THE EFFECTS OF ELEPHANTS ON THEIR HABITATS IN THE SHIMBA HILLS, KENYA

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Chapter 4. Elephant movements, home ranges and diurnal activity.

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Abstract

As human encroachment into elephant rangelands restricts elephant movements, it is increasingly critical to identify elephant range needs, and the effects of barriers to movements for the purpose of planning conservation areas. Home ranges and movements were documented for six African elephants in a small protected area comprising mixed tropical forest, woodland and open habitats. Data were collected using four conventional VHF radio tracking system (Telonics) collars on two cows and two bulls, and LOTEK GPS radio collars on one bull and one cow. None of the collars performed as well as was expected, however, the LOTEK GPS collars provided far superior data to the conventional VHF system.

The Shimba elephants occupied small home ranges (mean cows 54km^2, bulls 17km^2) that overlapped extensively within the confines of the protected area. The LOTEK GPS collars revealed that the cow was more active than the bull at all times, traveled further, and had a larger home range. However, both elephants traveled very short distances each day compared to other sites in Africa. Both elephants exhibited diurnal activity cycles that were influenced by temperature. Activity increased after 6 am and during mid day when temperatures peaked. The bull sustained medium levels of activity, while the cow exhibited a lull followed by a second peak of activity after the hottest temperatures had subsided. Both elephants exploited a variety of habitats, the cow utilized forest for a significant portion of the day, while the bull utilized open bush and grasslands. Night time habitat use was slightly different.

Seasonal changes in range use were described for one cow whose collar functioned for almost 10 months. She circled her range twice in ten months utilizing the northern drier areas during the rainy seasons, and retreating to the higher elevation wetter areas during the rest of the year. Activity peaked in September and October, and declined during the hottest months of December to February. Both elephants used an elephant corridor extensively as a core part of their range for movement and for foraging. These findings were used to guide management decisions affecting elephants in the Shimba Hills. GPS radio-tracking though very costly at the outset, was much more cost effective than conventional VHF collars considering the amount of data obtained per elephant. Using remotely gathered GPS information permitted an otherwise impossible view of elephant activity at night.

Introduction

The activities and movements of African elephants (*Loxodonta Africana and L. cyclotis)* in forest habitats are poorly known because they are notoriously difficult to follow and observe on the ground or even from the air. In contrast, the savanna elephants of Africa are among the best studied land mammals in the world and most of our knowledge of the behavior and ecology of African elephants is based on field studies from very few sites in savanna habitats (Moss 2001). With growing human populations in elephant ranges, conflict between humans and elephants has rapidly become one of the most serious threats to the livelihoods of farmers. Balancing the dual needs of elephants and their conservation with the needs of rural agricultural communities across different climatic and habitat zones is a major conservation challenge of the 21st Century. This study explores the ranging patterns of forest dwelling savanna elephants (*Loxodonta africana*) and compares it with the same species living in savanna regions and with *L. cyclotis* living in the central African rain forests.

Radio-telemetry is a key tool for studying elephants, and across Africa and Asia has been used to describe elephant home ranges, habitat use and preferences, and ranging patterns, seasonal use of habitats, effects of disturbance, and to describe the dynamic relationships between clans, herds and individuals (Douglas Hamilton and Krink 2001, De Boer et al 2000, Douglas-Hamilton 1998, Lindeque and Lindeque 1991, Viljoen 1989, Thouless 1995, Thouless 1996, Whyte 1993). These studies have revealed that elephant movements in African savannas are variable. In Lake Manyara, Tanzania, elephants occupied small home ranges some few tens of square kilometers (Douglas-Hamilton 1974, while in north western Namibia elephant home ranges extended some 10,000 km^2 (Lindeque and Lindeque, 1991). In northern Kenya, Botswana and in northern Cameroon, elephants utilize their range in a highly seasonal manner (Tchamba et al. 1994, Thouless, 1995, Verlinden and Gavor 1998). When combined with detailed habitat information, human effects and environmental information, these data can be used to describe how elephants utilize their habitats, the structure of home ranges, and differences in bull areas and family areas.

Radio-tracking of elephants has traditionally been conducted using the conventional VHF system (Whyte 1994). The traditional VHF system has been described in detail in Amlaner and Macdonald (1980). This system in forests has limited use due to attenuation of the signal by vegetation, and in hilly areas, signals can be reflected off topographic features leading to inaccuracies (Whyte 1996). Tracking from the air can reduce these errors, but this is expensive as it requires that an aircraft is regularly available to obtain every fix. The use of satellite radio-tracking is gaining currency for tracking elephants as this system has one important advantage over the conventional system; multiple data points can be stored and retrieved remotely. The LOTEK GPS radio tracking system receiver has a built in capacity to store over 3,500 data points and it can be programmed to search for the elephant at specific time intervals. In addition this system also records temperature and activity. It is described in detail in LOTEK Engineering Inc. (1997), (see also Douglas Hamilton (1998) and Blake et al. (2001)).

Since this is one of the first LOTEK GPS tracking studies of *L. africana* in forests, the performance of the system is discussed and compared to conventional radio-tracking. The study was conducted in the Shimba Hills ecosystem of south eastern Kenya. The site includes the Shimba Hills National Reserve (SHNR), the Mwaluganje Elephant Sanctuary (MES) and the Mwaluganje Forest Reserve (MFR) which comprise a fault mountain range with steep slopes and a plateau. The vegetation comprises a mosaic of closed forest to open grasslands and will be described in detail in Chapter 5 (see also Chapter 2). This radio tracking study was initiated as part of a study of elephant-habitat interactions, to understand ranging patterns and habitat use by elephants in a small protected area. The confinement of this population of elephants has raised conservation concern regarding impact on these unique forests (Hoft and Hoft 1995, Davies 1993), however the activity and movements of elephants have been difficult to study due to the vegetation cover and logistical impediments of accessing much of the range due to the hilly and wooded terrain.

The purpose of this study was to describe the home range size and shape, habitat use and movements of elephants in the Shimba Hills ecosystem, and to compare between bulls in bachelor groups with family groups were explored. Correlates between temperature and activity were examined. Radio-tracking was conducted using both conventional VHF collars and LOTEK GPS satellite radio collars, and additional observations of elephant behavior were also gathered.

Methods

Movements and home range

Two bulls and two cows were fitted with standard VHF radio telemetry system in 1995, and two additional elephants, one bull and one cow were fitted with LOTEK GPS satellite system in 1998. Home ranges were described for all six elephants and the relationship between temperature and activity were described for the bull and cow with LOTEK collars. These data were used to interpret independent observations of the diurnal behavior of elephants observed over an extended period. Since night time observations were not possible, the GPS satellite information was the only means by which to interpret elephant nocturnal activity.

VHF radio-telemetry

On January 10th, 1995, four elephants were immobilized from a helicopter and fitted with VHF radio-collars. The procedure was handled by Ted Goss who also piloted the helicopter, and the KWS veterinary service. A female (Freq no. 8) was a member of a family of 7 that was often observed in the central Shimba plains around the Longomwagandi Forest on the Shimba Plateau. Female 2 (Freq no. 2) was darted in southern Shimba in the center of dense forest. She was a matriarch in a family of 5. The two adult bulls (Freq no 4 and Freq no. 6) were darted in the MES which is a lower lying area between the SHNR and MFR. They were collared in bushed grassland. No difficulties were experience during the collaring.

Locations of all elephants were established from the air at approximately 2 week intervals however, data collection was halted after 6 months due to lack of access to aircraft. Attempts to locate the elephants from the ground using a hand held receiver were mostly unsuccessful due to terrain and logistics.

LOTEK GPS radio-collars

On May 10th 1998, one bull and one cow were immobilized and fitted with GPS radio - collars. The darting operation was uneventful (see Appendix 1). Attempts to download data were made approximately every 3 months. Due to high cost of the satellite collars (US$ 8,500) only two collars were available for this study as part of the broader study of elephant movements in different habitats in Africa. To document diurnal behavior, and to test the performance of this system, the collars were programmed to obtain fixes every hour for the first month, and this was then re-set to 3 hourly intervals to prolong the life of the collar. The collars were expected to function for 12 –18 months.

In addition to gathering position data, these collars also recorded elephant activity prior to each fix through vertical and horizontal motion sensors. The activity could reflect feeding as well as walking and though no calibration of activity was undertaken during the study, it is assumed here that lulls in activity reflect reduction in activity when elephants are resting. Sensors also recorded air temperature at each fix, however, as a result of an oversight, these sensors were not calibrated at the time they were fitted and therefore the data may not be accurate. To allow for direct comparisons between collars, minimum temperatures recorded were set to 20°C at 7:00 am based on average climatic records.

The data obtained included the activity level of the elephant, the environmental temperature and the location. Prior to downloading information, the collar was located using a traditional VHF receiver on an aircraft. Data were downloaded using a UHF modem link to a lap top computer and the collar RAM was cleared and the system was reprogrammed.

Observations of elephant daytime activity

Observations of elephants were used to infer habitat use at different times of the day. Sightings of elephants were collected independently in the Shimba Hills and in the Mwalguanje Elephant Sanctuary. Data were collected opportunistically during daylight hours (from 6.30 am to 7 pm) between 14th August 1995 to the 3rd November 1996 in the Mwaluganje, and from 3rd March 1991 to 17th October 1993 in the Shimba Hills. Climatic influence on movement and activity were inferred from climate data reported in detail in Chapter 2. For each elephant group observed, the date, location, time, group size and composition, activity, habitat and direction of movement were recorded. In the Shimba Hills, observations were made while conducting from a vehicle in the protected area. In the MES, observations were made from the Golini Ridge which overlooks most of the sanctuary, from the vehicle and from the ground.

Results

Radio-tracking success

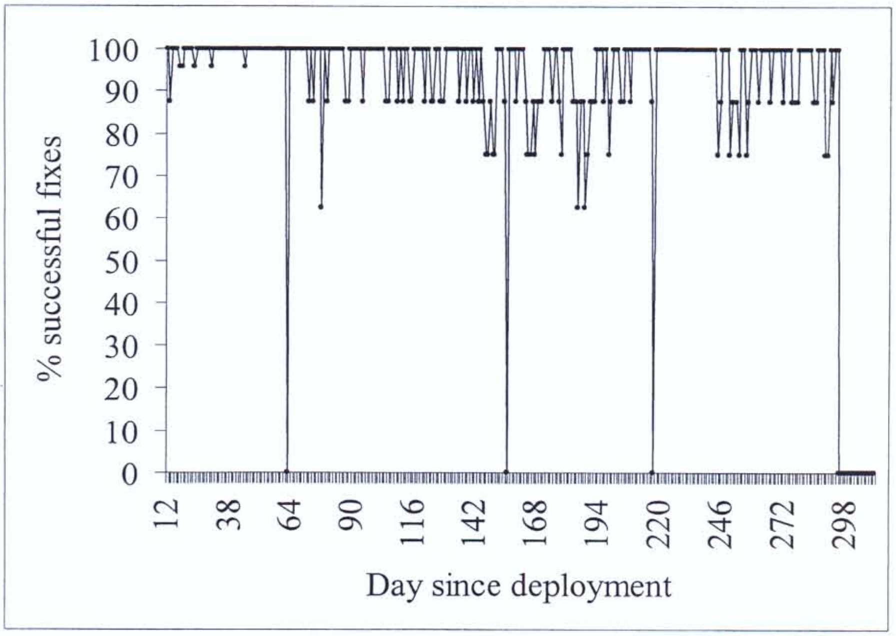
The four VHF collars generated limited information due to logistical problems. Only six months of data were obtained due to aircraft limitations. The results are interpreted with caution due to the small samples and short time intervals. Only ten data points were obtained for each of the 4 elephants.

The LOTEK GPS system was less disappointing although collar life was much shorter than expected (particularly in the case of the bull which functioned for only 1.9 months, the cow collar operated for 9.3 months). The collars were downloaded successfully twice, and 3,739 data points were downloaded. The collars reliably attempted to acquire fixes on the set frequency, and success rates of fix acquisition was 90% for both collars (see Table 4.1 and Figure 4.1). The proportion of 2D fixes (latitude and longitude) versus 3D fixes (latitude, longitude and altitude) were similar in both collars. Both collars stopped functioning prematurely. There was some decline in function in the days prior to complete failure in the bull collar, but not the cow collar. After these collars failed, several attempts to communicate with them were made by helicopter and fixed wing aircraft but without success. The cow has since been sighted and her collar appeared to be correctly placed. The bull has not been sighted again.

Elephant	2D Fix	3D Fix	No Fix	Total fix acquisition attempts
Cow Justina (%)	1165 (42.3)	1479 (53.7)	108 (3.9)	2753
Bull Ted (%)	467 (47.4)	433 (43.9)	86 (8.7)	986

***Table 4.1**. Summary of fix acquisition success for cow and bull collars*

a)



b)

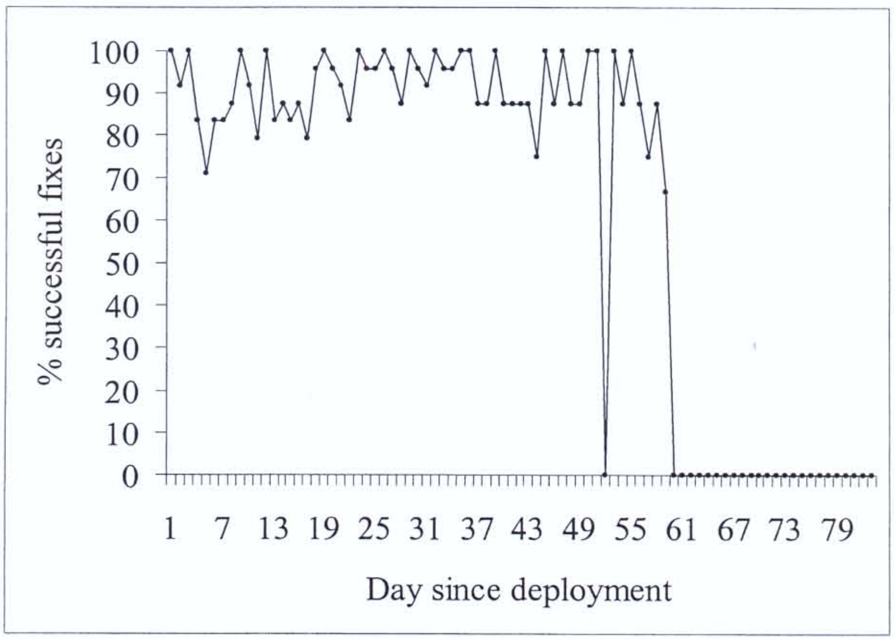


Figure. 4.1*. Fix acquisition success rate (% 2D and 3D fixes combined) for a) cow collar from 10th of May 1998 to the 15th of February 1999, and b) bull collar from 10th May to 8th July.*

Elephant movements and home range

Elephant home range were illustrated in Figure 4.2. The three bulls utilized the Mwaluganje Forest Reserve and Elephant Sanctuary throughout the period that they were tracked. One of the bulls with a conventional collar also moved into the SHNR making at least one foray south to central Shimba plateau and Longomwagandi Forest and grasslands. The other bull was recorded far outside of the protected area amongst farms east of the MFR. The bull with the LOTEK collar did not move far from the location of collaring. Between 11th May 1998 and 7th July 1998 this bull, 'Ted', remained in the MFR and ES area occasionally exiting the protected area through breaches in the fence to the west, though he did not venture far (Figure 4.3). The observation study confirmed that at least six other known bulls also moved south from the ES and MFR into the Marere area and central SHNR and one, sub-adult bull known from the SHNR was observed to leave the area and take up residence in the MFR/MES.

Two of the cows fitted with conventional collars also showed fidelity to the sites that they were collared. Cow No 25 (R family) was restricted to the Marere and central area though she ventured northwards into the southern part of the ES but was never recorded further north, in the Mwaluganje forests. No. 25's range did not extend as far south as or beyond Makadara forest in the SHNR. She was almost always located in heavily wooded areas on steep slopes of the western escarpment. She was also observed many times with her family in and around Longomwagandi Forest. Cow No. 7. was collared in Mkongani Forest in the south of the SHNR, and remained within the southern forested portion of the protected area occupying a range of 45km^2 (see Table 2,). During a 12 month period, this female was suspected to have made a rapid movement of 20 km into the Elephant Sanctuary where she visited for approximately 3 days in May as part of an aggregation of approximately 150 elephants that moved into the MES for three days before returning to the southern part of the Shimba Hills. Though her signal was detected, she was never sighted and so this could not be confirmed.

Great detail was obtained from the LOTEK collar on the cow Justina who was tracked for 9.7 months, and Ted who was tracked for 1.9 months. Justina's total home range was larger than any of the other elephants and duration of tracking reveals that her home range size estimate increased with time from 23 km^2 in the first month, to 94 km^2 eight months later. Her range extended from north east SHNR (the Marere site of the collaring), north into the MES and MFR as well as southwards into central SHNR. Her core areas included the Marere area, the Golini ridge, and the western slopes of the Shimba Hills, concentrating in the north east of the protected area. She did not venture into southern or eastern SHNR, or into the northern MFR forested area. Justina's range encompassed Ted's entire range (see Figure 4.3). Despite this overlap, she appeared to avoid the areas that were most intensely used by Ted. The estimate of home range size using MCP leveled after 8 months (Figure 4.4). During the first two months her range (25 km^2 was much larger than his (11-14 km^2).

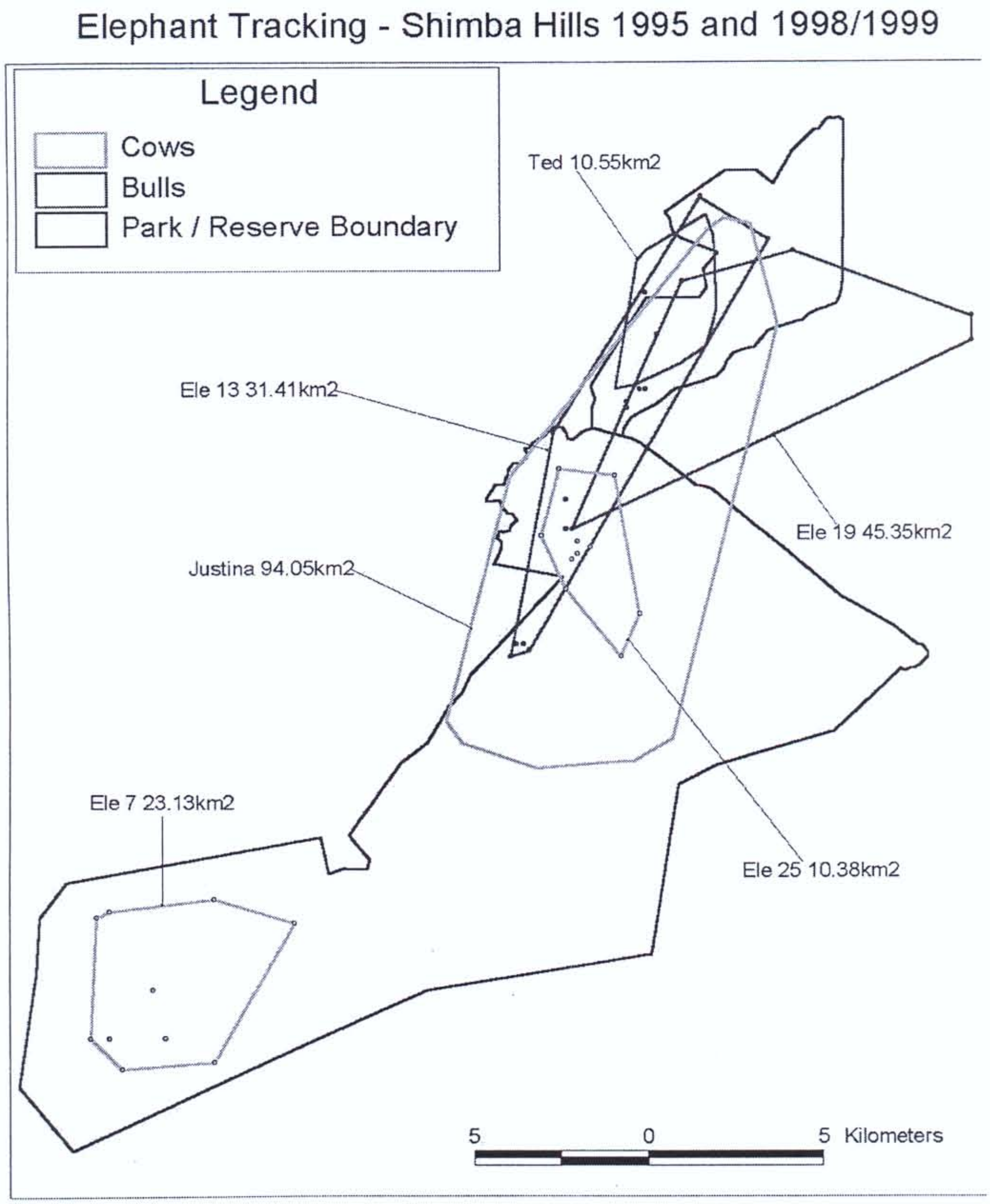


Figure 4.2. *Shimba elephant bull home ranges and cow home ranges.*

	Elephant					
Sex (identity)	Cow (no. 8)	Cow (no. 2)	Cow (Justina)	Bull (no. 4)	Bull (no. 6)	Bull (Ted)
Tracking system	Telonics VHF	Telonics VHF	LOTEK GPS	Telonics VHF	Telonics VHF	LOTEK GPS
Location collared	SHNS Marere	SHNR Mkongani	SHNR Marere	MES	MES	MFR
Date collared	10-Jan-1995	10-Jan-1995	12-May-1998	10-Jan-1995	10-Jan-1995	11-May-1998
First data date	10-Jan-1995	10-Jan-1995	May-1998	10-Jan-1995	10-Jan-1995	05-Nov-1998
Last data date	14-Jun-1995	14-Jun-1995	15-Feb-1999	14-Jun-1995	14-Jun-1995	07-Jul-1998
Duration (days)	155	155	279	155	155	57
Area used (MCP) Km^2	23	45	94	31	10	11
Area used (Grid) Km^2			35			14

***Table 4.2**. Home ranges of Shimba bulls and cows*

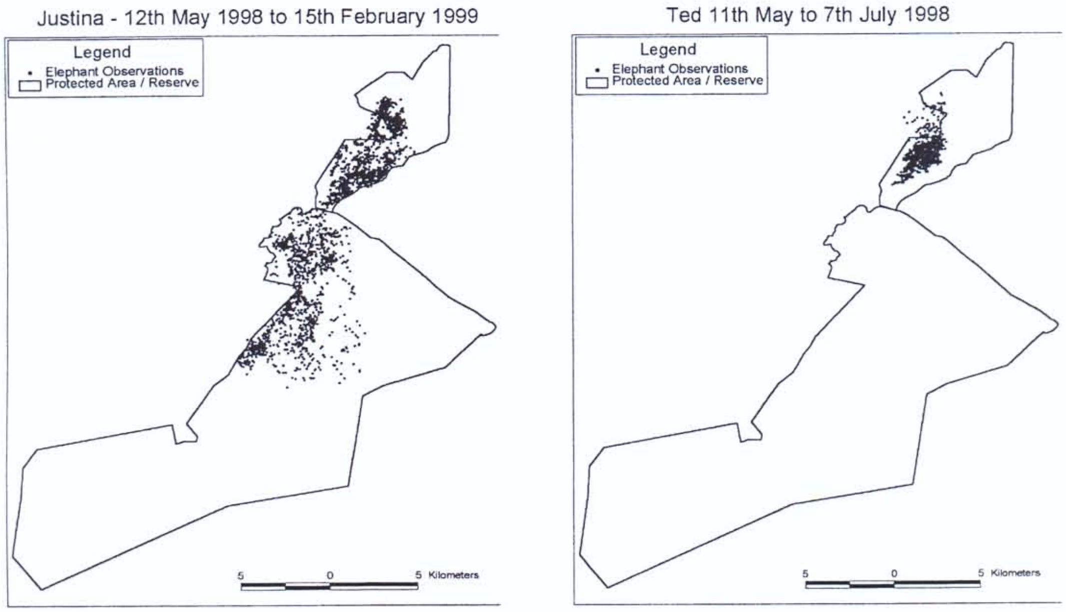


Figure 4.3. *Total range use by Justina (9.7 months) and Ted (1.9 months)*

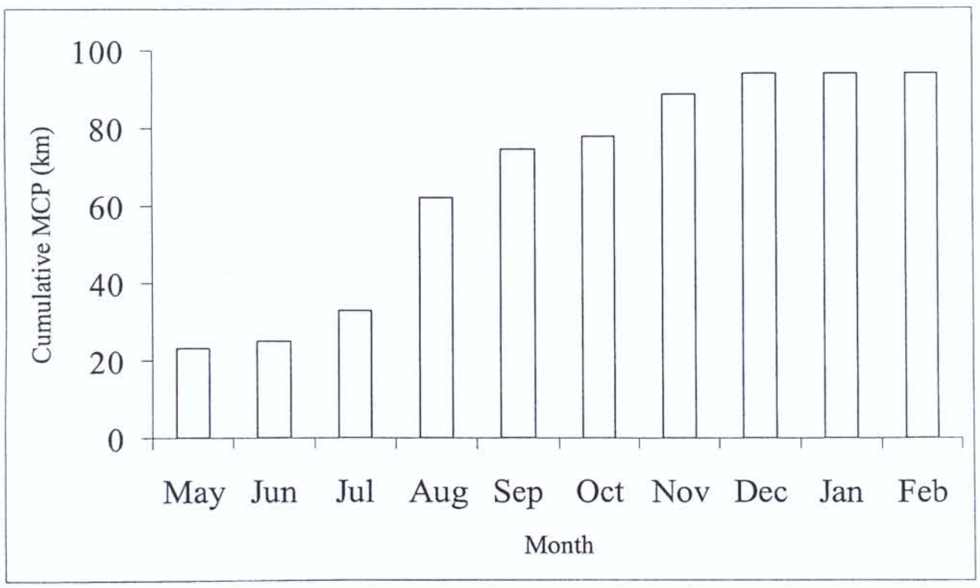


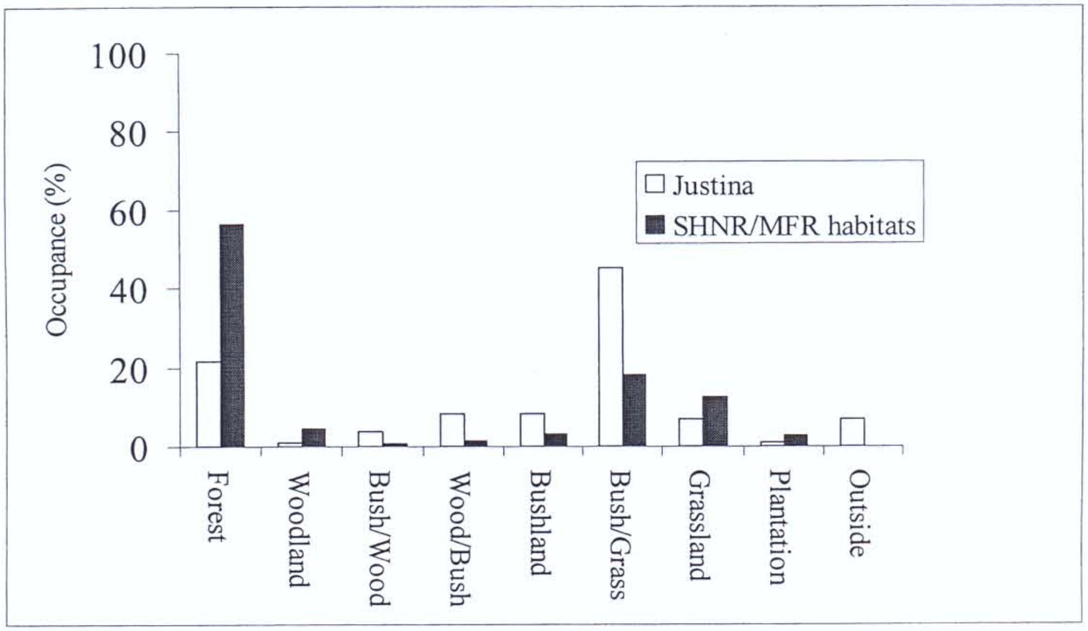
Figure 4.4. *Justina home range size estimate with cumulative data over 10 months.*

Habitat use

Since cows ranged throughout the protected area, habitat use was compared with availability throughout the range. Bulls however, were restricted to the bull area in the MFR and MES and therefore, available range was calculated for this subset of the entire area.

Neither the cow nor the bull used habitats in relation to availability (Chi Square Analysis cow: $\chi^2 = 1173.7$, P<.0001, df=8, bull $\chi^2 = 777.2$, P<.0001, df=8) (See Figure 4.5). Though the GPS system has an inherent error margin of approximately 100m, the patterns of movement and habitat use suggested real differences in preference. The cow and the bull also used habitats differently. Justina spent only 20% of her time in closed forest, and 35% of the time in all habitats that were wooded (Forest, woodland, bushed woodland and wooded bushland). These habitats occupied 65% of her available range which includes the SHNR, MES and MFR. She used bushed habitats (closed bush, grassed bushland and bushed grassland) 43% of the time, and spent a small amount of time (7%) outside of the protected area near the boundary along the Golini Ridge.

Similarly, the bull did not use habitats in relation to availability but used the bushed habitats more than would be expected over wooded based on availability. He used 8 and 88% of wooded versus bushed habitats even though his range (MES/MFR) had equal availability of these vegetation types. The bull data reflecting only 1.9 months also fell in the rainy season and therefore broad conclusions cannot be made at this point. Day and night patterns of habitat use were similar (Figure 4.6).



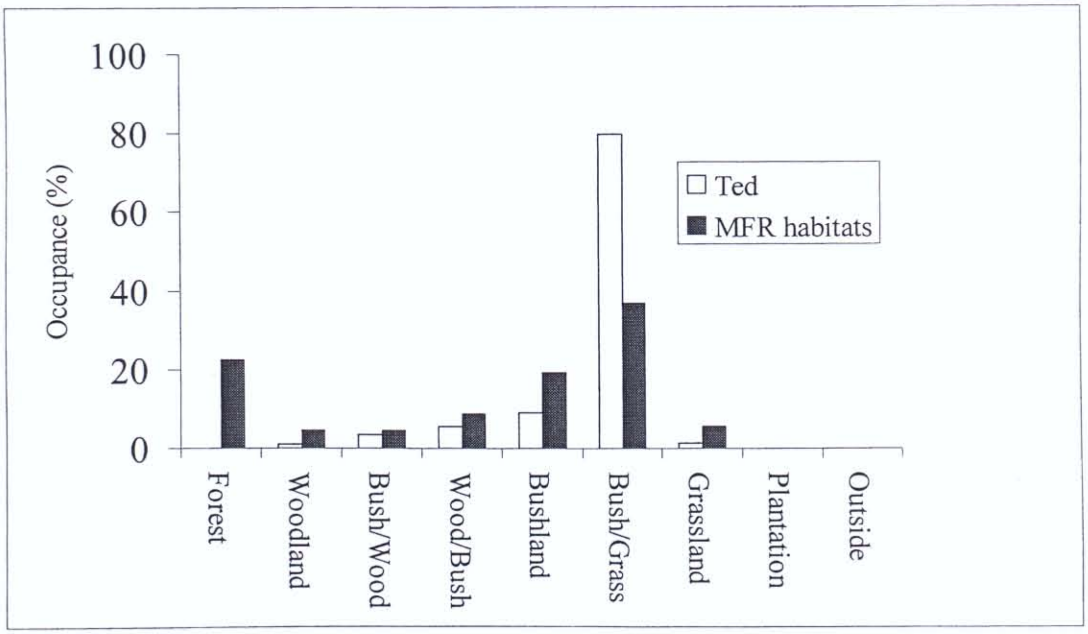
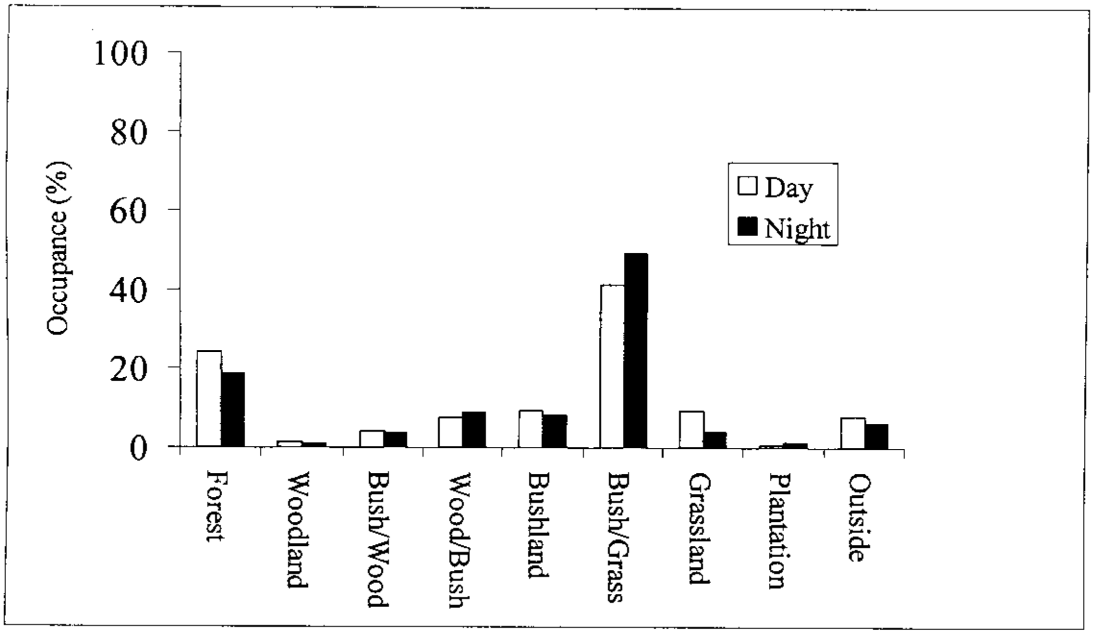


Figure 4.5. *Habitat use and availability by a cow and a bull from GIS radio-tracking*

a) Justina



b) Ted

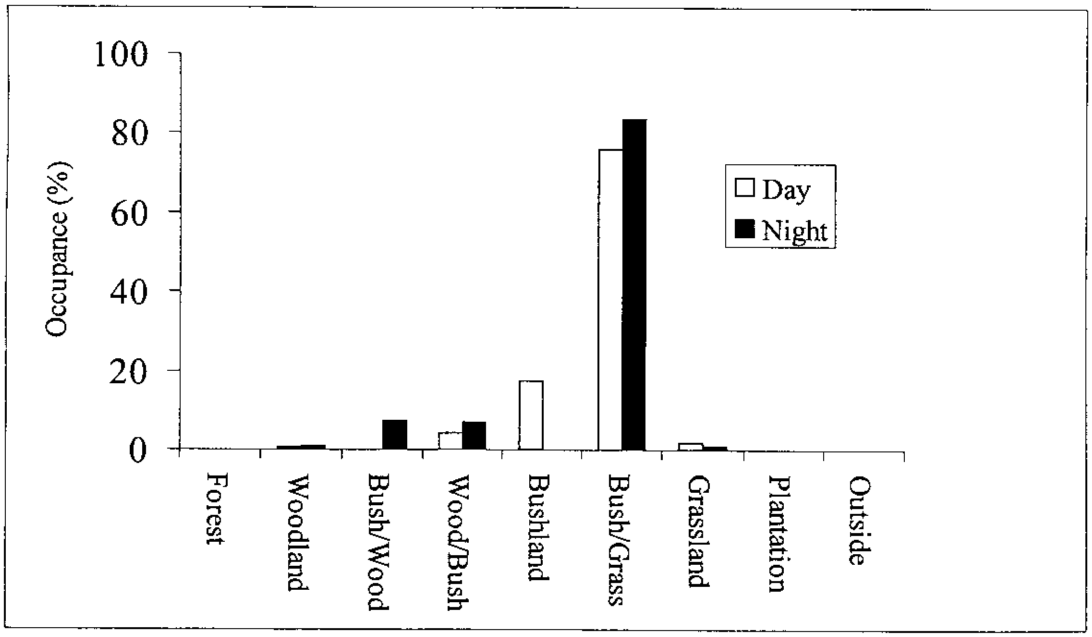


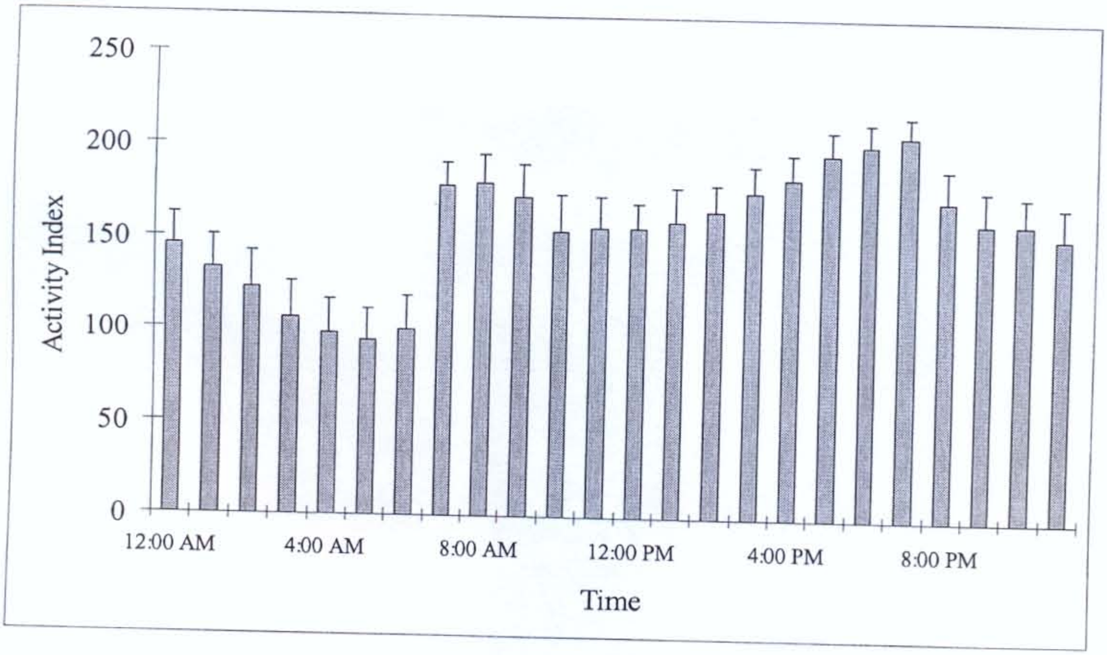
Figure 4.6. *Habitat use between day (8am to 8 pm) time and night time for two elephants a) Justina, b) Ted.*

Daily activity patterns and temperature

Activity and temperature were recorded with location every hour during the first 30 days and every 3 hours thereafter. Marked diurnal patterns in activity were exhibited by both Justina and Ted (see Figure 4.7 and 4.7). Lowest activity was recorded between 4 and 6 am on both collars. In May, Justina's level of activity increased rapidly between 7 and 8 am and she remained active throughout the day. Her activity peaked twice in the day, first at 9 am followed by a period of lower activity between 11am and 4 pm; a gradual rise in activity was followed by a second higher peak at 8 pm. After 8 pm, her activity gradually declined to the lowest levels of the 24 hour period. The bull's activity graph illustrates a similar rapid increase in activity between 7 and 8 am, when activity levels peaked and this level of activity was sustained until 8 pm except for a slight lull at 4 pm. Ted's activity declined rapidly after midnight to a low at 6 am.

Justina's temperature line shows a smooth rise and peak during the day time dropping smoothly to a low after dark to a minimum just before sunrise. Ted's temperature curve in contrast appears truncated and levels off between 12 pm and 4 pm which are the hottest hours of the day. Temperature was positively correlated with activity index for both Justina (Regression Analysis: R^2=.518, N=24, P>.0095) and Ted (R^2=.582, N=24, P>.00287), but not for movement in either of the elephants. A comparison of the difference between the activity and temperatures from the two collars (Justina minus Ted) reveals that Justina was always more active than Ted, but especially between 3pm and 8 pm (Figure 4.9). She also experienced higher temperatures than Ted at all times which was particularly marked between 12 pm and 5 pm.

a)



b)

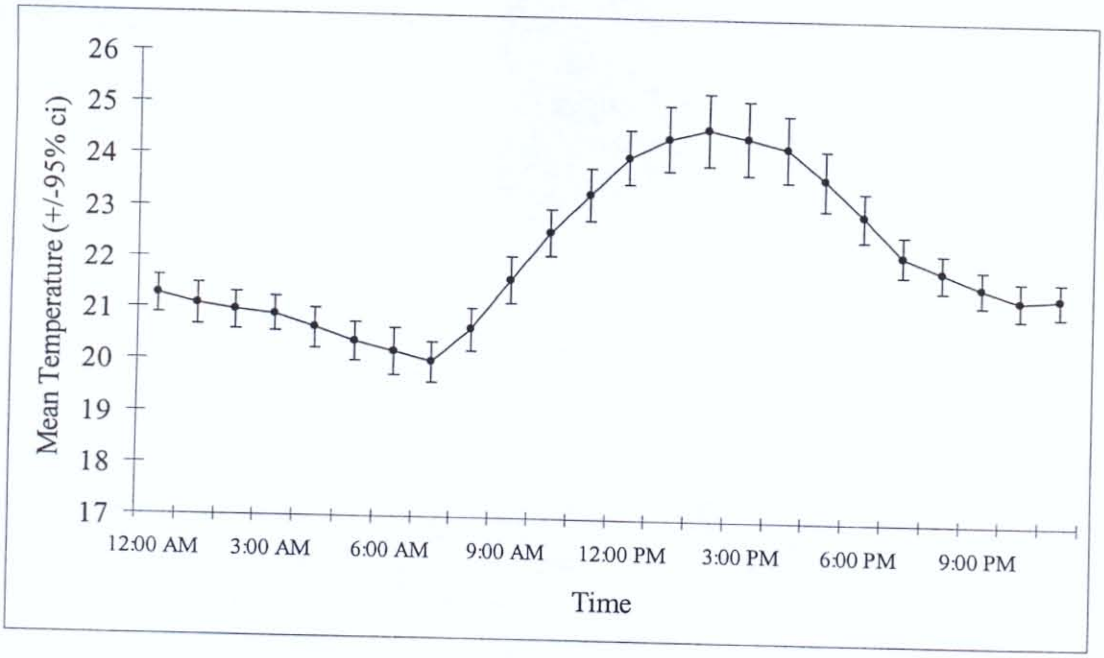
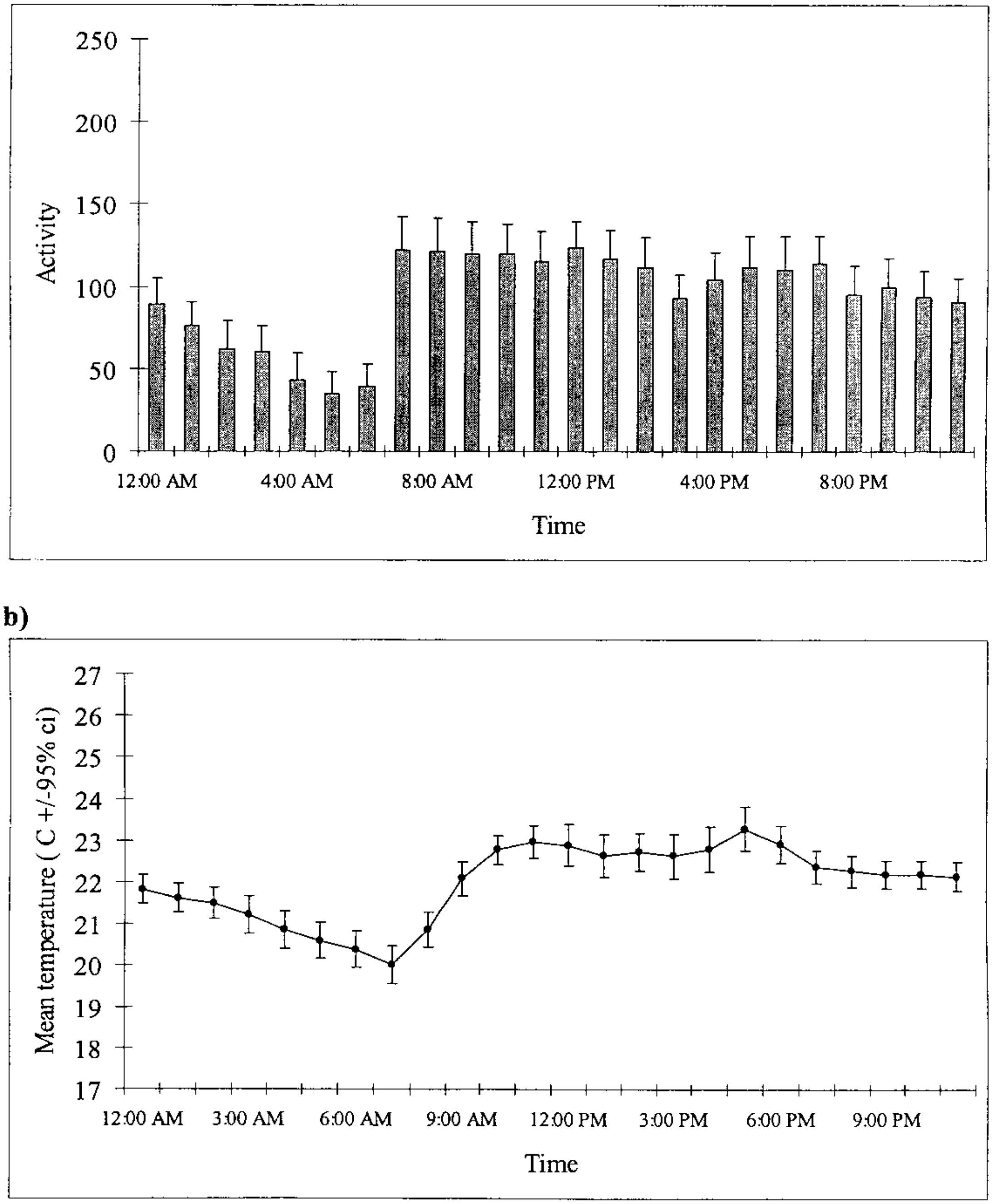


***Fig 4.7. a)** mean activity index and **b)** mean hourly temperature for a cow (Justina) between the 11th of May and the 13th of June 1998.*

a)



b)

Figure 4.8. a) *Mean activity index and* ***b)*** *change in temperature for a bull (Ted) between the 11th of May and the 13th of June 1998.*

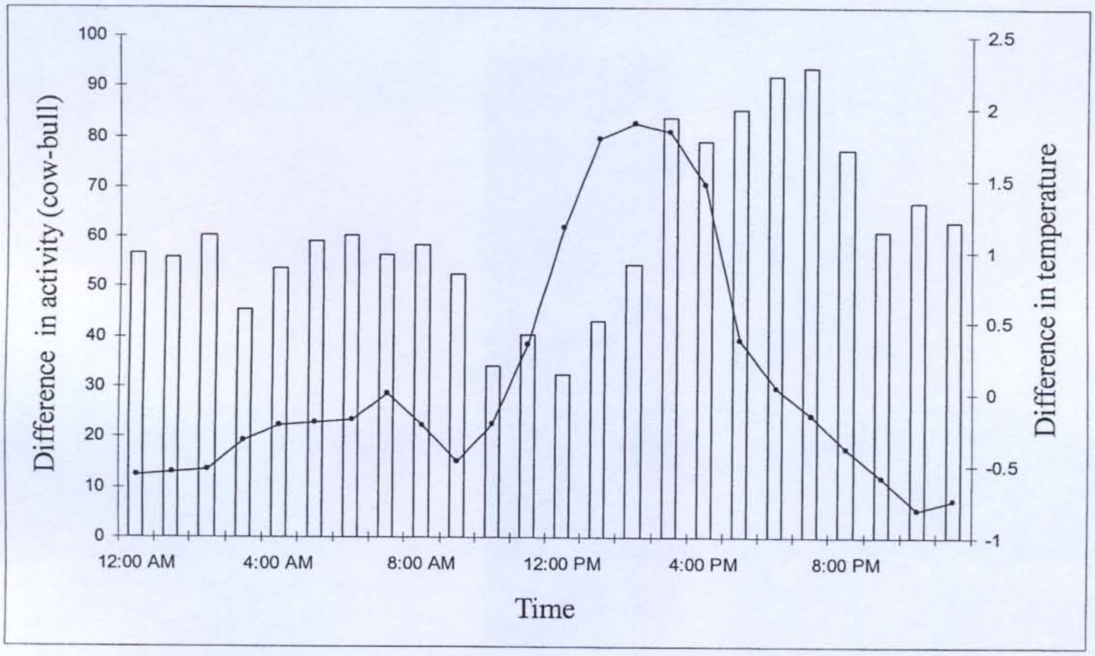


Figure 4.9. *Difference in activity levels and temperatures experienced between one cow and one bull.*

Movements

The total distance traveled per day was calculated as the sum of distances between each hour for each day. These data reveal that the total distance covered by the cow over the duration of 24 hours was 3.88 km (± .105km 95 % ci, n=933) while the bull traveled on average 2.82 km day^{-1} (± .07 km 95% ci, n=391). These figures were based on running averages because occasional collar failure reduced the actual sample size of days with full 24 hour data considerably.

The distance between resting periods from one day to the next, illustrate whether elephants return to the same place on a daily basis, or if they simply wonder through their range. Patterns of daily distances traveled by the two elephants were calculated between the periods of least activity (3 am to 3 am) between May 10th and July 7th. They were both likely to be within one km of their previous position (Figure 4.10). The bull was always within 3 km of his previous position while the cow was sometimes up to 6 km or more away from her previous position (Figure 4.10). The mean distance between resting locations was significantly greater for the cow (mean 1.39 km, range .144-5.43) than the bull (mean .92 km, range .121-2.3) (t=2.8, p (T<=t) .003).

Between the 10th of May and 7th of June Justina moved at a mean speed of 0.14 km $hour^{-1}$ (maximum 1.8 km $hour^{-1}$) compared to 0.11 km/hr (maximum 0.46 km hr^{-1}) for Ted. The cow exhibited two peaks of rapid movement that mirrored activity peaks (Figure 4.11). A weakly positive regression between movement and activity was observed in both (Cow, R^2=.490, p=.000129, N=24, bull R^2=.297, p>.0058, N=24)

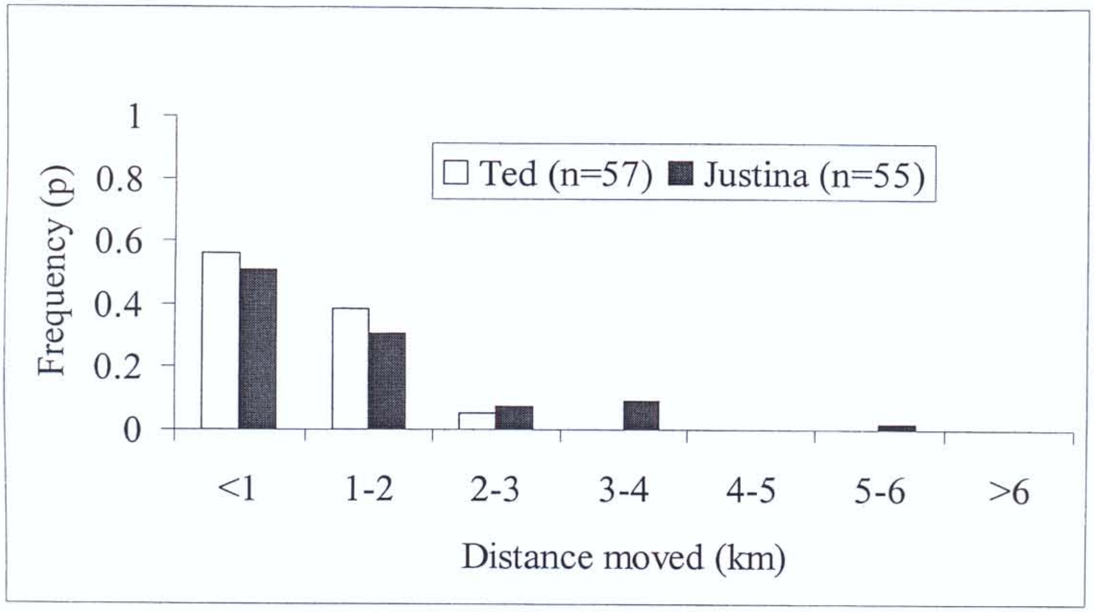


Figure 4.10. *Comparison of distances between locations at 3 am by a bull (Ted) and a cow (Justina) between 10th May and 7th July 1998.*

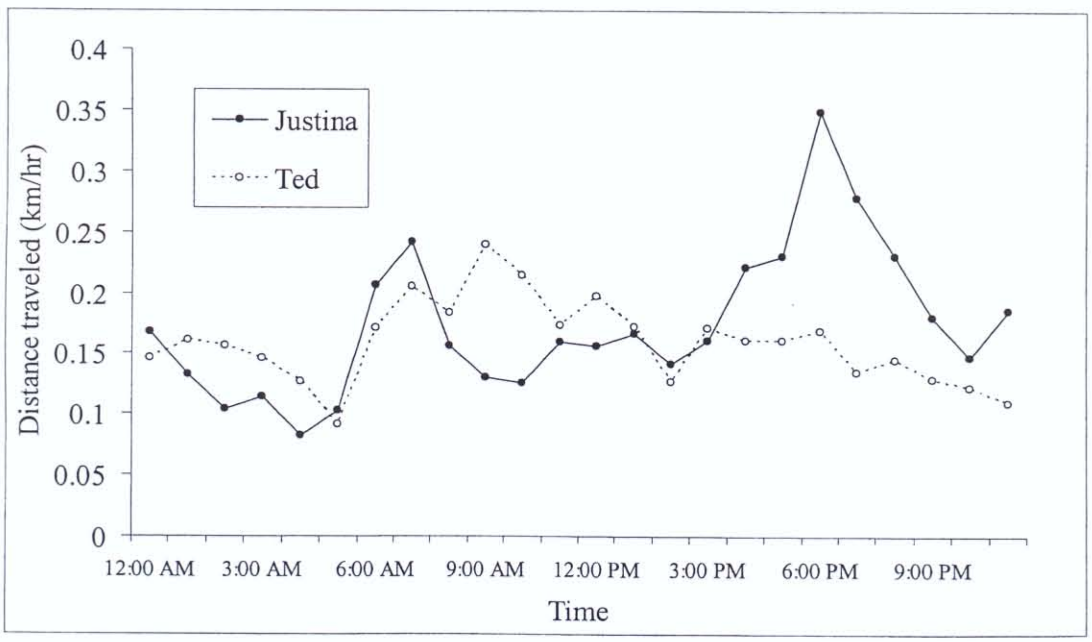


Figure 4.11*. Comparison of diurnal movements for two elephants in May/June 1988*

Seasonal range use, movements, activity and temperature for one cow

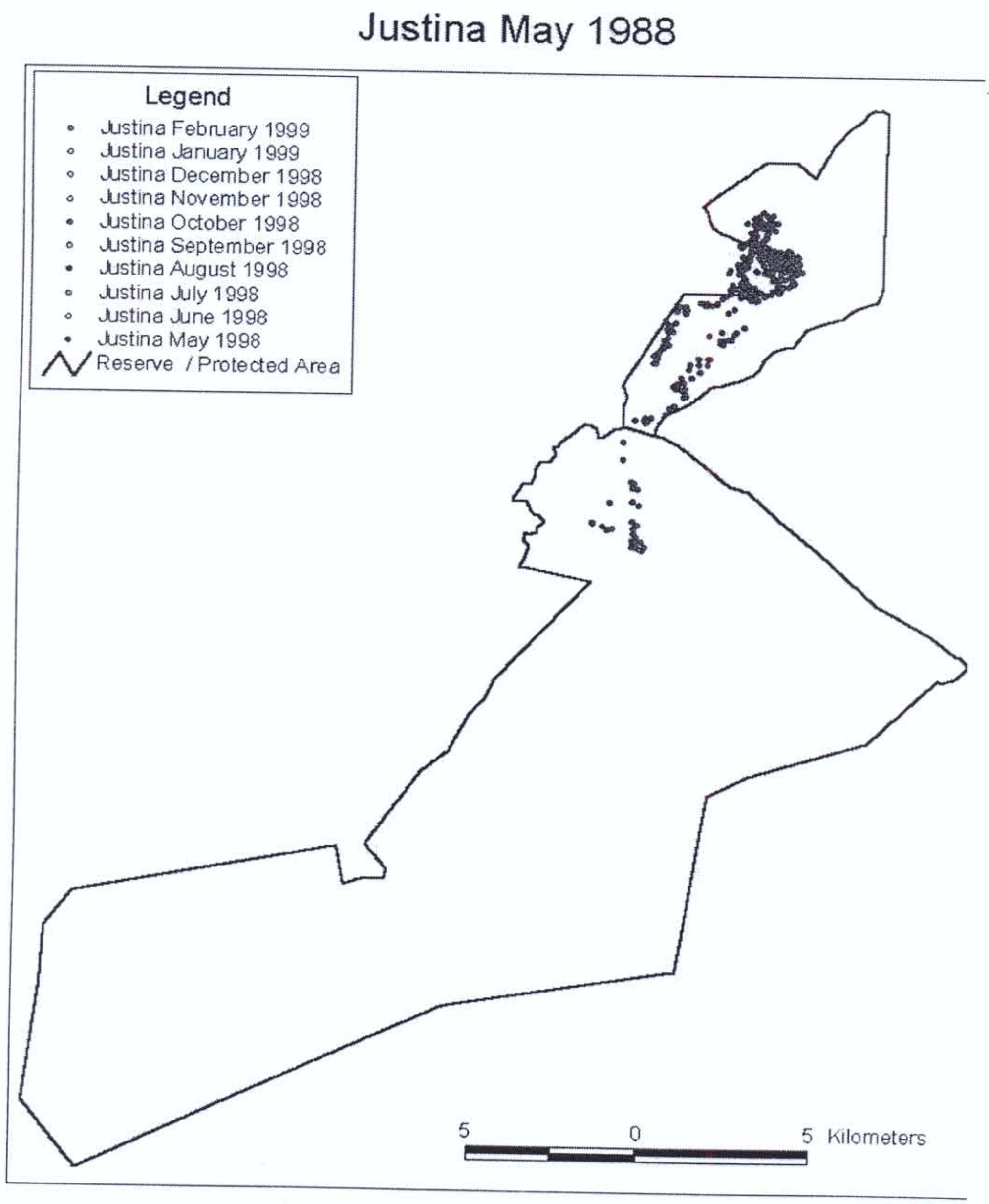
Seasonal movements were described only for Justina over 10 months (see Fig 4.12a-j). After Justina was fitted with a radio-collar in NW SHNR in mid May, she traversed her home range twice in 10 months. She used the MES/MFR during the rainy seasons and the SHNR during hot and dry seasons. Her initial movement was northwards into the MFR which she used exclusively until the end of June. This was during the long rainy season and she moved slowly but deliberately northwards covering only 200-400 m every three hours. Her diurnal activity schedule parallels her movements with the most rapid pace coinciding with the most active periods between 6 pm and 9 pm. It is interesting to note that while moving through the MES, Justina utilized the central area and eastern slopes, and moved mainly at night. Her activity in the MFR was concentrated around a hill, the Kaya Mtae and she never ventured further north into the MFR.

During the long rains (May June), Justina experienced higher than average temperatures (up to 4 ^{o}C above average) comparable only with the high temperatures in December. The daily temperature range was 4 ^{o}C. During July, Justina retreated southwards to the NW SHNR– her retreat was unhurried as she attained speeds of only 500 m every 3 hours in the afternoons and evenings between 3 pm and 9 pm. In contrast, during August, the coolest month, she used a more extensive area and was predominantly in the SHNR. Her movements were more rapid particularly in the mornings between 6 and 9 am and in the afternoon/evening between 3 and 9 pm. Though temperatures during July and August were lower than in the earlier moths, the diurnal range was similar (3.8 ^{o}C). Her activity schedule during these two months did not closely parallel distances moved.

In the months before September, Justina consistently rested between midnight and 6 am, however, by October she was especially mobile and appeared to be moving throughout the day and night, and most rapidly between 6-9 am as well as from 6 pm to midnight. Temperatures were slightly warmer in October than the preceding month and she utilized the Marere and central Shimba range but also made a brief foray to the MES and MFR. Her activity was only slightly elevated from the previous months, and peak activity paralleled movements except in the morning after 6 am when she was moving most rapidly.

In November Justina utilized both the MES and the central Shimba area, particularly the steep western slopes near the fence boundary in forests of Makadara and Pengo Hill. She traveled during the day time and in December (short rains and the hottest month), she returned briefly to the MES and MFR. While in the MES/MFR, Justina moved most rapidly between 6 and 9 am and again after 6 pm. In contrast, in January and February 1999 she utilized only SHNR and her most active periods were during the middle of the day between 9am and 6 pm. The temperature range between the hottest month (December), and the coolest, August, was approximately 3 °C. Though her overall activity pattern was similar in both months, she became active earlier (6 am) during the hot season became active earlier (6 am) compared to the cool season (9 am). Her first activity peak occurred at the same time of the day during both seasons, but she maintained a high level of activity during the mid day in August. The second peak in activity occurred at 6 pm in August and 9 pm in December. Her lowest activity was recorded at 12 pm in August and at 3 pm in December.

Figure 4.12 (a)


Justina May 1988
Legend
Justina February 1999
Justina January 1999
Justina December 1998
Justina November 1998
Justina October 1998
Justina September 1998
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Justina June 1998
Justina May 1998
Reserve / Protected Area
5
0
5 Kilometers

Figure 4.12 (b)

Justina June 1988

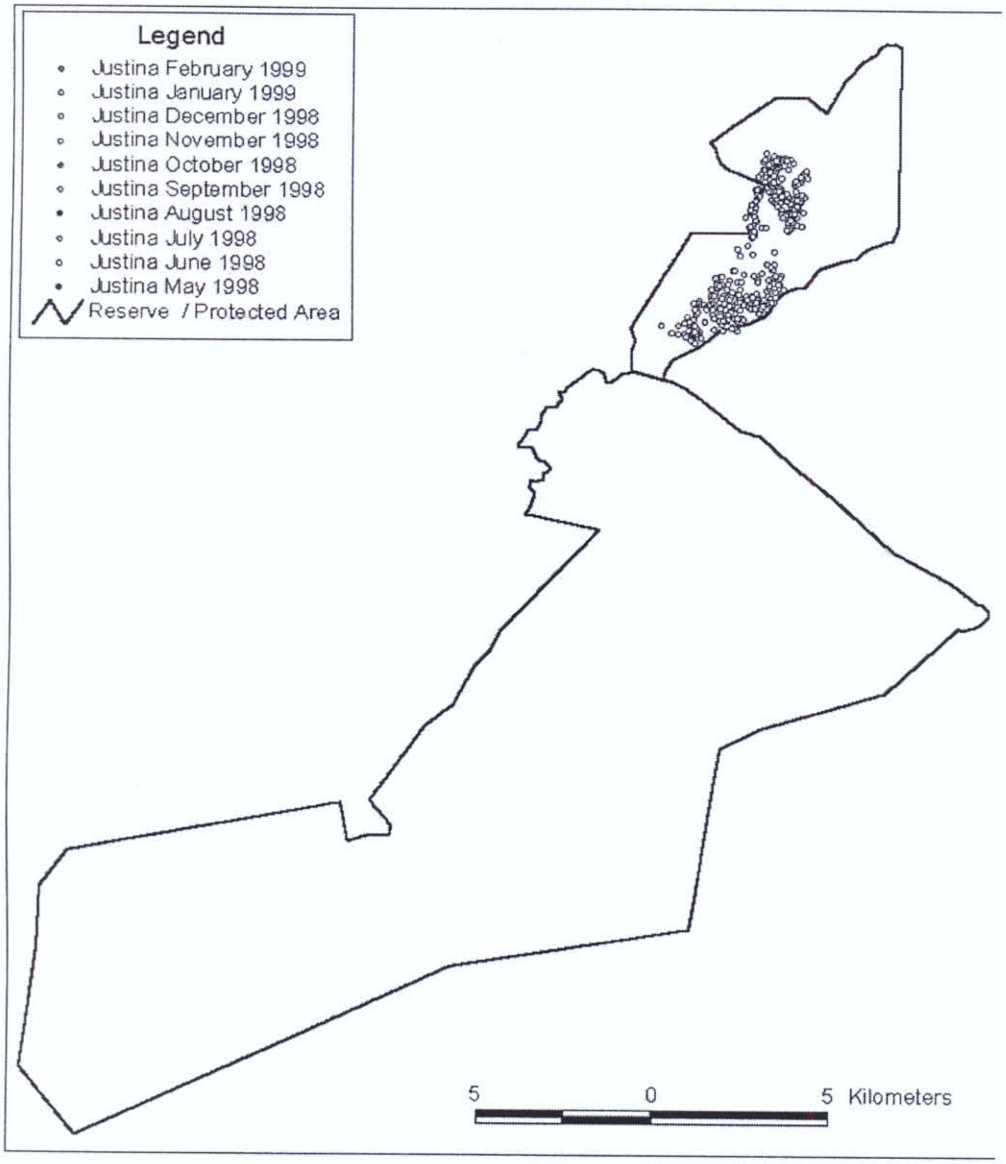


Figure 4.12 (c)

Justina July 1988

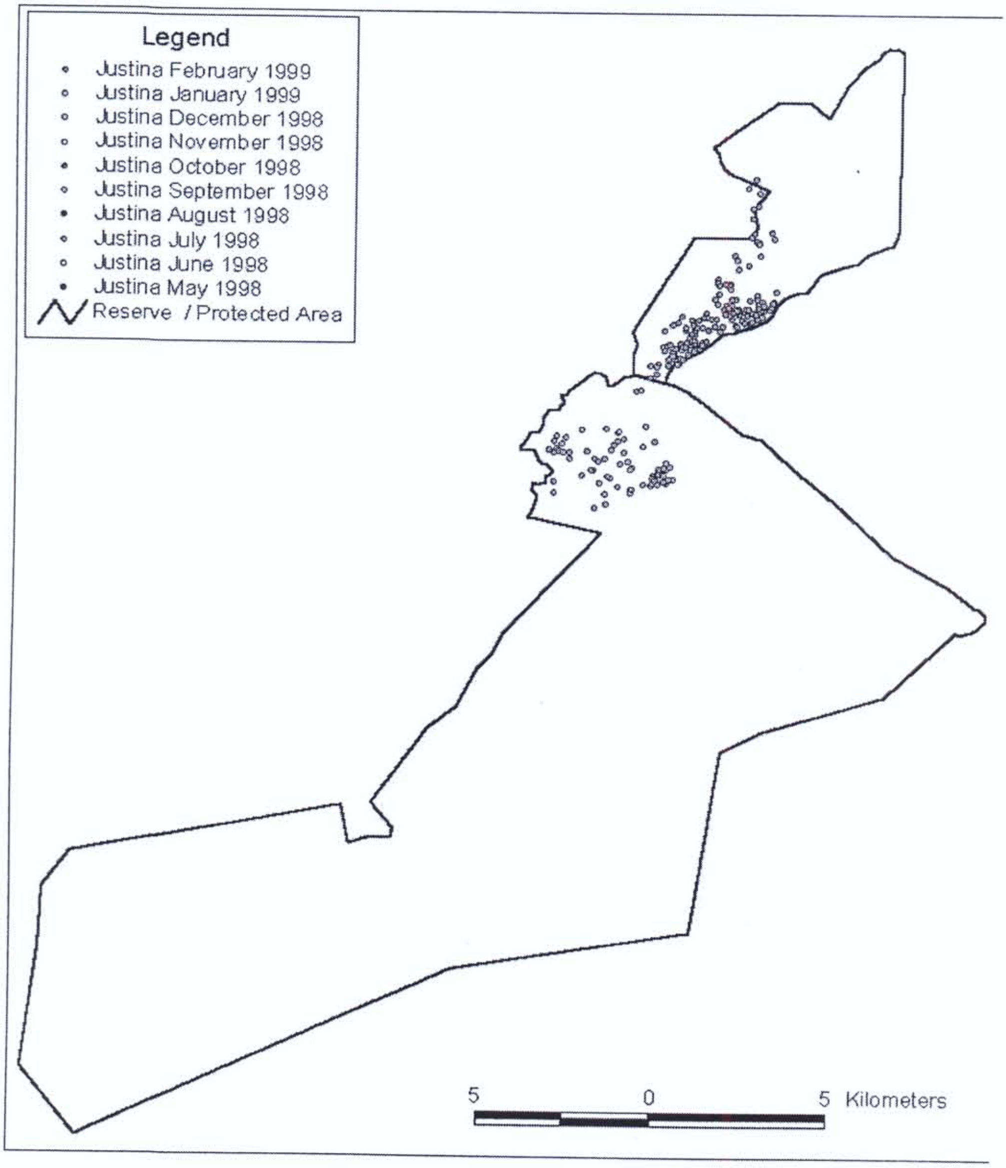
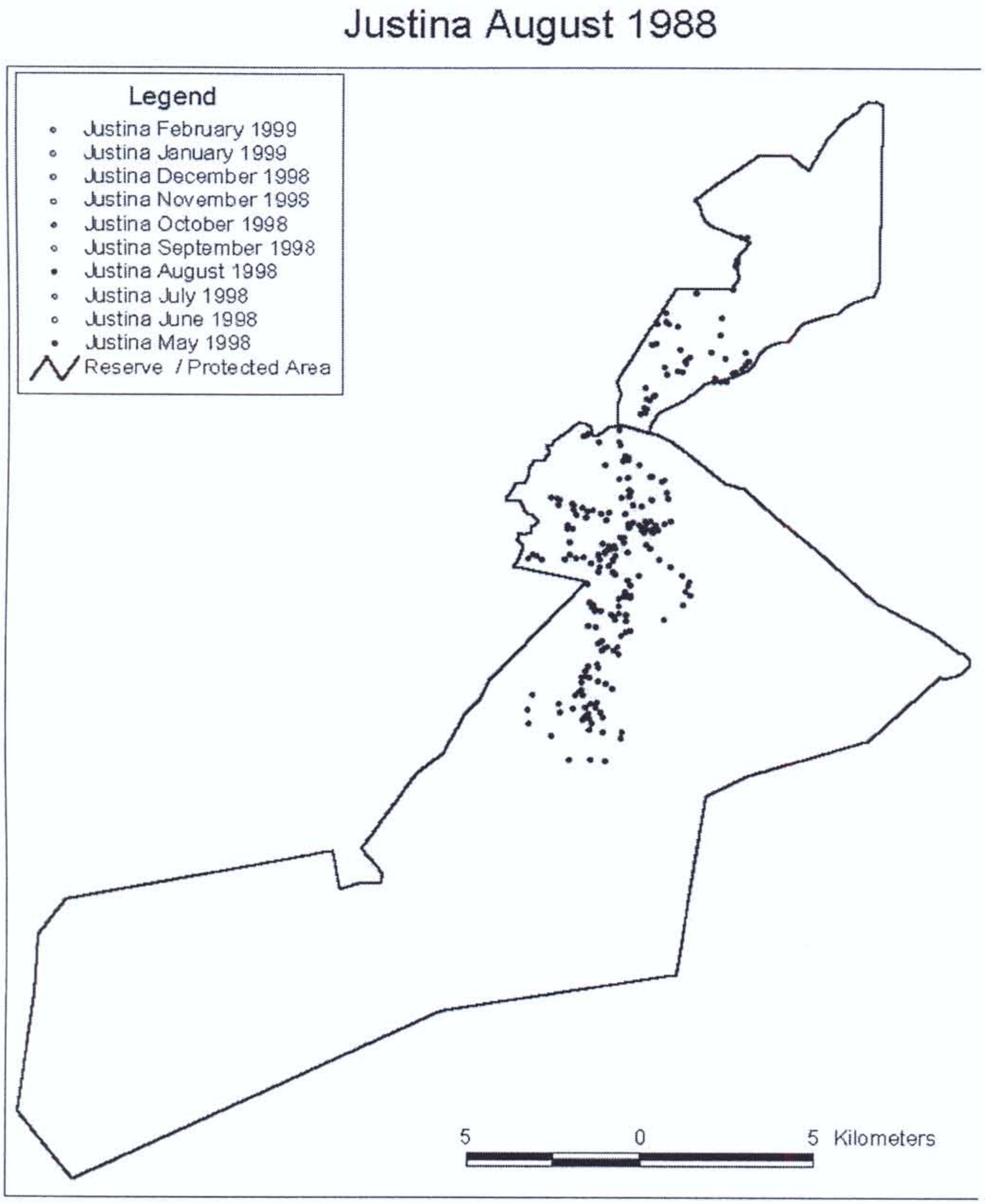


Figure 4.12 (d)



Justina August 1988
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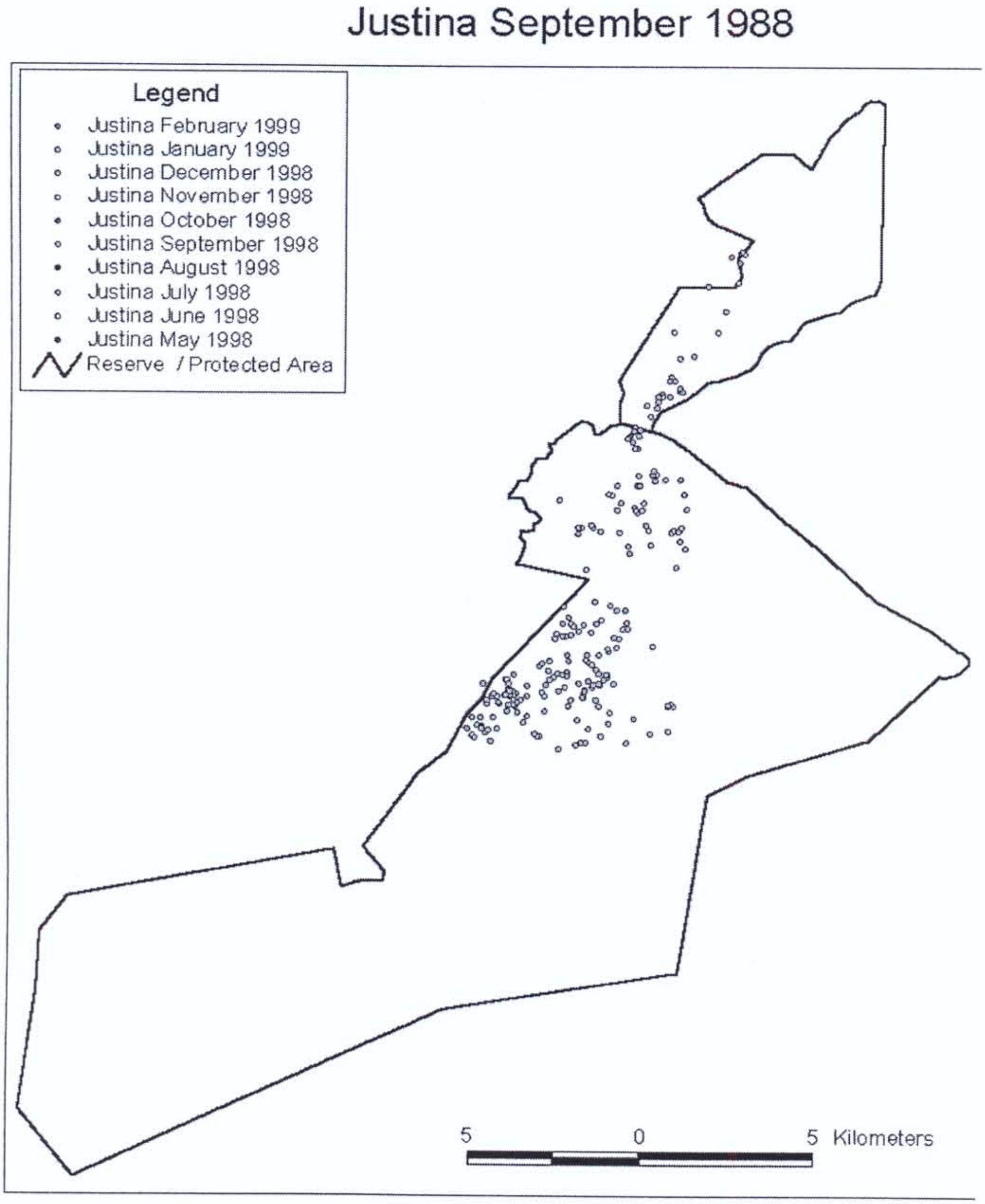
Figure 4.12(e)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Justina May 1998
Reserve / Protected Area
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Figure 4.12 (f)

Justina October 1988

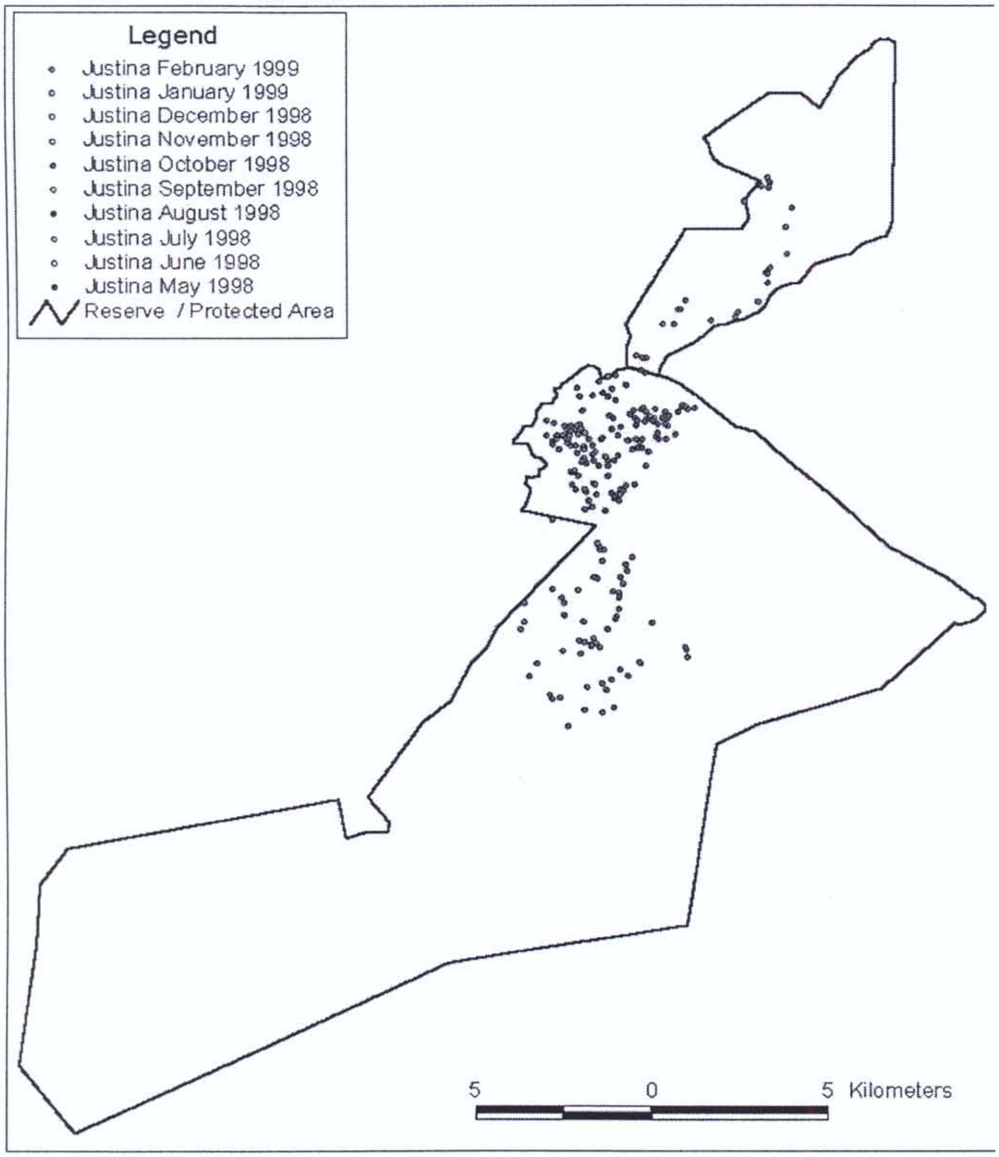
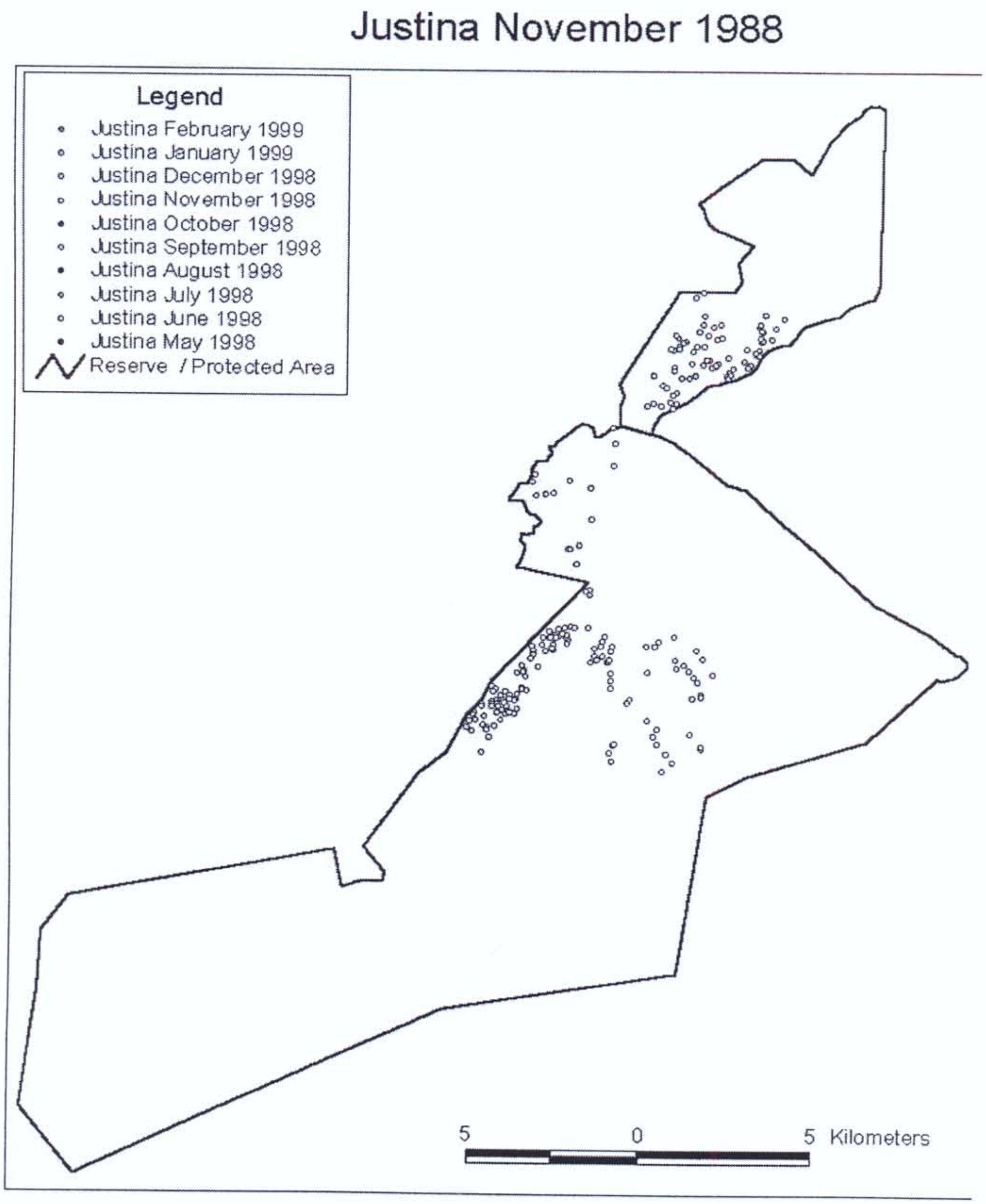


Figure 4.12 (g)



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Reserve / Protected Area
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5 Kilometers

Figure 4.12 (h)

Justina December 1988

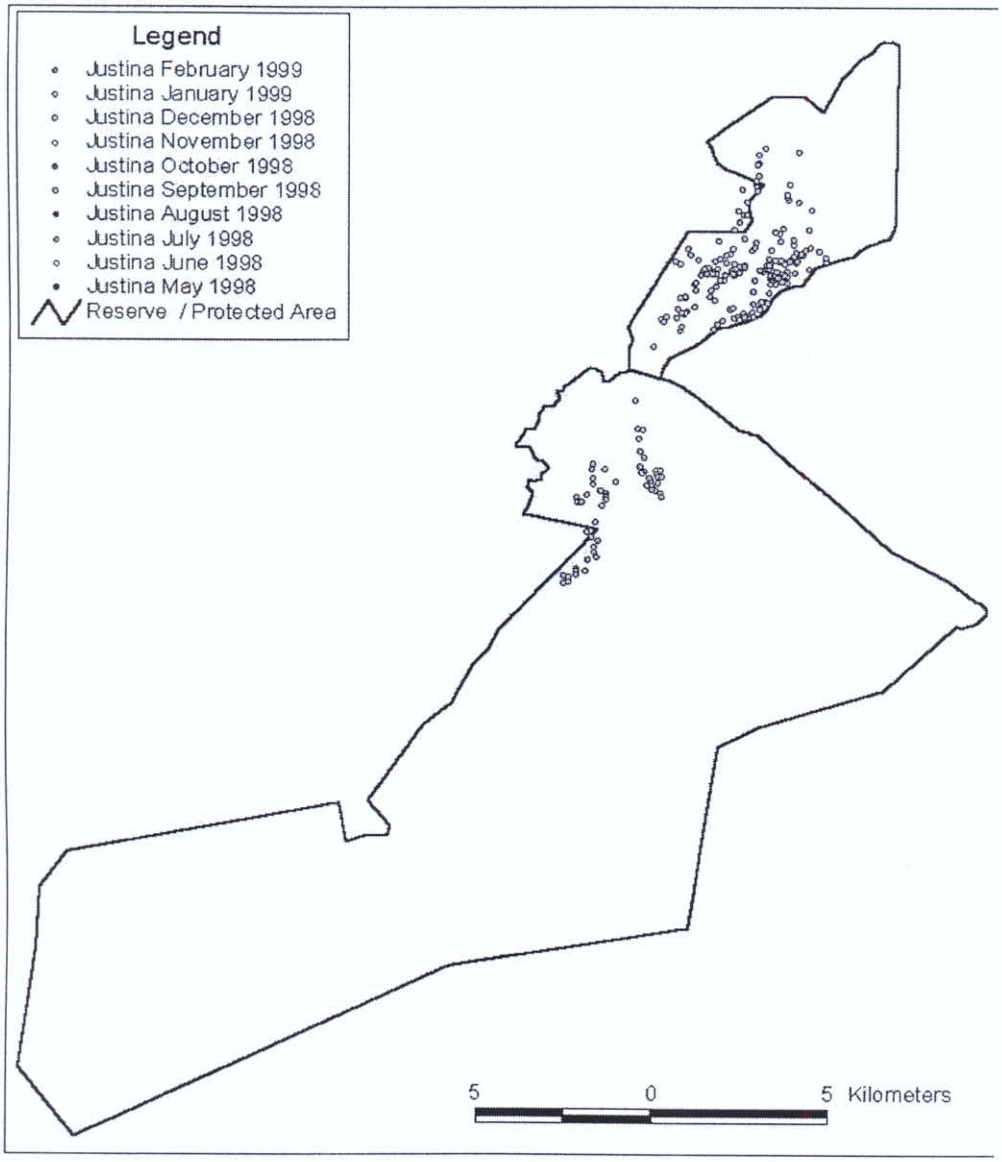
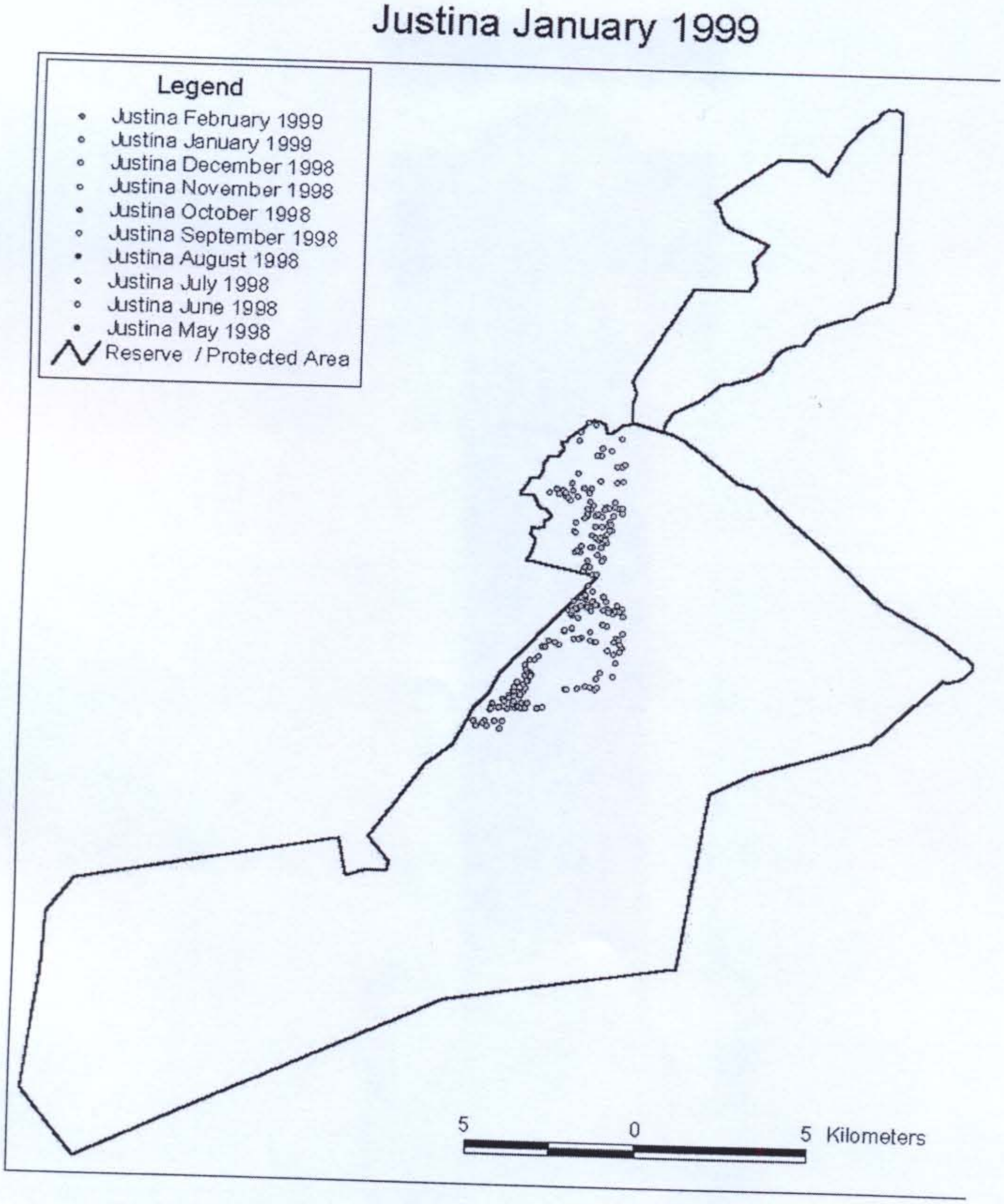


Figure 4.12 (i)


Justina January 1999
Legend
Justina February 1999
Justina January 1999
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Justina October 1998
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Justina June 1998
Justina May 1998
Reserve / Protected Area
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5 Kilometers

Figure 4.12 (j)

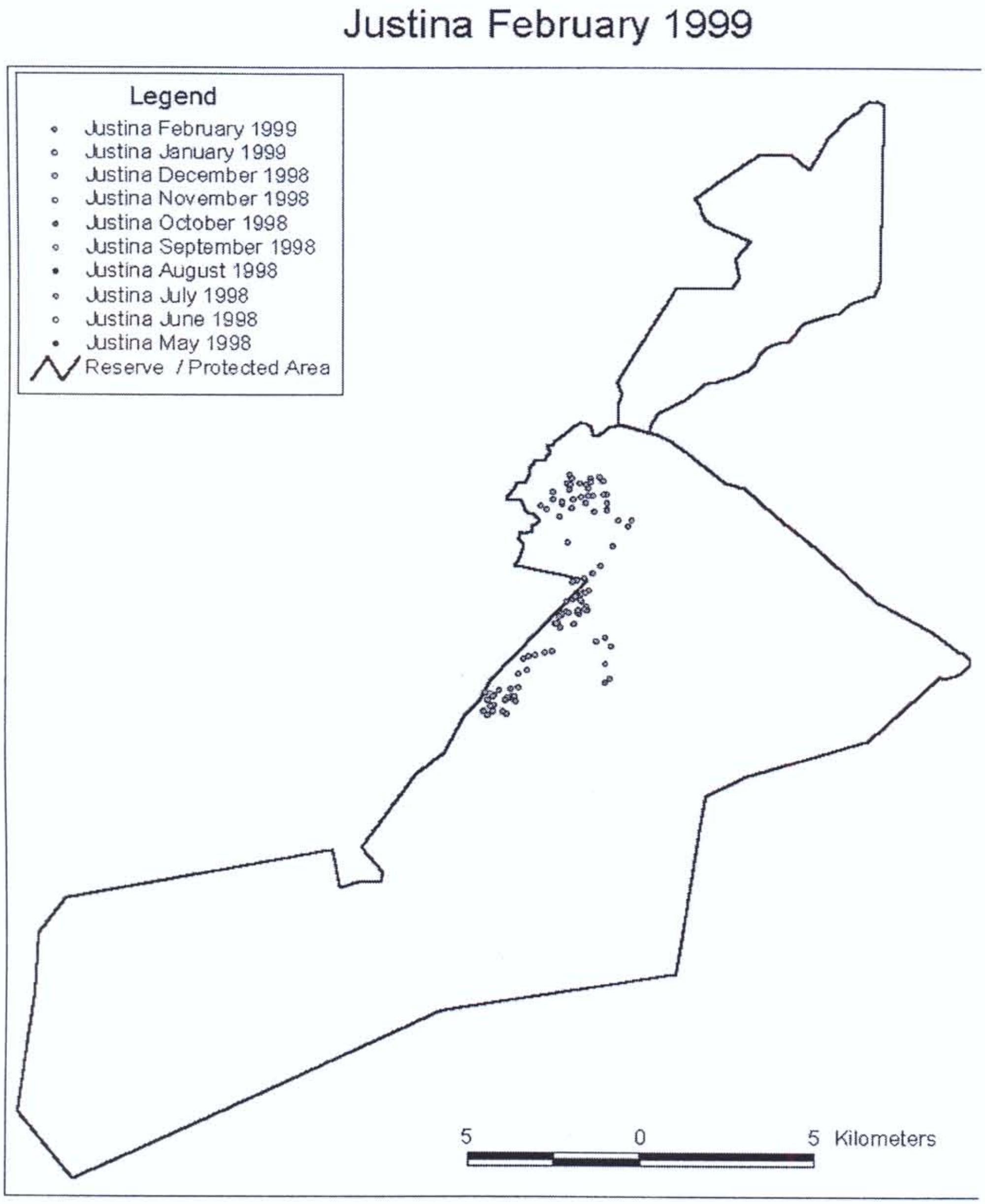
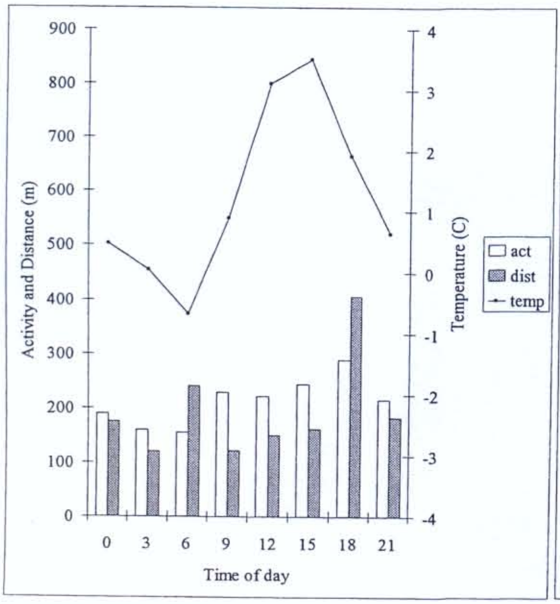
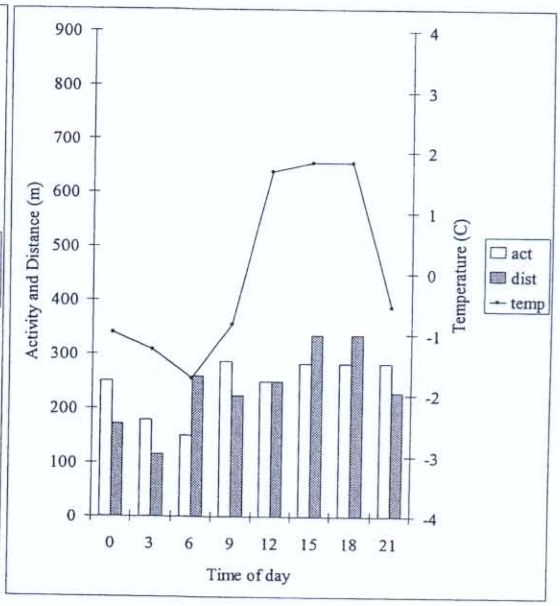


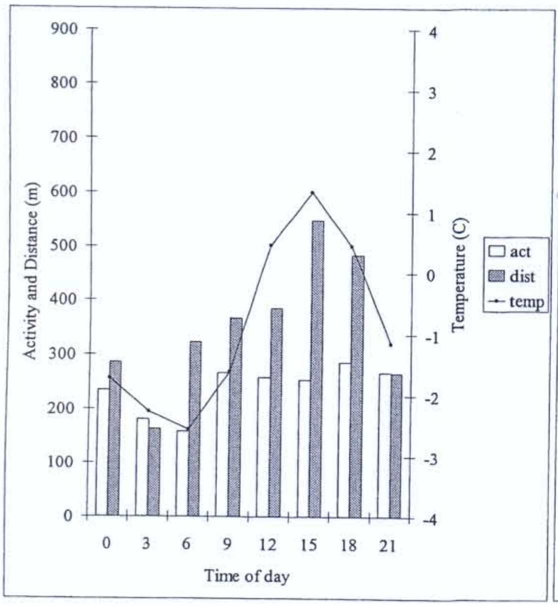
***Figure 4.12 (a-j)** Monthly locations of one cow, Justina.*



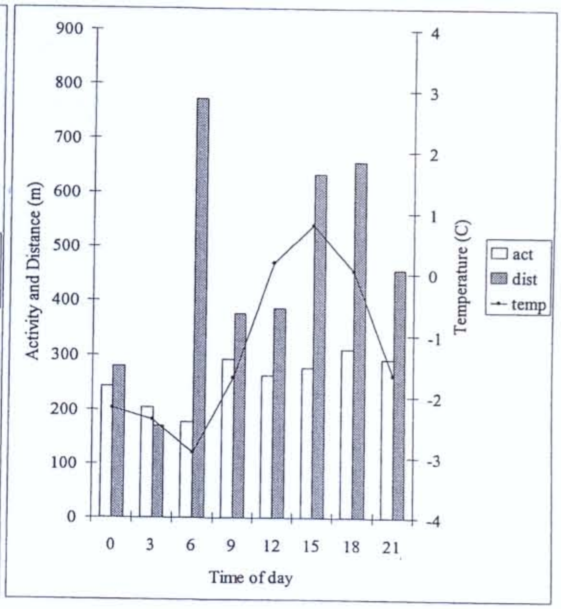
a) May 1998



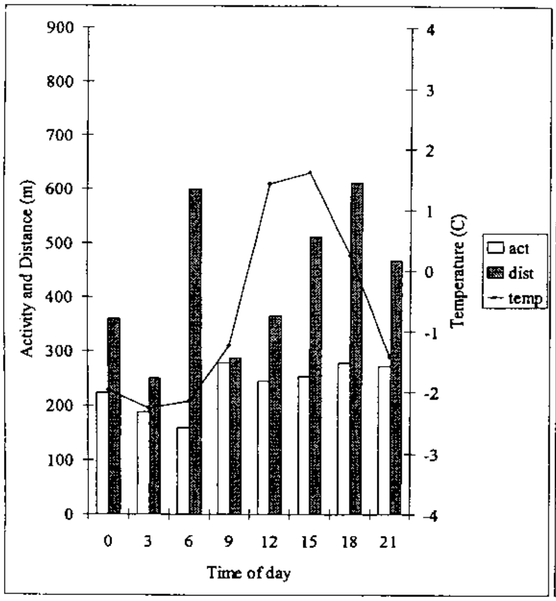
b) June 1998



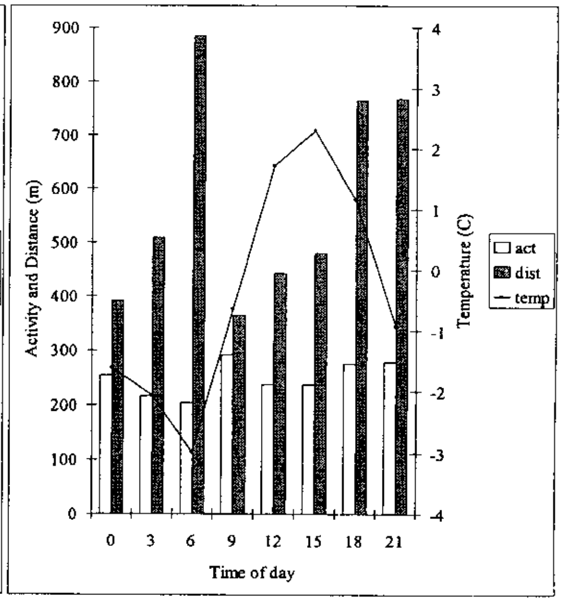
c) July 1998



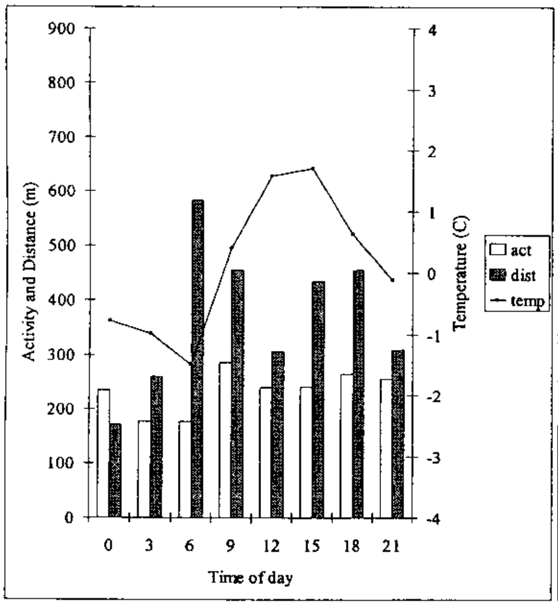
d) August 1998



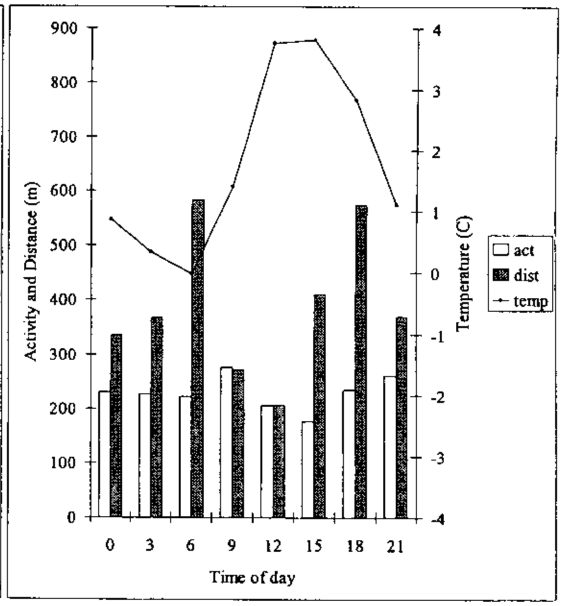
e) September 1998



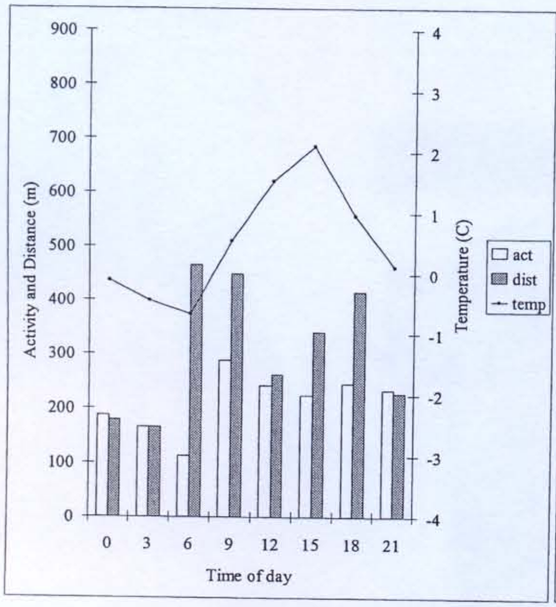
f) October 1998



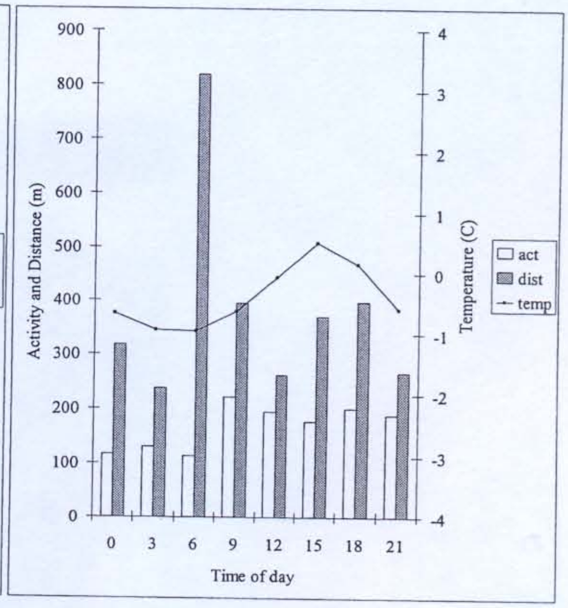
g) November 1998



h) December 1998



i) January 1999



j) February 1999

Figure 4.13 a-j *Monthly diurnal patterns of movement, activity and temperature for one elephant, Justina.*

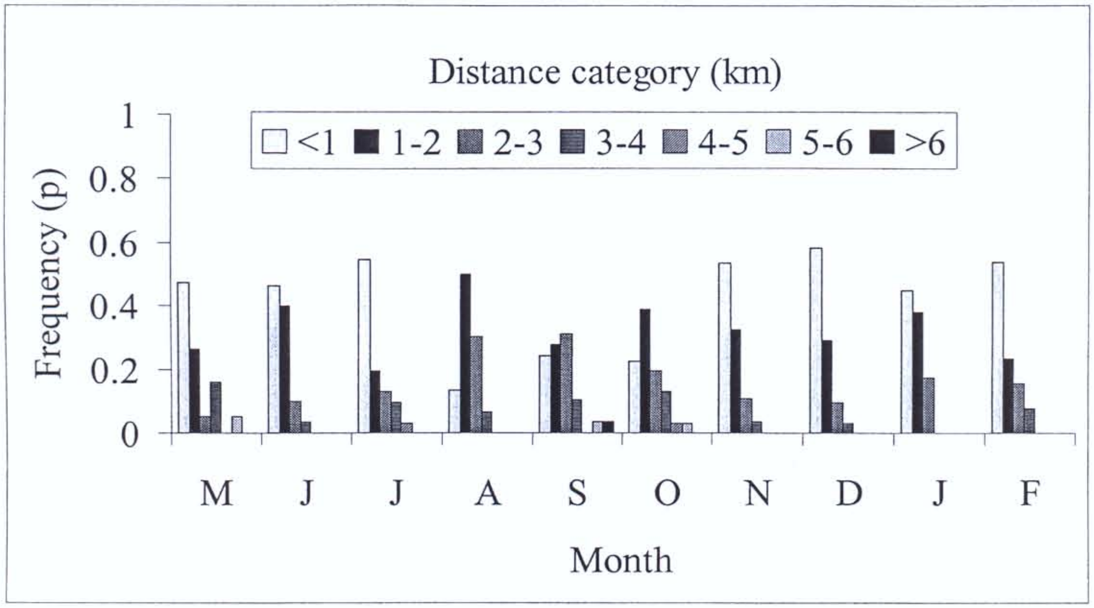


Figure. 4.13. *Daily distance moved by cow Justina between May 1998 and February 1999.*

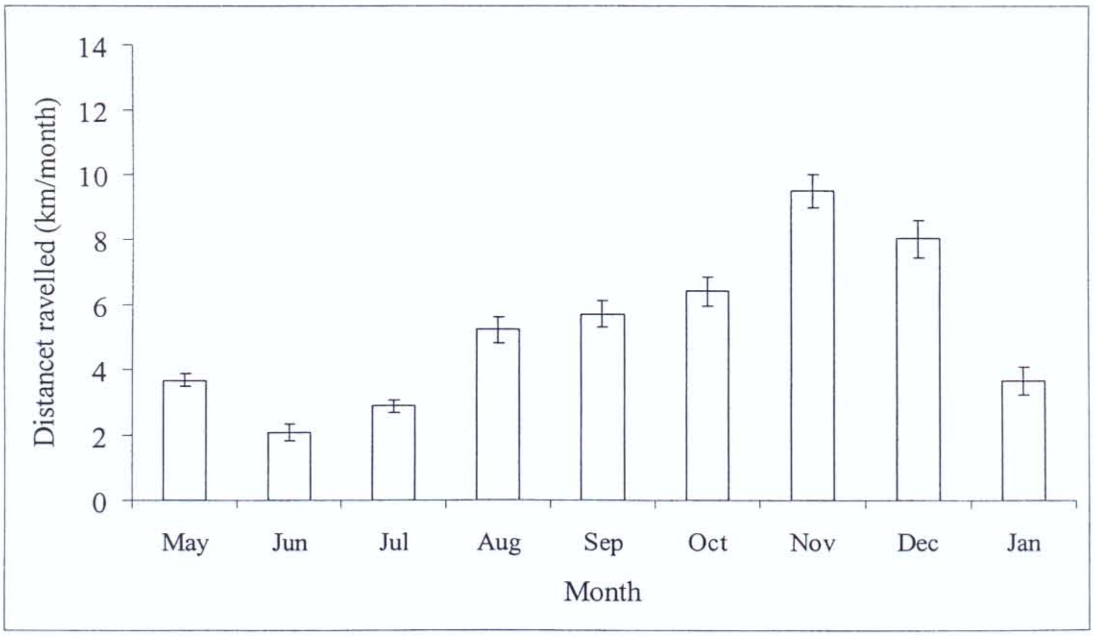


Figure 4.14*. Monthly distances (calculated between thirty day intervals) moved by Justina between May 1998 and February 1999 (±95% CI).*

Observations of elephant diurnal activity

One hundred and sixty-seven observations of elephants in the Shimba Hills were made over a 13 month period. These data were categorized into periods limited by the time when the most rapid temperature change in diurnal temperature occurred according to data provided in Glover (1968) and Hoft (1991); the morning period included observations before 10 am, mid day between 10am and 4 pm, and afternoon observations after 4 pm. The results (see Figure 4.15) reveal significant differences in habitat use between morning and mid day (Chi Square Analysis: $\chi^{2=}$21.29, p <.001, df=3), as well as morning and afternoon (Chi Square Analysis: χ^2=13.06,.001>p<.005,df=3) but not between mid day and afternoon. (Chi Square Analysis: χ^2=4.56,.25<p>.1,df=3). The main difference was in the probability of elephants being found in the open grasslands versus forests. In the mornings before 10 am, elephants are more likely to be observed in the open grasslands while after this time they moved into the bush and forest where they remained for the rest of the day. In total, more elephants were observed during the late afternoons when they were frequently moving between habitats, in contrast to feeding in the early morning.

Similar patterns of daily activity were observed in the Mwaluganje Elephant Sanctuary. The area comprised open or bushed grassland with occasional baobab trees (*Adansonia digitata*). Elephant groups were observed more frequently during the morning (before 10 am) and late afternoon (after 4 pm) than during the mid day and this was highly significant (Chi Square Analysis: χ^2=33.38, p <.001, v=2, n=159). It was noted that during the mid day hours, that elephants were shading under large trees, while during the early morning and late afternoon they were usually moving towards water.

Aggregations of elephants were observed in the MES in October in 1993, 1995, 1996 and 1997. In both 1991 and 1993 the local villagers burned the land in October to keep the elephants out of their farms, but the elephants remained in the vicinity and even appeared to investigate the burn site after the fires had been extinguished.

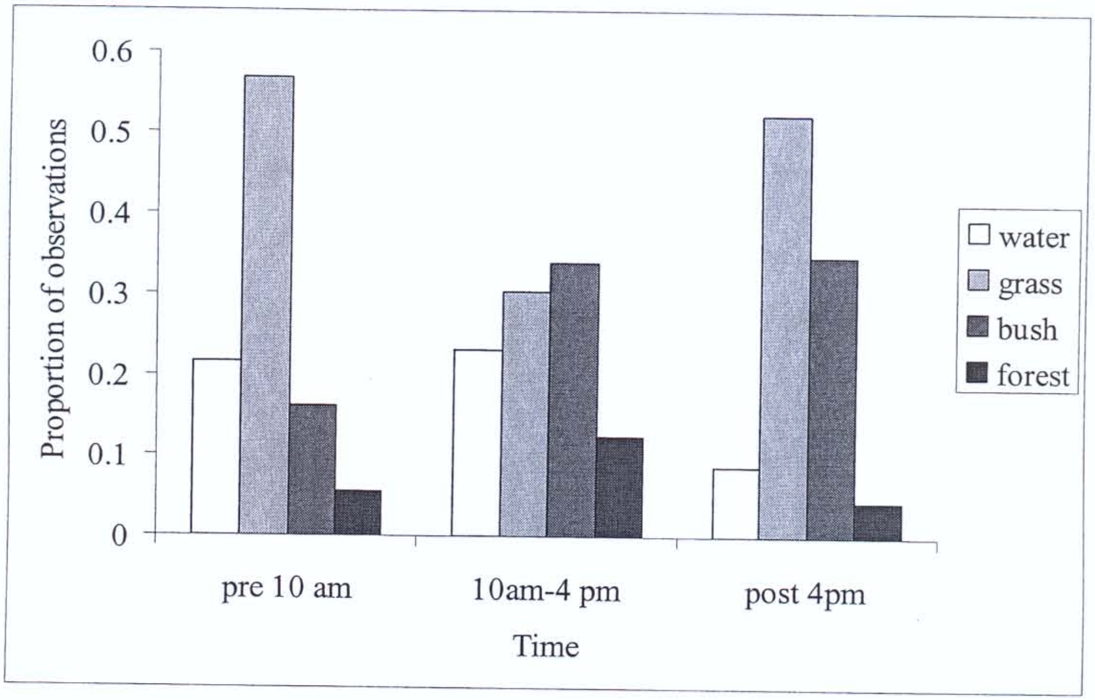


Figure 4.15. *Elephant diurnal habitat use based on sightings in the Shimba Hills*

Discussion

Performance of two radio-tracking systems in forests

The radio-tracking of elephants using the LOTEK GPS system revealed more detailed information on the diurnal activities of one elephant than has been obtained by the conventional system or even direct observations in this type of habitat. The collars performed very well when they were working and provided an insight into daily activity and movements of individual elephants and their families which is fundamental to understanding how they use their habitats. The cow collar in particular yielded the largest number of fixes in any forested ecosystem in Africa. While, the system performed well, the collars did not function for the duration anticipated. This was a disappointment in terms of the low return for a very high cost. Collar failure seems to be a design fault, the same collars failed after only one month in another forested ecosystem, the Nouabale-Ndoki and Dzanga-Ndoki National parks (Blake et al. 2001), while in savannas function of between 8 to 406 days has been reported (Douglas Hamilton and Krink 2001).

Despite the drawbacks (premature collar failure, small sample size), the two LOTEK GPS system provided far superior data for individual elephants to the four conventional collars. Though the initial outlay was expensive, a comparison of the cost of data reveal that for the two GPS collars, each data point cost US $4.76 compared to US$ 125 for each point obtained from the conventional collars. This was because the costs of retrieving data are much greater in the standard VHF system in this forested ecosystem, in savannas where towers and or hand held receivers can be used, the conventional system may be more cost effective than in forests. The GPS system, however, provides additional information on movements and activity at night which is not possible with the conventional collars.

Movements and home range size

Elephant home ranges were calculated for all six elephants using minimum convex polygons (MCP) however, the results must be interpreted cautiously because of the very small sample sizes in the case of the conventional collars, and short duration over which data were gathered which may have resulted in underestimates. The ten month data for the cow Justina suggests that a minimum of 7-8 months are required for accurate home range because she completed a circuit of her range twice a year. Thouless (1995) recommends that in populations that undertake annual migrations a minimum of 45 data points over a 12 month period are required for accurate home range estimation. The very small home range calculated for the bull almost certainly reflects only part of his range as he was tracked for only 1.9 months. Compared to the cow, however, during that same period he used an area approximately a half the size.

The reported home ranges were small compared to other sites in Africa. For example in the nearby Tsavo National Park, elephants range over 400 to 2,500 km^2 (Leuthold and Sale 1973) and in the arid northern Laikipia area of Kenya, migratory elephants home ranges varied from 2,650 to 5,527 km^2 (Douglas Hamilton and Krink 2001, Thouless 1996). The largest home ranges recorded are for migratory elephants in the Etosha National Park in Namibia (Lindeque and Lindeque 1991) where one individual ranged

10,738 km^2. Douglas Hamilton and Krink (2001) demonstrate that home ranges calculated by quantifying quarter kilometer grid square use is possible using GPS satellite tracking data, and they show that home ranges calculated using MCP are overestimates especially for very large home ranges of migratory elephants and in the case of complex home ranges. They refine estimates of elephant home ranges in Kenya to 210 km^2 (n=12 elephants).

Comparisons of elephant movements with other sites must be made cautiously because the resolution at which distances traveled are measured affect the result; distances traveled between 24 hour periods will not necessarily approximate daily distances estimated by the summation of distances moved between fixes. It was possible to directly compare the hourly movement rates obtained in other radio-tracking studies where the data were gathered in the same way. Movement rates of between .67 km hr^{-1} and .93 km hr^{-1}were recorded for three savanna elephants in Waza, Cameroon (Tchamba et al. 1995) compared to .14 and .11 km hr^{-1} for a cow and a bull in this study. Forest elephants (*L. cyclotis*) in central Africa reportedly move 8 km day^{-1} (Merz 1984), while in Bossemitié, Ivory Coast, elephant daily travel distance in forest averaged 6.1 km (range1.2 to 12.6km) (Theuerkauf and Ellenberg, 2000). This is comparable to 2.5 to 4.7 km day^{-1} recorded here, however, these forest studies obtained distances by measuring daily tracks which may bias the distances measured upwards. Some studies report the distance between location at the beginning and end of a set period of time; the mean monthly distances moved in Laikipia ranged from approximately 10 km to 60 km $month^{-1}$ (Thouless 1995), while in the DRC elephants moved 30-60 km per month (Blake et al

2001), compared to 2 – 9 km month^{-1} here. Though comparisons are made cautiously, all evidence suggests that the Shimba elephants achieve surprisingly slow movements of the bull and the cow compared to studies elsewhere suggest that the elephants here utilize their range differently.

The cow, Justina, appeared to move more rapidly at night in the MFR than during the day which she which suggests that she was less at ease here than in the SHNR where she was active during the night and day. This may have been due to perceived insecurity (due to humans and/or bulls in the MFR). This illumination of night time movements expose a weakness in studies that depend on observational data as important range use patterns are simply not possible to follow.

Elephants in the Shimba Hills used a small portion of the available range of 262 km^2. Though this was unusually small compared to most other sites with data (see Table 4.3) similarly small home ranges were typical of elephants in Lake Manyara National Park where small home ranges of 14-52 km^2 were documented in the 1960's when the elephant density was 5 km^{-2} (Douglas-Hamilton 1971 in Douglas-Hamilton 1998). However, in central African rainforests, despite high densities, elephants utilize large home ranges and have open access to vast ranges in the rain forest (Blake et al. 2000). In both the Shimba and Lake Manyara ecosystems therefore, high elephant density combined with a confined space, may have affected home range size. The largest home ranges in Africa are for migratory elephants that utlize highly seasonal habitats, in terms

	MCP (km2)	95% CI	N	Rainfall (mm)	Source
Amboseli, Kenya	175		2	250	Douglas Hamilton 1998
Damararland, Namibia	3511	1348	3	315	Lindeque and Lindeque 1991
Etosha, Namibia	6970	4978	3	315	Lindeque and Lindeque 1991
Ewaso Nyiro, Kenya	1967	417.5	3	550	Thouless 1996
Kaokoland, Namibia	9575	0	1	200	Lindeque and Lindeque 1991
Kaokoland, Namibia	2177	390	6	200	Viljoen 1989
Kruger, South Africa	436			550	Hall Martin 1984
Laikipia migrants, Kenya	4348	899.5	6	400	Thouless 1996
Lewa Downs, Kenya	1414	880.7	3	450	Thouless 1996
Manyara N. Park, Tanzania	57		2	1000	Douglas-Hamilton 1971 in Douglas Hamilton 1998
Maputo, Mozambique	129	0	1	845	DeBoer et al. 2001
Mathews Range, Kenya	1180	444	2	450	Thouless 1996
NNDC DRC	880		1	1500	Blake et al 2001
Ol Ari Nyiro, Kenya	121	23.4	3	750	Thouless 1996
Sabi Sand Reserve, Zimbabwe	200			300	Fairall 1979
Shimba Hills, Kenya	36		6	1000	This study
Tarangire N. Park, Tanzania	330			500	Douglas Hiamilton 1971
Tsavo East, Kenya	2380		8	250	Leuthold 1977 in Tchamba et al. 1995
Tsavo West, Kenya	408		2	550	Leuthold 1977 in Tchamba et al. 1995
Waza Cameroon	1660		2	700	Tchamba et al 1994
Zambezi Esc., Zambia	94			500	Dunham 1986
Zambezi Valley, Zambia	156		11	800	Dunham 1986
Zambezi Esc. Zambia	263			500	Dunham 1986

***Table 4.3**. Published elephant home range estimates using MCP in Africa*

of rainfall or fruit production in the case of Forest elephants *L. cyclotis* (Blake et al. 2001). No evidence of migrations were detected in any of the Shimba elephants, the greatest distance between sightings was 20 km in a straight line which is within the usual daily movement range in other ecosystems. Also noticeable in the Shimba Hills was that the cow and the bull seemed to use their range independently of one another, while in northern Kenya, coordinated movements of collared individuals have been observed (Douglas-Hamilton unpublished data).

Temperature and diurnal activity

The activity indices of two elephants show that they were active throughout the day with a lull between 3 and 6 am. The cow was more active than the bull, traveled greater distances and she also experienced a greater diurnal temperature range than the bull. The patterns of these two elephants were more similar to those described for savanna elephants in Amboseli (Douglas Hamilton 1998) than those described for two female forest elephants in the Congo (Blake et al. 2001) which exhibited no lull in activity during the hottest time of the day. Greater sample sizes are necessary to determine if these patterns are specific to the different species of elephant. The temperature recorded on the bull collar was puzzling. Until the collar is recovered, or further samples are obtained, it will not be possible to determine whether it was malfunctioning at high temperatures or if it represents a real biological phenomenon. In general both elephants avoided temperature extremes because their maximum daily temperature range was only half of the environmental range expected in the area (see Chapter 2).

The activity of these elephants was significantly affected by temperature. The cow was most active during the coolest month and least active during the hottest months and her activity suggested greater use of forests and wooded habitats during the day than at night. This was in agreement with field observations that showed elephants to utilize forest and woodland during the middle of the day. Though air temperature ranges 7-10 °C per day in this ecosystem, the maximum range experienced by the cow was 4 °C which suggests that she was able to some how to ameliorate the temperature extremes that she experienced especially in the MES and MFR which experience higher temperatures due to the lower elevations and adiabatic warming due to the leeward aspect. She achieved this by utilizing forest cover during the hottest time of the day and by utilizing higher elevations during warmer months. In contrast and for one month only, the bull did not use forest. It is surprising that his temperature curve was truncated as he was always s located in the open. I suspect that his temperature sensors was malfunctioning. He was much less active than the cow. Wing and Buss (1970) also noted predictable patterns of elephant movement and activity in the Budongo forest of Uganda up and down valleys, an into and out of forests. They speculated that these movements were related to thermoregulation and noted that a heavily pregnant cow was particularly inactive compared to others.

Justina also moved more during daylight hours in the SHNR but not in the MES or MFR and this suggests that she was making important range shift movements after dark along steep cliffs. This could be related to the heat constraint but it also could also suggest fear, as she moved under the cover of darkness in the open in an area that was until relatively recently inhabited by farmers.

Habitat use and foraging

The use of radio-tracking data illustrated the use of diverse habitats by the cow in contrast to the bulls preference for bush and grasslands. The temperature relations suggest that the cows utilize forests and woodlands to avoid high temperatures as they forage more in the open at night. These data were supported by independent observations of elephants. The radio-tracking data illuminated differences in diurnal habitat use between night and day which has implications for studies of elephant diet that are based on direct observation of foraging. Calibrating the foraging behavior in each habitat would be essential to refine our understanding of the importance of elephant foraging.

The pattern of movements made by the cow and bull suggest that they both forage and move gradually, rather than local foraging followed by long distance movements. However, the cow, intensively used an area during the wet season, returning after a 6 months. It is regrettable that the bull collar failed early on as his pattern of range use was quite different to the cows during the 2 months. If bull activity is characterized by prolonged feeding periods in the same location, this would result in different patterns of habitat impact than the cow. The radio-tracking data represents only two individual elephants and therefore cannot be used for broad generalizations. The introduction of GPS technology to radio-tracking allows us to ask new and different questions that would not be possible to investigate using other standard techniques. It is likely that the deployment of this technology across different climatic and vegetation zones will provide new insights into how elephants interact with each other and their resources.

References Cited

Amliner, C. J. and D. W. Macdonald (eds). 1980. A hand book on biotelemetry and radio tracking. Pergamon Press, Oxford.

Blake, S., I. Douglas-Hamilton, and W. Karesh. 2001. GPS telemetry of forest elephants in Central Africa, results of a preliminary study. Afr. J. Ecol. 39:178-186.

Davies. 1993. Shimba Hills, Mkongani and Maluganje Forests biodiversity overview. Report to the Kenya Indigenous Forest Conservation Center. National Museums of Kenya. Nairobi.

De Boer, W. F, C. P. Ntumi, A. U. Correia, and J M. Mafuca. 2000. Diet and distribution of elephant in the Maputo Elephant Reserve, Mozambique. Afr. J. Ecol 38:188-201.

Douglas-Hamilton, 1974. On the Ecology and Behaviour of the African Elephant. D. Phil thesis. University of Oxford.

Douglas-Hamilton, I. 1998. Tracking African elephants with a global positioning system (GPS) radio collar. Pachyderm. 25:82-91.

Douglas Hamilton, I., and T. Krink. 2001. Complex movements and home ranges of the African elephant, *Loxodonta Africana*. Manuscript in prep.

Dunham, K. M. 1986. Movements of elephant cows in the unfolooded middle Zambezi Valley, Zimbabwe. Afr. J. Ecol. 23:287-291

Fairall, N. 1980. A radio tracking study of young translocated elephants in: A handbook on biotelemetry and radiotracking (Amliner, C. J. and D. W. Macdonald (eds). 1980. Pergamon Press, Oxford.

Fay, J. M. and M. Agnananya. 1991. Forest elephant populations in the Central African Republic and Congo. Pachyderm. 14:3-19.

Glover, P. E. 1968. Report on an ecological survey of the proposed Shimba Hills National Reserve. E. Afr. Wildl. Soc., Nairobi.

Hall-Martin, A. J. 1984. Conservation and management of elephants in the Kruger National Park, South Africa. In The status and conservation of Africa's elephants (eds) D. H. M. Cumming and P. Jackson. IUCN. Gland.

Hoft, R., and M. Hoft. 1995. The differential effects of elephants on rain forest communities in the Shimba Hills, Kenya. Biol. Conserv. 73:67-79.

Hoft, R. 1991. Ecology of a tropical lowland rainforest. Plant communities, soil characteristics and nutrient analysis in the Shimba Hills National Reserve, Kenya. Dissertationes Botanicae. Berlin, Stuttgart

Hursh, C. R. and H. C. Pereira. 1953. Field moisture balance in the Shimba Hills, Kenya, E. Afr Agric J. 18:138-145.

Leuthold, W., and J. B. Sale. 1973. Movements and patterns of habitat utilization of elephants in Tsavo National Park, Kenya. E. Afr. Wildl. J. 11:369-384.

Lindeque, M. and P. M. Lindeque, 1991. Satellite tracking of elephants in north-western Namibia. Afr. J. Ecol. 29:196-206.

Lotek Engineering Inc. 1997. Lotek: The GPS Animal Location System. Users Manual Release 2.

Tchamba, M., H. Bauer, A. Hunia, H. H. De Iongh, and H. Planton. 1994. Some observations on the movements and home ranges of elephants in Waza national Park, Cameroon. Mammalia. 58:527-533.

Tchamba, M. T., H. Bauer, H.H. De Iongh. 1995. Applications of VHF-radio and satellite telemetry on elephants in northern Cameroon. Afr. J. Ecol. 33:335-346.

Theuerkauf, J. and H. Ellenberg. 2000. Movements and defaecation of forest elephants in the most semi-deciduous Bossematie Forest Reserve, Ivory Coast. Afr. J. Ecol. 38:258-261.

Thouless, C. R. 1995. Long distance movements of elephants in northern Kenya. Afr. J. Ecol. 33:321-334.

Thouless, C. R. 1996. Home ranges and social organization of female elephants in northern Kenya. Afr J. Ecol. 34:284-297.

Verlinden, A. and I.K N. Gavor. 1998. Satellite tracking of elephants in northern Botswana. Afr. J. Ecol. 36:105-116.

Viljoen, P. J. 1989. Spatial distribution and movements of elephants (Loxodonta Africana) in the northern Namib desert region of the Kaokoveld, South West Africa/Namibia. J. Zool. London. 219:19

White, L. J. T. 1994. *Socoglottis gabonensis* fruiting and the seasonal movements of elephants in the Lope Reserve, Gabon. J. Trop. Ecol 10:121-125.

Whyte, I. J. 1993. The movement patterns of elephants in the Kruger National Park in response to culling and environmental stimuli. Pachyderm. 16:27-80

Whyte, I.J1996. Studying elephant movements, In studying elephants (ed Kangawana), K. African Wildlife Foundation, Technical handbook series 7. pp 75-89.

Wing L. D. and Buss, I. O. 1970. Elephants and forests. Wildlife Monographs 19:92 p.