Speckled dwarf tortoise
Chersobius signatus

Studbook Management Plan

Version 11, January 2024

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VERSION HISTORY

Version	Date	Changes
1 (draft)	May 2008	-
2 (draft)	May 2008	Comments from genetic advisory board European Studbook Foundation implemented
	December 2011	Studbook meeting Isernhagen, Germany
3 (draft)	May 2012	Comments from South African authorities and studbook participants implemented
4 (final)	May 2012	Final review comments participants implemented
5 (final)	April 2013	Comments from South African authorities' formal review implemented
6 (draft)	February 2016	Updated after adding new founders
7 (final)	April 2016	Minor changes (no comments from South African authorities and studbook participants received)
8 (draft)	August 2018	Updated after elevation of conservation status taxon, and name change of taxon and organisation
9 (final)	September 2018	Minor changes (no comments from South African authorities and studbook participants received)
	September 2023	Studbook meeting Langenhagen, Germany
10 (draft)	December 2023	Updated after five years since last update
11 (final)	January 2024	Minor changes (no comments from studbook participants received)

This plan will be reviewed and updated once every five years, and after each supplementation of new founders or change in the IUCN conservation status of the taxon. Progress will be reported annually, in the annual reports of Dwarf Tortoise Conservation.

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1. INTRODUCTION

In 1995, four *Chersobius signatus* (then *Homopus signatus signatus*) were captured in the wild to initiate a studbook. At that time, little was known about husbandry methods and captive reproduction for this taxon. Since 1995, husbandry protocols have been developed, captive-breeding has been prosperous, and a small number of wild-caught individuals have been added to the captive population (Loehr 2015a; Loehr in press; annual reports Dwarf Tortoise Conservation (previously Homopus Research Foundation)). In 2011, the participants in the studbook, in consultation with the South African authorities, decided that the captive population should be managed and developed in such a way that it will remain suitable for future reintroductions should the need arise (i.e., conservation breeding). This aim was incorporated in a Studbook Management Plan. The current Studbook Management Plan updates draft version 10, which updates version 9 that was prepared in September 2018. The reason for the current update is the 5-yearly schedule at which the Studbook Management Plan is being revised.

In preparation for this updated Studbook Management Plan, progress made by the studbook was evaluated and a discussion paper drafted (Appendix 1). The discussion paper was used to consult all studbook participants. In addition, it was discussed with 12 studbook participants from seven countries on 9–10 September 2023 in Langenhagen, Germany. Recommendations were formulated in a meeting report (Appendix 2). All recommendations have been implemented in the current version of the Studbook Management Plan, as following:

Chapter 9: Novice keepers of *C. signatus* are provided with an information package about husbandry and breeding of *C. signatus*, and all participants have the opportunity to enrol in a WhatsApp group.

Chapter 9: An update of the Dwarf Tortoise Conservation website, including the implementation of a forum for studbook participants, was included in the action plan for 2024.

Chapter 10: The conservation breeding aim for the studbook was maintained.

Chapter 12: Additional founders will be collected and exported in smaller batches (i.e., maximum of three instead of five couples), to facilitate placement at expert keepers of *C. signatus*.

2. DISTRIBUTION

Chersobius signatus is restricted to northwestern South Africa (Branch 1998). It occurs in two provinces, the Northern Cape and the Western Cape. All records of *Chersobius* in Namibia have proven to be *Chersobius* (previously *Homopus*) *solus* (Branch 2007). *Chersobius signatus* populations show genetic differences, likely due to physical distances among populations (Fritz *et al.* 2022). Nevertheless, all populations are considered one monotypic species (Daniels *et al.* 2010; Fritz *et al.* 2022). Morphological differences among populations (Boycott, 1986) have been attributed to adaptations to local rock types (Daniels *et al.* 2010).

3. HABITAT

The habitat of *C. signatus* consists of rocky terrain in the Succulent Karoo and Fynbos biomes (Branch 1998; Boycott & Bourquin 2000). Consequently, its distribution is patchy. *Chersobius signatus* appears to favour intergrade areas between rocky hills (with few annual plants) and level areas (with abundant growth of annuals in spring; Loehr 2002b). This might relate to their diet and preference for shallow, concealed rock crevices as retreats (Loehr 2002a,b, 2006). Individual home ranges of *C. signatus* average 3,500 m^2, very small compared to home ranges of other tortoise species (Loehr 2015b).

4. PROTECTED STATUS

In its range provinces, *C. signatus* is protected fauna that may not be hunted, collected, or handled without permits from the provincial authorities. In the Northern Cape, the species is Specially Protected

according to the Northern Cape Nature Conservation Act (Act 9 of 2009) as implemented from January 2012. In the Western Cape, *C. signatus* is a Protected Wild Animal as listed in Schedule 2 of the Nature Conservation Ordinance No. 19 of 1974. This outdated Ordinance is being replaced by the Western Cape Biodiversity Act (Act 6 of 2021), under which *C. signatus* will likely be listed as Protected Species in terms of section 49(2)(e). Enforcement requires considerable capacity and budget due to the remoteness of some areas, making it difficult to patrol on a regular basis. Nevertheless, the attention to poaching by law enforcers, judges and journalists successfully contributes to the very limited presence of the species on overseas markets.

International trade of *C. signatus* is controlled through the Convention on Trade in Endangered Species (CITES). The species is listed in Appendix II, because it is not necessarily threatened with extinction, but utilisation may be incompatible with its survival. An export permit or re-export certificate (only if the specimen was imported in accordance with the convention) issued by the Management Authority of the country of export or re-export is required. An export permit may be issued only if the specimen was legally obtained and if the export will not be detrimental to the survival of the species. Furthermore, live *C. signatus* must be prepared and shipped in a way that minimises any risk of injury, damage to health or cruel treatment. Although CITES requires no import permit for species on Appendix II, it is a requirement in many national laws. Import permits in the European Union can only be issued after confirming the exporting country's non-detriment finding.

5. CONSERVATION STATUS

The conservation status of *C. signatus* in the IUCN Red List of Threatened Species is deteriorating. The species was originally placed in the category Lower Risk/Near Threatened in 1996, but this status was elevated to Vulnerable in 2013 (Baard & Hofmeyr 2017). In 2017, its status was elevated to Endangered (Hofmeyr *et al.* 2018). The population size of *C. signatus* was estimated to have been reduced at least 30–40% over the past 25–50 years due to anthropogenic land transformation and other threats. When considering past and projected future changes due to land transformation, climate change, invasive predators and poaching, the decline in population size is projected to be in excess of 50%.

6. STATUS IN CAPTIVITY

The global species information system Species365/ZIMS lists 5.5.5 (= number of males.females.juveniles) *C. signatus* at five public institutions (e.g., zoos). All institutions are located in Europe and participate in this studbook.

The studbook totals 35.33.17 live individuals; 5.5.5 at the five European Species365-institutions Amsterdam Zoo, Heidelberg Zoo, Plzen Zoo, Wroclaw Zoo and Wuppertal Zoo, 1.0.0 at Crocodile Zoo Prague, and the remaining 29.28.12 at private facilities. All studbook locations are in Europe.

Besides the animals listed here, several illegally exported *C. signatus* are present and reproduce in Europe. Similarly, illegally exported individuals may be present elsewhere. Given the small number of illegal founders, their offspring is likely to have a high level of inbreeding.

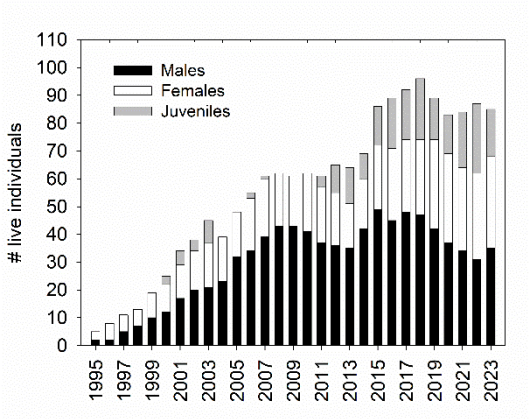

Figure 1. Numbers of live male, female and juvenile *C. signatus* in the studbook at the end of each year.

Chersobius signatus can successfully reproduce in captivity. Reproduction has succeeded at many locations (Loehr 1999b; Morgan 1993; Palmer 1994; Silva, 2021; Van Loon 2008; annual reports Dwarf Tortoise Conservation). A husbandry protocol and publications are available at the website of Dwarf Tortoise Conservation. Second- and (partial) third-generation reproduction has also been reported (Loehr 2004; annual reports Dwarf Tortoise Conservation; Table 1).

7. STUDBOOK COORDINATION AND CONTINUITY

To guarantee the continuity of the studbook, it is coordinated by two persons. Supervision of the European Studbook Foundation (ESF), a well-established private studbook organisation, gives access to a reservoir of experienced studbook coordinators. In addition, ESF provides cloud-based software for studbook management, guaranteeing access to the studbook registration in case both studbook coordinators would become unavailable. Dwarf Tortoise Conservation has also entered a formal agreement with the Dutch-Belgian Turtle and Tortoise Society, mandating the latter society to act as board of Dwarf Tortoise Conservation in case of unavailability of the Dwarf Tortoise Conservation board.

Currently, the studbook is coordinated by the following two persons:

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Mr. Martijn Kooijman (operational studbook management)
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8. PARTNERS AND STAKEHOLDERS

The studbook is a collaborative effort of Dwarf Tortoise Conservation and the European Studbook Foundation. Public facilities may participate in the studbook (Chapter 6). Forty-two private facilities in Belgium, Czech, France, Germany, Italy, Netherlands, Poland, Portugal, Sweden and UK harbour the majority of the tortoises. Any knowledgeable facilities in Europe or elsewhere interested in participation in the studbook are considered potential partners.

The primary stakeholders for the studbook are CapeNature and the Northern Cape Department of Agriculture, Environment Affairs, Rural Development and Land Reform. These South African authorities are responsible for the conservation of the taxon. The latter has provided the founder population to the studbook, and retains ownership of the studbook population as agreed in a memorandum of understanding in 2001 (e.g., making the captive population available for future reintroduction projects if necessary). Furthermore, the department is the competent authority for the issuance of permits to collect and export (CITES) *C. signatus* from the Northern Cape Province.

Further stakeholders are the land owners from where founder tortoises are collected. These may be private farmers, or municipalities. Which land owner this will concern will depend on land developments in the region, as founders are only collected on land that will likely become unsuitable as habitat for *C. signatus* (Chapter 13).

As agreed in the memorandum of understanding with the Northern Cape Province (2001), the studbook is strictly non-commercial. Therefore, commercial reptile dealers or breeders are not considered stakeholders.

9. SUITABILITY OF FACILITIES PARTICIPATING

Many of the current participants in the studbook are tortoise husbandry experts, with long-term breeding experience. Some of them also have field experience. *Chersobius signatus* is the world's smallest tortoise species and does not require large enclosures. Their subtropical arid climate is easily mimicked in indoor enclosures in temperate, warm, humid, and arid regions. *Chersobius signatus* requires a herbivorous diet consisting of readily available components. The most important factors for successful husbandry are well-structured enclosures, minimal disturbance and handling, appropriate annual temperature and photoperiodic cycle, and provision of adequate moisture for juveniles (Loehr 1999a). A husbandry protocol is available.

Nevertheless, the 1995–2022 median life expectancy of *C. signatus* in the studbook was a moderate 9.9 years (Loehr in press; Fig. 2), in part due to the absence of knowledge about captive husbandry and breeding of *C. signatus* in the early years of the studbook. The oldest live individual is more than 26 years old. Currently, novice keepers of *C. signatus* are pro-actively provided with information that helps them avoid known husbandry errors. In addition, all studbook participants have the opportunity to enrol in a WhatsApp group to improve information exchange among participants. The Dwarf Tortoise Conservation website will be expanded with an online forum for studbook participants in 2024.

Reproductive rates were lower than anticipated in previous versions of the Studbook Management Plan (Appendix 1). This was partly due to some participants assessing males and females as juveniles due to their small sizes, and subsequent solitary keeping of mature individuals. The information provided to novice keepers, the WhatsApp group, and online forum will help increase reproductive rates.

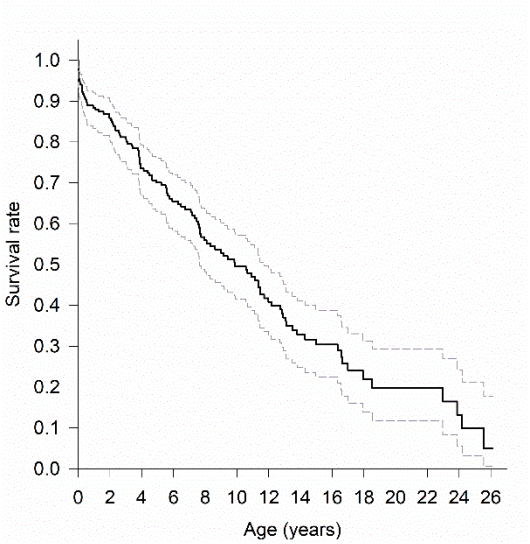

Figure 2. Survival curve with 95% confidence intervals of 217 *C. signatus* in the studbook between 1995 and 2022. Survival rates were similar between wild-caught and captive-bred individuals, and between males and females (Loehr in press).

Wild-caught individuals may require several years to fully adjust to captivity (Klerks 2002; Loehr 1999b) and are easily distressed when moved to a new enclosure. Recently captured wild-caught individuals will be housed at expert tortoise keepers, or at keepers with extensive experience keeping captive-bred *C. signatus*. Such tortoises should not be subjected to display at public facilities. A protocol for the acclimation of wild-caught *C. signatus* to captive conditions is available. Parameters that will be used by the studbook coordinators to select suitable keepers for wild-caught *C. signatus* are experience of a keeper caring for wild-caught tortoises in general, period of time keeping (captive-bred) *C. signatus*, mortality and reproduction rates, and commitment to participation in the studbook.

10. ULTIMATE GOAL FOR THE CAPTIVE POPULATION

The medium-term goal of the studbook of the past 10 years will remain in place for the next 40 years: Increasing the genetic variation of the captive population by adding new founders, and consolidating the diversity in multiple captive-bred generations (see detailed analysis in Chapter 11). The studbook encourages registration of each live *C. signatus* taken from the studbook's wild source population (e.g., legally captured, rescued, or confiscated individuals) in the studbook. Registration of all wild-caught *C. signatus* will reduce the need to collect founders specifically for the studbook population and will therefore limit pressure on the wild population.

On the longer term (40−90 years from now), the captive population should become semi-autonomous, requiring very few additions of wild-caught individuals. This would further relieve pressure on the species in the wild. The broad genetic basis established in the first 50 years after developing the goal for the studbook will ensure that the semi-autonomous captive population will remain genetically healthy.

Ultimately, this captive population should be suitable and available for reintroduction purposes should the need arise in the distant future. In tortoises, reintroducing captive individuals to the wild may be a useful conservation tool, although many factors will need to be addressed (Amavet *et al.* 2022; Bertolero *et al.* 2007; Hambler 1994; McGovern *et al.* 2020).

11. GENETIC AND DEMOGRAPHIC GOALS

11.1. Population size

Dwarf Tortoise Conservation has signed a memorandum of understanding (2001) with the South African authorities that requires that all future offspring will be registered in the studbook. For the studbook to remain manageable (i.e., containing a restricted number of facilities and tortoises), the total number of studbook participants should not exceed 200 (currently 31). This will probably limit the size of the captive population to 300−375 individuals, unless some facilities would be prepared to permanently and responsibly house a relatively large number of tortoises.

Ideally, the captive population should be housed at public and private facilities. Public facilities often have little space restrictions, whereas private facilities generally have little financial and time restrictions. Furthermore, public facilities offer an opportunity to educate the general public on the conservation of dwarf tortoises.

11.2. Number of founders

Given the maximum manageable population size (300−375 individuals), the captive population would require at least 62 founders. In this composition, the first generation (F1) would theoretically preserve approximately 99.9995% of the genetic material of the founders and retain 62 bloodlines, as each founder couple could produce approximately 12 offspring (i.e., 31 couples times 12 offspring makes 372 individuals). This number of founders is lower than advised for tortoises (i.e., 100 founders according to the ESF genetics advisory board), but a larger number would result in larger genetic losses in the first generation due to smaller numbers of F1 offspring per founder couple. Moreover, the deteriorating conservation status of *C. signatus* (Chapter 5) warrants a conservative approach regarding the number of founders removed from the wild. Increasing the generation time of subsequent generations (Paragraph 11.3) may reduce the rate of loss of genetic material, and counterbalance the relatively small number of founders.

The current number of founders in the studbook is 19, and the majority of all founders has reproduced. However, the genes of four founders were lost for the studbook, effectively leaving the studbook with 15 founders (24% of the anticipated total, Table 1).

11.3. Breeding strategy

Male and female *C. signatus* can usually be kept in couples year-round, so the studbook aims to form a population with similar numbers of males and females. An incubation protocol is available to reliably produce male and female offspring (annual reports of Dwarf Tortoise Conservation), and the current studbook population has a balanced sex ratio. Thus, each founder couple should produce 6.6 offspring (Paragraph 11.2), and each offspring couple in all subsequent generations should produce 1.1 replacement offspring. These are the offspring numbers that survive to maturity and reproduce, meaning that actual production should be larger. In particular, maximising generation time (Paragraph 11.2) implies increased losses of individuals prior to (delayed) reproduction. Considering life expectancy in the studbook population (Chapter 9), delaying reproduction to age 10 years (lower 95% confidence interval for survival rate = 0.43), as indicated in previous versions of the Studbook Management Plan, requires the production of 14.14 offspring from founder couples, and 4.4 (actually 3.3, but 4.4 simplifies develop a balanced sex ratio) offspring from offspring couples in subsequent generations.

Table 1. Production of offspring (numbers of males.females.juveniles) by founders and subsequent generations in 1995–2023, relatively to the Studbook Management Plan aims to produce 6.6 (surviving, reproducing) offspring per founder couple, and to produce 1.1 (surviving, reproducing) offspring from offspring couples in subsequent generations. Green numbers represent aims that were entirely reached, orange numbers represent aims that were not yet reached, and red numbers represent aims that will not be fully reached. Founders that died without reproducing (studbook numbers 4, 153 and 155) or without surviving offspring (studbook number 159), and two possibly inbred individuals (studbook numbers 72 and 215), have been excluded from the table.

Founder	F1 (aim: 6.6)	F2 (aim: 6 x 1.1)	F3 (aim: 6 x 1.1)
1 (dead)	6.6 (3.1 live) + 12.2.7 surplus (1.0.0 live)	6 x 1.1 (5 x 1.1 live) + 20.14.27 surplus (6.6.11 live)	0 x 1.1 + 3 x 0.0.2 + 2 x 0.0.1 (3 x 0.0.2 + 2 x 0.0.1 live) + 0.0.2 surplus (0.0.1 live)
2 (dead)	6.5 + 0.0.1 (0.1 live) + 0.0.2 surplus (0.0.0 live)	3 x 1.1 + 1 x 0.1.1 (2 x 1.1 + 0.1.1 live) + 7.6.4 surplus (2.1.2 live)	0 x 1.1 + 1 x 0.0.2 + 1 x 0.0.1 (0.0.3 live)

Founder	F1 (aim: 6.6)	F2 (aim: 6 x 1.1)	F3 (aim: 6 x 1.1)
3 (dead)	6.4 + 0.0.1 (3.0 live) + 7.0.3 surplus (0.0.0 live)	4 x 1.1 + 2 x 1.0 + 1 x 0.0.1 (3 x 1.1 + 1 x 1.0 + 1 x 0.0.1 live) + 12.10.21 surplus (3.4.7 live)	0 x 1.1 + 2 x 0.0.2 + 1 x 0.0.1 (0.0.4 live) + 0.0.3 surplus (0.0.2 live)
35 (live)	6.6 (6.6 live) + 9.7.2 surplus (1.1.0 live)	3 x 1.1 + 2 x 0.0.2 + 1 x 0.0.1 (3 x 1.1 + 1 x 0.0.2 + 3 x 0.0.1 live) + 6.8.17 surplus (2.4.7 live)	0 x 1.1 + 1 x 0.0.2 + 1 x 0.0.1 (0.0.3 live) + 0.0.3 surplus (0.0.2 live)
36 (dead)	6.6 (6.6 live) + 9.7.2 surplus (1.1.0 live)	3 x 1.1 + 2 x 0.0.2 + 2 x 0.0.1 (3 x 1.1 + 1 x 0.0.2 + 3 x 0.0.1 live) + 6.8.17 surplus (2.4.7 live)	0 x 1.1 + 1 x 0.0.2 + 1 x 0.0.1 (0.0.3 live) 0.0.3 surplus (0.0.2 live)
37 (live)	6.5 + 0.0.1 (6.3 live) + 11.0.0 surplus (2.0.0 live)	1 x 1.1 + 1 x 0.1.1 + 2 x 0.0.2 + 1 x 0.2.0 + 2 x 0.0.1 (all live except 0.2.0 is 0.1.0) + 0.1.6 surplus (0.0.3 live)	0 x 1.1
38 (dead)	6.2 + 0.0.1 (5.2 live) + 4.0.0 surplus (0.0.0 live)	1 x 1.1 + 1 x 0.1.1 + 1 x 0.0.2 + 1 x 0.2.0 + 1 x 0.0.1 (all live except 0.2.0 is 0.1.0) + 0.1.6 surplus (0.0.3 live)	0 x 1.1
60[1] (lost)	1.0 (1.0 live)	1 x 0.0.2 (1 x 0.0.1 live)	0 x 1.1
150 (live)	3.0 (2.0 live)	0 x 1.1	0 x 1.1
151 (dead)	3.1 + 0.0.1 (1.0 live)	0 x 1.1	0 x 1.1
152 (live)	0.2 + 0.0.1 (0.2.1 live)	0 x 1.1	0 x 1.1
153 (dead)	0.6 + 0.0.2 (0.5.0 live)	0 x 1.1 + 1 x 0.0.1 (1 x 0.0.1 live)	0 x 1.1
156 (live)	5.1 + 0.0.1 (3.0.0 live)	0 x 1.1	0 x 1.1
157 (live)	0.2 + 0.0.1 (0.2.1 live)	0 x 1.1	0 x 1.1
158 (dead)	0.6 + 0.0.2 (0.5.0 live)	0 x 1.1 + 1 x 0.0.1 (1 x 0.0.1 live)	0 x 1.1

[1] Founder not collected in the wild, but temporarily made available to the studbook. Hence, aims regarding offspring do not apply to this founder.

Table 1 provides an overview of reproduction in the studbook population between 1995 and 2023, relatively to the aim to produce 6.6 (surviving, reproducing) offspring from founder couples, and 1.1 (surviving, reproducing) offspring from offspring couples in subsequent generations. For seven founders, the aims were not entirely reached, resulting in slightly lower genetic variation in the studbook population than anticipated. Towards the end of the time-frame for the medium-term studbook goal (~2060; Chapter 10), it should be assessed if the population will require additional founders.

Table 2. Breeding combinations of founders (left column), and the distribution of their genetic material over subsequent generations. All numbers are studbook numbers. Capital letters indicate breeding combinations of founders producing genetically related offspring. Grey characters indicate combinations not yet available in the studbook.

Founders		(Partial) F1		(Partial) F2	
1 x 2	A	(1 x 2) x (37 x 38)	A x C	((1 x 2) x 37) x (35 x 36)	(A x 37) x B
1 x 3	A	(1 x 3) x (37 x 38)	A x C	((1 x 3) x 60) x (35 x 36)	(A x 60) x B
35 x 36	B	(1 x 2) x 37	A x 37	((1 x 2) x (37 x 38)) x 35	(A x C) x 35
37 x 38	C	(150 x 156) x (153 x 158)	D x F	((1 x 3) x (35 x 36)) x (37 x 38)	(A x B) x C
151 x 156	D	(151 x 156) x (153 x 158)	D x F	((1 x 2) x (37 x 38)) x (35 x 36)	(A x C) x B
150 x 156	D	…	E x G	…	(E x G) x (H x I)
152 x 157	E	…	H x I		
153 x 158	F			((1 x 3) x (35 x 36)) x (153 x 158)	(A x B) x F
…	G	(1 x 3) x 60[1]	A x 60[1]	…	(D x F) x (E x G)
…	H	(1 x 3) x (35 x 36)	A x B		
…	I	(35 x 36) (153 x 158)	B x F		

[1] Founder outside the studbook

To delay inbreeding, mixing of bloodlines is postponed for as long as possible (Table 2): Offspring from each specific founder couple is preferably combined with offspring from only one other specific founder couple (e.g., offspring from founder couple 1 x 3 is only combined with offspring from founder

couple 35 x 36). However, deviations from this procedure may occur when there is a risk of genetic material becoming extinct in the studbook population. For example, offspring from founder couple 1 x 3 was also combined with founder 60 that was in the studbook temporarily, and with offspring from founder couple 37 x 38 that had produced more offspring than could be combined with offspring from founder couple 1 x 2.

12. SOURCES FOR SPECIMENS INCLUDED IN THIS PLAN

The tortoises required to develop a semi-autonomous captive population in the next decades will originate from the wild. In part, these individuals may be collected specifically for the studbook, but rescued or confiscated individuals from South Africa or elsewhere would be valuable additions if they have known origins (i.e., originate from the same population as the founders in the studbook). Furthermore, third parties that might be granted collecting permits by the South African authorities could enrol in the studbook. It is important to note that the wild locality of the current founders in the studbook is increasingly disturbed and partly destroyed by anthropogenic activity. This locality will soon become unsuitable for *C. signatus*, so removal of additional tortoises here has little additional conservation impact. Founders collected in 2015 were captured under waste materials at housing construction sites (Figure 3).

Figure 3. Example of a founder *C. signatus* hiding under cardboard at a housing construction site in September 2015.

Ideally, all required founders should be added to the population simultaneously, to ensure that offspring will fall within the same age group. However, the risks involved with the simultaneous husbandry of dozens recent wild-caught *C. signatus* is not acceptable. Therefore, founders should be added in smaller batches. In 2015, five couples were added simultaneously. Their survival appeared lower than survival of previously imported founders, although most deaths were unrelated to husbandry. Nevertheless, as a precautionary measure, future batches should not be larger than three couples. Smaller batches will facilitate placement at participants with extensive experience (see also Chapter 9). The survival of founders will be carefully monitored and evaluated prior to collecting a new batch.

13. GENETIC ISSUES THAT NEED TO BE RESOLVED

There are no genetic issues that may affect the studbook, because the studbook is based on founders from a single, known locality. Genetic studies have demonstrated that *C. signatus* is a monotypic species, that is genetically different among populations (Daniels *et al.* 2010; Fritz *et al.* 2022). Consequently, development of the studbook population will be based on founders from the original locality.

14. MANAGING THE STUDBOOK

14.1. Dispersal of offspring

Currently, studbook participants that breed *C. signatus* usually recommend candidates for their offspring to the studbook coordinators. As long as transfers will benefit the studbook aims, recommendations are followed. Secondly, the studbook coordinators maintain a waiting list of facilities that have requested *C. signatus*. If facilities are suitable (e.g., have sufficient knowledge, understand and support the goals and methods of the studbook), offspring may be transferred.

The website of Dwarf Tortoise Conservation contains a procedure that needs to be followed in case anyone is interested in receiving *C. signatus* to participate in the studbook.

Important characteristics of this studbook are that all tortoises remain the formal property of the South African authorities (managed by Dwarf Tortoise Conservation), all tortoises and their offspring have to remain registered in the studbook, and no tortoises (regardless of ownership) may be used for commercial purposes. All transfers among studbook participants are loans. These conditions follow directly from the memorandum of understanding with the South African authorities (2001). To ensure compliance, all studbook participants must sign a formal agreement with Dwarf Tortoise Conservation.

14.2. Surplus

Since all future offspring needs to remain registered in the studbook, which is limited to 300–375 individuals, the studbook will not intentionally breed surplus tortoises. Each tortoise bred will have a role in forming the ultimate captive population. Therefore, it is of the utmost importance to determine which adult couple should breed how many offspring, and when. This will be a continuous process, and targets and results are presented in the annual reports and action plans of Dwarf Tortoise Conservation.

14.3. Individual identification

It is the responsibility of each studbook participant to individually recognise each tortoise. *Chersobius signatus* has a colourful shell that may be used for identification over short periods, but juvenile shells may change colour pattern rapidly (i.e., within one year, Loehr *et al.* 2006). Alternative methods to temporarily mark captive tortoises are numbered queen bee tags epoxied to the shell, nail polish dots, or writing the studbook number on the shell with a permanent marker.

When transferring a tortoise, the keeper should ensure that the receiving party is able to identify each tortoise. Permanent methods of marking are not currently used in the studbook; the body size of *C. signatus* is too small to safely use PIT tags, and notching the marginal scutes will only be useful when strictly coordinated for the studbook population as a whole.

15. REQUIREMENTS TO SUCCEED IN ESTABLISHING A LONG-TERM CAPTIVE COLONY

Table 3 summarises requirements for the establishment of a long-term captive population of *C. signatus*, along with measures intended to help meet the requirements.

Table 3. Requirements and supportive measures to obtain the aims in this studbook management plan.

Requirement	**Supportive measures**
A large number of capable and dedicated studbook participants prepared to follow the methods in this Studbook Management Plan, despite commercially available illegally imported *C. signatus* and their offspring.	Put emphasis on the fact that participation in the studbook will not merely provide personal pleasure, but is an important contribution to the taxon's conservation. Acknowledge the mutual dependence between participants and the management of the studbook.
Successful breeding (i.e., production of 28 offspring per founder couple, and 6 offspring per offspring couple).	Motivate and empower studbook participants to share experiences, and intervene when participants remain unsuccessful.
Permission from the South African authorities to collect and export additional founders in the next decades.	Involve the authorities in the development of the Studbook Management Plan, and ensure appropriate annual reporting. Practise full transparency and reliability in the reporting and communication.
Permission from the European authorities, and possibly other continents, to import wild-caught tortoises.	Practise full transparency and reliability.
Successor studbook coordinators in the next decades	Work with two coordinators to reduce work load and to facilitate personnel changes. Continue supervision by the European Studbook Foundation.

16. ACKNOWLEDGEMENTS

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Appendix 1: Discussion paper prepared in anticipation of Studbook Management Plan version 10

Appendix 2: Meeting report with recommendations for Studbook Management Plan version 10

Discussion
An evaluation of the studbook results shows that:

- there is no inbreeding in the studbook population despite 28 years of reproduction;
- average mortality is similar to mortality in the wild;
- mortality among the 5.5 founders imported in 2015 appears higher than mortality among previous imports of founders, albeit in part due to causes unrelated to captivity;
- several breeding couples are not reproducing as anticipated in the studbook management plan:
    - not all founders are producing 6.6 (surviving) F1 offspring;
    - not all F1 offspring produce a F2 generation;
- as many as nine breeding couples have matured and should have started reproduction in 2021–2023.

Consequently, founder genes are not uniformly distributed in the studbook population and the genes of several founders have gone extinct.

The meeting, and written responses on the discussion paper, made the following recommendations:

- Maintain the current conservation breeding aim for the studbook, given the deteriorating conservation status of the wild population, and solvable nature of the issues identified in the evaluation. This was a unanimous recommendation.
- If maintaining the conservation breeding aim would not be feasible (e.g., required permits), most participants preferred to downgrade the aim to a captive-conservation aim (i.e., managing the studbook to optimize genetic diversity without adding new founders).
- Reduce numbers of founders added to the captive population from 5.5 to 3.3 at a time, to enable all new founders to be acclimated and kept at participants who have been successful long-term. Relocate any possible long-term captive *C. signatus* already present at these locations.
- Lack of (sufficient) knowledge among some of the participants appears to be a central issue (e.g., participants are learning by doing, needlessly repeating mistakes that previous participants have already made). Implement the following to improve breeding results and (further) reduce mortality:
    - Prepare an information package for new studbook participants. This could include articles on husbandry and breeding of *C. signatus* that have been published in various languages, links to husbandry recommendations and annual reports with appendices that present information about husbandry and breeding, etc.
    - Facilitate horizontal information exchange among studbook participants; create a forum or app group that participants can use to discuss various issues related to husbandry and breeding. Preferably, this information should be retrievable using a search option at a later time.
    - Update the website of Dwarf Tortoise Conservation, and maintain it as the single portal for expert information about dwarf tortoises. It would be ideal if the forum or app group could be approached via this website.

These recommendations will be implemented in the update of the studbook management plan, and will be used to substantiate a permit application for additional founders.