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Population Density and Seasonal Detection Rates of a Unique Population of Critically Endangered Northern Madagascar Spider Tortoise (*Pyxis arachnoides brygooi*)

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***Abstract.*—The Madagascar Spider Tortoise (*Pyxis arachnoides*), endemic to the threatened southern dry forests of southwest Madagascar, is thought to display highly seasonal variations in activity. As we increase our knowledge of the population dynamics of this species, it is becoming increasingly evident that there are probable wide ranging intra-population concentrations and annual activity levels across the eight remaining populations, spanning three subspecies and two intergrade populations. We used a sweep search monitoring method across five 1-ha survey plots within an area of the northern subspecies' (*P. a. brygooi*) area of occupancy, close to the Baie des Assassins. We monitored these plots on 11 evenly spaced occasions between November 2010 and February 2012. We documented significantly greater detection of tortoises during the wet season of 9.2 (SD ± 6.9) tortoises per/ha as compared to 0.8 (SD ± 0.4) during the dry season, with detection peaking during January 2012 with an average density of 19.8 tortoises per/ha. Our results suggest that this population represents the highest known concentration of the species and a comparatively high proportion of juveniles within the population, compared to studies on other subspecies populations.**

Key Words.—Northern Madagascar Spider Tortoise; population density; *Pyxis arachnoides brygooi*; seasonal detection rates

Introduction

As more species come under increasing pressure from anthropogenic stressors, gaining a rigorous understanding of the population dynamics for species occupying narrow or dwindling ranges is often considered an important part of developing species conservation management strategies (Gaston 2003; Irwin et al. 2010). There are many shortcomings in the knowledge of the basic ecology and conservation status of many rare or threatened species (Gaston 2003; Brito 2010), particularly those with cryptic and seasonally dependent behaviour or activity levels (Walker et al. 2007). This lack of knowledge is often the greatest challenge facing conservation biologists when planning conservation management strategies (Brooks et al. 2006). Therefore, from a management perspective it is imperative to monitor such populations across seasons and conditions (Walker et al. 2007).

The Critically Endangered Madagascar Spider Tortoise, *Pyxis arachnoides*; endemic to the threatened coastal, dry forests of southwest Madagascar (Pedrono 2008; Walker and Rafeliarisoa 2012), is thought to show highly seasonally-dependent activity levels (Bour 1981; Walker et al. 2007; Pedrono 2008). This species has suffered a recent rapid contraction in distribution (Bour 1981; Pedrono 2008; Walker et al. 2012a; Walker et al. 2013), with this decline principally attributed to habitat loss through unsustainable, small-scale agricultural practices (Walker et al. 2012b). However, poaching to support the illegal, international pet trade and collection for consumption as local bush meat are also factors attributing to declines (Walker et al. 2004; Pedrono 2008; Walker 2010).

The Madagascar Spider Tortoise once occurred along an uninterrupted 555-km stretch of coastline, from the Mangoky River to Lac Anony (Bour 1981). However, the species is now confined to eight isolated populations (Fig. 1) consisting of approximately 664,980 (95% CI 492,680–897,550) individuals (Walker and Rafeliarisoa 2012), with Walker et al., (2012b) reporting a population decline of 1.4% per year for a population of tortoise within the core of the range, as a result of habitat loss. Recent spatial distribution work suggests that the species supports a current area of occupancy of 2,463 km^2 (Walker et al. 2013; Fig. 1), with the species divided into three genetically and morphologically distinct sub-species (Chiari et al. 2005). Currently, *P. a. brygooi* occurs across three fragmented populations in the north of the species range, occupying an area of occupancy of 500 km^2 between the Manombo River and the coastal community of Morombe (Walker at al. 2013; Fig. 1). A number of authors have

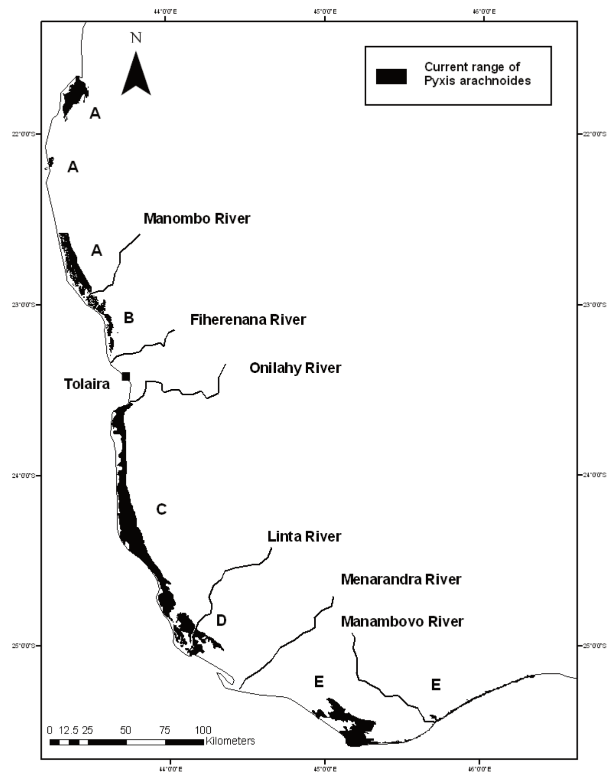

Figure 1. Current spatial distribution of populations of (A) *Pyxis arachnoides brygooi*, (B) *Pyxis a. brygooi* x *arachnoides* intergrades, (C) *Pyxis a. arachnoides*, (D) *P. a. arachnoides* x *oblonga* intergrades, and (E) *P. a. oblonga* within southwest coastal Madagascar. Reproduced from Walker et al. 2013.

speculated about the serious conservation risks facing this subspecies in particular and have suggested that more detailed work is needed to investigate the ecology of these small, isolated and fragmented populations (Pedrono 2008; Walker 2010). The species is thought to go through an annual stage of aestivation during the dry season, lasting up to eight months (Jesu and Schimmenti 1995; Pedrono 2008), whereby this cryptic species becomes harder to detect. However, these varying annual levels of detection have only been rigorously investigated within one population within the core of *P. a. arachnoides'* range (Walker et al. 2007), with the rarer, more vulnerable populations within the subspecies occupying the extremities of the species range, lacking such data.

This study aims to establish the population density and seasonal detection rate of a small isolated population of *P. a. brygooi*, which appeared to support an unusually concentrated population (Walker and Rafeliarisoa 2012). We note that this population could be considered important to the overall species conservation; however, it may also be highly vulnerable to extirpation, through habitat loss and local consumption as bush meat (Walker et al. 2013).

Materials and Methods

***Study area*.**—*Pyxis arachnoides brygooi* is endemic to the coastal, dry Mikea forest (Pedrono 2008; Walker 2010), a sub-habitat of the coastal dry spiny forests, which are ubiquitous to the coastal zone of southern and southwestern Madagascar (Fenn 2003). The Mikea forest historically stretched from the north of Toliara to approximately 30 km north of Morombe (Seddon et al. 2000) and has long been identified as extremely important for its biodiversity (Seddon et al. 2000; Fenn 2003). On account of the risk that the species faces from illegal commercial harvest and the exceptional numbers within the population, the authors are non-specific regarding the exact geographical location of the study area (Stuart et al. 2006).

We selected at random five one-hectare quadrats supporting habitat suitable for *P. a. brygooi*, consisting of loose, sandy substrate and low lying, coastal scrub from within a 10-km^2 region of coastal forest close to the Baie des Assassins (Walker 2010).

***Field methods*.—**We used a sweep search survey method (Walker 2007; Walker et al. 2012a, 2012b) across the five one hectare quadrats. We surveyed each quadrat once every six weeks between November 2010 and February 2012, with six visits undertaken during the wet season (December-April) and five visits undertaken during the dry season (June-November). Surveys were completed between 0600–1030 and 1530–1830, exploiting the species crepuscular behaviour (Walker et al. 2007).

Ten surveyors spread out along the line marking the southern boundary of the quadrant, approximately 10 m apart. Each surveyor walked slowly, in a northerly direction, carefully searching the vegetation and substrate for 5 m either side of themselves for tortoises. Upon encountering a tortoise, the tortoise sex was determined using the morphological characteristics of the plastron (Walker et al. 2007). If the individual had not developed sex dependent external morphological characteristics, the individual was categorized as a juvenile (Walker et al. 2012b). To avoid duplicate counting of the same tortoise during th esame month, we marked the marginal scutes of the tortoises with an identifying code using nail varnish .

We used Microsoft Excel (Microsoft, Redmond, Washington, USA) to calculate mean and standard deviation of density by sex and age class between seasons. We used an unpaired t-test (α = 0.05) to test for differences in detection between wet and dry season surveys using Minitab 14 (Minitab Inc. State College, Pennsylvania, USA). Prior to performing the unpaired t-test, all data were adjusted to follow a normal distribution using a Box-Cox transformation, following this, data were then re-tested for normal distribution using a Ryan-Joiner test for normality ($P = 0.05$).

Results

We recorded 292 tortoises across the five quadrats during the 11-mo survey (Table 1). We detected significantly more tortoises during the wet season than during dry season (unpaired t-test, $P = 0.005$), with a mean population density of 9.2 (SD ± 6.9) tortoises per hectare (per/ha) during the wet season, compared with a mean density of 0.8 (SD ± 0.2) per/ha during the dry season (Table 1). Detection varied by month with just two tortoises detected in November, whereas 99 tortoises were recorded in January, yielding an average density of 19.8 tortoises /ha for this sampling visit (Fig. 2). Juvenile activity peaked during the wet season with 88 individuals recorded during a 12-week period between the beginning of January 2012 and late February. Although juveniles were less commonly encountered during the dry season, they represented a larger proportion of the total number of tortoises found (62.5%), compared to the rainy season, when they comprised 48% of tortoises detected (Fig. 3).

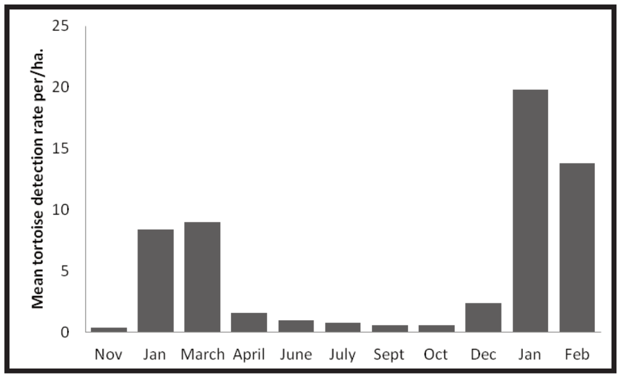

Figure 2. Mean tortoise detection rate across the 5 survey quadrats for each of the 11 survey visits between November 2010 and February 2012.

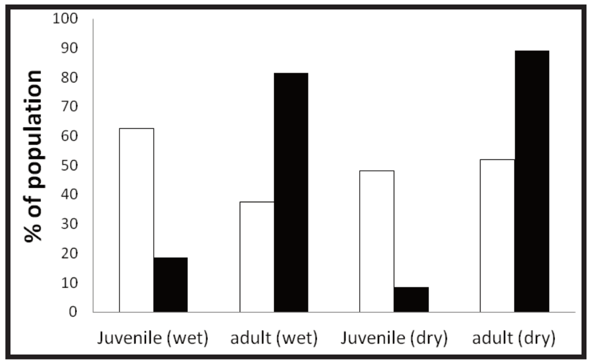

Figure 3. Percentage of the population detected within the wet and dry seasons divided into adult and juvenile cohorts for the study population (white) and the population of *P. a. arachnoides* sampled in Walker et al. (2007; black).

Discussion

Our surveys revealed the highest density of Spider Tortoises recorded to date across the species' current range. During peak wet season in January 2012, we observed nearly 20 tortoises/ha. Recent surveys established a mean population density of 2.3 Spider Tortoises per/ha

Table 1. Mean density of tortoises detected per hectare across the survey site during the wet and dry seasons.

	Juvenile per/ha.	Male per/ha	Female per/ha.	Total per/ha.
Wet season	5.4 (SD ± 4.2) n = 163	2.0 (SD ± 1.4) n = 61	1.7 (SD ± 2.1) n = 51	9.2 (SD ± 6.9) n = 275
Dry season	0.4(SD ± 0.2) n = 10	0.3(SD ± 0.3) n = 5	0.1(SD ± 0.2) n = 2	0.8(SD ± 0.4) n = 17

in wet season across the range of the species (Walker and Rafeliarisoa 2012). This study represents the first detailed population density study for the northern sub-species of Spider Tortoise (*P. a. brygooi*). Walker et al. (2007) and Walker et al (2012b) recorded mean densities of *P. a. arachnoides* of 4.6 (SD ± 1.6) per/ha and 6.6 (SD ± 5.9) per/ha respectively during the wet season within the Anakoa region. In addition, a preliminary study by Jesu and Schimmenti (1995) within the same area of forest, recorded *P.a. arachnoides* densities of approximately 3 per/ha. Therefore, the mean density of 9.2 (SD ± 6.9) individuals per/ha recorded within this study represents one of the most dense populations of this threatened species. Indeed, the levels of almost 20 tortoises per/ha recorded during this study in January 2012 suggests this may be an exceptional population, more numerous than the anecdotal density of approx. 16 tortoises per/ha reported by Pedrono (2008) for a population of *P. a. oblonga*, within the extreme south of the species' range.

The differences in detection of tortoises among seasons suggest that there is variation in behaviour between the subspecies. Detection of *P. a. brygooi* decreased by 96% between seasons compared to a 55% drop in detection for *P. a. arachnoides* (Walker et al. 2007), using similar sampling methods. We suggest that *P. a. brygooi* could aestivate deeper within the substrate and for longer periods of time during the dry season than *P. a. arachnoides*, reducing detection rates during this period of the year.

Previous work also suggests that juveniles are the most difficult cohort to detect within a population of Spider Tortoises as has been documented for other chelonians (Pike et al. 2008). For example Walker et al. (2012a) report that mean annual survival of juveniles could not be estimated within a mark-recapture study of *P. a. arachnoides,* due to low recapture. In contrast to the Walker et al. (2007) study in Anakao, our work on *P. a. brygooi* revealed that the juvenile cohort of the population was the most abundant, forming > 60% of the population during the wet and dry seasons. This could suggest that juveniles are more active within this northern region of the Spider Tortoises' range, or that this is a more productive population, producing higher numbers of offspring.

This population is afforded some level of protection occurring within one of the new IUCN Category V marine protected areas included within the recent expansion of the protected area system within Madagascar (Système d'Aires Protégées de Madagascar; SAPM; Gardner 2011). However, the management area of this Category V marine park does not include any terrestrial habitats due to issues of land ownership. Local community dependence on the unsustainable subsistence uses of Madagascar's southern dry forests normally remains unregulated (Gardner 2011). However, the local Vezo community has enacted a "Dina" on the hunting of the tortoises in the area, which equates to a traditionally binding moratorium on the collection of the species, with repercussions including fines for violators. In addition, the local Vezo people have a taboo against eating the tortoises; however, this taboo does not extend to the neighbouring Mikea tribe. Further, there is evidence of high levels of tortoise mortality within the spiny forest area from fires used by nomadic cattle herders. Up to 80 burned tortoise carapaces were found within the survey site during 2011 (Walker et al. 2013).

A number of small scale conservation projects are succeeding in the region to a reasonable extent (Rafeliarsoa et al. 2010). For example, a unique project is underway to provide local communities with reproductive health and family planning (Mohan 2009; Harris et al. 2012) which may help to alleviate local population pressure on fuel wood demands of suitable tortoise habitat within this population's range. Such conservation and development within the Spider Tortoises' range although locally successful, are often limited in their geographical scope and most areas within the region lack any kind of initiative to draw communities away from the heavy reliance and over exploitation of natural resources that result in habitat loss and exploitation of Spider Tortoises.

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Ryan Walker gained his Bachelors and Masters Degrees from Kingston University and the University of Newcastle, respectively, in the United Kingdom. He has recently completed his Ph.D. investigating the spatial distribution, conservation threats, and population trends of the Madagascar Spider Tortoise (*Pyxis arachnoides*) through the UK's Open University. He now works as a field based, freelance conservation biologist in Madagascar, Papua New Guinea, and his native United Kingdom. Ryan is a member of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, The Turtle Survival Alliance's Field Conservation Committee, The Chartered Institute for Ecology and Environmental Management, and is a Chartered Environmentalist through the UK's Institute for the Environment. (Photographed by Inge Smith).