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ECOLOGY AND DISTRIBUTION OF THE PANCAKE TORTOISE, *MALACOCHERSUS TORNIERI* IN KENYA

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ABSTRACT

Field investigations on the ecology, distribution and conservation of the pancake tortoise *Malacochersus tornieri* in Kenya were conducted from September to December 1998 and from March 2001 to April 2002. This crevice-dwelling tortoise inhabits Precambrian rock outcrops and kopjes that are discontinuously distributed throughout the arid and semi-arid lands of Kenya and Tanzania. However, suitable micro habitats are sparse and this accounts for its patchy distribution. The pancake tortoise is more widespread in Kenya than previously thought, ranging from the South-east to the North. Two sub-populations South and North of the volcanic Nyambene Hills exist. Density between study sites differed significantly and abundance of particular age groups is dependent on season. Activity outside crevices is very limited, occurring mainly during the wet season. In the dry season individuals aestivate. There is no marked sexual dimorphism in terms of size and colouration, and no significant difference in mean body weight and straight-line carapace length between sexes. There is a significant positive linear correlation between straight-line carapace length and body weight. The observed sex ratio is 1:1. Movement is very limited and centred around rock refuges. Males are more wide ranging than females. Adults dominate the age structure of the pancake tortoise population. Shifting cultivation is the major threat for its survival other than illegal trade. *In situ* conservation through establishment of publicly and/or privately owned nature reserves is recommended.

INTRODUCTION

The pancake tortoise *Malacochersus tornieri* (Seibenrock, 1903) is a small, soft-shelled, dorso-ventrally flattened, rock crevice inhabitant. Pancake tortoises are associated with scattered rocky hills, outcrops and kopjes in dry savannas of south-eastern and northern Kenya and northern, eastern and central Tanzania. Unlike domed land tortoises they have flattened and flexible shells that enable them to push and wedge themselves in rock crevices (Loveridge & Williams, 1957). Their unique appearance and behaviour made them popular in the international pet trade, leading to their listing on Appendix II of the Convention on International Trade in Endangered Species of wild fauna and flora (CITES).

In both Kenya and Tanzania much of the population occurs outside protected areas increasing their vulnerability to over-exploitation. In Tanzania, however the species has been recorded in protected areas such as Serengeti National Park (Broadley & Howell, 1991), Tarangire and Ruaha National Parks (Moll & Klemens, 1996) and Mkomazi Game Reserve (F. Mturi, *pers. comm.*).

Scientific data on the pancake tortoise in Kenya has been mostly limited to locality information in checklists (Loveridge, 1957). Procter (1922) provided the first description of the skeletal structure. Loveridge & Williams (1957) provided additional information on body structure, geographical range, reproduction, longevity, diet, ectoparasites and habitat. Wood and MacKay (1987) conducted a study on the natural history, distribution and status during two brief visits totalling 6 days to Nguni (Mwingi district then within Kitui) during the long dry season in July and September 1987. In Tanzania, Klemens & Moll (1995) and Moll & Klemens (1996) studied the ecology and assessed the effects of commercial exploitation.
This paper provides results of a study of ecological characteristics and distribution of the pancake tortoise in Kenya. Threats to Pancake tortoise populations, conservation and management strategies are discussed.

MATERIALS AND METHODS

Between September and December 1998, the ecology and natural history was studied in the vicinity of Nguni and Nuu (Mwingi district) in both dry and wet seasons. Between March 2001 and April 2002, the distribution in Kenya was investigated more extensively (table1 and figure 1). The different observation periods allow for comparison of natural populations during seasonal climatic extremes. The areas surveyed fall within the Precambrian granite rocks and hills of the basement complex system.

In the 2001–2002 study, eight sites with varying habitat quality and threats were selected out of about 25 for comparison of species density. These were Wamba (Samburu district), Chiakariga (Tharaka district), Ishiara (Mbeere district), Katse, Nguni, Nuu (Mwingi district), Endau and Voo (Kitui district). The selection criteria were: presence of high to low density of rock outcrops; high to low frequency of suitable and well-configured rock crevices; arid to semi-arid climate; low to high habitat destruction and low to high areas of tortoise exploitation. In the September–December 1998 study (Malonza, 1999), ten sites out of about 15 were randomly selected for comparison of species abundance and seasonal characteristics. These were Maai, Kalanga corner, Kalanga, Ivuusya, (Nguni division) Kamulewa, Kawelu, Wingemi, Kamumbi, Kanyungu, and Nzanzu (Nuu division) in Mwingi district.

Potentially suitable pancake tortoise habitats were located mainly by following climatic and geologic maps and examining areas within eco-climatic Zone V and/or overlying Precambrian rocks of the basement system (Pratt & Gywnne, 1977). Occasionally interviews with local people were used. Tortoise searches were done according to the methods described by Karns (1986) and Sutherland (1996). At least one strip transect about 5–20 km long and 0.5 km wide was used to estimate the tortoise density. Some bias cannot be excluded here since for practical reasons these transects followed the existing feeder roads within the study sites. Suitable rock crevices were searched with the aid of a spotlight and tortoises were extracted using a 2-m strong flexible hooked wire. Sampling time was from 07.00 h to18.00 h. The presence of one or more pancake tortoise in a refuge was occasionally signalled by faecal material littering the entrance. The number of tortoises found in each occupied crevices was recorded as well as their weight, straight-line carapace length (SCL), sex and age group (hatchling, juvenile, sub-adult, adult). If they could not be dislodged, size was estimated. Sex was mainly determined by the presence of the thick and elongated tail in males and short stumpy tail in females. Microhabitat characteristics and configurations were recorded as well as activities such as hiding, feeding and basking. Individuals captured were individually marked by cutting notches on the marginal scutes.

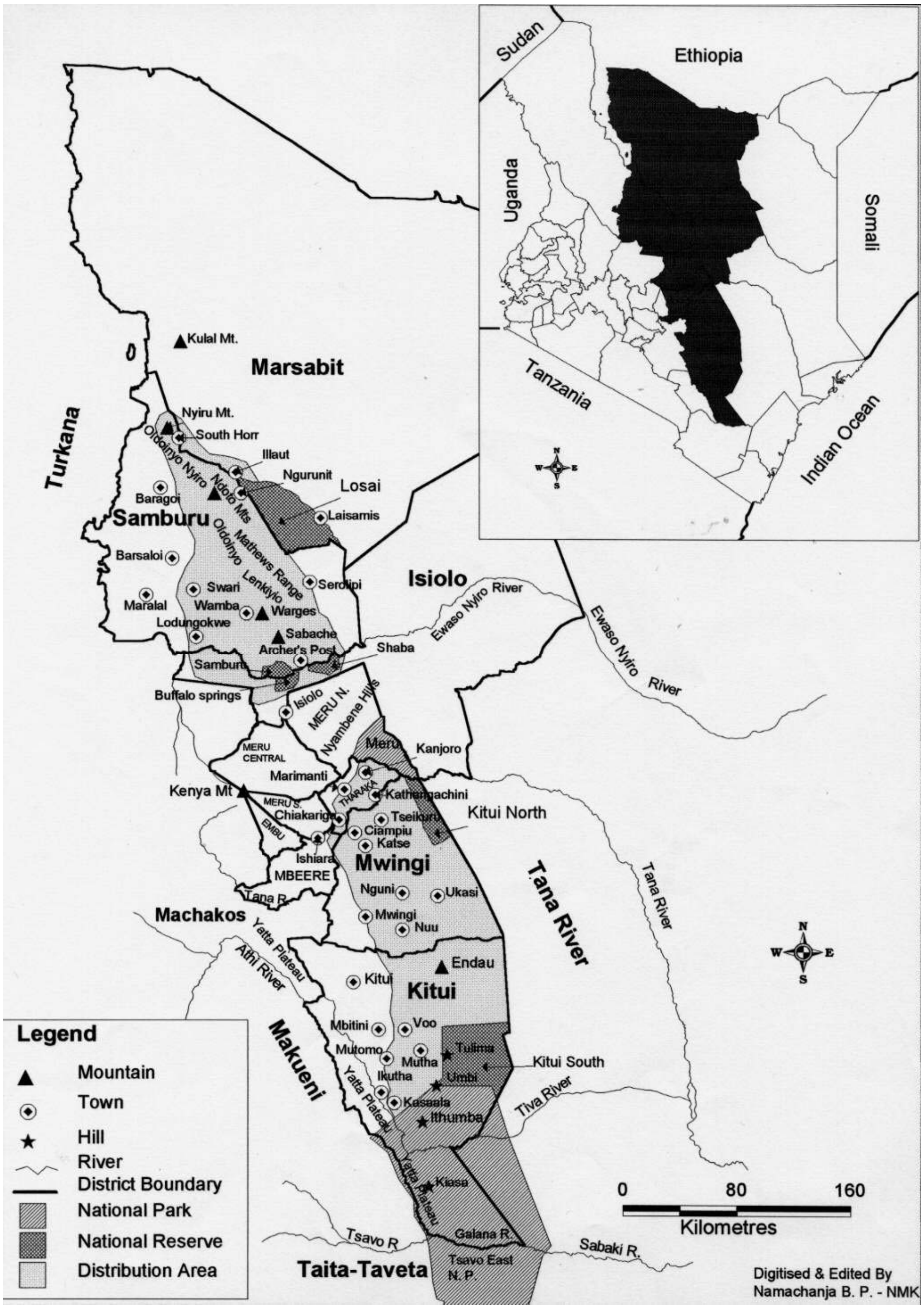

Figure 1. Map illustrating the distribution of the Pancake tortoise Malacochersus tornieri *in Kenya according to our surveys. Inset: Map of Kenya: location of the districts indicated in black.*

The tortoise group structure (solitary, sexual pair, group) and movement were recorded. Range behaviour was studied using the capture-mark-recapture technique (Brower, Zar & Von Ende 1989; Sutherland, 1996). When recaptured the tortoise position was marked with a stick or wooden peg and the distance from its previous capture point measured. The tortoises were marked once and recaptured two months later.

Human activities within and around the tortoise rock habitats, such as bush clearing and burning, farming, grazing, rock breaking, charcoal burning, human settlement and evidence of tortoise collection (broken rock slabs, presence of crevice probing sticks) were assessed and recorded.

The number of tortoises in different areas was qualitatively estimated by the frequency of encounter of individual pancake tortoises. Assuming that the number of tortoises examined is proportional to that not actually examined, species density in different study sites was estimated by dividing the total number of individuals counted in each transect line by its area. Total density of each study site was then calculated by taking the average densities of all its transect lines.

SCL and body weights of female and male tortoises were compared using a two-tailed t-test and a correlation analysis to test their relationships. One sample t-test was used to test the differences in species density. Association or dependence of particular age group with season was tested using Chi-square (contingency).

RESULTS AND DISCUSSION

Seasonal variation in tortoise numbers

The pancake tortoise population in Kenya is low in all areas surveyed with no significant seasonal variation in abundance. In the dry season, September–October 1998, 64 tortoises were extracted and six more were sighted but not extracted. In the wet season November–December 1998, 69 were captured and two were sighted. Results from a Chi-square contingency test indicated that the number of particular age groups was significantly dependent on season ($\chi^2 = 10.43$, d.f. = 3, $P < 0.05$). The number of hatchlings and juveniles was high during the wet season with no hatchlings observed in the dry season. (figure 2).

Absence of seasonal variation in total number is due to strong site fidelity with very limited movement. Their highly cryptic behaviour and the thick surrounding bush often make location of all suitable rock outcrops virtually impossible; there is no doubt that the study failed to locate a substantial number of individuals within the areas searched. With respect to specific age groups, more hatchlings and juveniles were counted during the wet than the dry season. The wet season especially November/December is the period of egg hatching and production of offspring. Studies have shown that many tropical animals have well defined seasonal peaks of abundance. Pomeroy and Service (1986) pointed out that this temporal seasonal fluctuation in population may result from the seasonality of mating and production of offspring, seasonal reduction in numbers as food supply drops, increased mortality from natural enemies and reduction in places to shelter or a combination of factors.

Variation in species density and habitat quality

In many respects, the observations on the Kenya pancake tortoise populations conform to those made in earlier studies in both Kenya and Tanzania (Loveridge & Williams 1957; Wood & MacKay 1987; Klemens & Moll 1995; Moll & Kemens 1996). In Kenya numbers and density of the pancake tortoise population varies from site to site. The density was highest in Voo (8.86 tortoises/km^2), followed by Katse (6.60), Nuu (3.54), Endau (2.95), Wamba (2.61), Ishiara (1.73), Chiakariga (1.72) and Nguni (1.20) respectively, with a significant difference (t-test for dependent samples, one-tailed; $n = 8$, $t = 114.06$, d.f.$=7$, $P < 0.05$). However, these densities are only for the suitable pancake tortoise habitat patches and not for the whole area. The high abundance and density of pancake tortoise in Katse can be attributed to the high density of rock outcrops and relatively high frequency of suitable rock crevices. Likewise that of Voo is due to very high frequency of well-configured rock crevices. The low density and abundance in Nguni is in part due to past commercial collection (Wood &MacKay, 1987). These results concur with the observations of Klemens & Moll (1995), Moll & Klemens 1996) and Malonza (1999).

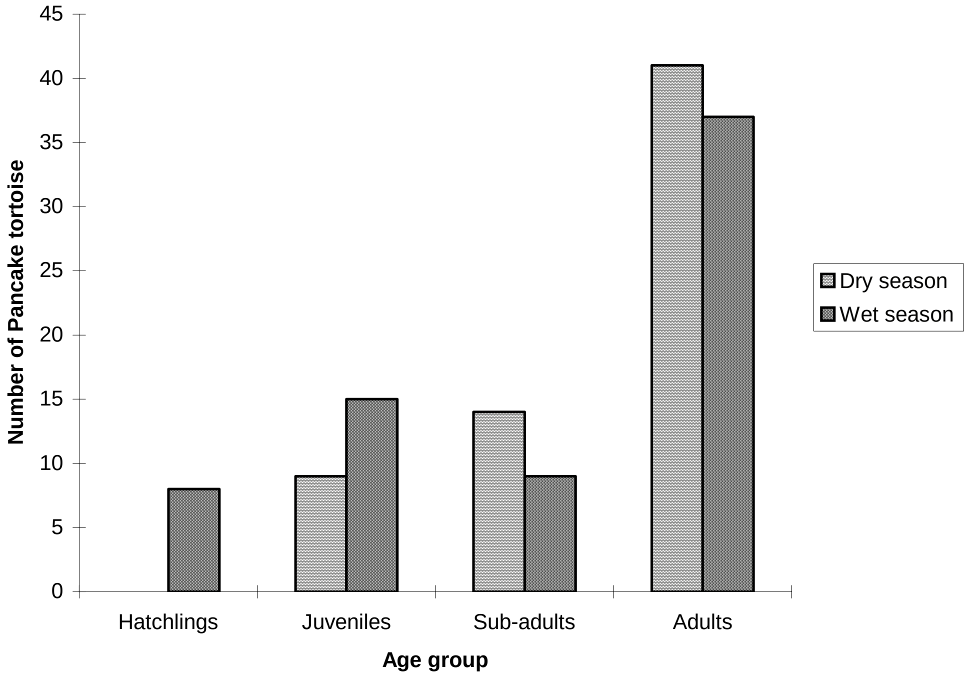

Figure 2. Number of Pancake tortoises recorded in each age group in wet and dry seasons in Nguni and Nuu areas, Mwingi district Kenya.

Habitat characteristics, selection, use and preference

Pancake tortoises were only found in suitable rock crevices in rock outcrops and kopjes in the arid and semi-arid *Acacia-Commiphora* bushland and thicket of the study areas (figure 3). The orientation of inhabited crevices varied from horizontal through diagonal to vertical with all degrees of inclination between these extremes (figure 4). Characteristically inhabited rock crevices narrow back from the entrance. Usually the above ground level is a relatively gentle descent point from the crevice entrance to the soil substrate at the base which usually has foraging material. The tortoises mainly live in scattered rock outcrops of exfoliating granite. The best habitats were granite outcrops that provided shelter underneath exfoliating rock slabs, and crevices of various stages of weathering in a matrix of gently rolling hillsides and plains.

The frequency of encounter and occurrence of multiple assemblages was higher on well vegetated rock outcrops. Such well sheltered rock crevices probably provide thermal buffering against overheating and desiccation during the dry season.

Figure 3. Typical Pancake tortoise habitat in Acacia-Commiphora bushland. Exfoliating rock slabs at Kalanga, Mwingi district.

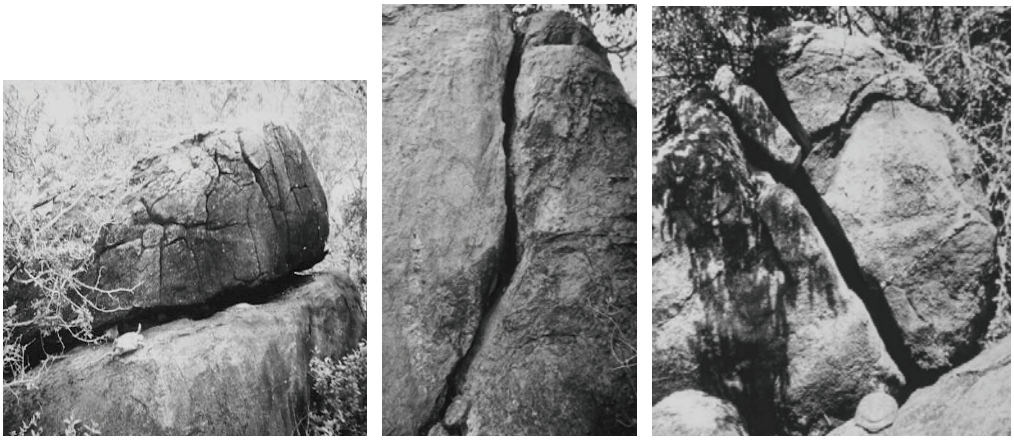

Figure 4. Three representative crevice configurations inhabited by pancake tortoise.

Optimal Pancake tortoise habitat is usually provided by rock outcrops and kopjes that have been exposed for a long time to weathering and erosion so as to produce suitable crevices. These micro-habitats represent only a small proportion of all crevices in any given area and are often widely separated from one another by large expanses of apparently unsuitable and unoccupied habitats. The frequency and location of these suitable micro-habitats ultimately determines the abundance and distribution of Pancake tortoise in any given area. These observations concur with the findings of Wood & MacKay (1987); Moll & Klemens (1996) and Malonza (1999).

Distribution of pancake tortoise populations

Populations of pancake tortoises are scattered discontinuously from northern Kenya southwards through eastern to south-eastern Kenya. The species ranges from Gatab on Mount Kulal southwards to, Marsabit, Samburu, Isiolo, Tharaka, Mbeere, Mwingi and Kitui districts into Tsavo East National Park area North of the Galana River (figure 1). A list of suitable sites that were surveyed is given in table 1.

Table 1. District and localities in Kenya surveyed for the presence of the pancake tortoise (Malacochersus tornieri) between September to December 1998 and March 2001 to April 2002

District / Date	Site
Kitui 03/2001 08/2001 04/2002	Endau Hill, Ngiluni, Malalani, Ilombe Imwe, Koi, Kinanie, Ndulani, Kalalani, Voo, Nzunguni, Mutha Hill, Kitui South National Reserve (Tulima Hill), Kinakoni, Ndui, Kyaango, Kithanake, Mutomo, Muamba, Muthue, Vendelani, Mavia, Kimathenya Hill, Kasaala, Tsavo East National Park North of Galana River & Yatta Plateau (Kiasa, Ithumba & Umbi Hills)
Mwingi 06/2001 08/2001 04/2002	Kyanundu, Nguni, Kalanga, Kalanga C, Maai, Mathiakani, Ivuusya, Nuu Hill, Kamulewa, Kawelu, Kamumbi, Wingemi, Kanyungu, Kalesi, Tseikuru, Kaivirya, Mumoni Hills, Katse, Muvinge, Katangini, Konyu, Kanzinwa, Gatoroni, Kanyangia, Ciampiu, Gakanga, Kamwerini, Nthangani, Kyuso, Mataka, Ngaai, Kimu, Kimangau, Katama, Miw'uni, Usueni, Ngomeni, Ukasi
Mbeere 06/2001 03/2002	Kianjeru, Kianthenge, Ivurori near Irira Tana River Bridge, Mutuobare* (Kiambere Hills)*
Tharaka 06/2001 03/2002	Chiakariga (Kijeege Hill), Mitaani, Matiri, Kamarandi, Mukumango, Rwakinanga, Marimanti, Gaciongo, Kanjoro, Kathangachini, Maranthiu
Meru North* 07/2001	Meru National Park*(Kiorimba, Shifta Rock, Kinduni & Muw'ongo Hills, Kiolu Sand River & Leopard rock outcrops)
Isiolo 06/2001)	Shaba National Reserve (Nartobe, Joy Adamson's camp rock outcrops), Buffalo Springs National Reserve rock outcrops near Samburu Serena Lodge
Samburu 06-07/2001 02-03/2002	Samburu National Reserve, Archer's Post, Nokowarak, Larata, Ololokwe (Mt. Sabache), Wamba, Mt. Warges, Matakwen, Lkisin, Lolkumanyi, Swari, Nagoruworu, Lodungokwe, Mugur, Namunyaka Wildlife Conservation Area (Sarara, Doldol, Soita Narok), Oldoinyo Lenkiyio (Mathews Range), Ndoto Mts, Oldoinyo Nyiro (Nyiru Range or Mt. Nyiru), Tum, South Horr, Ngurunit, Lmerin, Langata lanyuki, Milgis River
Marsabit 03/2002	Lepedera (Losai National Reserve) near Ngurunit, Gatab (Mt. Kulal)
Moyale* 03/2002	Turbi, Sololo and Moyale rocky hills & outcrops*
Taita-Taveta* 09/2001)	Tsavo East National Park South of Galana River & Yatta Plateau* (Mzinga Hill, Irima & Manyani rocky hills & outcrops, Mudanda Rock), Tsavo West National Park* (Kamboyo rock hill, Ngulia Hills, Tsavo River rock outcrops, Mlima Simba rock outcrops near L. Jipe), Taita-Rukinga Ranch* (Rukinga Hill, Pika Pika rock outcrops)
*Narok** ***09/2001***	Masai Mara National Reserve *(Sand River, Oloibomotanyi & Makari River rock outcrops)

* indicates that no tortoises were found

Geology has a profound influence on the distribution of pancake tortoise. In Kenya the species distribution overlaps with the occurrence of Precambrian rocks of the basement system mainly in climatic zone V (Malonza, 1999). Climatic zone V covers semi arid and arid lands in East Africa, and is characterised mostly by thorn-bushland, thickets, *Commiphora* woodland and grassland (Pratt & Gwynne, 1977). Generally, the species distribution in any given area strictly follows four main limiting factors, namely geology, climate, vegetation and altitude (Malonza, 1999). Pancake tortoises were sighted in altitudes between 442 and 1540 m above sea level, with most sightings (87%) below 1000 m. Due to the altitude factor the species is absent in many potential habitats on the moist high slopes. Currently there are two centres of distribution of pancake tortoise in Kenya, South and North of the quaternary volcanic Nyambene Hills in Meru North district (figure 1). These quaternary volcanic hills present a huge break and barrier in terms of geology, climate, vegetation and altitude.

Spawls *et al.* (2002) indicate a distribution in Kenya from Mount Nyiru in the North to the Yatta plateau in the South. This tertiary volcanic rock mass may be a barrier for spread of the species further South and West (Malonza, 1999; Spawls *et al.,* 2002). Apparently suitable habitats, both geologically and climatically, occur in many dry areas of Taita-Taveta and Makueni districts including Tsavo East & West National Parks. These were surveyed with no success. The absence of the species in Masai Mara National Reserve is probably due to its high altitude (>1750m) and the fact that it falls within a different climatic area (zones III & IV). From the results it is clear that the geographic range of pancake tortoise in Kenya is wider than was previously thought (Wood & MacKay, 1987; Malonza, 1999).

Colour pattern, size and growth

The Kenyan pancake tortoise population conforms to the general physical description characteristic of ontogenetic colour change and extensive degree of adult colour and pattern variation described for the species by Loveridge & Williams (1957). No two animals are alike. Adult colour patterns range from light yellow scutes with darker rays running through them, to the reverse, black scutes with yellow rays. Some of the seemingly old individuals have lost this carapacial-rayed pattern and were horn coloured. These variable colour patterns undoubtedly tend to camouflage the tortoise in its unique micro-habitat.

There are no pronounced sexual differences in colour and size between adult males and females. Measurements of 52 adult pancake tortoises (26 males, 26 females) randomly selected from a total of 108 individuals are given in table 2. The largest male was 175 mm and the largest female 162 mm. The smallest was a hatchling of 36 mm. There was no significant difference (t-test for independent samples, two-tailed; $n_1 = 14$, $n_2 = 14$, $t = 0.9$, d.f. $= 26$, $P > 0.05$) in mean SCL of males and females. The body weight of the smallest hatchling was 10 g. The heaviest animal was an adult male of 510 g. Again; there was no statistical significant difference (t-test for independent samples, two-tailed; $n_1 = 14$, $n_2 = 14$, $t = 0.08$, d.f. $= 26$, $P > 0.05$) between the mean weights of males and females. The absence of sexual dimorphism in the Kenyan population in terms of coloration, size and weight concurs with the findings of Wood & MacKay (1993). However, for the Tanzanian population, Moll & Klemens (1996) observed that females are significantly longer, wider and heavier than males. This is possibly due to the fact that fewer male tortoises were examined than females. A later study on Tanzanian tortoises observed no sexual differences in size, colour and weight (I. Kabigumila, pers. comm.). From the results of a correlation analysis of 28 randomly selected pancake tortoises, a highly significant (t-test for independent samples, two-tailed; $n_1 = 14$, $n_2 = 14$, $r = 0.964$, $t = 18.486$, d.f. = 26, $P < 0.01$) positive linear relationship between straight-line carapace length and body weight was observed.

Table 2. Morphometric characteristics of 26 male and 26 female adult pancake tortoises randomly selected from the population. Straight-line carapace length is expressed in mm and weight in g plus or minus one standard error (SE).

Measurement	Females (n = 26)	Males (n = 26)
Mean carapace length (± 1S.E, mm)	137.1 ± 4.5	143.15 ± 4.96
Range	132.6 - 141.6	138.2 - 148.1
Mean weight (± 1S.E, g)	299.0 ± 29.6	314.2 ± 32.7
Range	269.4 – 328.6	281.5 - 346.9

There was a highly significant difference (t-test for paired comparison of dependent samples, two-tailed; $n = 13$, $t = 3.635$, d.f. = 12, $P < 0.01$) in body weights of recaptured individuals from dry to wet season. Similarly, there was a highly significant difference (t-test for paired comparison of dependent samples, two-tailed; $n = 13$, $t = 4.182$, d.f. = 12, $P < 0.01$) in carapace length of individuals recaptured in the wet season. The tortoises are generally heavier and longer when recaptured in the wet season. For instance, an adult female had grown 2 mm in carapace length and was 65 g heavier. The marked increase in carapace length and body weight in the wet season is a result of food intake. During the dry season tortoises are usually aestivating and use their stored food reserves for maintenance.

Habits and defence behaviour

Pancake tortoises often crawl into rock crevices as far as their body size allows. They wedge themselves tightly by digging in their claws and simultaneously pushing their carapace against the crevice wall making it extremely difficult to dislodge them. On several occasions, tortoises could not be dislodged despite strenuous and prolonged efforts.

Loveridge & Williams (1957) suggested that this wedging behaviour is accomplished by inflating the lungs and simultaneously bracing their legs like struts. Moll & Klemens (1996), as well as our observations, support this view. Ireland and Gans (1972), however, have discounted their ability to inflate themselves and suggested that instead they dig in their forelegs to wedge their body in position.

When released, pancake tortoises run for shelter unlike other tortoises, which retract their head and limbs inside their shell. When hatchlings are approached outside their crevices however, they tend to become immobile at first and then rush for refuge. This behaviour is to avoid potential enemies since the soft shell in both adults and hatchlings offers little protection (Zug, 1993).

The observations by Loveridge & Williams (1957) on their ability to turn over when they land on their backs and their agility to climb up vertical surfaces were confirmed in the present study. Occasionally tortoises could be found lodged in very steep and inaccessible crevices, indicating their remarkable ability to climb.

Activity pattern

Loveridge & Williams (1957) suggested that pancake tortoises emerge to feed during the early mornings only. However, on three separate occasions during the wet season of November/December and March/April hatchlings and/or adults were found basking on rock surfaces in both morning and afternoon. During the wet season outside crevice activity was observed throughout the day but mainly on cool days. No tortoise was encountered outside a crevice during the dry season, though all those observed were alert within their crevice. In both seasons most tortoises encountered were hiding within their crevice. Their activity pattern is apparently diurnal since potential nocturnal predators, such as genets, civets and mongooses limit nocturnal activity. Loveridge and Williams (1957) encountered a young pancake tortoise basking on a rock slab at 9.00 h. and Moll & Klemens (1996) reported that outside activity might occur any time of the day. Elsewhere, studies on the Aldabran tortoise *Dipsochelys dussumieri* (Dumeril & Bibron, 1835) by Swingland & Frazier, (1978) and on Speke's hinge-back tortoise *Kinixys spekii* Gray, 1863 by Hailey & Coulson (1996) indicate that daily activity patterns are temperature dependent. Lariviere & Messier (1997), quoting from other sources, pointed out that the pattern of seasonal and daily activity of animals represents behavioural adaptations to variation of environmental factors such as photoperiod, temperature, and precipitation. Activity patterns also vary with social and ecological constraints such as mating, competition, foraging efficiency, predation risk, resource availability and vulnerability.

Age and sex ratio

Shell length was used to group the tortoise population into four age groups: hatchlings (less than 6 cm), juveniles (6–10 cm), sub-adults (10–13 cm) and adults (13–18 cm). Unlike the other age groups, which were equally abundant in both seasons, hatchlings were only observed during the wet season (November–December). The age ratio of the four age groups was 1:2:2:8 respectively, which indicates a population dominated by long-lived adults and low recruitment rates. However, since the data set was small, the pancake tortoise population structure elsewhere might be different.

Wood & MacKay (1993) and Moll & Klemens (1996) observed a 1:1 sex ratio in the Kenyan and Tanzanian pancake tortoise populations. In this study, the sex ratio of the sub-adults and adults was 1:1, 42 males and 40 females, with no statistical mean significant difference (t-test for independent samples, two-tailed; $n_1 = 9$, $n_2 = 9$, $t = 0.16$, d.f. $= 16$, $P > 0.05$).

Group structure

Solitary animals, as well as pairs and multiple assemblages, were present in suitable rock crevices in both dry and wet season surveys. Single individuals were most common (66.7%) followed by pairs (25.8%) but larger assemblages of tortoises (up to 6) were also occasionally encountered (figure 5). Adult and sub-adult individuals of the same sex were not observed in the same rock crevice. The solitary behaviour undoubtedly minimises their vulnerability to predation. In less disturbed habitats multiple crevice assemblages and/or pairs were more often present than in disturbed ones as also observed by Klemens & Moll (1995). Loveridge & Williams (1957) found eleven pancake tortoises beneath one flat rock slab. Eight specimens and a freshly laid egg were found inside a small vertically sloping crevice in a stumpy rock outcrop in Namunyak Wildlife Conservation Area (Samburu) during the dry season in July 2001. Multiple assemblages are more common during the dry than wet season, possibly because aestivating individuals prefer to congregate in the few well-sheltered rock crevices. Unsheltered crevices, often occupied in the wet season, were deserted in the dry season. As also observed by Klemens & Moll (1995), disturbed habitats were characterised by crevices occupied by a single individual or vacant crevices. With respect to adults, there was a high rate of male/female pairs of tortoises (20% of the encounters) in the same rock crevice, a behaviour also reported also by Wood & MacKay (1987). This male/female pair bonding is an unusual behaviour among turtles, terrapins and tortoises (Ernst & Barbour 1989).

Figure 5. A pair of pancake tortoises at Kawelu (Mwingi district).

Reproductive behaviour

Loveridge & Williams (1957) stated that the pancake tortoise produces a single egg in July or August. An adult female, which was encountered alone during the dry season (September 1998), was recaptured in the wet season (December 1998) paired with an unmarked male. One male was recaptured in the same rock crevice but the female he had initially paired with was absent. In another separate occasion, during the dry season, an assemblage of 2 males and 1 female was observed. Later one of the males and the female were recaptured in the same crevice while the other male had left. Two females, which were initially in pair with males in separate rock crevices, were found in the same place but with their partners absent. The male/female pairing is seasonal as the pairs mostly break after each season.

No mating was observed during this study. In Kenya mating probably occurs during the long rains of March to May, egg laying in the long dry season around June/July/August, and hatching of the eggs in November/December after the on-set of the short rains. Only juveniles but no hatchlings were observed during the long rains (March–May). However, Moll & Klemens (1996) observed hatchlings and small juveniles in all seasons. From the foregoing information it can be deduced that the pancake tortoise in Kenya probably produces 1 egg per year.

Movement

Although the data are limited, information was obtained on the movement of marked individuals between crevices and on crevice fidelity. Zug (1993) and Barbaresi *et al.* (1997) pointed out that animal movements are related to both acquisition of primary resources such as food, shelter and mate, and the avoidance of sources of stress such as predators, thermal extremes and dehydration.

Pancake tortoises were marked and recaptured between September and December 1998 in Nguni and Nuu areas (Mwingi district). Almost all individuals recaptured were found in the original rock crevice. Movement between crevices was found to occur only during the wet season. For example an adult male/female pair was recaptured in the same rock crevice when revisited one month later in the dry season. Of individuals recaptured during the wet season, an adult male that was in pair with a female had moved about 70 m to inhabit another crevice. Another solitary adult male in the dry season had moved about 30 m to inhabit a different crevice. A crevice inhabited by a male/female adult pair in the dry season was inhabited by the same female but the male was no longer present. A crevice inhabited by a solitary female in the dry season was inhabited by the same female in pair with an unmarked adult male. Three juveniles were located in the same crevice in dry and wet season.

Pancake tortoises use the same rock crevices as their home base from whence they disperse for foraging and then return. Studies on Bell's hinge-back tortoise, *Kinixys belliana* Gray, 1831, and leopard tortoise, *Geochelone pardalis* Bell, 1828, found that rainfall influenced tortoise movement (Bertram, 1979a, b). This observation agrees with the present findings since it is only during the rainy season that pancake tortoises are observed to leave their crevices. Bertram (1979a, b) also found that hinge-back and leopard tortoises have well-defined home ranges. Wilson (1968) found that leopard tortoises have a defined home range while Chelazzi & Carla (1996) observed that Hermann's tortoise, *Testudo hermanni* Gmelin, 1789, has a very stable home range and returns back after experimental displacement. With respect to sex, males are wide ranging and circulate among crevices inhabited by relatively sedentary females. Moll & Klemens (1996) also observed this behaviour. Pancake tortoises therefore appear to have well-defined home range. This spatial stability could be a multi-adaptive strategy that produces an overall familiarity with the environment and consequently optimises the cost/benefit ratio for access to resources and stress avoidance.

Micro-sympatric species

Moll & Klemens (1996) observed that the tawny plated lizard, *Gerrhosaurus major* Dumeril, 1851, and the pancake tortoise often occur micro-sympatrically and regarded it as a useful indicator species of suitable pancake tortoise micro-habitats. This is in agreement with the present study. Tawny plated-lizard, white-throated savanna monitor *Varanus albigularis* (Daudin, 1802), puff-adder *Bitis arietans* (Merrem, 1820), black-necked spitting cobra *Naja nigricollis* Reinhardt, 1843, five-lined skink *Mabuya quinquetaeniata* (Lichenstein, 1823) and red-headed rock agama *Agama agama lionotus* Boulenger, 1896 often occur micro-sympatrically in crevices inhabited by pancake tortoises. On one occasion at Kamulewa (Mwingi), a puff adder and a male adult pancake tortoise co-habited the same rock slab. The adaptive significance of this micro-sympatry with other reptiles is not clear.

Threats, conservation and management of pancake tortoise populations

Habitat alteration and the pet wildlife trade are the two main threats to pancake tortoise populations in Kenya (Malonza 1999) and Tanzania (Klemens & Moll, 1995).

Three habitat alteration threats were identified, namely shifting cultivation, charcoal burning, rock slab and ballast extraction. Shifting cultivation is the major threat and is rampant in many areas of Kitui, Mwingi, Mbeere and Tharaka districts. In Voo, Muamba and Vendelani areas of Kitui district there was physical evidence of past and present rock extraction for construction purposes. In many cases, rock outcrops harbouring tortoises were entirely surrounded by farmlands. Livestock grazing is compatible with pancake tortoise survival as there is less micro-habitat alteration (Malonza, 1999). In Samburu, Marsabit and Isiolo districts, where the local people are nomadic pastoralists, the species is not threatened *per se* as there is little micro-habitat destruction through livestock grazing. Even in extremely overgrazed areas in Wamba (Samburu district), pancake tortoises could be found.

Spellerberg (1992) suggests that the illegal trade in wildlife and their products threatens many species with extinction. Over-collection of tortoises for the international pet trade threatens the survival of the pancake tortoise population in Kenya. There are reports of illegal tortoise collection in many parts of Mwingi district and there was physical evidence of collection at Kawelu where a rock slab had been broken using another rock allowing freer access to the crevice inhabitants (figure 6). Tortoise collectors have visited most of the areas surveyed in Mwingi district and have had depleting effects in areas like Nguni. Incidentally, Mwingi district is the only area within the Kenyan range where local people are familiar with the species. In Isiolo, Marasbit and Samburu districts for instance most people are not familiar with the species and consequently there were no reports of tortoise trade. Collection of tortoises has a detrimental demographic effect on the population, a scenario described by Boycott & Bourquin (1988) and Klemens & Moll (1995).

Figure 6. Physical evidence of site exploitation in Kawelu area (Mwingi district). Note the broken down rock slab and the improvised hooked extraction sticks lying on top.

Most of the pancake tortoise populations occur in south-eastern Kenya where habitat alteration is a major problem. Whilst the highest priority for the conservation of biological diversity should go to *in situ* conservation of species, in certain circumstances, habitats have become so degraded or population size has fallen so low that it is not possible to guarantee the survival of certain species in the wild. Under these circumstances, it is recommended (Anonymous, 1991) that a comprehensive genetic conservation program should include both *in situ* and *ex situ* elements. Zug (1993) stresses that captive breeding is a viable solution only for the short-term and the ultimate goal should be of reintroduction into rehabilitated natural habitats. Refuges or nature reserves provide the best option if not the ideal solution. Similarly, Church *et al*. (1996) stated that, whilst preservation of species requires a complex suite of management strategies including intensive captive breeding programs and translocation, establishment of nature reserves where species can be protected with minimal human intervention is a necessary component of an integrated strategy. One initiative to improve the conservation status of pancake tortoise population would be the establishment of a system of publicly and/or privately-owned nature reserves. Similar interventions were used to conserve the geometric tortoise, *Psammobates geometricus* (Linnaeus, 1758), in South Africa (Boycott & Bourquin, 1988).

Conservationists have now realised that protection and sustainable use are intricately linked. Long term species and habitat conservation will only succeed if it can generate revenue, thus showing that wildlife is an asset and not a liability. Tortoise breeding could be established, but the sustainability of the operation is a major problem. A strictly controlled harvest might provide both capital and incentive to manage the pancake tortoise, but it may, in turn, encourage illegal trade (Klemens & Moll, 1995). Again, the use of prohibition tactics in trade restrictions will only encourage unscrupulous people to exploit and thus destroy the wild populations because the demand for pancake tortoise cannot be eradicated completely. Instead, national and international regulatory bodies should be empowered to provide controls for trade in farmed pancake tortoise with very stiff penalties for abusers.

Recognising that the stronghold areas for the pancake tortoise in Kenya occur on private lands (>95%), a concerted educational campaign is imperative. It is clear that the future viability of the pancake tortoise population hinges on the co-operation and support of the local people. This in turn depends on whether they will be able to derive some benefits from protecting the tortoise also pointed out by McNeely (1988). In many cases the local people were unaware of the species occurring on their land. Therefore, promotion of awareness of the presence and importance of this species is the cornerstone in the fight for conservation on private land. The most positive way to educate the community on the importance of the pancake tortoise is to empower them with the responsibility for its costs and benefits.

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