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Acclimation, husbandry and breeding of wild-caught Karoo Dwarf Tortoises, *Chersobius boulengeri* (Duerden, 1906)

Introduction

Karoo Dwarf Tortoises (*Chersobius boulengeri*) are among the rarest tortoises in captivity. They were listed on CITES Appendix II in 1975, and its only range country (South Africa) has permitted few exports. Until this study, only 19 (importer-reported) to 38 (exporter-reported) individuals were exported for the trade or for non-commercial purposes, the last ones in 1994 (UNEP-WCMC 2022). Moreover, Karoo Dwarf Tortoises are almost impossible to find in their natural habitat (Boycott 1989), particularly since many populations have been extirpated (Hofmeyr *et al.* 2018a). Previous husbandry experiences suggested that the species requires a particular diet and specific living conditions, as tortoises did not survive long in captivity (Boycott 1989, Boycott & Bourquin 2000). Consequently, it can be ruled out that the individuals exported >28 years ago are still alive, or that they have reproduced.

In 2018–2022, I have conducted a field-study on Karoo Dwarf Tortoises in a rare remnant wild population (Loehr *et al.* 2021, Loehr & Keswick 2022a). Unfortunately, the population was collapsing (Loehr 2022, Loehr & Keswick 2022b), so that some of the anticipated data could not be gathered. The South African authorities permitted the capture and export of two males and two females for a scientific study (i.e., for non-commercial purposes) on reproduction and growth in captivity, based on a detailed project proposal – for more information visit the Dwarf Tortoise Conservation website. Because the species' dire conservation status (Endangered and declining; Hofmeyr *et al.* 2018a) might necessitate conservation breeding in the future, this article aims to file how the tortoises were successfully acclimated, kept and bred during multiple years.

Karoo dwarf tortoises are not commercially available. If *Chersobius boulengeri* is offered, they are most likely poached and smuggled individuals. Do not support the illegal trade by buying them, but inform the CITES authority. For Germany, this is the BfN (Federal Agency for Nature Conservation), contact mail: citesma@bfn.de.

Description, natural range and habitat

The genus *Chersobius* (previously known as *Homopus*) currently comprises three species, which represent the world's smallest tortoises, attaining maximum straight carapace lengths just over 10 cm (Boycott & Bourquin 2000, Loehr 2004, Branch 2008). The Karoo Dwarf Tortoise (Fig. 1A) and Speckled Dwarf Tortoise (*C. signatus*; Fig. 1B) are endemic to respectively south-central and north-west South Africa, whereas the Nama Dwarf Tortoise (*C. solus*; Fig. 1C) is endemic to south-west Namibia. All three inhabit arid (rainfall <200 mm per annum), rocky slopes where they hide under and among rocks and boulders. Vegetation is scarce and consists of dwarf shrubs, grass tufts, geophytes, and

Fig. 1A-C. Karoo Dwarf Tortoise (*Chersobius boulengeri*; A), Speckled Dwarf Tortoise (*C. signatus*; B), and Nama Dwarf Tortoise (*C. solus*; C) Photo: A. Schleicher

succulents (Fig. 2). Only Speckled Dwarf Tortoises have been well-studied (Loehr 2015a, 2016, 2017, 2018, Loehr *et al.* 2015, 2019, Hofmeyr *et al.* 2018b, Galosi *et al.* 2021). Similarly to Karoo Dwarf Tortoises, they have been categorised Endangered and declining (Hofmeyr *et al.* 2018a). Threats to the survival of Karoo and Speckled Dwarf Tortoises include habitat degradation (e.g., overgrazing, rooibos plantations, mining) and predation by human-subsidised crows and ravens. In addition, human-induced climate change is expected to impact growth, reproduction and recruitment in Speckled Dwarf Tortoises. The conservation status of Nama Dwarf Tortoises is outdated in the IUCN Red List of Threatened Species (Branch 2018), but was considered Endangered in 2013 (Turtle Taxonomy Working Group 2017).

Like all *Chersobius* spp., Karoo Dwarf Tortoises have dorso-ventrally flattened shells (Fig. 1A). Their carapaces are uniformly brown to reddish, sometimes with olive colouration. Some individuals have black markings on the edges of the vertebral and costal scutes. The plastrons are yellow, with dark-brown pigmentation in the centre and at the scute edges. Very old individuals lack dark pigments on the carapace and plastron. The colour of the head, limbs and tail varies from yellow to dark-brown and red.

Collecting, transport and acclimation

Two males and two females (all adults) were collected in March 2019, during a severe drought. I selected individuals with a reasonable body condition (calculated following Loehr *et al.* 2007; Fig. 3A-B) that would enable them to survive transport. Nevertheless, female body conditions were very low compared to higher rainfall periods. In fact, many Karoo Dwarf Tortoises in the population were

Fig. 2. Natural habitat of Karoo Dwarf Tortoises (*Chersobius boulengeri*) during drought.

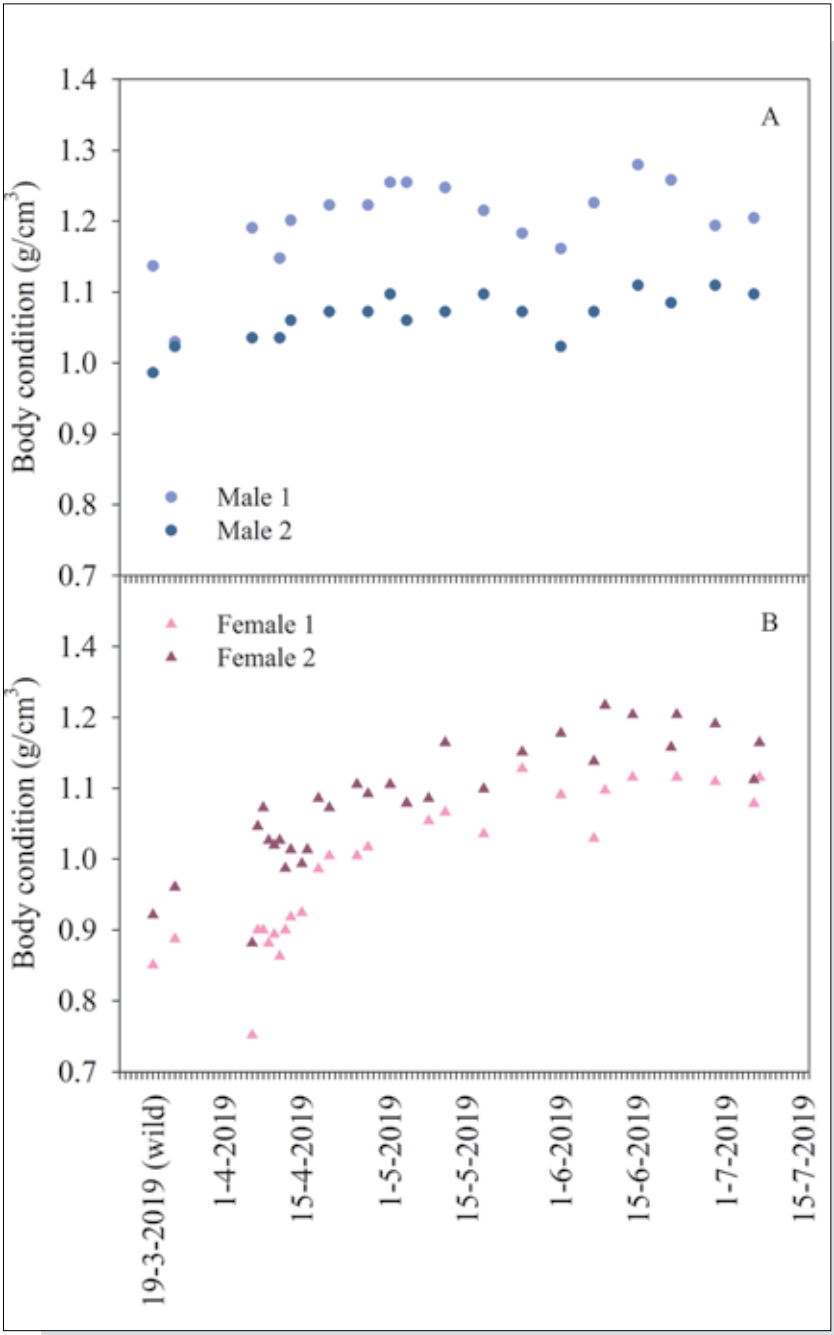

Fig. 3A-B. Body conditions of two male (A) and two female (B) Karoo Dwarf Tortoises (*Chersobius boulengeri*) in the wild, and during acclimation in captivity.

lethargic and struggled to survive in March 2019. Collected tortoises were given the opportunity to drink (which all did), placed in individual plastic containers in a cooler box, transported to the nearest road by hike, to the nearest airport by car, and to the Netherlands by plane. Encountered tortoises that were not collected also received water, to mitigate the effect of removing individuals with reasonable body conditions. Temperatures in the cooler box showed large fluctuations during travelling (Fig. 4), but remained within the natural range for the species (roughly 0–35°C). The time period between collecting in the wild and release in captivity was brief: four days for one couple and five days for the other couple.

Enclosures had already been prepared, based on extensive experience acclimating, keeping and breeding wild-caught Parrot-Beaked Dwarf Tortoises (*Homopus areolatus*), Greater Dwarf Tortoises (*H. femoralis*) and Speckled Dwarf Tortoises since 1995 (Loehr 1999a, b, 2009, 2015b, Klerks 2002). Nevertheless, acclimation of Karoo Dwarf Tortoises provided major challenges. Two open-top enclosures with opaque sides of 1 m^2 each (as recommended for similar-sized Speckled Dwarf Tortoise couples; Dwarf Tortoise Conservation 2022) were available in an attic with large, south-facing roof windows, and computer-controlled (Siemens LOGO!, Munich, Germany) climatic conditions (Loehr 2007). Enclosures were illuminated with a 70 Watt HQI lamp at times of low natural light intensity, and each had a 35 Watt UVB basking spot (Solar Raptor, Econlux, Cologne, Germany) positioned 20 cm from the soil surface for UVI ≈ 10. The enclosures contained

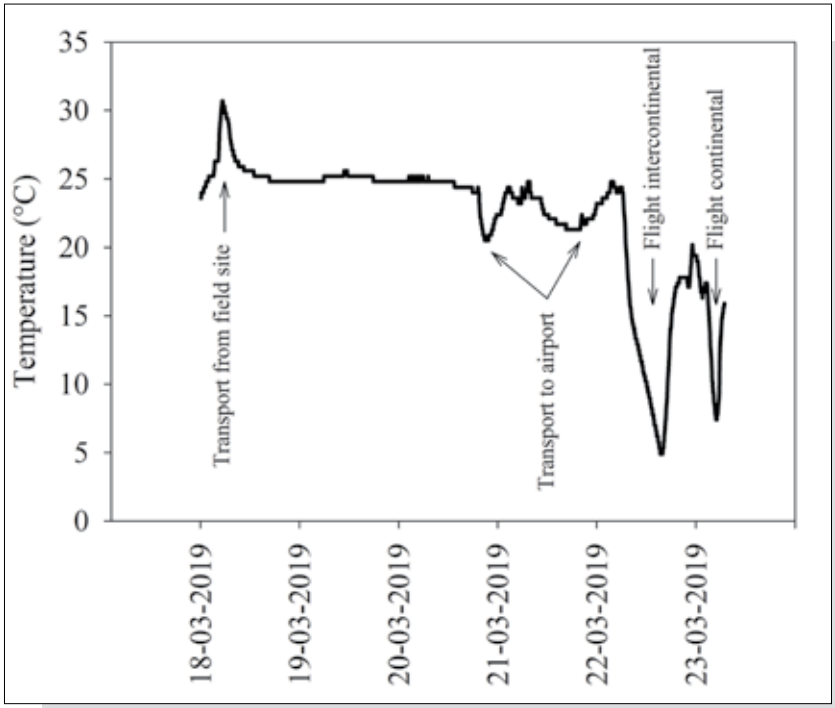

Fig. 4. Temperatures inside a cooler box with Karoo Dwarf Tortoises (*Chersobius boulengeri*) during transport from a collecting site in South Africa to the Netherlands.

a layer of compressed and dried sandy loam (sand:loam = 1:1, based on volume), multiple rocky retreats, and wood (Fig. 5). Feeding and water bowls were also present. Due to the low body condition of the tortoises, they were instantly switched to northern hemisphere (spring) climatic and photoperiodic conditions, despite autumn conditions at their southern hemisphere origin.

Upon releasing the tortoises in their enclosures, after providing fenbendazole (50 mg/kg body mass, repeated after 14 days) to suppress nematode infestations, they restlessly paced, and frequently climbed on top of rocks and wood to drop down, sometimes on their backs. Retreats were ignored. Moreover, the males bit and tried to mount the females. To reduce stress, males were moved to individual 1 m^2-enclosures after the first few days. An attempt to combine the two females in a 2 m^2-enclosure failed, due to intrasexual aggression. Eventually, in response to aggressive, mounting and restless behaviours, males and females were individually housed in 1 and 1.8–2 m^2-enclosures, respectively. In these enclosures, I replaced natural rock retreats by stacked concrete bricks (Fig. 6; total retreat height ≥11 cm) to disable tortoises to climb on top of retreats and fall down. In each enclosure, one retreat was fitted with a thermostatically operated heat mat (Fig. 7; temperature set at 28°C) to allow tortoises to bask inside retreats, as they do in the wild (Loehr *et al.* 2021). It took more than two weeks until all tortoises started using retreats during the night.

All tortoises began feeding within seven days. Males fed on chicory, but females initially refused all food items. This included a large variety consisting of endive, chicory, carrot, tomato, dandelion, plantain, clover, vetches, sprouted mung beans, various flowers, various fruits, and even (red-coloured) Japanese knotweed sprouts. Food was scattered throughout the enclosures, and tortoise behaviour was permanently monitored by camera. First food items accepted by females were succulent plants: *Haworthia* sp., followed by *Crassula muscosa* and *C. marnieriana*. Males and females were then accustomed to feeding bowls and a standard tortoise diet by mixing chicory with finely cut dandelion, plantain, clover and vetches, and succulent leaves, and gradually reducing the amount of succulents. It must be noted that succulents did not appear proper (staple) food for Karoo Dwarf Tortoises, as leaves were often defecated undigested in watery faeces. Succulents are also not quantitatively important food items for wild Karoo Dwarf Tortoises (V.J.T. Loehr, unpubl. data).

Female body conditions decreased to dangerously low levels during the first two weeks in captivity, despite both females feeding on succulents. To reverse this trend, females were force-fed with herbivore recovery food (Critical Care, Oxbow Animal Health, Omaha, NE, USA; 2% of body mass twice daily) on 1–4 days. Meanwhile, females began accepting more types of food. Body conditions steadily increased (Fig. 3B) and behaviour became less restless, although all four individuals maintained high activity levels. After two months, all tortoises had fully accustomed to the standard tortoise diet, without succulents, which was mixed with fibers (Pre Alpin Senior, Agrobs GmbH, Degerndorf, Germany), and vitamins and minerals (Calcicare 40+ [Witte Molen BV, Meeuwen, Netherlands] mixed with calcium lactate in a 1:1 weight ratio). Body conditions stabilised, and I considered tortoises successfully acclimated.

Permanent housing and husbandry

Having experienced that wild-caught Karoo Dwarf Tortoise were aggressive, prone to falling, and accepted artificial brick retreats, I optimised their enclosures. Concrete bricks were replaced by roughened and painted lightweight aerated concrete bricks (Fig. 8), at the same sites as original retreats, to facilitate inspections. Internal sizes of retreats remained 30 x 20 x 7 cm and 20 x 10 x 7 cm, with entrances of 15 x 7 cm and 10 x 7

cm, respectively. In each enclosure, one of the larger retreats had an integrated thermostatically-controlled heat mat. Furthermore, I replaced the sandy loam soil layer by 80 mm XPS foam covered with 6 mm EPDM rubber flooring (Neoflex, Rephouse Ltd., Malta). I cut holes in the foam and rubber at the back of the enclosures and inside retreats, and filled these areas with sandy loam soil (sand:loam = 10:1, based on volume) as nesting sites. This design provided relatively deep nesting sites while enclosure weight remained low, reduced the risk of damage when tortoises would drop from structures inside enclosures, and also reduced the risk of soil ingestion. The roughness of the rubber top layer provided excellent traction for tortoises to walk, and some flat pieces of sandstone assured wear of nails.

I maintained ambient temperatures similar to those at the site where the tortoises had been collected, i.e. monthly mean maximum temperatures between 16 and 33°C, and monthly mean minimum temperatures between 4 and 16°C. Minimum temperatures were often higher than those in the wild. UV spots provided opportunities to bask throughout the year, but switched off at times when natural sunlight was shining in the enclosures through the (glass) roof windows. Photoperiod followed an annual cycle adapted from the origin of the tortoises (i.e., 10–14 hours), yet converted to northern hemisphere. Tortoises readily drunk from their water bowls, so enclosures were not sprayed.

All tortoises were fed daily. However, from spring 2022 onwards, I left feeding dishes in enclosures for two consecutive days, providing dehydrated food on the second day. Dehydrated food was usually supplemented with commercially available dehydrated dandelion, plantain, clover, nettle, raspberry leaves, cornflower, and malva and hibiscus flowers. All individuals continued to be finicky about their food; succulents were favoured over chicory, chicory was favoured over most other food items, and commercial dehydrated foods were generally rejected.

Maintenance comprised daily removal of faeces and urine, and cleaning of water bowls. Remaining dirt on the rubber flooring was moistened with water and removed weekly. Each year in August, fenbendazole treatment was repeated to keep nematode infestations at bay.

Behaviour, reproduction and raising of hatchlings

Captive Karoo Dwarf Tortoises were active throughout the year, but males often had inactivity periods of several weeks in winter, and females had inactivity periods of several days in summer. Male mating behaviour (Fig. 9), which included chasing and vigorously biting females in shell and limbs, was most frequent in summer but occurred year-round. Consequently, males were only placed in female enclosures from mid-September until April, and removed when mating activity was intensive. When active, tortoises were usually walking or feeding. Basking under spotlights was only observed in winter, when heat mats in retreats were switched off from December–March. In other seasons, tortoises often adopted basking postures inside retreats.

All *Chersobius* spp. produce large, single eggs (Boycott & Bourquin 2000). The first Karoo Dwarf Tortoise egg was produced in May 2020, confirming successful acclimation. In total, 30 eggs were laid until December 2022, in two distinct egg-laying periods in spring and autumn (Fig. 10). Twenty-four (80%) of all eggs were laid in heated retreats, sometimes after I had moistened the soil, and sometimes in dry soil that had been moistne by the female. Eggs were incubated on foam, in individual plastic containers that also contained humid Seramis (Fig. 11). Incubation occurred in a temperature-calibrated lab incubator (Memmert IPP30Plus, Schwabach, Germany; Fig. 11), at a diurnal temperature cycle ramping between 33.0°C (11.5 hours) and 28.0°C (9.5 hours); the incubator was able to heat and cool, so that incubation temperatures were independent of

Fig. 5. Initial enclosures, each for one couple Karoo Dwarf Tortoises (*Chersobius boulengeri*).

Fig. 6. Enclosures, each for one solitary female Karoo Dwarf Tortoise (*Chersobius boulengeri*).

Fig. 7. Integration of a heat mat in a concrete brick retreat for Karoo Dwarf Tortoises (*Chersobius boulengeri*).

Fig. 8. Enclosures, each for one solitary female Karoo Dwarf Tortoise (*Chersobius boulengeri*), with an XPS foam bottom, EPDM rubber flooring and holes for nesting (A), and finished and decorated (B).

ambient temperatures. From incubation day 30 until 50, eggs were incubated at constant temperatures of 30.0°C or 33.0°C, to hatch males and females, respectively. This method yielded males and females as anticipated, but one female-incubated egg resulted in a male, and virtually all offspring had scute abnormalities. Therefore, the diurnal regime was changed to 31.0°C (11.5 hours) and 26.0°C (9.5 hours), at a general relative humidity >80% (Seramis in incubation containers was left to dry out), and the constant-temperature incubation period shifted to incubation day 23 until 43. The latter method appeared to reliably produce male and female offspring, but scute abnormalities remained in females, possibly requiring a reduction of the constant temperature. Sex determination in Karoo Dwarf Tortoises seemed to occur around incubation day 30, and threshold temperature was between 30.0 and 33.0°C.

Sixteen (62%) of all eggs laid until June 2022 hatched (Fig. 12), after 79–98 (mean 86) days. There was no statistical difference in hatching percentage among eggs laid by the two females in spring and in autumn (X^2 test, Yates' corrected $X^2_1 = 0.22$, $P = 0.64$). One embryo died just prior to hatching, possibly because it lacked an egg tooth. Remaining eggs failed to develop and may have been infertile. Mean straight carapace length of hatchlings was 35.2 mm, and mean body mass was 10.7 g. Up to two hatchlings were placed in open-top enclosures measuring 40 x 30 cm (Fig. 13), and moved to larger enclosures during growth (Fig. 14). Enclosures had a thin layer (10–15 mm) of compressed and dried sandy loam (sand:loam = 1:1, based on volume), and were decorated with natural rock and wood. During the first year, hatchlings were soaked weekly for 10 minutes and enclosures sprayed twice weekly to avoid

Fig. 9. Mating behaviour in Karoo Dwarf Tortoises (*Chersobius boulengeri*).

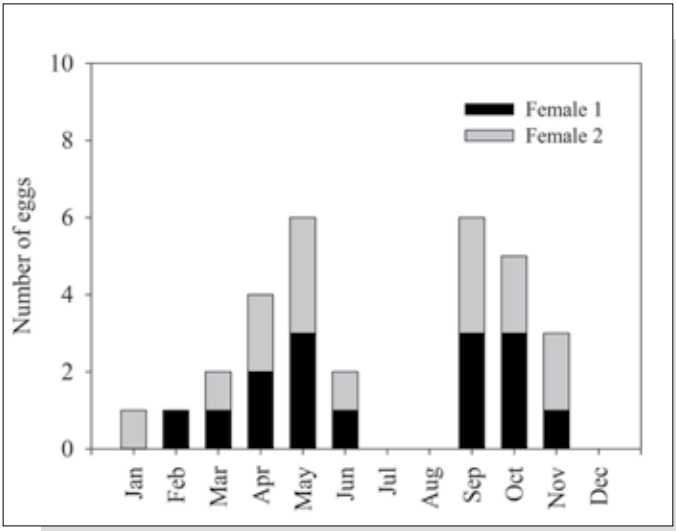

Fig. 10. Monthly egg-production by two female Karoo Dwarf Tortoises (*Chersobius boulengeri*), between May 2020 and July 2022.

dehydration. I assessed the behaviour of an adult female and two juveniles with straight carapace lengths of 54 and 66 mm placing all three in the female enclosure. It was observed that the adult female aggressively bulldozed the juveniles with its shell, after which the juveniles were removed from the enclosure.

Conclusions

In the past 30 years, tortoise husbandry techniques and knowledge have greatly advanced, which possibly explains why previous attempts to keep Karoo Dwarf Tortoises in captivity have failed, whereas the current attempt succeeded. The short duration between capture in the wild and release in captivity was probably an important factor. Karoo Dwarf Tortoises can be successfully acclimated, kept and bred in captivity, and certainly do not require a particular, natural diet. Nevertheless, wild-caught individuals were extremely demanding, requiring relatively large enclosures, constant monitoring to timeously detect behavioural and dietary issues, and previous experience with dwarf tortoises was instrumental to quickly implement appropriate measures. Wild-caught Karoo Dwarf Tortoises should not be kept by inexperienced keepers.

Hatching and raising captive-bred Karoo Dwarf Tortoises did not pose particular difficulties and is feasible for knowledgeable tortoise keepers. Incubation procedures will be optimised in the next years. It remains to be seen if captive-raised individuals, compared to wild-caught individuals, might be less aggressive inter- and intrasexually, especially when raised in couples or groups.

The information presented in this article results from Karoo Dwarf Tortoises collected and exported from South Africa for scientific study. Results from that study will be incorporated in scientific, peer-reviewed papers in the future.

Fig. 11. Incubation of Karoo Dwarf Tortoise (*Chersobius boulengeri*) eggs.

Fig. 12. Karoo Dwarf Tortoise (*Chersobius boulengeri*) immediately after hatching.

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Fig. 13 The small open-top enclosures for the hatchlings, separated from the room by panelling to avoid draught

Fig. 14. Juvenile Karoo Dwarf Tortoises (*Chersobius boulengeri*) of various ages.

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