded areas around Muzi-Sihangwana northern KwaZulu-Natal, whilst the remaining herds comprised only bulls (Klingelhoeffer 1987). According to the Red Data Book on large mammals of South Africa (Skinner, Fairall and Bothma 1977 cited by Klingelhoeffer 1987), the number of elephants estimated for northern Tongaland was not more than 30, where no confirmed sightings of breeding herds were reported since 1946.

The elephant populations of the Tembe Elephant Park and the MER use to be a single entity connected through the Futi Corridor (van Aarde & Fairall 2001). The separate sub-populations are seen as being maintained through an artificial barrier in the form of an electrified fence erected during 1989. The ecological consequences resulting from this fence have not been studied.

Space Use

Size and shape of individual home ranges

Differences in the size of the home ranges of elephants have been noted in other studies (Harris *et al.* 1990, Tchamba 1996 and references therein). Those differences are mainly due to the pattern of resource distribution (Douglas-Hamilton 1972, Hanks 1979, Dunham 1986, Laws *et al.* 1975, Whyte 2001), sex of the elephant (Owen-Smith 1988), environmental factors (Laws *et al.* 1975, Hanks 1979, Owen-Smith 1988, Whyte 2001) and to the method used to study the movements of the animals (as elephants are not the exception) (Kenward 1987, Garrot & White 1996, Harris *et al.*

[4] Maputaland is a recognised center of plant endemism (van Wyk 1994) and stretches across the international boundary between Mozambique and South Africa. It encompasses the area from Indian Ocean to Pongola River northern KwaZulu Natal and to the Lebombo mountains across Maputo River flood plains, southern Mozambique. This area has a high biodiversity, distributed over the Tembe – Ndumo area, Futi River floodplains and the Maputo Elephant Reserve. The sand forest and woody grassland are endemic to Maputaland (van Wyk & Smith 2000, cited by van Aarde & Fairall 2001). Floristically, the sand forest is unique and supports a large number of neo-endemics, suggesting recent and ongoing evolutionary processes (van Aarde & Fairall 2001).

1990, Seaman & Powell 1996, Powell 2000). Food quantity and quality, and the availability of water are the most important factors determining how far elephants move (Hanks 1979).

The results of the MCP, has highest variances (Garrot & White 1996, Harris *et al*. 1990, Seaman & Powell 1996, Powell 2000). The adaptive Kernel method of describing home ranges shows accurate estimates of home range areas and had the smallest variance (Powell 2000; Seaman & Powell 1996). According to Powell (2000) and Seaman & Powell (1996), the adaptive Kernel estimator overestimates true home range area by about 25 percent. Kernel estimators share three shortcomings with most other home range estimators. First, they ignore time sequence information available with most data on animal locations. Second, sometimes the method produces 95 percent home range outlines that have convoluted shapes or disjunctive islands of use. Third, the method does not estimate how important these disjointed islands of the home range are to the animal (Garrot & White 1990, Powell 2000).

The home range size of the tracked elephants in this study measured as MCP, is within the range of values recorded by Douglas-Hamilton (1972) for the Tarangire Game Reserve, Douglas-Hamilton (1972) for Lake Manyara Park, Tanzania, Fairall (1979) for Sabi Sand Reserve, Leuthold & Sale (1973) for Tsavo National Park, Hall-Martin (1984) for Kruger National Park, Whyte (2001) for Kruger National Park and Ntumi (1997) for MER (see Table 6). However, these values were well below those recorded elsewhere. For instance in the savanna of Tsavo East National Park, Kenya, female elephants were radio-tracked over areas of up to 1800 km^2 (Leuthold 1977a, Owen-Smith 1988). More recently, Lindeque & Lindeque (1991) recorded home ranges over 8700 km^2 in northwestern Namibia. The Etosha National Park, northwestern Namibia, is an arid environment with limited food and water, suggesting that elephants cope by being highly mobile and opportunistic (Lindeque & Lindeque 1991). The observed small and stable elephant home ranges in Kruger National Park by Whyte (2001) are seen as related to the existing artificial waterholes network throughout the Park and to the well distributed system of permanent and semi-permanent rivers. Thus, most of the tracked elephants by Whyte (2001) had direct access to the permanent rivers within their home range.

During the present study home range (position or area) was probably related to the distribution of water (Figs 4 and 5) and vegetation types in the MER (Fig. 10). Small home range sizes of family units in the Lake Manyara Park were observed in forest habitat with abundant ground water (Douglas-Hamilton 1972). Grasslands and sand forest mosaics dominates the eastern areas of the MER. The western side comprises of sand forest patches and green riverine vegetation along the Futi River (DCB 2000). Ntumi (1997) reported that water distribution did not limit elephant distribution in the MER. Many water sources are found throughout the MER such as the Lakes Chingute, Piti, Munde, Nele and Nhame, with low salinity for Lakes Piti, Munde and Nhame.During the present study elephants did not occur in the eastern areas of the MER. Aerial photographs taken during 1958 and comments by local people revealed that in the past, people occupied the eastern part of the MER and there were and intensely cultivated large portions thereof. This probably gave rise to the development of the grasslands and sand forests mosaics pattern, which is now common in the eastern part of the MER.

Fire decreases biomass in the short term (Mentis & Tainton 1984, Trollope 1984) and Bhima (1998) observed a small increase in height and crown volume of trees in burned plots in Liwonde National Park, Malawi. Nowadays, burning has been seen as playing a role in manipulating the distribution of elephants and their impact on vegetation in most African Parks (McShane 1987). Jachmann (1984) reported a negative relationship between elephant distribution and burnt areas in Kasungu National Park, Malawi. The reason that elephant tend to avoid burnt areas in Kasungu National Park is that burning scorches the leaves and thin twigs that make up an important component of their diet (Jachmann 1984). Plant productivity in tropical forest ecosystems is explained by a tight nutrient cycling, determined by the integration between the release of nutrients by decomposition and their uptake by the vegetation (Anderson & Swift 1983). In fact, tree ecosystems depend completely on input of natural N and leguminous trees and shrubs contribute to the nitrogen economy of tropical regions (Ishizuka 1992). The grasslands and woodlands in the eastern parts of the MER regularly burns. Through this both N and C are often volatized and removed from the system without replenishment. Fire may in this way reduce the fertility and productivity of the poor sandy soils of this part of the MER (Menaut *et al*. 1991, Holt & Coventry 1991, Scholes 1991).

Veld fires are common in the MER, especially in the open eastern areas. Few people are living here and human induced disturbances can thus not explain why elephants are not using this part of the MER. It is possible that the fire-induced reduction in vegetation cover as well as the low fertility of soils render this part less suitable for elephants than the other parts of the MER. However, range use may be affected by other factors and further increases in the elephant population may give raise these apparently marginal ranges also being used by elephants.

The distribution and supply of water affect home range size of elephants in most African Parks (Leuthold 1977b, Owen-Smith 1988, Viljoen 1988, Lindeque & Lindeque 1991, Tchamba 1996). According to Leuthold (1977b), the lack of open water in large parts of the Tsavo National Park limits their use by elephants during the dry seasons, as the elephants concentrated within reach of permanent water supplies. Water is widely distributed throughout the MER and is not a limiting factor (see Ntumi 1997) in both seasons. Owen-Smith (1988) pointed out that dry season range only covers 10% of the area of wet season range in different conservation areas as the elephants limit their movements to areas close to permanent water sources in the dry season. This was not the case in the present study, probably as a consequence of high plant productivity and food availability.

Home range size represents a compromise between individual metabolic requirements and social factors (Damuth 1981a cited by Owen-Smith 1988). Thus, for most African ungulates only female home ranges can be related directly to nutritional requirements, because male home range are more influenced by the fission-fusion patterns with breeding herds (Owen-Smith 1988). Different foraging strategies of females and males could explain the large home range of the male. Since the females are more selective than males (Owen-Smith 1988), they probably feed on more nutritious plants than the males, who need a larger amount of food, leading to the large home range recorded for the male during the present study.

Without a regular registration of the rainfall in the MER, travelled distance between successive locations cannot be discussed in relation to the local rainfall.

The larger distance between successive locations observed outside the MER suggests that elephants were more mobile, maybe because of conflicts with humans in Madjajane, Massuane and Salamanga as was observed in Cameroon by Tchamba (1996). Most of the excursions out of the MER were made during rainy season and the night by the male. This suggests that the roaming out of the MER is associated with feeding on agricultural crops and supports the Sukumar's (1989) observation that crop damage is caused mainly by male elephants rather than females, and normally takes place at night during the rainy season..

Another factor promoting increased nocturnal activity by megaherbivores is the maintenance of a thermal equilibrium. Metabolic rates are related to the proportion of surface area available for dissipating body heat (Owen-Smith 1988). It is advantageous for megaherbivores to be more active at night, when there is a reduced environmental heat load. But the small travelled distance between successive locations at night observed during this study, contradicts those explained above. It may due to the other external factors influencing elephant behaviour at the MER (see Chapter 3). Without a systematic ambient temperature record during this study it was not possible to correlate this factor to the calculated home range sizes.

Conclusions

The elephants of the MER confined their home range to the North West boundary of the MER. With absence of regular movements synchronised by season, I can conclude that there are no elephant migrations in the MER.

Small home range sizes of elephants were observed in this study and no significant differences were found between seasonal home ranges sizes. Short daily distance in the dry season was found. This result is consistent with expected dependence between elephants and surface water distribution and food as the MER receives from 690 to 1000 mm (see Appendix 4) of rain per year considerable more than of any of the mentioned areas in table 6. Therefore, I can conclude that, water and food distribution, determine the elephant space use in the MER.