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Learning from the Wild: Status of the Introduced Pancake Tortoise *Malacochersus tornieri* Population in Tsavo East National Park, Kenya

PATRICK K. MALONZA[1,*], DAVID K. KORIR[2], JOASH O. NYAMACHE[1], AND SOLOMON N. KYALO[3]

[1]*National Museums of Kenya, PO Box 40658-00100, Nairobi, Kenya [malonzapk@gmail.com; nyamachecj@yahoo.com];*
[2]*Wildlife Research and Training Institute, Tsavo Research Centre, PO Box 14-80300, Voi, Kenya [dkorir@wrti.go.ke];*
[3]*Kenya Wildlife Service, PO Box 40241-00100, Nairobi, Kenya [cites@kws.go.ke]*
**Corresponding author*

ABSTRACT. – **In April 2001, 187 illegally collected and confiscated pancake tortoises (*Malacochersus tornieri*) were released in Mzinga and Irima rocky hills in the southern part of Tsavo East National Park, an area where there were no free-ranging wild populations. The aim of this study was to establish the status of this introduced population and identify the lessons that can be learned to guide future reintroductions. Prior to release, the specimens were marked by cutting numbered notches on the marginal scutes based on a coding system. In June 2022, a revisit to the April 2001 release sites was done to retrace this population in an effort to both recapture some of the individuals or find a new juvenile cohort. After 21 yrs, only 15 individuals were found—10 of which were recaptures, representing 5.3% of the total release population. Of these 10 recaptures, only 2 had clear marks and could be traced to a specific number that showed they were mature adults when released. The 8 recaptured tortoises did not have marks and their carapaces were either worn out to plain brownish or had faded dark marks. It was assumed that these were likely those young specimens released with a carapace length of less than 130 mm and that the notch mark disappeared during body growth. Using a combination of the carapace length, carapace color pattern, and absence of notch marks, 5 specimens were confirmed to have been born after the initial release, representing a new cohort. Pancake tortoise carapace growth in captivity has been found to be very fast, and specimens reach sexual maturity at 150 mm and in about 6 yrs, and after this no significant carapace growth occurs. This fast growth rate is not possible in the wild, where there are long periods of inactivity during the dry season. Hence, it is assumed that growth in captivity should be twice or thrice that in the wild. Therefore, using our data from new and recaptured tortoises, and comparing it with the growth rate and color change in captive specimens, it is possible to estimate the age of wild individuals. This study also shows that there is carapace color and pattern change with carapace growth with age, until a time when the color pattern starts fading with little or no change in carapace length. The study found only a very small proportion of the total number of individuals released. This could be attributed to the fact that the majority of the individuals (82.9% being mature adults, > 130 mm) were about 15–20 yrs old, and 21 yrs later they likely would have naturally died after exceeding their lifespan of about 25 yrs. Others may have died of predation before breeding. What is clear is that, despite the low number of encountered individuals from new cohorts, reintroduction of confiscated tortoises is a viable initiative to boost depleted wild populations. Finally, given that there are viable populations at captive breeding facilities, it is highly recommended that the international pet trade should focus on getting captive-bred specimens and leave the wild ones to boost local tourism.**

KEY WORDS. – **mark–recapture; lifespan; rock crevices; species introduction; ecological characteristics; predation**

The pancake tortoise *Malacochersus tornieri* (Seibenrock 1903) is a small, soft-shelled, dorsoventrally flattened, rock crevice–dwelling species (Loveridge and Williams 1957). Adults are normally less than 20 cm in carapace length with a maximum weight of about 500 g (Moll and Klemens 1996; Malonza 2003). The species is found in scattered rocky hills, outcrops, and kopjes within the Precambrian basement rock system in arid and semiarid areas of south-eastern, central, and northern Kenya (Loveridge 1957; Malonza 2003; Spawls et al. 2018), northern, eastern, and central Tanzania (Loveridge 1957; Moll and Klemens 1996; Spawls et al. 2018), and northern Zambia (Chansa and Wagner 2006; Mwaya et al. 2018; Eustace et al. 2021). The major threat to this wild species has been over-collection for the international pet trade (Klemens and Moll 1995; Malonza 2003). The other threat in agro-pastoral areas of south-eastern Kenya is habitat destruction through slash-and-burn cultivation, but

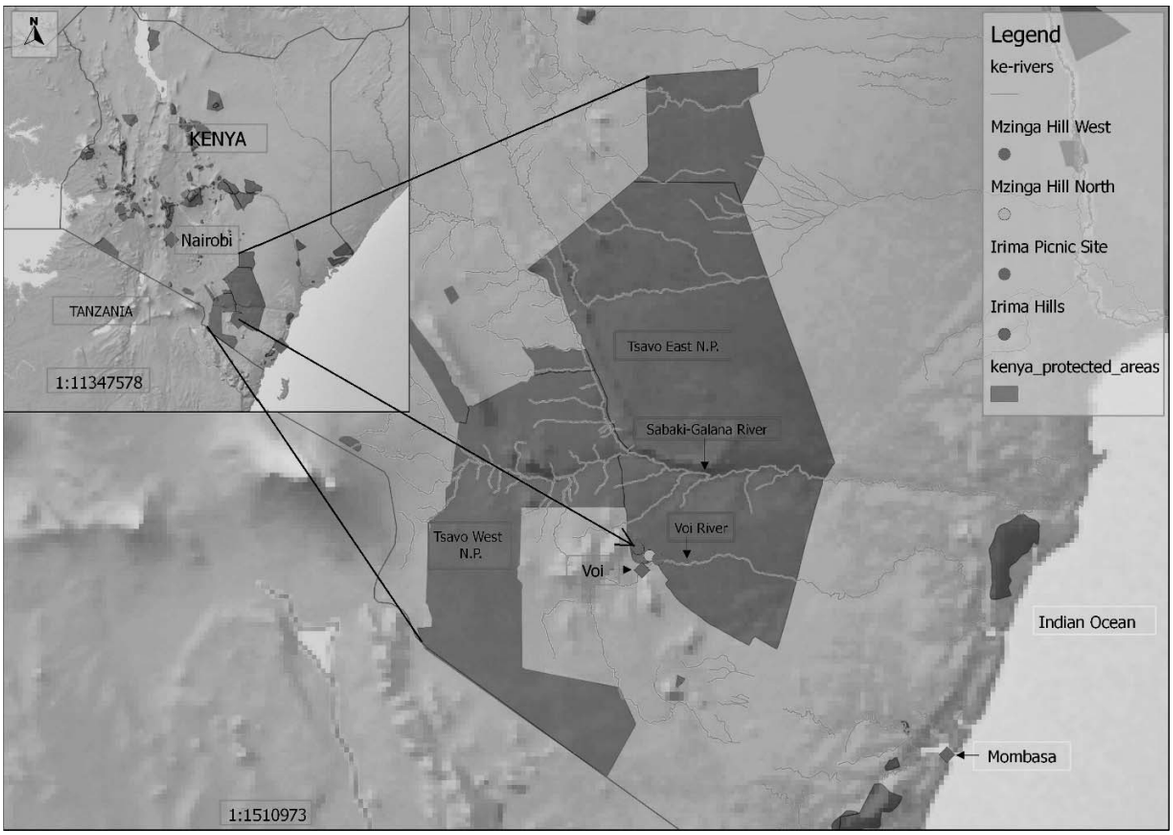

Figure 1. Map of Kenya showing the location of the sites within Tsavo East National Park.

unless there is illegal collection or direct destruction (or both) of the species' rocky microhabitats, populations normally recover over time (Malonza 2003). For example, in Kenya pancake tortoises have been found in microhabitats within actively cultivated farms and highly degraded or overgrazed arid lands (Malonza 2003). The species' appearance of having a colorfully patterned carapace and unique behavior of being a good climber—with the ability to rise up once it falls on its back—and fast movement has made it popular in the international pet trade. As a result of the above threats, the species is currently listed in Appendix I of the Convention on International Trade in Endangered Species (CITES) and categorized by International Union for Conservation of Nature (IUCN) as Critically Endangered (Mwaya et al. 2018; Eustace et al. 2021).

Illegal trade through the collection of wild specimens for international pet trade has been high in the past in Kenya and Tanzania (Wood and MacKay 1997; Malonza 2003). One notable case was the confiscation of 209 *M. tornieri* specimens in Uganda in January 2001, discovered in a public bus that was coming from Kenya; the tortoises were planned for export through Uganda. After the death of 16 specimens in Uganda and 5 in Kenya, the balance of 187 *M. tornieri* was released to the wild in April 2001 through collaboration between the Kenya Wildlife Service and the National Museums of Kenya. The agreed-upon best and safest site to release the tortoises was Tsavo East National Park, southern sector (south of Galana River and Yatta Plateau). This was because a previous countrywide survey had found the area to have rocky hills with suitable crevices without free-ranging wild *M. tornieri* populations (Malonza 2003). This area is close to the main park headquarters near Voi town and about 100 km from the Ithumba and Kiasa hills areas in the northern sector of the park where wild *M. tornieri* occur (Malonza et al. 2001).

The current study provides results of a revisit to the Tsavo East National Park southern sector in June 2022 to establish the status of this population 21 yrs after the initial release. In addition, we present lessons that can be learned to guide future tortoise reintroductions into the wild.

METHODS

Initial Release into the Wild. — The initial release was done in Tsavo East National Park, which is the largest protected area in Kenya covering an area of 13,747 km^2. On 2–6 April 2001, a total of 187 confiscated pancake tortoises were released at 5 different sites in the southern sector (south of Galana River) of the park (Fig. 1): 77 individuals at 2 sites in the Mzinga Hill northern slopes rock outcrops (Site 1: 03°20′45.1″S, 038°35′42.7″E, elevation, 642 m; Site 2: 03°20′49.1″S, 038°35′41.6″E, 656 m), 17 at the Mzinga Hill western rock outcrops (03°21′28.5″S, 038°35′15.4″E, 615 m), 63 at the Irima

Table 1. Summary of size group and sex of the 187 pancake tortoises (*Malacochersus tornieri*) released at 4 sites in April 2001. M = male; F = female.

Carapace length (mm)	Mzinga Hill West	Mzinga Hill North	Irima Hills	Irima Picnic Site
<60	0	0	0	0
60–100	1 (F)	0	0	1 (F)
100–130	2 (F)	14 (8 F, 6 M)	7 (3 F, 4 M)	2 (1 F, 1 M)
130–180	14 (7 F, 7 M)	63 (29 F, 34 M)	56 (28 F, 28 M)	27 (14 F, 13 M)
Total	17	77	63	30

Hills rock outcrops (03°20′45.1″S, 038°35′42.7″E, 642 m), and 30 at the Irima picnic site rock outcrops (03°19′55.8″S, 038°33′16.5″E, 626 m). The number of specimens and sex ratios released in each site is given in Table 1.

Tortoise Measurements and Sexing. — Prior to the release, the sex of each individual was determined following Malonza (2003) and based on a combination of the presence of a depressed (concave) plastron and elongated tail in case of the males, and depressed hind lobes and short, stumpy tail in the case of females. Measurements of individual body weight and straight-line carapace length (SCL) along the midline were taken. Body weight was measured using a 1000-g Salter scale calibrated in 1-g increments, while the SCL was measured using a 250-mm Vernier caliper. Coordinates of the release sites were taken with a hand-held Garmin geographic positioning system (GPS).

Tortoise Marking. — The specimens were systematically marked using a numbering and coding system by cutting notches (with a penknife) on the edge of the marginal scutes. The first 9 marginal scutes on the left side from the supracaudal toward the nuchal scute were designated numbers 1–9, while the first 9 marginals on the right side were designated numbers 10–90 sequentially, as used by Malonza (2003).

Author: Is this accurate? 9 scutes on the left are 1-9, but the 9 cutes on the right are 10-90?

Population Age Structure. — To understand the tortoise age structure, the specimens were grouped based on their carapace length as used by Malonza (2003). The age groups include hatchlings for specimens less than 60 mm SCL, juveniles (60–100 mm SCL), subadults (100–130 mm SCL), and adults (130–180 mm SCL). Population age structure is considered a good indicator of population viability and health (Sriprateep et al. 2013).

Change in Carapace Color and Pattern. — As pancake tortoises grow from hatchlings to adults, individuals typically undergo a change in carapace color and pattern. Here, a combination of carapace color and pattern in relation to carapace length was used in estimating the age of each encountered tortoise. For example, hatchlings are dark with the scute having a large cream center, but as they grow toward adult age the scute develops a dark-cream or yellowish radiation pattern. However, as they age further, the radiation pattern disappears, leaving the carapace virtually plain brownish. Past studies have observed a clear change in carapace color and pattern in pancake tortoise without any sexual dimorphism (Moll and Klemens 1996; Malonza 2003).

Pancake Tortoise Census. — The 5 sites at which the 187 pancake tortoises were originally released were revisited between 30 May and 4 June 2022 to establish the status of this introduced population. Surveys at each site used a time-constrained, search-and-seize method or time-limited search (Karns 1986; Sutherland 1996; Malonza et al. 2011; Dodd 2016). These are kinds of timed species count (TSC) methods that involve systematically searching and counting target herpetofauna species within its preferred microhabitat without setting boundaries and within a time period. The rocky sites where the specimens were released were all less than 1 km^2 and within similar habitat type and elevation range. One hour was spent in each site by 3 observers intensively searching for the pancake tortoise. In the case of pancake tortoises, the microhabitats are rock outcrops with crevices. The presence of a pancake tortoise in a rock crevice is indirectly shown by the presence on its base of droppings or scats (Moll and Klemens 1996; Wood and MacKay 1997; Malonza 2003). The crevices inhabited are normally narrow and tapering toward the end, and the tortoises firmly fit or wedge into the deepest part where they cannot be easily accessed by either predators or humans (Klemens and Moll 1995; Moll and Klemens 1996; Malonza 2003). A Maglite spotlight was used to illuminate or shine inside the dark crevices and, on finding individuals, a 5-foot strong flexible wire hooked at the end was used to dislodge and extract or remove the tortoises (Malonza 2003). Once removed, a specimen was checked for notch mark number (if new, noted and given a new mark number); afterward, standard biological data were taken including SCL, weight, and sex. Then the individual was released in the same crevice for future monitoring. SCL was taken using a digital Guanglu 300-mm Vernier caliper and body weight with an electronic Kitchen scale SF-400. Coordinates of points where specimens were found were taken using a Garmin InReach Explorer+ GPS unit. Photographs of the specimens and their microhabitats were taken using a Sony DSC-H20 digital camera.

Carapace Color Changes with Life Stage. — During the June 2022 survey, we estimated the life stage of each encountered tortoise based on carapace color and pattern.

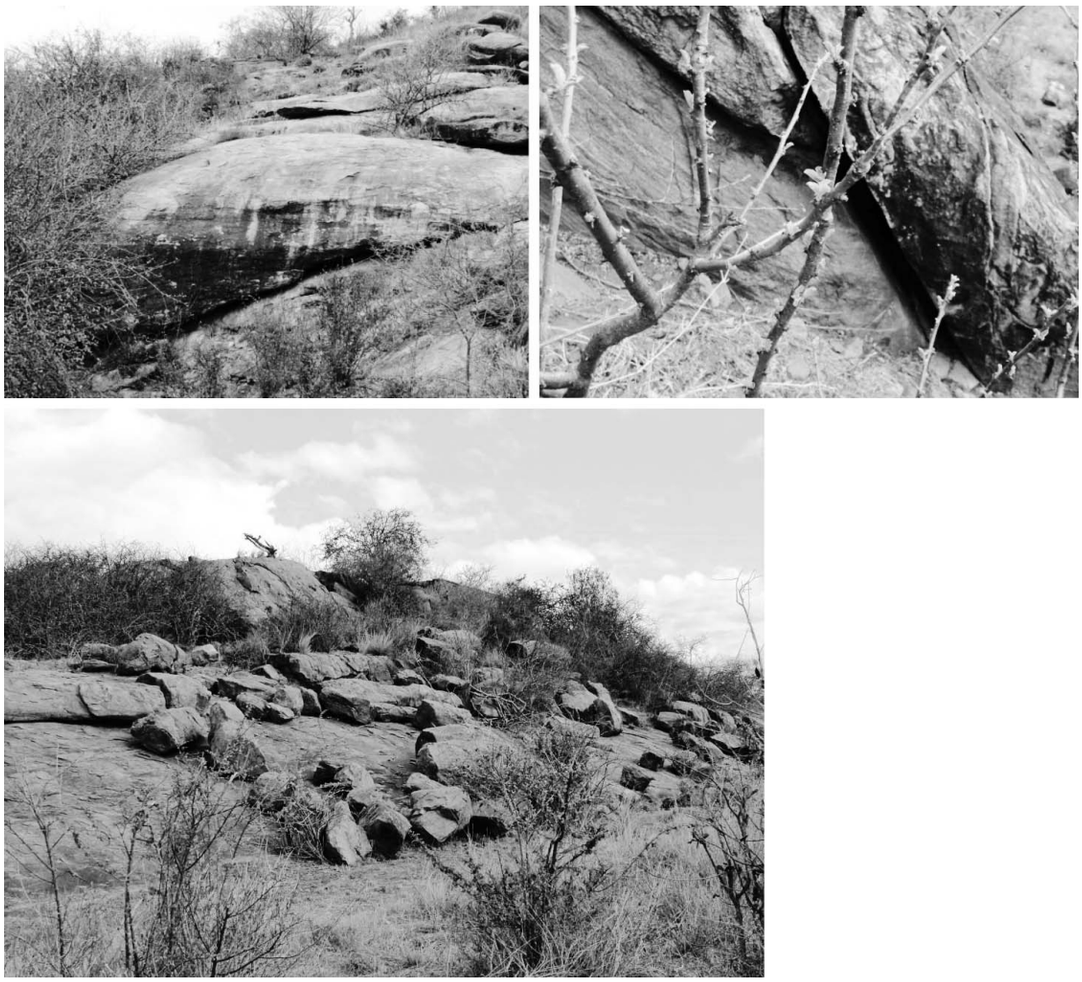

Figure 2. Photographs showing rock outcrops and crevices at 3 release sites for pancake tortoises (*Malacochersus tornieri*): Upper left, Mzinga Hill northern slopes (rock outcrops). Top right, Mzinga Hill west (rock crevice). Bottom, Irima picnic site (rock outcrops).

Hatchlings typically have dark scutes with a very large cream or yellowish center and juveniles have scutes with a smaller cream center area. In subadults the dark scute starts breaking into cream rays, and this radiation becomes very apparent in adults. As adults continue to age, the radiation pattern starts fading, resulting in plain cream or brownish scutes in very old individuals.

Statistical Analyses. — A chi-square test of independence was used to test the association of carapace length with color change, number of specimens of different sexes, and sites. A 1-sample *t*-test was used to test the independence of change in carapace length and color change. A 2-sample *t*-test for independent samples was used to compare the recorded means of carapace length of males and females. The data were analyzed with STATISTICA 7.0 software at a 5% level of significance.

RESULTS

The 187 specimens released in April 2001 ranged from 96 to 166 mm in SCL and from 110 to 495 g in body weight. The group was composed of 93 males and 94 females. Proportionally, 82.9% of the individuals were adults of more than 130 mm SCL. There were highly significant differences in the number of males and females released to different sites; sites with more suitable rock crevices received larger numbers of pancake tortoises (chi-square test: df_7, $\chi^2 = 50.65$, $p < 0.01$). In the released population, there was also a significantly greater number of subadults and adults than juveniles and hatchlings (chi-square test: df_7, $\chi^2 = 374.66$, $p < 0.01$). The tortoises were released in batches of 4–10 individuals per crevice, mostly in equal numbers of both sexes; deeper and well-sheltered crevices received larger numbers of individuals.

During the June 2022 survey, after a period of 21 yrs since the introduction, a total of 15 individuals were found in the 4 sites (Fig. 2). These included 10 females and 5 males, with SCL ranging from 119.42 to 162.09 mm and body weight from 225 to 512 g (Table 2). There was no significant difference in the mean SCL of males vs. females (*t*-test for independent samples: df_{13}, $\chi^2 = 0.88$, $p > 0.05$).

The greatest number of tortoises found at any one crevice was 6 in a single crevice located in Irima Picnic

Table 2. Characteristics of 15 pancake tortoise (*Malacochersus tornieri*) specimens recorded from different sites. M = male; F = female; SCL = straight-line carapace length; NG = new generation.

Site name	Notch no.	Sex	SCL (mm)	Body weight (g)	Coloration	Remarks	Age estimate (yrs)
Mzinga Hill North	1	M	144.72	322	Dark/cream radiation	NG	15–20
Mzinga Hill North	2	M	159.19	390	Brown with dark marks	Recapture	> 25
Mzinga Hill North	3	F	156.18	402	Brown with faded dark rays	Recapture	20–30
Mzinga Hill North	13	M	153.39	472	Brown with faded dark marks	Recapture	20–30
Mzinga Hill West	4	F	143.10	360	Dark with cream rays	NG	15–20
Irima Picnic Site	5	F	119.42	225	Dark with cream center	NG	< 10
Irima Picnic Site	109	F	154.15	512	Brown/faded dark rays	Recapture	> 35
Irima Picnic Site	6	F	162.09	421	Cream with dark rays	Recapture	20–30
Irima Picnic Site	7	F	159.60	445	Brown and worn-out	Recapture	> 30
Irima Picnic Site	8	M	160.05	380	Cream with faded marks	Recapture	20–30
Irima Picnic Site	9	F	155.56	373	Brown and worn-out	Recapture	> 30
Irima Picnic Site	10	M	149.23	360	Brown with faded dark marks	Recapture	25–30
Irima Picnic Site	11	F	125.40	230	Dark with cream radiation	NG	10–15
Irima Hills	12	F	132.38	262	Dark with cream rays	NG	10–15
Irima Hills	44	F	159.82	430	Brown/fade dark rays	Recapture	35–40

Site rock outcrops (Fig. 3). This was followed by 3 tortoises found in one crevice in Mzinga Hill northern slopes; all other tortoises found were solitary (Table 3).

Of the 15 individuals encountered during the June 2022 survey, 10 were recaptures (6 females; 4 males). Of these, only 2 were clear recaptures because they had traces of the notch marks; the additional 8 recaptured individuals had no notch marks but are assumed to have been those young individuals which were less than 130 mm SCL during the release time and whose marks likely disappeared after growth (Table 4). Recapture number 44, a female from Irima Hill rock outcrops, had increased in both SCL (147–159.8 mm, 8.7% increase) and weight (340–430 g, 26.5% increase). The other one was a female from Irima Picnic Site that had faded notch marks on marginal scute numbers 10 and 90 and, from the release record, the other mark should be 9, tallying it with individual number 109. This specimen had also grown in both SCL (146–154 mm, 5.5% increase) and body weight (395–512 g, 29.6% increase). Both represent an increment of about 10 mm in SCL and 100 g in body weight after 21 yrs. All the recaptures looked very old and their carapace was brown in color, with no or only traces of color pattern in addition to some having deformities (Fig. 4). The 5 filial generation (F1) tortoises born after the April 2001 introduction had a carapace length of about 120–145 mm and the mature individuals had a clear carapace, color pattern, or both.

Carapace Color. — There was a clear change in the color and pattern of the carapacial scutes of first-time captures (i.e., new generation) vs. recaptures. The recaptured individuals had either lost the entire color pattern or had only traces of dark or irregular markings. Of the 10 recaptured individuals, 8 had only traces of the radiation pattern or irregular marks, and their SCL ranged from 149.2 to 162.1 mm. The remaining 2 tortoises

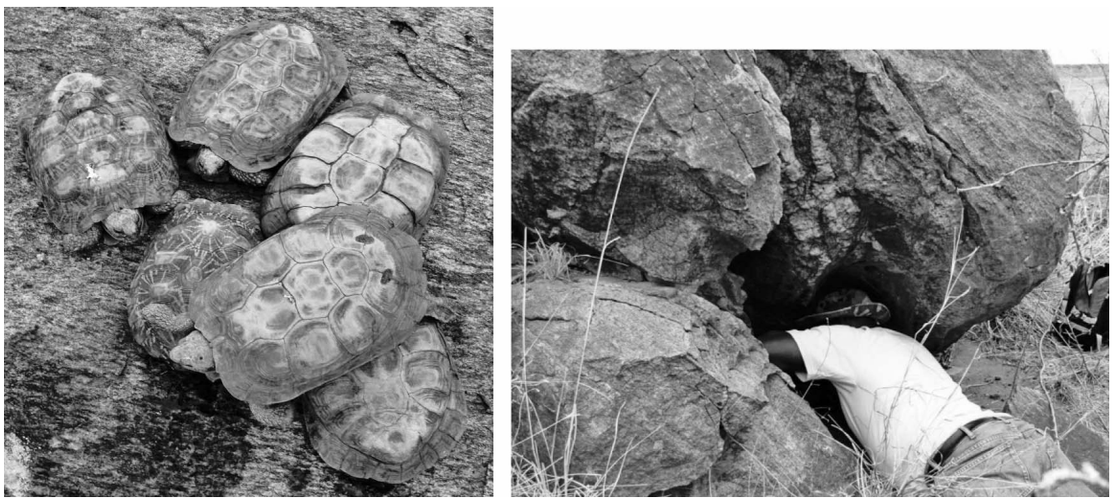

Figure 3. Left, evidence of carapace pattern differences among 6 recaptured pancake tortoises (*Malacochersus tornieri*) encountered in a single crevice at the Irima Picnic Site rock outcrops (right). The two well-patterned individuals are mature adults while those with worn-out carapaces are very old adults.

Table 3. Rock crevice configurations where the 15 pancake tortoises (*Malacochersus tornieri*) were found lodged.

Site name	Tortoise notch no.	Rock crevice type/ orientation
Mzinga Hill North	1, 2, 3	Under rock boulder
Mzinga Hill North	13	Under rock slab
Mzinga Hill West	4	Vertical rock crevice
Irima Picnic Site	5	Under rock slab
Irima Picnic Site	109	Under rock slab
Irima Picnic Site	6, 7, 8, 9, 10, 11	Vertical rock crevice
Irima Hills	12	Under rock slab
Irima Hills	44	Under rock slab

(SCL = 155.5 and 159.6 mm) had carapaces that were almost plain brown or tan colored; these are assumed to be older than those with traces of dark rays. All the new generation had a very clear radiation carapace pattern (Fig. 4; Table 4). In the 5 new-generation specimens, consisting mainly of subadults and adults, there was a highly significant difference of advancement in color pattern change with an increase in carapace length (1-sample *t*-test for independent samples: $df_{4,}$ $\chi^2 = 19.83$, $p < 0.01$).

Table 4. Age group, carapace size, and scute color and pattern for the 6 new-generation specimens.

Age group (carapace size, mm)	Scute color	No. of specimens
Hatchlings (0–60)	Dark with large cream center	0
Juveniles (60–100)	Dark with a small cream center	0
Sub-adult (100–130)	Cream rays start developing	2
Adult (130–180)	Well-developed cream rays	4

DISCUSSION

The configurations of rock crevices inhabited by pancake tortoise vary in orientation from horizontal to near-vertical, and these crevices comprise a very small proportion in any given rocky habitat (Moll and Klemens 1996; Wood and MacKay 1997; Malonza 2003). All the encountered individuals were adults and subadults, but we cannot rule out the presence of juveniles and hatchlings in the population. This sampling was done during the dry season when hatchlings and juveniles are rarely encountered (Malonza 2003). For example, past studies in the

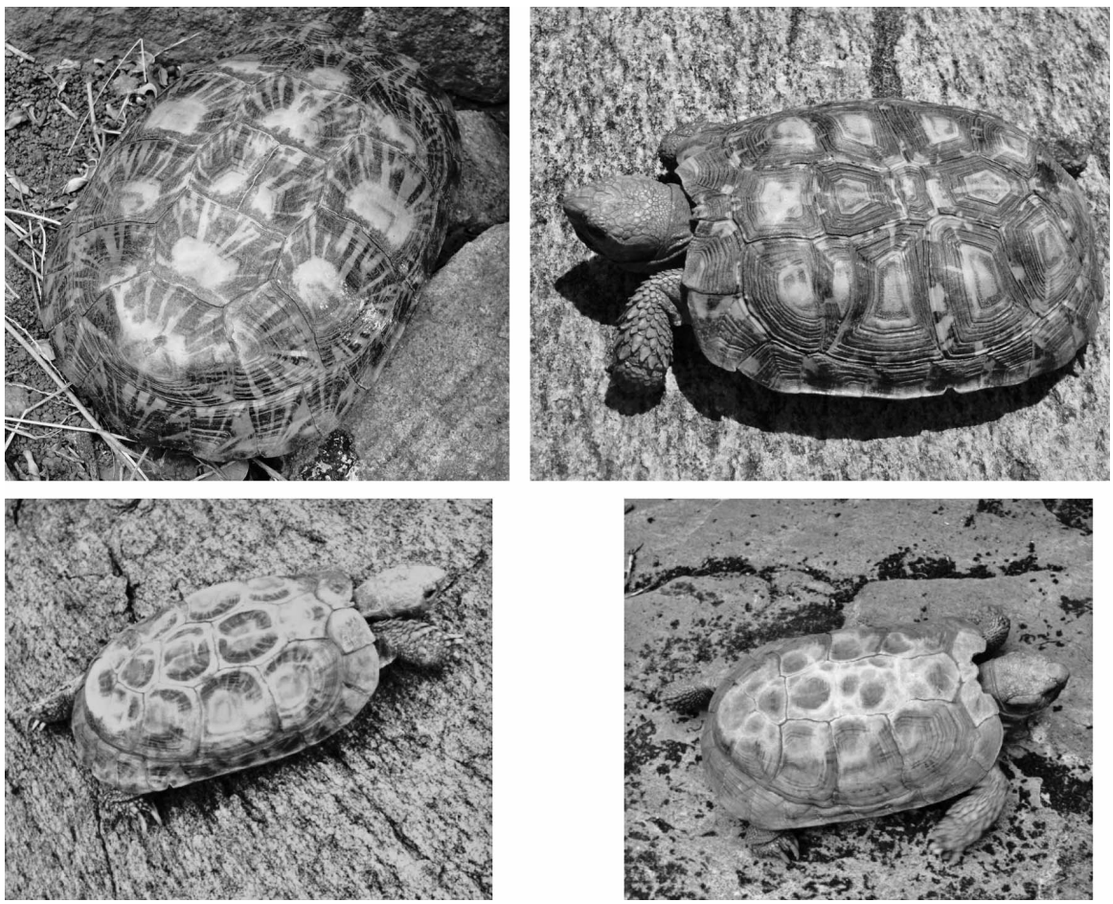

Figure 4. Photographs of adult pancake tortoises (*Malacochersus tornieri*). Note the difference in carapace scute patterns. Top left, a mature adult (number 4; SCL = 143.10 mm). Top right, a subadult (number 5; SCL = 119.42 mm). Bottom left, a recaptured old specimen (number 44, SCL = 159.82 mm). Bottom right, a recaptured old adult with broken marginal scutes on each side of the nuchal scute (number 13, SCL = 153.39 mm).

Mwingi-Kitui area of Kenya have found juveniles and hatchlings to inhabit temporary and unexpected crevices with no signs of fecal droppings and, unlike the adults, these smaller turtles are commonly found during the wet season (Malonza 2003). The older individuals, of about 150–162 mm SCL, were typically plain brown in color with only traces of faded dark marks. In pancake tortoises, there is normally ontogenetic change and variation in carapace color and pattern from hatchlings, juveniles, subadults, and adults up to very old adults (Moll and Klemens 1996; Malonza 2003). Hatchlings and juveniles are normally less than 60 and 100 mm, respectively, are dark, and have the center of the scute being yellow or cream (Malonza 2003). In captivity, the carapace radiation pattern starts to appear at about 7 mo when tortoises are ~ 100-mm in carapace length (Gibbons and Juvik 2013). In our new generation of turtles encountered in the wild, it is at the subadult stage (100–130 mm) that the dark color starts breaking into a very clear radiation pattern, and this reaches a peak radiation pattern in mature adults (130–150 mm) that consists of beautiful cream or yellow rays. However, from the recaptured specimens, which were about 150 mm, the dark color and markings disappear or fade and the specimen turns generally brown.

In wild pancake tortoises, age at the onset of sexual maturity is not precisely known. Research on Tanzanian population showed that males begin to mature at 90–100 mm and females at 130–140 mm carapace length (Moll and Klemens 1996). In captivity, pancake tortoises are known to reach sexual maturity at the age of 5–9 yrs and between 90 and 100 mm, depending on sex and growth rate; a life span of about 25 yrs has been reported (Mwaya et al. 2018 and references therein). Some captive facilities have even reported a lifespan of about 40 yrs (Association of Zoos and Aquariums-AZA, Species Survival Plans–SSP programs, www.aza.org). However, in captivity the growth rate is expected to be faster than in the wild because there are no climate-related periods of inactivity (Gibbons and Juvik 2013). We hypothesize that, due to resource limitations, wild pancake tortoise growth rate should be at least half of that for captive specimens. This is consistent with evidence from the 2 recaptured adults with clearly identifiable notch marks that showed that body growth is very slow after reaching maturity, because both were released when mature with about 150 mm carapace length and had only a small increase in both body length and body weight after 21 yrs.

A study on pancake tortoise husbandry at Behler Chelonian Center in Ojai, California, USA, found that females usually lay 2–3 clutches per year, with mostly 1 egg (2 on rare occasions) per clutch; the average incubation period and hatching success is 5.5 mo and 61%, respectively (Gibbons and Juvik 2013). They also found them to grow faster than other tortoise species, possibly because they do not need to ossify a large mass of dense shell bone for protection. For example, a hatchling of 1.5 inches (or 38.1 mm) reaches 3 inches (76.2 mm) in 1 yr. A captive-born female has been found to start reproducing after 6 yrs, with a carapace length of about 152.4 mm (or 6+ inches). They also found that growth rate in carapace length plateaus after 6 inches, with little or no growth. Past studies have estimated ages of pancake tortoises, as in other terrestrial tortoises, using scute rings that grow or develop annually or per rainy season (Wood and MacKay 1997). However, this may not be reliable because growth rings in pancake tortoises tend to wear out or disappear in older individuals. Estimating age using scute rings count has also been found to be reliable in juvenile and subadult elongate tortoises (*Indotestudo elongate*; Sriprateep et al. 2013). Again, due to their habit of dwelling inside rock crevices, pancake tortoises get worn out due to friction with the rock crevice ceiling.

For pancake tortoises, rather than basing on counts of growth rings, it may be possible to establish rough age estimates based on carapace patterns. The new generation specimens of about 130–145 mm have a very clear color pattern and radiation. For example, F1 specimens, number SCL 144.72 mm and SCL 143.1 mm, have a well-developed color pattern and radiation, and these should now be at least 15–20 yrs old. This is based on the assumption that they were born during the first few years after release. Those of about 130 mm should be about 10–15 yrs old. The specimens of about 100–120 mm are dark, with the center of the scute yellow without any radiation, and these should be younger than 10 yrs old. Similarly, those 30–100-mm individuals with a largely circular-shaped carapace should be younger than 5 yrs old. In the new generation, the specimen with 119.2 mm carapace length does not have a radiation, but it is present in the individual of 125.6 mm. This is contrary to findings in captivity whereby carapace radiation pattern was found to start when the specimen is about 100 mm carapace length and about 7 mo of age (Gibbons and Juvik 2013). However, this is in support of slow or delayed growth in wild populations due long times of inactivity because of erratic rains. The peak of having a very clear radiation is until sexual maturity at about 150 mm, after which the pattern and color start fading with age, with or without significant change in body carapace length. So the recaptured individuals with fading color patterns should be about 30 yrs old, and those with recaptured specimens, which are now largely brown with almost no or only traces of dark marks color, should be older than 35 yrs old.

Why So Few Tortoise Encounters in 2022? — Given that majority of the 187 tortoises released in April 2001 were adults with SCL > 130 mm, it is believed that many of the tortoises may have died within the first few years due to stress, old age, or both. In addition, predation was assumed to be a reason for the low encounter rate for pancake tortoises. Moll and Klemens (1996) reported that white-tailed mongoose (*Ichneumia albicauda*) and common genet (*Genetta genetta*) were potential predators of pancake tortoises in Tanzania. In Kenya, the same 2 species, plus the common slender mongoose (*Herpestes sanguineus*), were considered to be

Author: Should this text be changed to the following for sense: two F1 specimens with SCLs of 144.72 and 143.1 mm ??

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Figure 5. Evidence of predation attempts on a pancake tortoise (*Malacochersus tornieri*). Note the 2 deep predator marks on the posterior carapace.

potential predators. In addition, the honey badger (*Mellivora capensis*), Egyptian mongoose (*Herpestes ichneumon*), and white-throated monitor lizard (*Varanus albigularis*) have been identified via camera traps trying to access ~~and move around~~ pancake tortoise crevices during the ~~long~~ dry season of June to October (J.M. Ngwava, *pers. comm.*, ~~August~~ 2022). In Tsavo East National Park, ~~in addition to these potential small- to medium-sized mammal predators,~~ there are large mammals such as the spotted hyena (*Crocuta crocuta*), silver-backed jackal (*Lupulella* (*Canis*) *mesomelas*), African wild dog (*Lycaon pictus*), and perhaps even lions (*Panthera leo*) that may prey on tortoises found roaming outside the crevices. Carnivorous birds such as the southern ground hornbill (*Bucorvus leadbeateri*) and secretary bird (*Sagittarius serpentarius*) may also prey on smaller pancake tortoises.

In April 2001, the tortoises were released in large numbers and in small, unfamiliar areas, which likely presented unique challenges for survival. Indeed, it is possible that the tortoises started dispersing in search of other crevices, which would have made them very conspicuous to predators, especially considering that April marks the start of the long dry season with no good vegetation cover.

The low number of individuals recaptured, which represents 5.3% of those released, cannot be attributable to poaching. This is because the release sites are within a highly protected national park near the park headquarters and which have dangerous large mammals such as African elephants (*Loxodonta africana*), lions, leopards (*Panthera pardus*), and African buffalos (*Syncerus caffer*), all of which pose a high risk to poachers.

The soft shell of pancake tortoise makes it prone to predation from an array of predators. One specimen (mark number 9) had 2 deep marks on the back of the carapace, clear evidence of an unsuccessful predator attack (Fig. 5). Thus, its main protection technique is by wedging or squeezing itself to the narrowest point of the crevice, making it inaccessible to predators. While feeding, it has to do that within the vicinity of the rock crevices that are their ultimate refuge site. Therefore, it is expected that predation is high on the young tortoises that do not yet have well-developed predator-avoidance behaviors. For both the adults and young, predation occurs when they are outside the crevice either feeding or mating and laying eggs. They can also be preyed upon when lodged in unsecure crevices, especially those that are large enough to allow small carnivores to penetrate.

As a behavioral strategy to avoid predators, this could be the reason why, in Kenya, pancake tortoise individuals have mostly been found outside the crevice around midday (e.g., in Endau-Kitui and Tassia Lodge-Lekurruki Community ranch in Laikipia), when many predators have retreated or rested to avoid overheating. Notching the marginal scutes using a coding numbering system is the most basic method of marking pancake tortoises. However, from this study it was found that due to growth, after many years the notch on the marginal scute disappears, making identification very hard. Owing to body carapace growth, the notch mark is expected to disappear completely in marked hatchings and juveniles as compared with mature adults. Thus, notching may be most effective where there is yearly monitoring and individuals can be remarked by renewing the notch upon encounter. For long-term monitoring, there is a need to innovate a simple marking method, such as piercing or riveting a numbered aluminium tag on the underside of any of the first 3 supracaudal marginal scutes. Such tags would be easily observed, unlike the more technical use of passive integrated transponder (PIT) tags that require a scanner to identify the inserted tag number.

CONCLUSIONS

Past studies have shown that the proportion of suitable microhabitats (rock crevices of certain dimensions and configurations) where pancake tortoises reside is very small in any given rock outcrops habitat (Moll and Klemens 1996; Malonza 2003). Therefore, in the wild, finding 209 *M. tornieri* specimens—the number confiscated in Uganda in January 2001—would have required searching extremely large areas and many individual rock outcrop habitats. Considering that the 187 surviving tortoises were released (in April 2001) into such a small area, it is likely that insufficient crevice resources negatively impacted the overall survival of this group due to increased predation and other factors. This is because of extreme competition for food and shelter, which likely resulted in most tortoises dispersing and searching for alternative rock crevices that may not be in the vicinity. Past studies on pancake tortoise activity patterns have shown that feeding normally occurs during the wet season when there is enough green grass and herbaceous cover. These pancake tortoise specimens were released in April at the start of the long dry season, making it not an ideal period due to lack of food. We therefore recommend that any future release of confiscated pancake

tortoises occur at the beginning of the wet season to allow tortoises to feed and breed prior to entering into aestivation.

Data from a well-managed captive breeding facilities show that breeding a viable population is possible within a very short period to restock depleted wild populations from illegal collection for international pet trade. This also means that those who intend to keep pancake tortoises as pets can get them from captive breeding farms and leave the wild population to be used to boost and diversify local tourism. The results of this reintroduction effort for pancake tortoises in Tsavo East National Park show that, in general, it was successful due to the encounter of both new specimens and recaptures of the original group. This suggests that restocking or enriching depleted populations is possible and bodes well for future reintroduction efforts. Finally, it is highly recommended that this introduced population is regularly monitored on a seasonal basis to get a better understanding of the population in terms of survivorship, juvenile recruitment success, and individual growth rates.

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