Original Article

Unleashing the potential of local captive populations for conservation – the case study of the African spurred tortoise

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Abstract

We analysed the population characteristics of African spurred tortoises (*Centrochelys sulcata*) kept in captivity in cities in Burkina Faso (West Africa), a country where the species occurs naturally. We focused on two cities - Ouagadougou, the capital and the largest city in the country and Fada N'Gourma in the East of the country. We identified 50 households in Ouagadougou and 14 in Fada that kept spurred tortoises in captivity. We recorded a total of 310 tortoises from we took morphometric data of 281 individuals. Another 63 spurred tortoises were reported in other locations in Ouagadougou, but no access allowed by the owners. Most tortoises in Ouagadougou, were predominantly young and had an equal sex ratio. In Fada, most tortoises were adults and a practically even sex ratio. Population structure of the captive tortoises differed between cities, and about 30% of the Fada individuals were captured from the wild in the surroundings of the town. Body size of spurred tortoises in both cities differed between sexes: males were significantly heavier and had longer carapace and plastron than females. Body condition status was nearly identical in Ouagadougou and Fada. The distribution of tortoise numbers according to city sector in both cities was clumped. Tortoise owners varied in their socioeconomic background. Most tortoises are fed an omnivorous diet, but some were given a strictly herbivorous regime. Our results suggest that there is a significant potential to engage tortoise owners to use their animals in a collaborative captive breeding programme to produce hatchlings for reintroduction.

Keywords

Burkina Faso; captives for conservation; *Centrochelys sulcata*; interviews; reintroduction perspectives; Sahel; tortoise; traditional knowledge; West Africa

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1. Introduction

The African spurred tortoise (*Centrochelys sulcata*) is a species of tortoise, which inhabits the southern edge of the Sahara Desert, in the Sahel region of West and Central Africa. It is the second largest terrestrial chelonian in the world, reaching more than 100 kg in weight (Branch, 2008). This species remains threatened (Vulnerable by IUCN, 2019), and is fast declining in the wild due to habitat loss and overhunting (Vetter, 2005; Branch, 2008; Petrozzi et al., 2016, 2017a, b).

The distribution of the spurred tortoise in the wild is patchy, with remnant populations persisting at very low densities (Petrozzi et al., 2016, 2017a, b, 2018). Introduced spurred tortoise populations also thrive in non-native regions (Powell et al., 2011; Burney et al., 2012) and it has been reintroduced in a few localities within its native range where the species was recently extirpated (Garrigues and Cadi, 2011).

Spurred tortoises are easy to keep in captivity, being present in a large number of zoos and private collections worldwide (Vetter, 2005). They are also traditionally kept as pets by local communities in many towns and villages in the Sahel (Burney et al., 2012). No study has been undertaken on local captive spurred tortoise numbers, population structure and origin, or on the socio-cultural characteristics of their owners. Such animals can become an important source of animals for reintroduction to enhance its conservation in its natural range.

In this study, we analyse the population characteristics of spurred tortoises kept in captivity in Burkina Faso (West Africa), a country where the species occurs naturally (Petrozzi et al., 2016). We focus on two cities - Ouagadougou, the capital and the largest city in the country (> 2.5 million people), and Fada N'Gourma (hereafter Fada), a remote city in a savannah area where spurred tortoises still occur in the wild. We also explore whether these captive-held tortoises can be used to improve the conservation of these threatened chelonians in Burkina Faso, and more widely throughout the West African Sahel.

2. Study Areas

Ouagadougou, located in the Kadiogo Province in central Burkina Faso (12°21'58" N; 1°32'01' 'W), has a population of around 2.5 million inhabitants (Sources: INSD). The city spreads over 280,500 ha and is divided into 55 sectors within 12 districts. The northern part of the city is urbanised, but rural communes are found along the East (Pabré and Loumbila), South (Koubri and Komsilga) and West (Tanghin Dassouri).

Fada (13°7' 11°55' N; 0°7' W 1°25' E) is a city (3,400.2 km²) and an important market town in eastern Burkina Faso, in the Gourma province. Fada is 220 km East of Ouagadougou, has 11 city sectors, and a population of 41,785 inhabitants (RGPH, 2006, The Eastern Region in Figures / INSD, Dec. 2016). It is both the capital of the region and the province, reflecting its importance at the national level. The landscape around Fada is part of a vast flat plain, reaching around 200 m in elevation.

The climate of Burkina Faso is characterized by a dry season from November to May (with a cool, dry period, from November to February, and a warm period from March to May), and a rainy season from June to October (but with most rains being concentrated in August and September). The average temperature is 15 ° C at night, and 30 ° C during the day, except during the dry season when temperatures can rise to more than 38 ° C.

The natural vegetation within the two study areas is mainly wooded savannah and shrub savannah. In areas where anthropogenic pressures are more intense, the vegetation is severely degraded. The more common tree species are *Parkia biglobosa, Butysrospermum parkii, Anogeissus leiocarpus, Diospyros mespiliformis, Terminalia macroptera, Terminalia laxiflora*, etc.

3. Methods

3.1. The study species

In African spurred tortoises, sexual maturity is reached at about 35-50 cm carapace length and at 15-20 kg weight, that corresponds to about 10-12 years in females and 13-15 years in males (Vetter, 2005). Life expectancy in the wild is unknown, but in captivity it is at least 54 years(Biegler, 1966) and is estimated to exceed 75 years (Walls, 1997). For example, what is the longevity of

the species in captivity and the wild? What is the age at sexual

maturity? What were the criteria for assigning sampled individuals to

adult, subadult and juvenile stage classes? What do the authors mean

by "young" tortoises

3.2 Survey protocols

We conducted our field work over a period of seven months (January - July 2019). Meetings were first held with the heads of the local technical services (Environment, Livestock, etc.) before interviewing resource persons (traditional chiefs, traditional pharmaceutical sellers, etc.), high school and college students, and local community support individuals. By using Respondent-Driven Sampling (RDS) or snowball sampling (Heckathorn, 1997, 2002, Volz and Heckathorn, 2008), we were able to determine the whereabouts of a large number of tortoise owners in the two cities based on information gathered from our initial interviews.

In the presence of the owner, we collected morphometric data of each tortoise observed. This included: (i) curved carapace length; (ii) straight-line carapace length (in both cases measured from the anterior end of the breastplate, at the level of the intergular scales, to the tip of the supracaudal scales); (iii) plastron length and (iv) weight (kgs). Each individual was also sexed, based on external features. We also described the conditions in which the animals were kept (type of habitat, food, etc.). Tortoises were considered as juveniles (< 5 kg weight), subadults (5.1-15 kg weight) and adults (>15 kg weight). All surveys took place during the day.

We also gathered data on the social-cultural background of tortoise owners using a semi-directive interview method (Blanchet and Gotman 1992). Local scientists applied all interviews in the local language. Interviewed persons were informed of the aims of the project beforehand and were asked for their verbal consent before proceeding. No minors (<18 years) were approached. All interviews followed the ethical recommendations of the British Sociological Association.

3.3 Statistical analyses

For each tortoise, we assessed its body condition status by using the Donoghe's equation (Guillon, 2010) to calculate the theoretical weight of the tortoise and determine if the reptile was over- or underweight:

$$\text{Theoretical weight (in grams)} = 0.191 \times \text{straight carapace length (cm)}^3$$

Using this formula, we determined whether the weight of each observed tortoise was significantly different to the normal weight curve of the species i.e. the Body Condition Status (BCS):

$$\text{BCS} = \text{Theoretical weight} - \text{observed weight}$$

The actual weight of the animal should ideally be between 90% and 110% of the theoretical weight (Guillon, 2010). The formula is the same for all turtle species.

We used the Blackman's (1935) index to assess whether the distribution of tortoise owners was clumped or random by city sector in the two cities. Observed-versus-expected χ^2 tests were used to evaluate: (i) whether adult sex-ratio was even or not in each study area and overall; (ii) if there were frequency differences between the two study areas in terms of population structure (frequencies of adults, subadults and juveniles); (iii) if there were frequency differences among the type of feeding (herbivorous versus omnivorous) that was given to the tortoises by their owners. Pearson's χ^2 test was used for testing associations between sex of the owners and his/her declared reasons for keeping tortoises in captivity. Student t-tests were used to assess the intersexual differences in mean carapace length, plastron length, and weight. In order to test for the differences between Ouagadougou and Fada in terms of the slopes of the general regression between carapace length and weight in both sexes and in the juveniles, we used a heterogeneity of slopes test (Analysis of Covariance). Differences in body condition status medians (Guillon, 2010) of individual tortoises by owner's profession were tested using a Kruskal-Wallis ANOVA (data from the two cities being pooled due to small sample size). Student t-test was used to compare means of BCS of tortoises in Ouagadougou versus Fada. Means are presented ± 1 Standard Deviation.

4. Results

4.1 Population structure of captive African spurred tortoises

Overall, we identified 50 households in Ouagadougou and 14 households in Fada that kept spurred tortoises in captivity (Plate 1); all tortoise owners agreed to respond to our queries in both cities. We identified a total of 310 tortoises (77 females, 89 males and 144 immatures), but morphometric data were only taken for 281 individuals (75 males, 85 females and 121 immatures). We also observed one Bell's Hingeback Tortoise (*Kinixys nogueyi*) male in captivity. The presence of additional spurred tortoises was reported in other locations in Ouagadougou (n = 63 individuals), but no access allowed by the owners.

In Ouagadougou, the identified tortoise population (n = 230) was predominantly young (60% of the observed individuals), followed by adults (29%), and sub-adults (11%) (Figure 1). The sex-ratio was skewed towards

males (1.3:1), but the difference was not statistically significant (χ^2 = 0.97, df = 1, P = 0.324). In Fada, the captive tortoise population was predominantly made up of adults (53%) and sub-adults (31%) and less by juveniles (16%) (Figure 1). The adult sex ratio was 0.93 (13 males: 14 females), i.e. practically even. There were significant differences between the two cities in population structure of the captive tortoises (= frequencies of adults, subadults and juveniles) (χ^2 = 42.0, df = 2, P < 0.0001), but not in their sex ratio, male: female 1.16: 1 (χ^2 = 0.53, df = 1, P = 0.533). Overall, the proportion of juveniles was highest, followed by adults and then subadults (Figure 1).

Body size of spurred tortoises for both cities differed between sexes: males were significantly heavier and had longer carapace and plastron than females (P < 0.001 at Student t-test; Figures S1 and S2). There were no differences between the two cities in the regression slopes between carapace length and weight in both sexes and in juveniles (ANCOVA, P > 0.15). The correlation between carapace length and weight is given in Figure S3; it showed that large adults tended to be underweight compared to the theoretical optimal body condition. In addition, the body condition status was nearly identical in Ouagadougou (BCS = -1.55 ± 3.79) and Fada (BCS = - 1.51 ± 1.74) (Student t-test, t = -0.072, P = 0.943).

4.2 Distribution of tortoises by city sectors

The distribution of tortoise numbers according to city sector in both cities was uneven (Figure S4): in Ouagadougou, sector 42 had as many as 85 tortoises, with several sectors not containing any tortoise (Figure S4). In Ouagadougou, tortoises were found in 22 out of 55 sectors of the city. Most tortoise holders held a low number of tortoises: 44 holders with 1-5 tortoises, with only six holders with more than five animals (Figure S5). In Fada, sector 1 had the largest number of individual tortoises (n = 27), with some sectors without any (Figure S5). Overall, tortoises were found across 7 out of 11 city sectors. The Blackman index (BIOuagadougou = 44.92 > 1 and BIFada = 13.69 > 1) indicated that animals were clumped in both cities. Assuming that the number of captive tortoises observed in the surveyed sectors is representative of the whole city, we estimated a total range of 585-850 tortoises in Ouagadougou and 102-178 in Fada. Thus, the number of tortoise per person was much higher in Fada (approximately 0.0046 tortoise per person) than in Ouagadougou (approximately 0.0004 tortoises per person).

4.3 Origin of tortoises

According to interviewees, most tortoises in Ouagadougou were captive-bred or had been bought/obtained from abroad (reportedly mainly from Mali). However, there were several wild-caught individuals from other sites in Burkina Faso: 17 individuals from Fada, 5 from Pama, 1 from Ziniaré, and 1 from Loumbila. In Fada, by contrast, 29.4% of the tortoises were either wild caught in the adjacent savannah habitats or had been born from wild specimens captured in the same area. The frequency of individuals that were wild caught in Burkina Faso differed significantly between Ouagadougou and Fada ($\chi 2$ test, with df = 1, $P < 0.001$).

4.4 Owner characteristics and captive care

During our study, we conducted 51 interviews with tortoise owners; 37 in Ouagadougou and 14 in Fada. Interviewees belonged to different professions with very different annual incomes, including high incomes (e.g. medical doctors) or very low incomes (e.g., volunteers) (Figure 2). Most tortoise owners (94.7%) were men; 77.2% of the owners answered that it is out of "love for tortoises" that they keep these animals, with 16.0% declaring that they kept tortoises for cultural/traditional/religious reasons; only 6.8% of interviewees said they kept tortoises to sell them and make a profit. Overall, a Pearson's χ^2 test showed that there was a significant association between sex (= male) and reason for tortoise keeping (= love for these animals) (Pearson's $\chi^2 = 85.06$, df = 82, $P < 0.05$).

Kruskal-Wallis ANOVAs showed that the body condition status of tortoises varied significantly relative to the profession of their owners and with the declared reasons for keeping the animals (in both models, $P < 0.05$). Mann-Whitney pair-wise tests revealed that tortoise weight was significantly ($P = 0.012$) and negatively (MW = -18.875) correlated with whether the owner was retired, and significantly ($P = 0.044$) and positively (MW = 52.054) correlated with the reason "love for tortoises".

As many as 54.1% of the observed tortoises (n = 281) were fed an omnivorous diet (i.e. the owners gave fed the animals with almost everything they themselves ate), and 45.9% of animals were given a strictly herbivorous regime ($\chi^2 = 1.88$, df = 1, $P = 0.170$).

5. Discussion

Although it has been known that tortoises are often kept in houses throughout the Sahel region (Vetter, 2005; Burney et al., 2012), our study is the first to show that large numbers of African spurred tortoises are found in many households in two sampled cities in Burkina Faso.

We show clearly that in Ouagadougou most tortoises found were juveniles, whereas in Fada most were adults. This difference may point to a higher recruitment rate in Ouagadougou than in Fada (though the body size distribution and body condition status of adults did not differ significantly between cities). This can be explained by a combination of factors, including the fact that many young tortoises die before reaching the subadult age due to suboptimal keeping conditions (owners' personal communications). However, the lower recruitment rate in Fada may have been due to the fact that most individuals may have been wild caught, given that the species occurs naturally in the savannahs and bushlands of this area. In contrast, since the species is no longer found around Ouagadougou most tortoises here may have been captive born. Wild tortoises reproduce less frequently than captive-born individuals.

In both cities, the tortoise population showed a clumped distribution. This may be the result of fashion or contamination effect related to neighbourhood or kinship of the various owners. The spatial distribution of tortoises in Ouagadougou and Fada was not related to the means of the holder (i.e. not a luxury) nor was it affected by a residential effect linked to the owners' income. The keeping of spurred tortoises was not related to the profession of the holders, given that over 45% of the holders were pensioners whereas only about 15% of holders were persons who worked in the environment and nature conservation. Instead, we clearly showed that the main reason for owning a tortoise was cultural and, much more frequently, a "love and personal passion" for these reptiles (as confirmed by 77.2% of the interviewees). Since most of the interviewed persons that keep tortoises do it for love and only a very few are interested in selling the animals, convincing tortoise owners to contribute to urgently needed conservation actions for the species could be relatively simple. Indeed, most interviewees showed much interest in this topic when we raised this issue with them. Thus, we are persuaded that there is a significant potential to engage tortoise owners in Fada to use their animals in a collaborative captive breeding programme to produce hatchlings for reintroduction especially in eastern

Burkina Faso where these tortoises have been extirpated. From studies on the preferred habitat of this species (e.g., Petrozzi et al., 2016, 2017a, b, 2018, 2019), it would be possible to select suitable reintroduction sites within preferred habitats for the species. The reintroduction of African spurred tortoises in certain habitats may also encourage the proliferation of various savannah plants which depend on tortoises for their seed dispersal, as shown for closely related species (Milton, 1992; Strong and Fragoso, 2006; Stevenson and Guzmán, 2008) and even for conspecifics introduced in non-native habitats (Burney et al., 2012).

Author contributions Study design: EMH, FP, LL; data collection and fieldwork: LA, SK, DS, BGK; data analysis: LL, JEF; paper first drafting: LL, JEF; paper editing and reviewing: EMH, DS, BGK, FP.

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Conflicts of interest None.

Ethical standards This research complied with the ethical guidelines developed by the British Sociological Association.

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290 FIGURE 1. African spurred tortoises observed in captivity in Burkina Faso.

FIGURE 2. Population structure of African spurred tortoises, by site and by sex, in the two surveyed sites in

295 Burkina Faso. The overall sample is also presented in this figure.

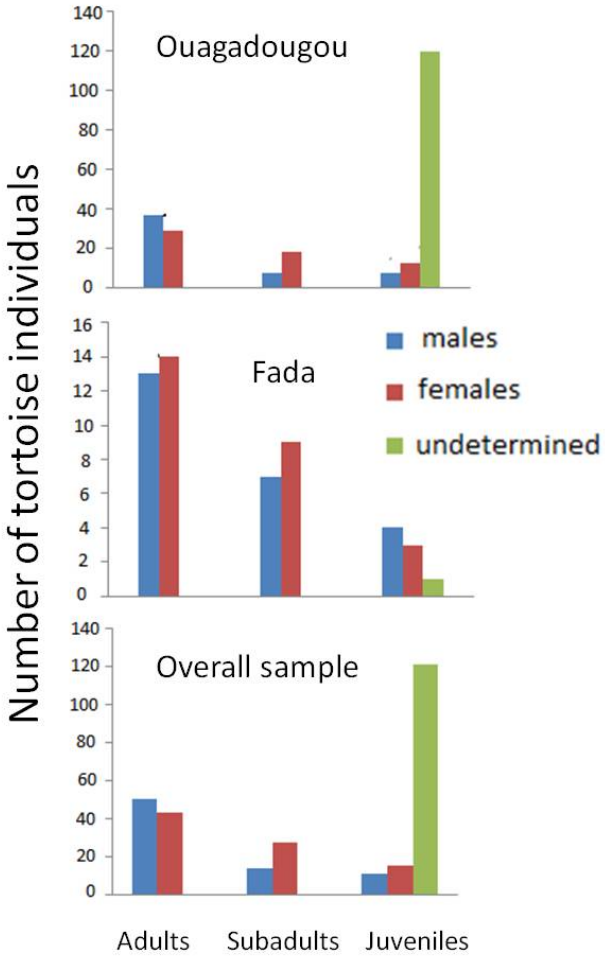
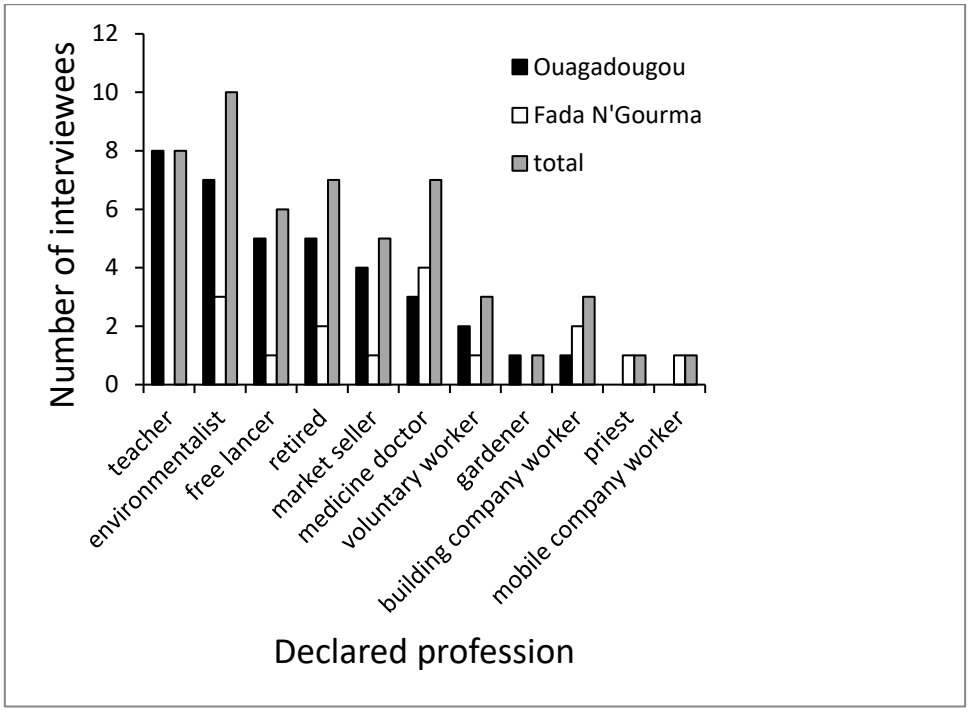


FIGURE 3. Frequency distribution of the various declared professions of tortoise owners by city in Burkina Faso.



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