The Karoo dwarf tortoise (*Chersobius boulengeri*): field report on a vanishing species

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Introduction

Among vertebrates, chelonians are proportionally more threatened with extinction than any sizeable mammal, bird or amphibian group (Stanford et al. 2020), but receive relatively little conservation attention. Currently, 52% of all assessed tortoise taxa have been classified (Critically) Endangered or Extinct (IUCN, 2020) and their roles in ecosystems are diminishing (Lovich et al. 2018). South Africa harbours more tortoise taxa than any other country (13-15 species and at least three unresolved taxa (Daniels et al. 2010; Turtle Taxonomy Working Group 2017; Zhao et al. 2020), most of which have modest conservation statuses (i.e. Least Concern, Near Threatened and Vulnerable; IUCN 2020). Nevertheless, three species are (Critically) Endangered and most have decreasing population sizes (IUCN 2020).

In the last few decades, the ecologies of some South African tortoise species have been investigated (Keswick et al. 2006; McMaster & Downs 2006; Leuteritz & Hofmeyr 2007; Loehr et al. 2009; Hofmeyr et al. 2012; Keswick & Hofmeyr 2013; Loehr 2017). However, other species remain mostly unknown, making it impossible to identify which conservation measures are needed. One of the most elusive South African tortoises is the endemic Karoo dwarf tortoise (*Chersobius boulengeri*; Fig. 1), one of the world's smallest tortoises (up to 110mm; Boycott & Bourquin 2000) that inhabits a relatively small, arid summer-rainfall range (Boycott & Bourquin 2000). Karoo dwarf tortoises were assessed Near Threatened in 2013 (Hofmeyr & Baard 2018), but proposed Vulnerable one year later (Turtle Taxonomy Working Group 2014). A subsequent assessment in 2017 concluded that the species' conservation status had further deteriorated to Endangered (IUCN 2020). Because currently just one, verifiable, small population subsists, it is imaginable that future assessments may classify Karoo dwarf tortoises as Critically Endangered, the final status before extinction. Thus, its ecology should be studied urgently.

Available life-history information on Karoo dwarf tortoises is limited to a few notes and assertions (Boycott 1989; Haagner 1990; Van Wijk & Bates

Fig. 1. Karoo dwarf tortoise male. All photos by Victor Loehr.

1999; Boycott & Bourquin 2000). Plans for a scientific field study were incepted as early as 2005, but field surveys between 2005 and 2017 failed to locate a study site with more than one or two individuals. In February 2017, a relatively dense population was finally found by a Dwarf Tortoise Conservation volunteer group, so that the anticipated field study could start after obtaining all required permissions.

Field study

Previous field studies on speckled and greater dwarf tortoises (*Chersobius signatus* and *Homopus femoralis*, respectively; Loehr 2002, 2006, 2010, 2012, 2015, 2017, 2018; Loehr et al. 2006, 2007a,b, 2011, 2015) had developed a study design that could be quickly and easily adapted for Karoo dwarf tortoises. Similar to all previous studies, the entire field study was managed and performed by volunteers, and focussed on the following aspects:

- ❏ Population structure and dynamics
- ❏ Activity and behaviour
- ❏ Home ranges
- ❏ Diet
- ❏ Reproduction
- ❏ Tortoise growth rates

Initially, sampling periods were scheduled based on the understanding that Karoo dwarf tortoise females would produce eggs in the summer rainfall season (Boycott & Bourquin 2000; Branch 2008), but the sampling schedule was rigorously altered and extended when we could not find gravid females in summer. An additional adjustment was made when the study site was struck by a severe drought, enabling us to compare reproduction among drought and non-drought years. Eventually, the study site was sampled during the following periods:

- ❏ February - March 2018 (6 weeks, summer)
- ❏ October - November 2018 (6 weeks, spring)
- ❏ February -March 2019 (6 weeks, summer)
- ❏ October 2019 (1 week, spring)
- ❏ February - March 2020 (6 weeks, summer)

In each summer sampling period, I searched for Karoo dwarf tortoises daily with small teams of volunteers and students, for a study total of 2,012 person-hours. When a tortoise was found, we recorded (Fig. 2) its sex, dimensions, mass, geographic coordinates, microhabitat and behaviour, and released it after notching the marginal scutes for future identification (Boycott & Bourquin 2000). Moreover, nine males and 16 females were equipped with radio transmitters in summer 2018 (and one additional female in spring 2018), allowing us to recapture those males and females in spring 2018 and summer 2019, and females additionally in spring 2019 and summer 2020. In summer and spring 2018 and 2019, we radiographed females to check if they were gravid. Any faeces produced during handling were air- or silica-dried and stored for dietary analysis, and in summer 2020 we also collected DNA samples of potential food plants to compare to DNA in faecal samples. Behavioural observations were supplemented with continuous behavioural recordings for nine males and 10 females in summer 2018 to construct behavioural time budgets, high-frequency tracking recordings in spring 2018 to identify population-level behavioural patterns, and focal feeding recordings in summer 2020 to add to the dietary dataset. Finally, in summer 2018, we also recorded infrared temperatures of tortoises, retreats and exposed rocks, and cloacal temperatures of tortoises, to establish if and how the tortoises thermoregulated. At the end of the study, all radio transmitters were removed and the tortoises released.

The study site was situated at a very remote place, so I installed a weather station at the start of the study to record daily temperatures and rainfall. The remoteness of the study site, along with low-quality roads and unpredictable weather, caused great difficulties to the field teams. In summer 2018, a rainfall event caused flash flooding and the loss of two of our vehicles (Fig. 3). In

Fig. 2. Volunteers making recordings on a Karoo dwarf tortoise located at the study site.

Fig. 3. Two vehicles washed down during flash flooding in summer 2018.

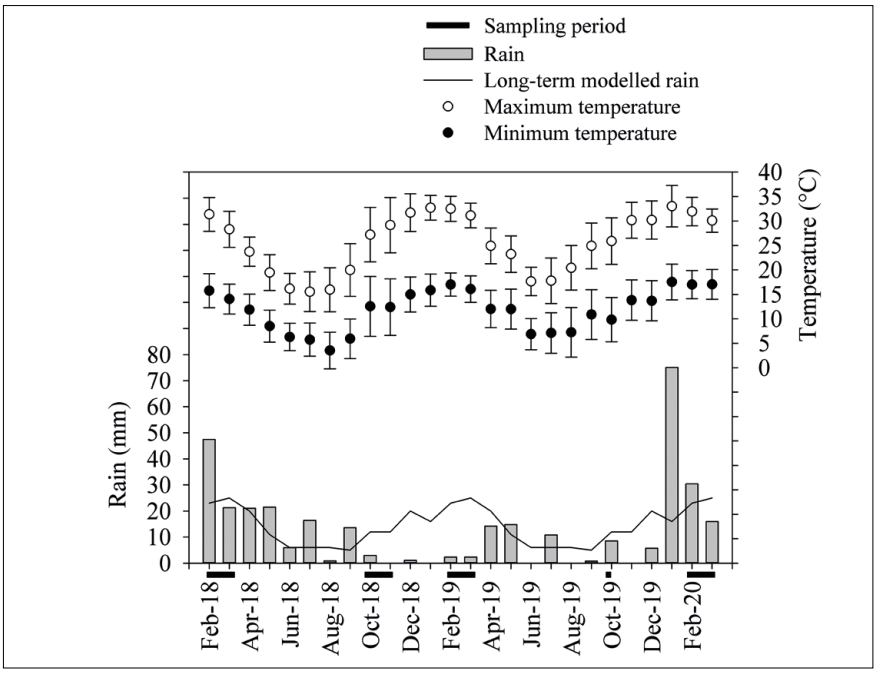

Fig. 4. Mean monthly minimum and maximum temperatures (± standard deviations), rainfall, modelled long-term rainfall (Meteoblue 2017) and sampling periods at the Karoo dwarf tortoise study site.

summer 2020, we were prepared and able to reach home despite flash floods; however, the nocturnal drive took us eight hours via washed-away roads that we had to clear of rocks, shrubs, fences and debris. In the rainfall season, roads were often degraded so that we had to use long detours that were accessible, and tyre punctures sometimes forced us to walk long distances to the nearest civilisation.

Preliminary results

Here I will present preliminary data gathered during the sampling periods. Because the sampling was completed recently, most data still need to be rigorously analysed and will be published in peer-reviewed journals in the next years.

Weather conditions

Temperatures and rainfall varied greatly throughout the study (Fig. 4). Temperature extremes that we recorded were -3.4 and 40.7°C, and monthly averages ranged from 3.5 to 33.0°C. The summer sampling periods in 2018 and 2020 had above-average rainfall that resulted in relatively lush, green and flowering vegetation, whereas the summer 2019 sampling period followed a five months drought and had limited plant growth.

Population structure and dynamics

In total, we captured 50 unique male, 37 unique female and five unique juvenile Karoo dwarf tortoises at and near the study site. Of the five juveniles, three had recently hatched, i.e. we found them near their eggshells (Fig. 5). Most adult individuals were recaptured in successive sampling periods and we found few deceased tortoises, even in the drought year. Although we could not establish the age of the tortoises that we captured, their worn shells indicated that many individuals were ancient. The smallest (hatchling) individual that we found had a straight carapace length of 31.3mm, and the largest individual was 103.1mm.

Activity and behaviour

Continuous behavioural observations in summer 2018 and population-level behaviours in spring 2018 showed that Karoo dwarf tortoises were mostly inactive. In summer, tortoises spent 90% of the observation time (i.e., nearly full days) in retreats, and in spring 82% of tracked tortoises were hiding in a retreat. When tortoises were active they spent most of the time scanning the area and walking, and fed for an average of only 11 minutes per day towards sunset. During our sampling activities, we opportunistically encountered one active tortoise every 120 person-hours (e.g. one person finding one active tortoise every three weeks). It is likely that we have overlooked some individuals, because their bodies mimicked the rocky environment extremely well (Fig. 6).

Retreating tortoises were able to elevate their body temperatures above temperatures of the retreat soil and ceiling. When ceilings became very warm, tortoises were also able to decelerate the increase of their body temperature. We noticed many cases of retreating tortoises that had bodily postures associated with heat transfer from or to the environment, although tortoises were in full shade. These results suggest that Karoo dwarf tortoises can thermoregulate inside their rock retreats.

Fig. 5. Hatchling Karoo dwarf tortoise with its eggshell.

Fig. 6. Karoo dwarf tortoise mimicry.

Home ranges

Because the study site included a mountain slope with 100m elevational difference, home range analysis will require the construction of a 3D elevational model in a geographic information system. This has not yet been done. Regardless, it appeared that most tortoises had relatively small home ranges of less than one hectare, and many home ranges overlapped one another.

Diet

The study site harboured at least 116 plant species. Forty-eight vegetation plots that we used for vegetation analysis contained 53 plant species, with iron grass (*Aristida diffusa*) being the most widespread. Tortoises were generalist feeders (Fig. 7), but for some plant species there was a marked difference between availability and presence in faecal or focal samples (DNA samples are still being processed). Iron grass and other grass species were not present in any of the dietary samples, and relatively rare species such as veined haworthia (*Haworthiopsis venosa tessellata*) and the legume *Dichilus* sp. were present in multiple dietary samples. Tortoise faeces also contained viable plant seeds.

Reproduction

None of the Karoo dwarf tortoise females was gravid in summer 2018 or 2019. In spring 2018, following relatively high rainfall, all females produced single eggs (Fig. 8) and several females produced multiple clutches. In contrast, in spring 2019 most females did not produce any eggs, although some were gravid despite the drought.

Tortoise growth rates

Since we found almost exclusively adult tortoises, we were unable to determine growth rates of differently-sized tortoises. As a replacement, I captured Karoo dwarf tortoises for a captive study of reproduction and growth. The tortoises acclimatised well, but turned out to be very demanding. Individuals required separate, relatively large enclosures with rock retreats that they could not climb on and drop off (Fig. 9), and were difficult to adjust to a captive diet. Eventually, all individuals fed well on a diet consisting of 3 parts coarsely cut chicory and 1 part finely cut endive or weeds, mixed with Agrobs Alpine Senior (fibres) and a Calcicare 40+/calcium lactate (1:1) additive. Various succulent species were accepted too. Twelve months after capture copulation occurred and 13 months after capture the first egg was produced (Fig. 10). This egg hatched almost three months later (Fig. 11).

Fig. 7. Karoo dwarf tortoise feeding on a slime-lily (*Albuca* sp.).

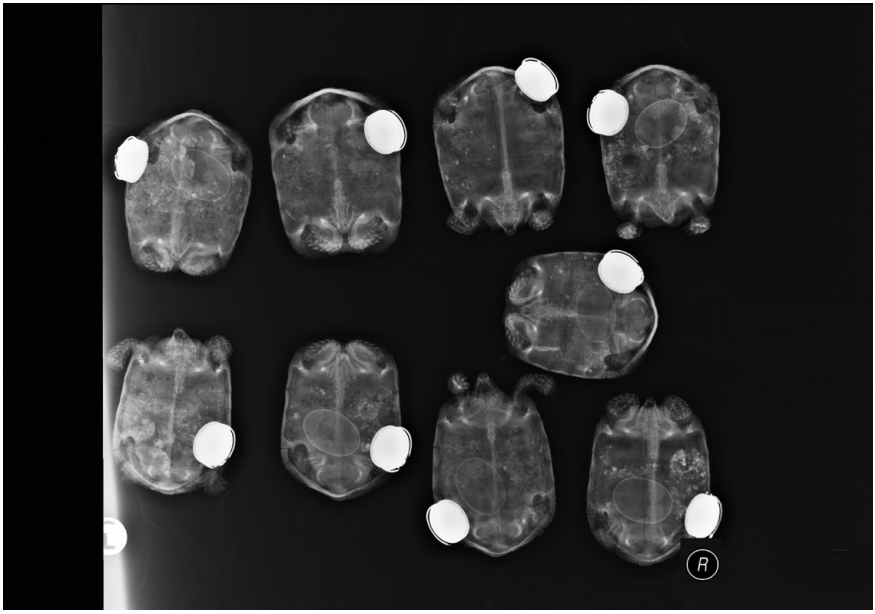

Fig. 8. Radiograph of gravid and non-gravid female Karoo dwarf tortoises. Bright white objects are radio transmitters. Image courtesy of Victor Loehr/Dwarf Tortoise Conservation.

Fig. 9. Two enclosures for wild-caught Karoo dwarf tortoises. Each enclosure measured approximately 2m^2 and was placed in a climate-controlled room.

Fig.10. Nest of a captive Karoo dwarf tortoise in an artificial rock retreat (i.e. concrete cover was removed and the egg partly exposed before the photograph was made).

Fig. 11. Captive-bred hatchling Karoo dwarf tortoise 12 hours after hatchling, with the female that had produced the egg.

Fig. 12. Dead Karoo dwarf tortoise female that had been forcefully smashed on a rock, presumably by a bird.

Discussion

Although some data collection and most data processing are still in progress, this study has already yielded important ecological information about Karoo dwarf tortoises. They seem to have very low resource demands (Pough 1980), enabling them to spend most time in retreats, which is likely to reduce their vulnerability to predation. Low resource demands were also illustrated by some females that managed to produce an egg in the drought year. Survival of the tortoises under drought conditions appeared high, as was the case in speckled dwarf tortoises (Loehr 2010), but more thorough data processing is needed because drought is associated with increased mortality in other arid-region tortoises (Peterson 1994; Longshore et al. 2003; Nagy et al. 2015).

The ectothermic metabolism requires tortoises to regulate their body temperatures to a favourable range. Karoo dwarf tortoises were able to achieve this with little basking in direct sunlight, which further helped them reduce predation risks. It is possible that Karoo dwarf tortoises require very specific retreat characteristics to maintain favourable body temperatures. Indeed, a small number of retreats at the study site were constantly used by several tortoises (sometimes two or three at the same time), whereas other retreats that looked suitable were never used. Retreat availability might be an important aspect in the conservation of the Karoo dwarf tortoise. Vegetation composition appeared less important, because tortoises had a generalist diet, but the importance of plant species that were favoured requires further investigation.

Despite potential benefits of Karoo dwarf tortoise behaviour to reduce predation, the study population appears under pressure. The presence of (old) adults and hatchlings, but entire lack of juvenile stages, implies that the population is not stable, i.e. deceased adults may not be replaced by maturing juveniles. We do not know the cause of the lack of juveniles, but predation by corvids is a likely explanation (Kristan & Boarman 2003; Nagy et al. 2015; Loehr 2017; Segura et al. 2020). During every sampling period, white-necked ravens (*Corvus albicollis*) were patrolling the site daily, and pied crows (*Corvus albus*) were present occasionally. Furthermore, we discovered several Karoo dwarf tortoise carcasses that had been forcefully smashed on rocks (Fig. 12).

Preliminarily, we have to conclude that the only verified Karoo dwarf tortoise population may be disappearing. Further investigations of causes of the lack of juvenile stages in the population are needed, but may come too late for this population. Moreover, changing rainfall patterns and wildfires are favouring grass cover in parts of the Karoo dwarf tortoise range (Masubelele et al. 2014; Du Toit et al. 2015), whereas this study shows that Karoo dwarf tortoises rely on non-grasses for food. I hypothesise that historic populations, which seemed to have disappeared when surveying in 2005-2017, have

undergone similar processes as the (remote) study population is undergoing right now. Measures that could benefit Karoo dwarf tortoise populations throughout their range, awaiting further studies, are as follows:

- ❏ Reduce advantages to corvids by removing obsolete telephone poles and windmills (i.e. nesting sites), covering waste dumps (i.e. food), and avoiding causing roadkills (i.e. food).
- ❏ Manage livestock grazing responsibly, to maintain diverse and natural plant communities.
- ❏ Have a fire management plan, to prevent occurrences and spreading of wildfires.

These measures relate to residents of the Karoo. To raise awareness among residents, a poster was prepared and distributed by the Endangered Wildlife Trust in collaboration with Dwarf Tortoise Conservation and the Dutch-Belgian Turtle and Tortoise Society (Fig. 13). To detect additional subsisting Karoo dwarf tortoise populations, surveys should continue and include inspections of potential retreats due to the inactive behaviour of Karoo dwarf tortoises.

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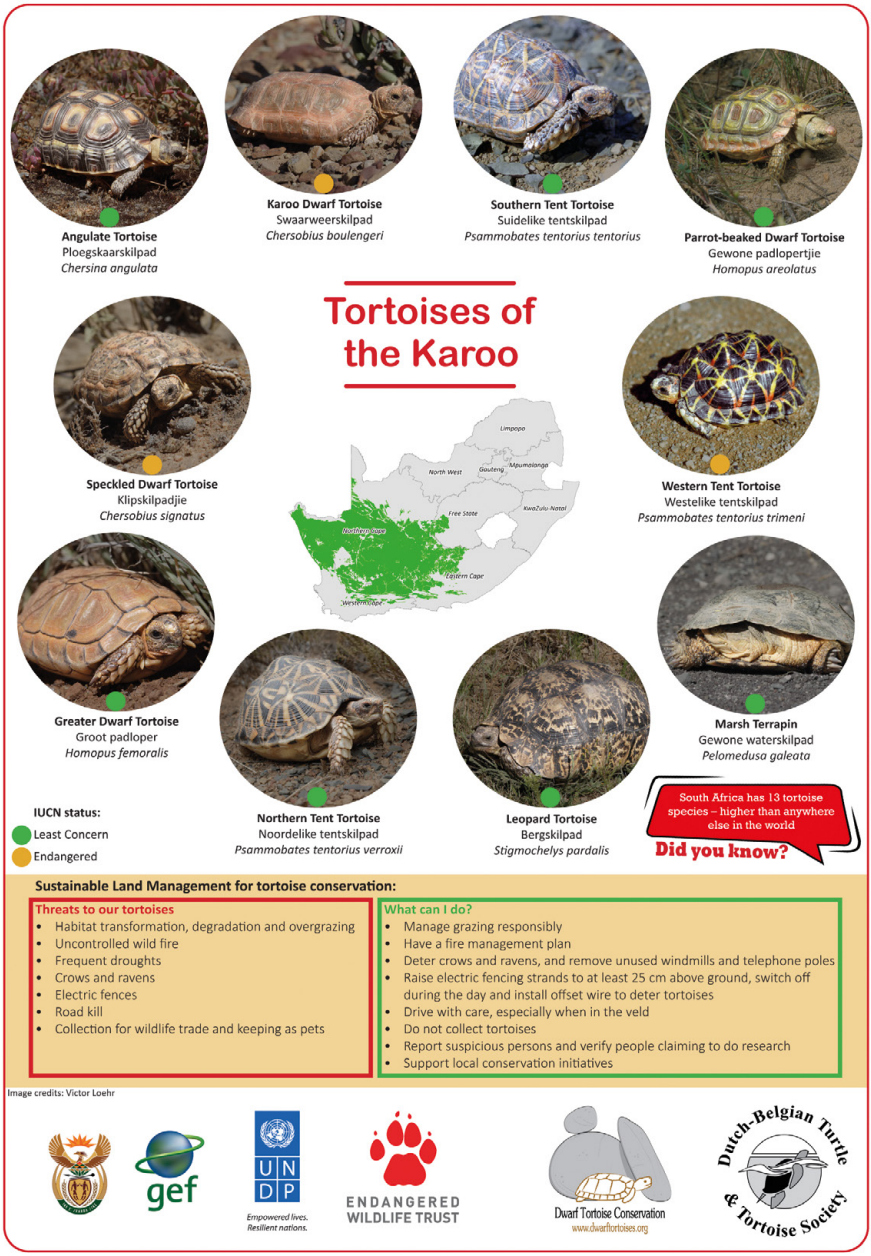

Fig. 13. Poster distributed among residents of the Karoo dwarf tortoise range, to raise awareness.

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