SHORT NOTE

Population study of *Pyxis arachnoides brygooi* (Vuillemin & Domergue, 1972) in the area surrounding the *Village des Tortues*, Ifaty-Mangily, southwest Madagascar

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ABSTRACT
The Madagascar spider tortoise (*Pyxis arachnoides* spp.) is faced with the threat of habitat destruction as well as the international pet trade. Habitat requirements and population structure of this species are largely unknown. Detailed studies have so far concentrated on the subspecies *Pyxis arachnoides arachnoides*. The present study surveyed a population of the western subspecies *Pyxis arachnoides brygooi* during the wet season from February to April 2008. The survey was carried out in the forest of Ifaty-Mangily, 20 km north of Toliara, and supported by a local tortoise centre, the *Village des Tortues*. Population densities were estimated from transect counts and plot surveys; they range from 0.33 to 1.72 animals per hectare. Both sexes were evenly represented in the field during the research period. Three individuals of the subspecies *Pyxis arachnoides arachnoides* were detected during this field survey. Their presence might be due to a transitional zone of both subspecies in the area of research.

RÉSUMÉ
La tortue araignée de Madagascar, *Pyxis arachnoides* spp. est menacée par la destruction de son habitat naturel et par les collectes illicites de spécimens destinés au commerce. Les besoins écologiques et la structure de la population naturelle de cette espèce sont encore peu connus. Jusqu'à présent, la plupart des études effectuées se sont concentrées sur la sous-espèce nominative *Pyxis arachnoides arachnoides*. La présente étude a été réalisée dans la partie sud-ouest de Madagascar, dans la forêt d'Ifaty-Mangily, à 20 kilomètres au nord de Toliara pendant la saison humide, entre février et avril 2008 sur une population de *Pyxis arachnoides brygooi*. Les travaux sur le terrain ont été effectués en coopération avec le « Village des Tortues » qui est un centre d'élevage et de sauvegarde des tortues confisquées par les autorités malgaches. La densité de la population étudiée sur le terrain varie de 0,33 à 1,72 individus par hectare ; cette estimation a été faite en se basant sur le suivi par transects et de parcelles d'une superficie d'un hectare. Le sexe ratio de ces tortues était équilibré au cours de la période d'étude. Les tortues ayant une longueur de carapace inférieure à 90 mm ont été classées en tant que juvéniles ou sub-adultes dans la mesure où ces individus ont été difficiles à sexer. La taille des individus recensés pendant cette étude varie de 37 à 122 millimètres et les femelles étaient en moyenne plus lourdes que les mâles. La présence des trois individus de *Pyxis arachnoides arachnoides* recensés dans la zone de recherche pourrait résulter d'une zone de transition entre les différentes sous-espèces.

KEYWORDS: *Pyxis arachnoides*, Madagascar spider tortoise, population density.
MOTS CLEFS : *Pyxis arachnoides*, Tortue araignée, Madagascar, densité de population.

INTRODUCTION
The Madagascar spider tortoise, *Pyxis arachnoides*, is one of the smallest and least studied of the five tortoise species found in Madagascar (Pedrono and Smith 2003, Pedrono 2008). This species is confronted by serious threats, such as hunting for food and collection for exotic pet markets (Behler 2002), population fragmentation (Durrell et al. 1989), and ongoing habitat destruction (Durrell et al. 1989, Seddon et al. 2000). At present the Madagascar spider tortoise is listed as Critically Endangered on the IUCN red list (IUCN 2011).

Pyxis arachnoides is divided into three subspecies that are separated from each other geographically (see Figure 1), predominantly by large rivers (Pedrono 2008). The subspecies are distinguished by differences in the mobility of their plastral hinge and variations in plastral colouration. The hinge of *P. a. oblonga* shows good mobility, in *P. a. arachnoides* the hinge is still flexible, whilst the western subspecies *P. a. brygooi* displays a pastron hinge somewhat more rigid (Durrell et al. 1989, Jesu and Schimmenti 1995, Pedrono and Smith 2003).

Detailed information on habitat requirements, population characteristics and the influence of human impact on *Pyxis arachnoides* is still lacking. A recent investigation in the area of Anakao, southwestern Madagascar, estimated densities of *P. a. arachnoides* to be between 2.08 and 4.63 animals per

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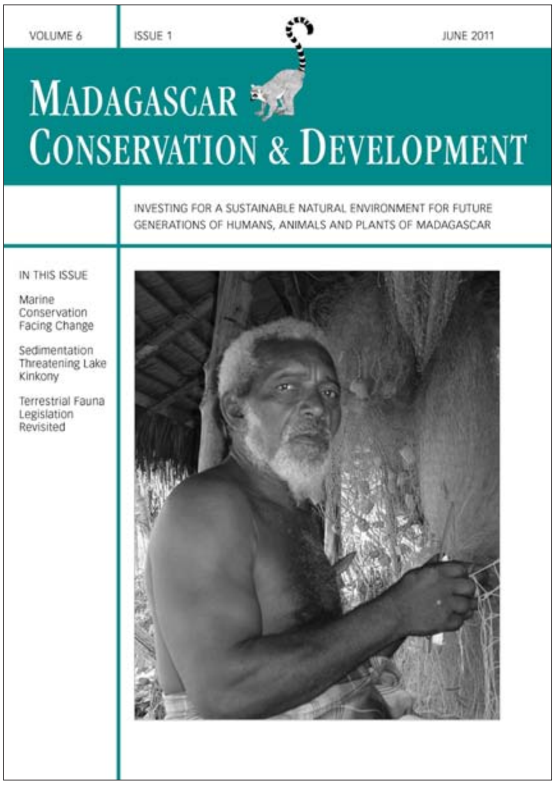

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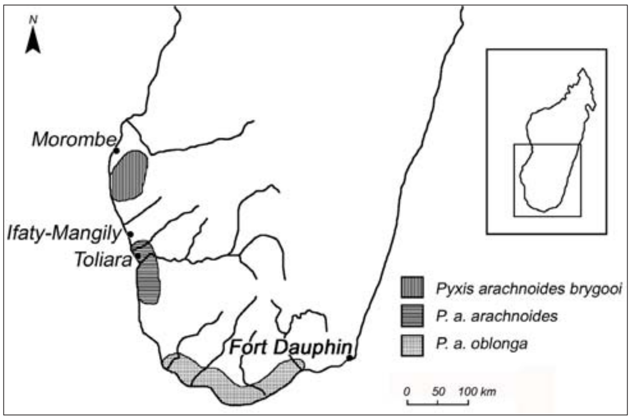

FIGURE 1. Distribution of *Pyxis arachnoides* spp. in southwestern Madagascar, modified from Pedrono and Smith (2003), showing the geographical distribution of the three subspecies. The study area lies about 27 km north of Toliara between the core ranges of *P.a. brygooi* and *P. a. arachnoides*.

hectare (Walker et al. 2008). Another study carried out some ten years earlier in the same area estimated tortoise densities to be greater than three animals per hectare (Jesu and Schimmenti 1995). A recent survey of *P. a. brygooi* revealed a decline in its range by nearly 80 % (Walker 2010).

In view of the demand to provide detailed up-to-date information, data are presented from a population of the western subspecies *P. a. brygooi* and the applicability of two different methods (transect and plot) is compared in order to establish the most effective population assessment.

METHODS

This survey was carried out during the wet season from February to April 2008. The research took place in the forest of Ifaty-Mangily, which is situated 20 km north of Toliara (Figure 1). The tortoise rescue centre, *Village des Tortues*, was used as the base camp for this study. Prior to the field research an introduction in tortoise handling and identification of *Pyxis a.* spp. was carried out in the afore-mentioned tortoise centre, where all three subspecies are held in enclosures.

In order to detect tortoise densities in the dry deciduous forest, three parallel transects were installed along existing pathways. These are referred to as Transect 1-3 (T1, T2 and T3). Geographical positioning of all transects was recorded with a GPS device. The transects had lengths of 580 m, 765 m and 950 m respectively, and were patrolled by foot from 22 February to 15 March and on 10 and 11 April 2008 between the hours of 08:00-12:00 and 15:00-18:00. One researcher was moving along each transect at a mean speed of 0.5 km / h. The transect coordinates are presented in the supplementary material. The perpendicular distance between each animal and the transect line was recorded upon every sighting, along with basic morphometric data. A mean visibility of three metres was estimated for density calculations along the transects, and the size of the area observed was calculated as: transect length x 2 x mean visibility = observed area. Tortoise densities were then estimated as mean number of animals per hectare.

For additional density comparisons, four one-hectare square survey plots (referred to as Q1, Q2, Q3 and Q4) were installed and surveyed six times respectively. Both transect and plot surveys are methods common in tortoise research (Leuteritz et al. 2005, Walker et al. 2008, Hammer and Ramilijaona 2009, Walker 2010). The plots were installed neighbouring the transects at a distance of 20 to 200 metres. The installation of the plots was performed by using a GPS device to ensure accurate mapping of the researched area. The plots were marked by coloured flagging tape at distances of five meters along the borders and assistants from a nearby village were employed to perform detailed searches. For each plot survey ten helpers were required. The observers were spaced at a distance of 10 m from each other in the field. Tortoise densities on the survey plots were calculated as the mean number of animals observed per hectare.

The tortoise data collected upon detection include straight carapace length and body mass measurements, using a sliding ruler and digital balance respectively. Sexual classification was based on the animals' tail lengths, with those of the male specimens being thicker and longer than the females' (Jesu and Schimmenti 1995). The tail of male specimens also ends in a spine-like terminal scale (Pedrono and Smith 2003). All animals whose carapace measured below 90 mm were classified as juveniles or subadults and were not sexed due to their size. External morphological characteristics, as described by Jesu and Schimmenti (1995), appeared to be less developed in smaller individuals. All tortoises studied within this survey were permanently marked by notching the marginal scutes using a saw blade. A numerical code was used for marking the animals to ensure individual and permanent identification and was generated in the order of detection. During the survey it was established that three animals belonged to the subspecies *Pyxis a. arachnoides* based on their characteristic plastron hinge (Pedrono and Smith 2003). The data collected from these three individuals were not used in population density estimations or population characterisation.

The description of the tortoises' size and body mass distribution was performed in SPSS 13.0. To examine for sex-dependent differences in body mass a linear regression was performed, using sex as an independent variable and body size as an independent continuous variable. The residuals were subsequently tested for differences using the Mann-Whitney U-Test.

RESULTS

A total of 55 individuals of *Pyxis arachnoides* were recorded during the survey (Table 1). The animals were identified as 52 individuals of *P. a. brygooi* and three individuals of *P. a. arachnoides.*

During transect and plot surveys 39 *Pyxis arachnoides* were detected, of which two individuals were classified as subspecies *P. a. arachnoides*. Another 16 tortoises were detected outside regular counts, including one individual of *P. a. arachnoides*. The data from all *P. a. brygooi* were used in the population structure analysis, whereas the density analysis was only performed with the data from tortoises detected during standardised searches. Recaptures did not occur within this study. Population densities of *P. a. brygooi* were calculated from tortoise counts presented in Table 1.

TRANSECT SURVEYS: In total 17 *Pyxis arachnoides brygooi* were detected within the transect surveys. Population densities of 2.9 (T1), 2.2 (T2) and 1.5 (T3) animals per hectare were calculated from the transect counts. The mean density from transect counts is therefore estimated as 2.2 tortoises per hectare.

TABLE 1. Tortoise counts of *Pyxis arachnoides brygooi* and *P. a. arachnoides* and densities of *P. a. brygooi* at the survey sites. M = male, F = female and J = juvenile. Animals too small to be sexed were classified as juveniles. * for *Pyxis arachnoides brygooi* only

Survey Site	Transect length / plot size	Number of tortoises		Density* (individuals per ha)
		P. a. brygooi	*P. a. arachnoides*	
Transect 1 (T1)	580 m	0 M / 1 F / 2 J		2.87
Transect 2 (T2)	765 m	2 M / 2 F/ 3 J	1 M / 0 F / 1 J	2.18
Transect 3 (T3)	950 m	0 M / 2 F / 5 J		1.54
All Transects		2 M / 5 F / 10 J		2.09
Plot 1	1 ha	3 M / 2 F / 1 J		1.00
Plot 2	1 ha	1 M / 1 F / 0 J		0.33
Plot 3	1 ha	2 M /0 F / 3 J		0.83
Plot 4	1 ha	4 M / 2 F / 1 J		1.17
All Plots		10 M / 5 F / 5 J		0.83
Tortoises outside transect/ plot surveys		4 M / 6 F / 5 J	1 F	
Totals		16 M / 16 F / 20 J	1 M / 1 F / 1 J	
		= 52 individuals	= 3 individuals	

PLOT SURVEYS: The plot surveys revealed a further 20 tortoises. The population density estimations obtained with this method were 1 (Q1), 0.3 (Q2), 0.8 (Q3) and 1.2 (Q4) animals per hectare when considering each plot individually. Population density estimates for all plots combined resulted in a density of 0.83 tortoises per hectare.

POPULATION STRUCTURE: During this study 16 males and 16 female tortoises *P. a brygooi* were detected, as well as 20 juveniles. The carapace length of juvenile tortoises was 69.5 mm ± 17.5 mm with a range of 37-89 mm. The mean carapace length of adult tortoises was 109.4 mm ± 8.9 mm, ranging from 91-122 mm for female specimens and 106.6 mm ± 7.1 mm with a range of 94-117 mm for male tortoises. The mean body mass of juvenile tortoises was 90.4 g ± 48.4 g, ranging from 15-150 g. The mean body mass of adult females was 271.8g ± 51.7g with a range of 172-365 g. Adult male tortoises showed a mean body mass of 234.0 g ± 58.6g, ranging from 122-350 g. The linear regression analysis of body size and weight revealed females to be significantly heavier than males (Mann-Whitney U-Test, $z = -2.19$, $p = 0.029$, $n = 32$).

DISCUSSION

At present all endemic Malagasy tortoise species are listed as Critically Endangered in the IUCN Red List (IUCN 2011). Walker (2010) points out that *Pyxis arachnoides* can only be found in reasonably intact habitats. Therefore, ongoing habitat destruction (Seddon et al. 2000, Ganzhorn et al. 2001) is a severe threat to the tortoise's survival as well as the illegal pet trade (Behler 2002). The range of the subspecies *P. a. brygooi* would seem to be very limited and no protected area appears to have been established in its range to date (Pedrono 2008).

Despite expectations to find only the subspecies *Pyxis arachnoides brygooi* in the study area (Durrell et al. 1989, Jesu and Schimmenti 1995), three individuals of *P. a. arachnoides* were detected within this survey. Subspecies of *P. arachnoides* are easily distinguishable as a result of the mobility of their plastron hinge, making a false identification unlikely. Our study area was situated between the core range areas of *P. a. brygooi* and *P.a. arachnoides*, previously defined as a transitional zone for these two subspecies (Walker 2010). Detailed studies on the subspecies' occurrence and distribution in this region should be carried out to provide further insight.

During this research period an even sex ratio of *Pyxis a. brygooi* was detected in the study area. While Walker et al. (2007) observed a greater abundance of female tortoises *Pyxis a. arachnoides* in the area of Anakao (a majority of 57 % during the wet season), Jesu and Schimmenti (1995) ascertained a ratio close to 1:1 in the same location.

Jesu and Schimmenti (1995) found female *Pyxis a. arachnoides* to be larger on average than males. Although the largest animal found in the present study was a female of 122 mm, no statistical difference in the carapace length of male and female tortoises *P. arachnoides brygooi* was observed. Even so, the body mass of female tortoises was documented to be significantly higher than that of their male counterparts within this study.

The most recent survey suggests that tortoise densities of *Pyxis a. arachnoides* range from 2.08 to 4.63 animals per hectare in the dry or wet season respectively (Walker et al. 2008). Tortoise densities are supposed to be greater than three animals per hectare according to Jesu and Schimmenti (1995). Density estimates in this study are lower. However, transect counts in this study still revealed a mean tortoise density of 2.2 animals per hectare, whereas the mean tortoise density from plot counts was estimated to be 0.83 animals per hectare. This survey was carried out from February to early April 2008 during the wet season when the greatest amount of tortoise activity can be expected (Pedrono and Smith 2003, Walker et al. 2008). There were, however, no tortoise recaptures during the field survey and, as a result, a mark-recapture examination could not be performed with the data that were recorded. Tortoises of the genus *Pyxis* are known to bury themselves in sandy substrate during the dry season (Jesu and Schimmenti 1995, Walker et al. 2008) and might even do so during the wet season due to the unpredictable weather conditions in this region (Gould et al. 1999, Dewar and Richard 2007). Consequently, the tortoise densities estimated within this study may be based on only one part of the population, namely those specimens that were active during the research period.

The suitability for rapid field surveys and the applicability of both the methods carried out within this study varies greatly. Transect surveys offer an easy means to estimate tortoise population densities if existing pathways can be used for the study. Animals studied in transect counts should be fixed at initial sighting position, they should not move before detection and not be counted twice (Krebs 1998). Considering these simple assumptions, tortoises appear well suited to transect studies. Moving slowly, they do not leave their sighting positions and they can easily be caught for further examination. Double counts do not occur as tortoises usually do not overtake the researcher. However, this method lacks some accuracy as inactive animals are unlikely to be found in transect counts. Hardly any animal will sleep at the side of a path, especially if it is used regularly by local people. If a lot of people pass by during a transect count, the resulting figures might be biased due to the animals being scared away. Still, this method offers a good opportunity to study tortoise populations for single researchers.

Plot counts are performed under the assumption that all animals in the selected area have been detected. This method, therefore, directly reflects population densities per area. Nevertheless, the animals' activity levels still influence density estimations as inactive tortoises *Pyxis arachnoides* spp. tend to keep out of sight by burying themselves in the sand (Jesu and Schimmenti 1995, Walker et al. 2008). Performing plot counts requires a group of assistants that are trained in locating tortoises. Since the study area was in close proximity to the village of Ifaty-Mangily there was no difficulty in finding assistants to help. In general, the plot count method seems to be the more accurate when it comes to studying animals that have a small home range. However, as a result of *Pyxis arachnoides* spp. concealing itself during periods of inactivity, the actual total number of tortoises might not be located during plot searches and this method, therefore, also lacks some accuracy.

In the area of Anakao, Jesu and Schimmenti (1995) note that there is a lack of predators, apart from bush pigs, that could reduce tortoise densities. Pigs are assumed to go for either eggs or juvenile specimens (Jesu and Schimmenti 1995). However, the forest around Ifaty-Mangily and the region to its south are clearly influenced by tourism, where forests are heavily exploited for construction material and charcoal production (Du Puy and Moat 1998, Seddon et al. 2000). In contrast to Walker et al. (2007) no empty shells were detected in the forest and no tortoise exploitation was observed during the research period.

CONCLUSIONS

This research contributes to the limited knowledge of the Malagasy tortoise species *Pyxis arachnoides* spp., whose survival in the wild is currently threatened. The presence of a transitional zone for the subspecies *P. a. brygooi* and *P. a. arachnoides* in the southwest of Madagascar has been acknowledged and further studies of this population are recommended. Despite low tortoise densities being detected within this study, a great abundance of juveniles was recorded along with a balanced sex ratio in *P. a. brygooi*, indicating a depleted but still viable population.

ACKNOWLEDGMENTS

The study was carried out under the Accord de Collaboration between ANGAP (now Madagascar National Parks), the Département de Biologie Animale, Université d'Antananarivo and the Department of Biology, Hamburg University. Our cooperating partner was the *Village des Tortues*, a rescue centre for tortoises which have been confiscated by customs or police authorities. We would like to thank them for their hospitality and support, especially Daniel Kotonirina Ramampiherika, Bernard Devaux and Olivier Ciprien Razandrimamilafiniarivo. We are grateful to the late Olga Ramilijaona, Daniel Rakotondravony and Miguel Vences for their help at various stages of the study, Jocelyn Rakotomalala and Domoina Rakotomalala (ANGAP Toliara) and WWF Madagascar for their logistical support in the field. The study was financed by grants from the German Academic Exchange Service (DAAD) to Jutta Hammer, DFG/BMZ (Ga 342/15-1), the European Association of Zoos and Aquaria (EAZA), and WWF Germany to Jörg Ganzhorn.

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SUPPLEMENTARY MATERIAL.

AVAILABLE ONLINE ONLY.

Coordinates and tortoise counts of all transects and plots in the research area. The starting and finishing point of each transect is listed along with the four corner points of each plot. Tortoise counts *Pyxis arachnoides brygooi* are divided by sex: M = male, F = female and J = juvenile. Animals too small to be sexed were classified as juveniles.