The status of wild populations of the Critically Endangered Madagascar spider tortoise *Pyxis arachnoides*.

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Introduction

The Madagascar spider tortoise (*Pyxis arachnoides* BELL, 1827) is a small, cryptic species endemic to southwest Madagascar (Fig. 1). This is one of the smallest species of tortoise in the world, with a domed carapace measuring up to 200mm (curved carapace length) in mature individuals (WALKER et al. 2007). The species inhabits the biologically unique dry coastal spiny forests of southwest Madagascar (PEDRONO 2008, WALKER et al. in press; Fig. 2), one of the most threatened habitats within Madagascar (HARPER et al. 2007, WALKER et al. 2012a, 2012b). Despite a recent greater understanding of the population dynamics of the species, there is still very little knowledge of the species' biology.

RHODIN et al. (2011) describe *P. arachnoides* as one of the world's top 40 threatened species of chelonian. Protecting wild populations of this species is a challenge due to the wide ranging conservation issues

Fig. 1
The small, cryptic spider tortoise (*Pyxis arachnoides*) within its coastal forest habitat of southwest Madagascar.

facing the tortoise. Since October 2004, CITES has placed a ban on the international trade in this species (Walker et al. 2004) by listing it under Appendix I. However, illegal tortoise collection and exportation continues to be fueled by the lucrative pet trade to some extent, with a particular demand stemming from the Southeast Asian market due to the recent economic development within the region creating a growing market for exotic pets. Despite this, habitat loss is probably the greatest threat facing the long term survival of the species (Walker et al. 2012b).

Current distribution and population status

Pyxis arachnoides is thought to comprise of three geographically divided, distinct subspecies (Chiari et al. 2005) (Fig. 3) with a plastral hinge mobility cline being the dominant defining physical characteristic across three subspecies (Pedrono 2008). *Pyxis arachnoides brygooi* (Vuillemin & Domergue 1972) inhabits the north of the range and displays a rigid hinge (Walker 2010, 2011). *Pyxis arachnoides arachnoides* inhabits the centre of the range and has a semi mobile plasteral hinge (Fig. 4), whilst, *P. a. oblonga* Gray, 1869, with its completely mobile hinge inhabits the most southerly portion of the range (Fig. 5). The southern subspecies also often displays dark pigmentation to the periphery of the plastron, in comparison to the completely pale plastron displayed by the two more northerly subspecies (Bour 1981, Pedrono 2008). The species supports a current area of occupancy of 2,464 km² (Walker et al. in press; Table 1). The cline in plasteral hinge mobility across the subspecies has been speculated to be an ecological adaptation to reduce moisture loss, as the environment becomes increasingly more arid the further south one travels throughout the range. However, this idea has never been rigorously tested and is mere speculation.

Recent work by Walker et al. (in press) has discovered two small population showing signs of intergradations (Fig. 3; Table 1) between *P. a. brygooi* and *P. a. arachnoides* to the south of the Manombo River mouth and the region north of Toliara, then between *P. a. arachnoides* and *P. a. oblonga* within the Linta River mouth region. These populations support animals which show morphological characteristics indicative of either

Fig. 2
Cap Sainte Marie Special Reserve home to one of the largest remaining populations of *Pyxis arachnoides oblonga*. The area is typically dominated by coastal dry spiny forest.

one of the two subspecies and also individuals displaying a mixture of both characteristics. This intergradation could have come about through the gradual aridification of southwest Madagascar since the late Pleistocene or early Holocene, (i.e. over the past ~12,000 years) (Burney 1993, 1997) allowing for the convergence of subspecies now able to mix as a result of seasonal drying of the Manombo and Linta Rivers.

Recent spatial studies to map the current area of occupancy of the species and spatially compare this against the suspected historical extent of occurrence by Walker et al. (in press) suggests that the original suspected historical distribution of the species (Bour 1981), was thought to encompassed a continuous belt off 555 km of coastline (Pedrono 2008). However, the species is now confined to eight distinct, fragmented sub populations, with *P. a. brygooi* and *P. a. oblonga* having thought to have suffered range contractions of around 80 % (Walker et al. in press; Fig. 3; Table 1). *P. a. arachnoides* still supports a relatively wide distribution and covers an area of occurrence of 1,029 km² (Fig. 3; Table 1).

The global population size currently stands at 664,980 tortoises (95 % CI 492,680–897,550), with a mean population density of 2.3 tortoises per ha. across the range (Walker & Rafeliarisoa 2012). However, tortoise density varies widely within the range (Jesu & Schimmenti 1995, Walker et al. 2007, Pedrono 2008, Rakotondriamanga et al. 2011).

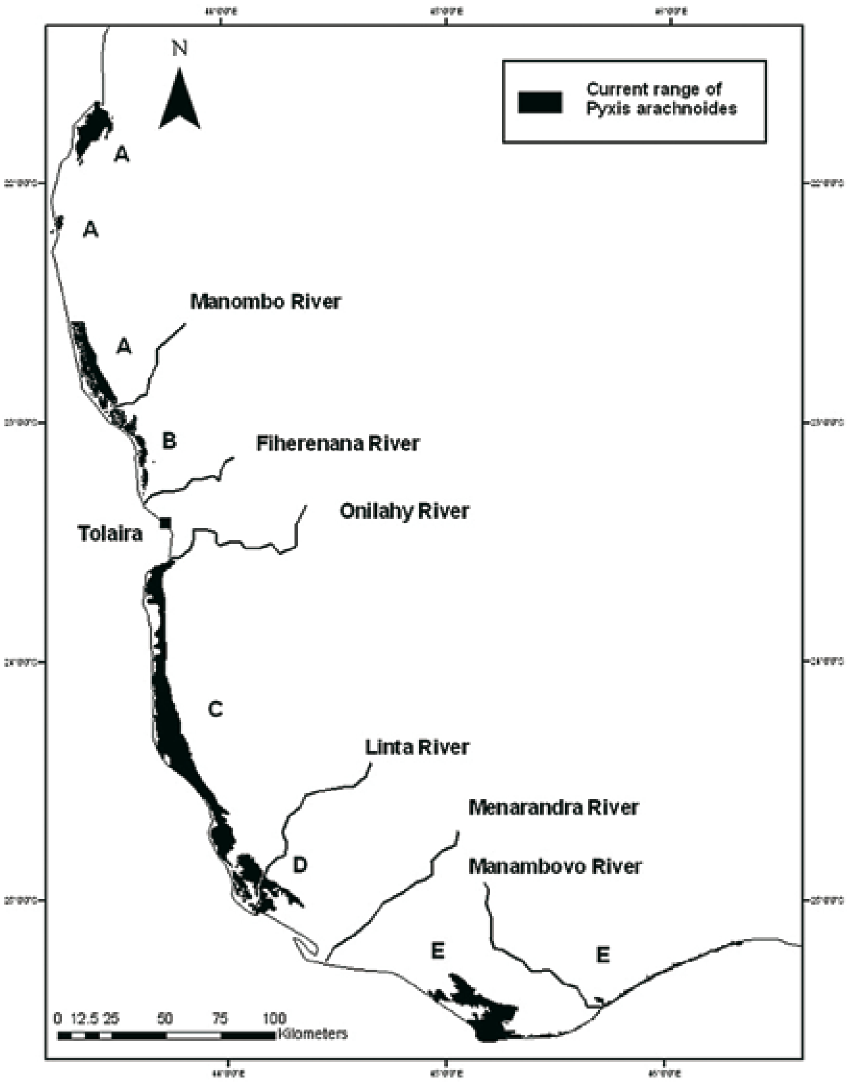

Fig. 3
Current area of occupancy of the fragmented relic population of *Pyxis arachnoides* within coastal southwest Madagascar; A= three sub populations of *P. a. brygooi*, B= 1 sub population of *P. a. brygooi/P. a. arachnoides* intergrades, C= 1 sub population of *P. a. arachnoides*, D= 1 sub population of *P. a. arachnoides/P. a. oblonga* intergrades, E= 2 sub populations of *P. a. oblonga* showing a very narrow area, occupied to the east of the range *P. a. oblonga*. Graph by Walker & Rafeliarisoa (2012).

Threats

Currently habitat loss is the greatest threat facing the long term survival of the spider tortoise (Walker et al. 2012a, 2012b, Walker & Rafeliarisoa 2012) with the southern dry spiny forests diminishing at a rate of 1.2 % per year (Harper et al. 2007, Walker et al. in press). Population matrix modeling for a population of tortoises within the Anakao region, has reviled a population is decline of 1.4 % per year (λ=0.983), with this population likely to become ecologically non viable towards the end of the next century.

Despite the species' up listing from CITES Appendix II to Appendix I, the pet trade has had a great impact on this species historically (Walker et al. 2004). More recently, this illicit trade, stemming mostly as a result of demand from southeast Asia has increased since early 2009 due to Madagascar going through a period of political unrest resulting in a sudden increase in wildlife smuggling (Ramahaleo & Virah-Sawmy in press). There is some anecdotal evidence to suggest that within some regions of southwest Madagascar spider tortoises have been collected for local consumption as bush meat (Fig. 6). It is thought that *P. a. brygooi* appears to have been hunted to extinction within some of its former range by the Mikea tribe (Walker 2010) and has been targeted particularly during periods of drought when other food sources have been scarce.

The Madagascan Government has recently granted mining concessions to large areas of the region of the species current range, for the exploitation of mineral sands, predominately Ilménite (Walker et al. in press; Table 1). Recent spatial analysis work by Walker et al. (in press) revealed that 18.3 % of the spider tortoise range falls within these proposed mineral extraction zones (Table 1), with currently, no impact mitigation plan in place for these or any other species or habitats potentially impacted by this change in land use (Walker et al. in press).

Conservation measures

National law in theory protects *P. arachnoides*, with consumption of tortoises prohibited, however national law has remained widely ineffective at preventing the persecution of the species and its habitat (Pedrono 2008). *Pyxis arachnoides* was included on the IUCN Red List of Threatened Species in 1986 as Indeterminate and then as Lower Risk-Conservation Dependent in 1994. Its status was later elevated to Vulnerable because of on-going habitat degradation and over-harvesting. The status of this species was elevated to Critically Endangered on the IUCN Red List for Threatened Species on the basis of habitat loss and non sustainable exploitation (criteria

Subspecies	Current AOO (km²)	% of current AOO in Protected Areas	% current AOO in proposed extraction areas	Protected areas	Proposed resource to be extracted
P. a. brygooi (A)*	500	100	0	Zone 1 - Mikea Forest National Park, Mangoky Ihotry Protected Area Complex, Zone 2 –Velondriake Community Managed Protected Area Zone 3 - Mikea Forest National Park	N/A
P. a. brygooi x *arachnoides* Übergang (B)*	100	55	38	PK32-Ranobe Protected Area	Zircon, Ilmenite
P. a. arachnoides (C)*	1029	77	20	Tsimanampesotse National Park Extension, Tsimanampesotse National ParkD, Tsinjoriake Protected Area, SAPM Unnamed/Unpromoted Protected Area	Lime, Ilmenite, Monazite, Zircon, Granite
P. a. arachnoides x *oblonga* Übergang (D)*	267	70	4	Southwestern Coastal Wetlands Protected Area, Mahafaly Plateau South, Unnamed/Unpromoted Protected Area	Ilmenite, Granite, Lime, Zircon
P. a. oblonga (E)*	568	47	25	Cap Sainte Marie Special Reserve, SAPM South Unpromoted Protected Area	Ilmenite, Zircon
Gesamt	2464	74	18		

Table 1
Current area of occupancy (AOO) of each subspecies population of *Pyxis arachnoides*, in addition to the extent of AOO for each population of tortoise that fall within existing or proposed protected areas or sites of proposed mineral extraction. Data reproduced from Walker et al. (in press). *Letters relate to the distribution of each subspecies within Figure 3.

A4cd + E) in 2008 (Leuteritz & Walker 2008), during the 2008 Madagascar Tortoise Red Listing Meeting in Antananarivo (Mittermeier et al. 2008).

Until recently the Madagascar protected area network encompassed woefully little of the biologically unique southern dry forest region of southwest Madagascar (Fenn 2003). However, as a result of a pledge made at the Vth World Parks Congress in Durban in 2003, Madagascar's government has increased the country's protected area coverage threefold through the Système d'Aires Protégées de Madagascar, with most newly gazetted parks established by 2012 (Rabearivony et al. 2010). Currently 73.5 % of the remaining spider tortoise range occurs within these protected areas (Walker et al. in press; Table 1).

Habitat degradation is the greatest management issue facing the remaining wild populations of spider tortoises (Walker et al. in press; Pedrono 2008). With the exception of the two National Parks (Mikea Forest and Tsimanampesotse) and Cap Sainte Marie Special Reserve, all new protected areas in the region are IUCN category III, V or VI multiple-use protected areas, co-managed by local community associations (Walker et al. in press; Gardner 2011). These protected areas seek to simultaneously conserve biodiversity while promoting the sustainable use of natural resources for poverty alleviation and local development (Gardner et al. 2008) and emphasise the avoidance of negative impacts on local communities through resource use restrictions. It would be simplistic to assume that very much will change in terms of forest loss due to predominantly wide spread, small scale, non sustainable fuel wood harvest. As a result, most of these protected areas are zoned so as to permit continued forest resource use and are likely to suffer continuing habitat degradation (Gardner 2009, Gardner 2011) with continued, potential negative implications for tortoise populations.

Despite this apparent bleak outlook for the species, there are a number of small scale, community focused conservation initiatives being currently driven forward for the species. A USAID funded family planning project within the region that supports the last strong hold of *P. a. brygooi* is having positive effects on reducing local resource pressure, in particular habitat loss due to fuel wood harvesting (Harris et al. 2012). In addition to this a number

Fig. 4
Pyxis arachnoides arachnoides within the forests of Tsimanampetsotsa National Park.

Fig. 5
Plastral hinge mobility can be seen in this *Pyxis arachnoides oblonga*.

of local NGOs and researchers have developed incentivized conservation strategies, whereby local communities and individuals are paid to collect biological data on the species. These communities derive small, but significant amounts of income from monitoring the species and preserving them in situ. These projects have generally been successful conservation tools; however larger areas of the species' dwindling range need to be targeted by such projects to prevent the species from further declines and ultimately extinction within the wild.

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Fig. 6
A pile of discarded *P. a. brygooi* carapaces, the tortoises were probably consumed and discarded by nomadic livestock headers, probably from the Mikea tribe.

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Fig. 7
This example of a *Pyxis arachnoides oblonga* within the south of the species' range shows the beauty and variation of some individual carapace patterning.