ADDIS ABABA UNIVERSITY

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STATUS, ECOLOGICAL CHARACTERISTICS AND CONSERVATION OF THE PANCAKE TORTOISE, *MALACOCHERSUS TORNIERI*, IN NGUNI AND NUU AREAS, KENYA

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DEDICATION

I dedicate this MSc thesis to my mother for her patience and for doing everything to ensure that I have higher education and also the people of Nguni and Nuu areas who thought that I was insane and risking my life by visiting rocky areas associated with dangerous animals.

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ABSTRACT

Pancake tortoise *Malacochersus tornieri* is a rock crevice-dwelling terrestrial testunid inhabiting rock outcrops and kopjes discontinuously distributed throughout the semi-arid and arid savannas (Somali-Masai floristic zone) of Kenya and Tanzania. Their distribution overlaps with that of Precambrian rocks of the basement complex system.

The capture-mark-recapture technique used showed that the species population size in Nguni and Nuu areas is low and declining. Crevice rich rock outcrops with well-vegetated substrates are specifically preferred. Pancake tortoises are thus patchily and discontinuously distributed within their overall range. The species is very specialized in its microhabitat requirements with regard to crevice configuration in which individuals, pairs and occasionally large assemblages reside. The orientation of inhabited rock crevices varies from horizontal to vertical. Suitable crevices that provide protection from predators, overheating and desiccation are limited in number and they may regulate population size.

The species pair bonding is seasonal and restricted to breeding season. There was no significant difference ($P > 0.05$) in mean body weight and straight-line carapace length of males and females. Sexual dimorphism is not well marked. There was a highly significant positive linear correlation ($r = 0.964$) between straight-line carapace length and body weight. Outside crevice activity is very limited and only some hatchlings were found basking on rock surfaces during the wet season. During the dry season all specimens were within their crevices presumably aestivating. Movement in Pancake tortoises is very limited and centered on their rock crevices as the core areas. Males are more wide ranging than females. Females are relatively sedentary. Age structure of Pancake tortoise shows that adults dominate the population with very few young signifying a declining population. Considerable variation in adult color patterns was observed. The use of growth rings in estimation of age was found to be less reliable as age increases. Habitat alteration by humans in the form of shifting cultivation was identified as the major threat to Pancake tortoise population. Isolation of suitable habitats coupled with limited dispersal abilities of the species and low recruitment rates make recovery of depleted populations unlikely. *In situ* conservation through establishment of publicly and/or privately owned nature reserves is recommended over that of tortoise farms. Tortoise farms may provide incentive to manage and conserve the species, although it may in turn encourage illegal off-take.

1 INTRODUCTION

The familiar land tortoises comprise the large Family Testudinidae (sub-order Cryptodira, Order Chelonii or Testudinata, Class Reptilia). With the exception of Australia, the Family is represented throughout the tropical and temperate regions of the world. Tortoises are fully adapted to a terrestrial way of life (Boycott and Bourquin, 1988). They are characterized by well-developed limbs covered in tough, enlarged scales; hard and horny domed shells (frequently with clearly defined concentric growth rings); almost exclusively terrestrial habitat, and predominantly herbivorous habit (Pritchard, 1967; Boycott and Bourquin, 1988).

The Family contains about 40 living species worldwide. The Family reaches its greatest diversity in Southern Africa where 12 species are known to occur (Boycott and Bourquin, 1988). Ten genera are included in the Family Testudinidae: *Testudo* (Mediterranean and Middle East); *Geochelone* (South America, Africa and South East Asia); *Gopherus* (North America); *Kinixys* (Africa); *Psammobates* (South Africa); *Pyxis* (Madagascar); *Acinixys* (Madagascar); *Malacochersus* (East Africa); *Homopus* (South Africa) and *Chersina* (South Africa) (Pritchard, 1967).

Africa has the highest species number of land tortoises in the world (Greig and Burdett, 1976). In Africa, the genus *Testudo* is restricted to the Mediterranean countries of North Africa (Morocco, Libya and Egypt). The genus *Geochelone,* represented by two species; *Geochelone sulcata*, the spurred tortoise, found in arid parts of North Africa from Eritrea and the Sudan west to Senegal (Pritchard, 1967). *Geochelone pardalis,* the Leopard tortoise, with two subspecies recognized: *Pardalis* in South West Africa (Namibia) and *Babcocki*, wide spread from Sudan and Ethiopia south to the southern Cape Province (Loveridge and Williams, 1957; Pritchard, 1967; Boycott and Bourquin, 1988). The bowsprit or angulate tortoise *Chersina angulata,* is endemic to the Cape Province in South Africa (Pritchard, 1967; Greig and Burdett, 1976; Boycott and Bourquin, 1988). However, the Pancake tortoise (*Malacochersus tornieri*) occurs only in Kenya and Tanzania (Loveridge and Williams, 1957). The genus *Kinixys* is widespread in the sub-Saharan Africa. However, the genera *Psammobates* and *Homopus* like *Chersina* are confined to Southern Africa (Loveridge and Williams, 1957; Greig and Burdett, 1976; Boycott and Bourquin, 1988).

Of the 12 species of land tortoises which occur in Southern Africa 10 are endemic to the sub-continent. Nine of these occur in the Cape Province. South Africa has the distinction of supporting more terrestrial tortoise species than any other country in the world. The Cape Province in particular is, in fact, the richest area in the world as far as species of land tortoises are concerned (Greig and Burdett, 1976; Boycott and Bourquin, 1988).

Kenya has 4 species of land tortoises. The Leopard tortoise (*Geochelone pardalis*) is more widely distributed throughout the country in suitable habitats in the highlands, savannas and tropical forests. In most of the areas it co-exists with the other three species. The Bell's Hingeback tortoise (*Kinixys belliana*) occurs in the western tropical forests of Kakamega and the surrounding areas and also in the coastal lowland forests. The Speke's or savanna hinged (hingeback) tortoise (*Kinixys spekii*) inhabits most of the country's semi-arid savanna areas. The Pancake tortoise (*Malacochersus tornieri*) though sympatrically occurring with the other two species (*Kinixys spekii* and *Geochelone pardalis*) has a restricted range in the country (Loveridge and Williams, 1957; Broadley and Howell, 1991).

The Pancake tortoise formerly referred to as soft-shelled, flower, crevice or tornier's tortoise is a saxicolous (living in and among rocks) testunid. This is a small soft-shelled, dorso-ventrally flattened, terrestrial rock inhabiting tortoise found in scattered rocky hills, outcrops and kopjes in arid scrub and savanna in southern Kenya and northern, eastern and central Tanzania (Loveridge, 1957; Loveridge and Williams, 1957; Grzimek, 1975; IUCN, 1982; Stuart and Adams, 1990; Broadley and Howell, 1991; IUCN, 1992; Klemens and Moll, 1995). Klemens and Moll (1995) refer these savanna areas as falling on the Somali-Masai floristic zone. Loveridge and Williams (1957) have given a more extensive former range for this species in both Kenya and Tanzania. Currently, due to habitat destruction, it has patchy and restricted range distribution in both Kenya and Tanzania (IUCN, 1982). The Pancake tortoise depends strongly upon rock crevice microhabitat or substrate association to avoid predators and to thermoregulate efficiently. Therefore, the Pancake tortoise shows microhabitat or niche specificity and specialization for survival.

Habitat loss and fragmentation and its subsequent deleterious effect of driving species towards extinction have raised a lot of concern. The extinction of species as a result of human-induced habitat destruction of contiguous habitats into isolated tracts creates problems and challenges to conservationists and natural resource managers. Spellerberg (1991), points out that species with patchy distribution or those, which utilize a range of microhabitats, are more vulnerable to losses in mosaics of habitats resulting from insularization.

The semi-arid savanna areas, which are the habitats for the Pancake tortoise, are in a state of transition. Originally they were occupied by pastoralists, but are being converted into agricultural land due to population increase and shift from pastoralism to sedentary life. As human population increases and more people move in from already over-populated high potential areas, the natural vegetation is cleared indiscriminately and the land is continuously divided into smaller units ultimately threatening the survival of the Pancake tortoise.

Pancake tortoises have depressed and compressible shells which enable them to push their way further into rock crevices than if they were convex (domed) like the other land tortoises (Loveridge and Williams, 1957). This distinctive shell configuration is perhaps an adaptation to the unique species microhabitat characteristics. It is quite agile and a good climber. When disturbed, the tortoise wedges itself under rocks or within crevices between rocks to such an extent as to make its removal extremely difficult (Loveridge and Williams, 1957; Ernst and Barbour, 1989). The pliability of its shell aids in this, and was previously thought that the tortoise inflated their lungs to help expand the shell to lock them in place (Loveridge and Williams, 1957; Mertens, 1960; Pritchard, 1967). However, Ireland and Gans (1972) have shown that no significant or sustained increase in intrapulmonary pressure is associated with this wedging action. Instead, disturbed tortoise digs in their fore-claws and rotates the forelimbs outward, wedging the body in position. The soft-shell presumably evolved in response to the advantage for entering and fitting into narrow crevices and for improved locomotor energetics (Ireland and Gans, 1972). These two mechanisms for wedging themselves in position had been observed by Loveridge and Williams (1957). Other behavioral characteristics are that they are never found far from rocky areas and when they fall on their backs, are extremely adroit at righting themselves (Loveridge and Williams, 1957).

Adult color of the carapace is pale yellow or black to horn colored in very old individuals with variable markings so that scarcely two are alike; dorsal pattern always distinctly rayed like members of the *Psammobates geometricus* group (Loveridge and Williams 1957).

The flattened shape and lizard like behavior distinguishes the Pancake tortoise from all other tortoises. This kind of behavior heightens its appeal to the international pet trade. Imports of pancake tortoise especially from Tanzania dramatically increased through the 1980s resulting in the pancake tortoise being listed as a significant trade species (IUCN, 1992). In Kenya it is also popular as live animal trade item (Stuart and Adams, 1990).

Currently the species is listed on Appendix II of CITES and its worldwide status is indeterminate (IUCN, 1979). It is also categorized as Insufficiently known (I) due to lack of research information on its distribution and status (IUCN, 1982).

The current national system of protected areas in Kenya is very comprehensive for the protection of rare and endangered species of larger mammals. It has provided a protective umbrella for some of the other animals including amphibians and reptiles. However, the Pancake tortoise occurs virtually outside protected areas in Kenya since no population is known within a national park or other effective conservation areas (IUCN, 1982). In Tanzania, the species is known from Ruaha and Serengeti National Parks (Broadley and Howell, 1991), Tarangire and Ruaha National Parks (Moll and Klemens, 1996). There were earlier doubtful records from Mathews range, Ewaso Nyiro and around Isiolo in northern Kenya (Loveridge 1957). The occurrence of this species outside protected areas makes it vulnerable to over-exploitation for pet trade and consequently threatening its survival in Kenya. In addition, presently known populations are in areas with fairly dense human population and the species would be particularly vulnerable should the export volume increase (IUCN, 1982).

Studies on herpetofauna have been largely overlooked in wildlife and land management considerations as opposed to higher animals like mammals and birds. As such, Kenyan studies on herpetofauna have mainly been published in the form of checklists of reptiles and amphibians (Loveridge, 1957; Loveridge and Williams, 1957; Spawls, 1978; Broadley and Howell, 1991 and Drewes, 1992). However, Loveridge and Williams (1957) have given a basic comprehensive description on the Pancake Tortoise, especially on body structure, geographical range, breeding, longevity, diet, ectoparasites, habits and habitat mainly based on collections from Tanzania.

In Kenya, relatively little attention has been given to the Pancake tortoise apart from short term preliminary observations on the species natural history, distribution and status in northern areas of Kitui District (now Mwingi) by Wood and MacKay (1993) only during the dry season. Therefore, the present population size and distribution of this species in Kenya is yet to be established. In May-July 1992, IUCN project research scientist conducted a conservation assessment of this species status in Tanzania collecting data on its distribution, abundance and habitat preferences. An analysis of the impacts of wildlife trade on this species and the economic benefits derived by the country was completed (IUCN, 1992). In Tanzania Klemens and Moll (1995), Moll and Klemens (1996) have conducted studies on ecological characteristics and an assessment of the effects of commercial exploitation of the species. For rare and endangered species it is important to know whether their populations are viable.

Priorities for conserving biological resources should derive from the knowledge of the distribution of biodiversity in relation to location and nature of threats to it (WCMC, 1994). Threats to components of biodiversity involve the themes of habitat change, introduced species, pollution and unsustainable harvesting (over-exploitation). All these threats tend to be accentuated by excessive human population densities. These factors have caused the extinction of many plants and animals, and many more are threatened with extinction. However, the greatest current threat is human destruction of habitats (habitat loss and fragmentation) worldwide (UNEP, 1993). The effects of this factor may even be worse for specific habitat dependent, patchily distributed and commercially valuable species like the Pancake tortoise.

The status and distribution of the species in Kenya is not well known due to scarcity of research information. Consequently, increase in human population concomitant with changes in land use threatens the survival of this species. In addition, the species behavioral aspects in terms of group structure and movement is relatively little known as compared to other kinds of behavior that can be learned in captivity.

The conservation of this species is very important since every species contains a unique reservoir of genetic material that can not be retrieved or duplicated if lost. At the same time, the role of each species in the ecosystem is unique and it is, therefore, important in maintaining the species diversity. Therefore, for the conservation of the species, the study of its status and ecological characteristics was very crucial.

1.1 Objectives

General objective

To determine the current population size and distribution of the Pancake tortoise in the study areas.

Specific objectives

- To determine the species habitat requirements with reference to microhabitat selection, use, preference and specificity.
- To investigate the species group structure, age/sex ratio and movement.
- To assess the effects of land use practices on the distribution and viability of the species.

2 STUDY AREA

2.1 Location

The study was carried out in areas with scattered rocky hills of Nguni and Nuu administrative divisions of Mwingi District, Kenya (Fig. 1).

Mwingi District is one of the twelve districts in Eastern Province. It was carved out of Kitui District in July 1993. It lies between Latitudes 0^0 03' and 1^0 12' South and Longitudes 37^0 47' and 38^0 57' East. The district borders Kitui District to South, Machakos to the West, Mbeere, Embu, Tharaka Nithi, Nyambene and Isiolo to the North and Tana River District to the East.

The district covers an area of approximately 9,791 km^2 It is divided into 8 administrative Divisions with Nguni (3,285 km^2) being the largest and Migwani (468 km^2) the smallest (Fig. 1). The other divisions are Nuu (1,710 km^2), Kyuso (802 km^2), Mumoni (1,052 km^2), Central (1,178 km^2), Tseikuru (1,296 km^2) Ngomeni Division was carved recently from Nguni Division (Republic of Kenya, 1997).

2.2 Topography and climate

The district has an undulating landscape giving way to plains towards the East. The Southern, Northern and Western parts are higher compared to the eastern part due to few hills, which are spread in the areas.

The district is generally plain with few hills in Mumoni, Nuu, and Migwani Divisions. The Eastern part of the district, which covers Ngomeni, Nguni and Nuu Divisions, lies at 600 m above sea level.

Nguni and Nuu Divisions are generally plain with an average altitude below 600 m above sea level, except in area where hills jut from this plain. Generally the land of the district slopes from the west to the east. The major seasonal rivers are Mui and Enziu.

The district is situated in an arid and semi-arid zone and its climate is hot and dry for most of the year. It has unreliable rainfall regime. It receives a bimodal pattern of rainfall with long rains between March and May and short rains from October to December.

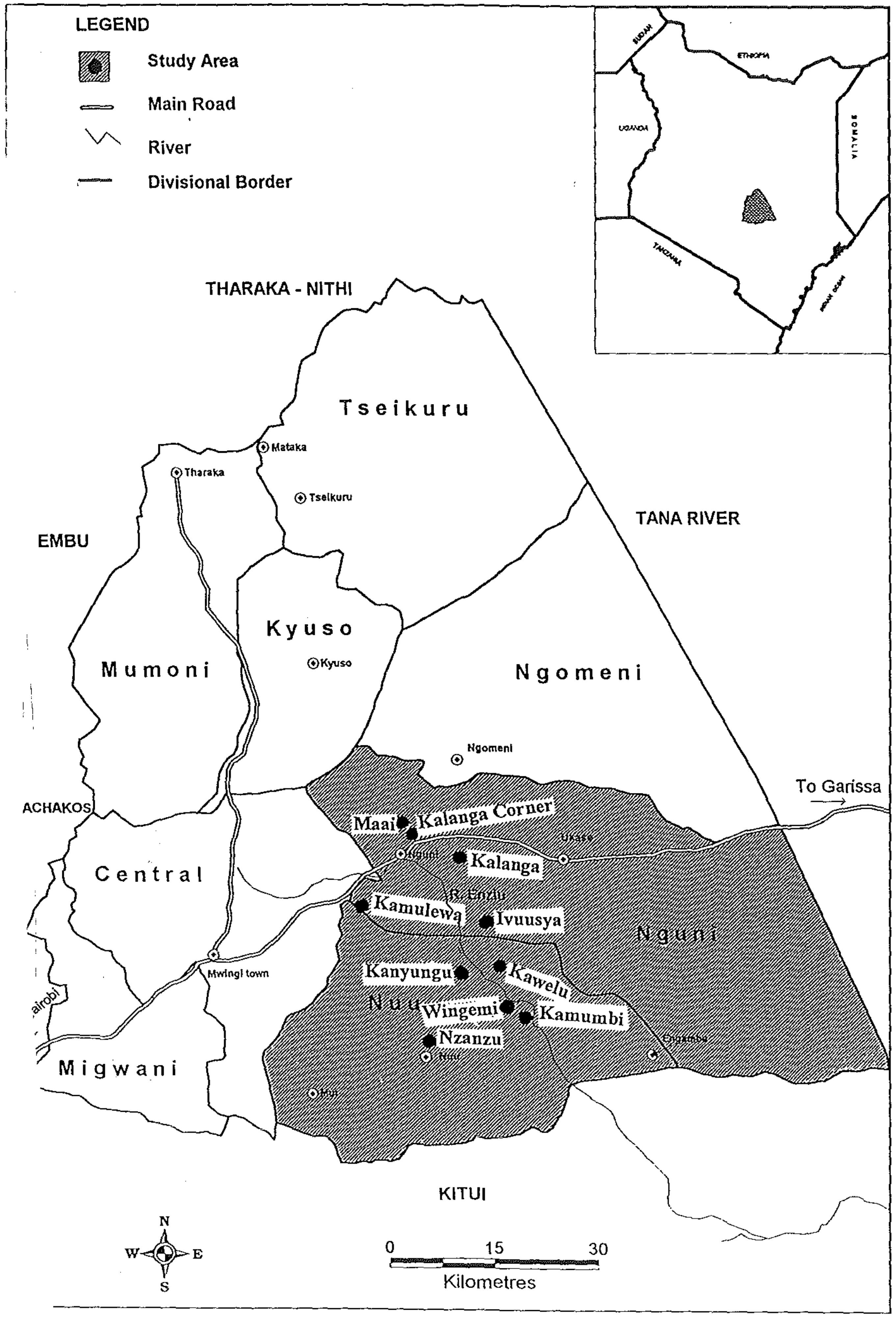


Figure 1. Map showing the study areas. Inset: A map of Kenya showing the location of Mwingi District

The short rains are more reliable than the long rains. Because of the unreliability of rainfall, the district is faced with recurrent droughts (Republic of Kenya, 1997).

The topographical features influence the amount of rainfall received. Hills such as Mumoni receive 500-760 mm of rainfall per year, while the eastern region which includes Nguni and Nuu generally receives less than 500 mm. In general, most of the district experiences less than 750 mm of rainfall per year (Republic of Kenya, 1994; 1997) (Fig. 2).

Temperature and evaporation rates are generally high with February and September being the hottest months of the year. The minimum mean annual temperature in the district varies between 14^0C and 22^0C, the maximum mean annual temperature ranges from 26^0C and 34^0C. The eastern and the northern parts are hotter than the western (Republic of Kenya, 1997).

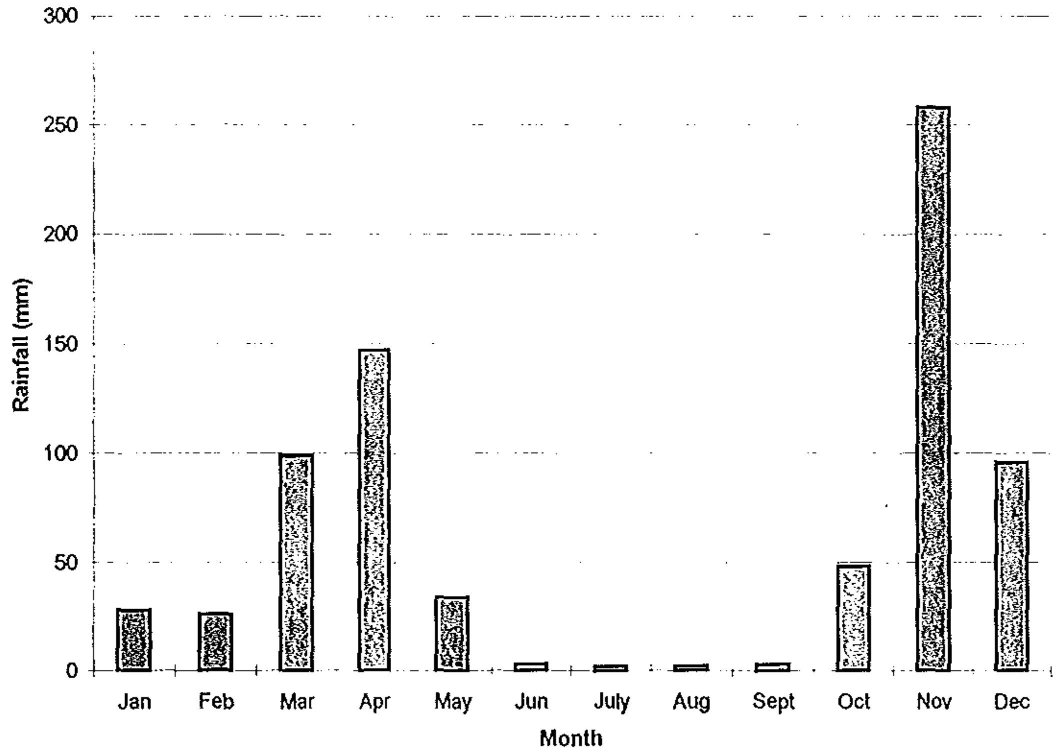


Figure 2. Rainfall pattern in the study area. Source: Meteorological Office Mwingi, 1998

2.3 Soils and Geology

Metamorphic and granitic rocks of the basement complex system (Republic of Kenya, 1994) characterize the geology of the district.

The geology of Nguni and Nuu area constitutes prominent Precambrian age granite hills with lower irregularly spaced and relatively small granite outcrops about the intervening terrain (Wood and MacKay, 1993).

The soils of the district are largely determined by the parent rock though most of them are of low fertility. This is characteristic of the red sandy soils and heavy clay soils in the eastern plains and western parts of the district respectively. However, the river valleys are covered by saline alluvial soils of moderate to high fertility, while the soils on the hills are shallow and stony. Soils in the district are not optimally used because rainfall is inadequate.

Although some areas of the district have fertile land suitable for crop farming, livestock rearing is the preferred activity (Republic of Kenya, 1997).

2.4 Vegetation

The natural vegetation of much of the area is deciduous *Acacia-Commiphora* bushland and thicket with occasional larger trees. The main component is the tree with the peeling blue bark *Commiphora baluensis*, with related species such as the twisted stem *Commiphora mildbraedii* and *Commiphora edulis* intermingled with among many different types of *Acacia*, the common being *Acacia senegal, Acacia tortilis, Acacia brevispica, Acacia nilotica* and *Acacia reficiens*.

Common smaller trees and shrubs are *Lannea alata, Steganotaenia araliacea,, Vitex payos, Premna resinosa, Combretum aculeatum* and an assorted species of *Combretum, Grewia, Cordia* and *Hibiscus*. At lower levels, shrubs such as *Indigofera, Tephrosia, Barleria* species among others form a dense tangle with *Sansevieria* and *Aloe* species growing in dense clumps that make passage through the bush extremely difficult.

Widely scattered large tree species projecting through the bush canopy are also a common feature of this type of habitat. Prevalent is *Delonix elata, Boswellia neglecta, Erythrina burttii, Sterculia africana, Dicrostachys cinerea, Terminalia brownii* and

Balanites aegyptiaca.

Dominating the whole scene is that giant of the African savanna the baobab (*Adansonia digitata*). The stunted evergreen *Boscia coriacea* is very common. Other common evergreen species are *Strychnos decussata, Trichilia emetica, Salvadora persica* and *Dobera glabra. Entada leptostachya* is a common climber in the thorn bushland.

Fringing the few seasonal watercourses such as Enziu River, *Acacia elatior* grow in dense stand associated with *Tamarindus indica*, *Ficus sycomorus* and *Kigelia africana.* Also common in the riparian habitats is the toothbrush bush *Salvadora persica* and *Capparis tomentosa.*

Growing in most of the rocky hills is an assortment of *Euphorbia, Commiphora, Sansevieria* species among other trees, shrubs and herbs. In the rain season creepers *Ipomoea mombassana, Ipomoea kituiensis, Cucumis dipsaceus* may cover much of the area, while ephemeral herbs such as *Commelina benghalensis, Bidens pilosa, Acanthospermum hispidum, Pupalia lepasea* among others covers much of the ground than grasses. Dominant grasses include *Enteropogon macrostachyus, Dactyloctenium aegyptium, Cenchrus ciliaris, Brachiaria spp., Chloris roxburghiana, Aristida Adscensionis, Panicum maximum, Latipes senegalensis* and *Eragrostis spp.* Lists of the dominant trees, shrubs, lianas, herbs and grasses are given in appendices 1 and 2. Voucher specimens of almost all the plant species in the study area have been preserved in the East African Herbarium at the National Museums of Kenya, Nairobi.

2.5 Land use practices

The land use of the area is dependent on the amount of rainfall received. Due to the unreliable rainfall and recurrent droughts, the main economic activities in these divisions (Nguni and Nuu) are livestock keeping and growing of drought resistant crops (Republic of Kenya, 1994; 1997).

The ethnic Kamba community practice sedentary agropastoralism growing crops such as bulrush millet *Pennisetum typoides*, Sorghum *Sorghum spp.*, maize *Zea mays,* Cowpeas, Pigeon peas, beans *Phaseolus vulgaris* and green grams. Small-scale traditional beekeeping, using traditional log beehives is done as a supplement source of income. Pastoralism is practiced by herding large herds of cattle *Bos taurus*, goats *Capra hireus* and sheep *Ovis aries*.

3 MATERIALS AND METHODS

3.1 Identifying seasons

The study was carried out between September and December 1998 for duration of 2 months each season. The dry season covered September and October and the wet from November to December. The study covered two distinct seasons, wet and dry. Distinction of season was necessary because seasons have influence on animal community and vegetation variables. This would allow the computation of the effect of each separate season on the Pancake tortoise distribution and abundance. Distinction of season was through change of rainfall pattern, grass greenness and per cent vegetation cover.

3.2 Selection and description of the study sites

Ten out of thirty study sites were randomly selected in different scattered rocky hills, rock outcrops and kopjes in the study area. These study sites were; Maai, Kalanga corner, Kalanga, and Ivuusya in Nguni Division; Kamulewa, Kawelu, Wingemi, Kamumbi, Kanyungu, and Nzanzu in Nuu Division (Fig. 1). Different human land use practices surrounded them.

The abundance and density of Pancake tortoise population is a function of habitat quality of the study site. High quality habitat characteristics include; well configured rock crevices, high vegetation cover over rock outcrops, and less human habitat destruction. Study sites such as Kawelu, Wingemi and Kamumbi are characterized by well-configured rock crevices, less human habitat destruction and less tortoise exploitation. Kalanga Corner, Kalanga and Ivuusya suffered indiscriminate Pancake tortoise over-collection in the past in addition to having high human population density. Maai, Kamulewa, Nzanzu characteristically have high human population. However, Kanyungu despite having high vegetation cover, less human population, had a very low proportion of well-configured rock crevices in relation to the total number of rock outcrops.

The selection of the study sites was after an initial reconnaissance of every rocky habitat to ascertain the presence of the study species. Same study sites were used for both seasons sampling.

3.3 Demarcation and layout of the study plots

At least one study plot was randomly selected and demarcated in each study site. The plots were marked at the corners by standing trees. The plots measured 800 m x 200m

3.4 Time constrained search-and-seize (hand-capturing) method

Most common survey methods employed to estimate the abundance of reptiles involve capturing individuals. This is for two reasons; i) reptiles tend to be mobile and/or shy and cryptic, so that not all members of a population will be visible at any one time, and ii) much more information such as weight, measurement, sexing, determination of an individuals reproductive condition and assessment of its parasite load, can be obtained from an animal that has been captured than can be obtained from direct observation. (Sutherland, 1996).

The pancake tortoise population census was accomplished by the use of time constrained search-and-seize (hand capturing) sampling method as described by Karns (1986). The census was conducted by walking slowly within the study plot and intensively searching for the species in its microhabitats and recording all individual specimens seen and/or captured. No spatial boundaries were set other than staying within the study plot. The time limit for each search was at least four hours.

Sampling was conducted from morning to evening between 0700 hr and 1800 hr with breaks depending on the prevailing weather conditions. The study plots were coded 1, 2, 3,... and counting was done in a rotational series. This rotational system was used to minimize censusing bias if counts were started from the same study plot always. The study sites were also coded A, B, C, ... and censused in a rotational fashion.

The species is known to be shy and cryptic. When disturbed it tends to run away and hides itself under rocks or within rock crevices making it impossible to remove (Loveridge and Williams, 1957). The researcher was therefore, forced to move quietly to avoid disturbance. Occasionally, the signs of the presence of one or more pancake tortoise were signaled by fecal material littering its entrance. A 2 m strong flexible hooked wire was used to retrieve individuals sighted in all rock crevices.

For each specimen captured, standard data were recorded. These include: locality, altitude, date and time of capture, sex and age group (hatchling, juvenile, sub-adult,

adult), weight and their corresponding measurement of straight-line carapace length (SCL) along the mid-line were taken. Carapace length was taken using a 250 mm vernier caliper and body weight with a 1000 g super Samson (salter) scale calibrated in 10 g increments. Age estimate was obtained by counting growth rings on the first left or right costal scute. These particular scutes were selected because in most of mature specimens the carapacial scutes were worn out partly to nearly completely smooth, presumably from constant scraping within their crevices. Sex was determined by a combination of the presence of depressed (concave) plastron or elongated tail in males and depressed hind lobes and short stumpy tail in females.

Individual specimens captured were marked by cutting notches on edge of marginal scutes to minimize double counting during the study period. Marks were applied using a coding system, and numbered to yield a large number of combinations as described by Sutherland (1996). The first nine marginals on the left side from the supra caudal towards the nuchal scute were arbitrarily designated numbers one through nine respectively, while the first nine marginals on the right represented numbers ten through ninety.

3.5 Spatio-temporal population dynamics

The study took into consideration weather conditions. These may greatly affect the activity, and therefore, the catchability of the tortoise. The effects of weather can vary seasonally, as well as on daily basis (Sutherland, 1996). Therefore, the study was carried out during the wet and dry seasons allowing for temporal and spatial changes in the species abundance to be assessed. Thus sampling was conducted between and within study sites for a given time.

3.6 Microhabitat selection

Each individuals' microhabitat components was noted so as to assess the general species habitat requirements. This was used to determine the species habitat preference and specificity. The following kinds of microhabitats or substrates were used: rock surface, ground, rock slab and rock crevice. The activity of individual species such as hiding, basking, feeding, mating or courting was recorded.

3.7 Group structure and movement

The tortoise group structure (solitary, pair, group) and movement were assessed and noted. Capture-mark-recapture (CMR) technique was used to study the individuals' movement (Brower *et al.*, 1989; Sutherland, 1996). Sighted and captured tortoises were marked on the carapace by "notching" the marginal scales and released for subsequent recapture to estimate the individuals' movement. When recaptured the tortoise position was marked with a stick or wooden peg placed on the ground and the distance from its previous location measured by pacing. It was assumed that the marked individual moves freely within its community.

3.8 Human impact assessment

Human activities within and around the tortoise rock habitats such as bush clearing and burning, farming, human settlement and evidence of tortoise collection were qualitatively assessed. These were used to assess their effects on the distribution and abundance of the pancake tortoise.

3.9 Data analysis

3.9.1 Estimation of population size

Peterson-Lincoln capture-mark-recapture method was used to estimate the population size (Brower *et al*, 1989; Sutherland, 1996). Marking was done during the dry season and recapture in the wet season. This method is based on recapture of marked animals. It involves marking and recapturing once respectively. It is taken that the ratio of the marked animals to the total population is equal to the ratio of animals marked and recaptured to the total number in the second capture.

$M/N = m/n$ Where M = Marked animals in first capture

N = Total population size

m = Animals marked and recaptured

n = Number of animals in the second capture

Therefore, $N = Mn/m$

Assumptions

1. Each individual has equal chances of being captured.
2. There are no births (recruitment) or immigrations into the area under study between the first and second trapping seasons.
3. There is no differential mortality or emigration between the marked and unmarked animals.
4. No marks are lost.

This method normally does not give an exact population size; therefore, there is a need to calculate confidence limits at 95% level, which is calculated from:

$S.E = \sqrt{M^2 n(n-m)/m^3}$ Where S.E = Standard error

M, n, m, are as in Lincoln Index above

Thus, to determine the limits within which the population lies at 95% Confidence Interval, two standard errors from the estimate were added or subtracted.

3.9.2 Estimation of individuals' movement

Marked and recaptured individuals were used to estimate the individuals' movement. This was obtained by estimating the distance between the point of recapture and its previous location.

3.9.3 Statistical tests

- Two-way analysis of variance (ANOVA) was used to test the differences in the number of individuals among study sites and seasons.
- Chi-square (Contingency) was used to test whether species abundance of each age group is dependent on season.
- Correlation analysis was used to test the relationship between the weight of the specimen and straight-line carapace length.
- Two-tailed t-test was used to compare the means of straight-line carapace length and body weights of male and female tortoises.

4 RESULTS

The outcome of the results obtained during the study period is presented in the following six separate sections. The first section deals with the results obtained on population size. The second section on abundance of Pancake tortoise. The third section outlines the species habitat characteristics and distribution. The fourth section describes the physical characteristics of the species. The fifth section gives the results on behavioral aspects. The sixth section shows results obtained on human impacts on the species survival. Finally, information is given on microsympatric species and predation.

4.1 Population size

Peterson-Lincoln Index was used in the calculation of population size since the study had only one recapture after marking the tortoises. Discounting the number of individuals sighted but not captured a total of 108 Pancake tortoises were counted during the two seasons. 64 and 69 tortoises were counted during the dry and wet seasons respectively. The wet season capture included 25 recaptures from the dry season.

From Peterson-Lincoln Index for estimation of population size, the population of Pancake tortoises in the sampled study sites is 177 if all assumptions are really fulfilled.

Since the method does not give an exact population size, a 95% Confidence Level shows that the population lies between 121 and 233 (177 ± 56).

4.2 Abundance of Pancake Tortoise

4.2.1 Differences in Seasonality

There was no marked difference in the total number of tortoises counted in both seasons. However, with respect to particular age groups there was a significant seasonal difference. Results from Chi-square Contingency test indicated that abundance of particular age groups was dependent on season ($X^2 = 10.43$, d.f. $= 3$, $P < 0.05$). Hatchlings and juveniles were more during the wet season whereas sub-adults and adults were comparatively abundant in the dry season (Table 1, Fig. 3).

Table 1. Number of Pancake Tortoise in each age group in the two seasons.

Age group	Dry season	Wet season	Total
Hatchlings	0	8	**8**
Juveniles	9	15	**24**
Sub-adults	14	9	**23**
Adults	41	37	**78**
Total	**64**	**69**	**133**

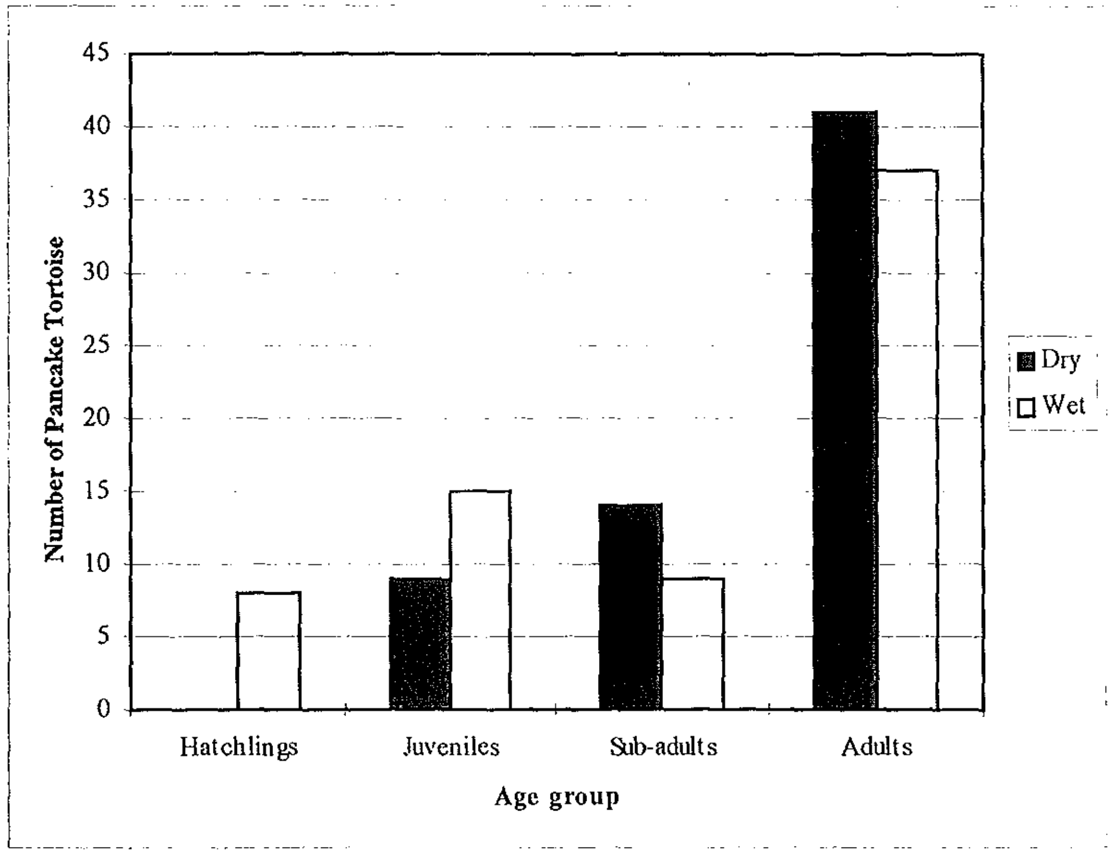


Figure 3. Number of Pancake tortoises in each age group in both seasons

4.2.2 Effects of habitat quality

Different study sites depending on their microhabitat quality had different numbers of Pancake tortoises. Some study sites had higher numbers than others Study sites of high quality habitat such as Kawelu, Wingemi and Kamumbi harbored high densities of Pancake tortoises. These study sites, unlike most of the others had a combination of high number of well-configured rock crevices; less human habitat destruction and high vegetation cover over most of the rock outcrops (Table 2, Fig. 4). Results from the 2-way ANOVA showed a highly significant difference ($F_{9,9} = 16.4$, $P < 0.01$) in Pancake tortoise abundance among study sites due to differences in habitat quality.

Table 2. Number of Pancake tortoises in different study sites in both seasons.

Study site	Dry season	Wet season	Total
Kalanga corner	0	0	**0**
Kalanga	0	2	**2**
Maai	4	7	**11**
Ivuusya	3	2	**5**
Kamulewa	3	5	**8**
Kawelu	18	21	**39**
Wingemi	16	11	**27**
Kamumbi	7	12	**19**
Kanyungu	2	1	**3**
Nzanzu	11	8	**19**
Total	64	69	**133**

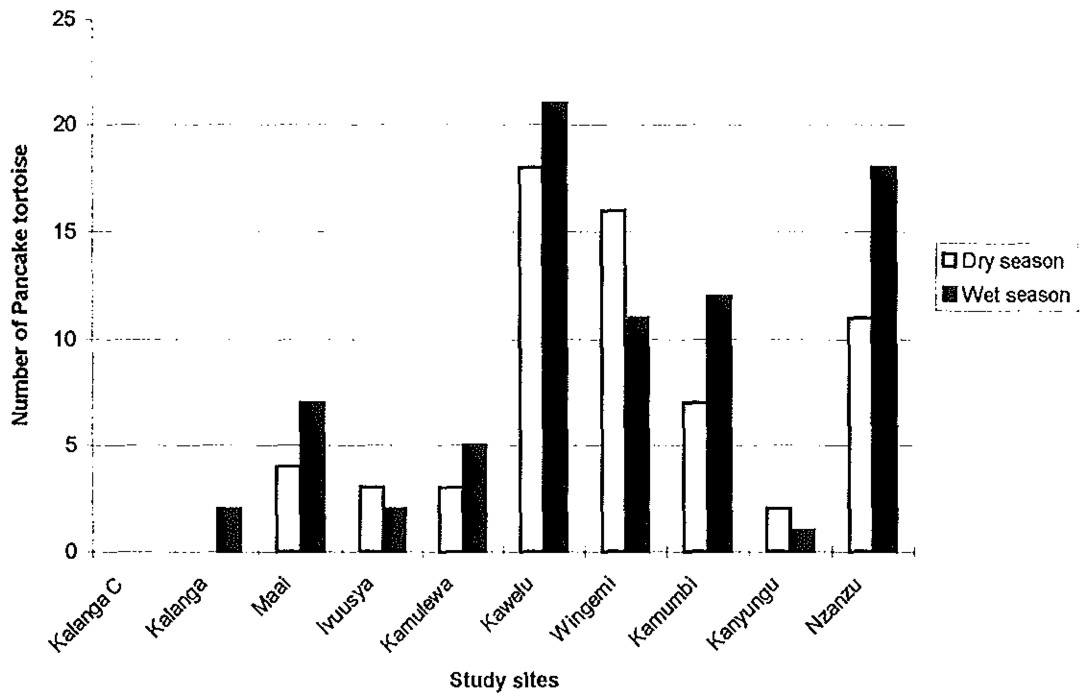


Figure 4. Number of Pancake Tortoises observed in different study sites in both seasons

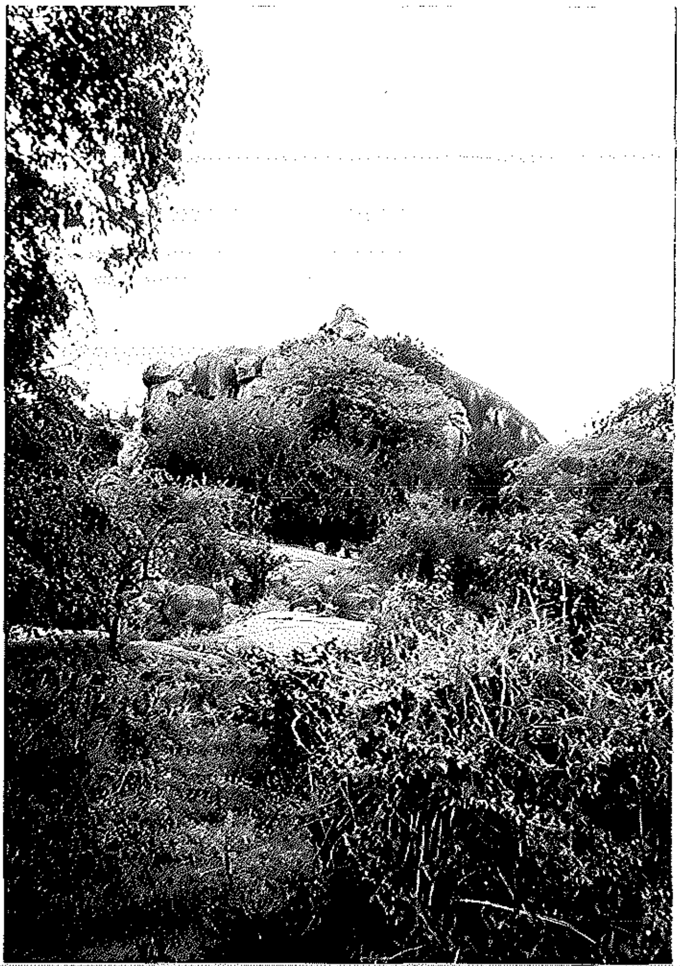
4.3 Habitat characteristics, selection, use and preference

Pancake tortoises were found only in rock crevices of suitable configuration in rock outcrops and kopjes in this *Acacia-commiphora* bushland habitat (Fig. 5). Tortoises spend most of the time hiding and aestivating within crevices and almost all those encountered in both seasons surveys were found in crevices. The orientation of inhabited crevices varied from horizontal to vertical (Fig. 6). Crevices inhabited by tortoises generally shared certain similarities including rock floors and frequently but not always the entrance of an inhabited crevice had tortoise droppings. The most definitive characteristic of tortoise inhabited crevice was that they taper back from the entrance. The tortoises retreat on the back narrow section. Usually they hide in crevices with only one entrance and no through way. Another general similarity of the inhabited rock crevices above the ground level is usually a relatively gentle descent point from the crevice entrance to the soil substrate at the base of the rocks.

The rock areas that contain the crevices the tortoises inhabited were mainly rock outcrops of exfoliating granite outcrops scattered about the intervening terrain occasionally along hillsides. In the areas covered, the best habitats were low gently rolling hillsides with numerous granite outcrops that provided many shelters underneath exfoliating rock slabs and crevices of various stages of weathering. These outcrops were discontinuously distributed in the area, *Acacia-Commiphora* bushland.

Apart from the few exfoliating rock slabs on the base, there was little success in isolated kopje-type of habitats. These kopjes usually have very large cave-like crevices mostly preferred by rock Hyraxes and African rock Python. Therefore, optimal Pancake tortoise is usually provided by rock outcrops and kopjes that have been exposed long to weathering and erosion to produce suitable crevices and collect substrates capable of sustaining vegetation.

Rock crevices, which were well vegetated and sheltered, were the most preferred and often harbored large tortoise assemblages. This kind of microenvironment undoubtedly provides protection from overheating, desiccation and predation. These microhabitats are often a small proportion of the crevices in any given area. These pockets of optimal habitat often are widely separated from one another by large expanses of apparently unsuitable and unoccupied habitat. Pancake tortoises usually leave their crevices to forage and mate in the immediate vicinity, however this dispersal is normally limited.



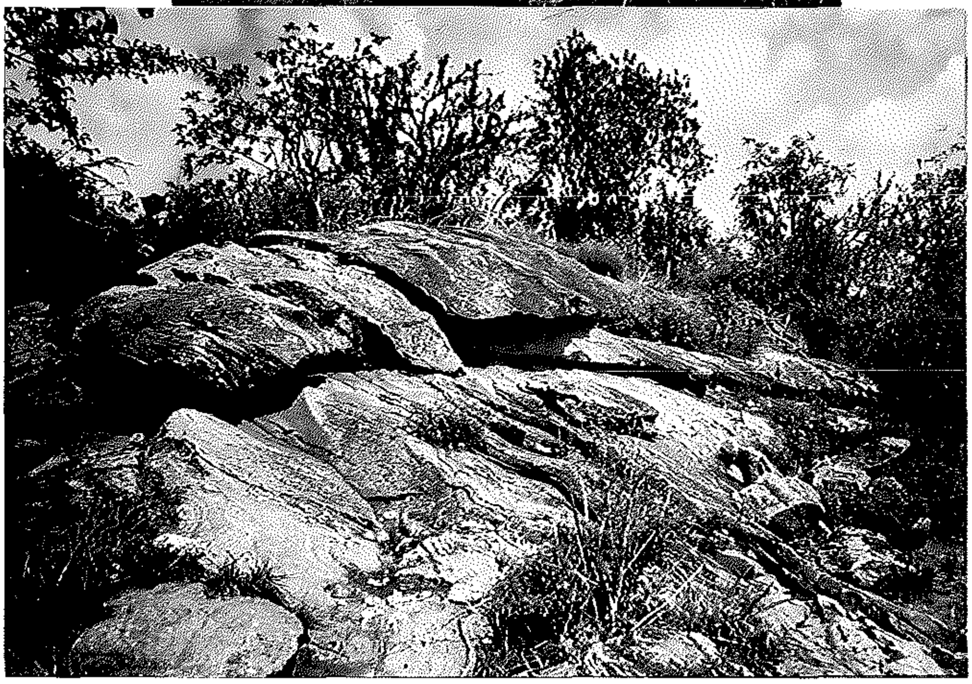


Figure 5. Typical Pancake tortoise habitat in *Acacia-Commiphora* bushland. A rock kopje (Top) at Nzanzu and exfoliating rock slabs (Bottom) at Kalanga

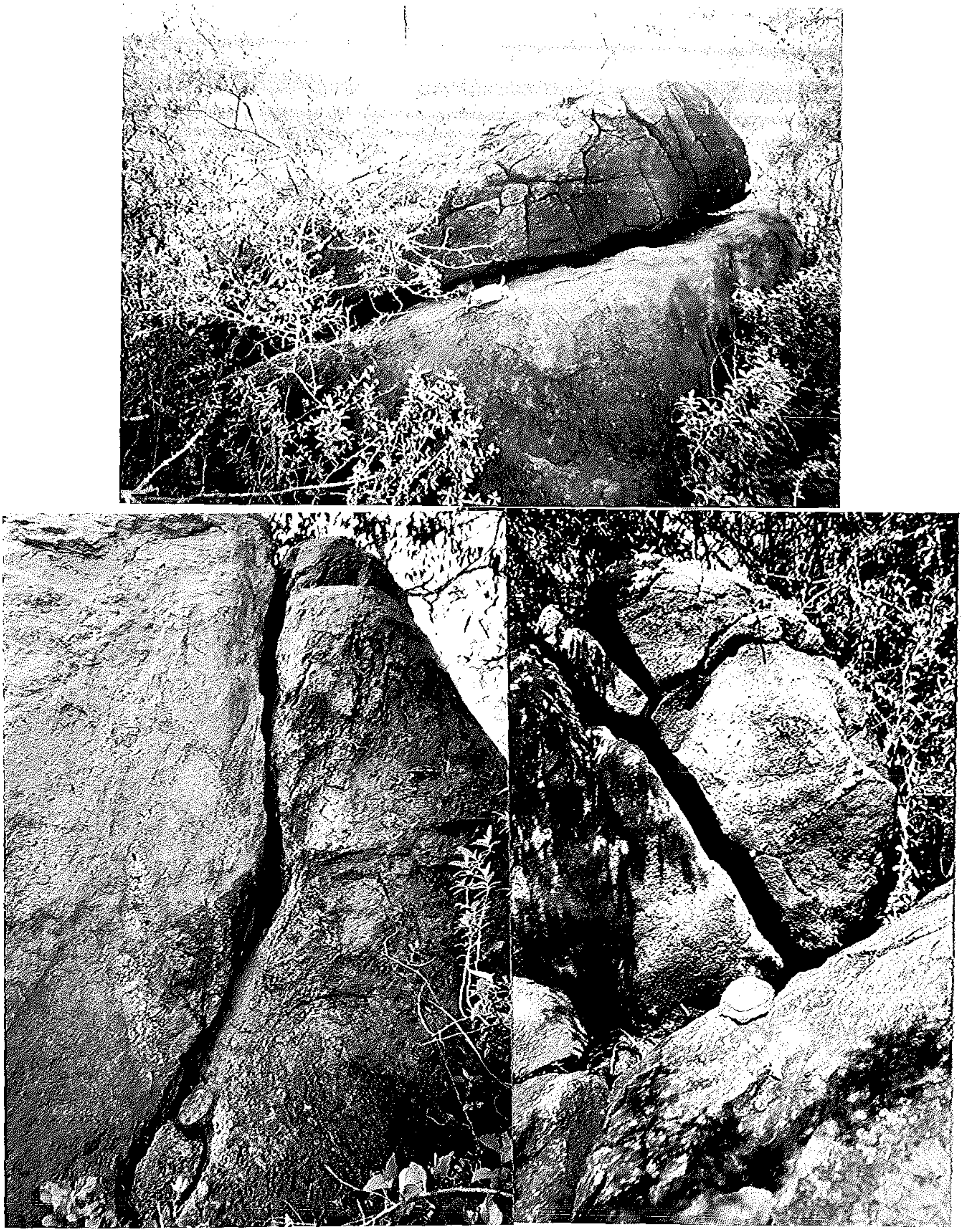


Figure 6. Several representative crevice configurations, all of which contain one or more Pancake tortoises.

4.3.1 Distribution of Pancake Tortoise

The distribution of Pancake tortoise follows the availability of suitable microhabitats for their survival. Populations of Pancake tortoises are scattered discontinuously possibly from northern Kenya southward through eastern into the Tsavo East National Park. In Mwingi District, the study confirmed the occurrence of the species in Nguni, Nuu and Ngomeni divisions. Other additional localities apart from the present study sites based on information from tortoise collectors are Mui, Tuvaani, Kiumbe, Iviani, Kavindu, Engamba areas in Nuu Division; Ukase in Nguni division, Mataka and Tharaka north of Kyuso (Fig. 7). Pancake tortoises have also been collected in Chiokarige area in Tharaka-Nithi District. Chiokarige market is to the Northwest of Tharaka market of Mwingi District.

Altitude seems to limit distribution of Pancake tortoise in the district. The average altitude of the areas sampled was 600 m asl. The lowest altitude where individuals were found was about 510 m and highest was 750 m above seas level. The species appears to be absent in high altitudes areas of Migwani and Mumoni divisions and some parts of central division which have altitudes above 1000 m asl. This may be due to high altitude, high human population density, habitat alteration or a combination of factors. This might have caused the species range to contract to the remote and less densely populated areas. Pancake tortoise appears to be patchily distributed in low altitude areas like eastern part of this Mwingi District with an average altitude of 600 m asl.

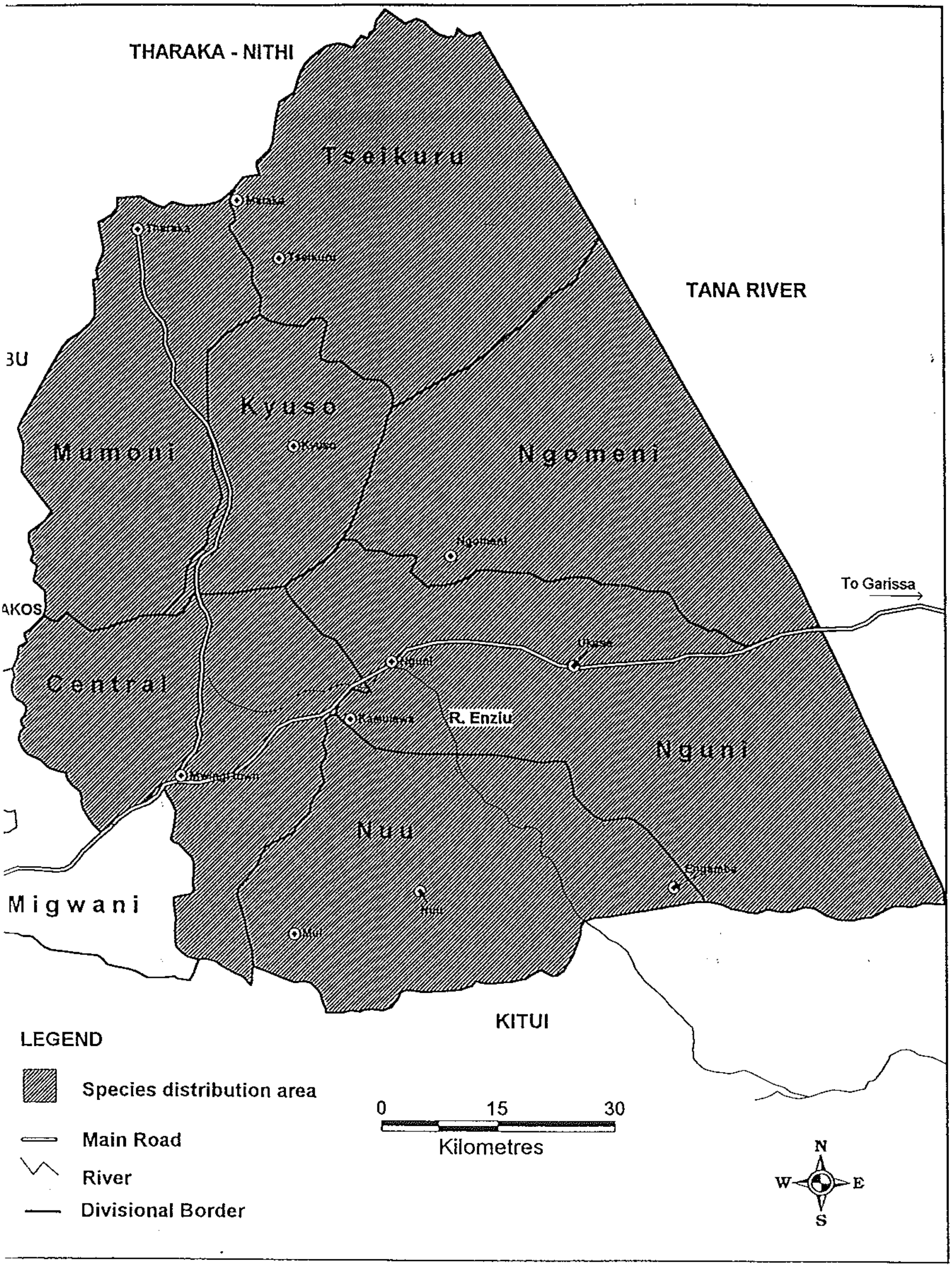


Figure 7. Map of Mwingi District showing the possible general distribution of Pancake Tortoise

4.4 Color pattern, Size and Growth

There was an extensive degree of adult color and pattern variation. Pattern wise, no two specimens are really alike. Adult color patterns are extremely variable ranging from light yellow with darker rays running through each scute to black with yellow rays running through the scutes. Most of the very old individuals have lost this carapacial geometric pattern and are horn colored (Fig. 8).

In terms of coloration and size, there were no marked sexual differences between adult males and females. A central plastral rhombus shaped light colored and unossified area was observed and is very distinct in very old tortoises. Measurements of 52 adult Pancake tortoises (26 males, 26 females) randomly selected from the whole population are given in Table 3. Mean (± 1 S. E.) body weights of males (314.2 ± 32.7, n = 26) and straight-line carapace length (143.15 ± 4.96, n = 26) were greater than those of females body weight (299.0 ± 29.6, n = 26) and straight-line carapace length (137.1 ± 4.5, n = 26). The straight-line carapace length of female ranged from 132.6 – 141.6 mm with a mean of 137.1 mm, and in males 138.2 – 148.1 mm with a mean of 143.15 mm. The largest specimen recorded was a male of 175 mm while for female it was 162 mm. The smallest was a hatchling of 36mm tentatively sexed male. 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 straight-line carapace length of males and females.

Body weights of males ranged from 281.5 – 346.9 g with a mean of 314.2 g and in females 269.4 – 328.6 g with a mean of 299.0 g. The body weight of the smallest hatchling was 10 g and the heaviest was an adult male of 510 g. The heaviest female was 480 g. Similarly, 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.

From the results of 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 has been demonstrated.

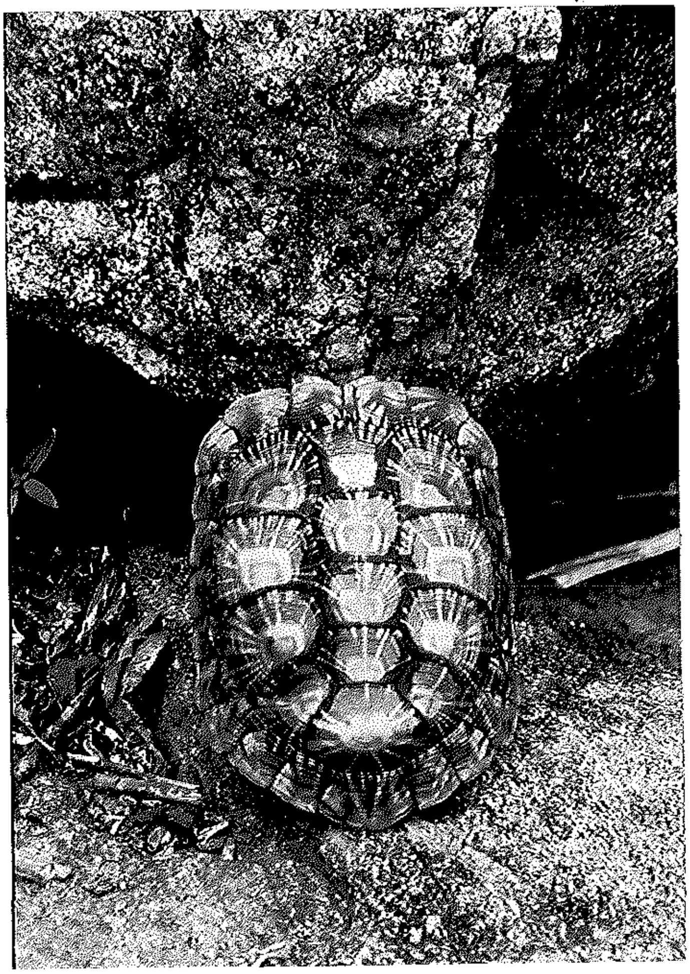


Figure 8. A representative color variety of a well-flowered and geometrically patterned Pancake tortoise.

Table 3. Mensural characteristics of 52 adult male and female Pancake Tortoises randomly selected from the population. Straight-line carapace length is expressed in mm and weight in g.

Measurement	Females (n = 26)	Males (n = 26)
Mean carapace length ± 1S.E	137.1 ± 4.5	143.15 ± 4.96
Range	132.6 - 141.6	138.2 - 148.1
Mean weight ± 1S.E	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 straight-line carapace length of individuals recaptured in the wet season.

An adult female had grown 2 mm in carapace length and 65 g heavier one month after the rains. The tortoises, generally recorded increments in both body weights and carapace length after being recaptured in the wet season two months later.

Up to 20 distinct growth rings on the carapacial scutes were observed. A characteristic double ring pattern in most of the specimens was observed which possibly represent two growth periods during the two rain seasons. The number of growth annuli was halved in the estimation of the age of individuals. In very old individuals, the growth rings tend to wear out and in others become overlapping while in some growth rings disappear in specimens with smooth carapace.

Marked changes with increasing age in growth rings are well defined in juveniles and sub-adults, but in adults, they tend to become obliterated. The smooth scute surfaces are the result of constant scrapping against the rock within which the tortoises hide. The age determination of Pancake tortoises by growth rings is less reliable since individuals of the same age group may have different numbers of growth annuli.

Variation in carapacial scute structure was observed whereby some individuals, especially, the old ones have keeled and even imbricate scutes.

4.5 Behavioral aspects

4.5.1 Habits

Pancake tortoises are usually very agile and good climbers. Occasionally individuals could be found in vertical and less accessible crevices. When they fall on their back they are very adroit at righting themselves. In addition, when they are captured and released, they tend to dash off for their crevices instead of withdrawing into their shell. However, for some hatchlings encountered outside their crevices, when approached, they tend to freeze and retract their head before running for shelter. They are equally harder to catch than adults as they are more agile.

Within the crevices, pancake tortoises wedge themselves tightly and are very difficult to dislodge. On several occasions, tortoises could not be dislodged despite strenuous and prolonged efforts. Males are more difficult to dislodge than females. In almost all occasions were a pair was found it was only the female that could be removed if not both. This wedging behavior was found to be effectively accomplished by digging in their claws and simultaneously pushing their carapace against the crevice ceiling.

4.5.2 Activity pattern

On three separate occasions during the wet season, hatchlings were found basking on rock slabs and surfaces in the morning (9:30 a.m., 11:10 a.m.) and in the evening (5:15 p.m.). When noticed, they usually retract their heads and freeze and on trying to grab them they dash for safety in the nearest crevice.

No tortoise was encountered outside crevices during the dry season. Therefore, Pancake tortoises rarely venture outside their crevices though all the tortoises observed were alert within their crevices. The activity pattern of the Pancake tortoise apparently appears to be diurnal but constrained by potential predators.

4.5.3 Age and sex ratio

The population sampled was tentatively grouped into four age groups: Hatchlings for specimens 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 on both seasons, hatchlings were only observed during the wet season after the onset of the rains. The age ratio of the four age groups was 1:2:2:8 respectively. This is typical of a narrow based or inverted population pyramid.

The sex ratio of the adults (> 10 cm) for males and females was 1:1, 42 males and 40 females (Table 4). There was no statistical mean significant difference (t-test for independent samples, two-tailed; $n_1 = 9$, $n_2 = 9$, $t = 0.16$, d.f. = 16, $P > 0.05$).

Table 4. Number of adult males and females in different study sites in both seasons.

Study site	Males	Females
Kamulewa	3	1
Ivuusya	2	3
Kawelu	12	10
Wingemi	7	9
Nzanzu	7	5
Kamumbi	6	7
Kanyungu	1	1
Maai	3	3
Kalanga	1	1
Total	**42**	**40**

4.5.4 Group structure (solitary, pair, and group)

Solitary, pair as well as multiple assemblages were present in suitable rock crevices in both dry and wet season surveys. Pancake tortoises were usually found in pairs (25.8%) or as single individuals (66.7%) of the total encounters in crevices, but larger assemblages of tortoises (up to 6) were also occasionally encountered. In less disturbed or commercially less exploited areas group assemblages were common. My field assistant with other tortoise collectors has in the past found 7, 8 and even 10 individuals under one rock slab. In areas with few suitable microhabitats, tortoises may aggregate in the available few rock crevices. For instance the 6 specimens found under one rock slab were new occupants since my field assistant had earlier removed 8 tortoises in 1996.

Solitary adult males and females were very common and hatchlings and juveniles were also most frequently encountered singly. With respect to adults, there was a high frequency (20% of the encounters) of male/female pair of tortoises in the same rock fissure.

Discounting hatchlings and juveniles, whose sexing was uncertain, individuals of the same sex were not observed in the same rock crevice. The group assemblages comprised mixtures of different sexes such 2 males and one female or 2 females, 1 male or even 3 females and 1 male. The 6 individuals found under one rock slab consisted of 3 pairs; one pair of adult male/female, a pair of sub-adults and the other of juveniles.

On seasonal basis, multiple assemblages appear to be common during the dry season as compared to wet season. No more than 3 specimens were found within one rock crevice in the wet season.

4.5.5 Breeding and mating system

As mentioned above, there was a high frequency of male/female pairing. However, this pair bonding is mostly confined only to breeding seasons. An adult female, which was encountered single during the dry season, was recaptured in the wet season but paired with an unmarked male. One male was recaptured in the same rock crevice but parted with the female he had initially paired with. Similarly, another male was recaptured elsewhere alone having parted with his partner. In another separate occasion, during the dry season, an assemblage of 2 males and 1 female, 1male and 1 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 singly recaptured in the same place but having been left by their partners. However, in one occasion a male/female pair was recaptured intact in the same rock fissure. However, this particular one was of sub-adults of 12.2 cm and 12.7 cm straight-line carapace length for male and female respectively. Reproduction is estimated to start in individuals of 13 cm and above straight-line carapace length. Breeding and mating occurs during pairing time and hatching of eggs after the onset of the rains in November.

4.5.6 Movement

Information on movement of Pancake tortoises was obtained from marked and recaptured individuals. Almost all individuals recaptured were found in the same rock crevice. Therefore, Pancake tortoise normally establishes permanent rock crevices as their homes.

Movement within crevice was found to occur only during the wet season. For example an adult pair of male/female was recaptured in the same rock crevice when revisited one month later within the dry season. However, after the rains, they had dispersed and left the crevice vacant.

For 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. The original crevice housed no tortoise. Another adult male solitary in the dry season had moved about 30 m to inhabit different crevice. A crevice inhabited by male/female adult pair in the dry season was inhabited by the same female but the male was no longer present. Similarly, a female of another male/female adult pair marked was still resident in the same crevice but the male was absent.

A crevice inhabited by a solitary female in the dry season was inhabited by the same female in pair with an unmarked adult male. In another crevice, assemblage of 2 adult males and 1 female marked in the dry season was now inhabited by an adult male/female of the same tortoises but the other male had left. A crevice inhabited by three juveniles was inhabited by the same during the wet season. Similarly, a crevice inhabited by a solitary juvenile was still inhabited by it. In addition, a crevice inhabited by an adult male and a juvenile was inhabited by the same juvenile but the adult male was no longer present. Males, therefore, seem to be more wide ranging while females and juveniles are relatively sedentary.

4.5.7 Swimming ability

On two separate trials (one with an adult male and the other with sub-adult male and a juvenile), the species' ability to swim was tested by submerging them in pools of water which are usually common on the rock surfaces in the wet season. In both cases, the individuals sunk with no effort to swim out or even float. This discounts the species ability to swim despite the fact that the carapace is so flattened to such an extend that the shell's dorsoventral profile resembles that of a highly aquatic chelonian rather than that of a terrestrial one.

4.6 Impacts of human activities

Collection of tortoises for the wildlife trade is one human activity found to affect the Pancake tortoise population in the study area. There was physical evidence of site exploitation at Kawelu in Nuu Division where a rock slab had been broken using another rock, apparently allowing freer access to the crevice inhabitants (Fig. 9).

Tortoise collectors had at one time visited all the sites sampled. This tortoise over-collection seem to have almost depleted the Pancake tortoise population in Nguni and the surrounding environs which was the center of tortoise collection in the past. For example, in Kabati, Mathiakani and Kalanga corner, despite serious searching, no individual specimen was found though in some deserted crevices their fecal material was littered. During the establishment of the Nguni-Kalanga corner tortoise farm in 1996, there was indiscriminately large-scale collection of tortoise in the present study area by my field assistant and other hired tortoise collectors. Cattle grazing unless accompanied by other factors such as bush clearing is compatible with the continued survival of the Pancake tortoise populations. Shifting cultivation, which is a very common activity due to the low fertility rate of the area soils, was the major threat identified. This is accomplished by bush clearing and burning which is usually done during the dry season (Fig.10). This is a very vulnerable time as all tortoises are aestivating inside their crevices where they get trapped and burned. In several instances, rock outcrops harboring

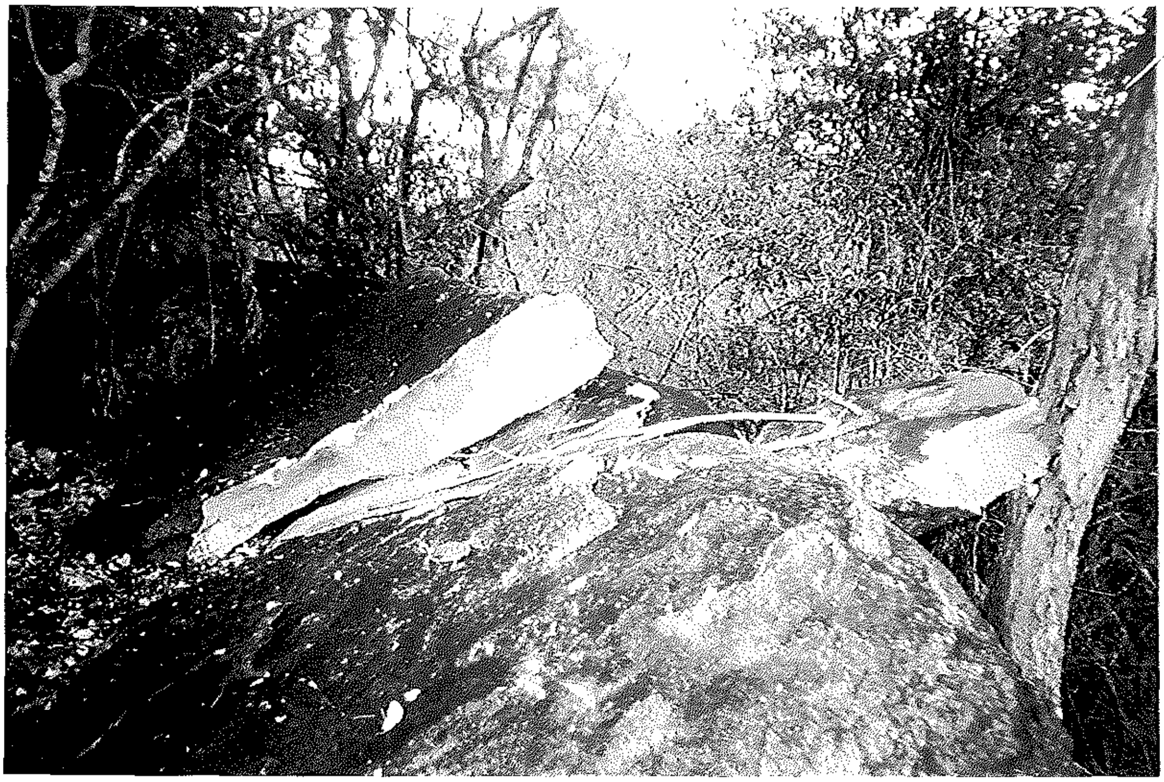


Figure 9. Physical evidence of site exploitation in Kawelu area. Note the broken down rock slab and the improvised hooked extraction sticks lying on top.

Figure 10. Physical evidence of bush clearing and burning around and within rock outcrops at Kamulewa.

tortoises were entirely surrounded by farmlands. Given the low dispersal ability of Pancake tortoises, recruitment from other population is very low in such situations.

4.7 Microsympatric species

All the rocky habitats in the study area were heavily inhabited by Rainbow Skink (*Mabuya quinquetaeniata*). Other reptiles, which were usually associated with Pancake tortoises, include common Agama (*Agama agama*), Tropical house Gecko (*Hemidactylus mabouia*), Tawny plated Lizard (*Gerrhosaurus major*), Savanna Monitor Lizard (*Varanus albigularis*), common Puff Adder (*Bitis arietans*), and the Common Spitting Cobra (*Naja nigricollis*). These often occurred microsympatrically in crevices inhabited by Pancake tortoises. On several occasions, Tawny plated Lizard was found lodged side by side with Pancake tortoises. On one occasion, a Puff Adder and a male adult Pancake tortoise cohabited the same rock slab. The large cave like crevices, which are homes for African rock Python (*Python sebae*) were also densely inhabited by the Rock Hyraxes (*Procavia capensis*). The rock surfaces provide basking grounds or sites for the Dwarf Mongoose (*Helogale parvula*).

4.8 Predation

A shell of a juvenile was found lying on a rock surface near a rock slab. The juvenile had been killed recently as signs of predator bite on the anterior marginals were visible. Another adult male had its several left marginals near the forelegs missing which had subsequently healed. This and other shell damages might represent unsuccessful attempt by predators. No direct observation of tortoise predation was made. However, the African Civet (*Viverra civetta*) has been observed and even trapped in the Nguni-Kalanga corner tortoise farm as one of the predators. Other potential predators include Large Grey Mongoose (*Herpestes ichneumon*), White-tailed mongoose (*Ichneumia albicauda*), Common Genet (*Genetta genetta*) and Large Spotted Genet (*Gennetta tigrina*). The close attachment of the tortoise to their rock crevices in addition to provision of protection from overheating and desiccation affords refuge against these agile predators.

5 DISCUSSION

The results show that there are no seasonal effects on the abundance of Pancake tortoise. Sixty-four and sixty-nine individuals were counted in both dry and wet seasons respectively. The population estimate ranges from 121 to 233. However, with respect to specific age groups, hatchlings and juveniles were more abundant during the wet season. This is because the wet season is the period of egg hatching and production of offspring. During the breeding season, male/female pair and hatching of the eggs into hatchlings occur after the onset of the rains. Since there are two distinct rain seasons in one year, hatching of eggs occurs twice. Hatchlings are commonly found around November and April during the beginning of the short and long rains respectively. Sub-adults and adults were equally abundant in both seasons but during the dry season, they are easier to find as the vegetation cover over most of the rock outcrops is low. In addition, due to the limited migration abilities of the Pancake tortoises there should be no marked seasonal variation in abundance. 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, reduction in places to shelter or a combination of factors.

Studies on sympatric Speke's Hingeback tortoise (*Kinixys spekii*) by Hailey and Coulson (1996a) and on Leopard tortoise (*Geochelone pardalis*) by Bertram (1979b), found more sighting in the wet season as compared to the dry season. These terrestrial testunids, unlike Pancake tortoise, normally aestivates during the dry season in very seclusive and inaccessible burrows including deep holes in rock outcrops. During the wet season, they wander around drinking and foraging and are therefore easily encountered. These observations clearly concur with the present findings where rainfall was correlated with season since it is during the wet season when Pancake tortoises normally leave their crevices for feeding.

Populations of any animal species invariably show that density differs from place to place. This spatial change in animal numbers is due to habitat preference. Pancake tortoises were found only in suitable rock crevices in rock outcrops and kopjes in the arid and semi-arid *Acacia-Commiphora* bushland of the study area. The orientation of inhabited crevices varied from horizontal through diagonal to vertical with all degrees of inclination between these extremes. These findings concur with Wood and MacKay (1993), and Moll and Klemens (1996) observations in study of Pancake tortoises in Kenya and Tanzania, respectively.

Characteristically inhabited rock crevices taper 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. This allows easy access to and from forage material growing at the base as also mentioned by Moll and Klemens (1996). However, occasionally, tortoises could be found lodged in less accessible crevices atop rock faces with steep slopes to the ground suggesting their remarkable climbing ability. This agrees with observations made by Loveridge and Williams (1957) and Moll and Klemens (1996).

Well vegetated rock outcrops are highly preferred to others since the frequency of encounter and occurrence of multiple assemblages were higher on such well sheltered deep rock crevices. These provide thermal buffering (suitable microclimate) against overheating and desiccation during the dry season. These optimal patches of microhabitats often are widely separated from one another by large expanses of apparently unsuitable and unoccupied habitats. The frequency and location of these suitable microhabitats ultimately determine the abundance and distribution of Pancake tortoise in any given area in Kenya. These observations concur with Wood and MacKay (1993), and Moll and Klemens (1996) findings on separate Kenyan and Tanzanian Populations.

The method of estimation of population size from recaptures used, of search and seize may have some bias. However, given the discontinuous and patchy distribution of suitable microhabitats and behavior of the species, this is the only appropriate method at the moment. The population size is 177 ± 56 Pancake tortoises. Due to the highly cryptic behavior of these tortoises, as well as the thick bush which often makes location of all suitable rock outcrops virtually impossible, there is no doubt that the study failed to locate a substantial number of specimens within the areas searched. In addition, the number of tortoises observed is a function of the number of people searching and their experience in identifying suitable rock crevices. Therefore, substantial Pancake tortoise populations may still occur in the study area. Similarly, Pancake tortoise populations still exist in remote, less exploited and inaccessible areas of Kenya. However, should extensive exploitation coupled with habitat destruction continue, these populations will be at risk. In addition, highly exploited areas such as around Nguni area, the species is depleted. No single individual specimen was sighted despite intensive searching in most localities around the specified area.

Based on different age groups, the population age structure is dominated by adults. This kind of age structure signifies a declining population where old tortoises outnumber the young. This is indicative of low recruitment rates presumably due to high mortality rates of hatchlings and juveniles from desiccation and predation. Hatchlings and juveniles usually hide in temporary rock crevices, which makes them vulnerable to overheating and predation. These lack learning experience of avoiding predators. Conversely, adults lodge in well-sheltered deep rock fissures. Hatchlings and juveniles less than 7 cm are virtually very hard to sex with certainty. With respect to adults, physical differences and distinctive tail morphology were used to qualitatively recognize males and females. Adult females have relatively short, stumpy tails whereas males have substantially thicker and longer tails. A less obvious, but fairly consistent characteristic is the anteroposterior contour of females where the carapace of adult females is usually slightly outwardly curved as compared to that of males which is usually flat or even depressed. This is presumably an adaptation to permit adequate space for egg development. This observation agrees with those of Wood and MacKay (1993). On the other hand, males have centrally depressed plastron. This may be an evolutionary adaptation to ease mounting of females during mating. Another physical characteristic with respect to adults is that females have depressed or inwardly curved plastral hide lobes whereas those of males are normally straight. This is possibly due to occasional mounting by males.

Pomeroy and Service (1986) have shown that many species of animals are patchily distributed within their overall range. Aggregated distributions are by far the commonest kind of dispersion. As most habitats are not uniform, it is hardly surprising that individual animals prefer some parts to others. This concurs with the present study findings whereby the distribution of Pancake tortoise population is a function of its suitable microhabitat characteristics. The areas sampled represents a small proportion of the whole species range and distribution. The distribution of Pancake tortoise population in Kenya is discontinuous and clustered in suitable microhabitats and geographic range.

As such, the geographic range of Pancake tortoise may even be greater than was previously thought. This confirms the suggestion put forward by Wood and MacKay (1993) on the distribution of the species in Kenya.

In Kitui District the species is more likely to occur in Endau which immediately borders Nuu division. However, no surveys have gone beyond Nuu area. Possible range extension areas in Kitui District include Endau, Mutitu, Zombe, Mbitini, Ikanga, Voo, Mutha, Mutomo, Kanziku, Kasaala, Ikutha and part of Tsavo East National Park (Fig. 11). These areas up to Tsavo East National park area North Yatta plateau have a combination of similar vegetation, climate, and topography (physiography) as the present study area.

Geology has a profound influence on the distribution of Pancake tortoise in both Kenya and Tanzania. The species distribution overlaps with that of Precambrian rocks of the basement system (Fig. 12). However, it is only in areas with exfoliating granite rock outcrops that provide crevices, where Pancake tortoises are to be found. These are normally patchily distributed. The unlikely occurrence of the species in Makueni and Taita-Taveta District is presumably due to the barrier of Yatta plateau, which is constituted of tertiary volcanic rocks. It separates Kitui District from the two districts (Fig. 11).

Eco-climatic zone V which covers semi arid and arid lands in East Africa, is characterized mostly by thorn-bushland, thickets, *Commiphora* woodland and grassland, overlies the Precambrian rocks (Pratt and Gwynne, 1977). Therefore, a combination of geology, climate and vegetation type of any given area is the basic indicator of suitable Pancake tortoise habitat. Kemens and Moll (1995) describe the region of vegetation type where Pancake tortoise occurs as the Somali-masai floristic zone.

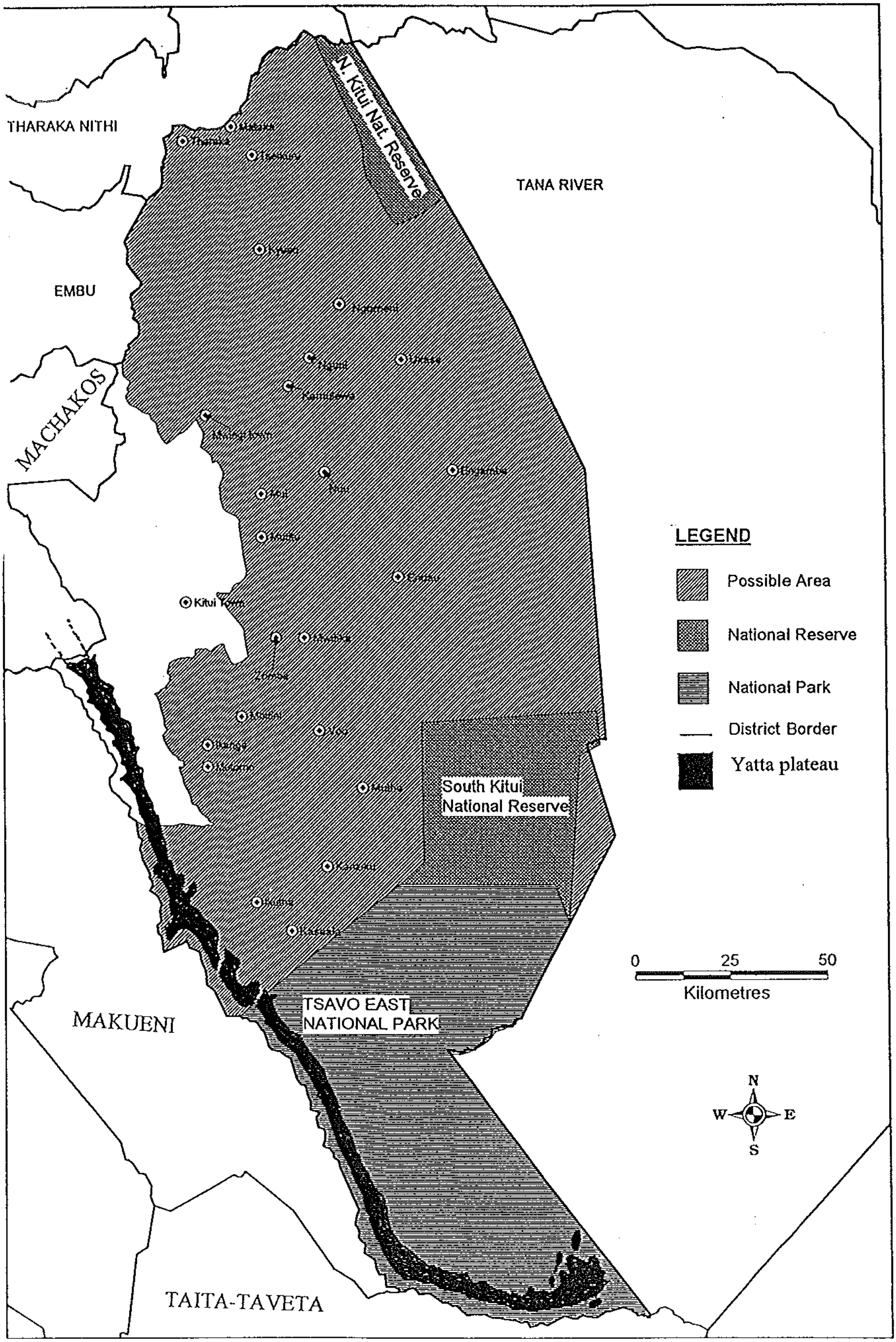


Figure 11. Map of the great Kitui District showing the possible range extension areas of Pancake Tortoise

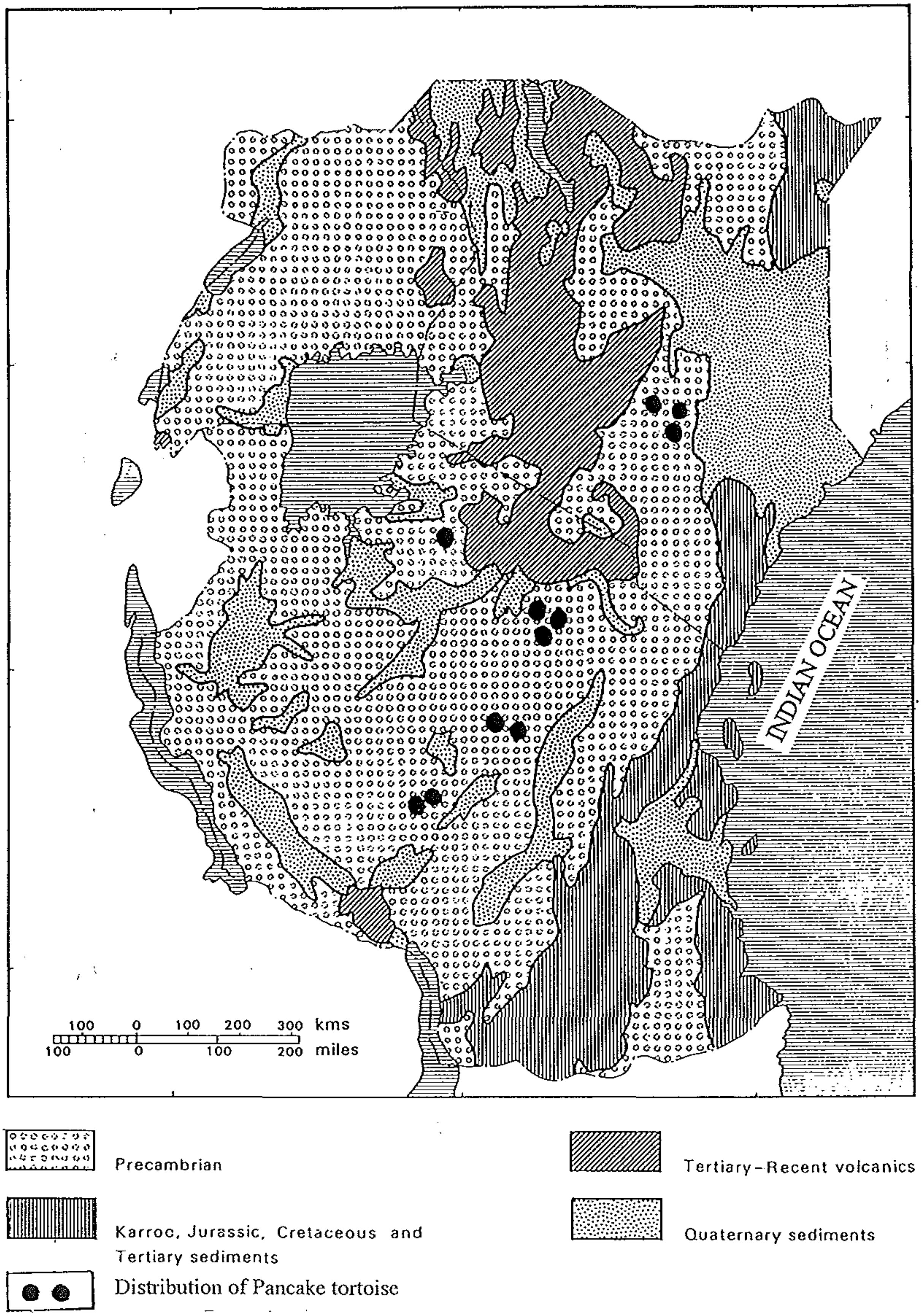


Figure 12. Geological map of East Africa showing the overlapping distribution of Pancake tortoise with Precambrian rocks

The Pancake tortoises' dwells in rock crevices and often creep very deep in these crevices as their body size can allow. Within the rock crevices, Pancake tortoise wedges themselves tightly between the floor and ceiling of the crevice and is extremely difficult to dislodge. On several occasions these tortoises could not be retrieved despite strenuous and prolonged efforts. Loveridge and Williams (1957) had shown that this wedging behavior is accomplished by inflating their lungs and simultaneously bracing their legs like struts. Moll and Klemens (1996) have also supported this view. However, Ireland and Gans (1972) discounted their ability to inflate themselves, but instead, dig in their forelegs to wedge their body in position. The present study observed that this wedging mechanism is accomplished effectively by digging in their claws and pushing their carapace against the crevice roof as the most effective behavioral mechanism compared to that of lungs inflation. This is from observation and exposure from using the extraction wire. However, in narrow part of the crevices the use of lungs inflation can not be discounted. When dislodged and handled, they often discharge relatively large amounts of fluid (which is usually very thick during the dry season and relatively dilute or watery in the wet season). This is possibly an anti-predatory strategy designed to intimidate potential predators.

Survey during the dry season showed that all the tortoises encountered were hiding in their rock crevices aestivating. Pomeroy and Service (1986) reported that dormancy in the form of aestivation in the tropics, which is confined to exotherms, is usually in response to dryness especially when accompanied by high temperature. This is typical of the climate of the study area, which is normally hot and dry most of the year. The tortoises aestivate in these cool deep crevices with suitable microenvironment that provides thermal buffering.

When released, the Pancake tortoise makes a dash for its home while other land tortoises momentarily retract their head and limbs inside their shell. This is possibly a behavioral mechanism to avoid potential enemies because the soft-shell affords little protection. Avoiding predators is the safest and usually the least energy demanding anti-predator defense. Zug (1993) has shown that hatchlings of tortoises must rely on crypsis and avoidance as the shell offers little protection.

Pancake tortoises are good climbers and when they fall off on their backs are quite adroit at righting themselves. All these observations confirm Loveridge and Williams (1957) findings on the rapid tortoise ability in turning over when they land on their backs and agility in climbing up vertical surfaces.

The activity time budget of the Pancake tortoise appears to be skewed towards spending much time hiding and little time foraging. The tortoises are active early in the morning, late afternoon and evening. At these time some hatchlings were found basking on rock surfaces. In both seasons all the tortoises encountered were hiding within their crevices. However, prior to and within the course of the study, reliable personal communication of Pancake tortoises observed outside crevices was obtained. Loveridge and Williams (1957) have encountered a young Pancake tortoise basking on a rock slab at 9 a.m. Pancake tortoises may be more active and less retiring in protected areas. Studies in Ruaha and Tarangire National Parks in Tanzania by Moll and Klemens (1996) indicate that outside activity may occur any time of the day. No individuals were found outside around midday and early afternoon, possibly to avoid overheating and acquire efficient behavioral thermoregulation. Elsewhere, daily activity patterns have been observed to be temperature dependent from studies on Aldabran tortoise (Swingland and Frazier, 1978) and on Speke's hingeback tortoise (*Kinixys spekii)* by Hailey and Coulson (1996b). Lariviere, and Messier (1997) quoting from other sources pointed out that patterns of seasonal and daily activity of animals represents behavioral adaptations to variation of environmental factors such as photoperiod, temperature, and precipitation. In addition, activity patterns may vary with socio-ecological constraints such as mating, competition, foraging efficiency, predation risk, resource availability and vulnerability.

The age ratio of young to adults was 1:3 indicating a population dominated by adults and declining. The adult sex ratio was 1:1. This confirms the earlier study by Wood and MacKay (1993) on Kenyan Pancake tortoise population who found an approximately 1:1 sex ratio. Moll and Klemens (1996) observed a similar result on Tanzanian Pancake tortoise population. This kind of sex ratio should be expected in monogamous animal species.

Pancake tortoises are normally solitary (67 %) and pair during the breeding seasons. In habitats which were less disturbed either by commercial tortoise collection or habitat destruction, multiple assemblages as well as single tortoises often were present in suitable crevices. This agrees with Klemens and Moll (1995) findings from Tanzanian populations. Loveridge and Williams (1957) found 11 Pancake tortoises beneath one flattish slab of rock at Dodoma in Tanzania. Multiple assemblages were commonly encountered during the dry season possibly aestivating and individuals have to congregate in the few well-sheltered rock crevices while in the wet season they disperse. As observed by Klemens and Moll (1995), exploited and much disturbed habitats were characterized by a single individual or vacant in each crevice.

With respect to adults, there was a high rate of male/female pair of tortoise in the same rock crevice. Wood and Mackay (1993) reported a high proportion of male/female pairs in the present study area. This male/female pair bonding seems a real phenomenon and may be an unusual behavior among chelonians. However, it was observed from recaptures that this pair bonding is restricted only to the breeding season.

Information from recaptured individuals showed that the male/female pairing is seasonal since the pairs break after each season. The mating system practiced by Pancake tortoise based on this information is seasonal or annual monogamy where the pair lasts through the breeding time for one season. In addition, it can be described as a serial or successive monogamy where one individual pairs with only one other individual at a time but with new individual over successive time. Therefore, Pancake tortoise appears to exhibit a seasonal and successive monogamy mating system. McFarland (1985) has shown that in monogamy both parents are required to raise the young. This mating system is very common in birds, were more than 90 per cent are monogamous. Monogamy is also common in species, which produce altricial young while polygyny is practiced by species that produce precocial young. Normally, the formation of pair bonds is associated with parental care. The young of Pancake tortoise, however, are fully precocial and independent of their parents. Sexual dimorphism is a result of sexual and/or natural selection but is common in monogamous species in which opportunities for the females to select mates are severely limited as compared with polygamous species. But sexual dimorphism in Pancake tortoise is not well defined. This breeding and mating behavior in Pancake tortoise is presumably an evolutionary behavioral strategy as a result of the nature of the microhabitats and body structure of the species which both limit the species' dispersal capabilities. Otherwise, promiscuity, where both males and females mate with more than one member of the opposite sex with no pair bonds and minimal parental care could be an ideal mating system. One of the fundamental influences on the social structure of a species, (McFarland 1985) is the species' mating system. This truly explains the group structure of Pancake tortoises, which predominantly comprise solitary individuals and/or pairs.

Barbaresi *et al* (1997) have pointed out that animal movements are related to both acquisition of primary resource such as food, shelter, mate, and host and the avoidance of sources of stress like predators, thermal extremes and dehydration. Most animals are capable of moving about, but often their movements are restricted to a limited area, 'the home range' as stated by Pomeroy and Service (1986). There are ultimate advantages of being able to return to a familiar place such as home. Grier (1985) outlined that such places may afford protection, hence increasing the animals' chances of survival. Information obtained from recaptured individuals revealed that Pancake tortoise use same rock crevices as their home base from where they disperse out for foraging and then return. Movement out of crevice was found to occur mainly during the wet season as exhibited especially by the males and young. Studies on other terrestrial tortoises by Bertram (1979a&b) on Bell's Hingeback tortoise (*Kinixys belliana*) and Leopard tortoise (*Geochelone pardalis*) at Serengeti in Tanzania found that rainfall had influence on the tortoise movement. This observation agrees with the present findings since it is only during the rain season when Pancake tortoises are observed to leave their crevices. Movement in Pancake tortoise is limited and centered on their crevices with very limited dispersal. Bertram (1979a&b) studying home range and homing behavior of Hingeback and Leopard tortoises in Serengeti found that they have a well-defined home range. Wilson (1968) found that Leopard tortoise have a definite home range while Chelazzi and Carla (1996) observed that Hermans tortoise (*Testudo hermanni*) has a very stable home range and returned back after experimental displacement. This spatial stability must be regarded as a multi-adaptive strategy. It produces an overall familiarity with the environment and consequently optimizes the cost/benefit ratio for access to resources and stress sources avoidance. With respect to sex, males were wide ranging and circulating among crevices inhabited by relatively sedentary females. Moll and Klemens (1996) also observed this behavior on Tanzanian Pancake tortoises. A sit-and-wait strategy of getting mates by females seems feasible. Males move around searching for unpaired females.

The Kenyan Pancake tortoise observed in this study conform to the general physical description, characteristic of ontogenetic color change, extensive degree of adult color and pattern variation described for the species by Loveridge and Williams (1957) and Moll and Klemens (1996). These variable color patterns undoubtedly tend to camouflage the tortoise in its unique microhabitat. Sexual dimorphism is not especially marked in pancake tortoise with reference to carapacial color patterns. There was no significant difference in either carapace length and body weight of males and females. This concurs with wood and Mackay (1993) findings on Kenyan population. However, on Tanzanian population, Moll and Klemens (1996) observed that females are significantly longer, wider and heavier than males. Further study should be carried out whether these are same or distinct species. Sexual dimorphism in adults, however is well marked in terms of tail morphology, carapacial and plastral configuration as discussed earlier. Information obtained from recapture of marked individuals indicated a marked increase in carapace length and body weight in wet season. During the dry season tortoises are usually aestivating and normally use stored food energy as the only source of energy for their maintenance ration. Increase in straight-line carapace length is a result of body growth especially in juveniles and sub-adults.

Age determination by use of growth rings was found to be quite unreliable, as there is a lot of misinterpretation and miscounting of individual growth rings with increasing age. There seem to be overlapping and wearing out of growth annuli as age increases. Growth rings are only well marked in juveniles and sub-adults. The presence of smooth carapacial scutes, presumably from constant scrapping against rocks in which they shelter compounds the whole problem. Carr (1952) lists the limitations of the use of growth rings in age estimation in chelonians (tortoises, turtles and terrapins). Among the limitations is that the more infantile (older) parts of each lamina wear away, destroying all but the more recently formed annuli. Therefore, the use of growth rings in age estimation should be in conjunction with other methods as a supplement.

Other reptiles that are associated with pancake tortoises in the examined rock habitats were Rainbow Skink (*Mabuya quinquetaeniata*), Rock Agama (*Agama agama*), Tawny plated Lizard (*Gerrhosaurus major*), Common Puff Adder (*Bitis arietans*), Rock Monitor Lizard (*Varanus albigularis*). These often occurred microsympatrically in crevices inhabited by Pancake tortoises. Tawny plated lizard was frequently encountered lodged together with the tortoises. This observation agrees with Moll and Klemens (1996) who regarded them as useful indicator species of suitable Pancake tortoise microhabitats on Tanzanian populations. Although the spatial niche of these other reptiles overlaps with that of Pancake tortoises, their feeding niche is quite different since unlike its commensals, Pancake tortoises are exclusively vegetarian. Therefore, none preys on them. However, the possibility of the Rock Monitor Lizard (*Varanus albigularis*) of preying on the eggs can not be discounted.

The present study obtained some information on habitat selection, use and preference, coloration, group structure, mating system and movement of the species. However, there is need for further long-term detailed ecological study on some aspects. The study was done for comparatively short time and might have given a snap shot picture on some aspects. Detailed research is needed on home range and movement using radio telemetry. The activity pattern and breeding habits of the species require further long-term examination. Age estimation by use of growth rings was found to be less reliable and subject to misinterpretation. Appropriate methods needs to be developed to supplement the use of growth annuli through more research.

6. THREATS TO PANCAKE TORTOISE POPULATIONS

Habitat alteration through shifting cultivation, which is a form of extensive agricultural practice, was identified as the major threat facing the survival of Pancake tortoise population in Kenya. This tends to be accentuated by excessive human population densities. This shifting cultivation is accomplished by bush clearing and burning. Unfortunately, this is done during the dry and hot season, which is a very vulnerable time as all the tortoises are normally aestivating in the rock crevices, where they undoubtedly get burned. A large proportion within and around the microhabitats has been destroyed especially in densely populated areas. Ultimately the Pancake tortoise microhabitats become isolated from each other like islands. The present study has observed that Pancake tortoises are very sensitive to the effects of fragmentation. They often show strong site fidelity and have limited dispersal capabilities. Hence, a relatively small degree of fragmentation could effectively isolate sub-populations. This may prevent 'rescue effect' of migrants from source sub-population that have diminished. Marsh and Pearman (1997) and Demaynadier and Hunter (1998) have found that forest fragmentation has profound effects on the abundance of amphibians. Reduction in area of natural communities affects population size. Fragmentation affects dispersion, leading to extinction. Species with patchy distribution or those, which utilize a range of microhabitats, are especially vulnerable to losses in mosaics of habitats. Insularization has both ecological and genetic implications and reduced genetic variability has long been recognized as a feature of small isolated populations due to inbreeding, genetic drift, 'the bottleneck' and 'founder effects' as indicated by Spellerberg (1991). Soule (1986) conclusively pointed out that deterioration of either habitat quality or quantity could extinguish a population.

Spellerberg (1992) suggested that illegal trade in wildlife and their products threaten many species with extinction. Collections of tortoise for the wildlife trade poses yet another threat to the survival of Pancake tortoise population in Kenya. In areas around Nguni, which was the center for collection in the past, the abundance of the tortoise is comparatively very low as compared to the less exploited Nuu areas. The establishment of Nguni-Kalanga Corner tortoise farm in 1996 was preceded by a large-scale over-collection of the Pancake tortoises in the present study area. This demographically affected the tortoise population. Boycott and Bourquin (1988) described a scenario on how wild removal of a few individuals could have serious consequences on a tortoise population. Once an individual has been removed from the wild population, it no longer contributes to the survival of that population. Some populations are more vulnerable than others. Each tortoise population consists of different ages. If young are removed, there will be fewer individuals to breed at a later stage. If adults are removed this will immediately affect the number of eggs laid and the young hatched. In any case, the population number declines. The population is then less successful at maintaining its numbers and the chances of survival are considerably reduced. If a natural disaster, be it drought or fire, occurs at such a vulnerable stage, the extinction of that population would almost certainly be ensured. The Nguni-Kalanga corner tortoise farm breeds the three sympatric tortoise species: Pancake tortoise, Leopard tortoise and Speke's Hingeback tortoise for international export. Kenya Wildlife Service, the custodian of wildlife resources in Kenya has licensed the farm to breed and export only 'juveniles'. The export price of a Pancake tortoise is about 40 USD (Ksh 2,400) and they usually sell to a retailer in Japan. United States is the major importer of Pancake tortoise from Tanzania (Klemens and Moll, 1995). However, the Kenyan dealer has not yet started exporting to the United States market. The collection of Pancake tortoise is well organized whereby the farmer place orders with local middlemen scattered in different places of the district. These middlemen in turn employ local people, usually teenagers and young men, to collect the tortoises. The tortoises are held at the collecting centers until the farmer returns to pick them up. The local collectors receive Ksh 20 (0.33 USD) per Pancake tortoise from the village middlemen who in turn receives Ksh 40 (0.67 USD) from the farmer. These low prices subsequently lead to over-exploitation through over-collection of large numbers. Some tortoises' even die at the local collection centers due to stress conditions while awaiting pick up. The present farm is only approximately 2500 m^2. This is a very small area for breeding the present population of the three tortoise species numbering 2000. Due to congestion and lack of suitable microhabitat characteristics and conditions for Pancake tortoise breeding, the farmer may be forced to occasionally send out local tortoise collectors for more tortoises from the wild to increase the existing stock and meet the market demand. The tortoise collectors are thus forced to go further afield in less exploited areas. Healthy Pancake tortoise populations may still exists in remote and inaccessible areas. However, should the exploitation of Pancake tortoise continue, these populations will be at risk. Surely, people in Kitui District are not aware of the commercial value of these tortoises like the locals of the present study area and where the species most likely occurs.

7. CONSERVATION AND MANAGEMENT OF PANCAKE TORTOISE POPULATIONS

One of the principal goals of biodiversity conservation and maintenance, whether *in situ* or *ex situ* is to ensure the long-term survival of species. Species survival is highly related to the protection of habitats and most countries have a network of protected areas (UNEP, 1993). The highest priority for the conservation of biological diversity is *in situ* conservation of species in their natural habitats. However, 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, IUCN/UNEP/WWF (1991) shows that a comprehensive genetic conservation program for such species should include both *in situ* and *ex situ* elements. Similarly, Church *et al*, (1996) stated that whilst preservation of species requires a complex suite of management strategies including intensive captive breeding programs, translocation of declining species; establishment of nature reserves where species can be protected with minimal human intervention is a necessary component of an integrated strategy.

Extensive agriculture and settlement have severely fragmented the natural ecosystem of the present study area. Intensification rather than extensification of agriculture is a feasible solution to save the dwindling Pancake tortoise microhabitats. However, increase in human population is higher than economic growth in the area. In such circumstances, it is hardly possible to effectively conserve the environment in a situation where the population is so high and the majority of the people are poor. One initiative to improve the conservation status of Pancake tortoise population is the establishment of a system of nature reserves, publicly and/or privately-owned. However, the question is how to conserve biodiversity in a biologically heterogeneous but fragmented and largely privately owned land. Similar management interventions were used for conservation and management of the Geometric tortoise (*Psammobates geometricus*) in South Africa. This species endemic to the Cape Province, South Africa is the rarest tortoise on mainland Africa, and one of the rarest species in the world. Boycott and Bourquin (1988) have pointed out that the establishment of public and private Geometric tortoise reserves has ensured the survival of the species in its natural habitat. The greatest threat to the species is man's alteration, degradation and destruction of its unique natural ecosystem.

Management considerations for species and genetic resource conservation given by IUCN/UNEP/WWF (1991) should include, close integration between *in situ* and *ex situ* programs. The captive breeding programs should be aimed at conserving the species in the wild by providing species for reintroduction. Appropriate management of captive populations is to ensure that they are genetically and demographically viable and do not require continuous addition of wild specimens. Žug (1993) stresses that captive breeding is a viable solution only for the short-term and the ultimate goal should be of reintroduction into reconstructed natural habitats. As such, refuges or nature reserves provide the best option if not the ideal solution.

The reduction or complete curtailment of wild tortoise collection is the most management option to effectively conserve Pancake tortoise populations. Conservationists have now realized that sustainable use and conservation are intricately linked. This may be the only way feasible to protect the species and safeguard wild over-exploitation for pet trade. Klemens and Moll (1995) suggested that a strictly controlled harvest might provide both capital and incentive to manage Pancake tortoise although it may in turn encourage illegal off take. Therefore, activities of tortoise farms such as Nguni-Kalanga Corner should be closely monitored to ensure that they do not harvest tortoise from the wild.

Presently, conservationists have realized the pivotal role of the grass-roots involvement in conservation of biodiversity. As such the adoption of bottom-up approaches and incorporation of indigenous knowledge in genetic resource conservation and management is now unquestionable. It is clear that the future viability of the Pancake tortoise conservation and management appears to hinge on the co-operation and support of local people. However, as suggested by Kaloki and Wamukoya (1996), this depends on whether the local people will be able to derive some benefits to warrant their participation.

Pancake tortoises were found to have very limited dispersal abilities by having very close attachment to their microhabitats. Normally these rock habitats can not be cropped, however, it was found that the vegetation overgrowing on these rock habitats is cleared and burned as a means of destroying dangerous snakes which are threat to both human and livestock. These snakes include Common Puff Adder (*Bitis arietans*), Common Spitting Cobra (*Naja nigricollis*), African Python (*Python sebae*), and the deadly and Africas' most feared Black Mamba (*Dendroaspis polylepis*).

The community was found to be aware of the exploitation done to them by the commercial tortoise collectors. They take the tortoise as their resource just like any other forest resource. In some areas, the private landowners refuse these tortoise collectors from collecting in their lands. Therefore, possibly if these locals are persuaded to set aside these microhabitat rock patches as nature reserves for their own benefit it is more likely that they will accept and adopt the practice. These reserves will provide long-term reservoirs for the declining or nearly depleted wild population. The harvesting, however, should be closely monitored and regulated to minimize over-exploitation through unsustainable harvesting.

The most effective way of involving the community in this conservation activity is to sensitize and educate them on the values of conserving the species and empowering them to manage the species especially those that are found on their lands. Various incentives could be instituted for this purpose. The most positive way to educate the community on the importance of the Pancake tortoise population conservation is first to empower them with the responsibility for its costs and benefits. McNeely (1988) stated that for people to accept sustainable use of resources and sustainable development there should be some incentives for sustainable use of resources and disincentives for harming ecosystems or exploiting natural resources. If these community-based tortoise projects are sustainably managed, the continued survival of the Pancake tortoise population in its natural habitat will be assured. The final responsibility for the fate of the Pancake tortoise population lies with the local people and that the problem of conservation is as much sociological as biological. Hence, there is a need to create and/or promote public awareness and involvement in conserving Pancake tortoise populations.

Establishment of commercial farms will only lead to increased over-exploitation and depletion of the species unless under very close control by wildlife authority. Mimicking the natural microhabitat characteristics of the tortoises is costly to a commercially oriented farmer. Elsewhere illegal collection and marketing may proceed under the umbrella of the established farm. At the same time, if the farm proves not to be self-sustaining, illegal collection will be forced to go further afield to obtain tortoises. Ultimately, establishing new collecting centers and depleting hitherto untapped populations.

8 CONCLUSIONS AND RECOMMENDATIONS

Based on the present study, the following conclusions have been forwarded:

- Pancake tortoise may have a considerably greater geographic range within Kenya but their habitat within this range is narrowly restricted to rocky outcrops with deeply incised crevices scattered throughout the arid and semi-arid savannas.
- Pancake tortoise seem to occur in low lying and often relatively small rock outcrops rather than on the slopes of the more massive rock hillsides which are common and prominent features of the landscape in the study area.
- High proportion of the adult specimens consists of a single adult male/female pair in the same crevice. This seems to represent a seasonal pair bonding. The mating system exhibited appears to be a seasonal and successive monogamy.
- Sexual dimorphism in terms of body size, carapacial color patterns and shell length is not well marked in Pancake tortoise population. However, sexual differences with respect to adults exist in tail morphology and in plastral and carapacial morphology and configuration.
- Movement in Pancake tortoises is very limited. Their dispersal capabilities are only limited to the rock habitats and males appear to be more wide ranging than females.
- Continuous and extensive human destruction of the habitat is the major threat. However, when coupled with commercial collection its consequences are quite detrimental, and
- Commercial collection of Pancake tortoise is very disastrous to the species demography, as it has taken the form of 'tortoise mining', where known microhabitat sites harboring tortoises are occasionally revisited for collection.

Based on the present study the following tentative recommendations are worth considering:

- Studies should be initiated to determine the full extent of the distribution of Pancake tortoise population in Kenya. Survey should be conducted northwards into Tharaka-Nithi, Isiolo, Samburu, and Marsabit districts and southwards through Kitui District into Tsavo National Park and Taita-Taveta District (Fig. 13).
- A strictly controlled harvest may provide both capital and incentive to manage and conserve Pancake tortoises while encouraging captive breeding. However, this may in turn encourage illegal off take and is not recommended at present.
- The activities of the current tortoise farm, Nguni-Kalanga Corner and other such future ventures should be closely monitored for adherence to stipulated regulations, and
- Establishment of on site tortoise reserves that are publicly and/or privately owned under very strict management is essential for the continued survival of the species. However, these community-based projects requires concerted public education and extension campaign on the importance and benefits of conserving Pancake tortoise population if they are to be sustainable.

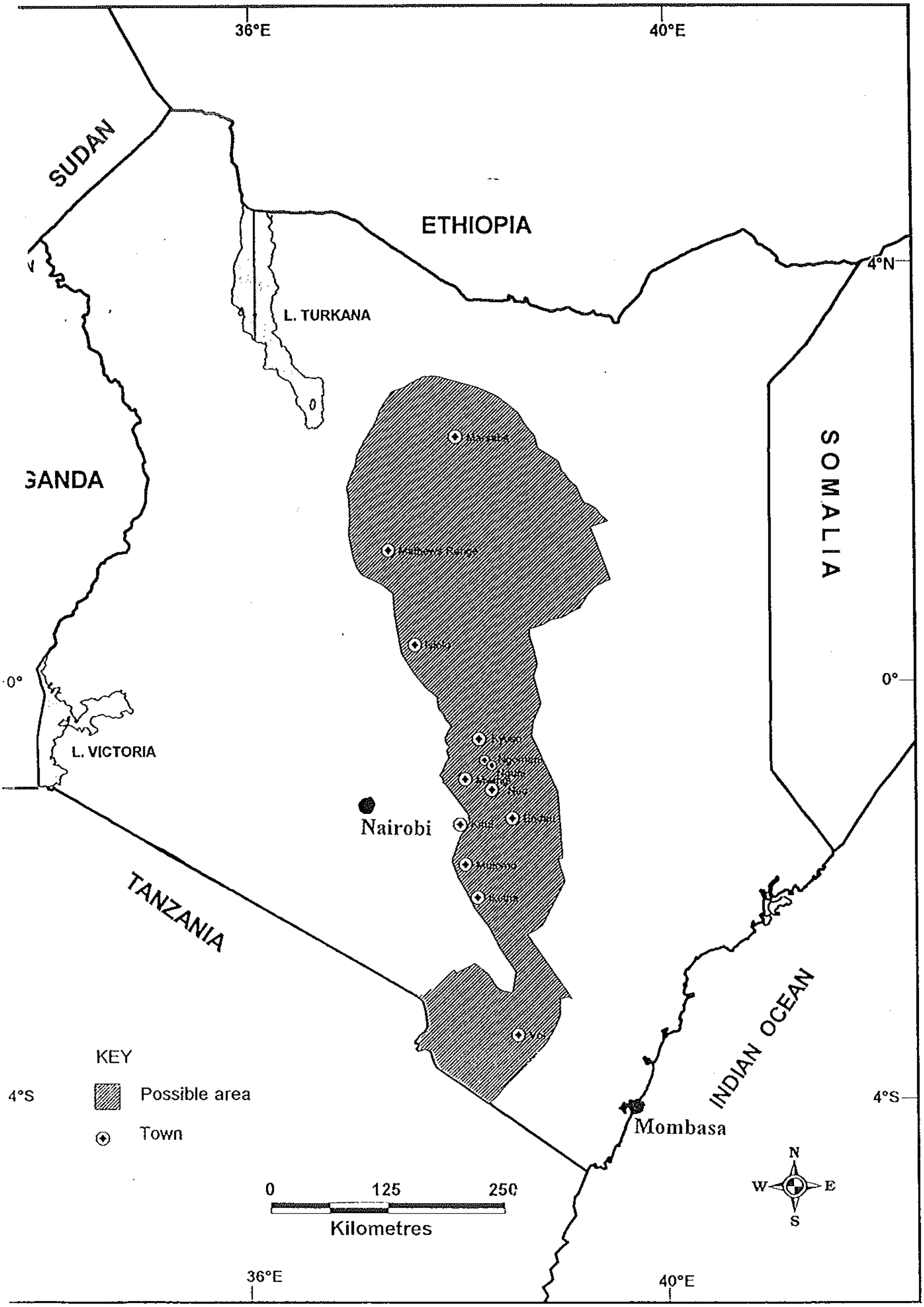


Figure 13. Map of Kenya showing the possible distribution of Pancake tortoise

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Appendix 1. A list of common trees, shrubs, lianas and herbs in the study area

Acacia brevispica

Acacia drepanolobium

Acacia elatior

Acacia mellifera

Acacia nilotica

Acacia reficiens

Acacia senegal

Acacia seyal

Acacia thomasii

Acacia tortilis

Acacia zanzibarica

Acalypha fruticosa

Acanthospermum hispidum

Acaranthus aspera

Adansonia digitata

Albizia anthelmintica

Aloe rabaiensis

Asparagus racemosus

Balanites aegyptiaca

Barleria taitensis

Berchemia discolor

Bidens pilosa

Boscia coriacea

Boswellia neglecta

Calotropis procera

Capparis tomentosa

Cassia abbreviata

Cassia longiracemosa

Combretum aculeatum

Combretum apiculatum

Combretum exalatum

Commelina benghalensis

Commiphora africana

Commiphora baluensis

Commiphora campestris

Commiphora edulis

Commiphora mildbraedii

Cordia monoica

Cordia sinensis

Croton dichogamus

Cucumis dipsaceus

Dalbergia melanoxylon

Dalechampia scadens

Delonix elata

Dicrostachys cinerea

Dobera glabra

Entada leptostachya

Erythrina abyssinica

Erythrina burttii

Erythrochlamys spectabilis

Euphorbia candelabrum

Euphorbia cuneata

Euphorbia bussei

Euphorbia robecchii

Euphorbia tirucalli

Ficus glumosa

Ficus sycomorus

Gnidia latifolia

Grewia bicolor

Grewia fallax

Grewia lilacina

Grewia villosa

Hibiscus micranthus

Indigofera arrecta

Ipomoea hildebrandtii

Ipomoea kituiensis

Ipomoea mombassana

Kigelia africana

Lannea alata

Lannea triphylla

Lippia kituiensis

Maerua decumbens

Maerua endlichii

Melia volkensii

Microglossa pyrifolia

Ochna inermis

Ormocarpum kirkii

Premna resinosa

Pupalia lepasea

Salvadora persica

Sansevieria conspicua

Sansevieria ehrenbergii

Sansevieria singularis

Solanum incanum

Steganotaenia araliacea

Sterculia africana

Sterculia stenocarpa

Strychnos decussata

Synadenium compactum

Tamarindus indica

Tennantia sennii

Tephrosia hildebrandtii

Terminalia brownii

Terminalia prunioides

Thunbergia holtsii

Thylachium thomasii

Tribulus terrestris

Trichilia emetica

Vitex payos

Zanthoxylum chalybeum

Appendix 2. A list of dominant grasses in the study area

Aristida adscensionis

Brachiaria brizantha

Brachiaria deflexa

Brachiaria leersioides

Cenchrus ciliaris

Chloris barbata

Chloris roxburghiana

Cynodon dactylon

Dactyloctenium aegyptium

Eleusine indica

Enteropogon macrostachyus

Eragrostis caespitosa

Eragrostis superba

Latipes senegalensis

Panicum maximum

Rynchelytrum repens

Seteria verticillata